NEC

$10.00

DISCRETE/OPTOELECTRONICS DATA BOOK

Edition I

NEC

NEC Electron

A Division of NEC Electronics U.S.A. Inc.

NEC

DISCRETE/OPTOELECTRONICS DATA BOOK

Edition I

Printed in USA

Contents

CONTENTS BY PART NUMBER

Contents

RELIABILITY AND QUALITY ASSURANCE SYSTEM OF NEC'S SEMICONDUCTOR DEVICES

GENERALS

NEC has been manufacturing semiconductor devices readily adaptable to a large number of applications ranging from consumer goods up to space electronics, including communication and industrial systems. Best efforts have been made to have individual device soak up its inherent reliability and to control its quality so as to enable customers to use it with confidence.

Descriptions on the reliability and quality assurance system for NEC semiconductor devices will be made for customer's information.

1. RELIABILITY OF SEMICONDUCTOR DEVICES

1-1. Function of Reliability

It is natural that equipment and components have lower performance as the longer and the more frequent use of them. This means that reliability decreases with the increase in time and frequency of use. Although reliability reduction depends greatly on the kinds of devices and the relationships between the kind and degree of stresses applied, failures modes can be roughly categorized into three modes by their natures as shown in Figure 1.

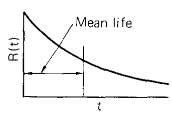
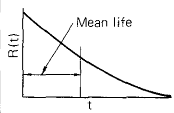
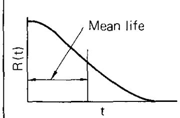
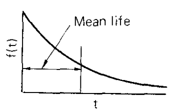
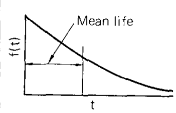
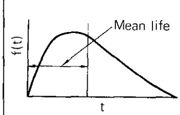
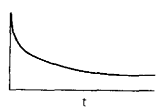
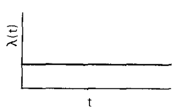
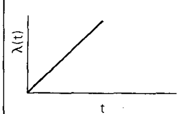
	Initial Failure	Random Failure	Wear-out Failure (Fatigue Failure)
Reliability Function (Survival Rate) R(t)			
Probable Density (Frequency Distribution) f(t)			
Failure Rate λ(t)			
Effectiveness of Periodic Repairs	Detrimental	Ineffective	Effective

Figure 1. Failure Modes

To make statistical study of these phenomena, distribution functions, such as Weibull distribution, gamma distribution, logarithmic-normal distribution, etc., are discussed. Weibull distribution, among these, is most likely discussed and seems to be the most suitable as a reliability function for semiconductor devices. The reliability of these products are expressed by the following factors in Weibull distribution.

Reliability function: $R(t) = \exp\left\{-\left(\frac{t-\gamma}{\eta}\right)^m\right\}$

Cumulative distribution function: $F(t) = 1 - \exp\left\{-\left(\frac{t-\gamma}{\eta}\right)^m\right\}$

Probable density function: $f(t) = \frac{m}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{m-1} \exp\left\{-\left(\frac{t-\gamma}{\eta}\right)^m\right\}$

Instantaneous failure rate: $\lambda(t) = \frac{m}{\eta^m}(t-\gamma)^{m-1}$

Mean life: $t_m = \eta \cdot \Gamma\left(1+\frac{1}{m}\right)$ note 1)

note 1)
Here, $\Gamma(\ )$ is gamma function. The relationship between m and $\Gamma(1+\frac{1}{m})$ is shown in Figure 2.

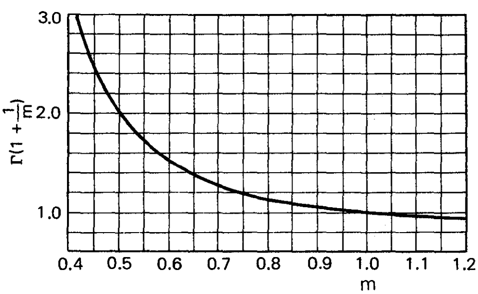


Figure 2. Relationship between Shape Parameter m and Gamma Function

This distribution function includes Location Parameter: γ, Scale Parameter: η, and Shape Parameter: m. The shape parameter can be utilized to determine the mode of each failure as follows:

$m < 1$ Initial failure
$m = 1$ Random failure (exponential distribution)
$m > 1$ Wear-out failure

In checking whether the reliability function complies with Weibull function or not and obtaining the above parameters, γ, η, m, Weibull probability paper can be utilized.

1-2. Measure to Express Reliability, Failure Rate and Reliability Index.

Failure rate is defined as "the rate that a system, equipment, devices (such as semiconductor devices), etc. which have been in operation would develop failures per unit time ." If reliability function is R(t), failure rate which is also a function of time can be expressed as

$$\lambda(t) = -\frac{dR(t)}{dt} \cdot \frac{1}{R(t)}$$

In general, failure rate has two kinds: instantaneous failure rate and mean failure rate. "Failure rate" in a simple statement often refers to instantaneous failure rate. The failure rate $\lambda(t)$ in this paper also means the same.

Mean failure rate $\overline{\lambda}(t)$ can be obtained from the following formula.

$$\overline{\lambda}(t) = \frac{\text{Total number of failures in a certain period}}{\text{Total operating hours}} = \frac{n}{\sum_{j=1}^{n} t_j n_j + (n_0 - n)t}$$

Where n_j is the number of failures at time t_j, n is the number of failures in the observation period t, and n_0 is the number of devices put to testing or operation. When n_0 is sufficiently large, the mean failure rate can be expressed as follows:

$$\overline{\lambda}(t) = \frac{1-R(t)}{\int_0^t t \cdot f(t)dt + t \cdot R(t)} = \frac{1-R(t)}{\int_0^t R(t)dt}$$

where f(t) is probable density function.

However, instantaneous failure rate $\lambda(t)$ and mean failure rate $\overline{\lambda}(t)$ as defined above cannot easily be obtained from the test results or practical data.

Therefore, the following formula has been used conventionally as the measure of failure rate.

$$RI(t) = \frac{1}{R(0)} \cdot \frac{1-R(t)}{t} = \frac{n}{n_0 \times t}$$

This expression has such a practical effect that the approximate number of failures in a certain period and thus the approximate reliability can be estimated instantly. Here, RI(t) is called reliability index and should be distinguished from $\lambda(t)$ and $\overline{\lambda}(t)$.

In discussing the results of accelerated life test, all of reliability index, instantaneous failure rate, and mean failure rate use %/1000 h as a rule. In describing the value in actual operation, the unit of

FIT (failure in time) = 10^{-9} /h has been used increasingly.

If it is proved that $R(t_i)$ is 99 % in a certain period of time t_i, the mean failure rate after t_i can be estimated as shown in Figure 3(a), the reliability index after t_i as shown in Figure 3(b), and the instantaneous failure rate after t_i as shown in Figure 3(c). In the curves of Figure 3(b), the value of reliability index is not constant but varies with time even with m = 1.0. On the contrary, in the curves of Figures 3(a) and 3(c), reliability factors are always constant regardless of time if m=1.0. Also, with m other than 1.0, the relationship between reliability factor and time shows considerable difference among Figures 3(a), 3(b), and 3(c).

For this reason, the followings must be taken into account.

(1) Reliability index RI(t) may frequently be accompanied by some error when it is used as a direct mean to assume instantaneous failure rate $\lambda(t)$ and mean failure rate $\overline{\lambda}(t)$. And such error would become greater as the value of m deviates more from 1.0.

(2) If m=1.0, or reliability function is determined by exponential distribution, failure rate is said to be constant regardless of time. However, this applies only to instantaneous failure rate and mean failure rate but not to reliability index.

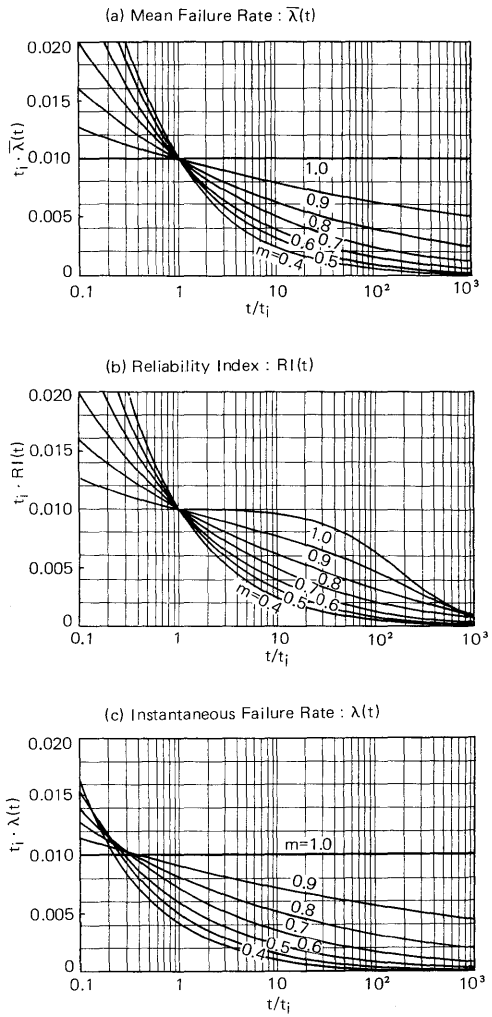


Figure 3. Reliability to be Estimated after $t=t_i$ When R(t)=0.99 was Recognized

1-3. Reliability of Equipment

With the recent astounding progress in electronics, electronic equipment have become larger in size and more complicated in composition, which necessitates an extremely large number of components in system or a equipment.

Suppose equipment has n_0 numbers of semiconductor devices and is used under the condition that its t-hour-later reliability will be r(t), the reliability R(t) of this device based on the failures of the devices can be obtained from the following equation:

$$R(t) = \left\{ r(t) \right\}^{n_0}$$

However,

$$r(t) = \exp\left\{ -\left(\frac{t}{\eta}\right)^m \right\} = \exp\left(-\frac{\lambda(t) \cdot t}{m}\right)$$

Therefore,

$$R(t) = \left\{ \exp\left(-\frac{\lambda(t) \cdot t}{m}\right) \right\}^{n_0} = \exp\left(-\frac{n_0 \lambda(t) \cdot t}{m}\right)$$

And, furthermore, more appoximation can be attained as

$$R(t) = 1 - \frac{n_0 \lambda(t) \cdot t}{m}$$

As seen from these equations, the more components are employed in an equipment the more careful consideration should be given to the selection and use of them.

In considering the reliability of an equipment a measure called MTBF (Mean Time Between Failures) is often used. MTBF is the average of operation times between failures, and the MTBF of the above-mentioned equipment which has n_0 numbers of semiconductor devices and is used under the condition that its t-hour-later instantaneous failure rate will be $\lambda(t)$ based on the failures of its semiconductor devices is as follows:

$$MTBF = \frac{m}{n_0 \lambda(\eta)} \Gamma\left(1 + \frac{1}{m}\right)$$

2. FAILURES OF SEMICONDUCTOR DEVICES

2-1. Features of Semiconductor Device's Failure

Conventionally, the failure rates of electronic components and those of system and equipment which incorporate these components are often indicated by a bath-tub curve. Since, however, semiconductor devices may provide the shape parameter m which is smaller than 1 (i.e. 0.5 to 0.95 usually) so far as the conditions applied are not too specific, the failures of these devices will be classified into initial failure which shows a curve different from the bath-tub curve. That is, semiconductor devices would have a longer initial failure time, more than 6 months in many cases, and the changing from initial failure period to random failure period is not always distinct. These characteristics are illustrated in Figure 4.

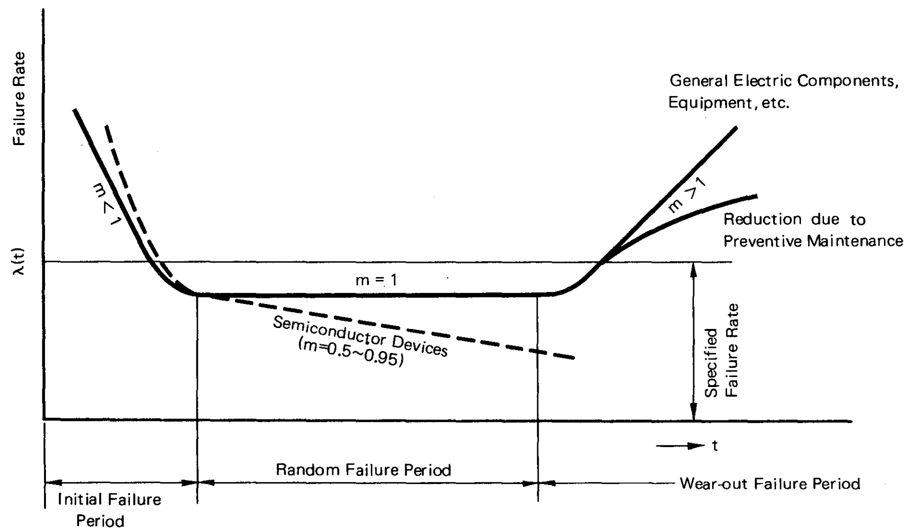


Figure 4. Failure Rate Curves (Bath-tub Curve) for Semiconductor Devices and General Electric Components and Equipment

For instance, reliability to be estimated after $t=t_i$ when $R(t_i)=99$ % was recognized according to the value from shape parameter: m, as shown in Figure 5.

This means that semiconductor devices have far longer life than other equipment belong to exponential distribution (m=1).
In other words, the semiconductor devices which can be used without failure up to the period have longer reliability after that period, so regularly replacement for maintenance will be detrimental for reliability of the equipment.

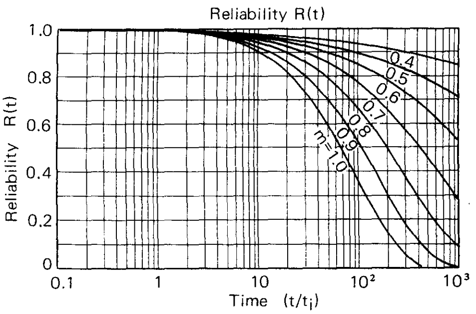


Figure 5. Reliability to be Estimated after $t=t_i$ when R(t)= 0.99 was recognized.

2-2. Failure Analysis

Failures of semiconductor devices are attributable to their own defects or their operating or environmental conditions. Figure 6 shows a result of failure investigations in terms of classified modes of failures after inspection of the semiconductor devices that were returned in complaint of failure in the field. As indicated by the example, unexpectedly many failures can be attributed to design and use of the device, beyond expectations.

In any case, failure investigation for semiconductor devices are quite important to the improvement of reliability and quality from the viewpoint of design, manufacture and application of those products. We are always making our best to study such investigation results and feed them back to our development, design, manufacturing and sales departments so that they can be served to research and development of new devices, improvement of device, improvement of manufacturing and screening processes, study of inspection method, application technologies, etc., and thus to supply better products to every customers.

In the following description, characteristics of failures, reliability, and major failure modes of semiconductor devices are discussed.

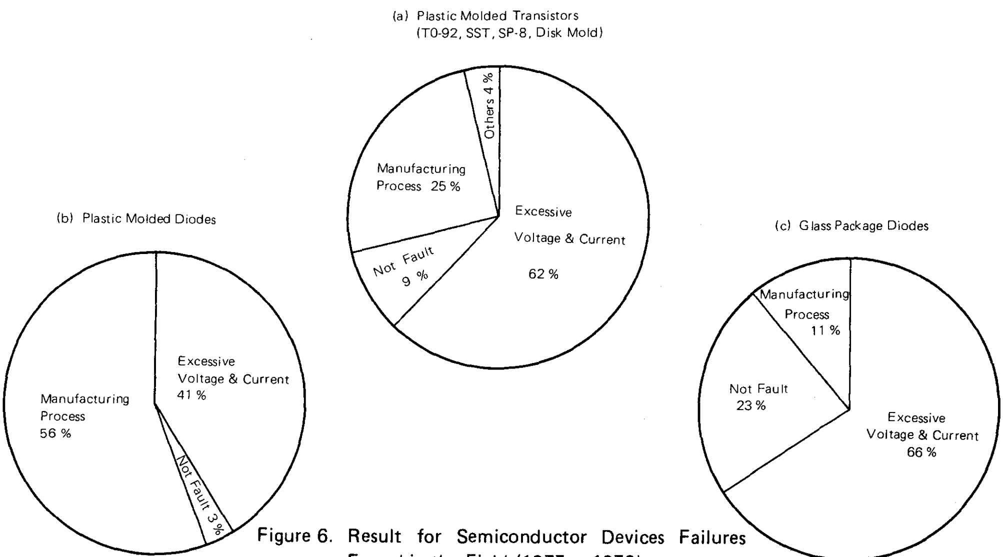


Figure 6. Result for Semiconductor Devices Failures Found in the Field (1977 ~ 1979)

2-3. Failure Mechanism

1) Connecting Portion

A package and elements are usually connected by gold wires, and this connecting portion can be the cause of failures.

The material or size of wires and bonding methods are all fully taken into account in designing and manufacturing so that they can meet the most severe of all the conditions thus assuring the quality of semiconductor devices. However, if such products are exposed to the condition exceeding the rating, there may occur failures such as open or partial open.

Some classified examples of failures in connecting portions are given in Table 1, and it is seen that similar failures may occur due to the faults in design or manufacture. And very often it is difficult to find the causes of such failures by investigating the defective devices.

Table 1. Examples of Failures in Connecting Portion and Their Causes

Failures in Connecting Portion	Mechanical causes	Excessive mechanical shock Incomplete bonding Defective pointed tools Inadequate wire shape
	Chemical causes	Corrosion by contamination Formation of compounds among Al ~ Au metals {Heating {Heat generation by current
	Electrical causes	Melting and fusing by excess current {Misuse {Surge

2) Junction Region

Junction region can be broken by the outbreak of surge or hot spot. Overvoltages applied from the outside are considered to be the major causes of those breaks.

3) Packaging

As for the failures related to packages, failure modes are remarkably different according to their structures, but any package failure may be a cause of a serious failure of semiconductor devices.

4) Metallization Wiring

Elements in a semiconductor device are usually connected together by aluminum metallization wiring. Failures related to this connection are, for example, scratches and current capacity shortage caused by a step portion of oxidization layer. Substandard devices have been removed by screening in the manufacturing process. If, however, devices are exposed to the conditions exceeding maximum rating, it cannot be avoided that the occurrence of open circuits in such weak points in metallization wiring.

As the corrosion by the humidity of aluminum electrodes is caused by the coexistence of moisture and an extremely small quantity of impurities, the use of plastic molded packages may cause troubles; especially when the humidity is extremely high, it can not be denied that plastic molded packages are inferior in reliability to hermetically sealed packages.

5) Surface Deterioration

Though the oxidized surface of semiconductor devices are protected with resin, the surface is sometimes deteriorated, and in many cases the deterioration is liable to be accelerated by the effect of voltage or temperature.

Surface deterioration — called channel — of those products sometimes causes an increase of leakage current, but heating of them will restore their characteristics. The deterioration through channel formation is often observed in forced deterioration tests, but it is hardly found in the field except for MOS devices.

6) Incomplete Manufacture

Failures due to incomplete manufacture may be caused by, for example, imperfect diffusion process or incomplete chip mounting. However, the defective devices owing to these failures are almost perfectly removed through the above-mentioned quality control activities in the manufacturing process, so practically no defective devices will be delivered to customers.

Major failure features and modes of semiconductor devices were described above, and in the following Table 2, kinds, modes, and causes of these failures are tabulated:

Table 2. Kind, Mode, Cause of Failures Related to Chips

Item	Kind of Failure	Failure Mode	Cause
Wire Bonding	Wire disconnection	Open	Incomplete manufacture or misuse
	Wire short	Short	
	Purple plague	Open, high resistance	
	Bond detaching	Open, high resistance	
	Misplaced bonding, loose contact	Open, high resistance short	Incomplete manufacture
	Improper bond shape	Open, high resistance	
	Erroneous bonding	Open, high resistance	
Junction Region	Destruction by surge	Low breakdown voltage, short, open	Incomplete manufacture or misuse
	Hot spot		
Case	Lead disconnection	Open, high resistance	Ditto
	Lead short	Short, high leakage	
Seal	Incomplete seal	Breakdown voltage deterioration, high leakage	Ditto
	Enclosed high humidity gas		
	Contamination of surface		
	Dust and dirt	Short, low breakdown voltage, large leakage	
Metallization	High current density	Open, high resistance	Misuse
	Electromigration		
	Scratch	Open, short	Incomplete manufacture
	Insufficient thickness	Open, high resistance	
	Excessive etching		
	Contamination, dust and dirt	Open, high resistance	Incomplete manufacture or misuse
	Poor wiring and element connection		
Chip Mounting	Chip crack	Open, short	Ditto
	Chip detaching	Open, short, high thermal resistance	
Oxidized Film	Pinhole, crack	Low breakdown voltage, short	Incomplete manufacture
	Insufficiently Oxidized film thickness	Low breakdown voltage	
Surface Treatment	Channel formation	Low breakdown voltage high leakage	Ditto
	Contamination		
Mask	Insufficient P.R.	Low breakdown voltage, short, open, high leakage	Ditto
	Mask misalignment		
Material and Diffusion	Improper impurity density	Ditto	Ditto

3. RELIABILITY AND QUALITY ASSURANCE SYSTEM FOR NEC SEMICONDUCTOR DEVICES

3-1. Cycle of Reliability and Quality Control System

Reliability and quality assurance of semiconductor devices can be achieved by building reliability into the devices in each process from market survey and collection of user's requirements to the development and manufacturing design, and purchase of materials and parts, and also by means of the direct quality assurance by the quality control, reliability test and examination relating to the manufacture, as well as the shipment control and after-sale service, all being performed under a consolidated system.

The system is outlined in Figure 7. Control activities for each item in the system will be described below.

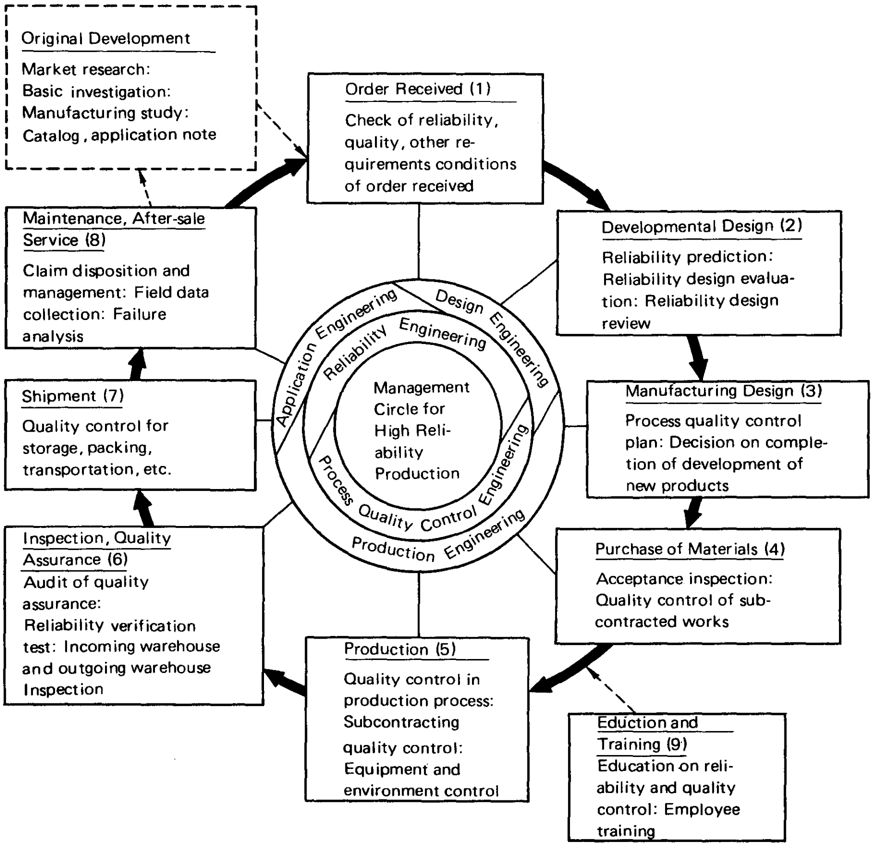


Figure 7. Cycle of Reliability and Quality Control System

3-2. Order Received

In order to manufacture and supply devices which meet the purpose of application, it is essential to build reliability and quality required or expected by the users at large into the design of the devices. Accordingly, prior to the development and order receiving kinds of equipment to be used and environmental conditions, circuit operations and so on, in addition to the performance required and allowable field failure rates must be investigated together with the price, time for delivery and quantity, and then the development plan of new products and new order receiving plan are established.

3-3. Development Design

New product development plan is determined after careful investigations performed by various departments in charge of design, manufacturing engineering reliability and quality control and so forth. According to this development plan, design, trial run and evaluation are performed. Mass production is released only when the evaluation results which are fully satisfactory have been obtained.

At the stage where the design has been completed, design review is performed to exclude defects in the design. In this review, the design is compared with the design standard, and other factors which influence the reliability and quality are examined carefully. As the result of it, if necessary, the design is partially modified or entirely redesigned.

When the design has passed the review, trial run is performed to check whether the product satisfies the required characteristics and reliability, and also to verify the stability in the manufacturing process.

When the pre-production shifts to actual mass production, various kinds of reliability and quality verification test are performed by the reliability and quality control department in accordance with the quality verification system. When it is confirmed that there is no problem in the quality, various standards for the mass production are made, and the mass production is started. Processes described above are shown in Figure 8.

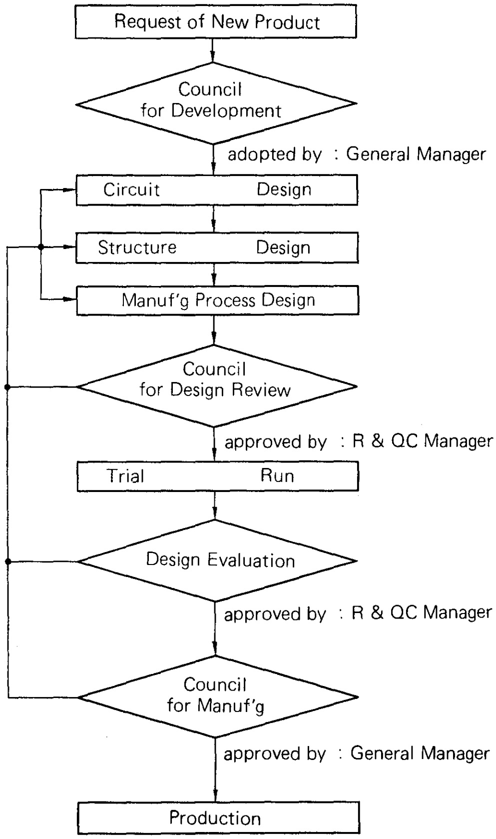


Figure 8. Flow Chart of New Product Development

3-4. Manufacturing Design

When it is confirmed that the quality required can be achieved by the quality verification system, the process shifts to the mass production based on the written mass production plan. Prior to the shift, however, the design department prepares a document for manufacturing plan including the reliability and quality control relating to the manufacturing processes, such as necessary materials, equipment, manufacturing conditions environment and so on, and thus establishes the mass production system. Even after the mass production has started, the standards for the manufacture and control are always re-examined to improve and rationalize them.

3-5. Purchase of Material

Quality of materials and parts purchased is also an important factor which influences the reliability and quality of the final products. Therefore, quality control for those materials and parts is performed carefully and systematically. Purchase specifications have been established, and acceptance test is performed for those materials and parts to be purchased in accordance with the specifications. The test is performed mainly in accordance with sampling methods stipulated in MIL-STD-105.

The acceptance test results are always examined and accumulated for each supplier and devices by the quality control department. If any of the materials and parts does not meet the specifications, NEC does make the supplier improve it.

In addition to the utilization of test results, inspection of the supplier's factory is performed periodically or at any time to assure the required quality and to stabilize it.

3-6. Manufacturing Process

As described above, a plan has been established by which a satisfactory high quality can be expected at the stage of design. Furthermore, at the manufacturing stage, quality control is performed most carefully to maintain the quality aimed at the design. Factors which influence the quality at the manufacturing stage are main materials, subsidiary materials, manufacturing equipment, manufacturing conditions, workers, manufacturing environments and so on. These factors must be controlled at the most suitable conditions.

1) Subsidiary Materials

Subsidiary materials such as high purity gas, chemicals, and deionized water are used in the manufacturing process, and those having quality which is suitable for the purpose of use must be selected. Inert gas to be enclosed in the semiconductor package and other gases such as hydrogen and oxygen to be used in the manufacturing process are purchased from specified manufacturer in accordance with the high purity specifications especially established by NEC. Sometimes gases are directly sent to NEC factory for use through pipe lines extended from the gas manufacturer in order to maintain the purity of gas and for the economy. Chemicals and chemical materials of specific and highest purity are used according to their usage. For instance, chemicals qualified in accordance with "NEC Semiconductor Specifications" which have been specifically established by NEC are used to improve the quality of products, and this procedure has proved quite effective.

2) Manufacturing Equipment

Manufacturing equipment of high precision and stability is used not only to minimize failure rates, but also to reduce the drift in characteristics and to improve the reliability. In addition, automated equipment is used everywhere possible to prevent human errors. This method has proved to be effective especially in the manufacturing of devices and quality inspection. As the maintenance of the manufacturing equipment is essential to keep the stabilized quality, daily check, and periodical check are standarized to keep the precision and to insure normal operation of the equipment. Thus, special care is paid to keep the equipment in its best conditions.

3) Manufacturing Conditions

NEC enforces check of processing conditions everywhere in the manufacturing process in order to perform perfect control of the manufacturing conditions. This is to prevent erroneous processings and malfunctioning of the manufacturing equipment, and is effective for the speedy adjustment of the misprocessing, supported by the intermediate inspection. This check is also executed at the key points in the course of processing on the most effective items at the most effective frequency. Necessary measures are immediately taken according to the check results. The results of check and measures taken are kept in records, which are utilized as the data for the improvement of process control.

4) Manufacturing Environment

Temperature, humidity and dust are important factors influencing the quality. Semiconductor devices are sensitive to these factors, so the stringent control is applied to keep these factors within the required limits throughout the manufacturing processes. Humidity is a quite important factor, since contaminating even the least amount of water influences the quality of the semiconductor devices seriously. Some processings that require an extremely low humidity are carried out in a dry box maintaining the necessary low humidity. Small dirt and dust often affect the semiconductor devices having a minute structure seriously. Therefore, a stringent control corresponding to each grade is necessary to prevent them. In the factory, a control based on stipulations of Fed-STD-209a is applied. For processings that require a specifically high cleanliness, clean room, clean bench, uniform of special make, etc. are adopted. Periodic measurement of dust and dirt in the room and over the clean bench is conducted, and if they do not meet the standards, the processings are stopped or improved.

5) Screening

As the semiconductor element devices have generally sensible structure, even if they may be made under a strict quality control and on a high grade line, some substandard devices which do not meet the quality standards would inevitably be mixed with those of standard quality due to the distribution of materials and parts and processings, as well as the inaccuracy of the manufacturing equipment and other various causes. In order to detect and remove these substandard products, screening is performed.

The screening is classified into two, i.e., an accelerated aging and characteristic selection. The accelerated aging stabilizes characteristics and at the same time detects substandard products by applying voltage, heat, mechanical shock of specified value. After the aging, a complete inspection is performed by physical or electrical measurement to remove substandard products. The screening can remove substandard products which can not be removed only by the characteristic inspection and tends to degrade the quality. Since the stability of characteristics of entire products is increased by the screening, the reliability is effectively improved by it.

3-7. Inspection and Other Quality Assurance Activities

1) Inspection and Quality Assurance Activities

In the manufacture of semiconductor devices, NEC has been making a full and continuous effort in building reliability into the products as has been described above. For this purpose, NEC performs various controls putting emphasis on the key points throughout the entire manufacturing processes, and verifies and assures the quality at the final examination. A variety of automatic measuring instruments is used for the intermediate test in the manufacturing process to obtain high efficiency and at the same time to exclude human errors. Results of the inspection are fed back to the preceeding process as an important quality information to improve the manufacturing procedures.

At the final stage of the manufacturing process, quality assurance test and warehousing inspection are performed to assure the reliability and quality of the products.

In general, the quality assurance test is roughly classified into two, i.e., initial stage characteristic test which assures external view, outline dimension, electrical characteristics and son on, and reliability test which assures life, failure rates, mechanical strength and so on. These tests are performed for almost all of the characteristics to be assured usually. However, when the distribution of characteristics sufficiently surpasses the standards or when the cost of the test is extremely high, the tests are sometimes simplified. Even in this case, verification test is performed periodically at an appropriate interval. Inspection method and inspection item of the quality assurance test and warehousing inspection as the final inspection differ depending on the feature of the products and user's requirements. An example which is closest to the standard test method is shown in Table 3.

Table 3. Sampling Inspection Plan and Average Outgoing Quality for Initial Characteristics

Classification	Item	*Sampling Inspection Plan	Acceptance Limit	Average Outgoing Quality
Major Defect	No Marking, Wrong Configuration Open, Short, etc.	LTPD 1 %	0	AOQ 0.02 %
	Item that affect Reliability most strongly (Breakdown Voltage Leakage Current, etc.)	LTPD 3 %	1	AOQ 0.3 %
Minor Defect	Item that affect Dynamic Characteristic most strongly, and also affect Reliability (h_{FE}, $V_{CE(sat)}$, NV, etc.)	LTPD 5 %	1	AOQ 0.5%
	Item that not affect Reliability much, but affect Dynamic Characteristics (f_T, C_{ob}, etc.)	LTPD 7 %	1	AOQ 1 %
	Item that not affect Reliability or Dynamic Characteristic much (Appearance, etc.)	LTPD 10 %	1	AOQ 2 %

* by MIL-STD-19500 Sampling Inspection Table

2) Other Quality Assurance Activities

Quality control system for the manufacturing of semiconductor devices is as described above, and a number of other quality control activities associated with the system are performed. Of these, a few major activities will be explained below.

(a) Periodic Process Test

Manufacturing process test is performed 1~2 times a month for the purpose of checking the actual condition of standard processing and maintenance condition of the manufacturing equipment and measuring instrument. In this test, the detection and adjustment of discrepancy between the specified processing and actual processing, as well as the check of periodical maintenance and calibration of the manufacturing equipment and measuring instruments are performed. In addition, manufacturing environments such as temperature, humidity, water, gas, dust, etc. are also periodically inspected.

(b) Utilization of Work History

Work history in the manufacturing process is recorded in the work history card. The record is utilized as follows:

(i) Investigation of control condition and feed back of the results to the relevant area
(ii) Analysis of process quality drift
(iii) Analysis of manufacture total yield rate drift
(iv) Statistical investigation of process yield rate
(v) Statistical investigation of manufacture total yield rate
(vi) Lot tracing investigation of rejected devices returned from users
(vii) Statistical control of the loss.

(c) Control of Abnormality

When any abnormality occurred in any stage of incoming, manufacturing and final inspections, it is reported immediately to the reliability and quality control department and also to every other department concerned, and immediate counter-measures are taken.

Figure 9 shows abnormality reporting route. Abnormal lot determination standard is established based on the lot distribution status and reliability. Even after the establishment of the standard, it is periodically checked up with the process capability, and its appropriateness is examined.

Quality control of semiconductor devices in the manufacturing process has been outlined above, and the quality control system is shown in Figure 10.

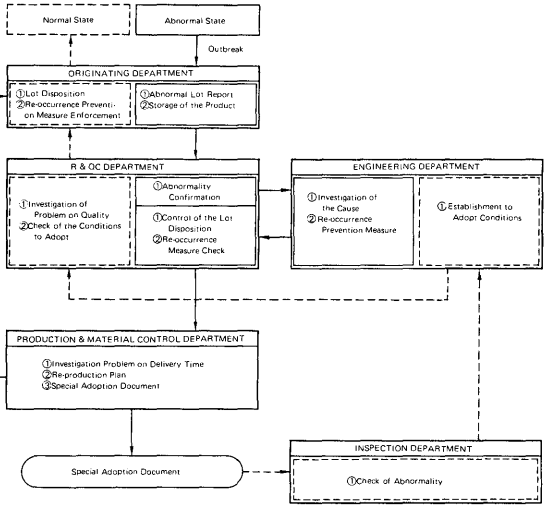


Figure 9. Abnormality Reporting Route

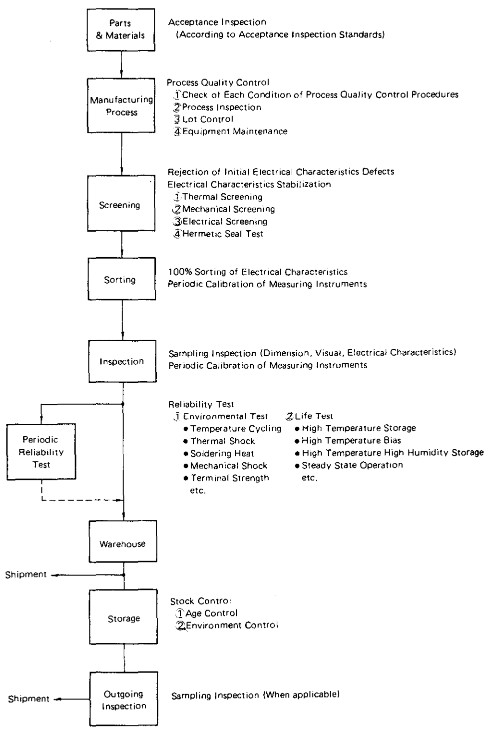


Figure 10(a) General Process Flow Chart

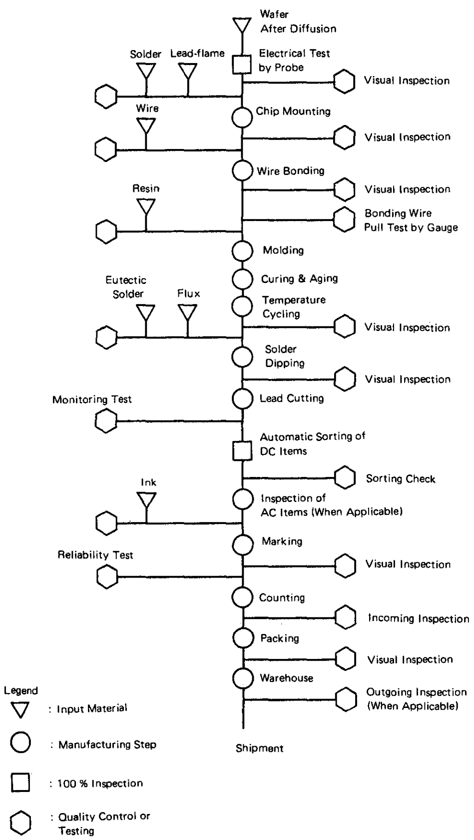


Figure 10(b) Manufacturing Process of Small Signal Transistors

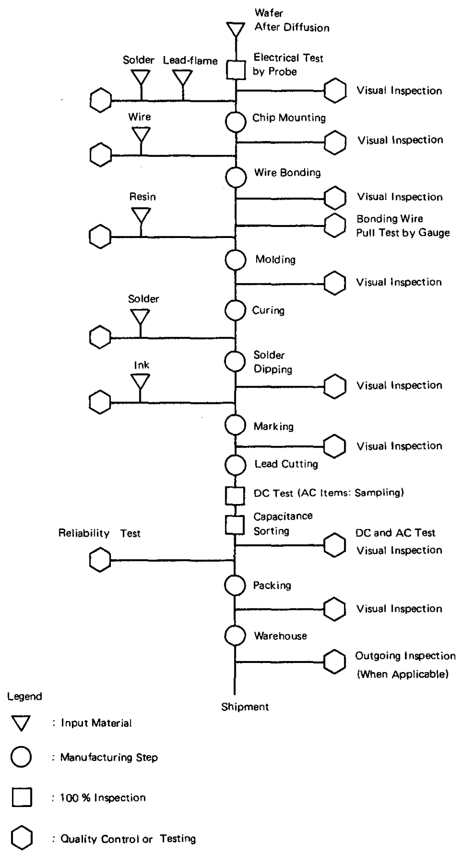


Figure 10(c) Manufacturing Process of Plastic Molded Diodes

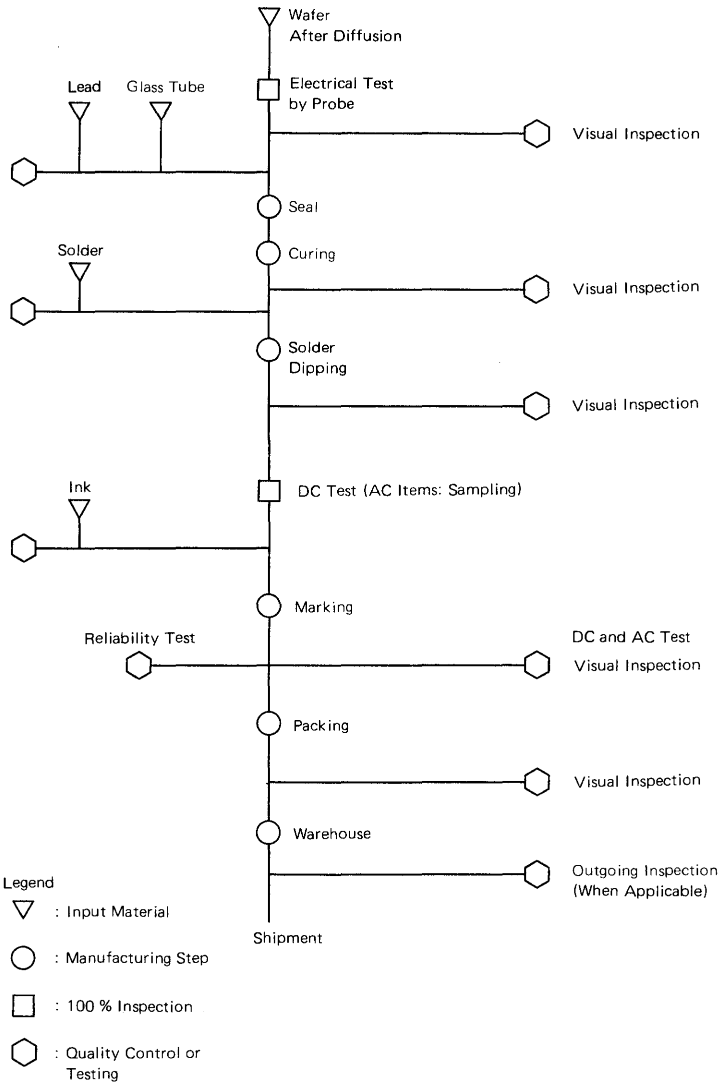


Figure 10(d) Manufacturing Process of Glass Package Diodes

(d) Control System of Engineering Changes

In order that our semiconductor devices may be used with satisfaction by our customers, needless to say stable level of reliability must always be maintained, and in addition, we deem that the improvement of reliability to keep up with the requirements of the times is also an important factor.

In order to create a stable reliability level, strict reliability and quality assurance control is exercised through the aggregation of the feed-forward and feed-back of date of the principal processes that affect the reliability of products, the adoption of improved production methods and structural materials for semiconductor devices in step with the advances of technology, and the study of field data. However, we never rest satisfied with once established standards and are constantly making efforts to improve the reliability of products to meet the requirements of our customers.

When undertaking revisions of the design or manufacturing processes that are brought about by the above improvements, basically the problem is grappled with employing the same idea as when developing and mass producing new product, and thorough evaluation and starting-up control are exercised. Changes in the control system brought about by the above revisions will differ according to the extent of the revision, an example is shown in Figure 11.

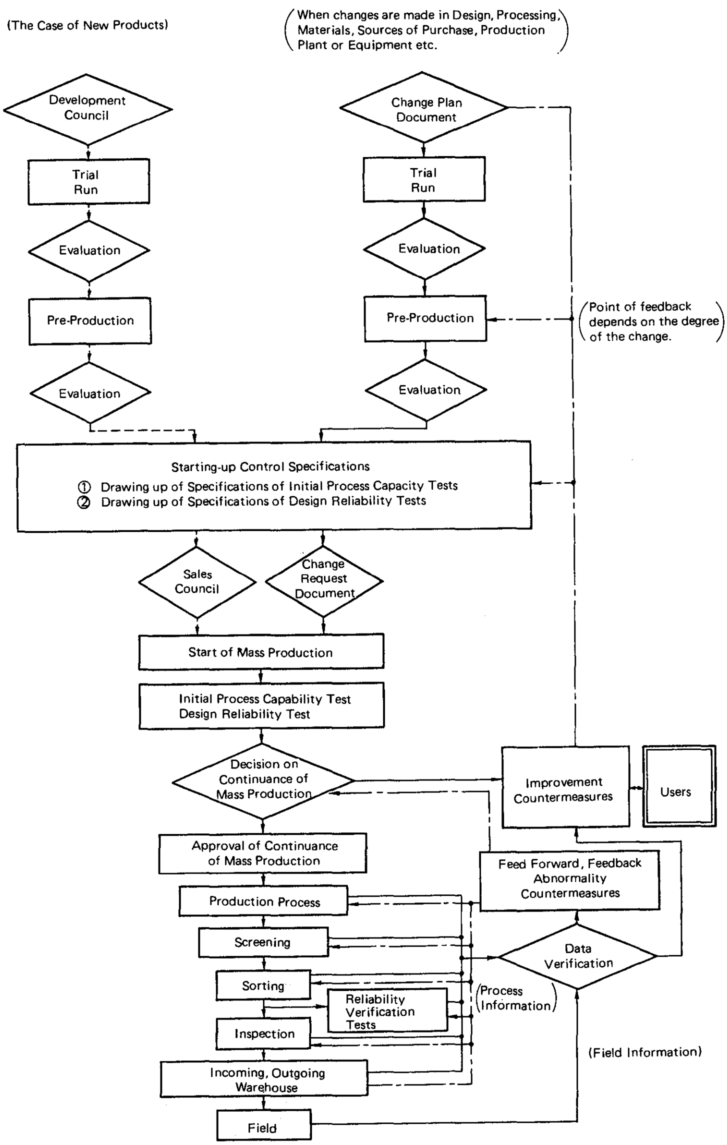


Figure 11. Control System for Engineering Changes

3-8. Shipment

Products which passed the final inspection are put in a container suitable for storage. Each container accommodates a fixed number of products and is stored in the product warehouse. These products are controlled so that they are not stored in the warehouse too long. For shipment, outgoing inspection is performed based on the specification which is set with due care for the quality degradation. Devices are packed up in due method such as individual divice packing, internal and external packing, and are transported in such a best way appropriate for delivery.

The control status of storage and shipment is checked by periodic patrol of the quality control department to find out problems and to correct them.

3-9. After-Sale Service

Field quality information after shipment is an essential factor for improvement of product quality. Especially, investigation of field failure and feed back of the investigation results are the duty and service for customers and also these data serve as direct guides to the improvement of reliability and quality. So best effort has been made on this point.

Devices which have failed after shipment are returned by user's requirement or NEC request. Sales department investigates in detail the devices used, circuit, process to the failure, and failure occurring condition, and makes failure investigation card. The card is sent to the investigation department together with the device failed.

The investigation department investigates characteristics of the returned device and its internal structure to probe into the cause of the failure. The results of the investigation are fed back to the user and departments in charge of manufacture, to obtain a user's consent and to be used for the improvement of quality. Figure 12. shows the route of these processings. Collection of information, investigation and summing up of field failures of semiconductor devices are carried out with cooperation of users, and a large amount of data have been accumulated. Correlation between these data and forced deterioration test, process quality information, inspection results and so on are studied, and good results have been obtained in improving reliability and quality of products.

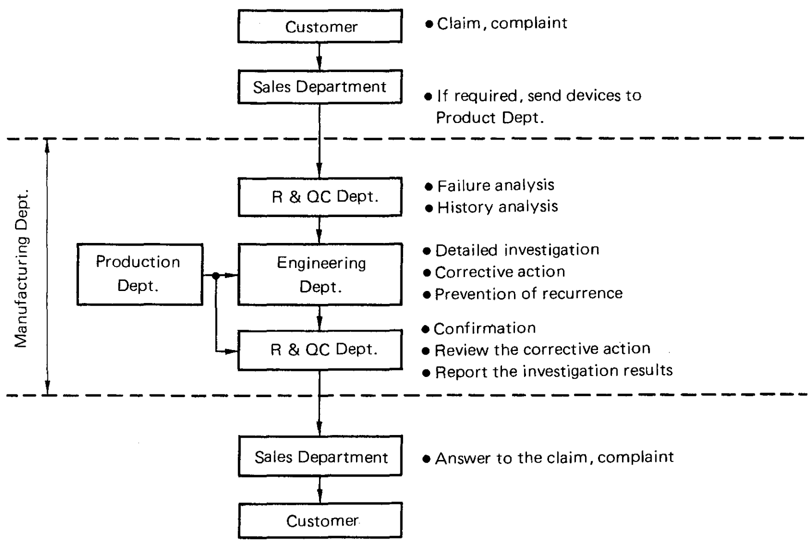


Figure 12. Procedure Route for Claim and Complaint

4. RELIABILITY OF NEC SEMICONDUCTOR DEVICES

4-1. Reliability Test

As described in preceding paragraph, NEC semiconductor devices are designed, manufactured, managed so as to maintain high reliability and quality. Method of reliability test to be performed to verify the reliability will be described below.

The reliability test of semiconductor devices is executed mainly in accordance with MIL-STD-750, MIL-STD-202, JIS-C-7021, etc. Especially for the semiconductor devices, accelerated operating life test at maximum rating is performed, putting emphasis on important points. In addition, high temperature high humidity test and pressurized vapor test are applied as moisture resistance test for the plastic package of which material characteristic is rather important.

4-2. Example of Reliability Test Result

Following data show the reliability test results of NEC semiconductor devices.

These test data are evaluated as a whole together with the number of failures and check results of the characteristic drift occuring as time elapses, and are used for the estimation of field failure rates.

Table 4. Reliability Test (Small Signal Transistors)
(a) Example of Reliability Test (Small Signal Transistors)

Item	Applied Test Method JIS-C-7021	Correlative Test Method		Condition	Number of Samples /Lot	Acceptance Number Ac =
		MIL-STD-202	MIL-STD-750			
Solderability	A–2	208	2026	T_{sol} = 230 °C, 5 sec. Once with Flux	22	0
Soldering Heat	A–1 Condition: A	210 Condition: B	2031	T_{sol} = 260 °C, 10 sec. Once without Flux	22	0
Temperature Cycling	A–4	107	1051	T_{stg} min. ~ T_{stg} max. 30 min., 30 min. 30 cycles	100	0
Thermal Shock	A–3 Method: II	–	1056 Condition: B	Ta = 100 ~ 0 °C 5 min., 5 min., 5 cycles	22	0
Terminal Strength (Lead Fatigue)	–	211 Condition: C	2036 Condition E	W = 227 g, 90 ° 3 times	11	0
Salt Spray	A–12 Condition: B	101	1042	Ta = 35 °C, 5% 24 hours	11	0
Steady-State Operation	B–4	–	1026	Ta = 25 °C, P_T max. 1000 hours	20	0
High Temperature Storage	B–10	108	1031	T_{stg} max. 1000 hours	20	0
Low Temperature Storage	B–12	–	–	T_{stg} min. 1000 hours	20	0
High Temperature High Humidity Storage	B–11 Condition: B or C	103	–	Ta=60 °C, RH=90%, 1000 hours or Ta=85 °C, RH=85%, 500 hours	20	0
Pressure * Cooker	–	–	–	Ta = 125 °C, RH=100% 2.3 atm., 24 hours	22	0
Boiling *	–	–	–	Ta = 100 °C, 24 hours In Tap Water	22	0
Bomb *	–	–	–	Ta = 25 °C, 3.5 atm. 24 hours	22	0
High Temperature* Reverse Bias	B–8	–	–	T_{stg} max., 1000 hours V_{CB} max. × 0.8	20	0

* When applicable, this test is performed.

(b) Failure Criterion (Small Signal Transistors)

Parameter	Symbol	Life End Limit		Unit
		MIN.	MAX.	
Collector Cutoff Current	I_{CBO}	–	USL x 2	μA
Emitter Cutoff Current	I_{EBO}	–	USL x 2	μA
DC Current Gain	h_{FE}	LSL x 0.8	USL x 1.2	–
h_{FE} Variation Ratio	Δh_{FE}	–25	+50	%

Note 1) USL: Upper Specification Limit
2) LSL: Lower Specification Limit
3) Δh_{FE} = Initial Value/After Test Value

(c) Environmental Test Result (Small Signal Transistors)

Item	Condition	Type No.			
		2SC945		2SA733	
		Number of Samples	Number of Failure	Number of Samples	Number of Failure
Solderability	T_{sol}=230 °C, 5 s Once with Flux	352	0	352	0
Soldering Heat	T_{sol} = 260 °C, 5 s Once without Flux	352	0	352	0
Temperature Cycling	T_{stg} = –55 ~ +125 °C 30 min., 30 min., 30 cycles	1600	0	1600	0
Thermal Shock	Ta = 0 ~ 100 °C 5 min., 5 min., 5 cycles	352	0	352	0
Terminal Strength (Lead Fatigue)	W=227 g, 90 °C 3 times	176	0	176	0
Salt Spray	Ta=35 °C, 5 % 24 hours	176	0	176	0
Pressure Cooker	Ta = 125 °C, RH = 100% 2.3 atm., 24 hours	660	0	660	0
Boil	Ta = 100 °C, 24 hours Tap Water	1320	0	1320	0
Bomb	Ta = 25 °C, 3.5 atm. 24 hours	1320	0	1320	0

(d) Life Test Result (Small Signal Transistors)

Item	Condition **	2SC945				2SA733			
		Number of Samples	Total Test Time (h)	Number of Failure	Failure Rate* (%/1000 h)	Number of Samples	Total Test Time (h)	Number of Failure	Failure Rate* (%/1000 h)
Steady-State Operation	Ta = 25 °C, P_T = 250 mW V_{CB} = 25 V, 1000 hours	1200	1.2×10^6	0	0.076	1200	1.2×10^6	0	0.076
High Temperature Storage	Ta = 125 °C, 1000 hours	1200	1.2×10^6	0	0.076	1200	1.2×10^6	0	0.076
Low Temperature Storage	Ta = –55 °C, 1000 hours	1200	1.2×10^6	0	0.076	1200	1.2×10^6	0	0.076
High Temperature High Humidity Storage	Ta = 60 °C, RH = 90 % 1000 hours	1200	1.2×10^6	0	0.076	1200	1.2×10^6	0	0.076
High Temperature Reverse Bias	Ta = 125 °C, V_{CB} = 25 V 1000 hours	600	0.6×10^6	0	0.150	600	0.6×10^6	0	0.150

* Confidence Level : 60%
** Negative sign for PNP type is omitted.

Table 5. Reliability Test (Plastic Molded Diodes)

(a) Example of Reliability Test (Plastic Molded Diodes)

Item	Applied Test Method JIS-C-7021	Correlative Test Method		Condition	Number of Samples /Lot	Acceptance Number Ac =
		MIL-STD-202	MIL-STD-750			
Solderability	A–2	208	2026	T_{sol}=230 °C, 5 s Once with Flux	22	0
Temperature Cycling	A–4	107	1051	T_{stg} min. ~ T_{stg} max. 30 min., 30 min. 30 cycles	22	0
Thermal Shock	A–3 Method: II	–	1056 Condition: B	Ta = 100 ~ 0 °C 5 min., 5 min., 5 cycles	22	0
Mechanical Shock	A–7 Condition: F	213	2016	1500G, 0.5 ms., 3 times Each direction of X, Y and Z Axis	22	0
Vibration (Variable Frequency)	A–10 Condition: D	–	2056	100 ~ 2000 ~ 100 Hz, 20 G 4 min., 4 times, Each direction	22	0
Terminal Strength (Lead Fatigue)	–	211 Condition: C	2036 Condition: E	W = 227 g, 90 ° 3 times	11	0
Salt Spray	A–12 Condition: B	101	1041	Ta = 35 °C, 5% 24 hours	11	0
High Temperature Storage	B–10	108	1031	T_{stg} max. 1000 hours	20	0
Low Temperature Storage	B–12	–	–	T_{stg} min. 1000 hours	20	0
High Temperature Reverse Bias	B–13	–	–	Specified V_R, Ta 1000 hours	20	0
High Temperature High Humidity Reverse Bias	–	–	–	Specified V_R, Ta, RH 1000 hours	20	0

(b) Failure Criterion (Plastic Molded Diodes)

Parameter	Symbol	Life End Limit		Unit
		MIN.	MAX.	
Reverse Current	I_R	–	USL x 2	μA
Forward Voltage	V_F	–	USL x 1.1	V

Note USL : Upper Specification Limit

(c) Environmental Test Result (Plastic Molded Diodes)

Item	Condition	1S2208	
		Number of Samples	Number of Failure
Solderability	T_{sol} = 230 °C, 5 sec. Once with Flux	286	0
Temperature Cycling	T_{stg} = −65 ~ +125 °C 30 min., 30 min., 5 cycles	286	0
Thermal Shock	T_a = 0 ~ 100 °C 5 min., 5 min., 5 cycles	286	0
Mechanical Shock	1500G, 0.5 ms., 3 times Each direction of X, Y and Z Axis	286	0
Vibration (Variable Frequency)	100 ~ 2000 ~ 100 Hz, 20G 4 min., 4 times Each direction of X, Y and Z Axis	286	0
Terminal Strength (Lead Fatigue)	W=227 g, 90 °C 3 times	143	0
Salt Spray	Ta = 35 °C, 5 % 24 hours	143	0

(d) Life Test Result (Plastic Molded Diodes)

Item	Condition	Type No. 1S2208			
		Number of Samples	Total Test Time (h)	Number of Failure	Failure Rate* (%/1000 h)
High Temperature Storage	Ta = 125 °C, 1000 h	260	2.6 x 10^5	0	0.35
Low Temperature Storage	Ta = −65 °C, 1000 h	260	2.6 x 10^5	0	0.35
High Temperature Reverse Bias	Ta = 125 °C, V_R = 28V 1000 h	260	2.6 x 10^5	0	0.35
High Temperature High Humidity Reverse Bias	Ta = 40 °C, RH = 90 % V_R = 28 V, 1000 h	260	2.6 x 10^5	0	0.35

* Confidence Level : 60 %

Table 6. Reliability Test (Glass Package Diodes)

(a) Example of Reliability Test (Glass Package Diodes)

Item	Applied Test Method JIS-C-7021	Correlative Test Method MIL-STD-202	Correlative Test Method MIL-STD-750	Condition	Number of Samples /Lot	Acceptance Number Ac =
Soldering Heat	A–1 Condition: A	210 Condition: B	2031	T_{sol}=260 °C, 10 s Once without Flux	22	0
Temperature Cycling	A–4	107	1051	T_{stg} min. ~ T_{stg} max. 30 min., 30 min. 5 cycles	22	0
Thermal Shock	A–3 Method: II	–	1056 Condition: B	Ta = 100 ~ 0 °C 5 min., 5 min., 5 cycles	22	0
Moisture Resistance (Cyclic)	A–5 Method: I	106	1021	Specified Condition (Ta, RH), 10 cycles	22	0
Mechanical Shock	A–7 Condition: F	213	2016	1500G, 0.5 ms., 3 times Each direction of X, Y and Z Axis	22	0
Vibration (Variable Frequency)	A–10 Condition: D	–	2056	100 ~ 2000 ~ 100 Hz, 20 G 4 min., 4 times, Each direction of X, Y and Z Axis	22	0
Constant Accelation	A–9 Condition: A	212	2006	20000G, 1 min. Each direction of X, Y and Z Axis	22	0
Terminal Strength (Lead Fatigue)	–	211 Condition: C	2036 Condition: E	W = 227 g, 90 ° 3 times	11	0
Salt Spray	A–12 Condition: B	101	1041	Ta = 35 °C, 5% 24 hours	11	0
Steady-State Operation	B–2	–	1026	Ta = 25 °C Specified I_O, V_R 1000 hours	20	0
High Temperature Storage	B–10	108	1031	T_{stg} max. 1000 hours	20	0
Low Temperature Storage	B–12	–	–	T_{stg} min. 1000 hours	20	0

(b) Failure Criterion (Glass Package Diodes)

Parameter	Symbol	Life End Limit MIN.	Life End Limit MAX.	Unit
Reverse Current	I_R	–	USL x 2	μA
Forward Voltage	V_F	–	USL x 1.1	V

Note USL : Upper Specification Limit

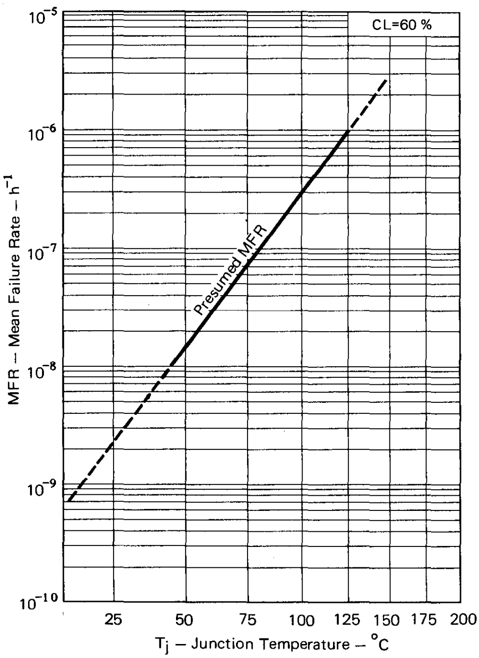
(c) Environmental Test Result (Glass Package Diodes)

Item	Condition	1S953		1SS53	
		Number of Samples	Number of Failure	Number of Samples	Number of Failure
Soldering Heat	T_{sol} = 260 °C, 10 s Once without Flux	264	0	264	0
Temperature Cycling	T_{stg} = −65 ~ +125 °C 30 min., 30 min., 5 cycles	264	0	264	0
Thermal Shock	T_a = 0 ~ 100 °C 5 min., 5 min., 5 cycles	264	0	264	0
Moisture Resistance (Cyclic)	Specified Condition 10 cycles	264	0	264	0
Mechanical Shock	1500G, 0.5 ms., 3 times Each direction of X, Y and Z Axis	264	0	264	0
Vibration (Variable Frequency)	100 ~ 2000 ~ 100 Hz, 20G 4 min., 4 times Each direction of X, Y and Z Axis	264	0	264	0
Constant Accelation	20000 G, 1 min. Each direction of X, Y and Z Axis	264	0	264	0
Terminal Strength (Lead Fatigue)	W=227 g, 90 °C 3 times	132	0	132	0
Salt Spray	Ta = 35 °C, 5 % 24 hours	132	0	132	0

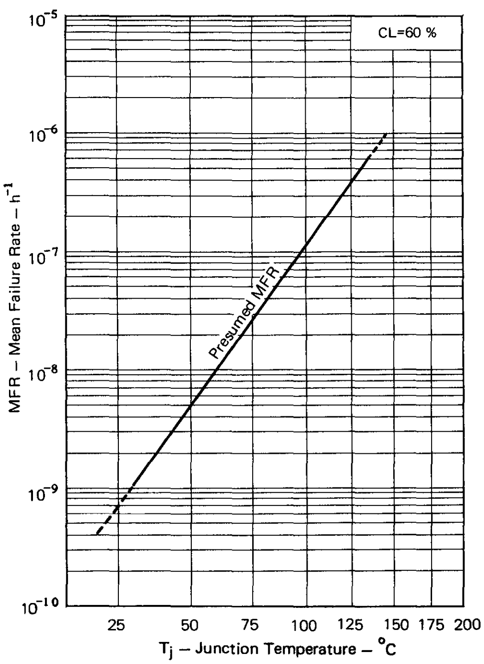
(d) Life Test Result (Glass Package Diodes)

Item	Condition	1S953				1SS53			
		Number of Samples	Total Test Time (h)	Number of Failure	Failure Rate* (%/1000 h)	Number of Samples	Total Test Time (h)	Number of Failure	Failure Rate* (%/1000 h)
Steady-State Operation	Ta = 25 °C, I_O = 100 mA V_R = 35 V, 1000 hours	560	5.6 x 10^5	0	0.16	880	8.8 x 10^5	0	0.10
High Temperature Storage	Ta = 200 °C, 1000 hours	560	5.6 x 10^5	0	0.16	1520	15.2 x 10^5	0	0.06
Low Temperature Storage	Ta = −65 °C, 1000 hours	560	5.6 x 10^5	0	0.16	680	6.8 x 10^5	0	0.13

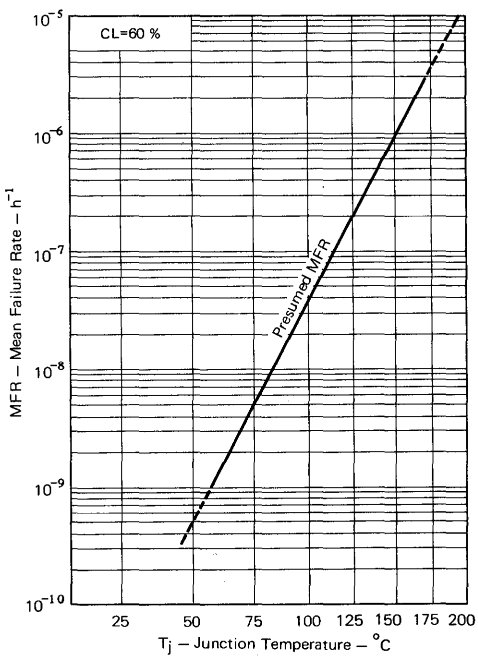
* Confidence Level : 60%



(a) Small Signal Transistors



(b) Plastic Molded Diodes



(c) Glass Package Diodes

Figure 13. Presumed Mean Failure Rate

4-3. Procedure of Failure Analysis

We analyze the failed semiconductor devices found in manufacturing process, reliability verification test and field use by following procedure in Figure 14.

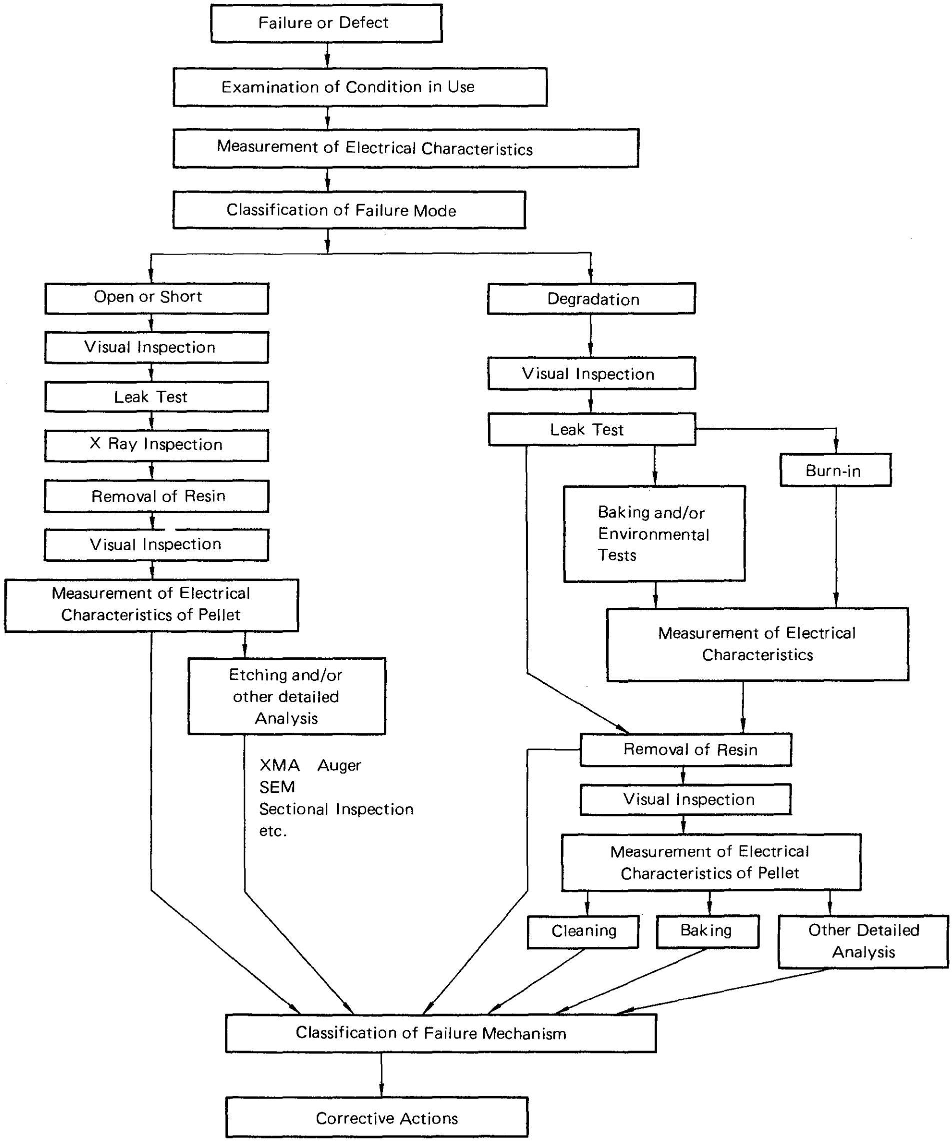


Figure 14. Procedure of Failure Analysis

5. USE OF SEMICONDUCTOR DEVICES TO MAINTAIN RELIABILITY

External factors that influence reliability of semiconductor devices are voltage, current, power, temperature, humidity, dust, gas, vibration, shock, radiation, etc. Influential factors are so varied that if the devices are used improperly, expected reliability will not come true, no matter how reliably they were designed and manufactured.

As shown in Figure 6, 1/3~2/3 of the failed semiconductor devices in use were chiefly damaged by some surge or other, and this is consipicuous among the failures. Therefore, careful attention should be given to the following points in order to use the devices, without hurting their inherent reliability.

(1) The most important factor influencing the reliability of the devices is the temperature generated at the junction region in actual applications. Therefore, for the increase of reliability, it is very effective to enhance heat dissipation capability by using radiators or to decrease temperature rise in an equipment by improving the mounting of devices.

(2) When power consumption is performed in pulses, it is necessary to see that the power or voltage does not exceed the absolute maximum ratings of the devices at the transient. In particular, when inductive loads such as relays or transformers are used, induced high voltage or surge is liable to be generated at ON-OFF operation of such devices. So it is very important to pay special attention to these points. Some devices have protection circuits to meet these conditions.

(3) When power consumption is the same, a high operating voltage usually causes a high failure rate. An example shows that when the voltage applied to a transistor was decreased to 50 % of absolute maximum rating, the failure rate reached 1/20 ~ 1/50.

(4) It is absolutely necessary to avoid bending strongly the roots of leads of semiconductor devices when assembling or checking them. It is because glass or resin is always used at the roots of these leads. If stress is given to those parts, the reliability of the devices will be deteriorated.

(5) In soldering, semiconductor devices must not be heated hastily at a high temperature or for a long time.

(6) For the semiconductor devices with mounting stud, the recommended torque value must be observed by using a torque wrench or other means; because too weak fastening will cause poor heat dissipation, and too strong fastening will cause semiconductor devices severe damages.

(7) A semiconductor device is an element that is extremely sensitive to humidity. Therefore, it is important to use such a device packed in an appropriate material suited for the degree of ambient humidity and expected reliability.

(8) The environment in which semiconductor devices are directly exposed to dust and dirt salt, or acid gas such as SO_2 gas may be usually the cause of leakage between leads and elements or rust.

Contents

NEC
ELECTRON DEVICE

NPN SILICON TRANSISTORS
2N3903, 2N3904

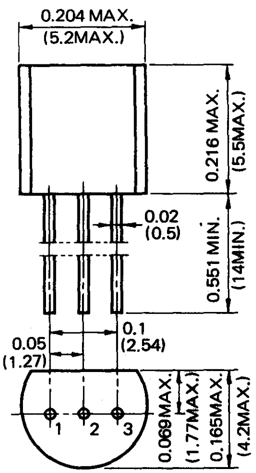
GENERAL PURPOSE SWITCHING AND AMPLIFIER NPN SILICON EPITAXIAL TRANSISTOR

2

DESCRIPTION

The 2N3903, 2N3904 are NPN transistors, designed for general purpose switching and amplifier application, feature injection-molded plastic package for high reliability.

PACKAGE DIMENSIONS
in inches (millimeters)



1. Emitter
2. Base
3. Collector JEDEC:TO-92

FEATURES

- High Power . . . . . P_T 625mW at 25°C
- High Voltage . . . . V_{CEO} 40V
- High DC Current Gain . . . . . h_{FE} 100~300 at 10mA (2N3904)
- For Complementary Use with PNP Type 2N3905, 2N3906

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta=25°C)			
Collector to Base Voltage ($R_{BE}=\infty$)	V_{CBO}	60	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	40	V
Emitter to Base Voltage	V_{EBO}	6.0	V
Collector Current	I_C	200	mA
Maximum Power Dissipation (Ta=25°C)			
Collector Power Dissipation	P_C	625 310	mW*1 mW*2
Derate above 25°C		5 2.81	mW/°C*1 mW/°C*2
Maximum Temperatures			
Storage Temperature	Tstg	−65 to 150 −55 to 135	°C*1 °C*2
Operating Junction Temperature	T_j	150 135	°C*1 °C*2
Thermal Resistance			
Junction to Ambient	Rth	0.2	°C/mW

*1 NEC guarantees these values in addition to the JEDEC registered values.

*2 JEDEC registered values.

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

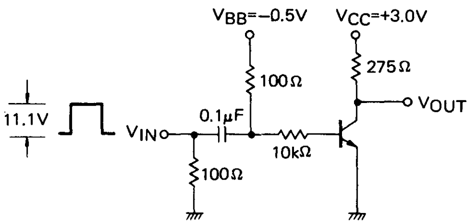
CHARACTERISTIC	SYMBOL	2N3903		2N3904		UNIT	TEST CONDITIONS
		MIN.	MAX.	MIN.	MAX.		
Collector-Base Breakdown Voltage	BV_{CBO}	60		60		V	I_C=10μA, I_E=0
Collector-Emitter Breakdown Voltage	BV_{CEO}*3	40		40		V	I_C=1.0mA, I_B=0
Emitter-Base Breakdown Voltage	BV_{EBO}	6.0		6.0		V	I_E=10μA, I_C=0
Collector Cutoff Current	I_{CEX}		50		50	nA	V_{CE}=30V, V_{BE}=–3V
Base Cutoff Current	I_{BEX}		–50		–50	nA	V_{CE}=30V, V_{BE}=–3V
DC Current Gain	h_{FE1}*3	20		40			V_{CE}=1.0V, I_C=100μA
	h_{FE2}*3	35		70			V_{CE}=1.0V, I_C=1mA
	h_{FE3}*3	50	150	100	300		V_{CE}=1.0V, I_C=10mA
	h_{FE4}*3	30		60			V_{CE}=1.0V, I_C=50mA
	h_{FE5}*3	15		30			V_{CE}=1.0V, I_C=100mA
Collector Saturation Voltage	$V_{CE(sat)1}$*3		0.2		0.2	V	I_C=10mA, I_B=1.0mA
	$V_{CE(sat)2}$*3		0.3		0.3	V	I_C=50mA, I_B=5.0mA
Base Saturation Voltage	$V_{BE(sat)1}$*3	0.65	0.85	0.65	0.85	V	I_C=10mA, I_B=1.0mA
	$V_{BE(sat)2}$*3		0.95		0.95	V	I_C=50mA, I_B=5.0mA
Gain Bandwidth Product	f_T	250		300		MHz	V_{CE}=20V, I_C=10mA
Output Capacitance	C_{ob}		4.0		4.0	pF	V_{CB}=5.0V, I_E=0, f=100kHz
Input Capacitance	C_{ib}		8.0		8.0	pF	V_{EB}=0.5V, I_C=0, f=100kHz
Input Impedance	h_{ie}	1.0	8	1.0	10	kΩ	V_{CE} = 10V, I_C = 1mA, f = 1kHz
Voltage Feedback Ratio	h_{re}	0.1	5.0	0.5	8.0	$x10^{-4}$	
Small Signal Current Gain	h_{fe}	50	200	100	400		
Output Admittance	h_{oe}	1.0	40	1.0	40	μ℧	
Noise Figure	NF		6.0		5.0	dB	V_{CE}=5.0V, I_C=0.1mA, R_G=1kΩ, f=10Hz to 15.7 kHz

*3 These parameters must be measured pulse techniques. $t_w \leq 300$ μs, duty cycle $\leq$ 2%

SWITCHING CHARACTERISTICS (Ta = 25 °C)

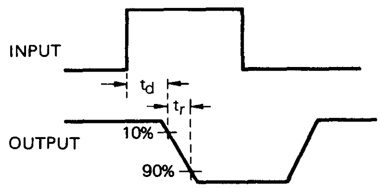
CHARACTERISTIC	SYMBOL	2N3903		2N3904		UNIT	TEST CONDITIONS
		MIN.	MAX.	MIN.	MAX.		
Delay Time	t_d		35		35	ns	V_{CC}=3V, V_{BB}=−0.5V I_C=10mA, I_{B1}=1.0mA
Rise Time	t_r		35		35	ns	
Storage Time	t_{stg}		175		200	ns	V_{CC}=3V, I_C=10mA I_{B1}=−I_{B2}=1mA
Fall Time	t_f		50		50	ns	

SWITCHING TIME TEST CIRCUIT

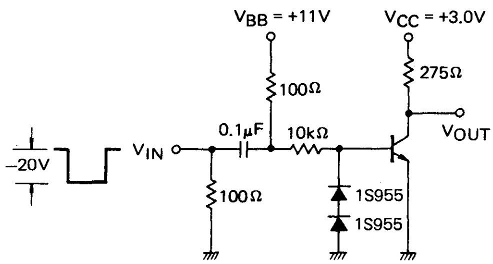


t_r < 1.0 ns
PW ≧ 300 ns
Duty cycle = 2%

t_{on} SWITCHING

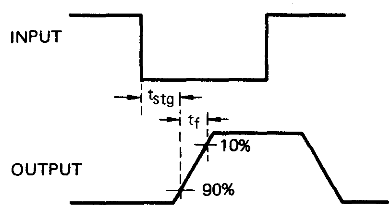


VOLTAGE WAVEFORMS



t_r < 9.0 ns
PW ≧ 300 ns
Duty cycle = 2%

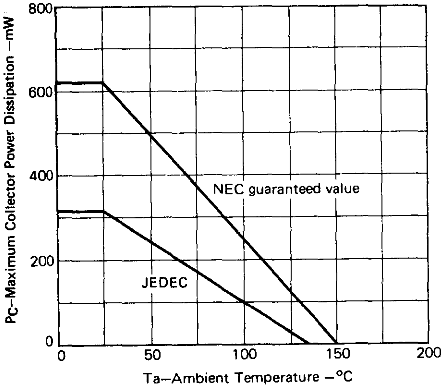
t_{off} SWITCHING



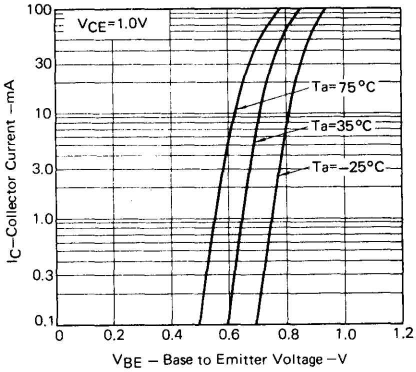
VOLTAGE WAVEFORMS

TYPICAL CHARACTERISTICS (Ta = 25°C)

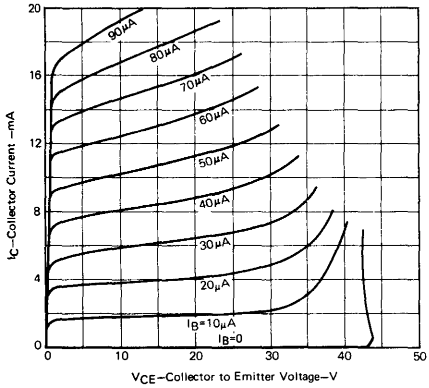
COLLECTOR POWER DISSIPATION vs. AMBIENT TEMPERATURE



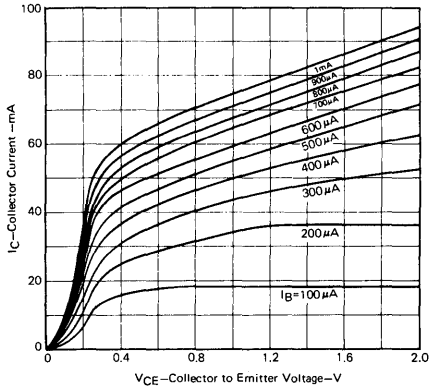
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



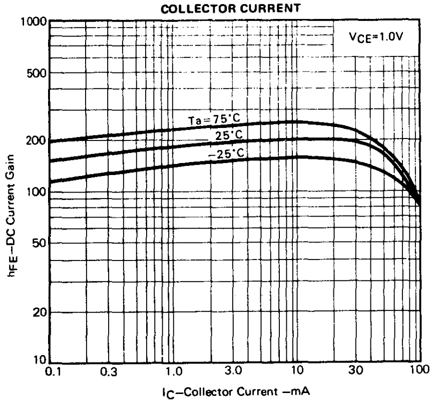
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



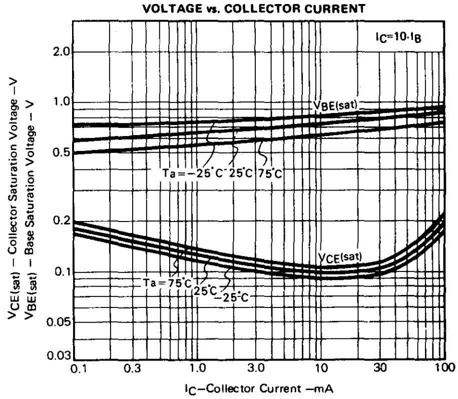
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



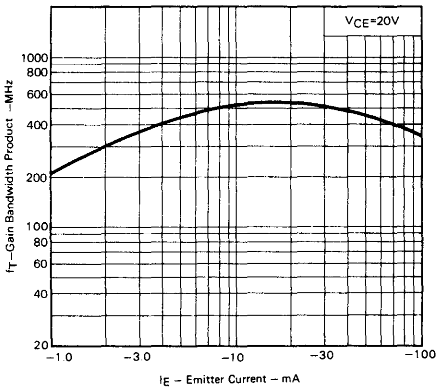
DC CURRENT GAIN vs. COLLECTOR CURRENT



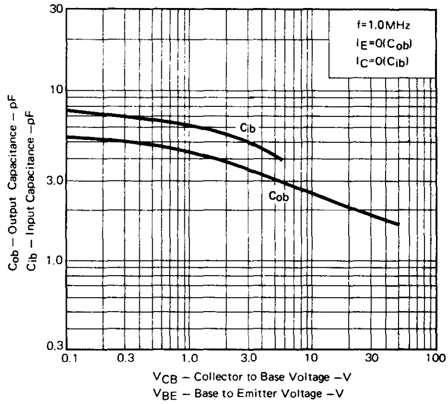
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



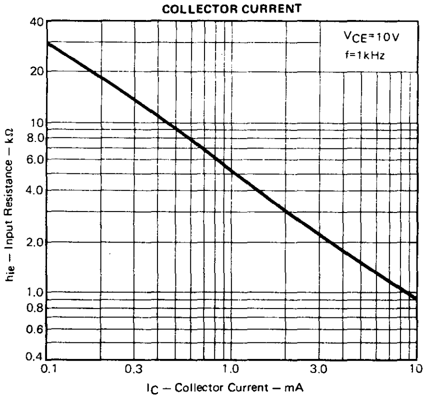
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



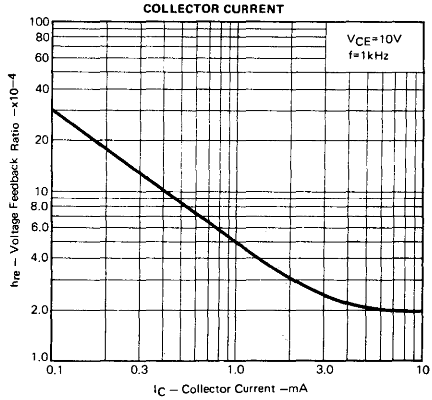
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



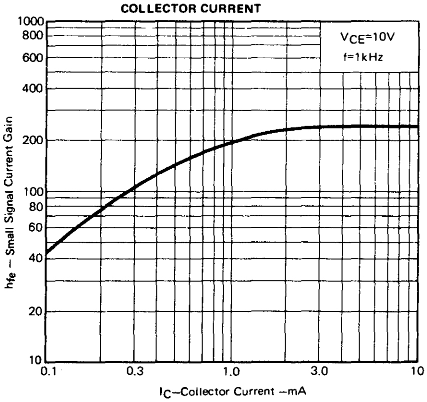
INPUT RESISTANCE vs. COLLECTOR CURRENT



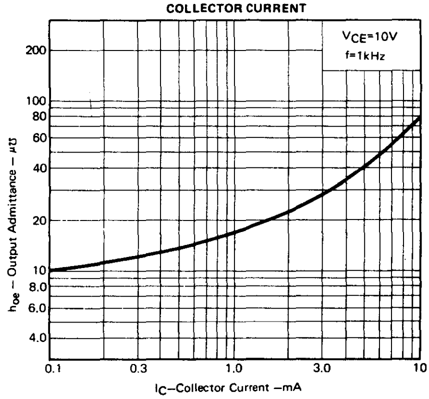
VOLTAGE FEEDBACK RATIO vs. COLLECTOR CURRENT



SMALL SIGNAL CURRENT GAIN vs. COLLECTOR CURRENT

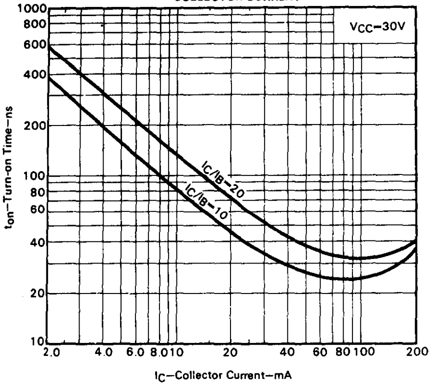


OUTPUT ADMITTANCE vs. COLLECTOR CURRENT

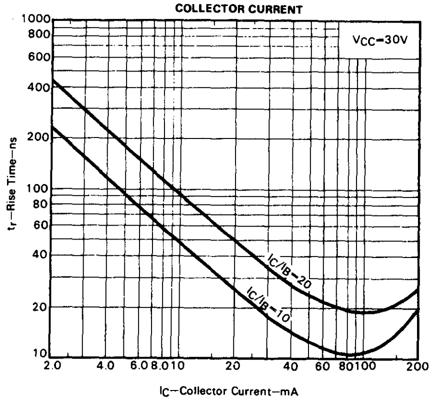


2

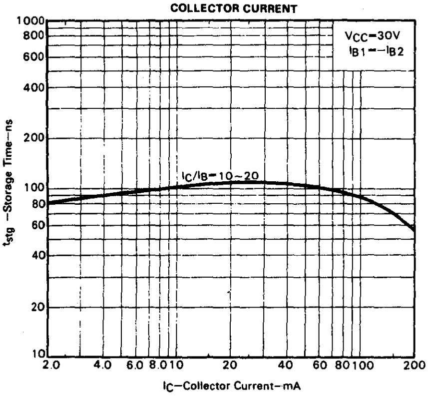
TURN-ON TIME vs.
COLLECTOR CURRENT



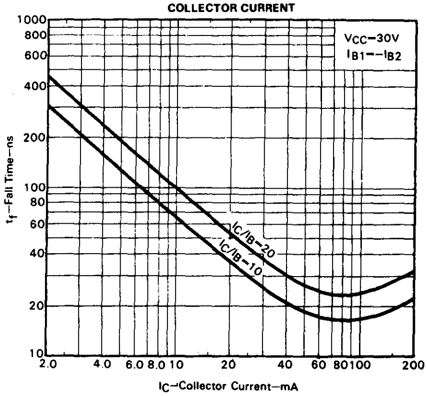
RISE TIME vs.
COLLECTOR CURRENT



STORAGE TIME vs.
COLLECTOR CURRENT



FALL TIME vs.
COLLECTOR CURRENT



NEC
ELECTRON DEVICE

PNP SILICON TRANSISTORS
2N3905, 2N3906

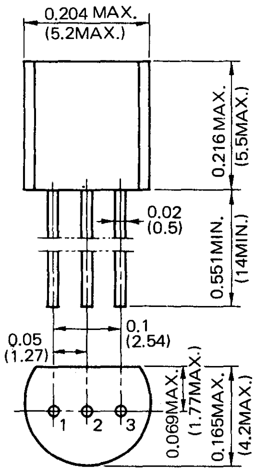
GENERAL PURPOSE SWITCHING AND AMPLIFIER PNP SILICON EPITAXIAL TRANSISTOR

2

DESCRIPTION

The 2N3905, 2N3906 are PNP transistors, designed for general purpose switching and amplifier application, feature injection-molded plastic package for high reliability.

PACKAGE DIMENSIONS
in inches (millimeters)



1. Emitter
2. Base
3. Collector   JEDEC:TO-92

FEATURES

- High Power . . . . . P_T 625mW at 25° C
- High Voltage . . . . . V_{CEO} −40V
- High DC Current Gain h_{FE} 100 ~ 300 at −10mA (2N3906)
- For Complementary Use with NPN Type 2N3903, 2N3904

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta = 25°C)			
Collector to Base Voltage ($R_{BE}=\infty$)	V_{CBO}	−40	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	−40	V
Emitter to Base Voltage	V_{EBO}	−5.0	V
Collector Current	I_C	−200	mA
Maximum Power Dissipation (Ta=25°C)			
Collector Power Dissipation	P_C	625	mW*1
		310	mW*2
Derate above 25°C		5	mW/°C*1
		2.81	mW/°C*2
Maximum Temperatures			
Storage Temperature	Tstg	−65 to 150	°C*1
		−55 to 135	°C*2
Operating Junction Temperature	T_j	150	°C*1
		135	°C*2
Thermal Resistance			
Junction to Ambient	Rth	0.2	°C/mW

*1 NEC guarantees these values in addition to the JEDEC registered values.

*2 JEDEC registered values.

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	2N3905 MIN.	2N3905 MAX.	2N3906 MIN.	2N3906 MAX.	UNIT	TEST CONDITIONS
Collector-Base Breakdown Voltage	BV_{CBO}	−40		−40		V	I_C=−10μA, I_E=0
Collector-Emitter Breakdown Voltage	BV_{CEO}*3	−40		−40		V	I_C=−1.0mA, I_B=0
Emitter-Base Breakdown Voltage	BV_{EBO}	−5.0		−5.0		V	I_E=−10μA, I_C=0
Collector Cutoff Current	I_{CEX}		−50		−50	nA	V_{CE}=−30V, V_{BE}=3.0V
Base Cutoff Current	I_{BEX}		50		50	nA	V_{CE}=−30V, V_{BE}=3.0V
DC Current Gain	h_{FE1}*3	30		60			V_{CE}=−1.0V, I_C=−0.1mA
	h_{FE2}*3	40		80			V_{CE}=−1.0V, I_C=−1.0mA
	h_{FE3}*3	50	150	100	300		V_{CE}=−1.0V, I_C=−10mA
	h_{FE4}*3	30		60			V_{CE}=−1.0V, I_C=−50mA
	h_{FE5}*3	15		30			V_{CE}=−1.0V, I_C=−100mA
Collector Saturation Voltage	$V_{CE(sat)1}$*3		−0.25		−0.25	V	I_C=−10mA, I_B=−1.0mA
	$V_{CE(sat)2}$*3		−0.4		−0.4	V	I_C=−50mA, I_B=−5.0mA
Base Saturation Voltage	$V_{BE(sat)1}$*3	−0.65	−0.85	−0.65	−0.85	V	I_C=−10mA, I_B=−1.0mA
	$V_{BE(sat)2}$*3		−0.95		−0.95	V	I_C=−50mA, I_B=−5.0mA
Gain Bandwidth Product	f_T	200		250		MHz	V_{CE}=−20V, I_C=−10mA
Output Capacitance	C_{ob}		4.5		4.5	pF	V_{CB}=−5.0V, I_E=0, f=100 kHz
Input Capacitance	C_{ib}		10		10	pF	V_{EB}=−0.5V, I_C=0, f=100kHz
Input Impedance	h_{ie}	0.5	8.0	2.0	12	kΩ	V_{CE}=−10V I_C=−1.0mA f=1.0kHz
Voltage Feedback Ratio	h_{re}	0.1	5.0	1.0	10	$x10^{-4}$	
Small Signal Current Gain	h_{fe}	50	200	100	400		
Output Admittance	h_{oe}	1.0	40	3.0	60	μ℧	
Noise Figure	NF		5.0		4.0	dB	V_{CE}=−5V, I_C=−0.1mA R_G=1kΩ, f=10Hz to 15.7kHz

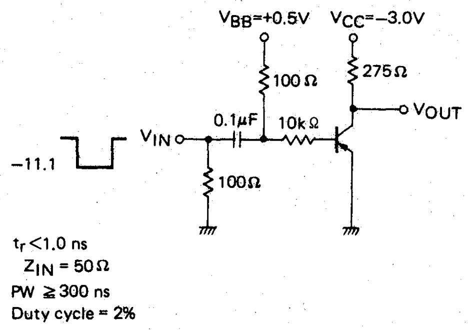
*3 These parameters must be measured pulse techniques. tw≦300μs, duty cycle≦2%

SWITCHING CHARACTERISTICS (Ta=25°C)

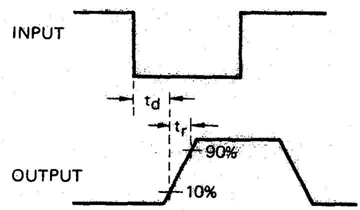
CHARACTERISTIC	SYMBOL	2N3905		2N3906		UNIT	TEST CONDITIONS
		MIN.	MAX.	MIN.	MAX.		
Delay Time	t_d		35		35	ns	V_{CC}=−3V, V_{BB}=0.5V
Rise Time	t_r		35		35	ns	I_C=−10mA, I_{B1}=−1.0mA
Storage Time	tstg		200		225	ns	V_{CC}=−3V, I_C=−10mA
Fall Time	tf		60		75	ns	I_{B1}=−I_{B2}=−1.0mA

2

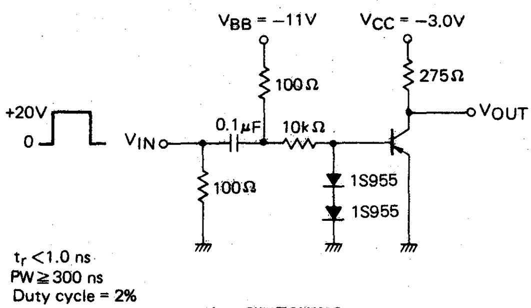
SWITCHING TIME TEST CIRCUIT



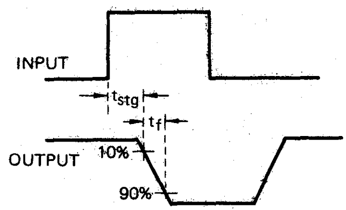
t_{on} SWITCHING



VOLTAGE WAVEFORMS



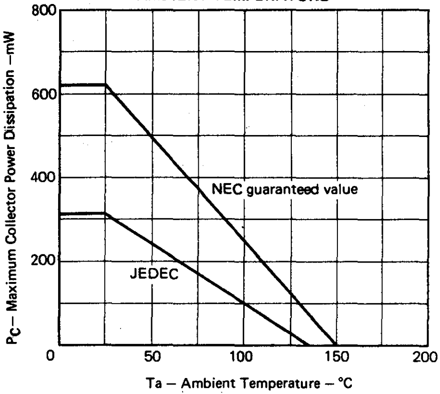
t_{off} SWITCHING



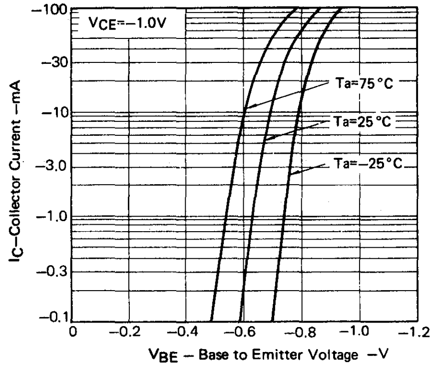
VOLTAGE WAVEFORMS

TYPICAL CHARACTERISTICS (Ta = 25 °C)

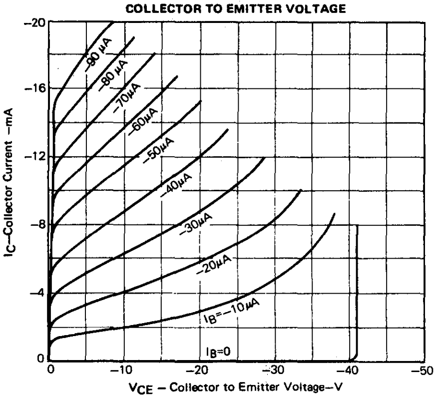
COLLECTOR POWER DISSIPATION vs. AMBIENT TEMPERATURE



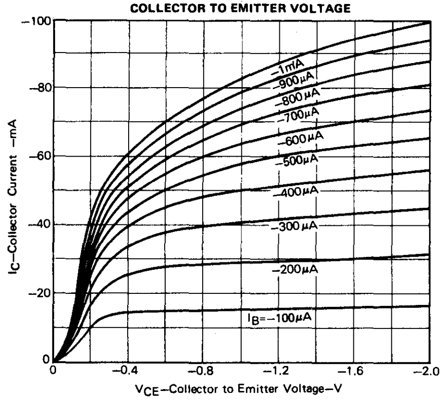
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



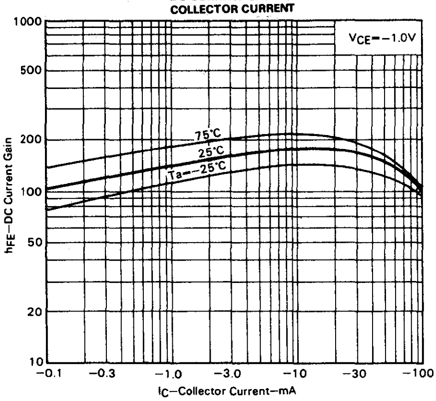
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



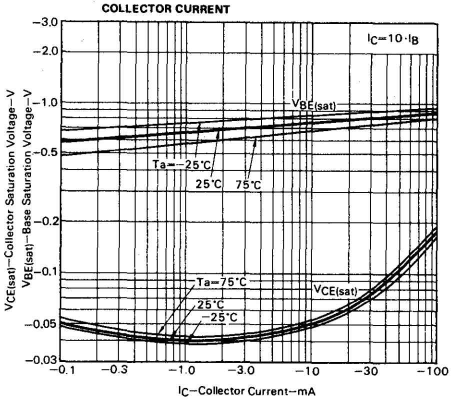
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



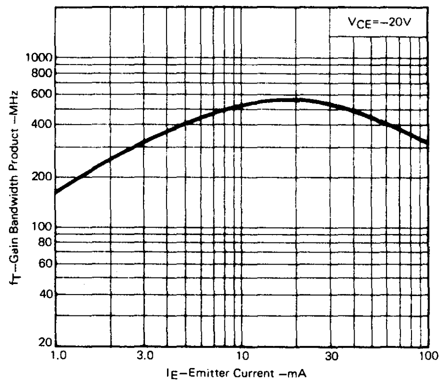
DC CURRENT GAIN vs. COLLECTOR CURRENT



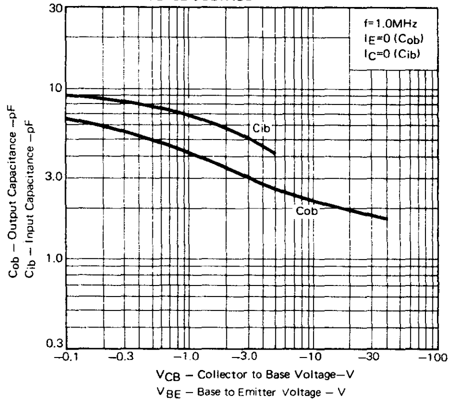
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT

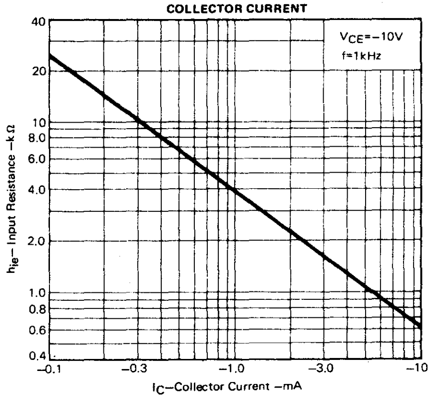


INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE

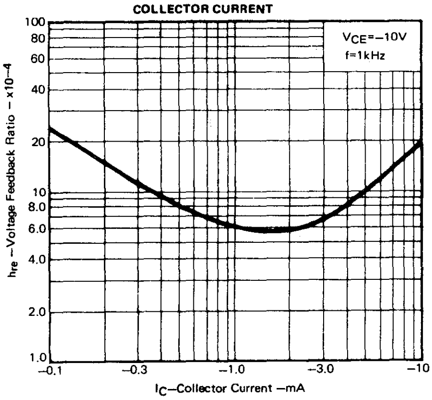


2

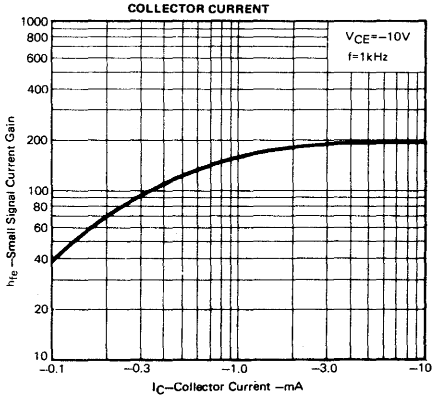
INPUT RESISTANCE vs. COLLECTOR CURRENT



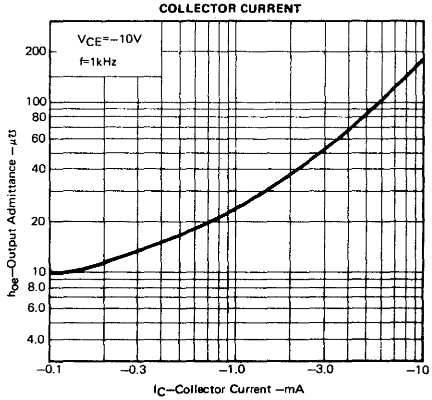
VOLTAGE FEEDBACK RATIO vs. COLLECTOR CURRENT



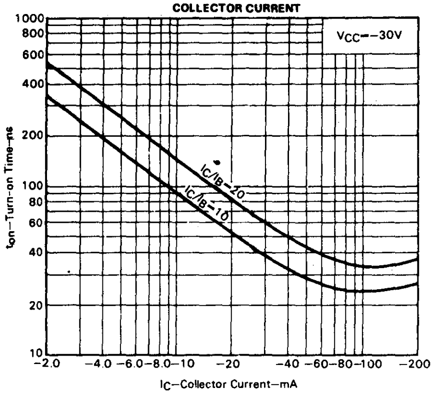
SMALL SIGNAL CURRENT GAIN vs. COLLECTOR CURRENT



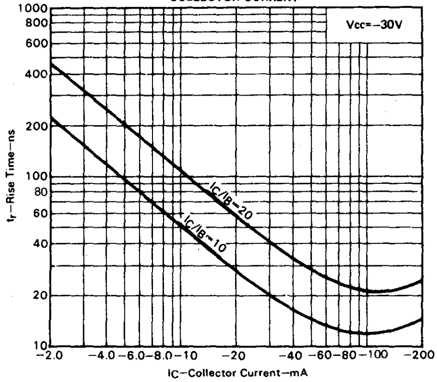
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



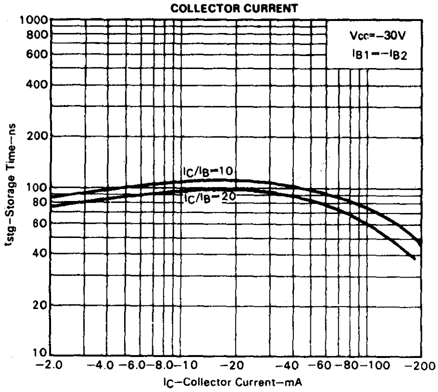
TURN-ON TIME vs. COLLECTOR CURRENT



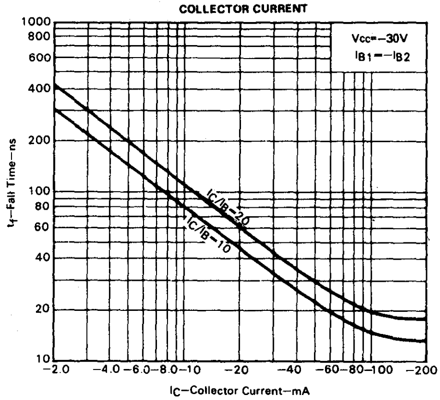
RISE TIME vs. COLLECTOR CURRENT



STORAGE TIME vs. COLLECTOR CURRENT



FALL TIME vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

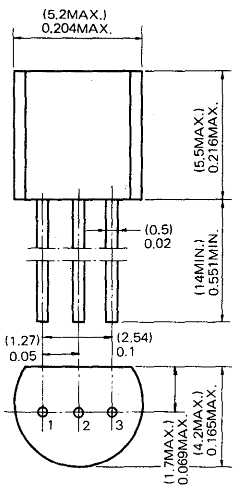
NPN SILICON TRANSISTORS
2N4123, 2N4124

GENERAL PURPOSE SWITCHING AND AMPLIFIER
NPN SILICON EPITAXIAL TRANSISTOR

DESCRIPTION

2N4123, 2N4124 are NPN transistors, designed for general purpose switching and amplifier applications, feature injection-molded plastic package for high reliability.

PACKAGE DIMENSIONS in inches (millimeter)



1. Emitter   JEDEC : TO-92
2. Base
3. Collector

FEATURES

- High Power . . . P_T 625mW at 25°C
- High h_{FE} . . . . 120–360 at 2mA (2N4124)
- For Complementary Use with PNP Type 2N4125, 2N4126

ABSOLUTE MAXIMUM RATINGS

		2N4123	2N4124	
Maximum Voltages and Current (Ta=25°C)				
Collector to Base Voltage ($R_{BE}=\infty$)	V_{CBO}	40	30	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	30	25	V
Emitter to Base Voltage	V_{EBO}	5	5	V
Collector Current	I_C	200		mA
Maximum Power Dissipation (Ta=25°C)				
Total Power Dissipation	P_T	625		mW*1
		310		mW*2
Derate above 25°C		5		mW/°C *1
		2.81		mW/°C *2
Maximum Temperatures				
Storage Temperature	Tstg	–65 to +150		°C*1
		–55 to +135		°C*2
Operating Junction Temperature	Tj	150		°C*1
		135		°C*2
Thermal Resistance Junction to Ambient	Rth	0.2		°C/mW

*1 NEC guarantees these value in addition to the JEDEC registered values.

*2 JEDEC registered values.

ELECTRICAL CHARACTERISTICS (Ta=25°C) *3

CHARACTERISTIC	SYMBOL	2N4123		2N4124		UNIT	TEST CONDITIONS
		MIN.	MAX.	MIN.	MAX.		
Collector-Base Breakdown Voltage	BV_{CBO}	40		30		V	I_C=10μA, I_E=0
Collector-Emitter Breakdown Voltage	BV_{CEO}*4	30		25		V	I_C=1.0mA, I_B=0
Emitter-Base Breakdown Voltage	BV_{EBO}	5.0		5.0		V	I_E=10μA, I_C=0
Collector Cutoff Current	I_{CBO}		50		50	nA	V_{CB}=20V, I_E=0
Emitter Cutoff Current	I_{EBO}		50		50	nA	V_{EB}=3.0V, I_C=0
DC Current Gain	h_{FE1}*4	50	150	120	360		I_C=2.0mA, V_{CE}=1.0V
	h_{FE2}*4	25		60			I_C = 50mA, V_{CE} = 1.0V
Collector Saturation Voltage	$V_{CE(sat)}$*4		0.3		0.3	V	I_C=50mA, I_B=5.0mA
Base Saturation Voltage	$V_{BE(sat)}$*4		0.95		0.95	V	I_C=50mA, I_B=5.0mA
Small Signal Current Gain	h_{fe}	50	200	120	480		I_C=2.0mA,V_{CE}=10V,f=1.0kHz
High Frequency Current Gain	$\|h_{fe}\|$	2.5		3.0			I_C=10mA,V_{CE}=20V,f=100MHz
Gain Bandwidth Product	f_T	250		300		MHz	I_C=10mA,V_{CE}=20V,f=100MHz
Output Capacitance	C_{ob}		4.0		4.0	pF	V_{CB}=5.0V,I_E=0,f=100kHz
Input Capacitance	C_{ib}		8.0		8.0	pF	V_{EB}=0.5V,I_C=0,f=100kHz
Noise Figure	NF		6.0		5.0	dB	I_C=100μA,V_{CE}=5.0V,R_S=1kΩ f=10Hz to 15.7kHz

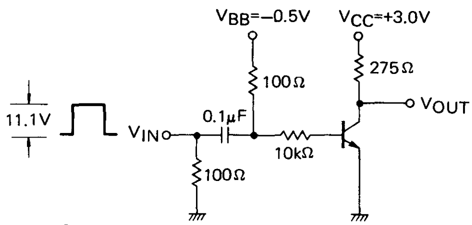
*3 JEDEC registered data for the 2N4123 and 2N4124.

*4 These parameters must be measured pulse techniques. tw≦300μs, duty cycle≦2%

SWITCHING CHARACTERISTICS (Ta=25°C)

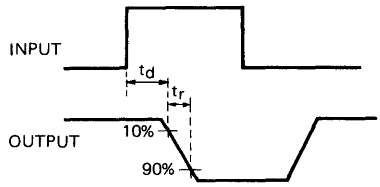
CHARACTERISTIC	SYMBOL	TYP.	UNIT	TEST CONDITIONS
Delay Time	t_d	20	ns	I_C=10mA, V_{CC}=3V
Rise Time	t_r	13	ns	$V_{EB(off)}$ = −0.5V, I_{B1} = 1mA
Storage Time	t_{stg}	100	ns	I_C=10mA, V_{CC}=3V
Fall Time	t_f	21	ns	I_{B1}=−I_{B2}=1mA

SWITCHING TIME TEST CIRCUIT

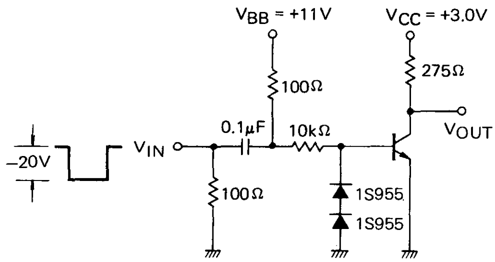


$t_r < 1.0$ ns
PW ≧ 300 ns
Duty cycle = 2%

t_{on} SWITCHING

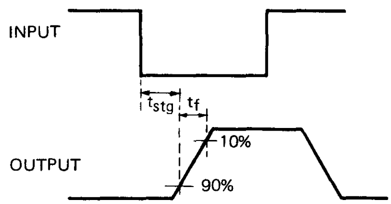


VOLTAGE WAVEFORMS



$t_r < 9.0$ ns
PW ≧ 300 ns
Duty cycle = 2%

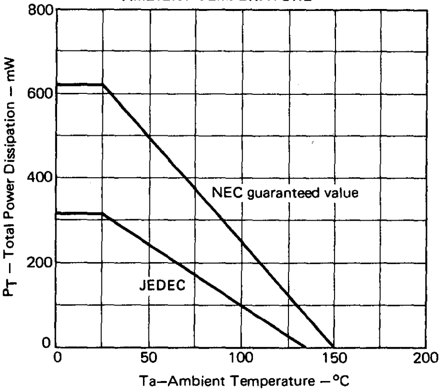
t_{off} SWITCHING



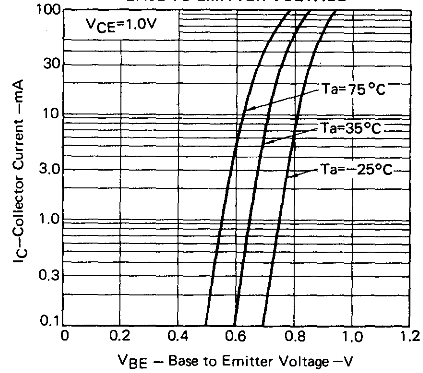
VOLTAGE WAVEFORMS

TYPICAL CHARACTERISTICS (Ta = 25°C)

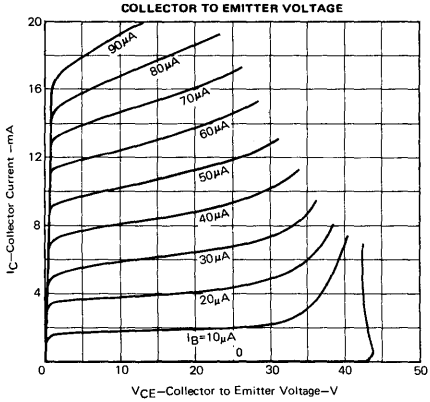
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



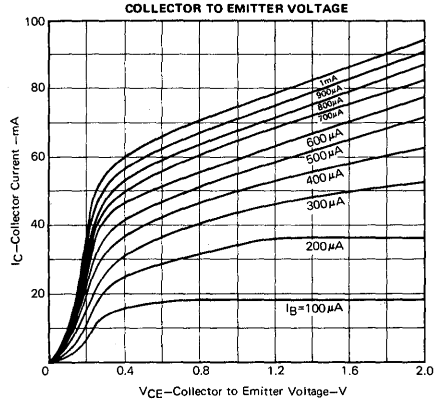
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



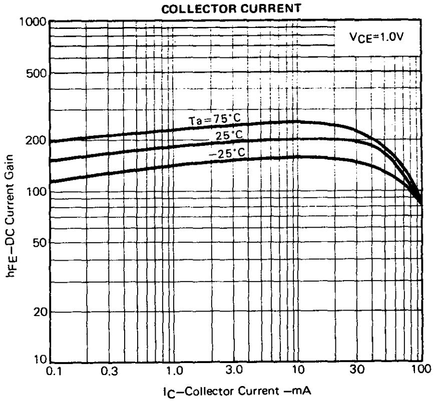
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



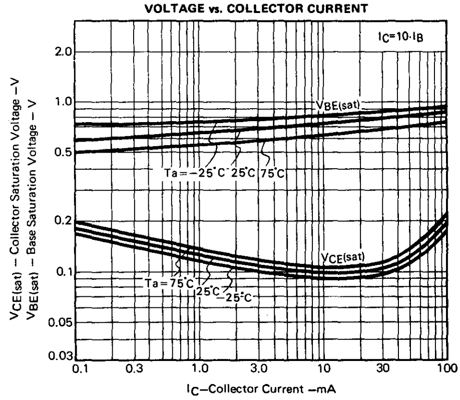
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



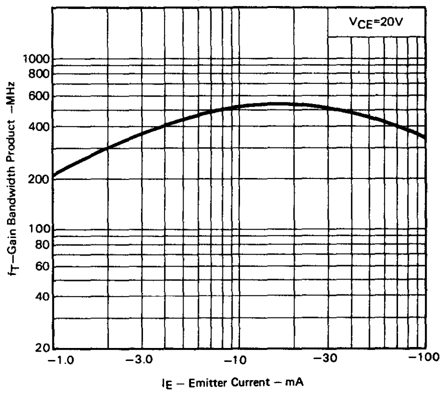
DC CURRENT GAIN vs. COLLECTOR CURRENT



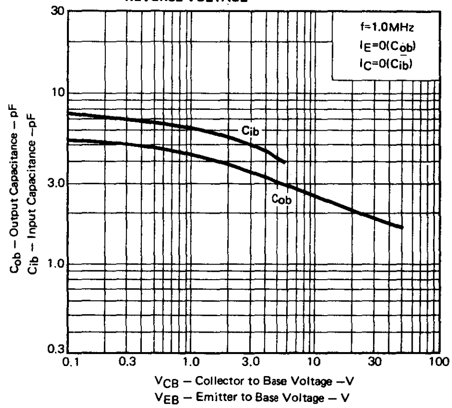
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



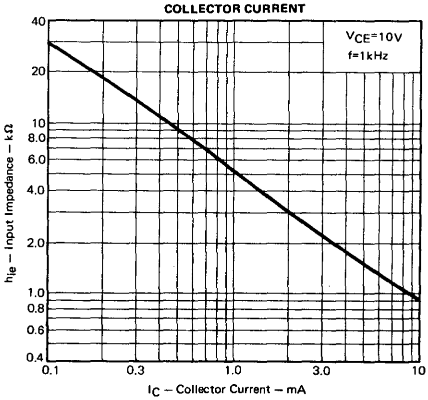
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



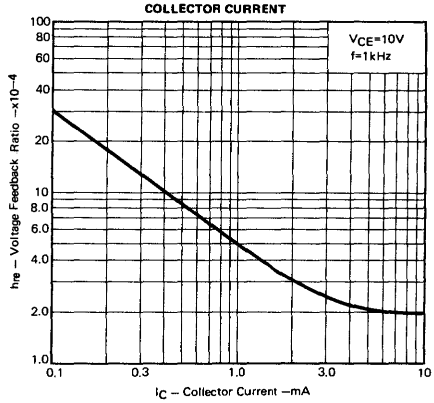
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



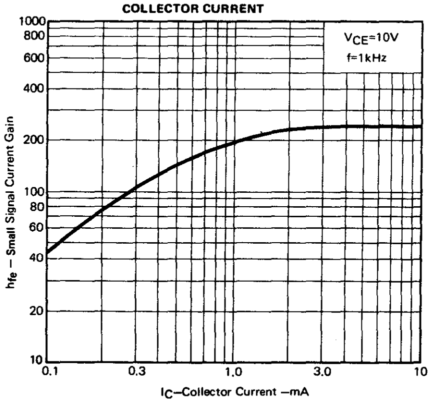
INPUT IMPEDANCE vs. COLLECTOR CURRENT



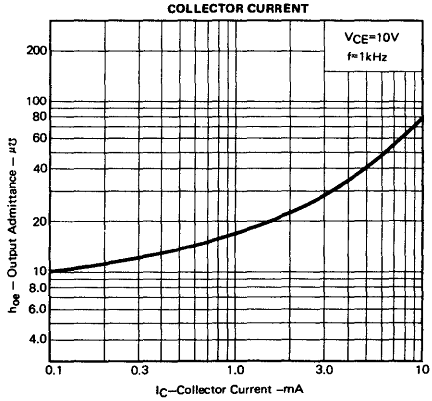
VOLTAGE FEEDBACK RATIO vs. COLLECTOR CURRENT



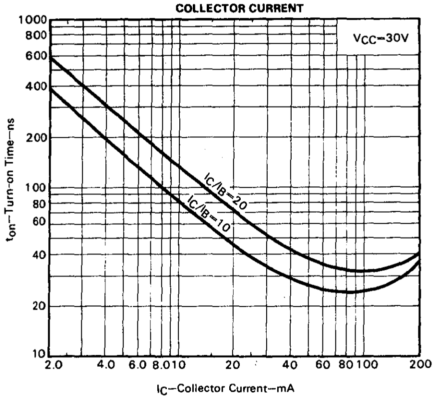
SMALL SIGNAL CURRENT GAIN vs. COLLECTOR CURRENT



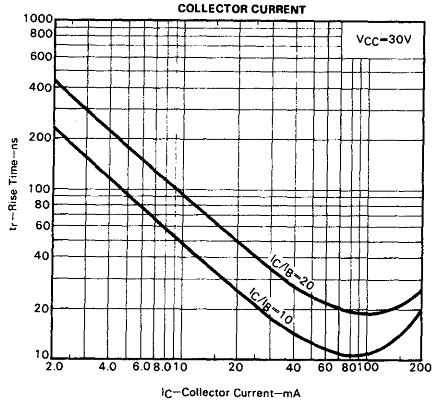
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



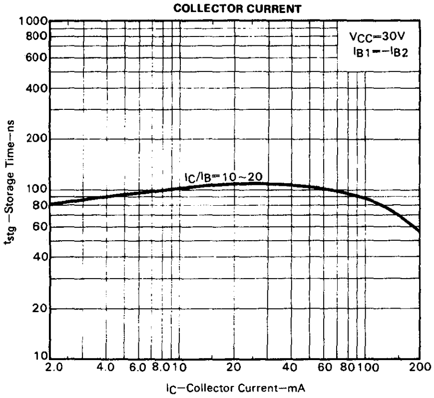
TURN-ON TIME vs. COLLECTOR CURRENT



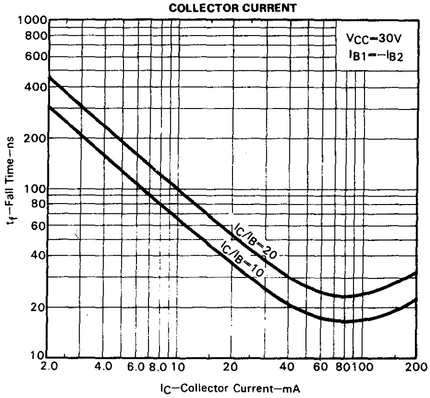
RISE TIME vs. COLLECTOR CURRENT



STORAGE TIME vs. COLLECTOR CURRENT



FALL TIME vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

PNP SILICON TRANSISTORS
2N4125, 2N4126

GENERAL PURPOSE SWITCHING AND AMPLIFIER
PNP SILICON EPITAXIAL TRANSISTOR

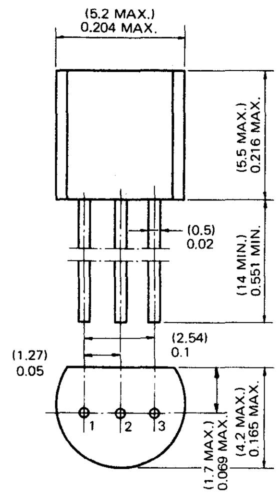
2

DESCRIPTION

2N4125, 2N4126 are PNP transistors, designed for general purpose switching and amplifier applications, feature injection-molded plastic package for high reliability.

PACKAGE DIMENSIONS

in (millimeters) inches



1. Emitter JEDEC : TO-92
2. Base
3. Collector

FEATURES

- High Power P_T 625 mW at 25 °C
- High h_{FE} 120 ~ 360 at 2 mA (2N4126)
- For Complementary Use with NPN Type 2N4123, 2N4124

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta=25 °C)		2N4125	2N4126	
Collector to Base Voltage ($R_{BE}=\infty$)	V_{CBO}	−30	−25	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	−30	−25	V
Emitter to Base Voltage	V_{EBO}	−4.0	−4.0	V
Collector Current	I_C	−200		mA

Maximum Power Dissipation (Ta=25 °C)			
Total Power Dissipation	P_T	625	mW*1
		310	mW*2
Derate above 25 °C		5	mW/°C*1
		2.81	mW/°C*2
Maximum Temperatures			
Storage Temperature	Tstg	−65 to +150	°C*1
		−55 to +135	°C*2
Operating Junction Temperature	Tj	150	°C*1
		135	°C*2
Thermal Resistance Junction to Ambient	R_{th}	0.2	°C/mW

*1 NEC guarantees these value in addition to the JEDEC registered values.

*2 JEDEC registered values.

ELECTRICAL CHARACTERISTICS (Ta=25 °C) *3

CHARACTERISTIC	SYMBOL	2N4125		2N4126		UNIT	TEST CONDITIONS
		MIN.	MAX.	MIN.	MAX.		
Collector-Base Breakdown Voltage	BV_{CBO}	–30		–25		V	I_C=–10 μA, I_E=0
Collector-Emitter Breakdown Voltage	BV_{CEO}*4	–30		–25		V	I_C=–1.0 mA, I_B=0
Emitter-Base Breakdown Voltage	BV_{EBO}	–4.0		–4.0		V	I_E=–10 μA, I_C=0
Collector Cutoff Current	I_{CBO}		–50		–50	nA	V_{CB}=–20 V, I_E=0
Emitter Cutoff Current	I_{EBO}		–50		–50	nA	V_{EB}=–3.0 V, I_C=0
DC Current Gain	h_{FE1}*4	50	150	120	360		I_C=–2.0 mA, V_{CE}=–1.0 V
	h_{FE2}*4	25		60			I_C=–50 mA, V_{CE}=–1.0 V
Collector Saturation Voltage	$V_{CE(sat)}$*4		–0.4		–0.4	V	I_C=–50 mA, I_B=–5.0 mA
Base Saturation Voltage	$V_{BE(sat)}$*4		–0.95		–0.95	V	I_C=–50 mA, I_B=–5.0 mA
Small Signal Current Gain	h_{fe}	50	200	120	480		I_C=–2.0 mA, V_{CE}=–1.0 V, f=1.0 kHz
High Frequency Current Gain	$\lvert h_{fe} \rvert$	2.0		2.5			I_C=–10 mA, V_{CE}=–20 V, f=100 MHz
Gain Bandwidth Product	f_T	200		250		MHz	I_C=–10 mA, V_{CE}=–20 V, f=100 MHz
Output Capacitance	C_{ob}		4.5		4.5	pF	I_E=0, V_{CB}=–5.0 V, f=100 kHz
Input Capacitance	C_{ib}		10		10	pF	I_C=0, V_{EB}=–0.5 V, f=100 kHz
Noise Figure	NF		5.0		4.0	dB	I_C=–100 μA, V_{CE}=–5.0 V, R_S=1 kΩ f=10 Hz to 15.7 kHz

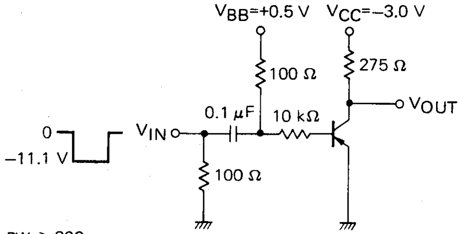
*3 JEDEC registered data for the 2N4125 and 2N4126.

*4 These parameters must be measured pulse techniques. tw ≦ 300 μs, duty cycle ≦ 2 %

SWITCHING CHARACTERISTICS (Ta=25°C)

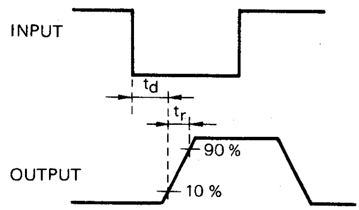
CHARACTERISTIC	SYMBOL	TYP.	UNIT	TEST CONDITIONS
Delay Time	t_d	8.0	ns	I_C=–10 mA, V_{CC}=–3 V
Rise Time	t_r	28	ns	$V_{EB(off)}$=0.5 V, I_{B1}=–1 mA
Storage Time	t_{stg}	130	ns	I_C=–10 mA, V_{CC}=–3 V
Fall Time	t_f	40	ns	I_{B1}=–I_{B2}=–1 mA

SWITCHING TIME TEST CIRCUIT

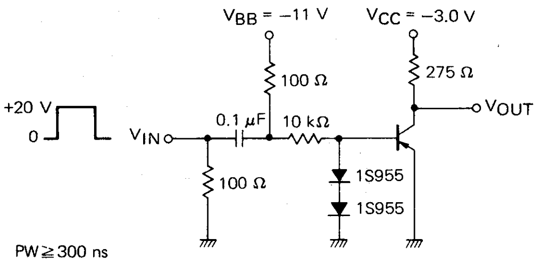


PW, ≧ 300 ns
t_r <1.0 ns
Z_{IN} = 50 Ω
Duty cycle = 2 %

t_{on} SWITCHING

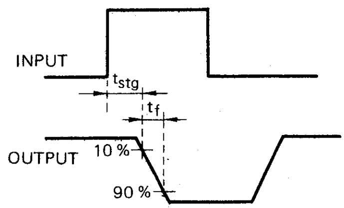


VOLTAGE WAVEFORMS



PW≧300 ns
t_r <1.0 ns
Duty cycle = 2 %

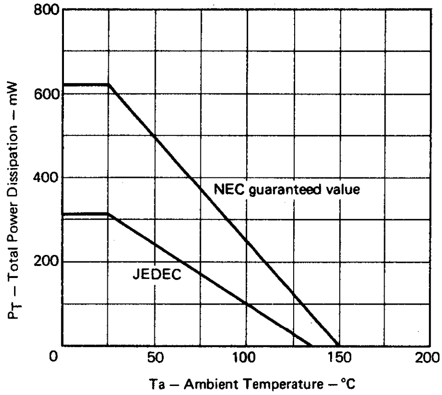
t_{off} SWITCHING



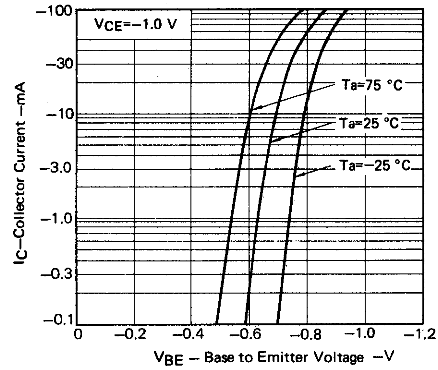
VOLTAGE WAVEFORMS

TYPICAL CHARACTERISTICS (Ta = 25 °C)

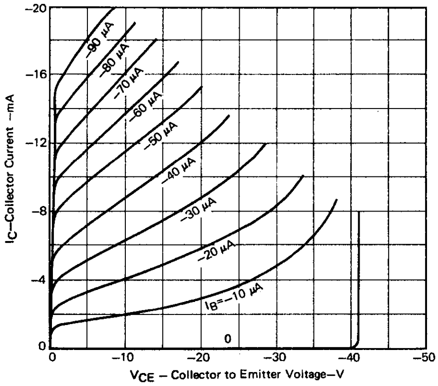
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



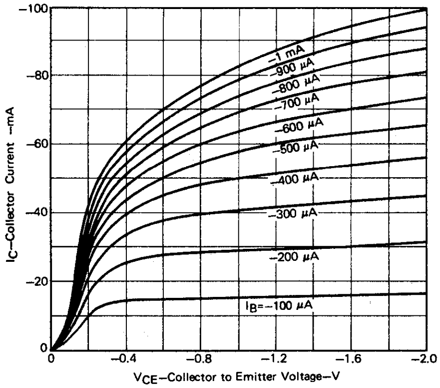
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



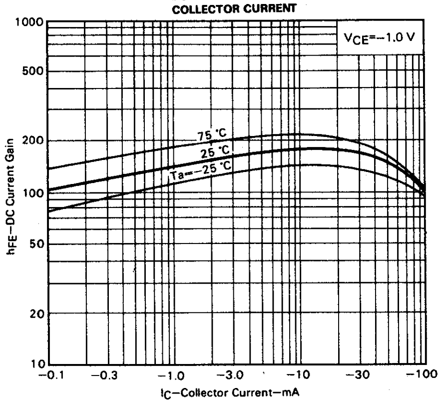
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



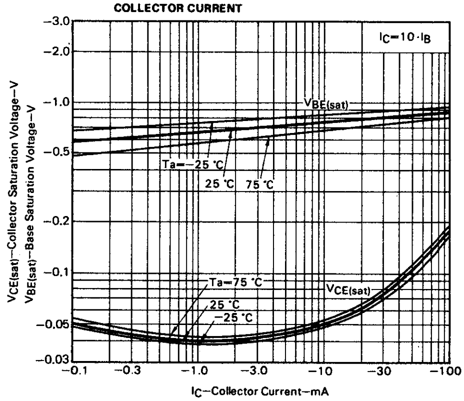
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



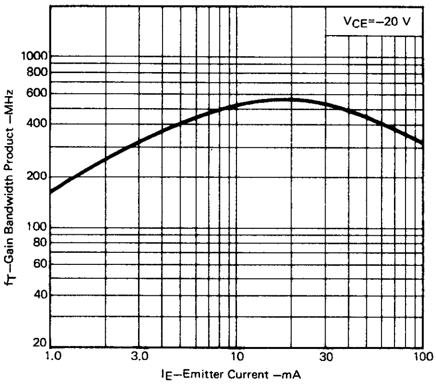
DC CURRENT GAIN vs. COLLECTOR CURRENT



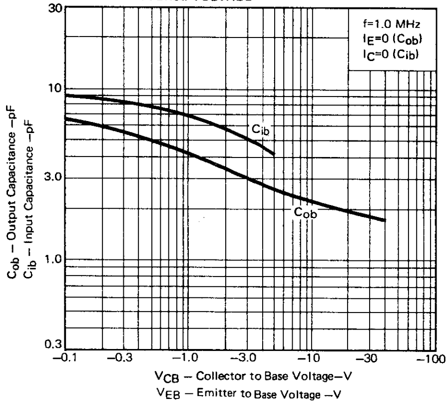
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



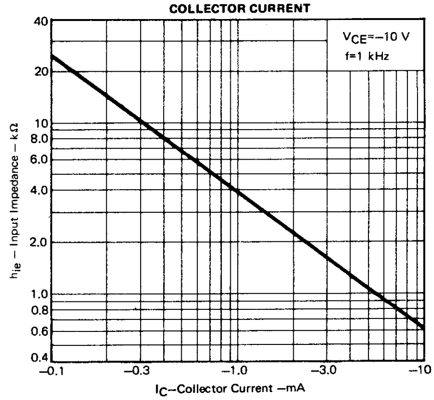
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



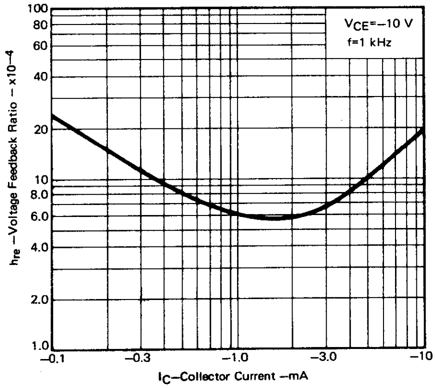
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



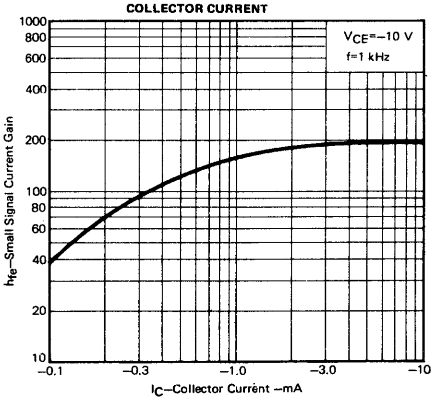
INPUT IMPEDANCE vs. COLLECTOR CURRENT



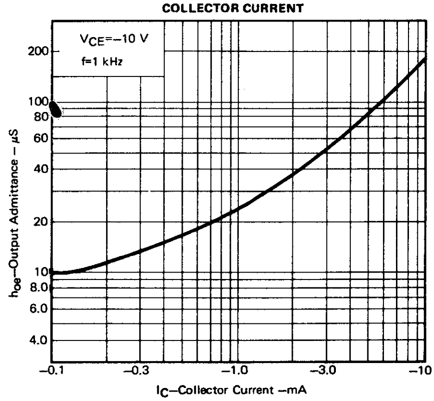
VOLTAGE FEEDBACK RATIO vs. COLLECTOR CURRENT



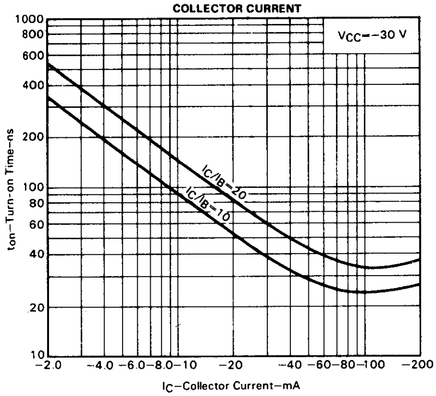
SMALL SIGNAL CURRENT GAIN vs. COLLECTOR CURRENT



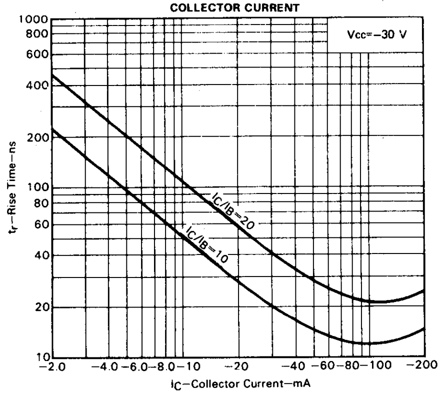
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



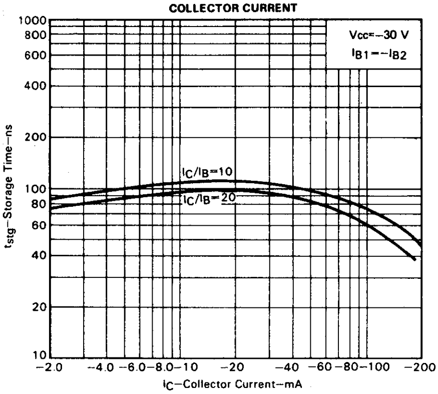
TURN-ON TIME vs. COLLECTOR CURRENT



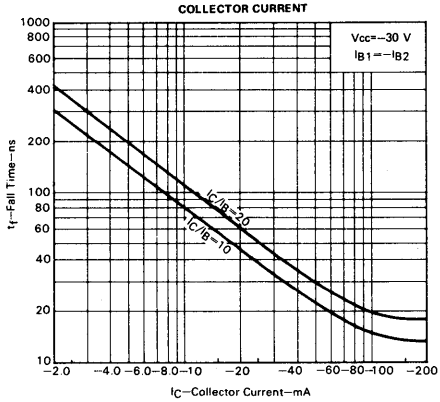
RISE TIME vs. COLLECTOR CURRENT



STORAGE TIME vs. COLLECTOR CURRENT



FALL TIME vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

NPN SILICON TRANSISTORS
2N4400,2N4401

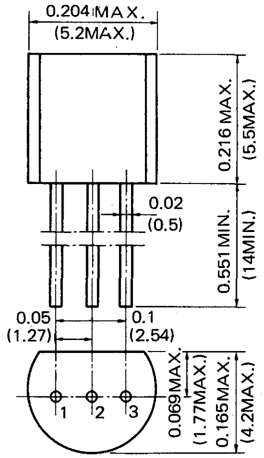
GENERAL PURPOSE SWITCHING AND AMPLIFIER NPN SILICON EPITAXIAL TRANSISTOR

2

DESCRIPTION

2N4400, 2N4401 are NPN transistors, designed for general purpose switching and amplifier applications, feature injection-molded plastic package for high reliability.

PACKAGE DIMENSIONS in inches (millimeter)



1. Emitter
2. Base
3. Collector

JEDEC : TO-92

FEATURES

- High Power .... P_T 625mW at 25°C
- High Voltage ... V_{CEO} 40V
- High DC CURRENT GAIN h_{FE} 100 ~ 300 at 150mA (2N4401)
- For Complementary Use with PNP Type 2N4402, 2N4403

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta = 25°C)			
Collector to Base Voltage (R_{BE} = ∞)	V_{CBO}	60	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	40	V
Emitter to Base Voltage	V_{EBO}	6.0	V
Collector Current	I_C	600	mA
Maximum Power Dissipation (Ta = 25°C)			
Total Power Dissipation	P_T	625	mW*1
		310	mW*2
Derate above 25°C		5	mW/°C *1
		2.81	mW/°C *2
Maximum Temperatures			
Storage Temperature	Tstg	−65 to+150	°C*1
		−55 to+135	°C*2
Operating Junction Temperature	T_j	150	°C*1
		135	°C*2
Thermal Resistance			
Junction to Ambient	Rth	0.2	°C/mW

*1 NEC guarantees these values in addition to the JEDEC registered values.

*2 JEDEC registered values.

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

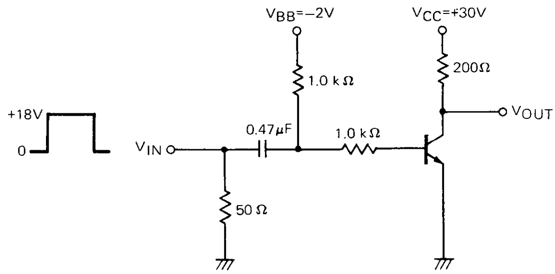
CHARACTERISTIC	SYMBOL	2N4400		2N4401		UNIT	TEST CONDITIONS
		MIN.	MAX.	MIN.	MAX.		
Collector-Base Breakdown Voltage	BV_{CBO}	60		60		V	I_C=100μA,I_E=0
Collector-Emitter Breakdown Voltage	BV_{CEO}*3	40		40		V	I_C=1.0mA,I_B=0
Emitter-Base Breakdown Voltage	BV_{EBO}	6.0		6.0		V	I_E=100μA,I_C=0
Collector Cutoff Current	I_{CEX}		100		100	nA	V_{CE}=35V,V_{BE}=−0.4V
Base Cutoff Current	I_{BEX}		−100		−100	nA	V_{CE}=35V,V_{BE}=−0.4V
DC Current Gain	h_{FE1}			20			V_{CE}=1.0V,I_C=100μA
	h_{FE2}	20		40			V_{CE}=1.0V,I_C=1.0mA
	h_{FE3}	40		80			V_{CE}=1.0V,I_C=10mA
	h_{FE4}*3	50	150	100	300		V_{CE}=1.0V,I_C=150mA
	h_{FE5}*3	20		40			V_{CE}=2.0V,I_C=500mA
Collector Saturation Voltage	$V_{CE(sat)1}$*3		0.4		0.4	V	I_C=150mA,I_B=15mA
	$V_{CE(sat)2}$*3		0.75		0.75	V	I_C=500mA,I_B=50mA
Base Saturation Voltage	$V_{BE(sat)1}$*3	0.75	0.95	0.75	0.95	V	I_C=150mA,I_B=15mA
	$V_{BE(sat)2}$*3		1.2		1.2	V	I_C=500mA,I_B=50mA
Gain Bandwidth Product	f_T	200		250		MHz	V_{CE}=10V,I_C=20mA
Output Capacitance	C_{ob}		6.5		6.5	pF	V_{CB}=5.0V,I_E=0,f=100kHz
Input Capacitance	C_{ib}		30		30	pF	V_{EB}=0.5V,I_C=0,f=100kHz
Input Impedance	h_{ie}	0.5	7.5	1.0	15	kΩ	V_{CE} = 10V I_C = 1.0mA f = 1kHz
Voltage Feedback Ratio	h_{re}	0.1	8.0	0.1	8.0	X10−4	
Small Signal Current Gain	h_{fe}	20	250	40	500		
Output Admittance	h_{oe}	1.0	30	1.0	30	μ℧	

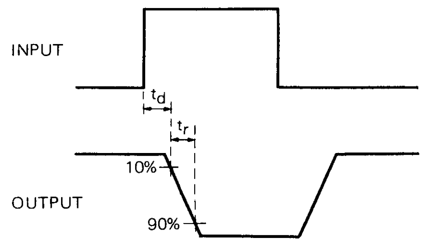
*3 These parameters must be measured pulse techniques. tw=300μs duty cycle≦2%

SWITCHING CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	2N4400		2N4401		UNIT	TEST CONDITIONS
		MIN.	MAX.	MIN.	MAX.		
Delay Time	t_d		15		15	ns	V_{CC} = 30V, I_C = 150mA
Rise Time	t_r		20		20	ns	I_{B1} = 15mA , V_{EB}=−2V
Storage Time	t_{stg}		225		225	ns	V_{CC} = 30V, I_C = 150mA
Fall Time	t_f		30		30	ns	I_{B1} = −I_{B2} = 15mA

SWITCHING TIME TEST CIRCUIT

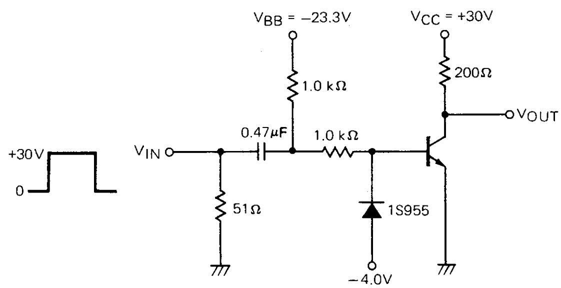


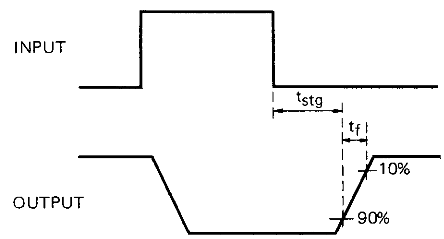


$t_r < 2.0$ ns
PW = 1.0 μs
DC = 2%

t_{on} SWITCHING

VOLTAGE WAVEFORMS



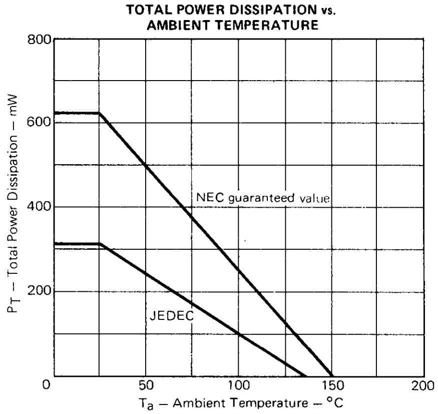


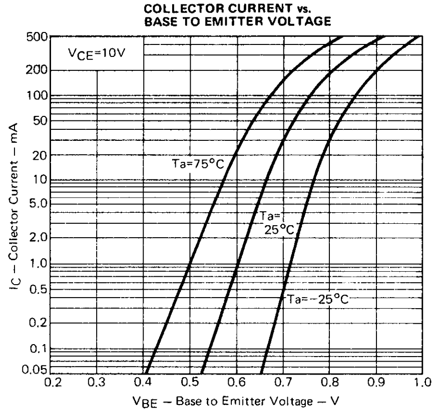
$t_r \leqslant 2.0$ ns
PW = 1.0 μs
DC = 2%

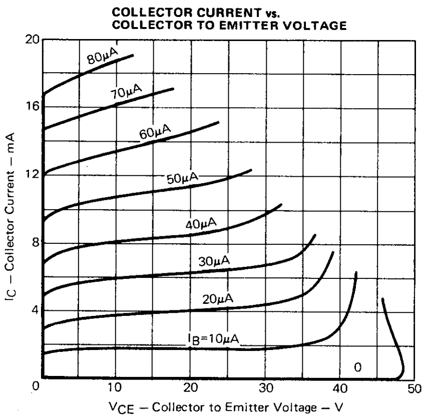
t_{off} SWITCHING

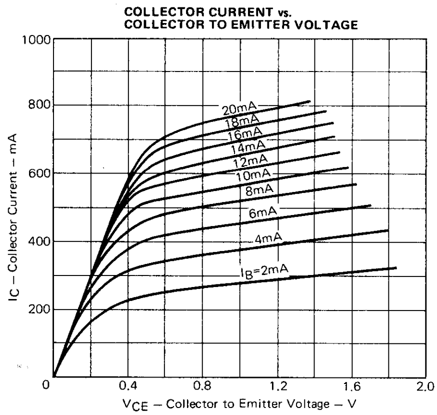
VOLTAGE WAVEFORMS

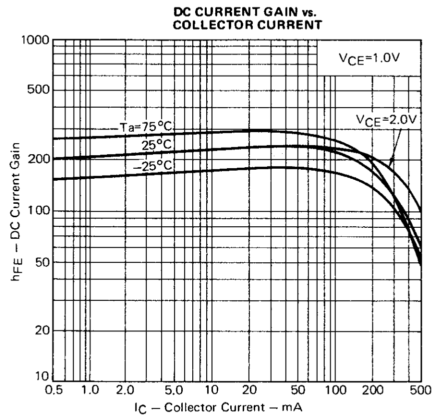
TYPICAL CHARACTERISTICS (Ta=25°C)

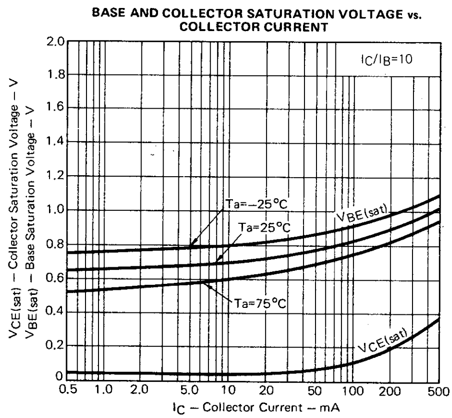




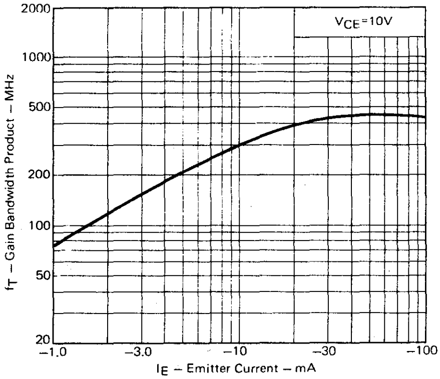




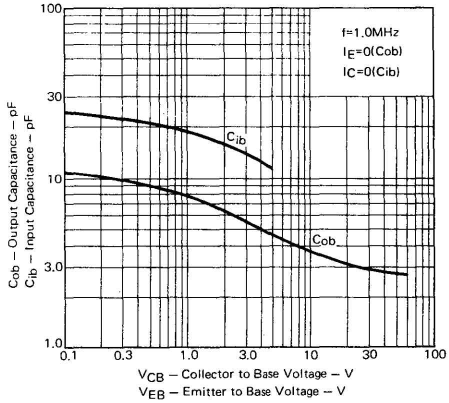




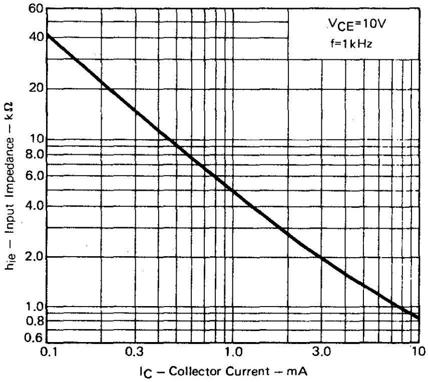
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



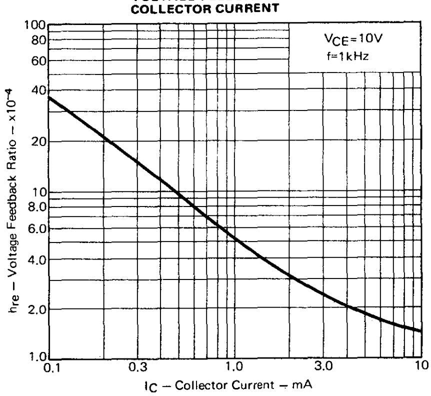
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



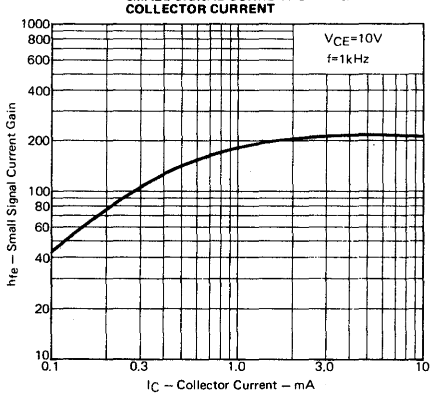
INPUT IMPEDANCE vs. COLLECTOR CURRENT



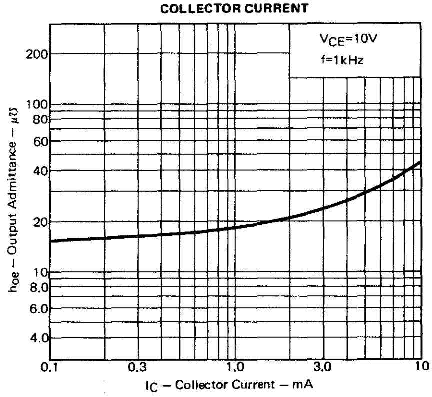
VOLTAGE FEEDBACK RATIO vs. COLLECTOR CURRENT



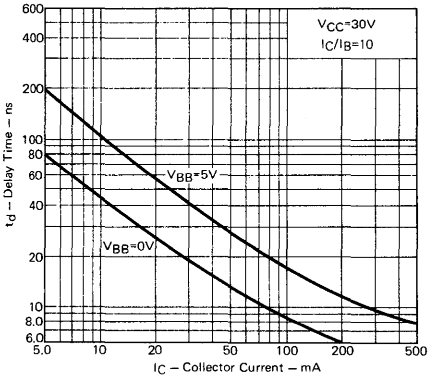
SMALL SIGNAL CURRENT GAIN vs. COLLECTOR CURRENT



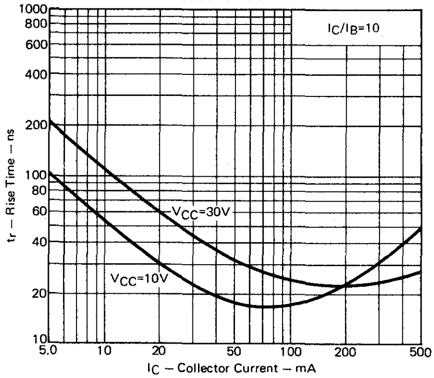
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



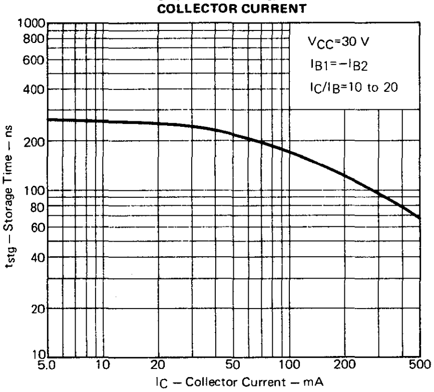
DELAY TIME vs. COLLECTOR CURRENT



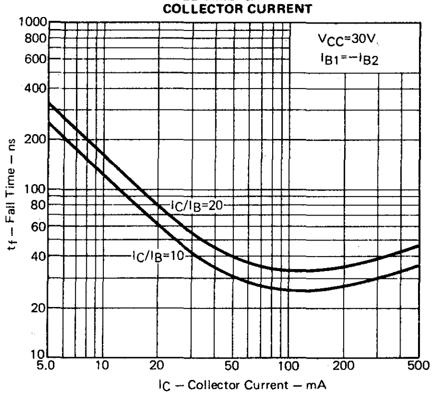
RISE TIME vs. COLLECTOR CURRENT



STORAGE TIME vs. COLLECTOR CURRENT



FALL TIME vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

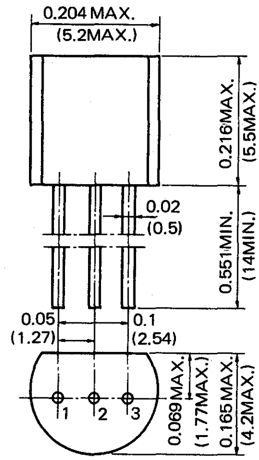
PNP SILICON TRANSISTORS
2N4402, 2N4403

GENERAL PURPOSE SWITCHING AND AMPLIFIER PNP SILICON EPITAXIAL TRANSISTOR

DESCRIPTION

2N4402, 2N4403 are PNP transistors, designed for general purpose switching and amplifier applications, feature injection-molded plastic package for high reliability.

PACKAGE DIMENSIONS
in inches (millimeter)



1. Emitter
2. Base
3. Collector

JEDEC : TO-92

FEATURES

- High Power . . . P_T 625mW at 25°C
- High Voltage . . V_{CEO} −40V
- High DC Current Gain h_{FE} 100 − 300 at 150mA (2N4403)
- For Complementary Use with NPN Type 2N4400, 2N4401

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta = 25°C)			
Collector to Base Voltage ($R_{BE} = \infty$)	V_{CBO}	−40	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	−40	V
Emitter to Base Voltage	V_{EBO}	−5.0	V
Collector Current	I_C	−600	mA
Maximum Power Dissipation (Ta = 25°C)			
Total Power Dissipation	P_T	625	mW*1
		310	mW*2
Derate above 25°C		5	mW/°C*1
		2.81	mW/°C*2
Maximum Temperatures			
Storage Temperature	Tstg	−65 to +150	°C*1
		−55 to +135	°C*2
Operating Junction Temperature	T_j	150	°C*1
		135	°C*2
Thermal Resistance			
Junction to Ambient	Rth	0.2	°C/mW

*1 NEC guarantees these values in addition to the JEDEC registered values.
*2 JEDEC registered values.

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

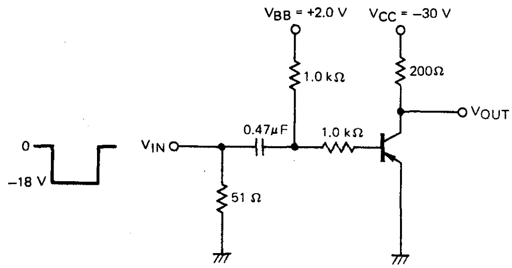
CHARACTERISTIC	SYMBOL	2N4402		2N4403		UNIT	TEST CONDITIONS
		MIN.	MAX.	MIN.	MAX.		
Collector-Base Breakdown Voltage	BV_{CBO}	−40		−40		V	$I_C=-100\mu A, I_E=0$
Collector-Emitter Breakdown Voltage	BV_{CEO}*3	−40		−40		V	$I_C=-1.0mA, I_B=0$
Emitter-Base Breakdown Voltage	BV_{EBO}	−5.0		−5.0		V	$I_E=-100\mu A, I_C=0$
Collector Cutoff Current	I_{CEX}		−100		−100	nA	$V_{CE}=-35V, V_{BE}=0.4V$
Base Cutoff Current	I_{BEX}		−100		−100	nA	$V_{CE}=-35V, V_{BE}=0.4V$
DC Current Gain	h_{FE1}			30			$V_{CE}=-1.0V, I_C=-100\mu A$
	h_{FE2}	30		60			$V_{CE}=-1.0V, I_C=-1.0mA$
	h_{FE3}	50		100			$V_{CE}=-1.0V, I_C=-10mA$
	h_{FE4}*3	50	150	100	300		$V_{CE}=-2.0V, I_C=-150mA$
	h_{FE5}*3	20		20			$V_{CE}=-2.0V, I_C=-500mA$
Collector Saturation Voltage	$V_{CE(sat)1}$*3		−0.4		−0.4	V	$I_C=-150mA, I_B=-15mA$
	$V_{CE(sat)2}$*3		−0.75		−0.75	V	$I_C=-500mA, I_B=-50mA$
Base Saturation Voltage	$V_{BE(sat)1}$*3	−0.75	−0.95	−0.75	−0.95	V	$I_C=-150mA, I_B=-15mA$
	$V_{BE(sat)2}$*3		−1.3		−1.3	V	$I_C=-500mA, I_B=-50mA$
Gain Bandwidth Product	f_T	150		200		MHz	$V_{CE}=-10V, I_C=-20mA$
Output Capacitance	C_{ob}		8.5		8.5	pF	$V_{CB}=-10V, I_E=0$, f=100kHz
Input Capacitance	C_{ib}		30		30	pF	$V_{EB}=-0.5V, I_C=0$, f=100kHz
Input Impedance	h_{ie}	0.75	7.5	1.5	15	kΩ	$V_{CE}=-10V$ $I_C=-1.0mA$ f=1.0kHz
Voltage Feedback Ratio	h_{re}	0.1	8.0	0.1	8.0	$\times 10^{-4}$	
Small Signal Current Gain	h_{fe}	30	250	60	500		
Output Admittance	h_{oe}	1.0	100	1.0	100	μ℧	

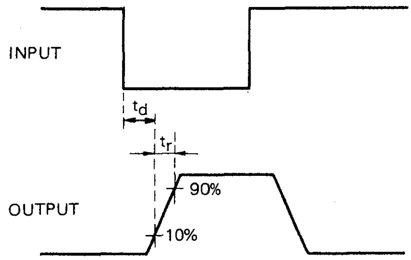
*3 These parameters must be measured pulse techniques. tw = 300μs duty cycle ≦ 2%

SWITCHING CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	2N4402		2N4403		UNIT	TEST CONDITIONS
		MIN.	MAX.	MIN.	MAX.		
Delay Time	t_d		15		15	ns	$V_{CC}=-30V, I_C=-150mA$
Rise Time	t_r		20		20	ns	$I_{B1}=-15mA$ $V_{EB}=2V$
Storage Time	t_{stg}		225		225	ns	$V_{CC}=-30V, I_C=-150mA$
Fall Time	t_f		30		30	ns	$I_{B1}=-I_{B2}=-15mA$

SWITCHING TIME TEST CIRCUIT

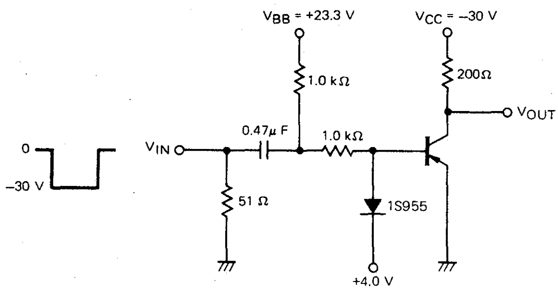


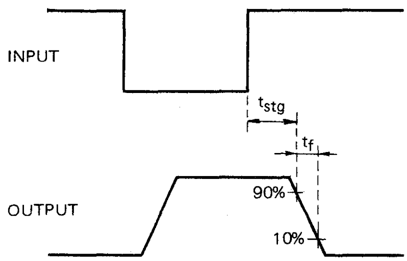


$t_r < 2.0$ ns
PW = 1.0 μs
DC = 2%

t_{on} SWITCHING

VOLTAGE WAVEFORMS





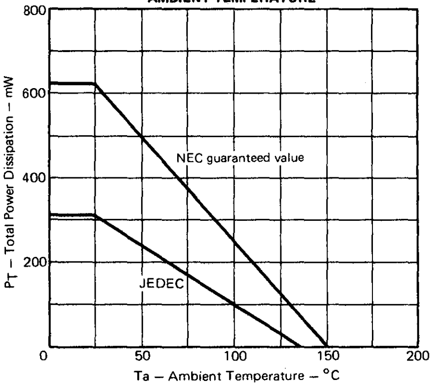
$t_r \leqslant 2.0$ ns
PW ⩾ 1.0 μs
DC = 2%

t_{off} SWITCHING

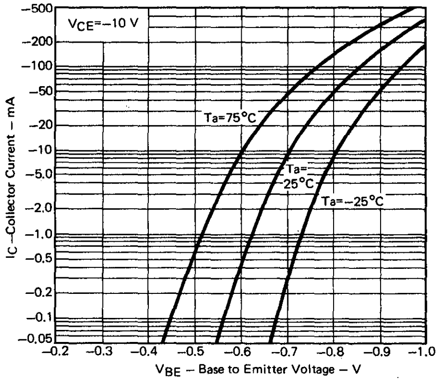
VOLTAGE WAVEFORMS

TYPICAL CHARACTERISTICS (Ta=25°C)

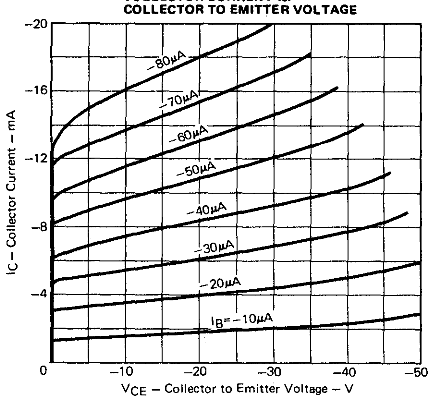
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



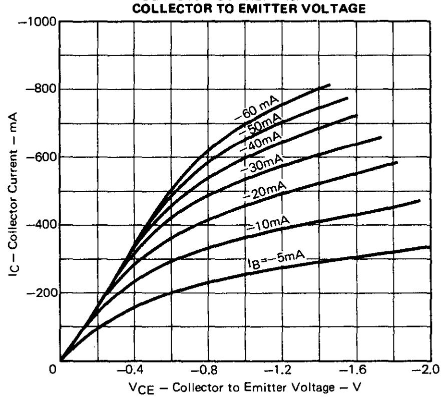
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



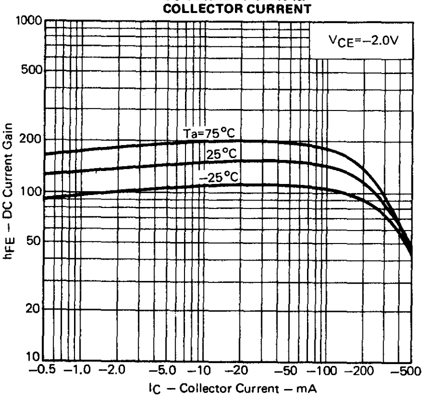
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



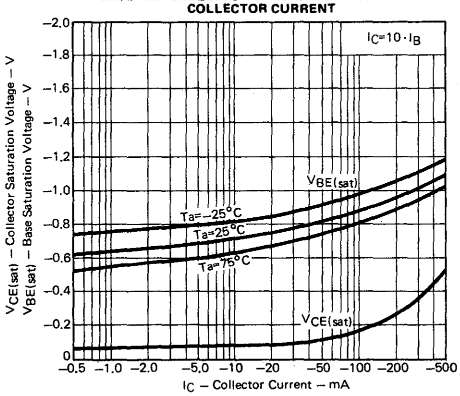
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



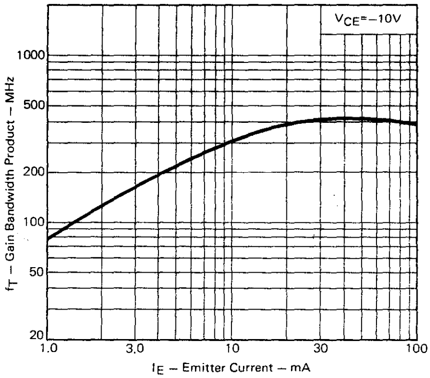
DC CURRENT GAIN vs. COLLECTOR CURRENT



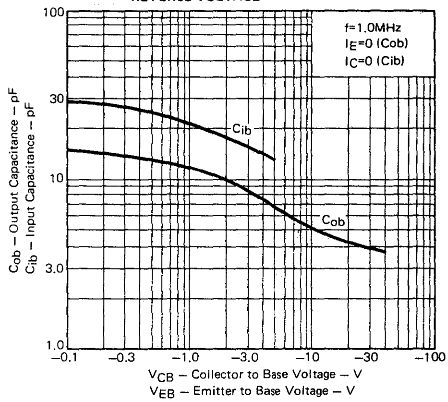
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT

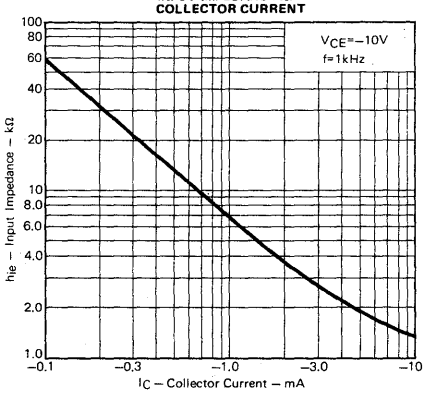


INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE

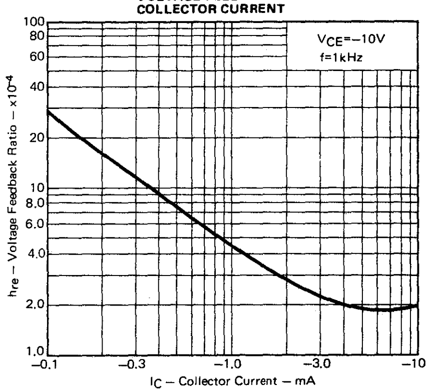


2

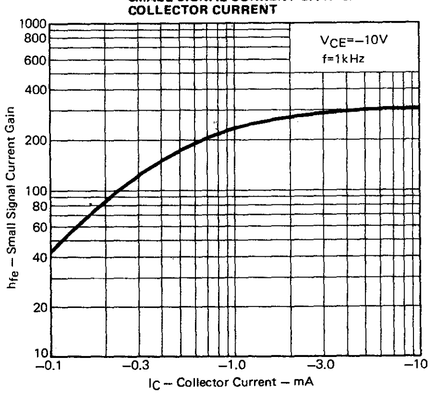
INPUT IMPEDANCE vs. COLLECTOR CURRENT



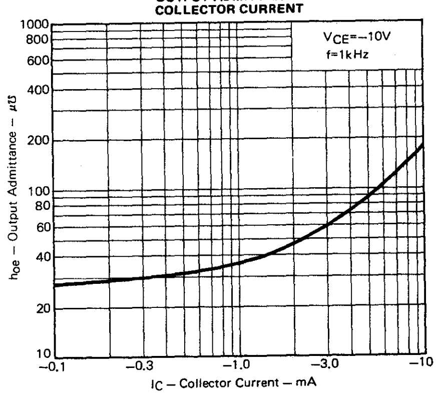
VOLTAGE FEEDBACK RATIO vs. COLLECTOR CURRENT



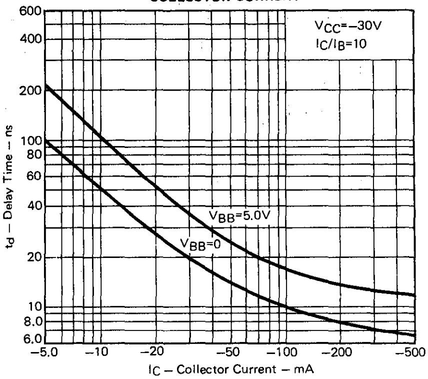
SMALL SIGNAL CURRENT GAIN vs. COLLECTOR CURRENT



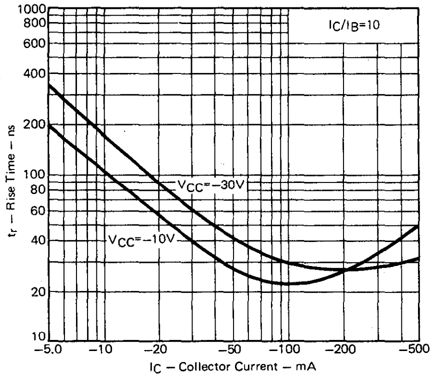
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



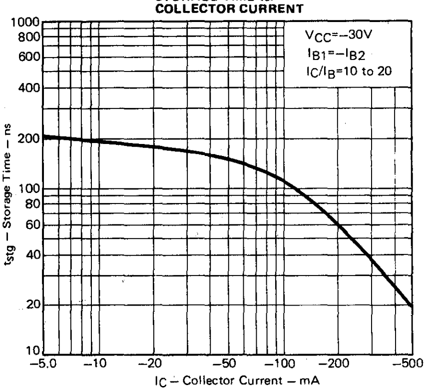
DELAY TIME vs. COLLECTOR CURRENT



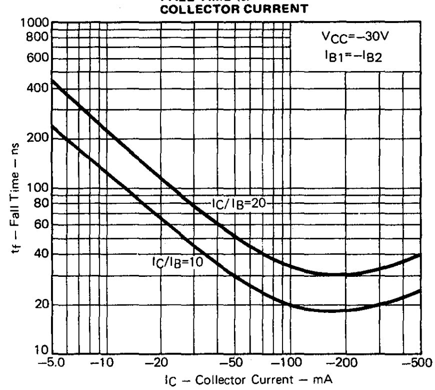
RISE TIME vs. COLLECTOR CURRENT



STORAGE TIME vs. COLLECTOR CURRENT



FALL TIME vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

NPN SILICON TRANSISTORS
NT2222, NT2222A

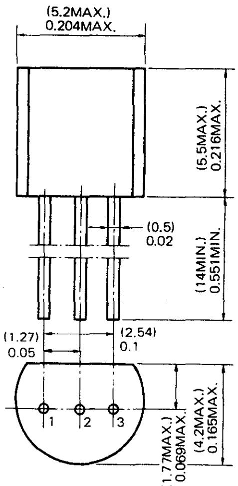
GENERAL PURPOSE AMPLIFIER AND HIGH-SPEED, MEDIUM-POWER SWITCHING NPN SILICON EPITAXIAL TRANSISTOR

2

DESCRIPTION

The NT2222, NT2222A are NPN transistors, designed for general purpose amplifier and high-speed, medium-power switching applications, feature injection-molded plastic package for high reliability.

PACKAGE DIMENSIONS
in (millimeters) inches



1. Emitter JEDEC : TO-92
2. Base
3. Collector

FEATURES

- High Frequency Current Gain.
- Low Collector Saturation Voltage.
- High speed Switching.
- For Complementary Use with PNP Type NT2907, NT2907A.
- NT2222, NT2222A Electrically Similar to 2N2222, 2N2222A.

ABSOLUTE MAXIMUM RATINGS

		NT2222	NT2222A	
Maximum Voltages and Current (T_a=25°C)				
Collector to Base Voltage ($R_{BE}=\infty$)	V_{CBO}	60	75	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	30	40	V
Emitter to Base Voltage	V_{EBO}	5.0	6.0	V
Collector Current	I_C	800		mA
Maximum Power Dissipation (T_a=25°C)				
Total Power Dissipation	P_T	625		mW
Maximum Temperatures				
Storage Temperature	Tstg	−65 to +150		°C
Operating Junction Temperature	Tj	150		°C
Thermal Resistance Junction to Ambient	R_{th}	0.2		°C/mW

NT2222
ELECTRICAL CHARACTERISTICS (Ta=25°C)

CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT	TEST CONDITIONS
Collector-Base Breakdown Voltage	BV_{CBO}	60		V	I_C=10μA, I_E=0
Collector-Emitter Breakdown Voltage	BV_{CEO}*	30		V	I_C=10mA, I_B=0
Emitter-Base Breakdown Voltage	BV_{EBO}	5.0		V	I_E=10μA, I_C=0
Collector Cutoff Current	I_{CBO1}		10	nA	V_{CB}=50V, I_E=0
	I_{CBO2}		10	μA	V_{CB}=50V, I_E=0, Ta=150°C
Emitter Cutoff Current	I_{EBO}		10	nA	V_{EB}=3.0V, I_C=0
DC Current Gain	h_{FE1}	35			V_{CE}=10V, I_C=100μA
	h_{FE2}	50			V_{CE}=10V, I_C=1mA
	h_{FE3}*	75			V_{CE}=10V, I_C=10mA
	h_{FE4}*	100	300		V_{CE}=10V, I_C=150mA
	h_{FE5}*	30			V_{CE}=10V, I_C=500mA
	h_{FE6}*	50			V_{CE}=1.0V, I_C=150mA
Collector Saturation Voltage	$V_{CE(sat)1}$*		0.4	V	I_C=150mA, I_B=15mA
	$V_{CE(sat)2}$*		1.6	V	I_C=500mA, I_B=50mA
Base Saturation Voltage	$V_{BE(sat)1}$*		1.3	V	I_C=150mA, I_B=15mA
	$V_{BE(sat)2}$*		2.6	V	I_C=500mA, I_B=50mA
High Frequency Current Gain	$\lvert h_{fe} \rvert$	2.5			V_{CE}=20V, I_C=20mA, f=100MHz
Gain Bandwidth Product	f_T	250		MHz	V_{CE}=20V, I_C=20mA, f=100MHz
Output Capacitance	C_{ob}		8	pF	V_{CB}=10V, I_E=0, f=100kHz
Input Capacitance	C_{ib}		30	pF	V_{EB}=0.5V, I_C=0, f=100kHz

* These parameters must be measured using pulse techniques. tw ≦ 300μs, duty cycle ≦ 2%

NT2222A
ELECTRICAL CHARACTERISTICS (Ta=25°C)

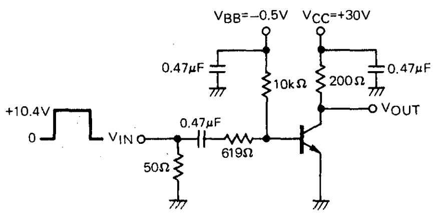
CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT	TEST CONDITIONS
Collector-Base Breakdown Voltage	BV_{CBO}	75		V	I_C=10μA, I_E=0
Collector-Emitter Breakdown Voltage	BV_{CEO}*	40		V	I_C=10mA, I_B=0
Emitter-Base Breakdown Voltage	BV_{EBO}	6.0		V	I_E=10μA, I_C=0
Collector Cutoff Current	I_{CEX}		10	nA	V_{CE}=60V, V_{BE}=−3V
Emitter Cutoff Current	I_{BEX}		−20	nA	V_{CE}=60V, V_{BE}=−3V
Collector Cutoff Current	I_{CBO1}		10	nA	V_{CB}=60V, I_E=0
	I_{CBO2}		10	μA	V_{CB}=60V, I_E=0, Ta=150°C
Base Cutoff Current	I_{EBO}		10	nA	V_{EB}=3.0V, I_C=0
DC Current Gain	h_{FE1}	35			V_{CE}=10V, I_C=100μA
	h_{FE2}	50			V_{CE}=10V, I_C=1mA
	h_{FE3}*	75			V_{CE}=10V, I_C=10mA
	h_{FE4}*	100	300		V_{CE}=10V, I_C=150mA
	h_{FE5}*	40			V_{CE}=10V, I_C=500mA
	h_{FE6}*	50			V_{CE}=1.0V , I_C=150mA
	h_{FE7}*	35			V_{CE}=10V,I_C=10mA, Ta=−55°C
Collector Saturation Voltage	$V_{CE(sat)1}$*		0.3	V	I_C=150mA, I_B=15mA
	$V_{CE(sat)2}$*		1.0	V	I_C=500mA, I_B=50mA
Base Saturation Voltage	$V_{BE(sat)1}$*	0.6	1.2	V	I_C=150mA, I_B=15mA
	$V_{BE(sat)2}$*		2.0	V	I_C=500mA, I_B=50mA
High Frequency Current Gain	$\|h_{fe}\|$	3.0			V_{CE}=20V, I_C=20mA, f=100MHz
Gain Bandwidth Product	f_T	300		MHz	V_{CE}=20V,I_C=20mA,f=100MHz
Output Capacitance	Cob		8	pF	V_{CB}=10V, I_E=0, f=100 kHz
Input Capacitance	Cib		25	pF	V_{EB}=0.5V, I_C=0, f=100 kHz
Input Impedance	h_{ie1}	2.0	8.0	kΩ	V_{CE}=10V, I_C=1.0mA, f=1kHz
	h_{ie2}	0.25	1.25	kΩ	V_{CE}=10V, I_C=10mA, f=1kHz
Voltage Feedback Ratio	h_{re1}		8.0	$\times10^{-4}$	V_{CE}=10V, I_C=1.0mA, f=1kHz
	h_{re2}		4.0	$\times10^{-4}$	V_{CE}=10V, I_C=10mA, f=1kHz
Small-Signal Current Gain	h_{fe1}	50	300		V_{CE}=10V, I_C=1.0mA, f=1kHz
	h_{fe2}	75	375		V_{CE}=10V, I_C=10mA, f=1kHz
Output Admittance	h_{oe1}	5.0	35	μ℧	V_{CE}=10V, I_C=1.0mA, f=1kHz
	h_{oe2}	25	200	μ℧	V_{CE}=10V, I_C=10mA, f=1kHz
Collector-Base Time Constant	$C_{c} \cdot r_{b'b}$		150	ps	V_{CB}=20V, I_E=20mA, f=31.8MHz
Noise Figure	NF		4.0	dB	V_{CE}=10V, I_C=100μA, R_S=1kΩ f=1.0kHz

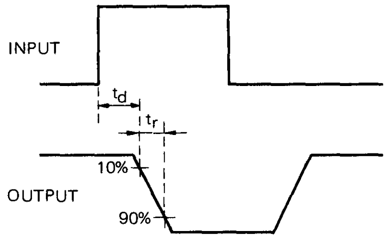
* These parameters must be measured using pulse techniques. tw≦300μs, duty cycle≦2%

SWITCHING CHARACTERISTICS (Ta=25°C)

CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT	TEST CONDITIONS
Delay Time	t_d		10	ns	V_{CC}=30V, V_{BE}=−0.5V
Rise Time	t_r		25	ns	I_C=150mA, I_{B1}=15mA
Storage Time	t_{stg}		225	ns	V_{CC}=30V, I_C=150mA
Fall Time	t_f		60	ns	I_{B1}=−I_{B2}=15mA

SWITCHING TIME TEST CIRCUIT



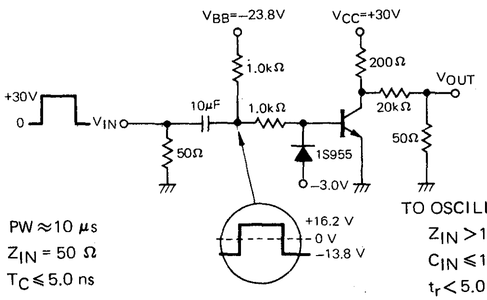


PW≤200 ns
t_r≤2.0 ns
Z_{IN} = 50Ω

TO OSCILLOSCOPE
Z_{IN} > 100 kΩ
C_{IN} ≤ 12 pF
t_r ≤ 5.0 ns

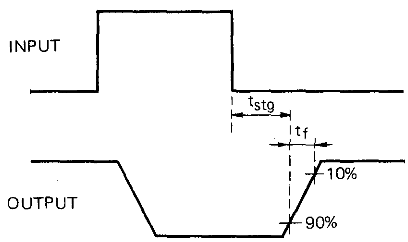
VOLTAGE WAVEFORMS

t_{on} SWITCHING



PW ≈10 μs
Z_{IN} = 50 Ω
T_C≤5.0 ns

TO OSCILLOSCOPE
Z_{IN} >100 kΩ
C_{IN} ≤12 pF
t_r< 5.0 ns



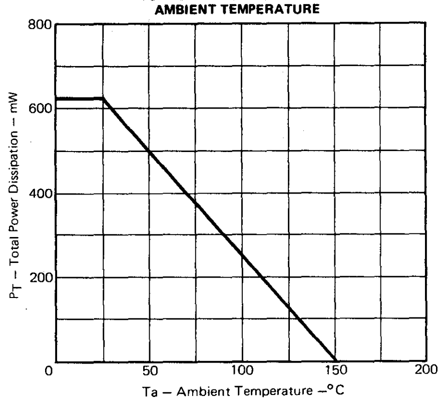
The 20 kΩ and 50 Ω resistors on the output of the test circuit are normally omitted, due to the excessive attenuation of the collector waveform. The collector voltage is monitored directly with a high impedance oscilloscope probe.

VOLTAGE WAVEFORMS

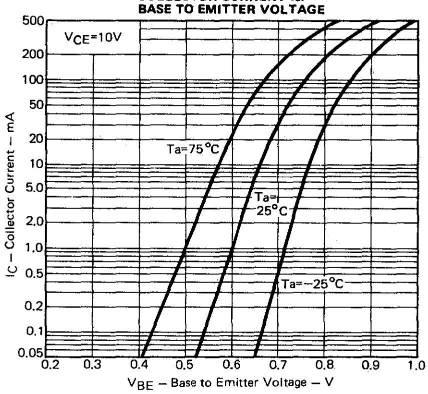
t_{off} SWITCHING

TYPICAL CHARACTERISTICS (Ta=25°C)

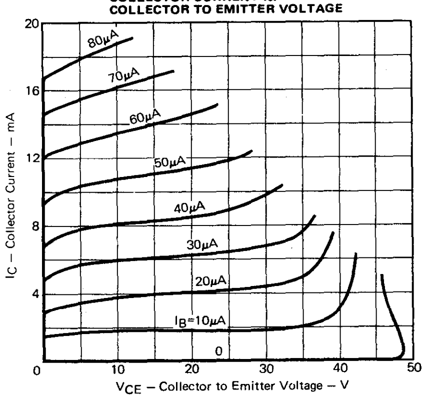
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



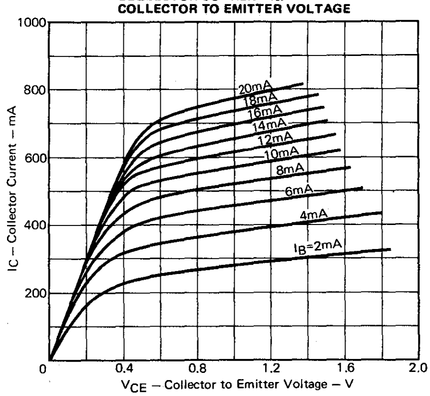
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



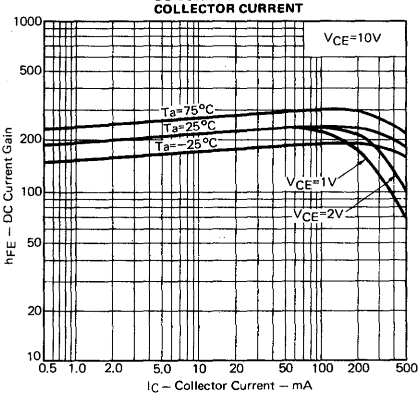
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



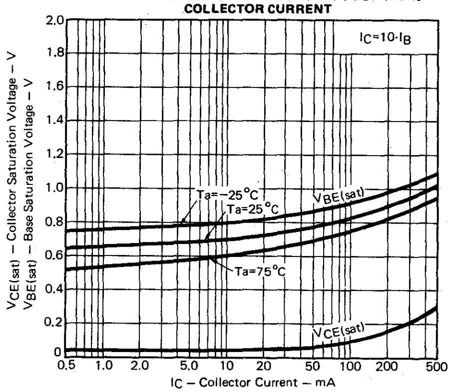
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



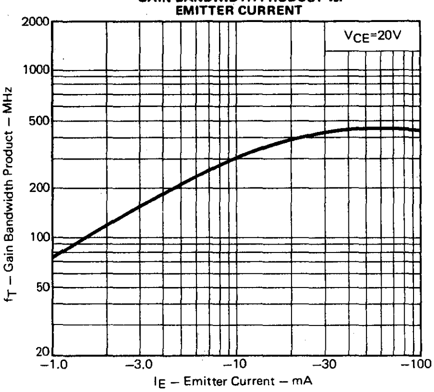
DC CURRENT GAIN vs. COLLECTOR CURRENT



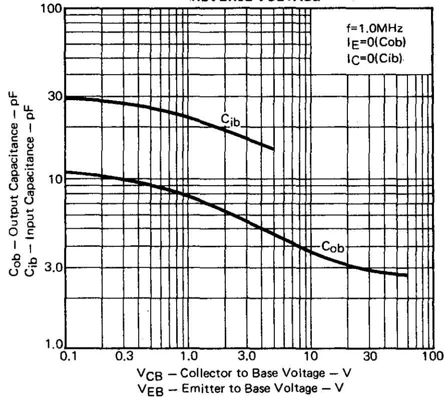
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



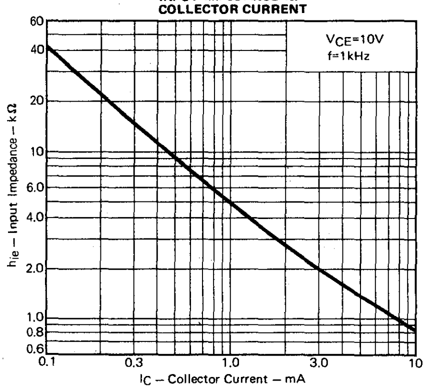
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



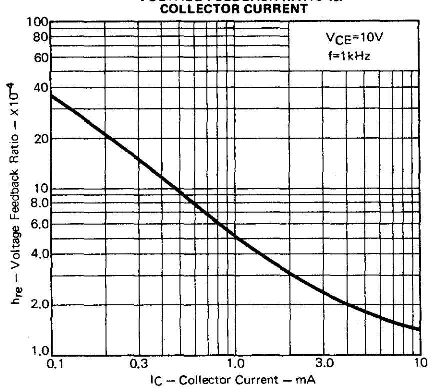
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



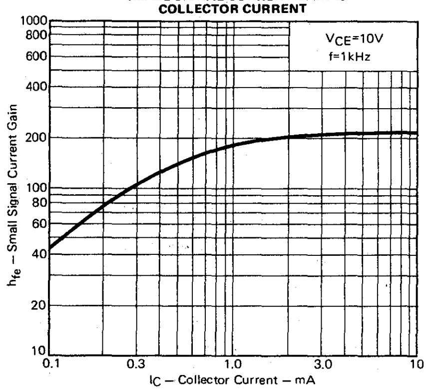
INPUT IMPEDANCE vs. COLLECTOR CURRENT



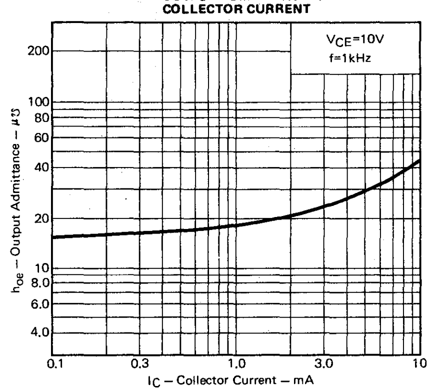
VOLTAGE FEEDBACK RATIO vs. COLLECTOR CURRENT

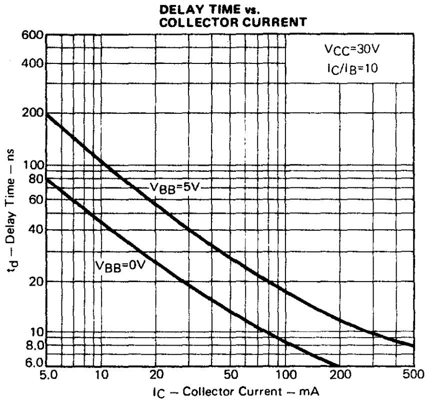


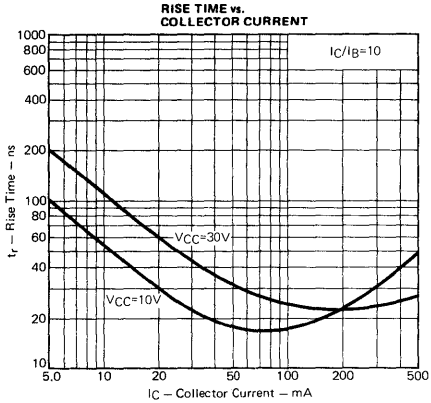
SMALL SIGNAL CURRENT GAIN vs. COLLECTOR CURRENT

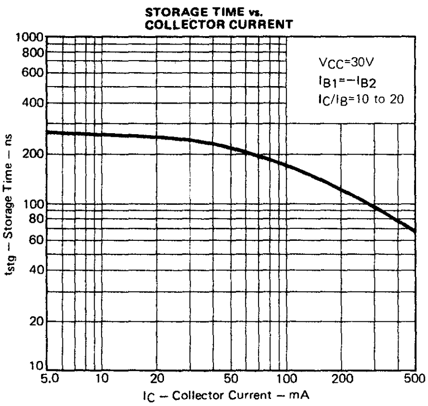


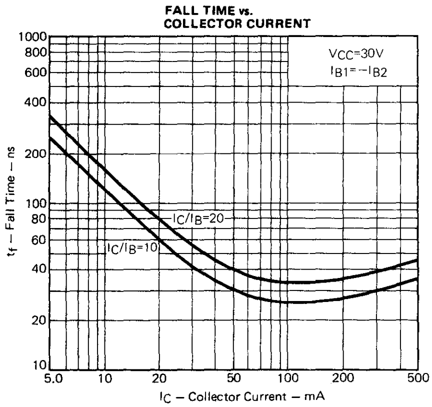
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT




DELAY TIME vs. COLLECTOR CURRENT
VCC=30V
IC/IB=10
VBB=5V
VBB=0V
td – Delay Time – ns
IC – Collector Current – mA


RISE TIME vs. COLLECTOR CURRENT
IC/IB=10
VCC=30V
VCC=10V
tr – Rise Time – ns
IC – Collector Current – mA


STORAGE TIME vs. COLLECTOR CURRENT
VCC=30V
IB1=–IB2
IC/IB=10 to 20
tstg – Storage Time – ns
IC – Collector Current – mA


FALL TIME vs. COLLECTOR CURRENT
VCC=30V
IB1=–IB2
IC/IB=20
IC/IB=10
tf – Fall Time – ns
IC – Collector Current – mA

2

NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR

NT2369A

DESCRIPTION The NT2369A is designed for general purpose amplifier and high speed switching applications.

FEATURES

- High Frequency Current Gain.
- High Speed Switching.
- NT2369A Electrically Similar to 2N2369A.

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . –65 to +150 °C

Junction Temperature . . . . 150 °C Maximum

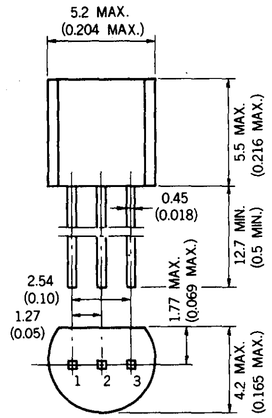
Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation . . . . 625 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO}	Collector to Base Voltage	40 V
V_{CES}	Collector to Emitter Voltage	40 V
V_{CEO}	Collector to Emitter Voltage	15 V
V_{EBO}	Emitter to Base Voltage	4.5 V
I_C	Collector Current	200 mA
I_C	Collector Current (10 μs pulse)	500 mA

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. BASE JEDEC : TO-92
3. COLLECTOR IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
t_{on}	Turn-on Time			12	ns	V_{CC}=3.0 V, I_C=10 mA, I_{B1}=3.0 mA, V_{BE}=–1.5 V
t_{off}	Turn-off Time			18	ns	V_{CC}=3.0 V, I_C=10 mA, I_{B1}= 3.0 mA, I_{B2}=–1.5 mA
t_{stg}	Storage Time			13	ns	I_C=10 mA, I_{B1}=–I_{B2}=10 mA
f_T	Gain Bandwidth Product	500	750		MHz	V_{CE}=10 V, I_C=10 mA, f=100 MHz
C_{ob}	Output Capacitance		1.8	4.0	pF	V_{CB}=5.0 V, I_E=0, f=1 MHz
h_{FE1}*	DC Current Gain	40	85	120	–	V_{CE}=0.35 V, I_C=10 mA
h_{FE2}*	DC Current Gain	30	60		–	V_{CE}=0.4 V, I_C=30 mA
h_{FE3}*	DC Current Gain	20	35		–	V_{CE}=1.0 V, I_C=100 mA
h_{FE4}*	DC Current Gain	20			–	V_{CE}=0.35 V, I_C=10 mA, Ta=–55 °C
$V_{CE(sat)1}$*	Collector Saturation Voltage		0.15	0.2	V	I_C=10 mA, I_B=1.0 mA
$V_{CE(sat)2}$*	Collector Saturation Voltage		0.20	0.25	V	I_C=30 mA, I_B=3.0 mA
$V_{CE(sat)3}$*	Collector Saturation Voltage		0.35	0.5	V	I_C=100 mA, I_B=10 mA
$V_{CE(sat)4}$*	Collector Saturation Voltage			0.3	V	I_C=10 mA, I_B=1.0 mA, Ta=125 °C

* Pulsed PW ≦350 μs, duty cycle ≦2 %

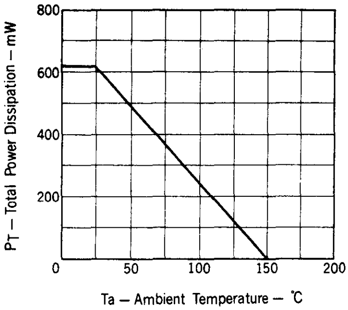
Additional characteristics on following page.

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{CES}	Collector Cutoff Current			0.4	μA	V_{CB}=20 V, V_{BE}=0
I_{CBO}	Collector Cutoff Current			30	μA	V_{CB}=20 V, I_E=0, Ta=150 °C
BV_{CBO}	Collector to Base Breakdown Voltage	40			V	I_C=10 μA, I_E=0
BV_{CES}	Collector to Emitter Breakdown Voltage	40			V	I_C=10 μA, V_{BE}=0
BV_{CEO}*	Collector to Emitter Breakdown Voltage	15			V	I_C=10 mA, I_B=0
BV_{EBO}	Emitter to Base Breakdown Voltage	4.5			V	I_E=10 μA, I_C=0
$V_{BE(sat)1}$*	Base Saturation Voltage	0.7	0.78	0.85	V	I_C=10 mA, I_B=1.0 mA
$V_{BE(sat)2}$*	Base Saturation Voltage		0.85	1.15	V	I_C=30 mA, I_B=3.0 mA
$V_{BE(sat)3}$*	Base Saturation Voltage		1.05	1.6	V	I_C=100 mA, I_B=10 mA
$V_{BE(sat)4}$*	Base Saturation Voltage	0.59		1.02	V	I_C=10 mA, I_B=1.0 mA, Ta=−55 to +125 °C

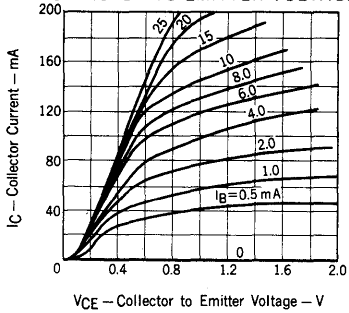
* Pulsed PW ≦350 μs, duty cycle ≦2 %

TYPICAL CHARACTERISTICS (Ta=25 °C)

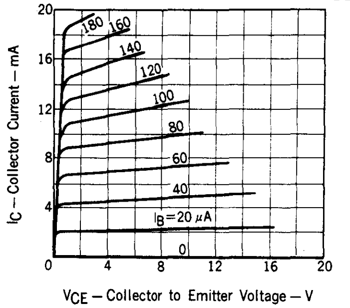
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



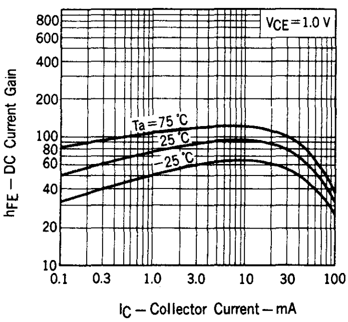
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



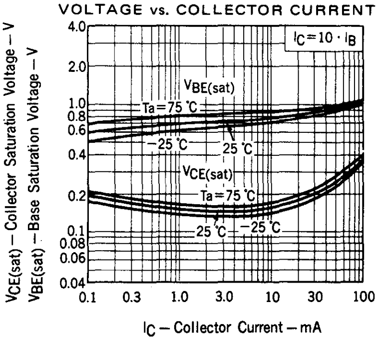
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



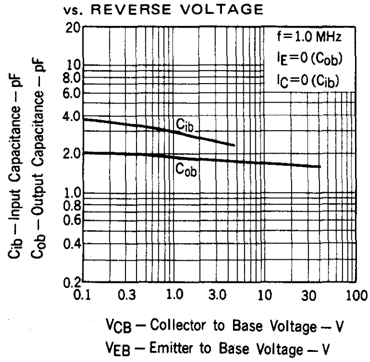
DC CURRENT GAIN vs. COLLECTOR CURRENT



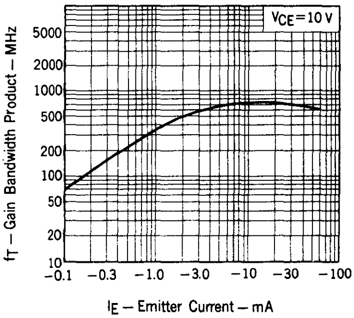
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



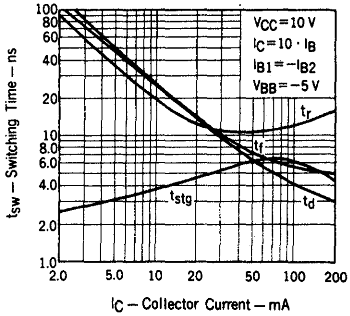
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



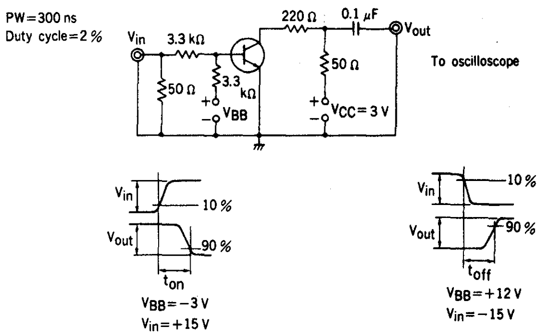
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



SWITCHING TIME vs. COLLECTOR CURRENT

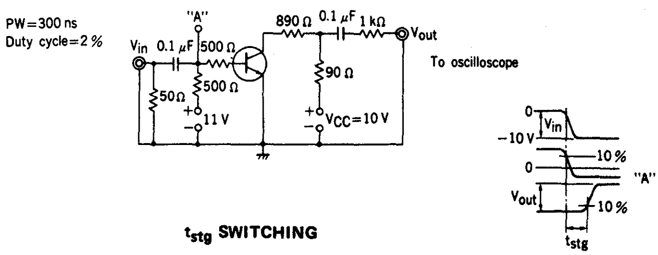


SWITCHING TIME TEST CIRCUIT



Voltage waveforms

t_{on}, t_{off} SWITCHING



t_{stg} SWITCHING

Voltage waveforms

NEC
ELECTRON DEVICE

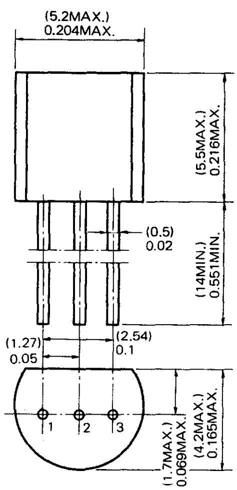
PNP SILICON TRANSISTORS
NT2907, NT2907A

GENERAL PURPOSE AMPLIFIER AND HIGH-SPEED, MEDIUM-POWER SWITCHING PNP SILICON EPITAXIAL TRANSISTOR

DESCRIPTION

The NT2907, NT2907A are PNP Transistors, designed for general purpose amplifier and high speed, medium-power switching applications, feature injection-molded plastic package for high reliability.

PACKAGE DIMENSIONS in (millimeter) inches



1. Emitter JEDEC : TO-92
2. Base
3. Collector

FEATURES

- High Frequency Current Gain.
- Low Collector Saturation Voltage.
- High Speed Switching.
- For Complementary Use with NPN Type NT2222, NT2222A.
- NT2907, NT2907A Electrically Similar to 2N2907, 2N2907A.

ABSOLUTE MAXIMUM RATINGS

		NT2907	NT2907A	
Maximum Voltages and Current (Ta=25°C)				
Collector to Base Voltage ($R_{BE}=\infty$)	V_{CBO}	−60	−60	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	−40	−60	V
Emitter to Base Voltage	V_{EBO}	−5.0	−5.0	V
Collector Current	I_C	−600		mA
Maximum Power Dissipation (Ta=25°C)				
Total Power Dissipation	P_T	625		mW
Maximum Temperatures				
Storage Temperature	Tstg	−65 to +150		°C
Operating Junction Temperature	T_j	150		°C
Thermal Resistance				
Junction to Ambient	Rth	0.2		°C/mW

ELECTRICAL CHARACTERISTICS (Ta=25°C)

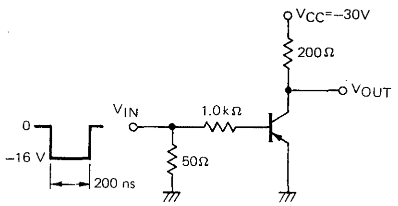
CHARACTERISTIC	SYMBOL	NT2907		NT2907A		UNIT	TEST CONDITIONS
		MIN.	MAX.	MIN.	MAX.		
Collector-Base Breakdown Voltage	BV_{CBO}	−60		−60		V	I_C=−10μA, I_E=0
Collector-Emitter Breakdown Voltage	BV_{CEO}*1	−40		−60		V	I_C=−10mA, I_B=0
Emitter-Base Breakdown Voltage	BV_{EBO}	−5.0		−5.0		V	I_E=−10μA, I_C=0
Collector Cutoff Current	I_{CEX}		−50		−50	nA	V_{CE}=−30V, V_{BE}=0.5V
	I_{CBO1}		−20		−10	nA	V_{CB}=−50V, I_E=0
	I_{CBO2}		−20		−10	μA	V_{CB}=−50V, I_E=0, Ta=150°C
Base Cutoff Current	I_{BEX}		50		50	nA	V_{CE}=−30V, V_{BE}=0.5V
DC Current Gain	h_{FE1}	35		75			V_{CE}=−10V, I_C=−100μA
	h_{FE2}	50		100			V_{CE}=−10V, I_C=−1mA
	h_{FE3}	75		100			V_{CE}=−10V, I_C=−10mA
	h_{FE4}*	100	300	100	300		V_{CE}=−10V, I_C=−150mA
	h_{FE5}*	30		50			V_{CE}=−10V, I_C=−500mA
Collector Saturation Voltage	$V_{CE(sat)1}$*		−0.4		−0.4	V	I_C=−150mA, I_B=−15mA
	$V_{CE(sat)2}$*		−1.6		−1.6	V	I_C=−500mA, I_B=−50mA
Base Saturation Voltage	$V_{BE(sat)1}$*		−1.3		−1.3	V	I_C=−150mA, I_B=−15mA
	$V_{BE(sat)2}$*		−2.6		−2.6	V	I_C=−500mA, I_B=−50mA
High Frequency Current Gain	$\|h_{fe}\|$	2		2			I_C=−50mA, V_{CE}=−20V, f=100MHz
Gain Bandwidth Product	f_T	200		200		MHz	I_C=−50mA, V_{CE}=−20V, f=100MHz
Output Capacitance	C_{ob}		8.0		8.0	pF	V_{CB}=−10V, I_E=0, f=100kHz
Input Capacitance	C_{ib}		30		30	pF	V_{EB}=−2V, I_C=0, f=100kHz

* These parameters must be measured using pulse techniques. tw≤300μs duty cycle≤2%

SWITCHING CHARACTERISTICS (Ta=25°C)

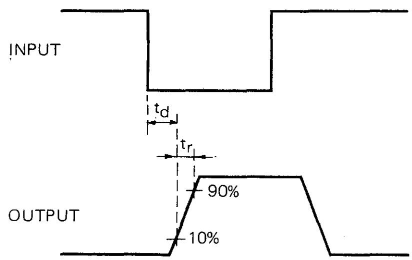
CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT	TEST CONDITIONS
Delay Time	t_d		10	ns	V_{CC}=–30V, I_C=–150mA, V_{BE}=0, I_{B1}=–15mA
Rise Time	t_r		40	ns	
Turn-On Time	t_{on}		45	ns	
Storage Time	t_{stg}		80	ns	V_{CC}=–6V, I_C=–150mA, I_{B1}=–I_{B2}=–15mA
Fall Time	t_f		30	ns	
Turn-Off Time	t_{off}		100	ns	

SWITCHING TIME TEST CIRCUIT



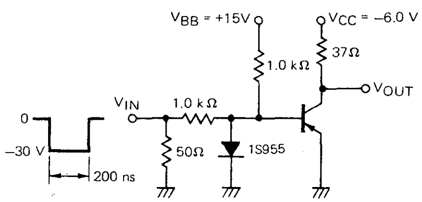
Z_O = 50Ω
PRF = 150 pps
$t_r \leq 2.0$ ns

TO OSCILLOSCOPE
$t_r \leq 5.0$ ns
Z_{IN} = 10 MΩ



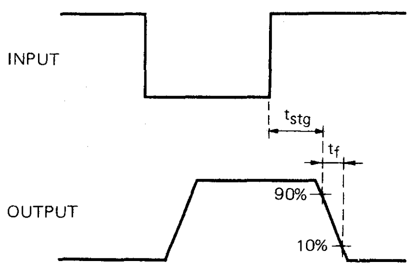
VOLTAGE WAVEFORMS

t_{on} SWITCHING



Z_O = 50Ω
PRF = 150 pps
$t_r \leq 2.0$ ns

TO OSCILLOSCOPE
$t_r \leq 5.0$ ns
Z_{IN} = 10 MΩ

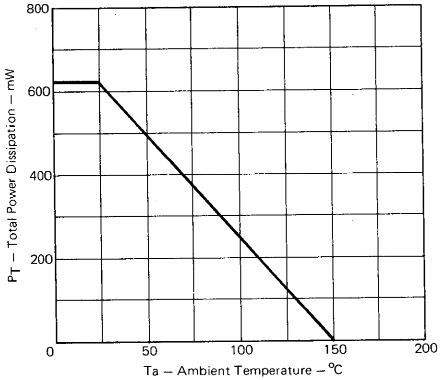


VOLTAGE WAVEFORMS

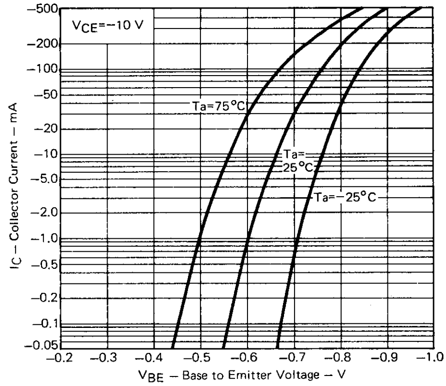
t_{off} SWITCHING

TYPICAL CHARACTERISTICS (Ta=25 °C)

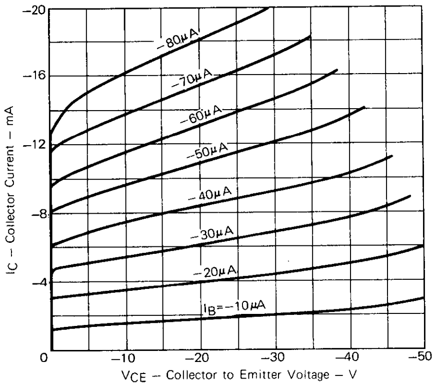
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



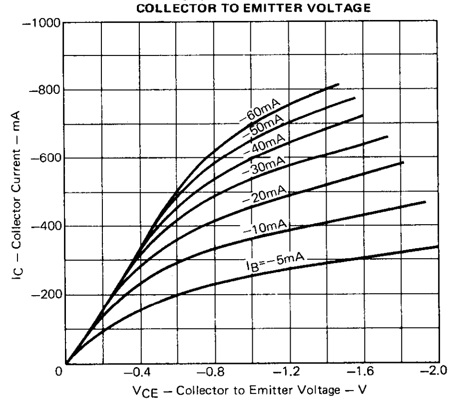
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



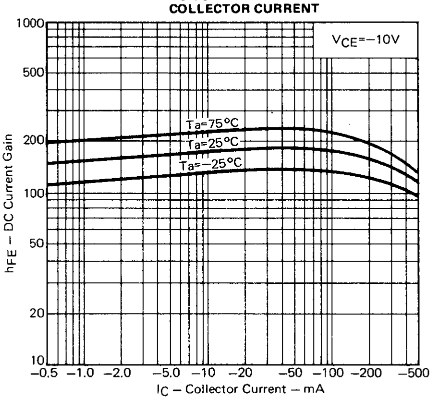
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



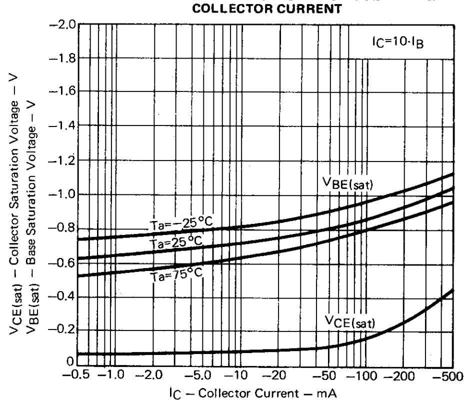
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT

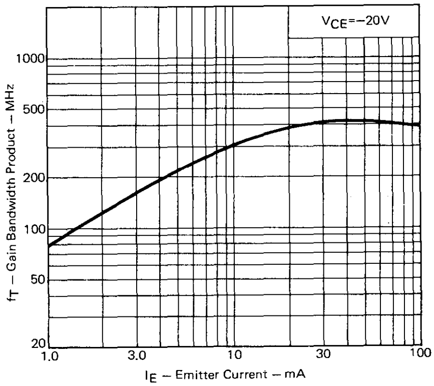


BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

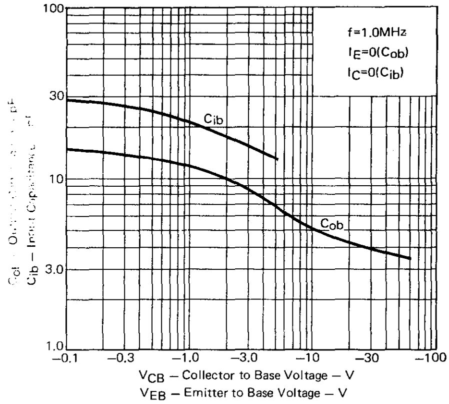


2

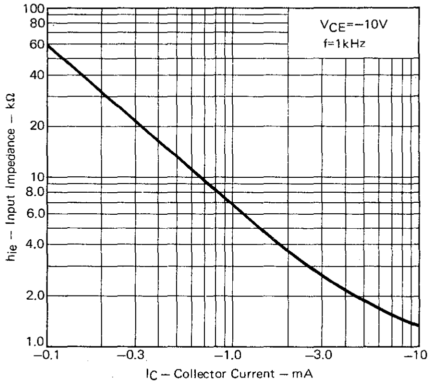
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



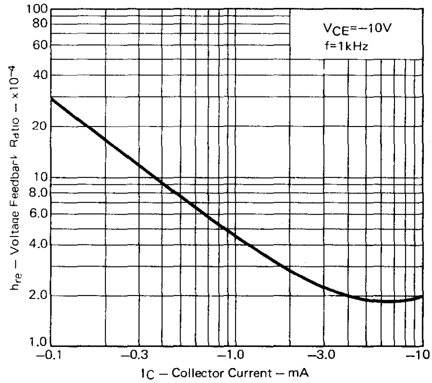
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



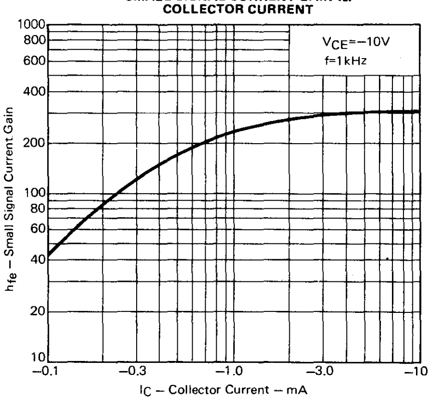
INPUT IMPEDANCE vs. COLLECTOR CURRENT



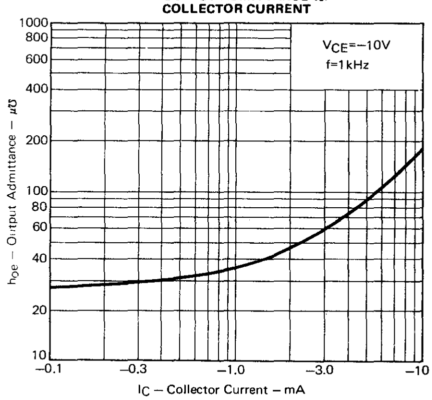
VOLTAGE FEEDBACK RATIO vs. COLLECTOR CURRENT



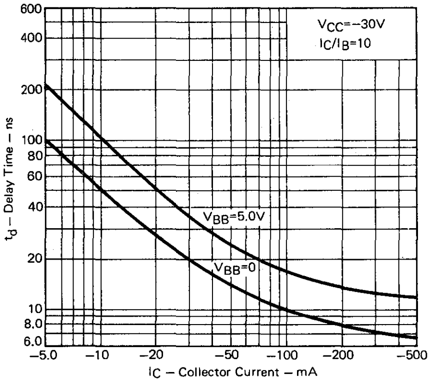
SMALL SIGNAL CURRENT GAIN vs. COLLECTOR CURRENT



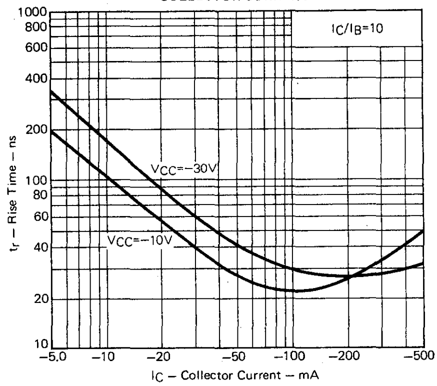
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



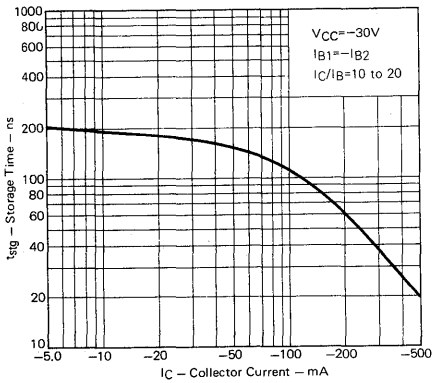
DELAY TIME vs. COLLECTOR CURRENT



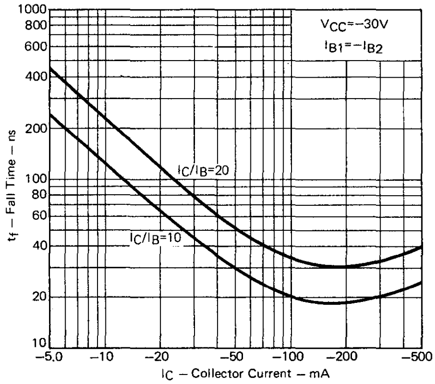
RISE TIME vs. COLLECTOR CURRENT



STORAGE TIME vs. COLLECTOR CURRENT



FALL TIME vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
JE7001

DESCRIPTION

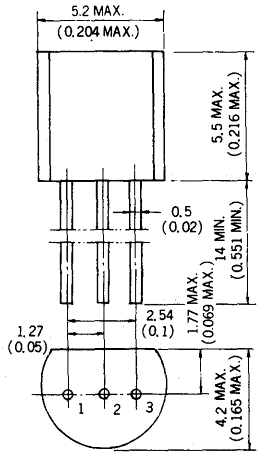
The JE7001 is an NPN silicon epitaxial transistor intended for use as VHF and UHF oscillators and a VHF mixer in a tuner of a TV receiver.

The device features stable oscillation and small frequency drift against any change of the supply voltage and the ambient temperature.

FEATURES

- High gain bandwidth product;
  f_T=1 100 MHz TYP.
- Low collector to base time constant;
  $C_c \cdot r_{b'b}$=10 ps TYP.
- Low output capacitance;
  C_{ob}=1.5 pF MAX.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base — EIAJ : SC-43
2. Emitter — JEDEC : TO-92
3. Collector — IEC : PA33

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures

Storage Temperature . . . . –55 to +150 °C

Junction Temperature . . . . +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation . . . . 400 mW

Maximum Voltages and Currents (Ta=25 °C)

V_{CBO}	Collector to Base Voltage	30	V
V_{CEO}	Collector to Emitter Voltage	15	V
V_{EBO}	Emitter to Base Voltage	4.0	V
I_C	Collector Current	50	mA
I_B	Base Current.	10	mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	60	100	270		V_{CE}=10 V, I_C=5.0 mA
f_T	Gain Bandwidth Product	800	1 100		MHz	V_{CE}=10 V, I_E=–5.0 mA
C_{ob}	Output Capacitance			1.5	pF	V_{CB}=10 V, I_E=0, f=1.0 MHz
$C_c \cdot r_{b'b}$	Collector to Base Time Constant		10	15	ps	V_{CE}=10 V, I_E=–5.0 mA, f=31.9 MHz
$V_{CE(sat)}$	Collector Saturation Voltage			0.5	V	I_C=10 mA, I_B=1.0 mA
I_{CBO}	Collector Cutoff Current			0.1	μA	V_{CB}=12 V, I_E=0

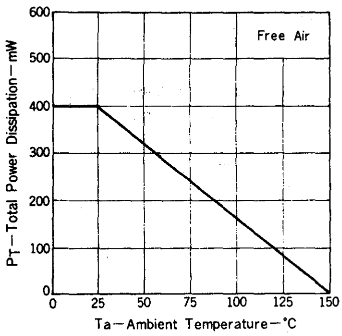
Classification of h_{FE}

Rank	L	K	J
Range	60 – 120	90 – 180	135 – 270

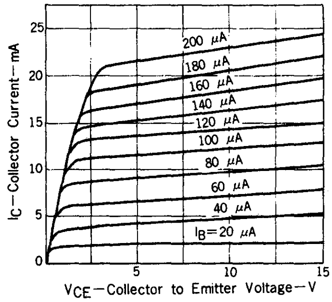
h_{FE} Test Conditions: V_{CE}=10 V, I_C=5.0 mA

TYPICAL CHARACTERISTICS (Ta=25 °C)

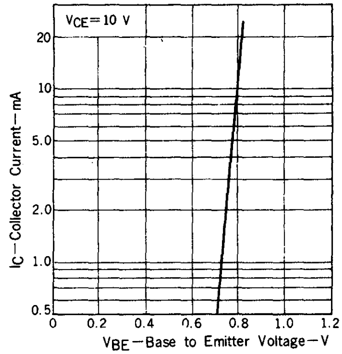
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



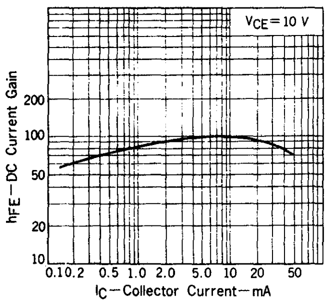
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



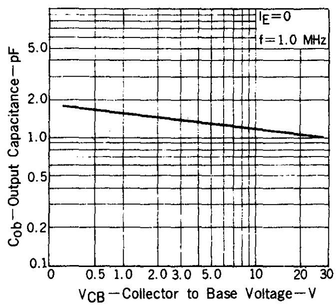
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



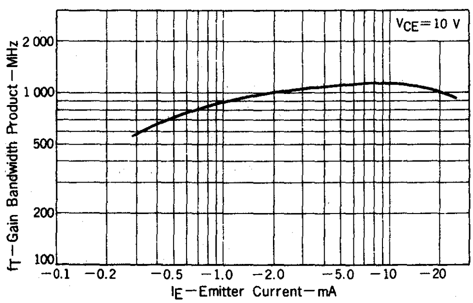
DC CURRENT GAIN vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE

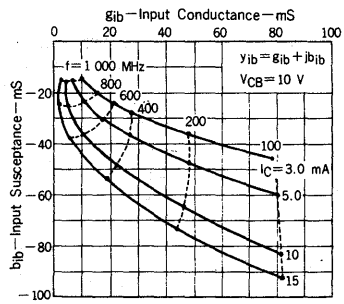


GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT

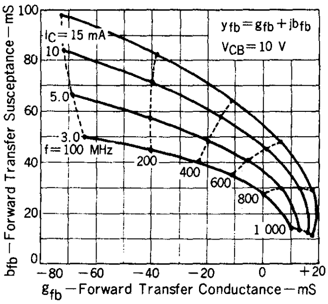


TYPICAL CHARACTERISTICS of "Y" PARAMETERS

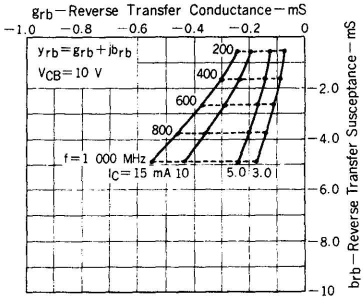
INPUT ADMITTANCE (y_{ib}) vs. FREQUENCY



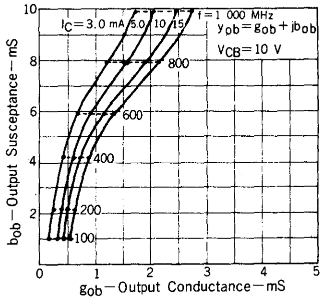
FORWARD TRANSFER ADMITTANCE (y_{fb}) vs. FREQUENCY



REVERSE TRANSFER ADMITTANCE (y_{rb}) vs. FREQUENCY



OUTPUT ADMITTANCE (y_{ob}) vs. FREQUENCY



2

NEC
ELECTRON DEVICE

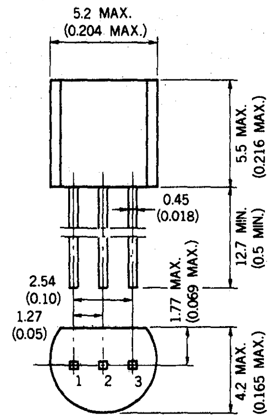
NPN SILICON TRANSISTOR
JE8050

DESCRIPTION The JE8050 is designed for use in 2 W output amplifier of portable radios in class B push-pull operation.

FEATURES

- High total power dissipation. (P_T : 2.0 W, T_C = 25 °C)
- High collector current. (I_C : 1.5 A)
- Complementary to JE8550.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. BASE
3. COLLECTOR

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature . . . . −65 to +150 °C
- Junction Temperature . . . . . . +150 °C Maximum

Maximum Power Dissipations
- Total Power Dissipation (Ta = 25 °C) . . . . . 1.0 W
  Transistor mounted on printed circuit board, max. lead length 4 mm, mounting pad for collector lead min. 10 mm x 10 mm.
- Total Power Dissipation (T_C = 25 °C) . . . . 2.0 W
- Thermal Resistance (Ta = 25 °C) (Junction to Ambient) . . . 156.25 °C/W

Maximum Voltages and Currents (Ta = 25 °C)
- V_{CBO} Collector to Base Voltage . . . . 40 V
- V_{CEO} Collector to Emitter Voltage . . . . . 25 V
- V_{EBO} Emitter to Base Voltage . . . . 6.0 V
- I_C Collector Current . . . . 1.5 A
- I_B Base Current . . . . 0.5 A

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	45	135		–	V_{CE}=1.0 V, I_C=5.0 mA
h_{FE2}	DC Current Gain	85	160	300	–	V_{CE}=1.0 V, I_C=100 mA
h_{FE3}	DC Current Gain	40	110		–	V_{CE}=1.0 V, I_C=800 mA
f_T	Gain Bandwidth Product	100	190		MHz	V_{CE}=10 V, I_C=50 mA
C_{ob}	Output Capacitance		9.0		pF	V_{CB}=10 V, I_E=0, f=1.0 MHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB}=35 V, I_E=0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE}=25 V, I_B=0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB}=6.0 V, I_C=0
V_{BE}	Base to Emitter Voltage		0.66	1.0	V	V_{CE}=1.0 V, I_C=10 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.28	0.5	V	I_C=800 mA, I_B=80 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.98	1.2	V	I_C=800 mA, I_B=80 mA
BV_{CBO}	Collector to Base Breakdown Voltage	40			V	I_C=0.1 mA, I_E=0
BV_{CEO}	Collector to Emitter Breakdown Voltage	25			V	I_C=2.0 mA, I_B=0
BV_{EBO}	Emitter to Base Breakdown Voltage	6.0			V	I_E=0.1 mA, I_C=0

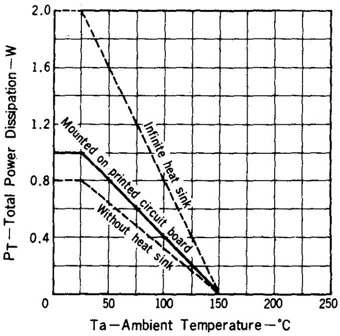
Classification of h_{FE2}

Rank	B	C	D
Range	85 – 160	120 – 200	160 – 300

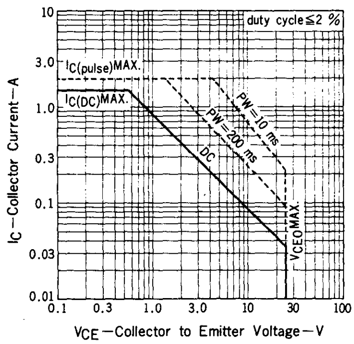
h_{FE} Test Conditions : V_{CE} = 1.0 V, I_C = 100 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

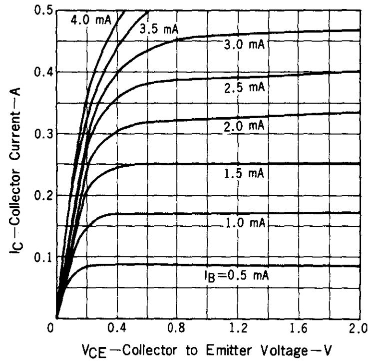
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



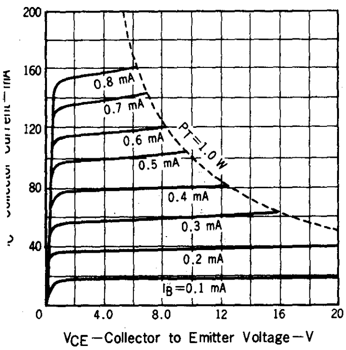
SAFE OPERATING AREA



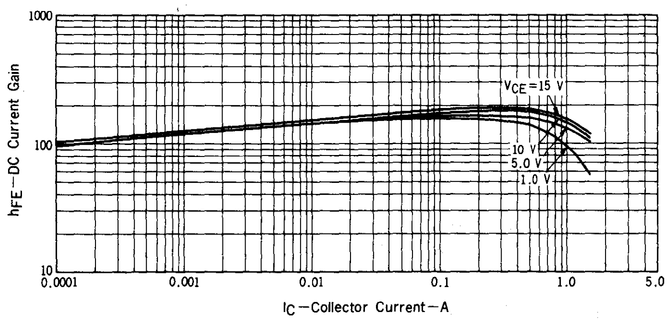
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



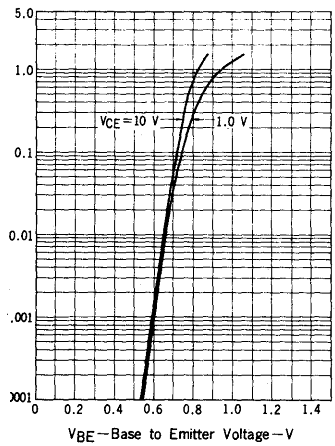
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



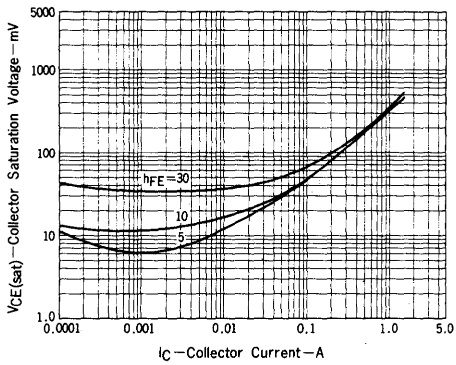
DC CURRENT GAIN vs. COLLECTOR CURRENT



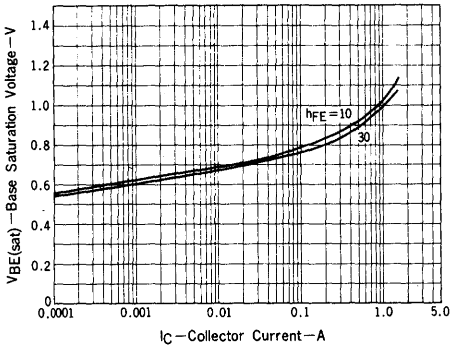
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



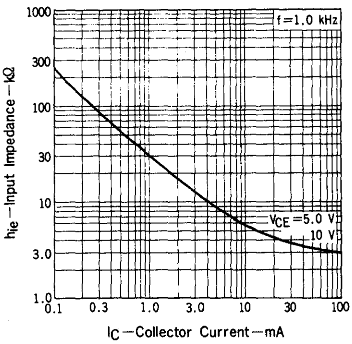
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



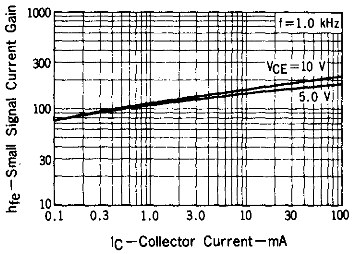
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



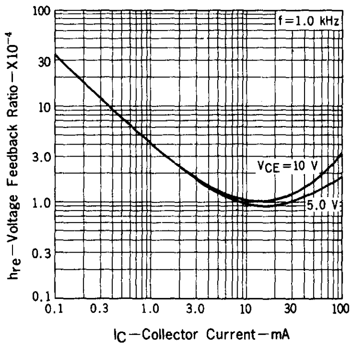
INPUT IMPEDANCE vs. COLLECTOR CURRENT



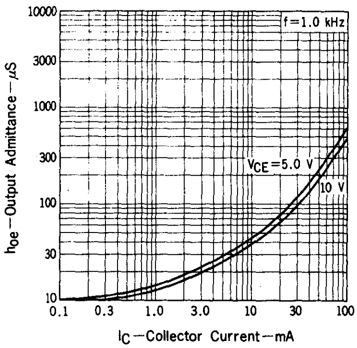
SMALL SIGNAL CURRENT GAIN vs. COLLECTOR CURRENT



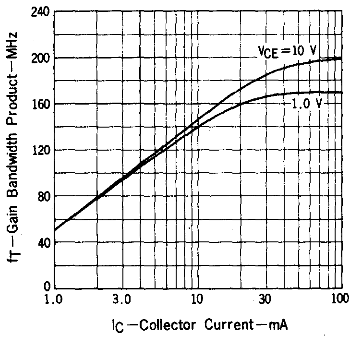
VOLTAGE FEEDBACK RATIO vs. COLLECTOR CURRENT



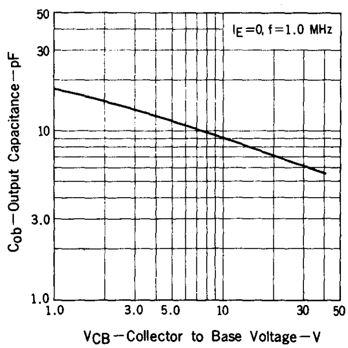
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

PNP SILICON TRANSISTOR
JE8550

DESCRIPTION The JE8550 is designed for use in 2 W output amplifier of portable radios in class B push-pull operation.

FEATURES

- High total power dissipation. (P_T : 2.0 W, T_C = 25 °C)
- High collector current. (I_C : −1.5 A)
- Complementary to JE8050.

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

- Storage Temperature . . . . −65 to +150 °C
- Junction Temperature . . . . +150 °C Maximum

Maximum Power Dissipations

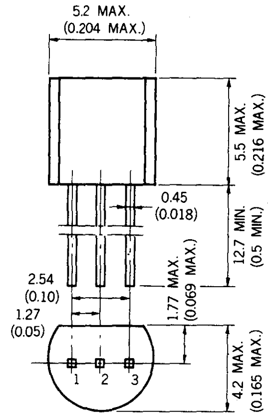
- Total Power Dissipation (Ta = 25 °C) . . . . 1.0 W

  Transistor mounted on printed circuit board, max. lead length 4 mm, mounting for collector lead min. 10 mm x 10 mm.
- Total Power Dissipation (T_C = 25 °C) . . . . 2.0 W
- Thermal Resistance (Ta = 25 °C) (Junction to Ambient) . . . . 156.25 °C/W

Maximum Voltages and Currents (Ta = 25 °C)

- V_{CBO} Collector to Base Voltage . . . . −40 V
- V_{CEO} Collector to Emitter Voltage . . . . −25 V
- V_{EBO} Emitter to Base Voltage . . . . −6.0 V
- I_C Collector Current . . . . −1.5 A
- I_B Base Current . . . . −0.5 A

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. BASE
3. COLLECTOR

EIAJ : SC-43
JEDEC: TO-92
IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	45	170		–	V_{CE}=−1.0 V, I_C=−5.0 mA
h_{FE2}	DC Current Gain	85	160	300	–	V_{CE}=−1.0 V, I_C=−100 mA
h_{FE3}	DC Current Gain	40	80		–	V_{CE}=−1.0 V, I_C=−800 mA
f_T	Gain Bandwidth Product	100	200		MHz	V_{CE}=−10 V, I_C=−50 mA
C_{ob}	Output Capacitance		15		pF	V_{CB}=−10 V, I_E=0, f=1.0 MHz
I_{CBO}	Collector Cutoff Current			−100	nA	V_{CB}=−35 V, I_E=0
I_{CEO}	Collector Cutoff Current			−1.0	μA	V_{CE}=−25 V, I_B=0
I_{EBO}	Emitter Cutoff Current			−100	nA	V_{EB}=−6.0 V, I_C=0
V_{BE}	Base to Emitter Voltage		−0.66	−1.0	V	V_{CE}=−1.0 V, I_C=−10 mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.28	−0.5	V	I_C=−800 mA, I_B=−80 mA
$V_{BE(sat)}$	Base Saturation Voltage		−0.98	−1.2	V	I_C=−800 mA, I_B=−80 mA
BV_{CBO}	Collector to Base Breakdown Voltage	−40			V	I_C=−0.1 mA, I_E=0
BV_{CEO}	Collector to Emitter Breakdown Voltage	−25			V	I_C=−2.0 mA, I_B=0
BV_{EBO}	Emitter to Base Breakdown Voltage	−6.0			V	I_E=−0.1 mA, I_C=0

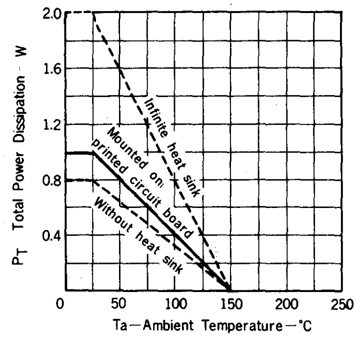
Classification of h_{FE2}

Rank	B	C	D
Range	85 – 160	120 – 200	160 – 300

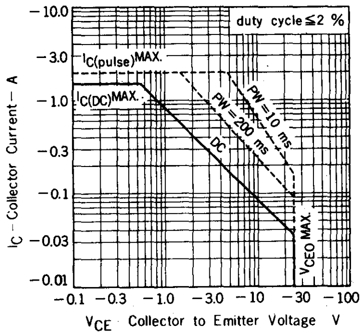
h_{FE} Test Conditions : V_{CE} = −1.0 V, I_C = −100 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

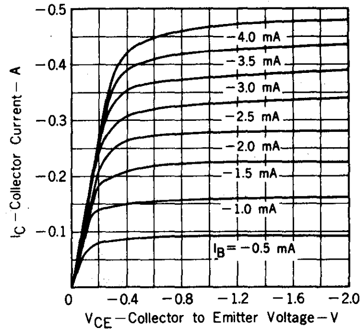
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



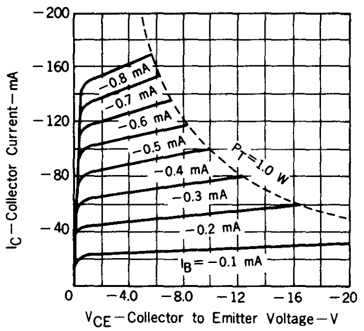
SAFE OPERATING AREA



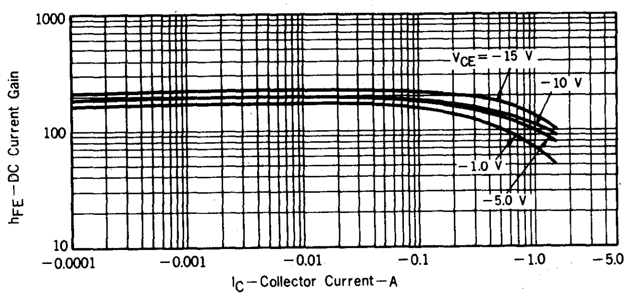
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



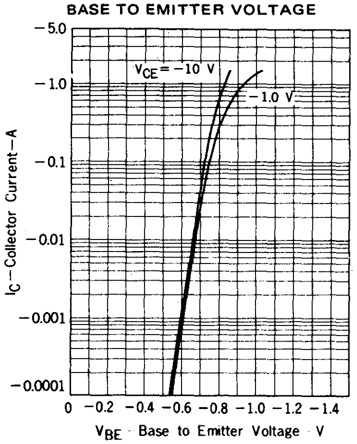
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



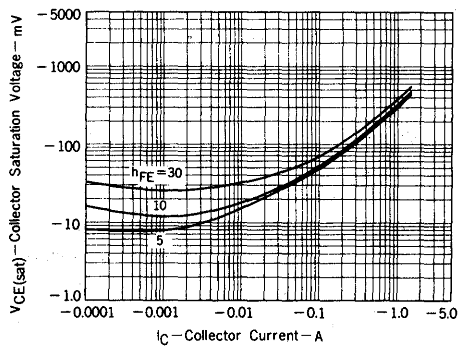
DC CURRENT GAIN vs. COLLECTOR CURRENT



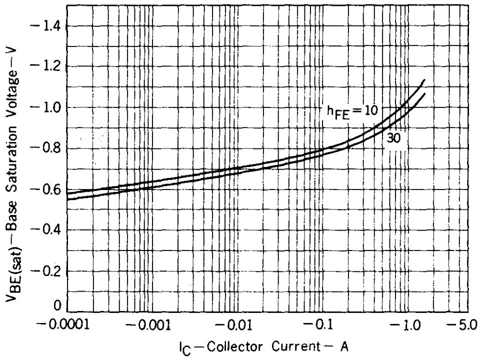
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



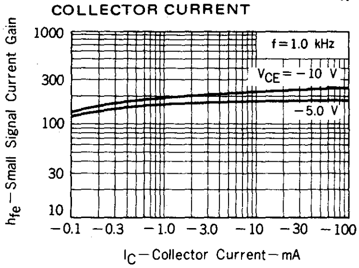
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



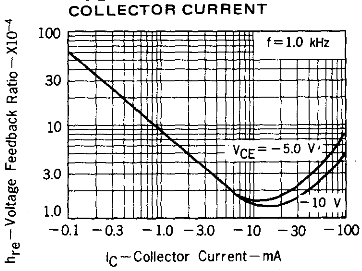
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



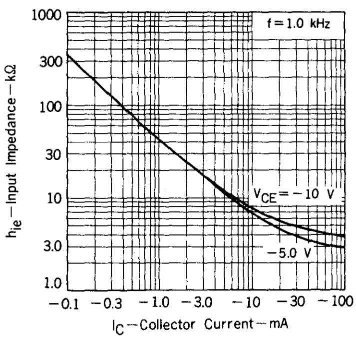
SMALL SIGNAL CURRENT GAIN vs. COLLECTOR CURRENT



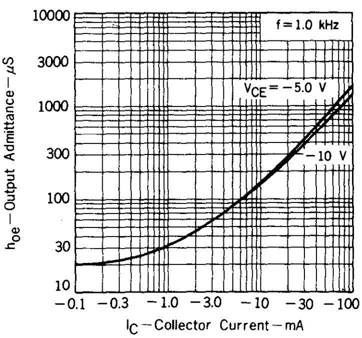
VOLTAGE FEEDBACK RATIO vs. COLLECTOR CURRENT



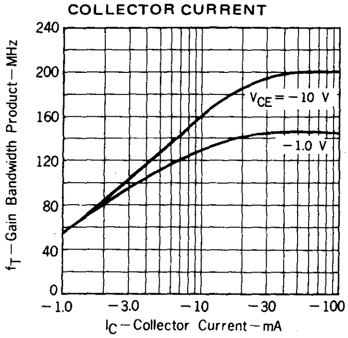
INPUT IMPEDANCE vs. COLLECTOR CURRENT



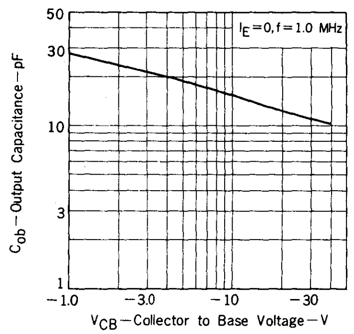
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
JE9011

DESCRIPTION The JE9011 is designed for use in AM converter, AM/FM IF amplifier and general purpose amplifier.

FEATURES

- High total power dissipation. (P_T : 400 mW)

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature .... −55 to +150 °C

Junction Temperature .... +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation .... 400 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO} Collector to Base Voltage .... 50 V

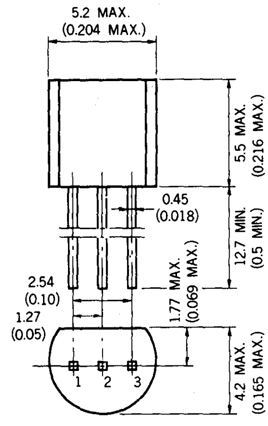
V_{CEO} Collector to Emitter Voltage .... 30 V

V_{EBO} Emitter to Base Voltage .... 5.0 V

I_C Collector Current................. 30 mA

I_B Base Current .... 10 mA

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. BASE
3. COLLECTOR

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	28	90	198	–	V_{CE} = 5.0 V, I_C = 1.0 mA
C_{ob}	Output Capacitance		1.5		pF	V_{CB} = 10 V, I_E = 0, f = 1.0 MHz
NF	Noise Figure		2.0	4.0	dB	V_{CE} = 5.0 V, I_C = 1.0 mA, R_G = 500 Ω, f = 1.0 MHz
f_T	Gain Bandwidth Product	150	370		MHz	V_{CE} = 5.0 V, I_C = 1.0 mA
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB} = 50 V, I_E = 0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB} = 5.0 V, I_C = 0
V_{BE}	Base to Emitter Voltage	0.65	0.70	0.75	V	V_{CE} = 5.0 V, I_C = 1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.08	0.3	V	I_C = 10 mA, I_B = 1.0 mA
BV_{CBO}	Collector to Base Breakdown Voltage	50			V	I_C = 0.1 mA, I_E = 0
BV_{CEO}	Collector to Emitter Breakdown Voltage	30			V	I_C = 1.0 mA, I_B = 0
BV_{EBO}	Emitter to Base Breakdown Voltage	5.0			V	I_E = 0.1 mA, I_C = 0

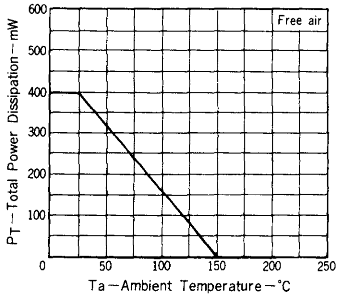
Classification of h_{FE}

Rank	D	E	F	G	H	I
Range	28 – 45	39 – 60	50 – 80	72 – 108	97 – 146	132 – 198

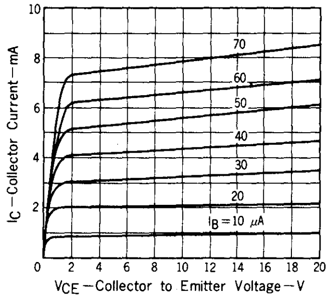
h_{FE} Test Conditions : V_{CE} = 5.0 V, I_C = 1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

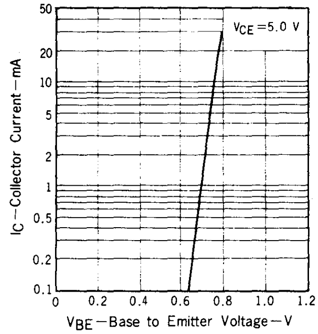
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



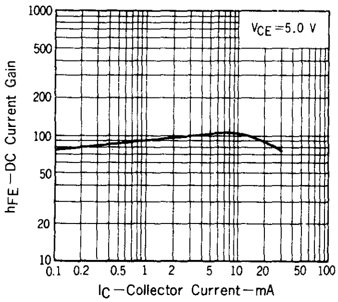
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



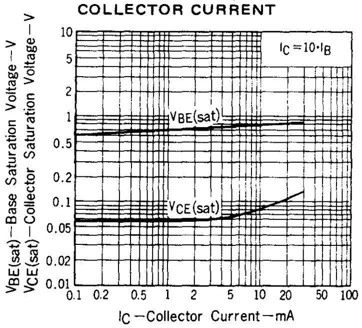
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



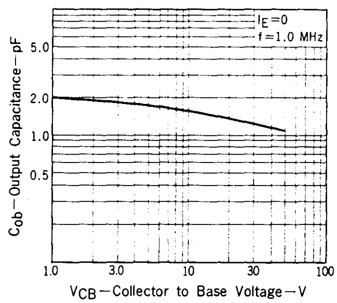
DC CURRENT GAIN vs.
COLLECTOR CURRENT



BASE AND COLLECTOR
SATURATION VOLTAGE vs.
COLLECTOR CURRENT

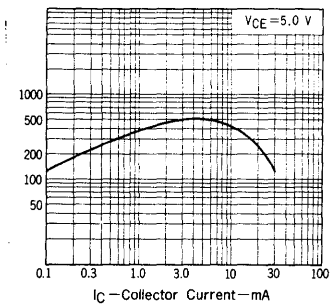


OUTPUT CAPACITANCE vs.
COLLECTOR TO BASE VOLTAGE

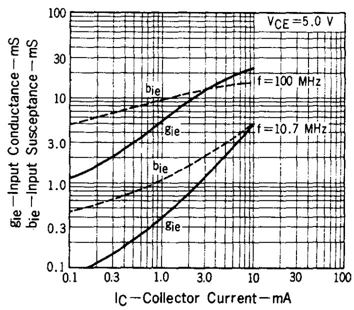


TYPICAL SMALL SIGNAL "y" PARAMETERS COMMON EMITTER

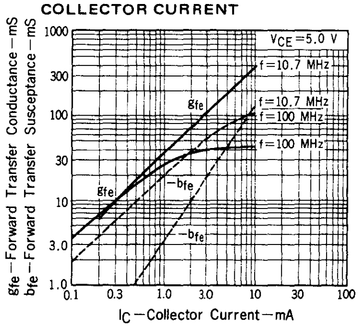
GAIN BANDWIDTH PRODUCT
vs. COLLECTOR CURRENT



INPUT ADMITTANCE vs.
COLLECTOR CURRENT

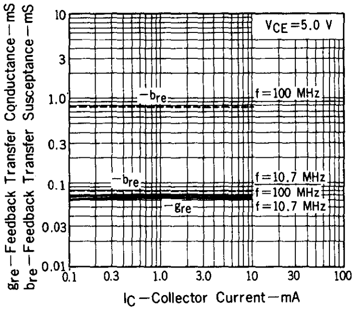


FORWARD TRANSFER ADMITTANCE vs.
COLLECTOR CURRENT

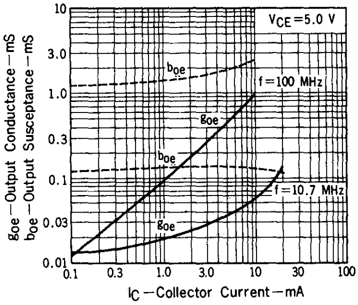


COMMON BASE

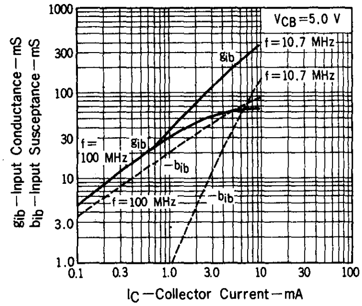
FEEDBACK TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



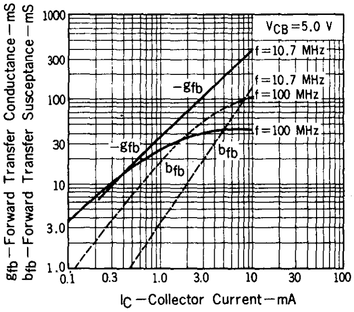
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



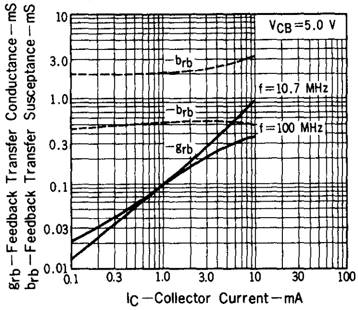
INPUT ADMITTANCE vs. COLLECTOR CURRENT



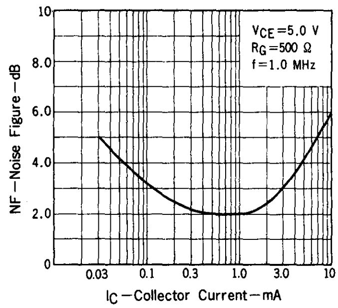
FORWARD TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



FEEDBACK TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



NOISE FIGURE vs. COLLECTOR CURREN



NEC
ELECTRON DEVICE

PNP SILICON TRANSISTOR
JE9012

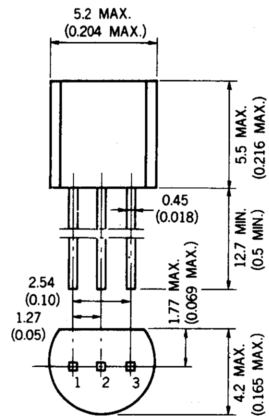
2

DESCRIPTION The JE9012 is designed for use in 1 W output amplifier of portable radios in class B push-pull operation.

FEATURES

- High total power dissipation. (P_T: 625 mW)
- High collector current. (I_C : −500 mA)
- Complementary to JE9013.
- Excellent linearity.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. BASE JEDEC : TO-92
3. COLLECTOR IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature .... −55 to +150 °C
- Junction Temperature .... +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation .... 625 mW

Maximum Voltages and Currents (Ta = 25 °C)
- V_{CBO} Collector to Base Voltage .... −40 V
- V_{CEO} Collector to Emitter Voltage ...... −20 V
- V_{EBO} Emitter to Base Voltage .... −5.0 V
- I_C Collector Current. .... −500 mA
- I_B Base Current .... −100 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	64	120	202	–	V_{CE} = −1.0 V, I_C = −50 mA
h_{FE2}	DC Current Gain	40	90		–	V_{CE} = −1.0 V, I_C = −500 mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.18	−0.60	V	I_C = −500 mA, I_B = −50 mA
$V_{BE(sat)}$	Base Saturation Voltage		−0.95	−1.20	V	I_C = −500 mA, I_B = −50 mA
V_{BE}	Base to Emitter Voltage	−0.60	−0.67	−0.70	V	V_{CE} = −1.0 V, I_C = −10 mA
BV_{CBO}	Collector to Base Breakdown Voltage	−40			V	I_C = −0.1 mA, I_E = 0
BV_{CEO}	Collector to Emitter Breakdown Voltage	−20			V	I_C = −1.0 mA, I_B = 0
BV_{EBO}	Emitter to Base Breakdown Voltage	−5.0			V	I_E = −0.1 mA, I_C = 0
I_{CBO}	Collector Cutoff Current			−200	nA	V_{CB} = −25 V, I_E = 0
I_{EBO}	Emitter Cutoff Current			−200	nA	V_{EB} = −3.0 V, I_C = 0

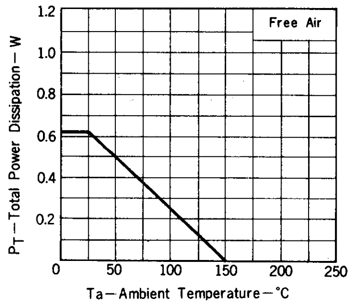
Classification of h_{FE1}

Rank	D	E	F	G	H
Range	64–91	78–112	96–135	112–166	144–202

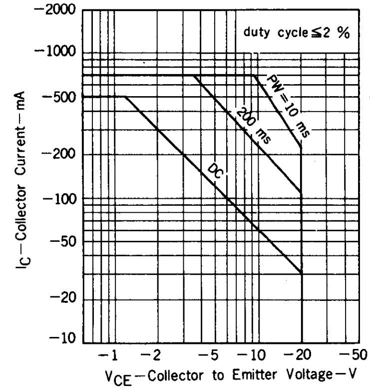
h_{FE} Test Conditions : V_{CE} = −1.0 V, I_C = −50 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

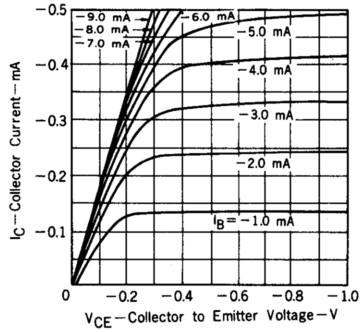
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



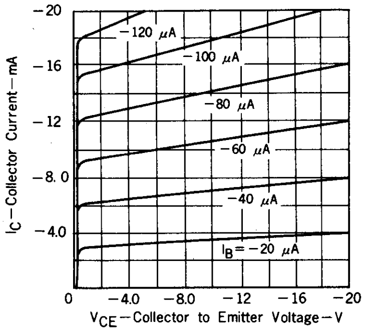
SAFE OPERATING AREA



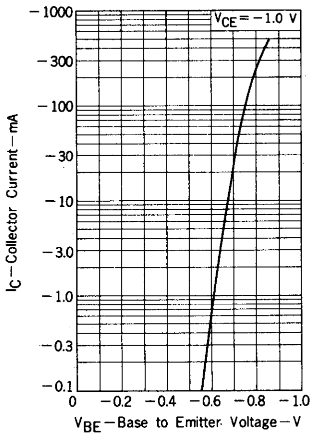
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



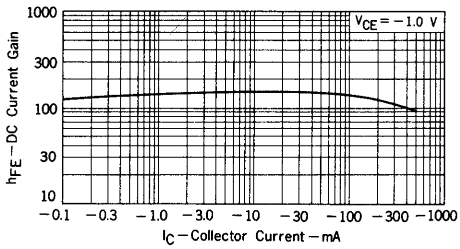
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



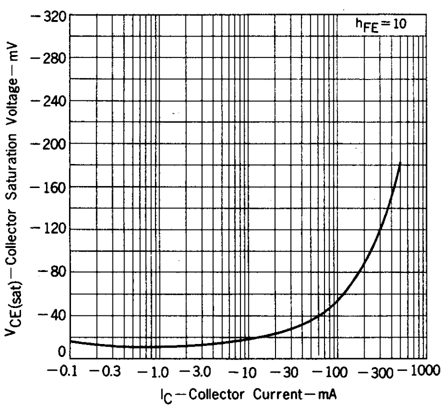
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



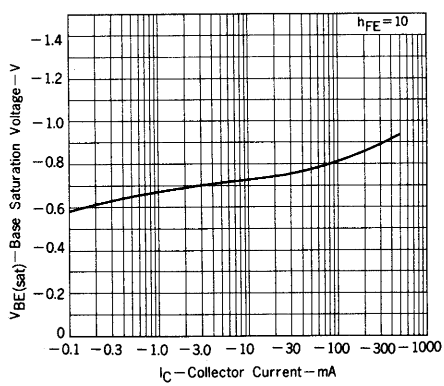
DC CURRENT GAIN vs. COLLECTOR CURRENT



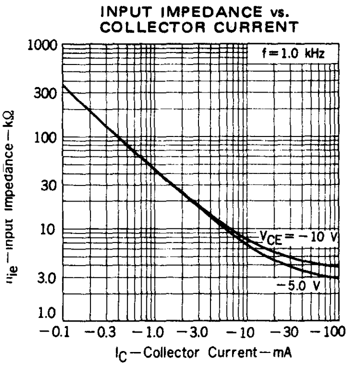
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

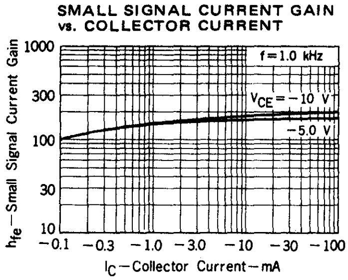


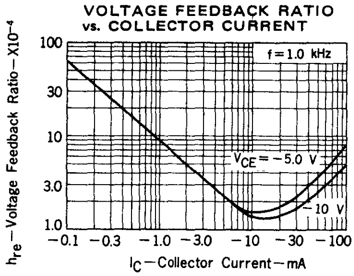
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



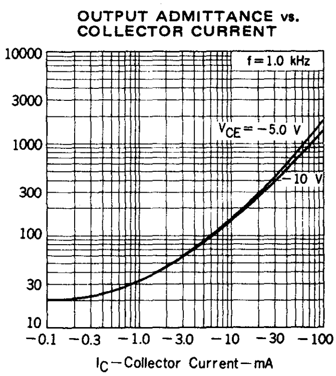
TYPICAL SMALL SIGNAL "h" PARAMETERS COMMON EMITTER







2



NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
JE9013

DESCRIPTION

The JE9013 is designed for use in 1 W output amplifier of portable radios in class B push-pull operation.

FEATURES

- High total power dissipation. (P_T: 625 mW)
- High collector current. (I_C: 500 mA)
- Complementary to JE9012.
- Excellent h_{FE} linearity.

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature .... −55 to +150 °C

Junction Temperature .... +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

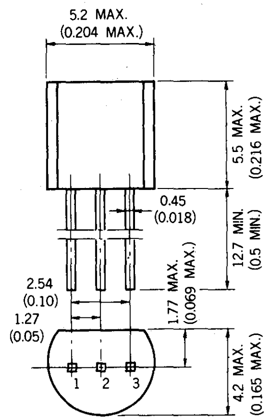
Total Power Dissipation .... 625 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO}	Collector to Base Voltage	40	V
V_{CEO}	Collector to Emitter Voltage	20	V
V_{EBO}	Emitter to Base Voltage	5.0	V
I_C	Collector Current	500	mA
I_B	Base Current	100	mA

PACKAGE DIMENSIONS

in millimeters (inches)



1. EMITTER
2. BASE
3. COLLECTOR

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	64	120	202	–	V_{CE} = 1.0 V, I_C = 50 mA
h_{FE2}	DC Current Gain	40	120		–	V_{CE} = 1.0 V, I_C = 500 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.16	0.60	V	I_C = 500 mA, I_B = 50 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.91	1.20	V	I_C = 500 mA, I_B = 50 mA
V_{BE}	Base to Emitter Voltage	0.60	0.67	0.70	V	V_{CE} = 1.0 V, I_C = 10 mA
BV_{CBO}	Collector to Base Breakdown Voltage	40			V	I_C = 0.1 mA, I_E = 0
BV_{CEO}	Collector to Emitter Breakdown Voltage	20			V	I_C = 1.0 mA, I_B = 0
BV_{EBO}	Emitter to Base Breakdown Voltage	5.0			V	I_E = −0.1 mA, I_C = 0
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB} = 25 V, I_E = 0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB} = 3.0 V, I_C = 0

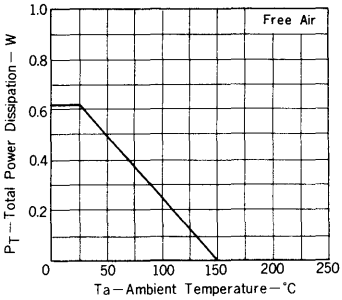
Classification of h_{FE1}

Rank	D	E	F	G	H
Range	64–91	78–112	96–135	112–166	144–202

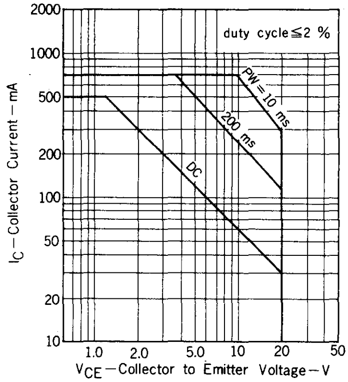
h_{FE} Test Conditions : V_{CE} = 1.0 V, I_C = 50 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

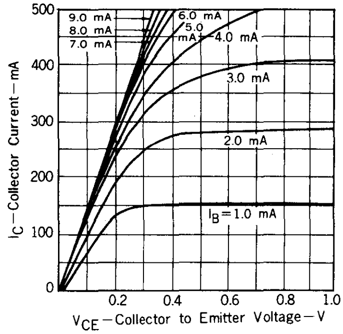
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



SAFE OPERATING AREA

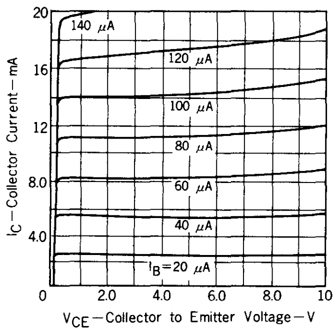


COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

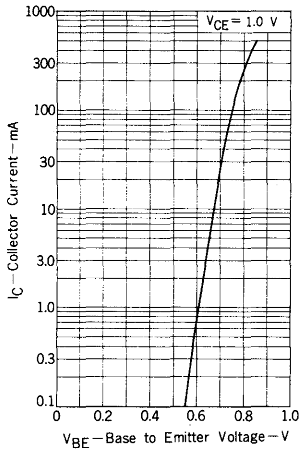


2

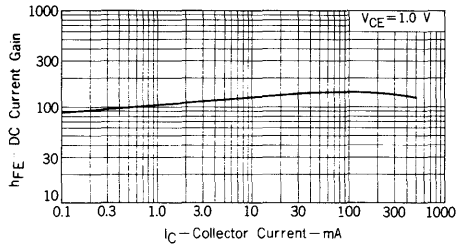
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



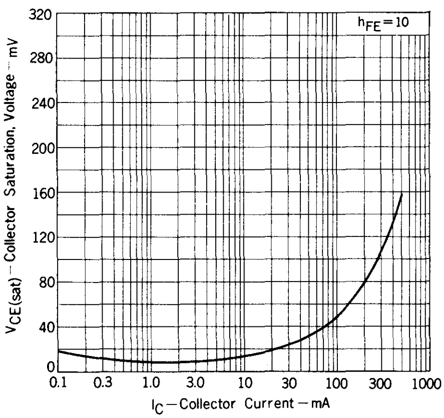
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



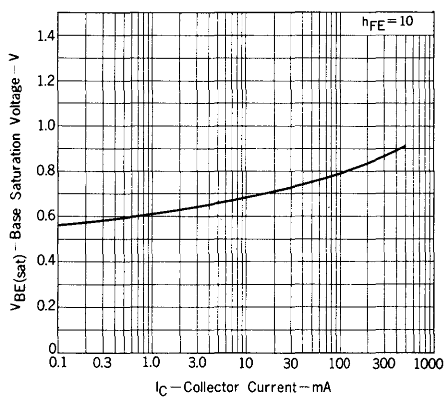
DC CURRENT GAIN vs. COLLECTOR CURRENT



COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

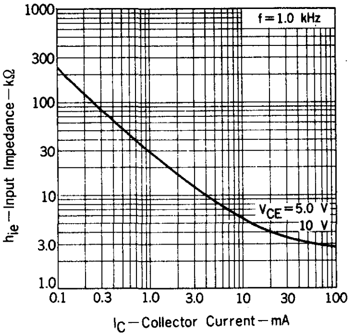


BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT

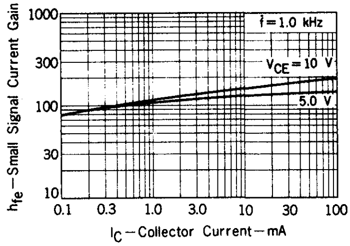


TYPICAL SMALL SIGNAL "h" PARAMETERS COMMON EMITTER

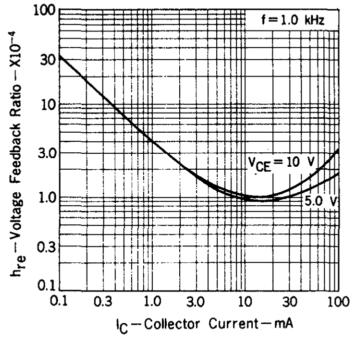
INPUT IMPEDANCE vs. COLLECTOR CURRENT



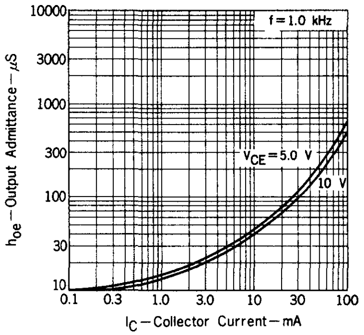
SMALL SIGNAL CURRENT GAIN vs. COLLECTOR CURRENT



VOLTAGE FEEDBACK RATIO vs. COLLECTOR CURRENT



OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
JE9014

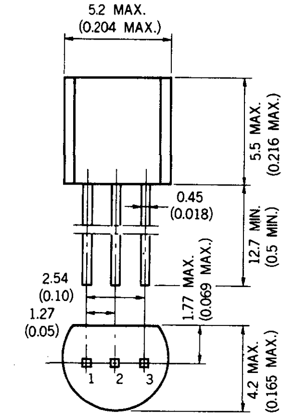
2

DESCRIPTION The JE9014 is designed for use in pre-amplifier of low level and low noise.

FEATURES

- High total power dissipation. (P_T : 625 mW)
- Complementary to JE9015.
- High h_{FE} and good linearity.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. BASE
3. COLLECTOR

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature .... −55 to +150 °C

Junction Temperature .... +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation .... 625 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO} Collector to Base Voltage .... 50 V

V_{CEO} Collector to Emitter Voltage .... 45 V

V_{EBO} Emitter to Base Voltage .... 5.0 V

I_C Collector Current .... 100 mA

I_B Base Current .... 100 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	60	280	1000	–	V_{CE}=5.0 V, I_C=1.0 mA
C_{ob}	Collector to Base Capacitance		2.2	3.5	pF	V_{CB}=10 V, I_E=0, f=1.0 MHz
NF	Noise Figure		0.9	10	dB	V_{CE}=5.0 V, I_C=0.2 mA, R_G=2.0 kΩ, f=1.0 kHz, Δf=200 Hz
f_T	Gain Bandwidth Product	150	270		MHz	V_{CE}=5.0 V, I_C=10 mA
I_{CBO}	Collector Cutoff Current			50	nA	V_{CB}=50 V, I_E=0
I_{CEO}	Collector Cutoff Current			500	nA	V_{CE}=45 V, I_B=0
I_{EBO}	Emitter Cutoff Current			50	nA	V_{EB}=5.0 V, I_C=0
BV_{CBO}	Collector to Base Breakdown Voltage	50			V	I_C=0.1 mA, I_E=0
BV_{CEO}	Collector to Emitter Breakdown Voltage	45			V	I_C=1.0 mA, I_B=0
BV_{EBO}	Emitter to Base Breakdown Voltage	5.0			V	I_E=0.1 mA, I_C=0
V_{BE}	Base to Emitter Voltage	0.58	0.63	0.70	V	V_{CE}=5.0 V, I_C=2.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.14	0.70	V	I_C=100 mA, I_B=5.0 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.84	1.00	V	I_C=100 mA, I_B=5.0 mA

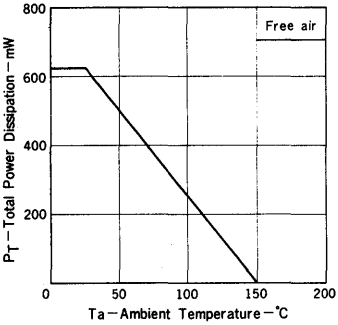
Classification of h_{FE}

Rank	A	B	C	D
Range	60 – 150	100 – 300	200 – 600	400 – 1000

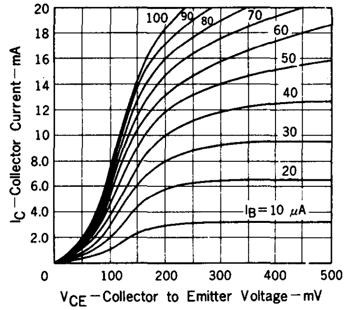
h_{FE} Test Conditions : V_{CE} = 5.0 V, I_C = 1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

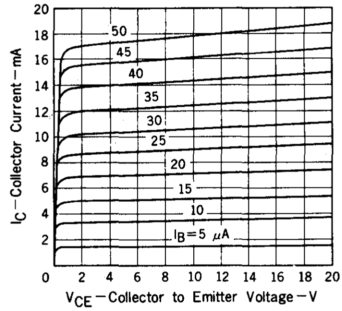
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



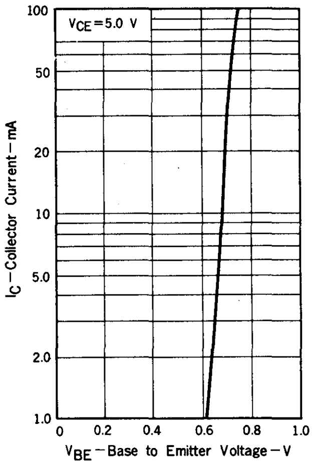
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



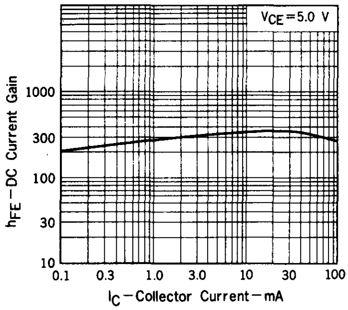
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



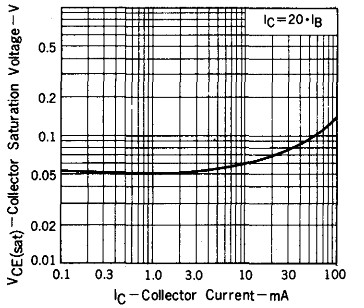
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



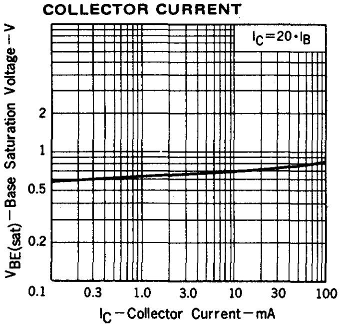
DC CURRENT GAIN vs. COLLECTOR CURRENT



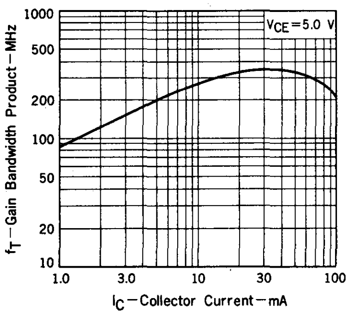
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



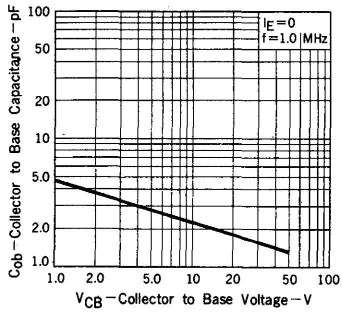
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



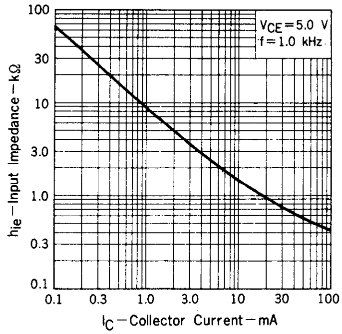
COLLECTOR TO BASE CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



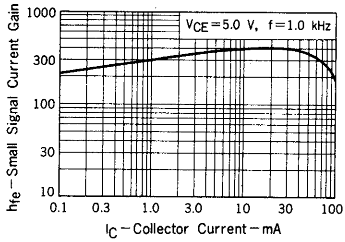
2

TYPICAL SMALL SIGNAL "h" PARAMETERS COMMON EMITTER

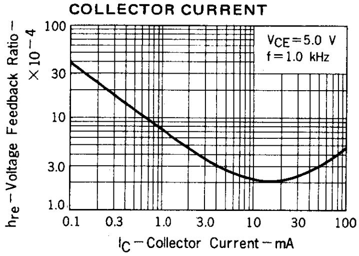
INPUT IMPEDANCE vs. COLLECTOR CURRENT



SMALL SIGNAL CURRENT GAIN vs. COLLECTOR CURRENT

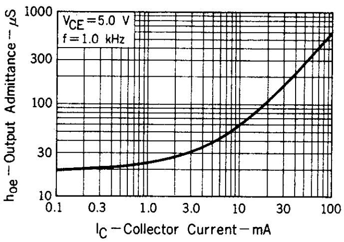


VOLTAGE FEEDBACK RATIO vs. COLLECTOR CURRENT

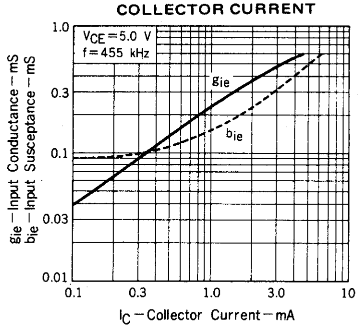


TYPICAL SMALL SIGNAL "y" PARAMETERS COMMON EMITTER

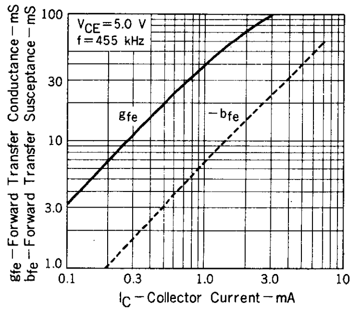
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



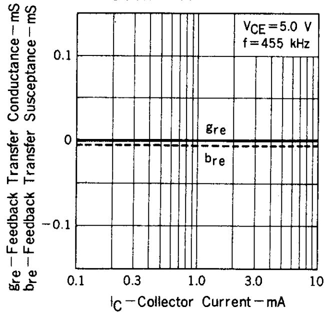
INPUT ADMITTANCE vs. COLLECTOR CURRENT



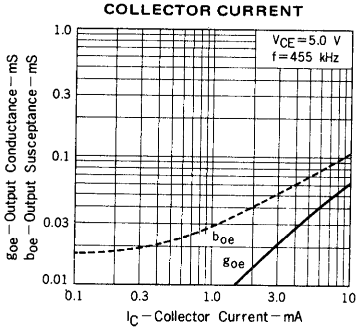
FORWARD TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



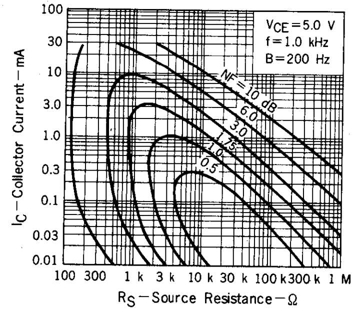
FEEDBACK TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



NF MAP



NEC
ELECTRON DEVICE

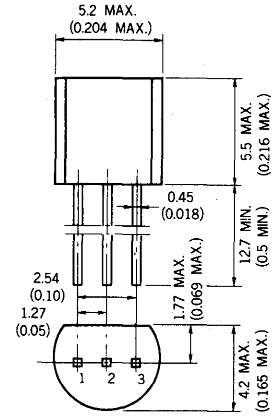
PNP SILICON TRANSISTOF
JE9015

DESCRIPTION The JE9015 is designed for use in pre-amplifier of low level and low noise.

FEATURES

- High total power dissipation. (P_T: 625 mW)
- Complementary to JE9014.
- High h_{FE} and good linearity.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. BASE JEDEC : TO-92
3. COLLECTOR IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature .... −55 to +150 °C

Junction Temperature .... +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation .... 625 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO} Collector to Base Voltage .... −50 V

V_{CEO} Collector to Emitter Voltage ..... −45 V

V_{EBO} Emitter to Base Voltage .... −5.0 V

I_C Collector Current .... −100 mA

I_B Base Current .... −100 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	60	200	600		V_{CE}=−5.0 V, I_C=−1.0 mA
C_{ob}	Collector to Base Capacitance		4.5	7.0	pF	V_{CB}=−10 V, I_E=0, f=1.0 MHz
NF	Noise Figure		0.7	10	dB	V_{CE}=−5.0 V, I_C=−0.2 mA, R_G=2.0 kΩ, f=1.0 kHz, Δf=200 Hz
f_T	Gain Bandwidth Product	100	190		MHz	V_{CE}=−5.0 V, I_C=−10 mA
I_{CBO}	Collector Cutoff Current			−50	nA	V_{CB}=−50 V, I_E=0
I_{CEO}	Collector Cutoff Current			−500	nA	V_{CE}=−50 V, I_B=0
I_{EBO}	Emitter Cutoff Current			−50	nA	V_{EB}=−5.0 V, I_C=0
BV_{CBO}	Collector to Base Breakdown Voltage	−50			V	I_C=−0.1 mA, I_E=0
BV_{CEO}	Collector to Emitter Breakdown Voltage	−45			V	I_C=−1.0 mA, I_B=0
BV_{EBO}	Emitter to Base Breakdown Voltage	−5.0			V	I_E=−0.1 mA, I_C=0
V_{BE}	Base to Emitter Voltage	−0.60	−0.65	−0.75	V	V_{CE}=−5.0 V, I_C=−2.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.20	−0.70	V	I_C=−100 mA, I_B=−5.0 mA
$V_{BE(sat)}$	Base Saturation Voltage		−0.82	−1.0	V	I_C=−100 mA, I_B=−5.0 mA

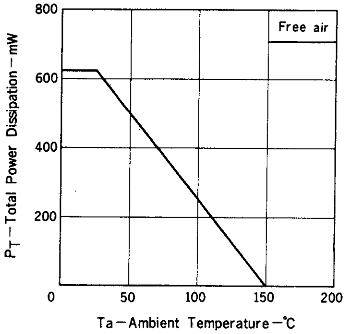
Classification of h_{FE}

Rank	A	B	C
Range	60 – 150	100 – 300	200 – 600

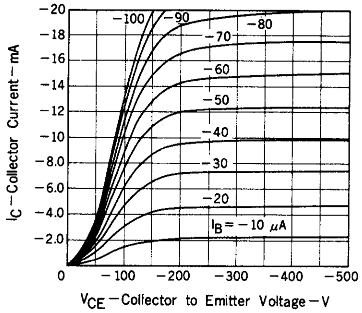
h_{FE} Test Conditions : V_{CE} = −5.0 V, I_C = −1.0 mA

TYPICAL CHARACTERISTICS (Ta=25 °C unless otherwise noted)

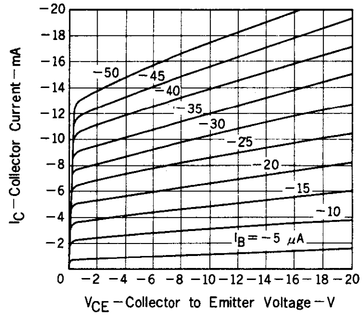
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



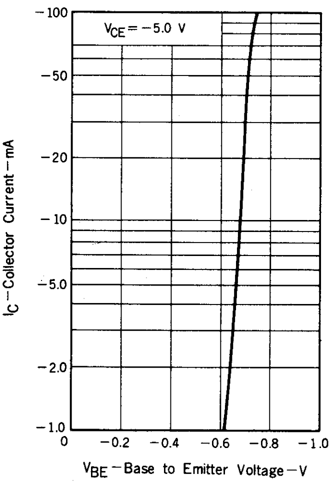
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



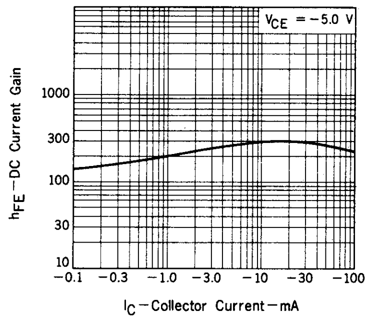
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



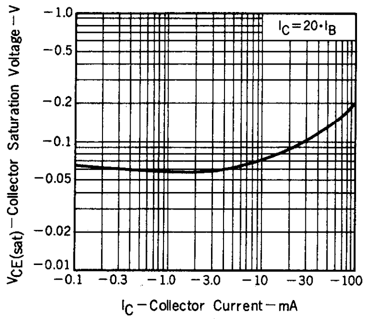
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



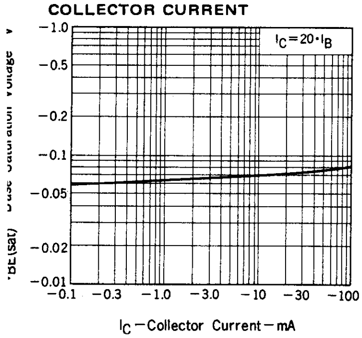
DC CURRENT GAIN vs. COLLECTOR CURRENT



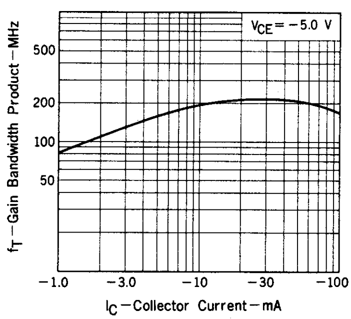
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



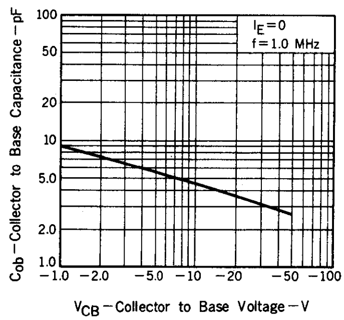
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT

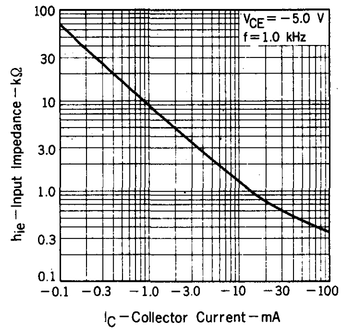


COLLECTOR TO BASE CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE

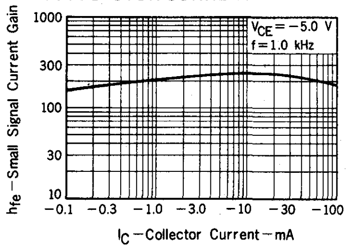


TYPICAL SMALL SIGNAL "h" PARAMETERS COMMON EMITTER

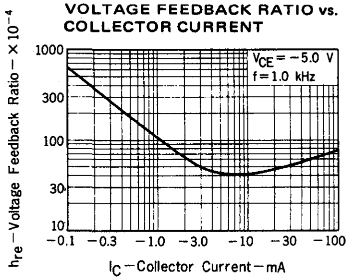
INPUT IMPEDANCE vs. COLLECTOR CURRENT



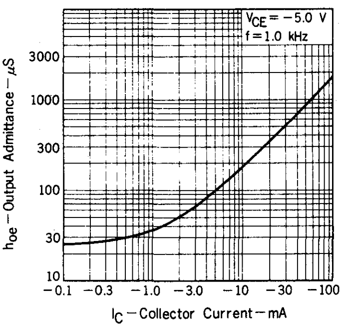
SMALL SIGNAL CURRENT GAIN vs. COLLECTOR CURRENT



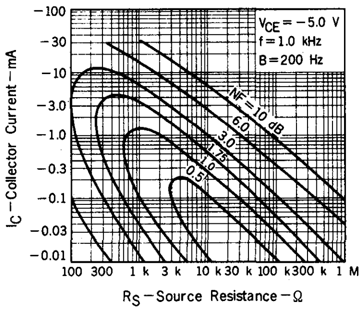
VOLTAGE FEEDBACK RATIO vs. COLLECTOR CURRENT



OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



NF MAP



NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR

JE9016

DESCRIPTION

The JE9016 is designed for use in AM converter and FM RF amplifier of low noise.

FEATURES

- High total power dissipation. (P_T : 400 mW)

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature .... −55 to +150 °C

Junction Temperature .... +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation .... 400 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO} Collector to Base Voltage .... 30 V

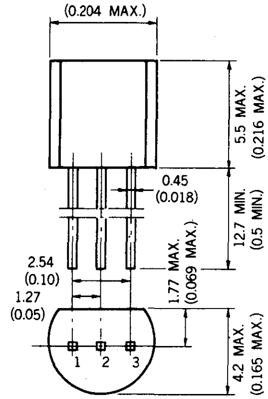
V_{CEO} Collector to Emitter Voltage .... 20 V

V_{EBO} Emitter to Base Voltage .... 4.0 V

I_C Collector Current .... 25 mA

I_B Base Current .... 5.0 mA

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. BASE
3. COLLECTOR

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	28	90	198	—	V_{CE} = 5.0 V, I_C = 1.0 mA
C_{ob}	Collector to Base Capacitance		1.2	1.6	pF	V_{CB} = 10 V, I_E = 0, f = 1.0 MHz
NF	Noise Figure		3.0	5.0	dB	V_{CE} = 5.0 V, I_C = 1.0 mA, R_G = 50 Ω, f = 100 MHz
f_T	Gain Bandwidth Product	400	620		MHz	V_{CE} = 5.0 V, I_C = 1.0 mA
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB} = 30 V, I_E = 0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB} = 4.0 V, I_C = 0
BV_{CBO}	Collector to Base Breakdown Voltage	30			V	I_C = 0.1 mA, I_E = 0
BV_{CEO}	Collector to Emitter Breakdown Voltage	20			V	I_C = 1.0 mA, I_B = 0
BV_{EBO}	Emitter to Base Breakdown Voltage	4.0			V	I_E = 0.1 mA, I_C = 0
V_{BE}	Base to Emitter Voltage		0.72		V	V_{CE} = 5.0 V, I_C = 1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.1	0.3	V	I_C = 10 mA, I_B = 1.0 mA

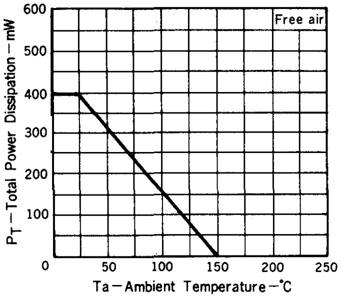
Classification of h_{FE}

Rank	D	E	F	G	H	I
Range	28 – 45	39 – 60	54 – 80	72 – 108	97 – 146	132 – 198

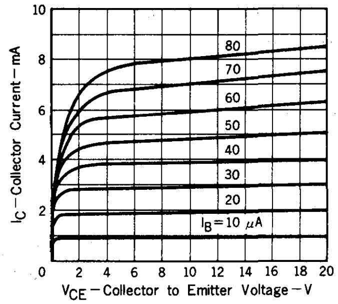
h_{FE} Test Conditions : V_{CE} = 5.0 V, I_C = 1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

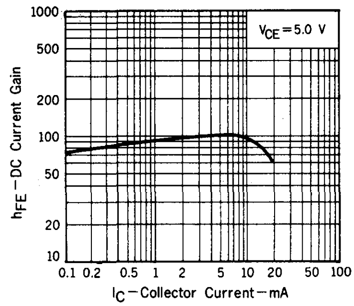
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



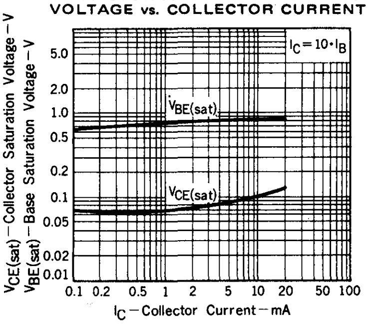
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



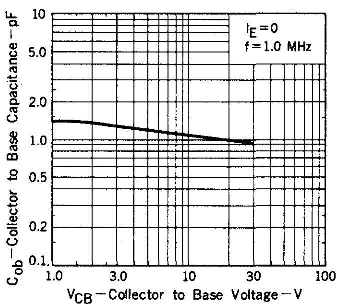
DC CURRENT GAIN vs. COLLECTOR CURRENT



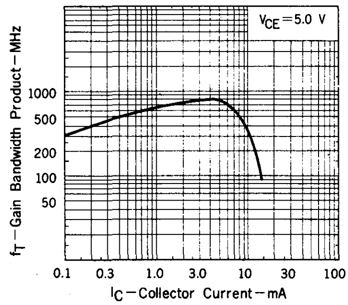
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



COLLECTOR TO BASE CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE

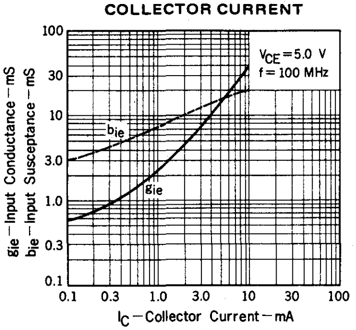


GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT

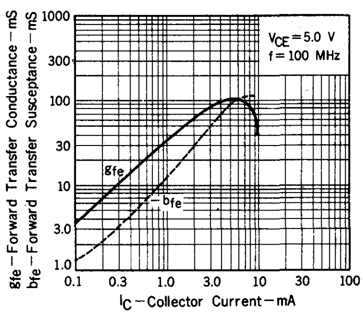


TYPICAL SMALL SIGNAL "y" PARAMETERS COMMON EMITTER

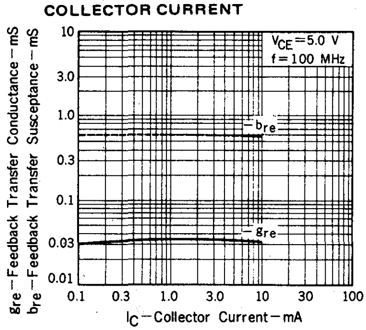
INPUT ADMITTANCE vs. COLLECTOR CURRENT



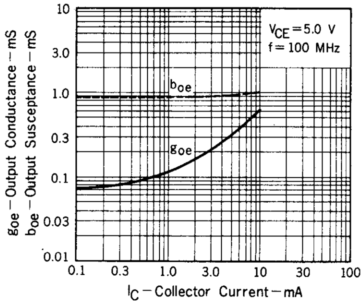
FORWARD TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



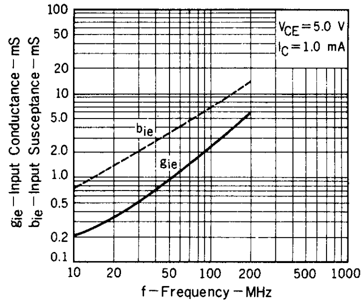
FEEDBACK TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



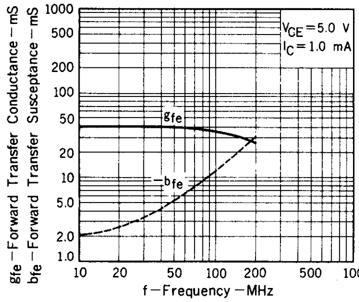
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



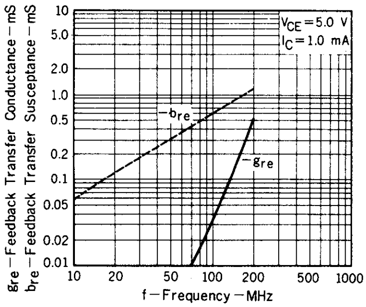
INPUT ADMITTANCE vs. FREQUENCY



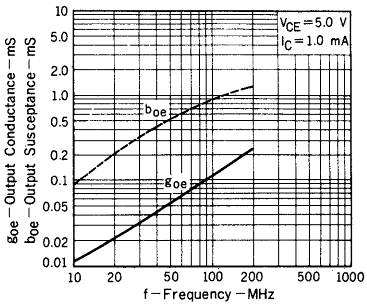
FORWARD TRANSFER ADMITTANCE vs. FREQUENCY



FEEDBACK TRANSFER ADMITTANCE vs. FREQUENCY

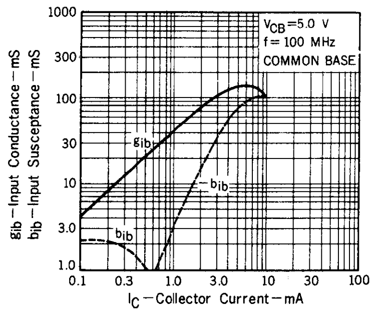


OUTPUT ADMITTANCE vs. FREQUENCY

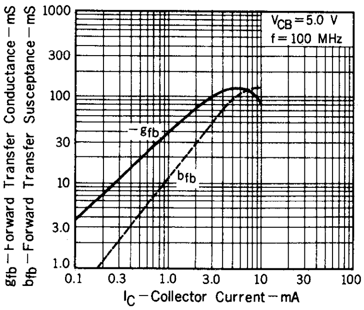


COMMON BASE

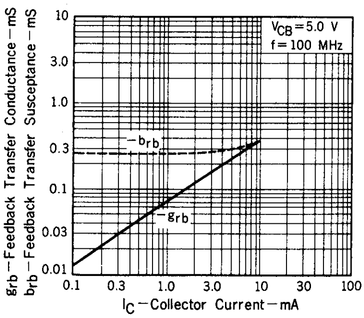
INPUT ADMITTANCE vs. COLLECTOR CURRENT



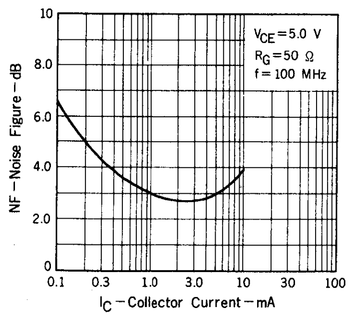
FORWARD TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



FEEDBACK TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



NOISE FIGURE vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

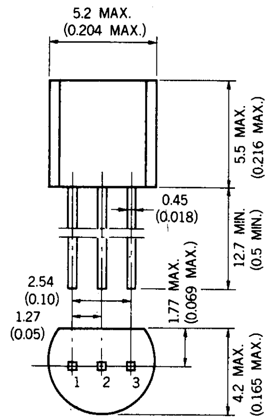
NPN SILICON TRANSISTOR
JE9018

DESCRIPTION The JE9018 is designed for use in AM/FM IF amplifier and local oscillator of FM/VHF tuner.

FEATURES

- High total power dissipation. (P_T : 400 mW)
- High gain bandwidth product. (f_T=1 100 MHz TYP.)
- Stable oscillation and small frequency drift for supply voltage and ambient temperature change.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. BASE JEDEC : TO-92
3. COLLECTOR IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature .... −55 to +150 °C

Junction Temperature .... +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation .... 400 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO} Collector to Base Voltage ....30 V

V_{CEO} Collector to Emitter Voltage ....15 V

V_{EBO} Emitter to Base Voltage ....5.0 V

I_C Collector Current .... 50 mA

I_B Base Current.................... 10 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	28	100	198	–	V_{CE} = 5.0 V, I_C = 1.0 mA
C_{ob}	Output Capacitance		1.3	1.7	pF	V_{CB} = 10 V, I_E = 0, f = 1.0 MHz
f_T	Gain Bandwidth Product	700	1100		MHz	V_{CE} = 5.0 V, I_C = 5.0 mA
I_{CBO}	Collector Cutoff Current			50	nA	V_{CB} = 12 V, I_E = 0
BV_{CBO}	Collector to Base Breakdown Voltage	30			V	I_C = 0.1 mA, I_E = 0
BV_{CEO}	Collector to Emitter Breakdown Voltage	15			V	I_C = 1.0 mA, I_B = 0
BV_{EBO}	Emitter to Base Breakdown Voltage	5.0			V	I_E = 0.1 mA, I_C = 0
$V_{CE(sat)}$	Collector Saturation Voltage			0.5	V	I_C = 10 mA, I_B = 1.0 mA

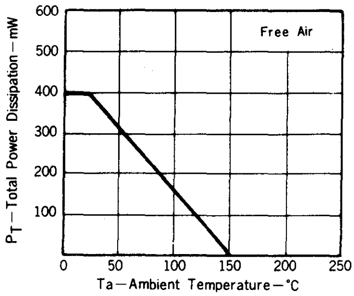
Classification of h_{FE}

Rank	D	E	F	G	H	I
Range	28–45	39–60	54–80	72–108	97–146	132–198

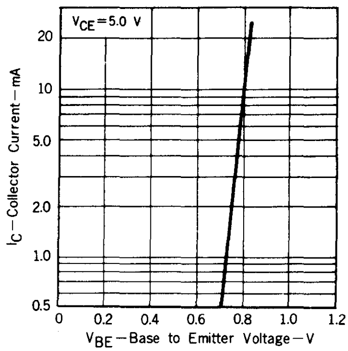
h_{FE} Test Conditions : V_{CE} = 5.0 V, I_C = 1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

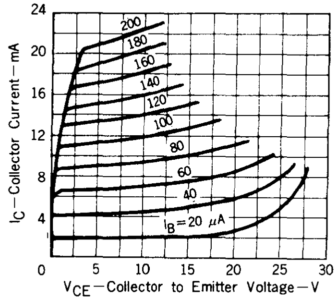
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



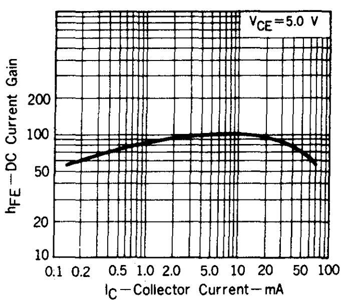
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



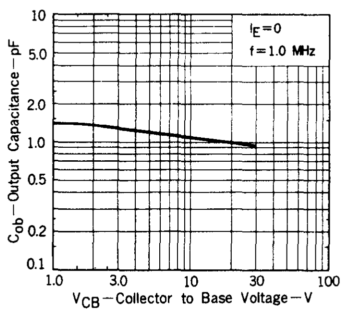
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



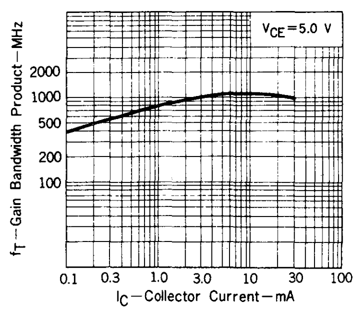
DC CURRENT GAIN vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



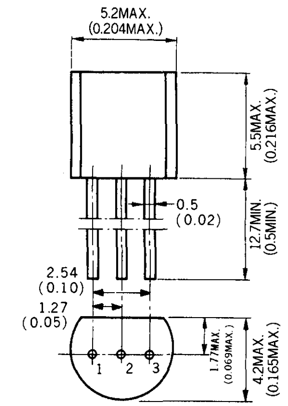
NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
JE9100

DESCRIPTION The JE9100 is designed for use in general purpose amplifier.

FEATURES
- High total power dissipation (P_T : 625 mW)
- Small capacitance

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. BASE
3. COLLECTOR

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Temperatures
- Storage Temperature . . . . 55 to +150°C
- Junction Temperature . . . . +150°C Maximum

Maximum Power Dissipation (Ta = 25°C)
- Total Power Dissipation . . . . 625 mW

Maximum Voltages and Currents

V_{CBO}	Collector to Base Voltage	60 V
V_{CEO}	Collector to Emitter Voltage	60 V
V_{EBO}	Emitter to Base Voltage	7.0 V
I_C	Collector Current	100 mA
I_B	Base Current	100 mA

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	50	180	550	–	V_{CE} = 10V, I_C = 2.0 mA
f_T	Gain Bandwidth Product	150	300		MHz	V_{CE} = 5.0V, I_C = 10 mA
C_{ob}	Output Capacitance		1.6	4.0	pF	V_{CB} = 10V, I_E = 0, f = 1.0 MHz
C_{ib}	Input Capacitance		5.0	12	pF	V_{EB} = 0.5V, I_C = 0, f = 1.0 MHz
NF	Noise Figure		2.6		dB	V_{CE} = 5.0V, I_C = 0.2mA, R_G = 2.0kΩ, f = 30 ~15kHz
t_{on}	Turn on Time		60		ns	Test Circuit
t_{off}	Turn off Time		1.5		μs	Test Circuit
I_{CBO}	Collector Cutoff Current			50	nA	V_{CB} = 40V, I_E = 0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB} = 7.0V, I_C = 0
BV_{CBO}	Collector to Base Breakdown Voltage	60			V	I_C = 0.1 mA, I_E = 0
BV_{CEO}	Collector to Emitter Breakdown Voltage	60			V	I_C = 1.0 mA, R_{BE} = ∞
BV_{EBO}	Emitter to Base Breakdown Voltage	7.0			V	I_E = 0.1 mA, I_C = 0
V_{BE}	Base to Emitter Voltage	0.63	0.68	0.73	V	V_{CE} = 5.0V, I_C = 2.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.07	0.2	V	I_C = 10 mA, I_B = 1.0 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.75	1.0	V	I_C = 10 mA, I_B = 1.0 mA

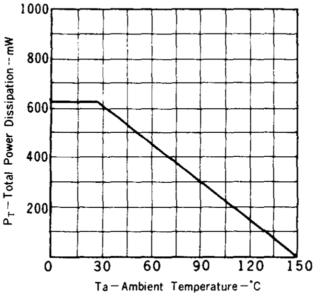
Classification of h_{FE}

Rank	A	B	C	D	E	F	G
Range	50 – 104	85 – 130	100 – 160	125 – 185	150 – 222	180 – 295	240 – 550

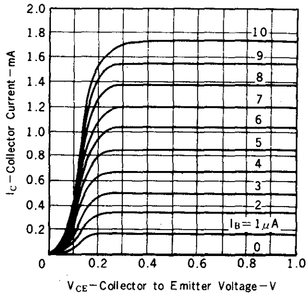
h_{FE} Test Conditions: V_{CE} = 10V, I_C = 2.0 mA

TYPICAL CHARACTERISTICS (Ta=25°C)

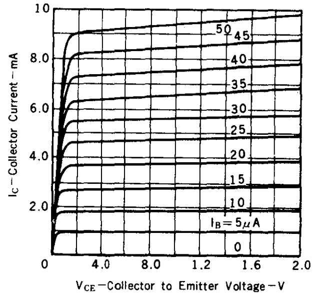
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



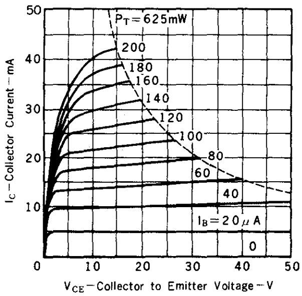
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



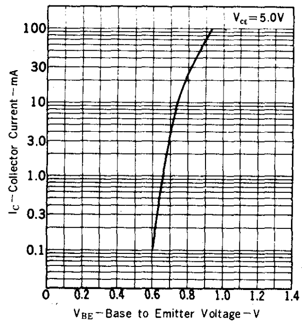
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



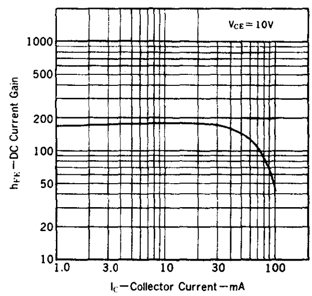
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



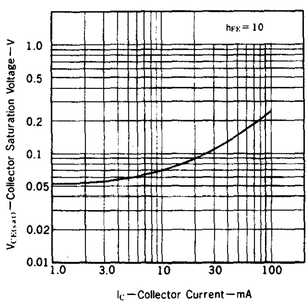
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



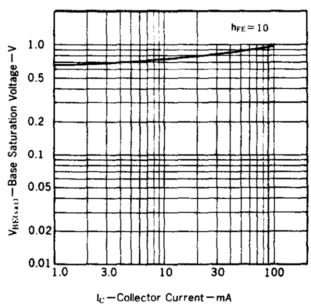
DC CURRENT GAIN vs. COLLECTOR CURRENT



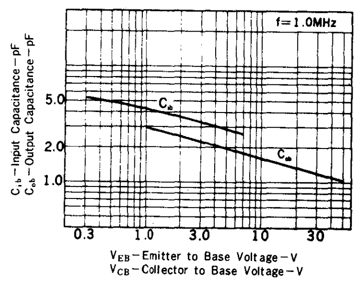
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



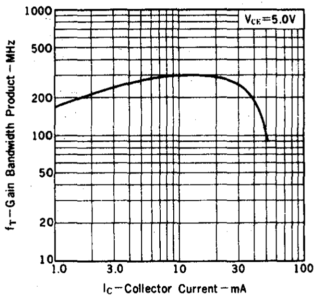
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



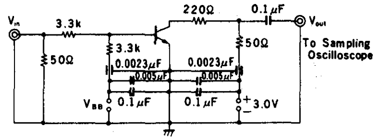
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE

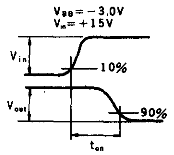


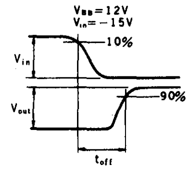
GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



t_{on}, t_{off} Test Circuit







NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
JE9101

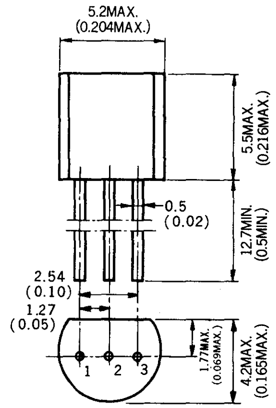
2

DESCRIPTION The JE9101 is designed for use in general purpose amplifier.

FEATURES

- High total power dissipation (P_T : 625 mW)
- Small capacitance

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER	EIAJ	: SC-43
2. BASE	JEDEC	: TO-92
3. COLLECTOR	IEC	: PA33

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Temperatures
Storage Temperature . . . . 55 to +150°C
Junction Temperature . . . . +150°C Maximum
Maximum Power Dissipation (Ta = 25°C)
Total Power Dissipation . . . . 625 mW
Maximum Voltages and Currents

V_{CBO}	Collector to Base Voltage	40 V
V_{CEO}	Collector to Emitter Voltage	30 V
V_{EBO}	Emitter to Base Voltage	7.0 V
I_C	Collector Current	100 mA
I_B	Base Current	100 mA

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	50	200	700	–	V_{CE} = 10V, I_C = 2.0 mA
f_T	Gain Bandwidth Product	150	300		MHz	V_{CE} = 5.0V, I_C = 10 mA
C_{ob}	Collector to Base Capacitance		1.6	4.0	pF	V_{CB} = 10V, I_E = 0, f = 1.0 MHz
C_{ib}	Emitter to Base Capacitance		5.0	12	pF	V_{EB} = 0.5V, I_C = 0, f = 1.0 MHz
NF	Noise Figure		2.6		dB	V_{CE} = 5.0V, I_C = 0.2mA, R_G = 2.0kΩ, f = 30 ~ 15kHz
t_{on}	Turn on Time		60		ns	Test Circuit
t_{off}	Turn off Time		1.5		μs	Test Circuit
I_{CBO}	Collector Cutoff Current			50	nA	V_{CB} = 40V, I_E = 0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB} = 7.0V, I_C = 0
BV_{CBO}	Collector to Base Breakdown Voltage	40			V	I_C = 0.1 mA, I_E = 0
BV_{CEO}	Collector to Emitter Breakdown Voltage	30			V	I_C = 1.0 mA, R_{BE} = ∞
BV_{EBO}	Emitter to Base Breakdown Voltage	7.0			V	I_E = 0.1 mA, I_C = 0
V_{BE}	Base to Emitter Voltage	0.63	0.68	0.73	V	V_{CE} = 5.0V, I_C = 2.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.07	0.2	V	I_C = 10 mA, I_B = 1.0 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.75	1.0	V	I_C = 10 mA, I_B = 1.0 mA

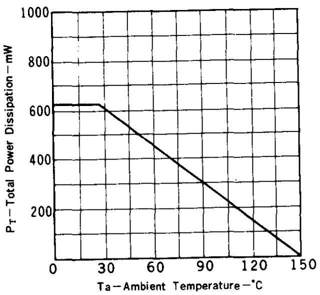
Classification of h_{FE}

Rank	A	B	C	D
Range	50 – 110	100 – 200	180 – 400	350 – 700

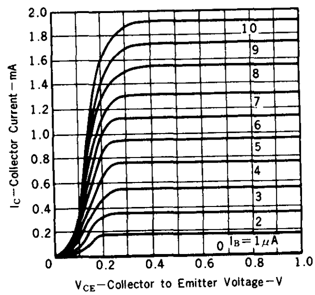
h_{FE} Test Conditions: V_{CE} = 10 V, I_C = 2.0 mA

TYPICAL CHARACTERISTICS (Ta=25°C)

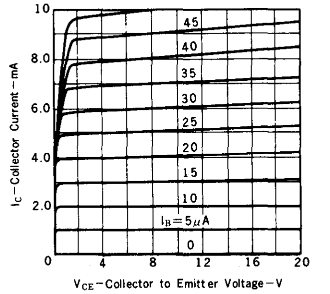
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



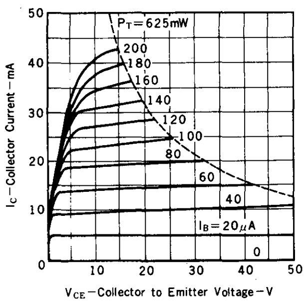
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



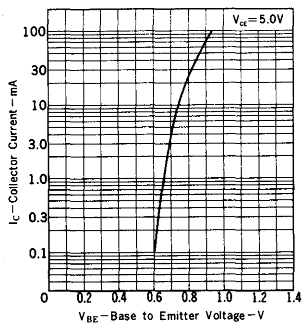
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



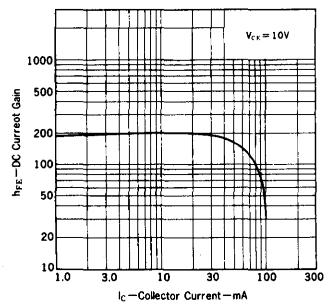
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



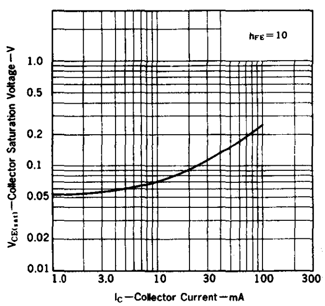
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



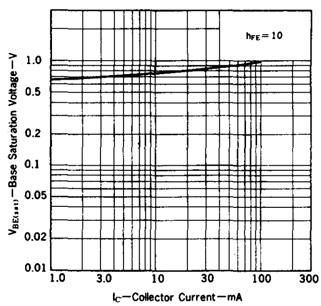
DC CURRENT GAIN vs. COLLECTOR CURRENT



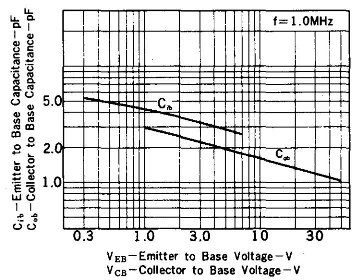
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT

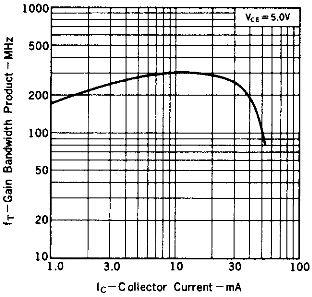


CAPACITANCE vs. REVERSE VOLTAGE

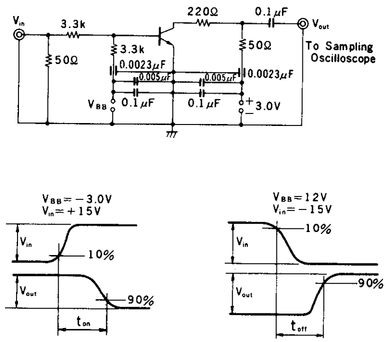


2

GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



t_{on}, t_{off} Test Circuit



NEC
ELECTRON DEVICE

PNP SILICON TRANSISTOR
JE9112

DESCRIPTION

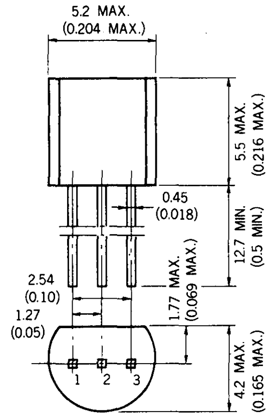
The JE9112 is designed for use in output amplifier of portable radios in class B push-pull operation.

FEATURES

- High total power dissipation. (P_T : 2.0 W, T_C = 25 °C)
- High collector current. (I_C : −1.5 A)
- Complementary to JE9113.

PACKAGE DIMENSIONS

in millimeters (inches)



1. EMITTER
2. BASE
3. COLLECTOR

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −65 to +150 °C

Junction Temperature . . . . +150 °C Maximum

Maximum Power Dissipations

Total Power Dissipation (Ta = 25 °C) . . . . . . 1.0 W

Transistor mounted on printed circuit board, max. lead length 4 mm, mounting pad for collector lead min. 10 mm x 10 mm.

Total Power Dissipation (T_C = 25 °C) . . . . . . 2.0 W

Thermal Resistance (Ta = 25 °C)
(Junction to Ambient) . . . 156.25 °C/W

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO} Collector to Base Voltage . . . . −35 V

V_{CEO} Collector to Emitter Voltage . . . . . . −25 V

V_{EBO} Emitter to Base Voltage . . . . −6.0 V

I_C Collector Current . . . . −1.5 A

I_B Base Current . . . . −0.5 A

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	40	180		–	V_{CE} = −1.0 V, I_C = −5.0 mA
h_{FE2}	DC Current Gain	60	180	300	–	V_{CE} = −1.0 V, I_C = −100 mA
h_{FE3}	DC Current Gain	30	110		–	V_{CE} = −1.0 V, I_C = −1000 mA
f_T	Gain Bandwidth Product	10	50		MHz	V_{CE} = −5.0 V, I_C = −10 mA
C_{ob}	Output Capacitance		26		pF	V_{CB} = −10 V, I_E = 0, f = 1.0 MHz
I_{CBO}	Collector Cutoff Current			−100	nA	V_{CB} = −35 V, I_E = 0
I_{CEO}	Collector Cutoff Current			−1.0	μA	V_{CE} = −25 V, I_B = 0
I_{EBO}	Emitter Cutoff Current			−100	nA	V_{EB} = −6.0 V, I_C = 0
V_{BE}	Base to Emitter Voltage		−0.96	−1.0	V	V_{CE} = −1.0 V, I_C = −800 mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.2	−0.5	V	I_C = −800 mA, I_B = −80 mA
$V_{BE(sat)}$	Base Saturation Voltage		−0.95	−1.2	V	I_C = −800 mA, I_B = −80 mA
BV_{CBO}	Collector to Base Breakdown Voltage	−35			V	I_C = −0.1 mA, I_E = 0
BV_{CEO}	Collector to Emitter Breakdown Voltage	−25			V	I_C = −2.0 mA, I_B = 0
BV_{EBO}	Emitter to Base Breakdown Voltage	−6.0			V	I_E = −0.1 mA, I_C = 0

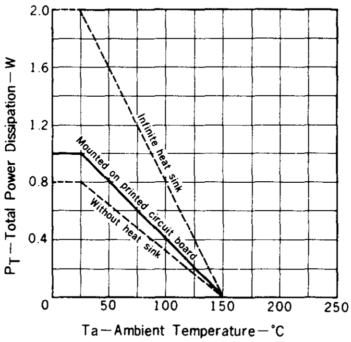
Classification of h_{FE2}

Rank	A	B	C	D
Range	60 – 120	85 – 160	120 – 200	160 – 300

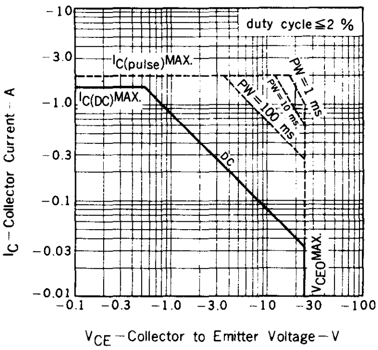
h_{FE} Test Conditions : V_{CE} = −1.0 V, I_C = −100 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

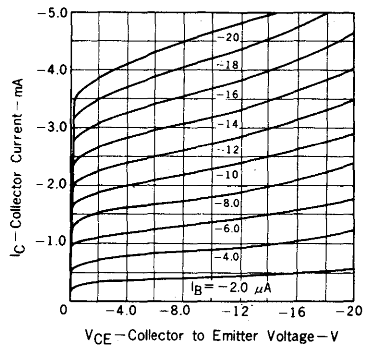
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



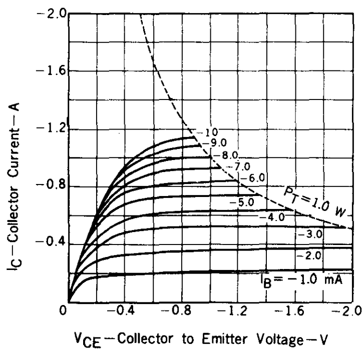
SAFE OPERATING AREA



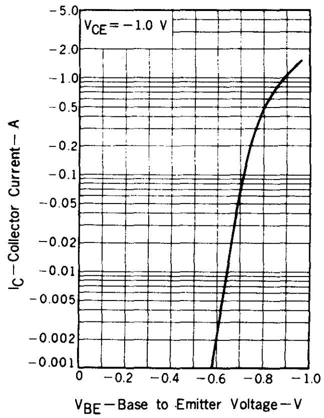
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



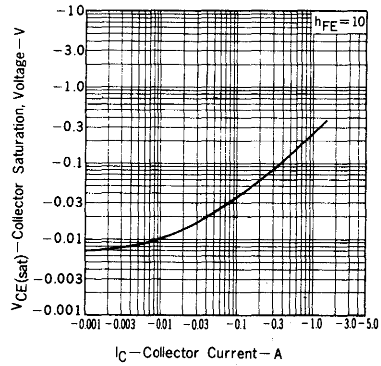
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



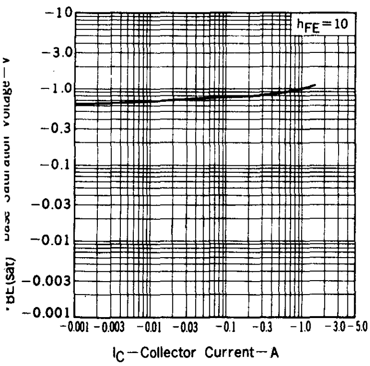
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



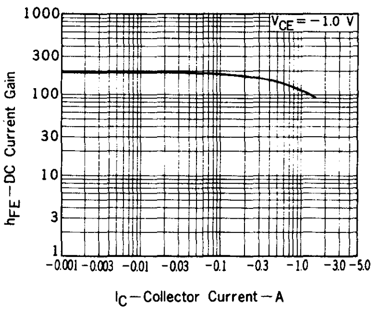
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



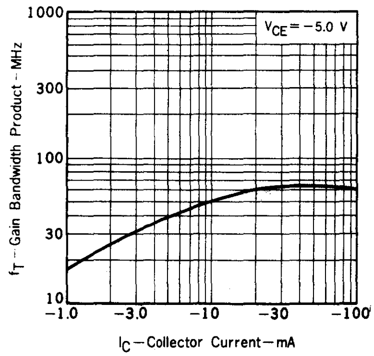
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



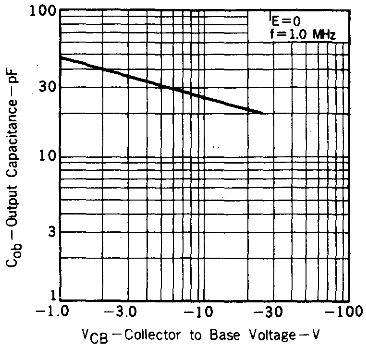
DC CURRENT GAIN vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs.
COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
JE9113

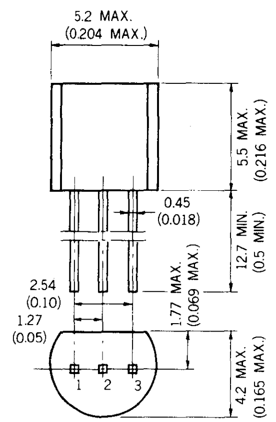
DESCRIPTION

The JE9113 is designed for use in output amplifier of portable radios in class B push-pull operation.

FEATURES

- High total nower dissipation. (P_T : 2.0 W, T_C=25 °C)
- High collector current. (I_C : 1.5 A)
- Complementary to JE9112.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. BASE
3. COLLECTOR

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature . . . . −65 to +150 °C
- Junction Temperature . . . . . . +150 °C Maximum

Maximum Power Dissipations
- Total Power Dissipation (Ta = 25 °C). . . . . . 1.0 W
  Transistor mounted on printed circuit board, max. lead length 4 mm, mounting pad for collector lead min. 10 mm x 10 mm.
- Total Power Dissipation (T_C = 25 °C) . . . . . 2.0 W
- Thermal Resistance (Ta=25 °C) (Junction to Ambient) . . 156.25 °C/W

Maximum Voltages and Currents (Ta = 25 °C)
- V_{CBO} Collector to Base Voltage . . . . 35 V
- V_{CEO} Collector to Emitter Voltage . . . . . 25 V
- V_{EBO} Emitter to Base Voltage . . . . 6.0 V
- I_C Collector Current . . . . 1.5 A
- I_B Base Current . . . . 0.5 A

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	40	170		–	V_{CE}=1.0 V, I_C=5.0 mA
h_{FE2}	DC Current Gain	60	180	300	–	V_{CE}=1.0 V, I_C=100 mA
h_{FE3}	DC Current Gain	30	130		–	V_{CE}=1.0 V, I_C=1000 mA
f_T	Gain Bandwidth Product	30	140		MHz	V_{CE}=5.0 V, I_C=10 mA
C_{ob}	Output Capacitance		17		pF	V_{CB}=10 V, I_E=0, f=1.0 MHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB}=35 V, I_E=0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE}=25 V, I_B=0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB}=6.0 V, I_C=0
V_{BE}	Base to Emitter Voltage		0.96	1.0	V	V_{CE}=1.0 V, I_C=800 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.15	0.5	V	I_C=800 mA, I_B=80 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.95	1.2	V	I_C=800 mA, I_B=80 mA
BV_{CBO}	Collector to Base Breakdown Voltage	35			V	I_C=0.1 mA, I_E=0
BV_{CEO}	Collector to Emitter Breakdown Voltage	25			V	I_C=2.0 mA, I_B=0
BV_{EBO}	Emitter to Base Breakdown Voltage	6.0			V	I_E=0.1 mA, I_C=0

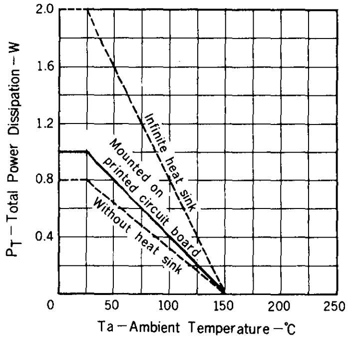
Classification of h_{FE2}

Rank	A	B	C	D
Range	60 – 120	85 – 160	120 – 200	160 – 300

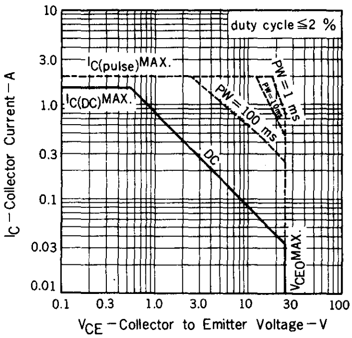
h_{FE2} Test Conditions : V_{CE} = 1.0 V, I_C = 100 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

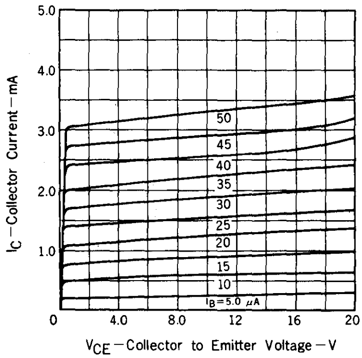
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



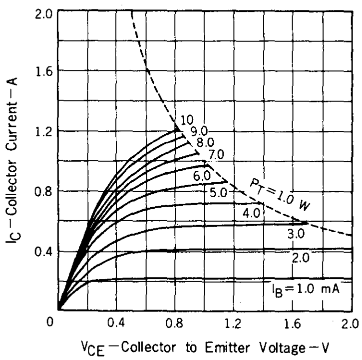
SAFE OPERATING AREA



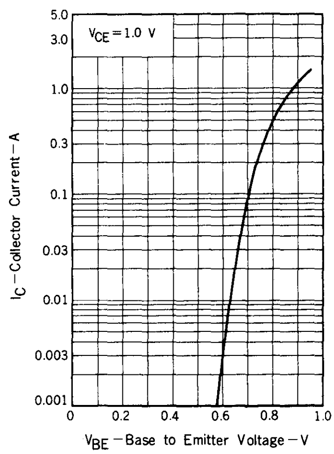
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



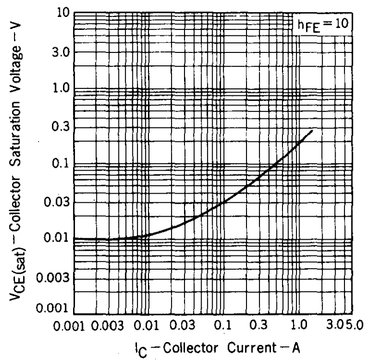
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



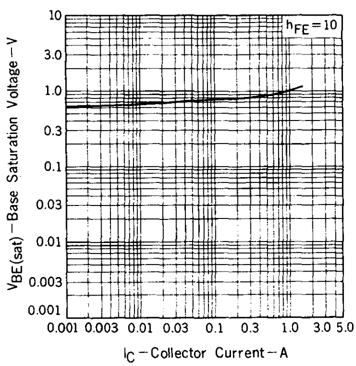
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



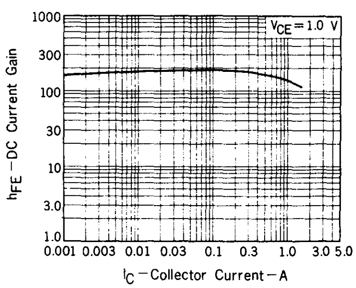
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



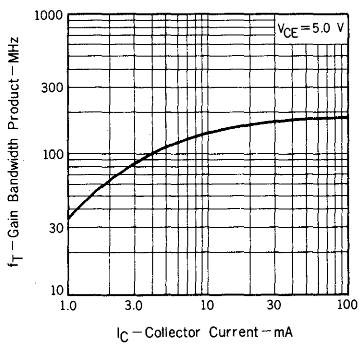
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



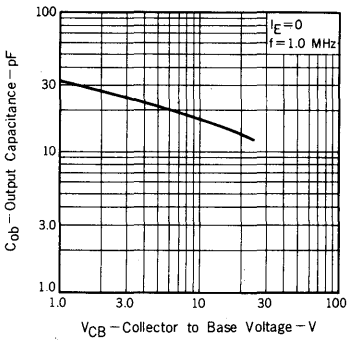
DC CURRENT GAIN vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs.
COLLECTOR TO BASE VOLTAGE



ELECTRON DEVICE

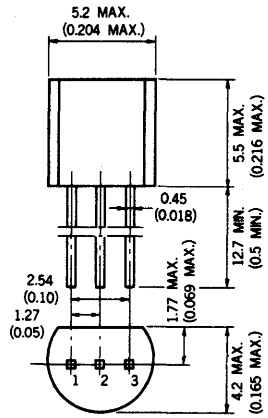
PNP SILICON TRANSISTOR
2SA639Ⓢ

DESCRIPTION The 2SA639Ⓢ is designed for use high voltage switching application.

FEATURES

- High breakdown voltage BV_{CER} : −180 V

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. COLLECTOR JEDEC : TO-92
3. BASE IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature .... −55 to +125 °C

Junction Temperature .... 125 °C Maximum

Maximum Power Dissipation (Ta=25 °C)

Total Power Dissipation .... 250 mW

Maximum Voltages and Current (Ta=25 °C)

V_{CBO}	Collector to Base Voltage	−180 V
V_{CER}	Collector to Emitter Voltage	−180 V
V_{EBO}	Emitter to Base Voltage	−5.0 V
I_C	Collector Current	−50 mA

ELECTRICAL CHARACTERISTICS (Ta=25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	50	120		–	V_{CE}=−3.0 V, I_C=−1.0 mA
h_{FE2}	DC Current Gain	30	100	330	–	V_{CE}=−6.0 V, I_C=−15 mA
f_T	Gain Bandwidth Product		130		MHz	V_{CE}=−10 V, I_E=10 mA
C_{ob}	Output Capacitance		4.5		pF	V_{CB}=−10 V, I_E=0, f=1.0 MHz
BV_{CER}	Collector to Emitter Breakdown Voltage	−180	−240		V	I_C=−100 μA, R_{BE}=30 kΩ
I_{CBO}	Collector Cutoff Current			−1.0	μA	V_{CB}=−100 V, I_E=0
I_{EBO}	Emitter Cutoff Current			−1.0	μA	V_{EB}=−3.0 V, I_C=0
$V_{CE(sat)}$	Collector Saturation Voltage		−0.22	−0.9	V	I_C=−10 mA, I_B=−1.0 mA
$V_{BE(sat)}$	Base Saturation Voltage		−0.75	−1.0	V	I_C=−10 mA, I_B=−1.0 mA

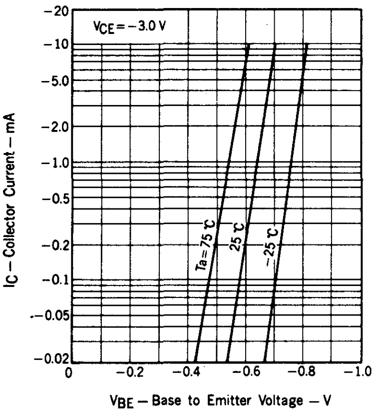
Classification of h_{FE2}

Rank	R	Q	P
Range	30 – 130	100 – 220	150 – 330

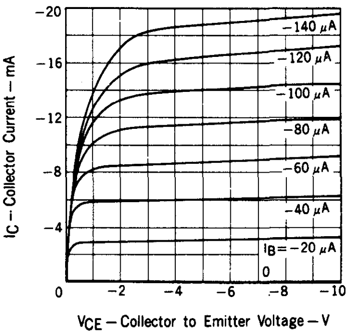
Test Conditions : V_{CE}=−6.0 V, I_C=−15 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

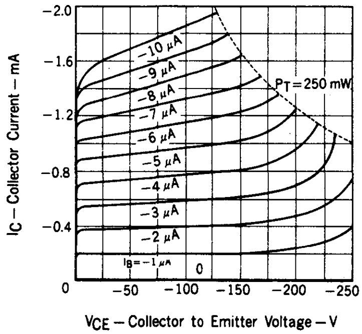
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



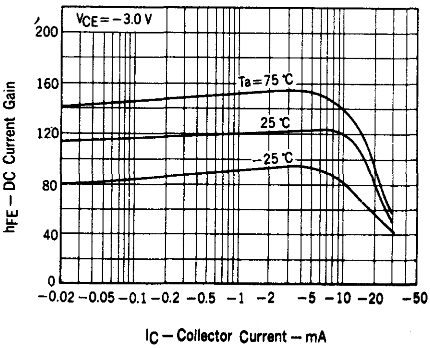
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



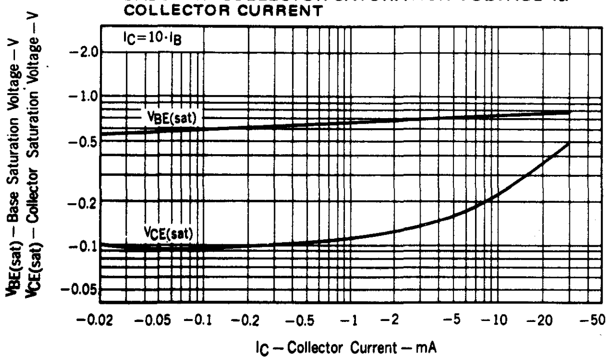
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



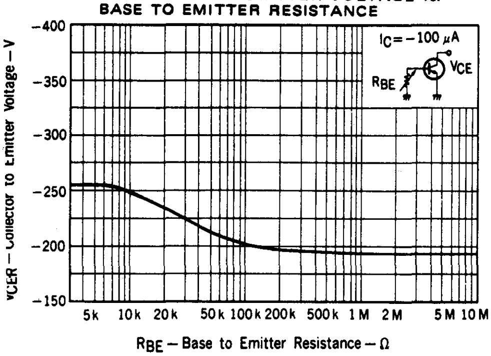
DC CURRENT GAIN vs.
COLLECTOR CURRENT



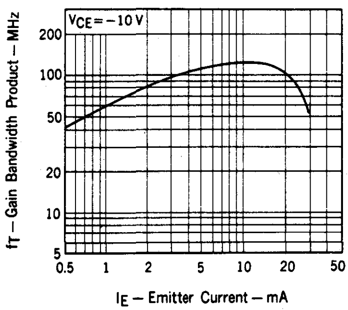
BASE AND COLLECTOR SATURATION VOLTAGE vs.
COLLECTOR CURRENT



COLLECTOR TO EMITTER VOLTAGE vs.
BASE TO EMITTER RESISTANCE



GAIN BANDWIDTH PRODUCT vs.
EMITTER CURRENT



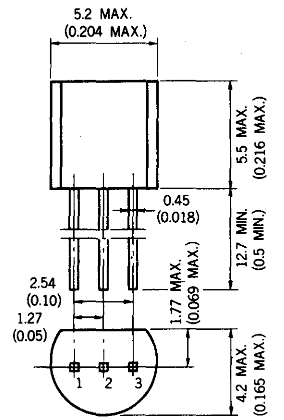
NEC
ELECTRON DEVICE

PNP SILICON TRANSISTOR
2SA640

DESCRIPTION The 2SA640 is designed for use in AF low noise amplifier of STEREOSET, RADIO and TAPE RECORDER.

FEATURES
- High h_{FE} : 450 TYP.
  h_{FE} ($I_C = -0.5$ mA, $V_{CE} = -3.0$ V)
- Low Noise Voltage : 25 mV TYP.
  NV ($G_V = 80$ dB, RIAA AMP.)

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. COLLECTOR JEDEC : TO-92
3. BASE IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature . . . . −55 to +125 °C
- Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents (Ta = 25 °C)
- V_{CBO} Collector to Base Voltage . . . . −50 V
- V_{CEO} Collector to Emitter Voltage . . . . −50 V
- V_{EBO} Emitter to Base Voltage . . . . −5.0 V
- I_C Collector Current . . . . −50 mA
- I_B Base Current . . . . −10 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	190	430		–	V_{CE}=−3.0 V, I_C=−0.1 mA
h_{FE2}	DC Current Gain	225	450	1000	–	V_{CE}=−3.0 V, I_C=−0.5 mA
NF_1	Noise Figure		5.0	15	dB	V_{CE}=−6.0 V, I_C=−0.3 mA, R_G=10 kΩ, f=10 Hz
NF_2	Noise Figure		1.5	4.0	dB	V_{CE}=−6.0 V, I_C=−0.3 mA, R_G=10 kΩ, f=100 Hz
NV	Noise Voltage		25	30	mV	See test circuit
I_{CBO}	Collector Cutoff Current			−50	nA	V_{CB}=−50 V, I_E=0
I_{CEO}	Collector Cutoff Current			−1.0	μA	V_{CE}=−40 V, I_B=0
I_{EBO}	Emitter Cutoff Current			−50	nA	V_{EB}=−5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	−0.55	−0.58	−0.65	V	V_{CE}=−3.0 V, I_C=−0.5 mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.3	−0.5	V	I_C=−30 mA, I_B=−3.0 mA
$V_{BE(sat)}$	Base Saturation Voltage		−0.82	−1.0	V	I_C=−30 mA, I_B=−3.0 mA
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE}=−6.0 V, I_E=1.0 mA
C_{ob}	Output Capacitance		6.5	10	pF	V_{CB}=−10 V, I_E=0, f=1.0 MHz

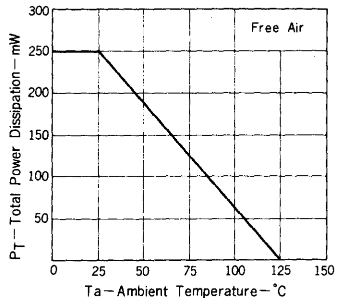
Classification of h_{FE2}

Rank	F	E	U
Range	225 – 450	350 – 700	500 – 1000

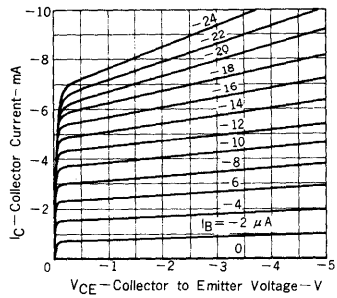
h_{FE} Test Conditions : $V_{CE} = -3.0$ V, $I_C = -0.5$ mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

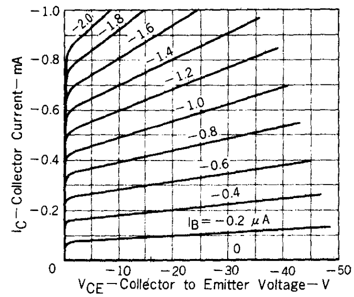
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



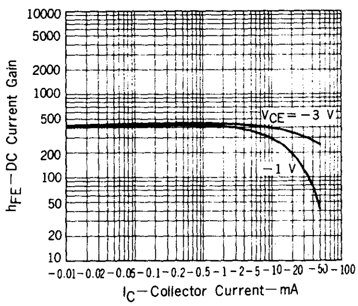
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



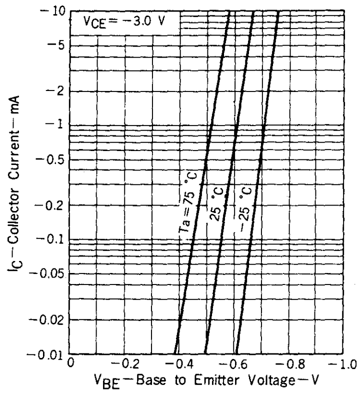
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



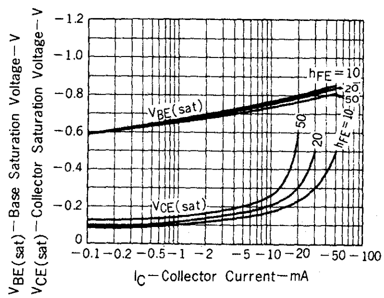
DC CURRENT GAIN vs. COLLECTOR CURRENT



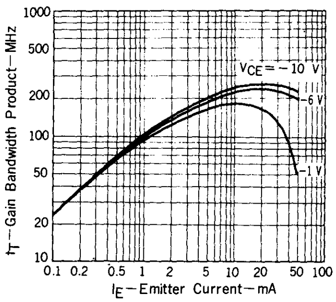
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



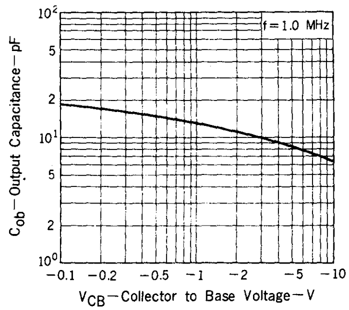
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



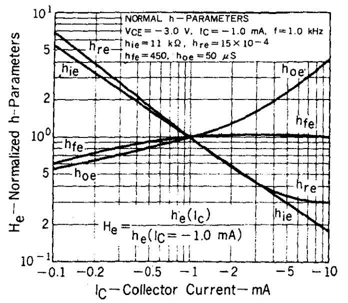
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



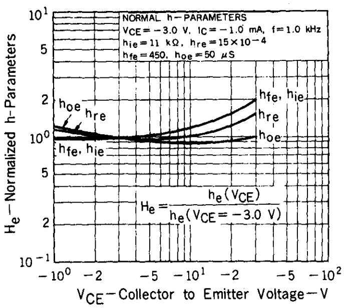
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



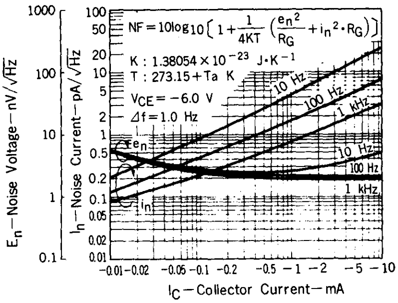
NORMALIZED h-PARAMETERS vs. COLLECTOR CURRENT



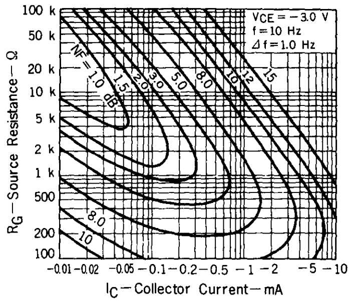
NORMALIZED h-PARAMETERS vs. COLLECTOR TO EMITTER VOLTAGE



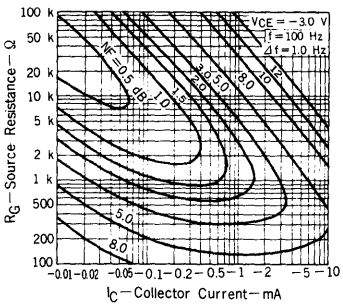
En AND In vs. COLLECTOR CURRENT



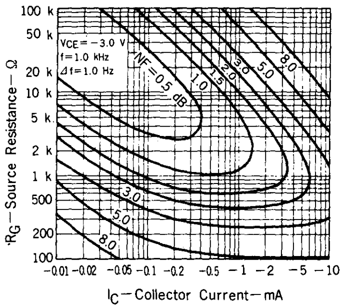
NOISE FIGURE MAP 1



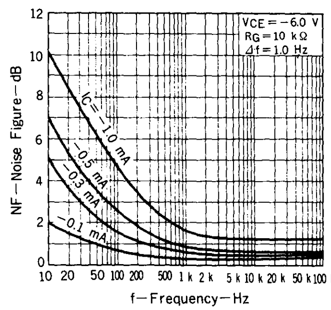
NOISE FIGURE MAP 2



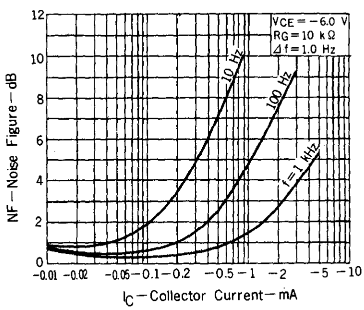
NOISE FIGURE MAP 3



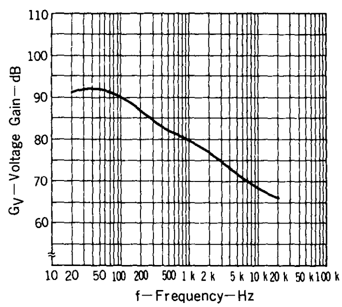
NOISE FIGURE vs. FREQUENCY



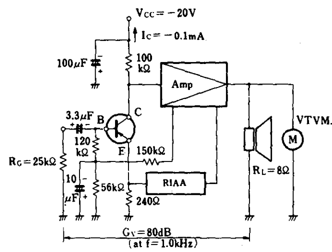
NOISE FIGURE vs. COLLECTOR CURRENT



VOLTAGE GAIN vs. FREQUENCY



NOISE VOLTAGE TEST CIRCUIT



NEC
ELECTRON DEVICE

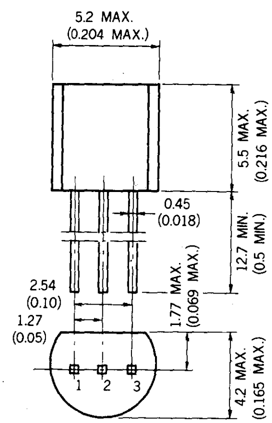
PNP SILICON TRANSISTOR
2SA641

DESCRIPTION The 2SA641 is designed for use in AF amplifier and high-gain amplifier.

FEATURES

- High h_{FE}
  h_{FE} (I_C = −0.5 mA, V_{CE} = −3.0 V) : 450 TYP.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

- Storage Temperature . . . . −55 to +125 °C
- Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

- Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents (Ta = 25 °C)

- V_{CBO} Collector to Base Voltage . . . . −50 V
- V_{CEO} Collector to Emitter Voltage . . . . −50 V
- V_{EBO} Emitter to Base Voltage . . . . −5.0 V
- I_C Collector Current . . . . −50 mA
- I_B Base Current . . . . −10 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	190	430		−	V_{CE}=−3.0 V, I_C=−0.1 mA
h_{FE2}	DC Current Gain	225	450	1000	−	V_{CE}=−3.0 V, I_C=−0.5 mA
NF	Noise Figure			20	dB	V_{CE}=−6.0 V, I_C=−0.3 mA, R_G=10 kΩ, f=100 Hz
I_{CBO}	Collector Cutoff Current			−50	nA	V_{CB}=−50 V, I_E=0
I_{CEO}	Collector Cutoff Current			−1.0	μA	V_{CE}=−40 V, I_B=0
I_{EBO}	Emitter Cutoff Current			−50	nA	V_{EB}=−5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	−0.55	−0.59	−0.65	V	V_{CE}=−3.0 V, I_C=−0.5 mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.3	−0.5	V	I_C=−30 mA, I_B=−3.0 mA
$V_{BE(sat)}$	Base Saturation Voltage		−0.82	−1.0	V	I_C=−30 mA, I_B=−3.0 mA
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE}=−6.0 V, I_E=1.0 mA
C_{ob}	Collector to Base Capacitance		6.5	10	pF	V_{CB}=−10 V, I_E=0, f=1.0 MHz

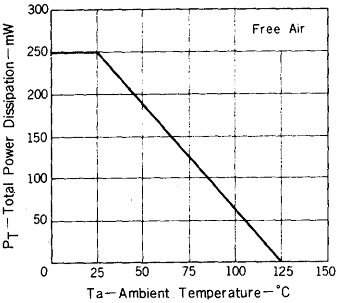
Classification of h_{FE2}

Rank	F	E	U
Range	225 − 450	350 − 700	500 − 1000

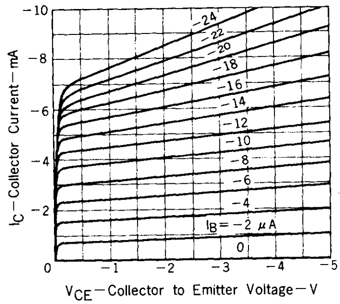
h_{FE} Test Conditions : V_{CE} = −3.0 V, I_C = −0.5 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

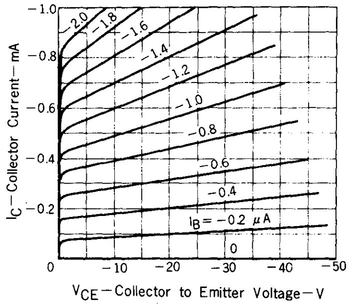
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



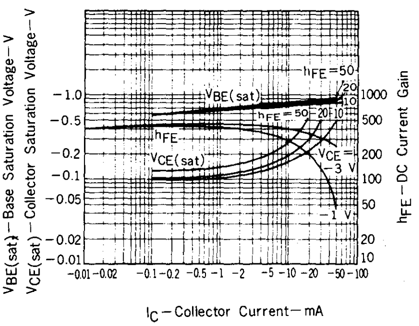
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



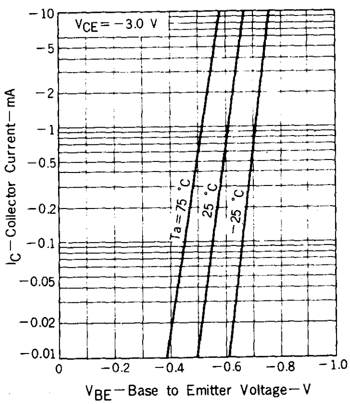
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



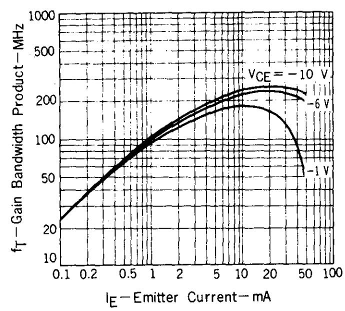
DC CURRENT GAIN, BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



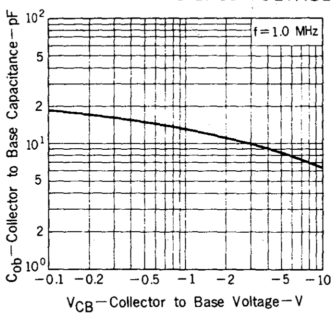
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



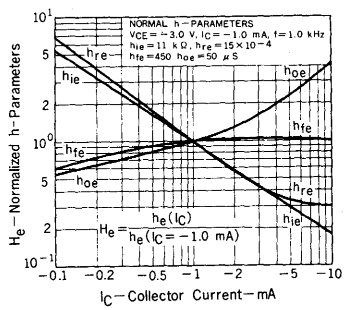
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



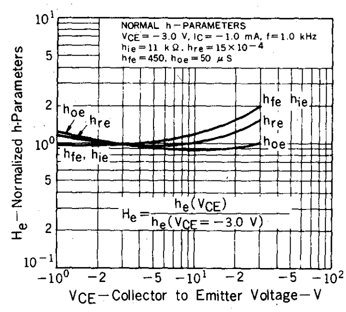
COLLECTOR TO BASE CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



NORMALIZED h-PARAMETERS vs. COLLECTOR CURRENT



NORMALIZED h-PARAMETERS vs. COLLECTOR TO EMITTER VOLTAGE



NEC
ELECTRON DEVICE

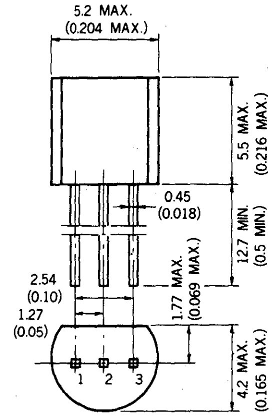
PNP SILICON TRANSISTOR
2SA733

DESCRIPTION The 2SA733 is designed for use in driver stage of AF amplifier.

FEATURES

- High h_{FE} and Excellent Linearity : 200 TYP.
  h_{FE} (V_{CE} = −6.0 V, I_C = −1.0 mA)

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER	EIAJ	: SC-43
2. COLLECTOR	JEDEC	: TO-92
3. BASE	IEC	: PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature .... −55 to +125 °C
- Junction Temperature .... +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation .... 250 mW

Maximum Voltages and Currents (Ta = 25 °C)
- V_{CBO} Collector to Base Voltage .... −60 V
- V_{CEO} Collector to Emitter Voltage .... −50 V
- V_{EBO} Emitter to Base Voltage .... −5.0 V
- I_C Collector Current .... −100 mA
- I_B Base Current .... −20 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	90	200	600		V_{CE}=−6.0 V, I_C=−1.0 mA
NF	Noise Figure		6.0	20	dB	V_{CE}=−6.0 V, I_C=−0.3 mA, R_G=10 kΩ, f=100 Hz
f_T	Gain Bandwidth Product	100	180		MHz	V_{CE}=−6.0 V, I_E=10 mA
C_{ob}	Output Capacitance		4.5	6.0	pF	V_{CB}=−10 V, I_E=0, f=1.0 MHz
I_{CBO}	Collector Cutoff Current			−0.1	μA	V_{CB}=−60 V, I_E=0
I_{EBO}	Emitter Cutoff Current			−0.1	μA	V_{EB}=−5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	−0.55	−0.62	−0.65	V	V_{CE}=−6.0 V, I_C=−1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.18	−0.3	V	I_C=−100 mA, I_B=−10 mA

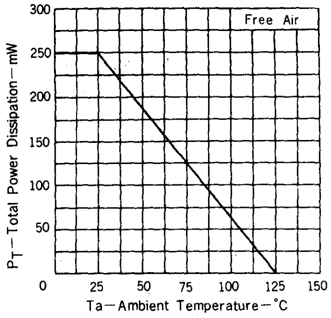
Classification of h_{FE}

Rank	R	Q	P	K
Range	90 − 180	135 − 270	200 − 400	300 − 600

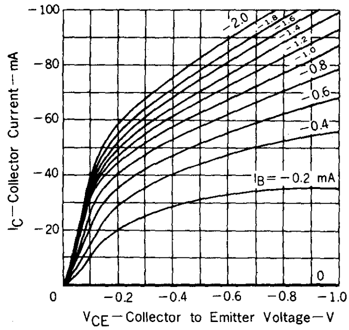
h_{FE} Test Conditions : V_{CE}=−6.0 V, I_C=−1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

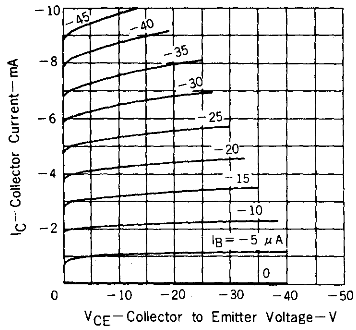
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



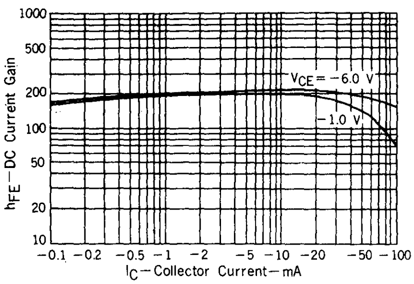
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



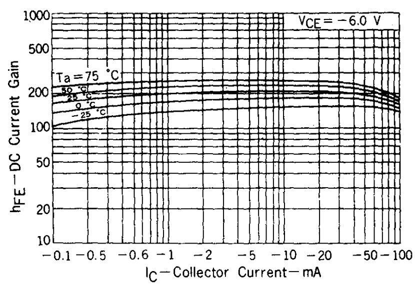
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



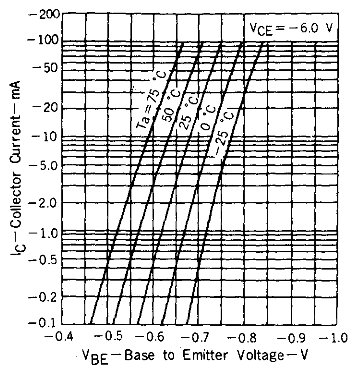
DC CURRENT GAIN vs. COLLECTOR CURRENT



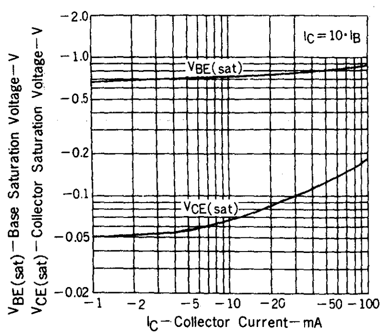
DC CURRENT GAIN vs. COLLECTOR CURRENT



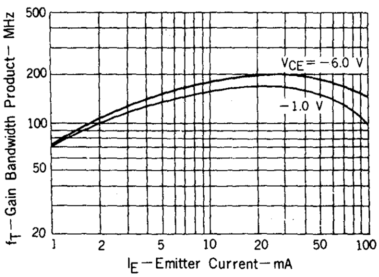
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



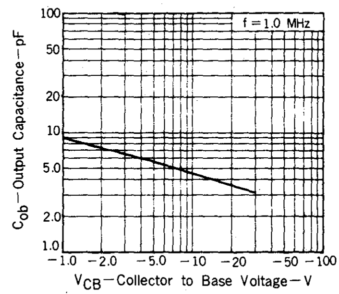
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT

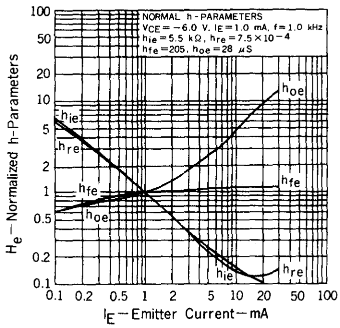


OUTPUT CAPACITANCE vs. REVERSE VOLTAGE

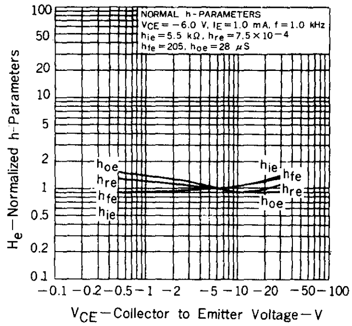


2

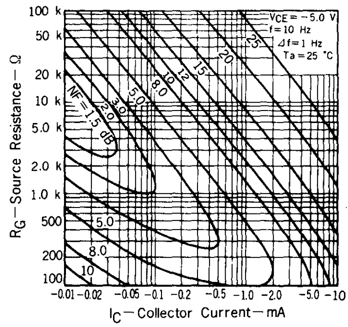
NORMALIZED h-PARAMETERS vs. EMITTER CURRENT



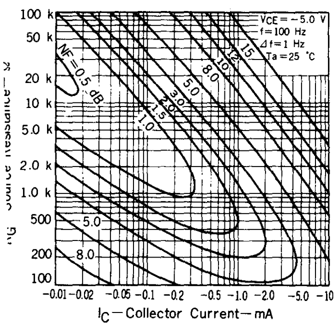
NORMALIZED h-PARAMETERS vs. COLLECTOR TO EMITTER VOLTAGE



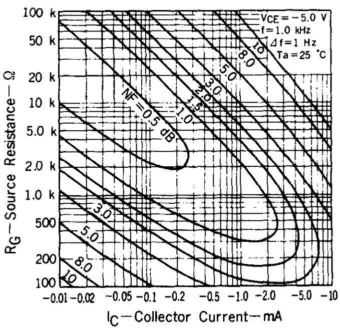
NOISE FIGURE MAP 1



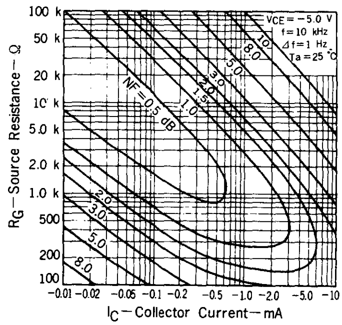
NOISE FIGURE MAP 2



NOISE FIGURE MAP 3



NOISE FIGURE MAP 4



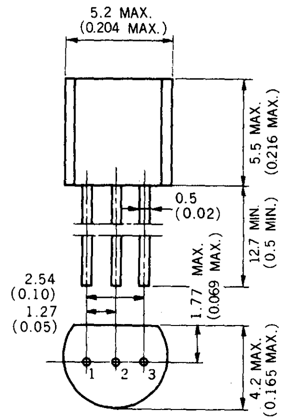
NEC
ELECTRON DEVICE

PNP SILICON TRANSISTOR
2SA750

DESCRIPTION The 2SA750 is designed for use in AF low noise amplifier of high-class STEREOSET, RADIO and TAPERECORDER.

FEATURES
- High h_{FE} : 450 TYP.
  h_{FE} (I_C = -0.5 mA, V_{CE} = -3 V)
- Low Noise Voltage NV : 22 mV TYP.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures
- Storage Temperature . . . . -55 to +125 °C
- Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents
- V_{CBO} Collector to Base Voltage . . . . -50 V
- V_{CEO} Collector to Emitter Voltage . . . . -50 V
- V_{EBO} Emitter to Base Voltage . . . . -5.0 V
- I_C Collector Current . . . . -50 mA
- I_B Base Current . . . . -10 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	190	430		–	V_{CE}=-3.0 V, I_C=-0.1 mA
h_{FE2}	DC Current Gain	225	450	1000	–	V_{CE}=-3.0 V, I_C=-0.5 mA
NF_1	Noise Figure		3.0	10	dB	V_{CE}=-6.0 V, I_C=-0.3 mA, R_G=10 kΩ, f=10 Hz
NF_2	Noise Figure		0.8	3.0	dB	V_{CE}=-6.0 V, I_C=-0.3 mA, R_G=10 kΩ, f=100 Hz
NV	Noise Voltage		22	25	mV	See test circuit
I_{CBO}	Collector Cutoff Current			-50	nA	V_{CB}=-50 V, I_E=0
I_{CEO}	Collector Cutoff Current			-1.0	μA	V_{CE}=-40 V, I_B=0
I_{EBO}	Emitter Cutoff Current			-50	nA	V_{EB}=-5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	-0.55	-0.59	-0.65	V	V_{CE}=-3.0 V, I_C=-0.5 mA
$V_{CE(sat)}$	Collector Saturation Voltage		-0.3	-0.5	V	I_C=-30 mA, I_B=-3.0 mA
$V_{BE(sat)}$	Base Saturation Voltage		-0.82	-1.0	V	I_C=-30 mA, I_B=-3.0 mA
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE}=-6.0 V, I_E=1.0 mA
C_{ob}	Collector to Base Capacitance		6.5	10	pF	V_{CB}=-10 V, I_E=0, f=1.0 MHz

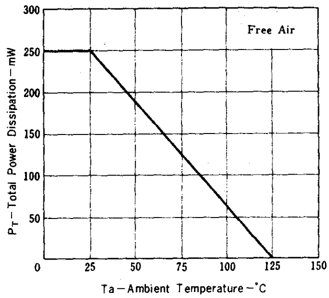
Classification of h_{FE}

Rank	F	E	U
Range	225 – 450	350 – 700	500 – 1000

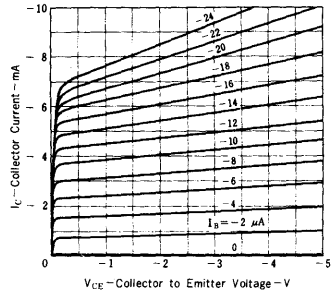
h_{FE} Test Conditions : V_{CE} = -3.0 V, I_C = -0.5 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

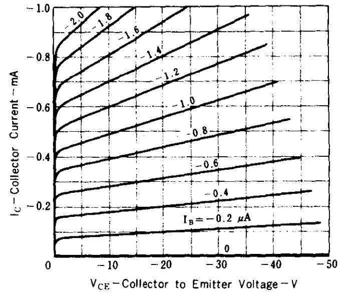
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



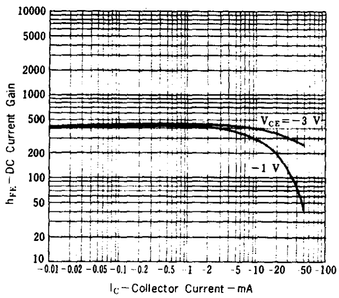
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



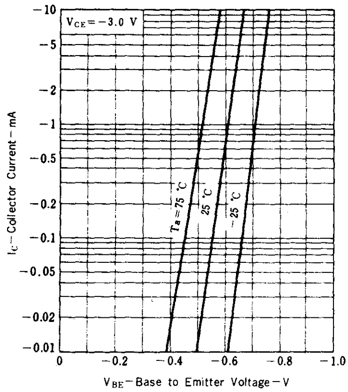
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



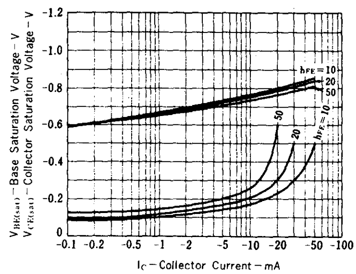
DC CURRENT GAIN vs. COLLECTOR CURRENT



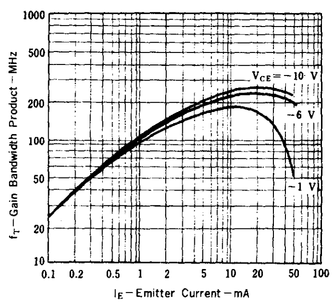
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



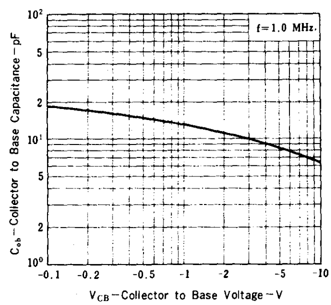
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



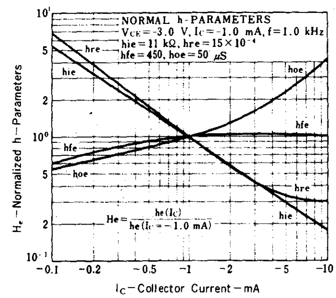
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



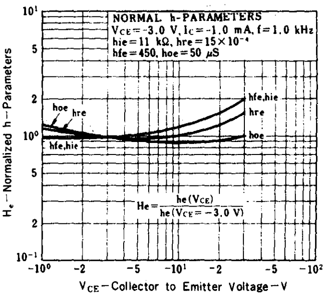
COLLECTOR TO BASE CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



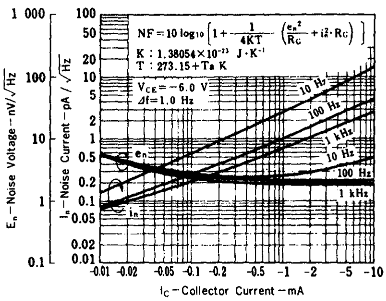
NORMALIZED h-PARAMETERS vs. COLLECTOR CURRENT



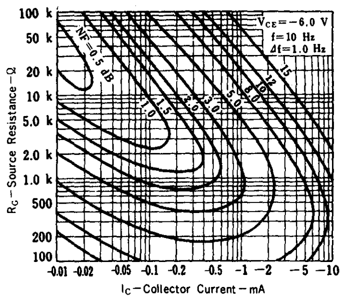
NORMALIZED h-PARAMETERS vs. COLLECTOR TO EMITTER VOLTAGE



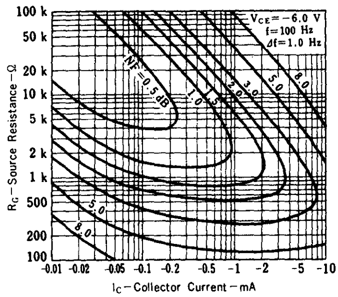
En AND In vs. COLLECTOR CURRENT



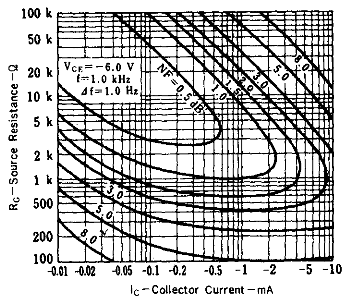
NOISE FIGURE MAP 1



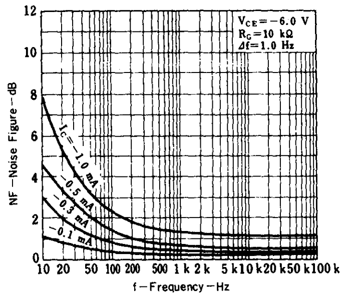
NOISE FIGURE MAP 2



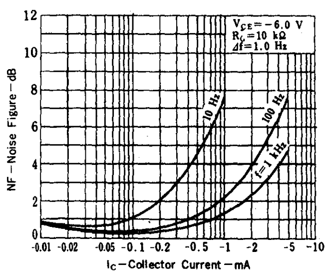
NOISE FIGURE MAP 3



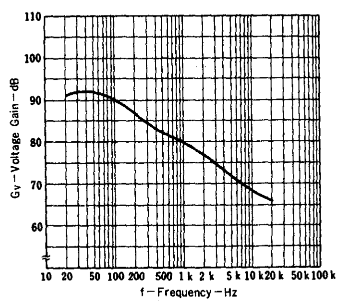
NOISE FIGURE vs. FREQUENCY



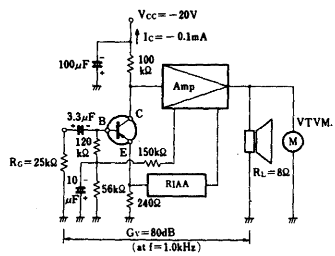
NOISE FIGURE vs. COLLECTOR CURRENT



VOLTAGE GAIN vs. FREQUENCY



NOISE VOLTAGE TEST CIRCUIT



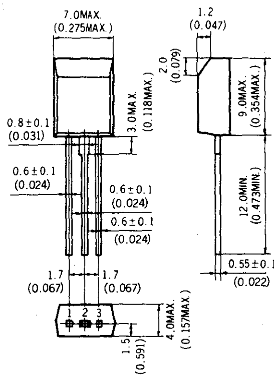
NEC
ELECTRON DEVICE

PNP SILICON TRANSISTOR
2SA915

DESCRIPTION The 2SA915 is designed for use in driver stages of audio frequency amplifiers.

FEATURES
- High Total Power Dissipation and High Breakdown Voltage: 1.0W at 25°C Ambient Temperature/V_{CEO} = −120V
- Complementary to the NEC 2SC1940 NPN Transistor.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Collector
3. Base

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −55 to +150°C

Junction Temperature . . . . +150°C Maximum

Maximum Power Dissipation (Ta=25°C)

Total Power Dissipation 1.0W

Thermal Resistance(Junction to Ambient). . . .125°C/W

Maximum Voltages and Currents (Ta=25°C)

V_{CBO} Collector to Base Voltage . . . . −120 V

V_{CEO} Collector to Emitter Voltage . . . . −120 V

V_{EBO} Emitter to Base Voltage . . . . −5.0 V

I_C Collector Current . . . . −50 mA

I_B Base Current . . . . −10 mA

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	90	200	400	–	V_{CE}=−10V, I_C=−10mA
h_{FE2}	DC Current Gain	50	200		–	V_{CE}=−10V, I_C=−1.0mA
f_T	Gain Bandwidth Product	50	80		MHz	V_{CE}=−10V, I_E=10mA
C_{ob}	Output Capacitance		2.5	3.5	pF	V_{CB}=−10V, I_E=0, f=1.0MHz
I_{CBO}	Collector Cutoff Current			−100	nA	V_{CB}=−120V, I_E=0
I_{EBO}	Emitter Cutoff Current			−100	nA	V_{EB}=−5.0V, I_C=0
V_{BE}	Base to Emitter Voltage	-650	-695	-750	mV	V_{CE}=−10V, I_C=−10mA
$V_{CE(sat)}$	Collector Saturation Voltage		-0.18	-0.6	V	I_C=−20mA, I_B=−2.0mA
$V_{BE(sat)}$	Base Saturation Voltage		-0.79	-1.0	V	I_C=−20mA, I_B=−2.0mA

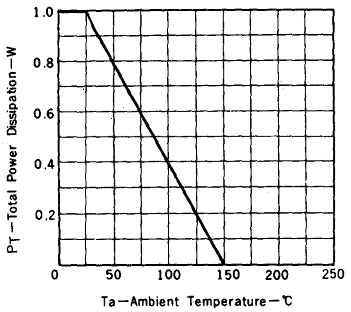
Classification of h_{FE1}

Rank	M	L	K
Range	90 − 180	135 − 270	200 − 400

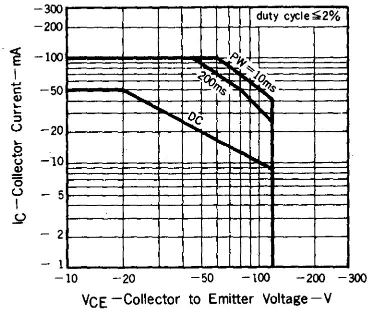
h_{FE1} Test Conditions: V_{CE}=−10V, I_C=−10mA

TYPICAL CHARACTERISTICS (Ta=25°C unless otherwise noted)

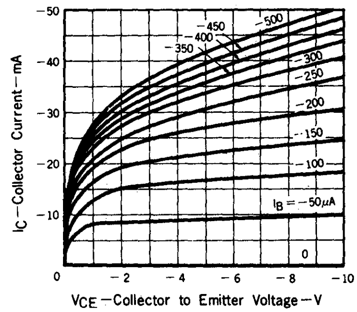
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



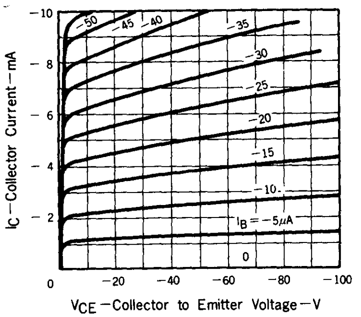
SAFE OPERATING AREAS (TRANSIENT THERMAL RESISTANCE METHOD)



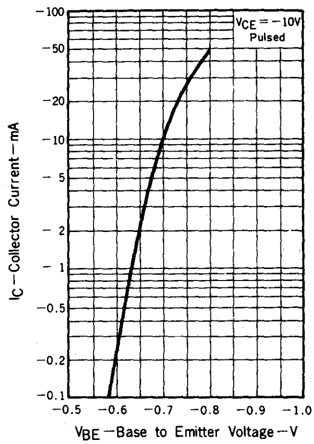
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



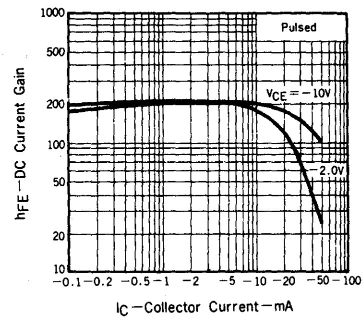
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



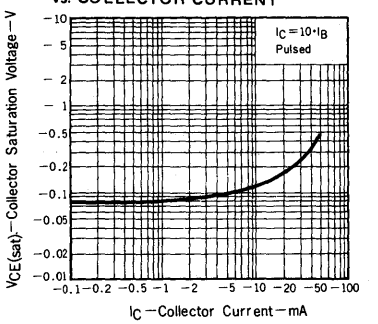
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



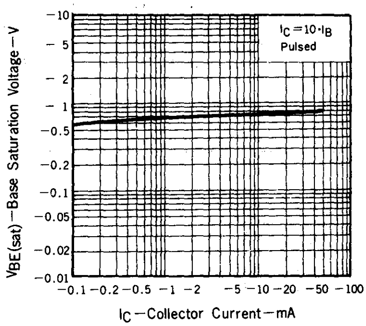
DC CURRENT GAIN vs. COLLECTOR CURRENT



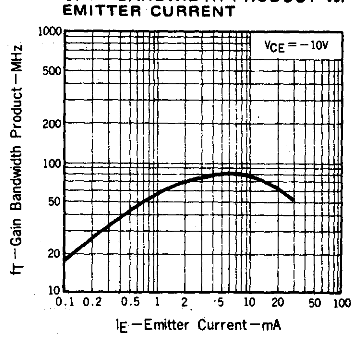
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



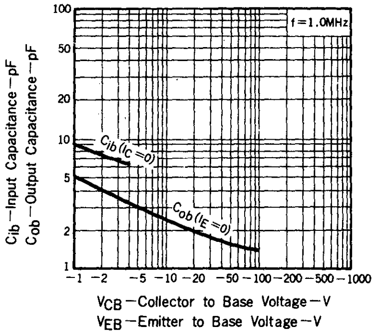
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

PNP SILICON TRANSISTOR
2SA916

DESCRIPTION The 2SA916 is designed for use in driver stages of audio frequency amplifiers.

FEATURES
- High Total Power Dissipation and High Breakdown Voltage: 1.0W at 25°C Ambient Temperature/V_{CEO} = −160V
- Complementary to the NEC 2SC1941 NPN Transistor.

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature .... −55 to +150°C

Junction Temperature .... +150°C Maximum

Maximum Power Dissipation (Ta = 25°C)

Total Power Dissipation 1.0W

Thermal Resistance (Junction to Ambient). . . .125°C/W

Maximum Voltages and Currents (Ta = 25°C)

V_{CBO} Collector to Base Voltage .... −160 V

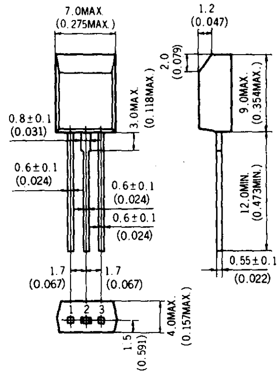
V_{CEO} Collector to Emitter Voltage .... −160 V

V_{EBO} Emitter to Base Voltage .... −5.0 V

I_C Collector Current .... −50 mA

I_B Base Current .... −10 mA

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Collector
3. Base

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	90	200	400	–	V_{CE} = −10V, I_C = −10mA
h_{FE2}	DC Current Gain	50	200		–	V_{CE} = −10V, I_C = −1.0mA
f_T	Gain Bandwidth Product	50	80		MHz	V_{CE} = −10V, I_E = 10mA
C_{ob}	Output Capacitance		2.5	3.5	pF	V_{CB} = −10V, I_E = 0, f = 1.0MHz
I_{CBO}	Collector Cutoff Current			−100	nA	V_{CB} = −160V, I_E = 0
I_{EBO}	Emitter Cutoff Current			−100	nA	V_{EB} = −5.0V, I_C = 0
V_{BE}	Base to Emitter Voltage	−650	−695	−750	mV	V_{CE} = −10V, I_C = −10mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.18	−0.6	V	I_C = −20mA, I_B = −2.0mA
$V_{BE(sat)}$	Base Saturation Voltage		−0.79	−1.0	V	I_C = −20mA, I_B = −2.0mA

Classification of h_{FE1}

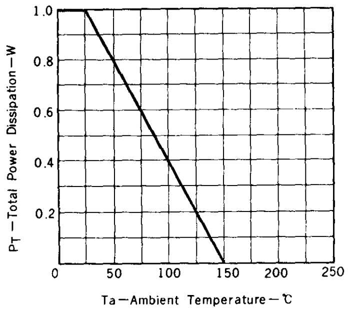
Rank	M	L	K
Range	90 − 180	135 − 270	200 − 400

h_{FE1} Test Conditions: V_{CE} = −10V, I_C = −10mA

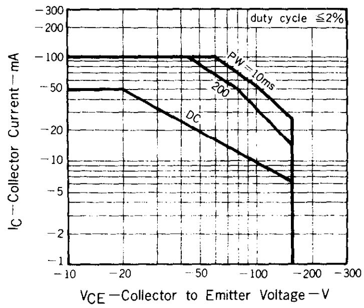
2

TYPICAL CHARACTERISTICS (Ta=25°C unless otherwise noted)

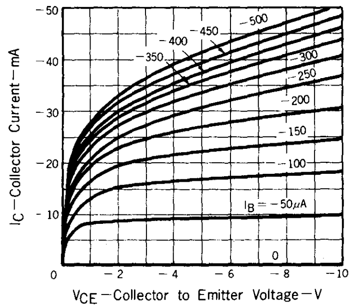
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



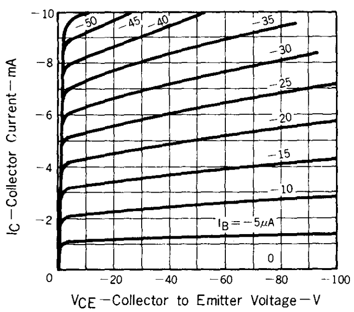
SAFE OPERATING AREAS (TRANSIENT THERMAL RESISTANCE METHOD)



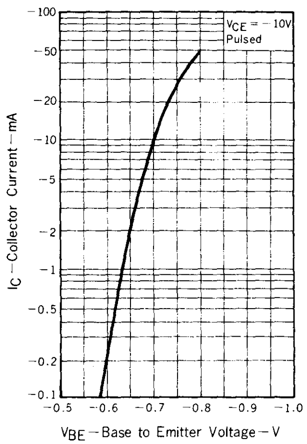
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



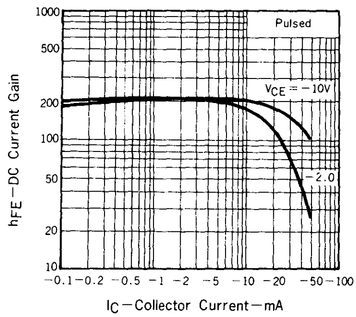
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



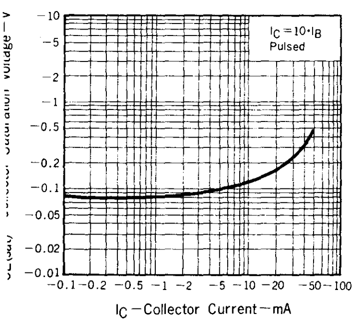
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



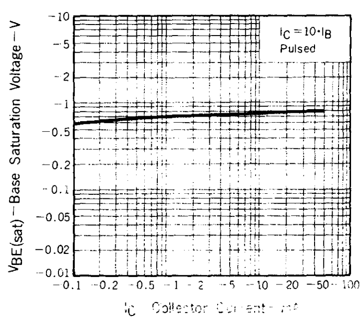
DC CURRENT GAIN vs. COLLECTOR CURRENT



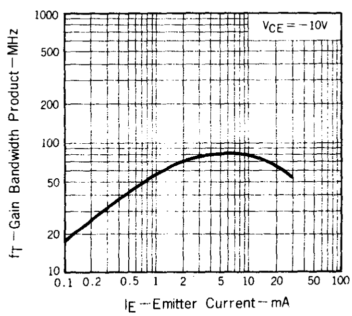
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



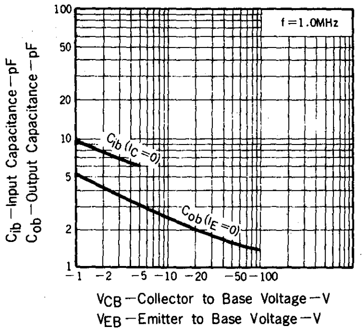
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

PNP SILICON TRANSISTOR
2SA952

DESCRIPTION

The 2SA952 is designed for use in output stage of portable radio and cassette type tape recorder, general purpose applications.

FEATURES

- High total power dissipation.
  P_T = 600 mW
- High h_{FE} and low $V_{CE(sat)}$.
  h_{FE} (I_C = −100 mA) : 200 TYP.
  $V_{CE(sat)}$ (−700 mA) : −0.25 V TYP.

ABSOLUTE MAXIMUM RATINGS

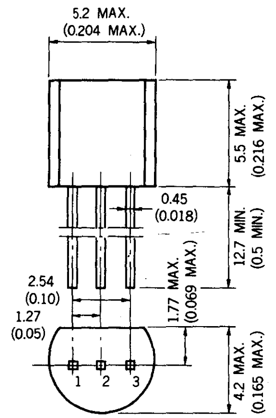
Maximum Temperatures
- Storage Temperature . . . . −55 to +150 °C
- Junction Temperature . . . . +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation . . . . 600 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO}	Collector to Base Voltage	−30	V
V_{CEO}	Collector to Emitter Voltage	−25	V
V_{EBO}	Emitter to Base Voltage	−5.0	V
I_C	Collector Current	−700	mA
I_B	Base Current	−150	mA

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}*	DC Current Gain	90	200	400	−	V_{CE} = −1.0 V, I_C = −100 mA
h_{FE2}*	DC Current Gain	50	100		−	V_{CE} = −1.0 V, I_C = −700 mA
C_{ob}	Collector to Base Capacitance		17	40	pF	V_{CB} = −6.0 V, I_E = 0 f = 1.0 MHz
f_T	Gain Bandwidth Product	50	160		MHz	V_{CE} = −6.0 V, I_E = 10 mA
V_{BE}*	Base to Emitter Voltage	−600	−640	−700	mV	V_{CE} = −6.0 V, I_C = −10 mA
$V_{CE(sat)}$*	Collector Saturation Voltage		−0.25	−0.6	V	I_C = −700 mA, I_B = −70 mA
$V_{BE(sat)}$*	Base Saturation Voltage		−0.95	−1.2	V	I_C = −700 mA, I_B = −70 mA
I_{CBO}	Collector Cutoff Current			−100	nA	V_{CB} = −30 V, I_E = 0
I_{EBO}	Emitter Cutoff Current			−100	nA	V_{EB} = −5.0 V, I_C = 0

*Pulsed PW ≦ 350 μs, duty cycle ≦ 2.0 %

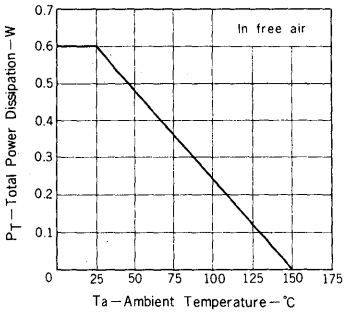
Classification of h_{FE1}

Rank	M	L	K
Range	90 − 180	135 − 270	200 − 400

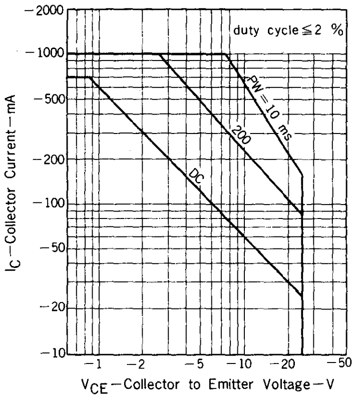
h_{FE} Test Conditions : V_{CE} = −1.0 V, I_C = −100 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

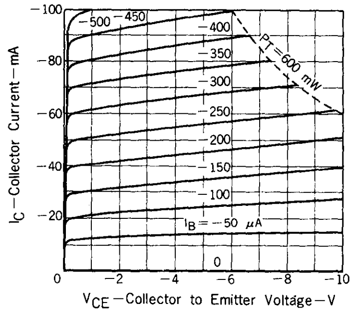
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



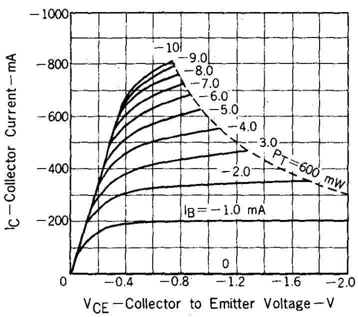
SAFE OPERATING AREAS (TRANSIENT THERMAL RESISTANCE)



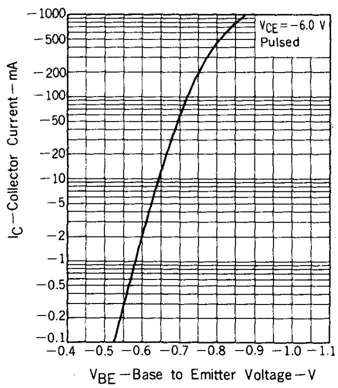
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



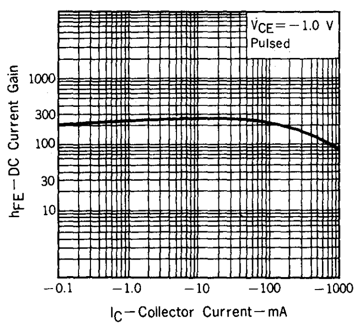
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



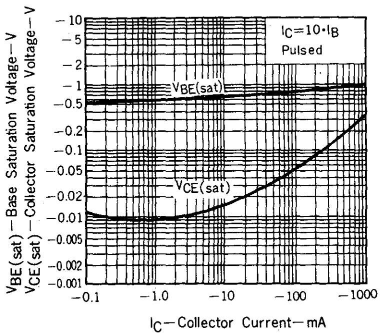
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



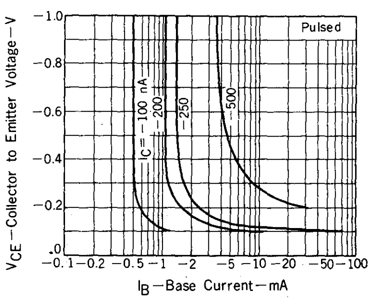
DC CURRENT GAIN vs. COLLECTOR CURRENT



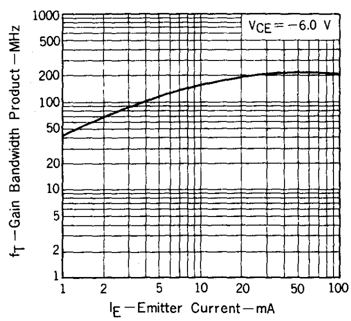
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



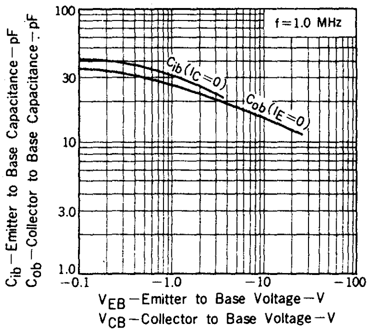
COLLECTOR TO EMITTER VOLTAGE vs. BASE CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



EMITTER TO BASE AND COLLECTOR TO BASE CAPACITANCE vs. REVERSE VOLTAGE



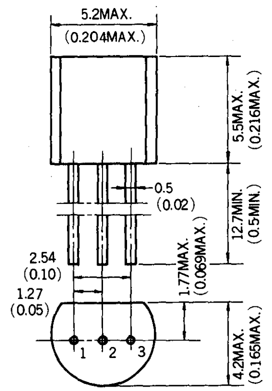
NEC
ELECTRON DEVICE

PNP SILICON TRANSISTOR
2SA953

DESCRIPTION The 2SA953 is designed for use in driver stage of high voltage audio equipment.

FEATURES
- High total power dissipation.
  P_T = 600 mW
- High h_{FE} and high voltage.
  h_{FE} (I_C = −50 mA) : 200 TYP.
  V_{CEO} : 60 V

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC: TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Temperature
- Storage Temperature .... −55 to +150°C
- Junction Temperature .... +150°C Maximum

Maximum Power Dissipation (Ta = 25°C)
- Total Power Dissipation .... 600 mW

Maximum Voltages and Currents
- V_{CBO} Collector to Base Voltage .... −60 V
- V_{CEO} Collector to Emitter Voltage .... −60 V
- V_{EBO} Emitter to Base Voltage .... −5.0 V
- I_C Collector Current .... −300 mA
- I_B Base Current .... −60 mA

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}*	DC Current Gain	90	200	400	–	V_{CE}=−1.0V, I_C=−50mA
h_{FE2}*	DC Current Gain	30	80		–	V_{CE}=−1.0V, I_C=−300mA
C_{ob}	Collector to Base Capacitance		13	25	pF	V_{CB}=−6.0V, I_E=0 f=1.0MHz
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE}=−6.0V, I_E=10mA
V_{BE}*	Base to Emitter Voltage	−600	−660	−700	mV	V_{CE}=−6.0V, I_C=−10mA
$V_{CE(sat)}$*	Collector Saturation Voltage		−0.15	−0.6	V	I_C=−300mA, I_B=−30mA
$V_{BE(sat)}$*	Base Saturation Voltage		−0.85	−1.2	V	I_C=−300mA, I_B=−30mA
I_{CBO}	Collector Cutoff Current			−100	nA	V_{CB}=−60V, I_E=0
I_{EBO}	Emitter Cutoff Current			−100	nA	V_{EB}=−5.0V, I_C=0

* Pulsed PW≦350 μs duty cycle≦2.0%

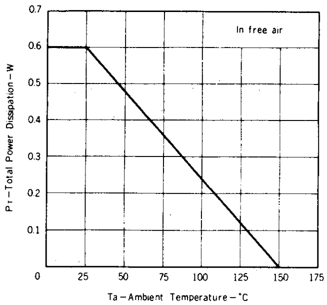
Classification of h_{FE}

Rank	M	L	K
Range	90 – 180	135 – 270	200 – 400

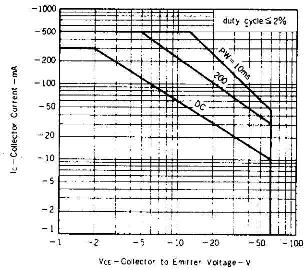
h_{FE} Test Conditions: V_{CE} = -1.0V, I_C = - 50mA

TYPICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

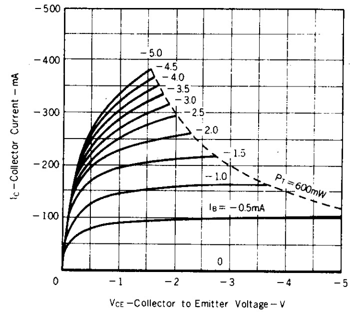
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



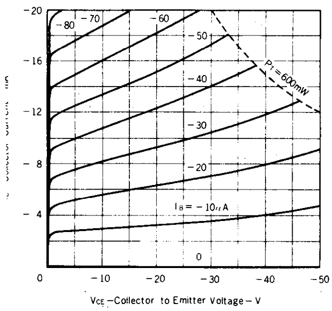
SAFE OPERATING AREAS (TRANSIENT THERMAL RESISTANCE)



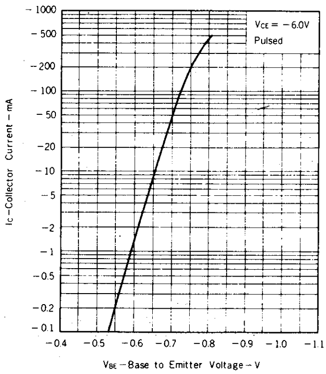
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



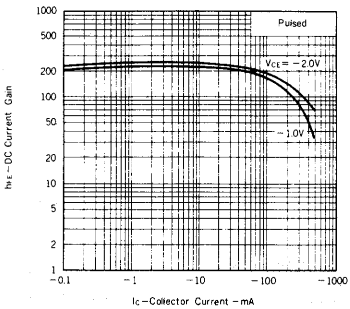
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



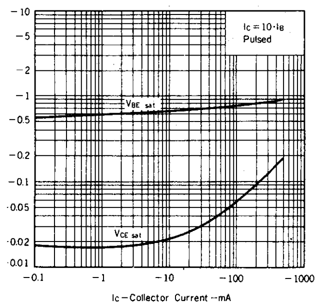
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



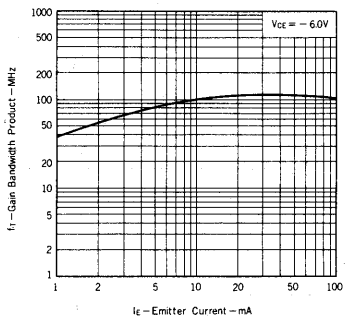
DC CURRENT GAIN vs. COLLECTOR CURRENT



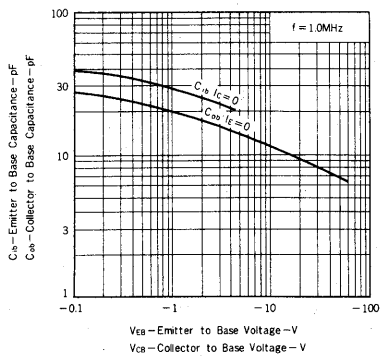
AND COLLECTOR SATURATION VOLTAGE
LLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



EMITTER TO BASE AND COLLECTOR TO BASE CAPACITANCE vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

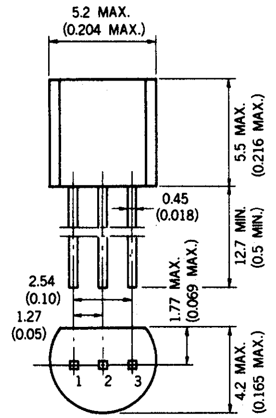
PNP SILICON TRANSISTOR
2SA954

DESCRIPTION The 2SA954 is designed for use in driver stage of high voltage audio equipment.

FEATURES

- High total power dissipation.
  P_T = 600 mW
- High h_{FE} and high voltage.
  h_{FE} (I_C = −50 mA) : 200 TYP.
  V_{CEO} : −80 V

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature .... −55 to +150 °C
- Junction Temperature .... +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation .... 600 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO}	Collector to Base Voltage	−80	V
V_{CEO}	Collector to Emitter Voltage	−80	V
V_{EBO}	Emitter to Base Voltage	−5.0	V
I_C	Collector Current	−300	mA
I_B	Base Current	−60	mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}*	DC Current Gain	90	200	400	–	V_{CE} = −1.0 V, I_C = −[illegible] mA
h_{FE2}*	DC Current Gain	30	80		–	V_{CE} = −1.0 V, I_C = −300 mA
C_{ob}	Collector to Base Capacitance		13	25	pF	V_{CB} = −6.0 V, I_E = 0 f = 1.0 MHz
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE} = −6.0 V, I_E = 10 mA
V_{BE}*	Base to Emitter Voltage	−600	−660	−700	mV	V_{CE} = −6.0 V, I_C = −10 mA
$V_{CE(sat)}$*	Collector Saturation Voltage		−0.15	−0.6	V	I_C = −300 mA, I_B = −30 mA
$V_{BE(sat)}$*	Base Saturation Voltage		−0.85	−1.2	V	I_C = −300 mA, I_B = −30 mA
I_{CBO}	Collector Cutoff Current			−100	nA	V_{CB} = −80 V, I_E = 0
I_{EBO}	Emitter Cutoff Current			−100	nA	V_{EB} = −5.0 V, I_C = 0

* Pulsed PW ≦ 350 μs, duty cycle ≦ 2.0 %

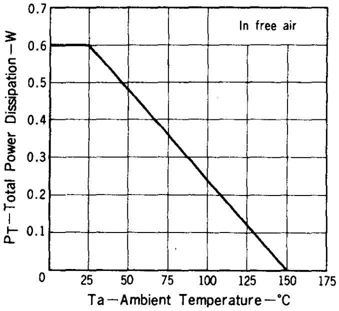
Classification of h_{FE1}

Rank	M	L	K
Range	90 – 180	135 – 270	200 – 400

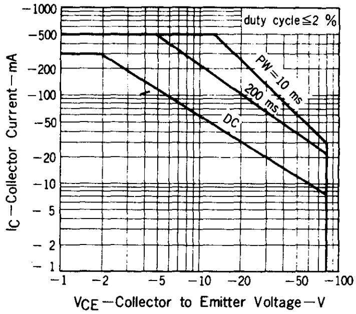
h_{FE} Test Conditions : V_{CE} = −1.0 V, I_C = −50 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

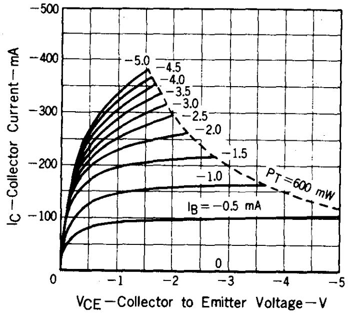
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



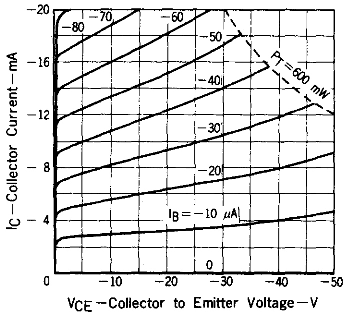
SAFE OPERATING AREAS (TRANSIENT THERMAL RESISTANCE)



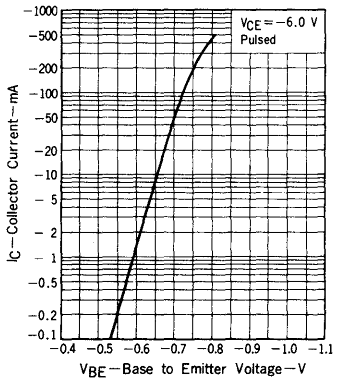
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



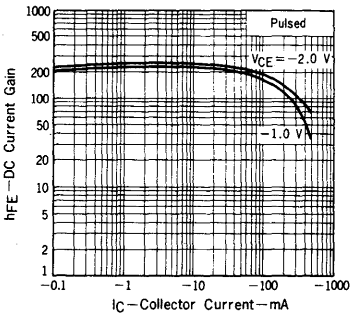
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



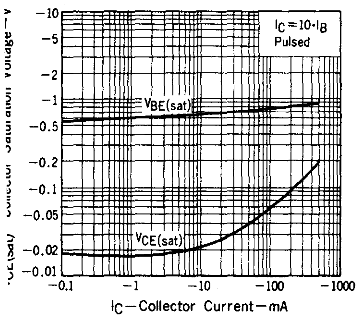
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



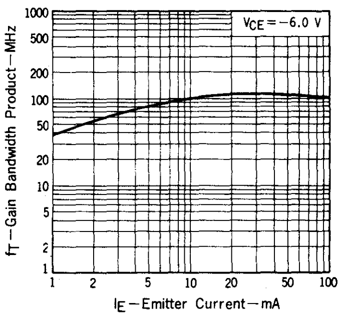
DC CURRENT GAIN vs. COLLECTOR CURRENT



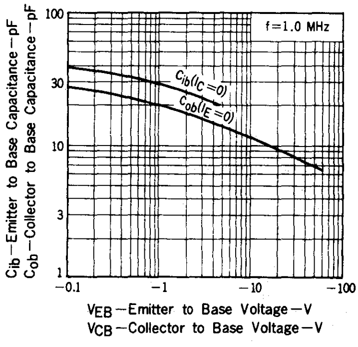
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



EMITTER TO BASE AND COLLECTOR TO BASE CAPACITANCE vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

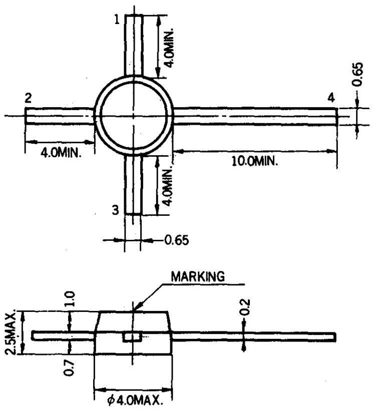
SILICON TRANSISTOR
2SA983

RF AMP, FOR UHF TV TUNER
PNP SILICON TRANSISTOR
"DISK MOLD"

The 2SA983 is specifically designed for UHF RF amplifier applications. The 2SA983 features high power gain, low noise, and excellent forward AGC characteristics in a tiny four-lead plastic package designed to realize easy and economical mounting.

- Packaged in tiny plastic mold package.
- Easy & economical mounting realizable with plastic mold package.
- Forward AGC characteristic.
- Balanced base.

PACKAGE DIMENSIONS
(Unit: mm)



1. Base
2. Emitter
3. Base
4. Collector

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Collector to Base Voltage	V_{CBO}	–30	V
Collector to Emitter Voltage	V_{CEO}	–25	V
Emitter to Base Voltage	V_{EBO}	–4.0	V
Collector Current	I_C	–20	mA
Total Power Dissipation	P_T	200	mW
Junction Temperature	T_j	125	°C
Storage Temperature	T_{stg}	-55 to +125	°C

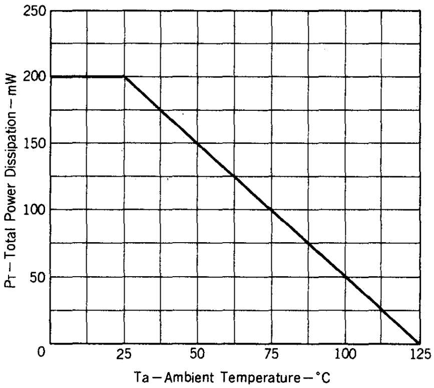
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			– 0.1	μA	V_{CB}=–25V, I_E=0
DC Current Gain	h_{FE}	40		200		V_{CE}=–10V, I_C=–3.0mA
Gain Bandwidth Product	f_T	800	1000		MHz	V_{CE}=–10V, I_E=3.0mA
Output Capacitance	C_{ob}		0.5	0.7	pF	V_{CB}=–10V, I_E=0, f=1MHz
Noise Figure	NF		4.5	5.5	dB	V_{CE}=–12V, I_E=3.0mA, f=900MHz
Power Gain	G_{pb}	14			dB	V_{CE}=–12V, I_E=3.0mA, f=900MHz
AGC Current	I_{AGC}	7.2		9.8	mA	I_E for which G_{pbAGC}=G_{pb}–20dB

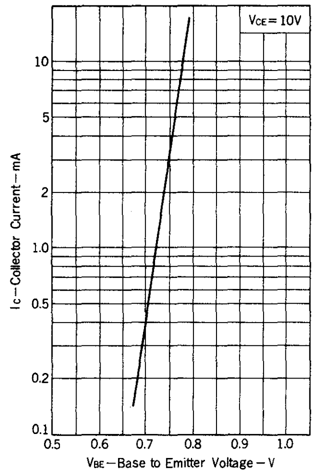
I_{AGC} Classification M: 7.2～8.5mA, L: 8.0～9.0mA, K: 8.5～9.8mA

TYPICAL CHARACTERISTICS (T_a = 25°C)

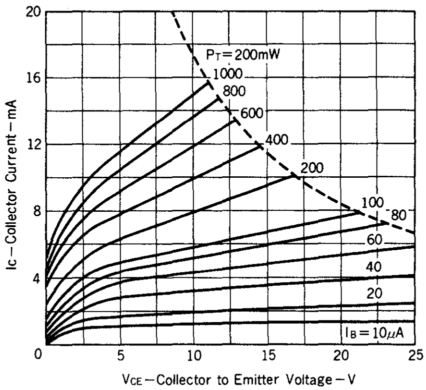
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



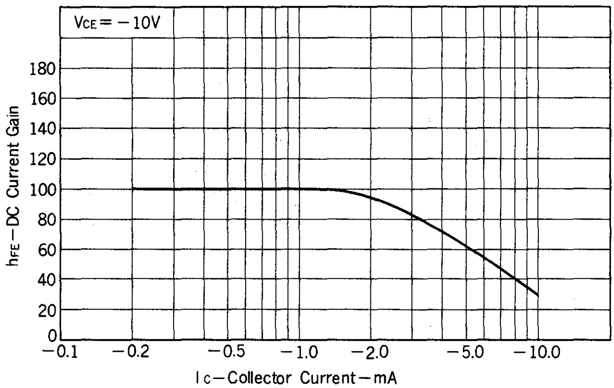
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



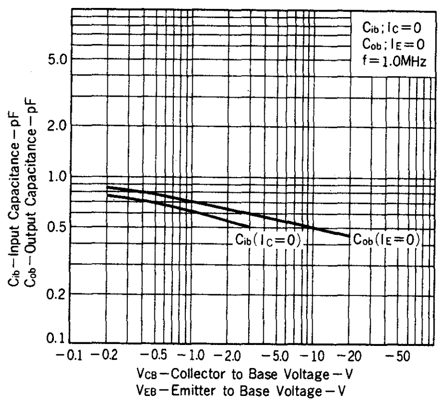
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



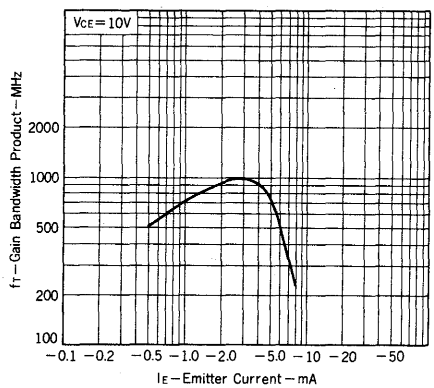
DC CURRENT GAIN vs. COLLECTOR CURRENT



INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE

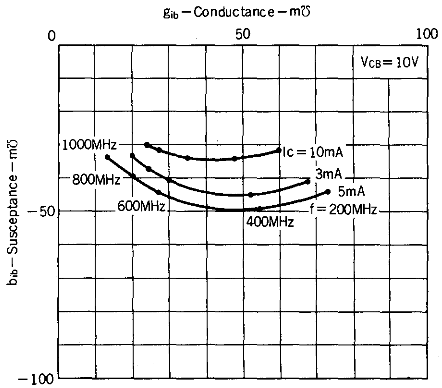


GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT

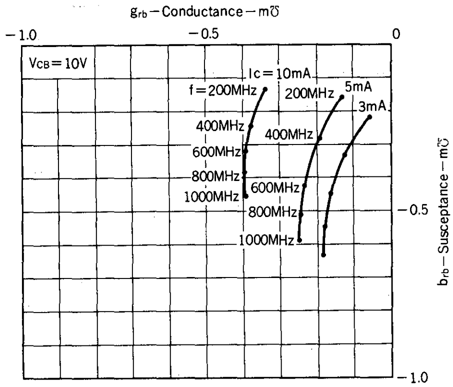


TYPICAL CHARACTERISTICS OF "Y" PARAMETERS

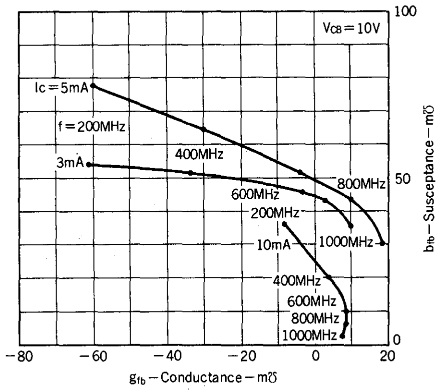
INPUT ADMITTANCE (Y_{ib}) vs. FREQUENCY



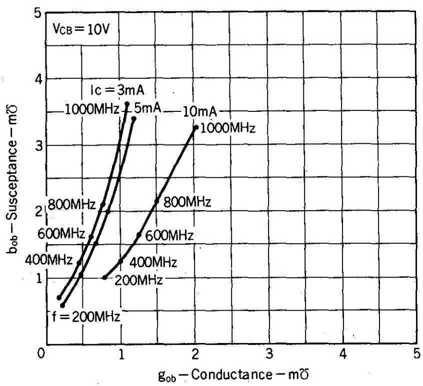
REVERSE TRANSFER ADMITTANCE (Y_{rb}) vs. FREQUENCY



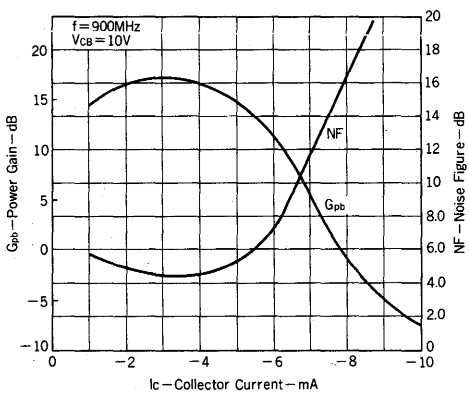
FORWARD TRANSFER ADMITTANCE (Y_{fb}) vs. FREQUENCY



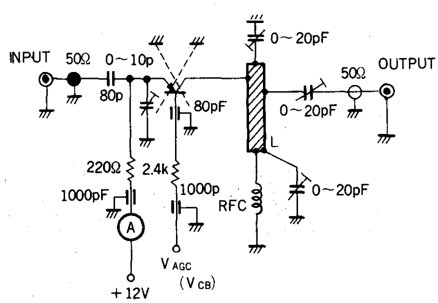
OUTPUT ADMITTANCE (Y_{ob}) vs. FREQUENCY



POWER GAIN AND NOISE FIGURE vs. COLLECTOR CURRENT

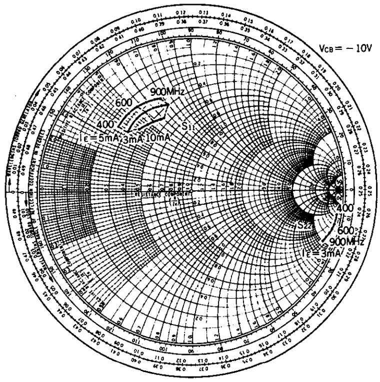


900 MHz Gpb & NF Test Circuit

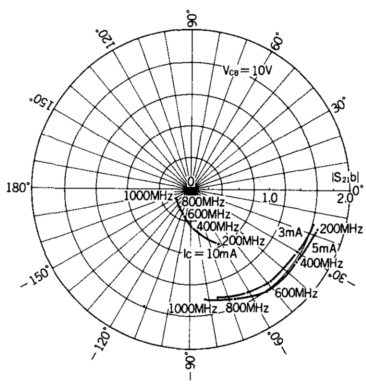


L = 25 × 5 × 0.5mm (Cu)

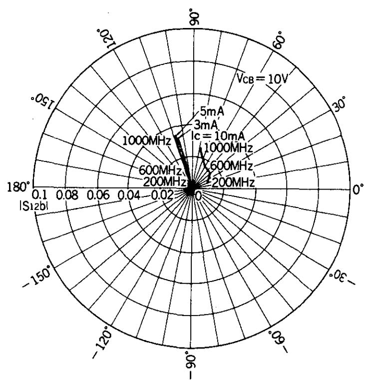
$S_{11} - f, S_{22} - f$



$S_{21} - f$



$S_{12} - f$



NEC
ELECTRON DEVICE

PNP SILICON TRANSISTOR
2SA987

DESCRIPTION The 2SA987 is designed for use in an AF amplifier and general purpose.

FEATURES

- High h_{FE}. h_{FE} : 400 TYP. (V_{CE} = −6.0 V, I_C = −1.0 mA)
- Complementary to 2SC1840.

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −55 to +125 °C

Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

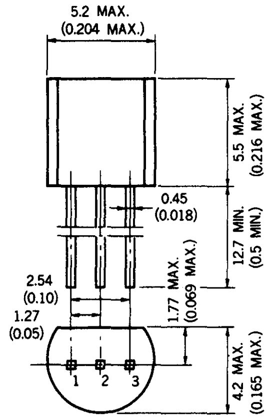
Total Power Dissipation . . . . 500 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO}	Collector to Base Voltage	-40	V
V_{CEO}	Collector to Emitter Voltage	-35	V
V_{EBO}	Emitter to Base Voltage	-5.0	V
I_C	Collector Current	-100	mA
I_B	Base Current	-20	mA

PACKAGE DIMENSIONS

in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	150	380		–	V_{CE} = −6.0 V, I_C = −0.1 mA
h_{FE2}	DC Current Gain	200	400	800	–	V_{CE} = −6.0 V, I_C = −1.0 mA
f_T	Gain Bandwidth Product	50	90		MHz	V_{CE} = −6.0 V, I_C = −1.0 mA
C_{ob}	Output Capacitance		5.5	10	pF	V_{CB} = −10 V, I_E = 0, f = 1.0 MHz
I_{CBO}	Collector Cutoff Current			−50	nA	V_{CB} = −40 V, I_E = 0
I_{CEO}	Collector Cutoff Current			−1.0	μA	V_{CE} = −30 V, R_{BE} = ∞
I_{EBO}	Emitter Cutoff Current			−50	nA	V_{EB} = −5.0 V, I_C = 0
V_{BE}	Base to Emitter Voltage	-0.55	-0.60	-0.65	V	V_{CE} = −6.0 V, I_C = −1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		-0.18	-0.50	V	I_C = −100 mA, I_B = −10 mA

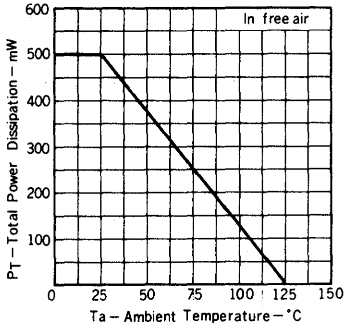
Classification of h_{FE2}

Rank	P	F	E
Range	200 – 400	300 – 600	400 – 800

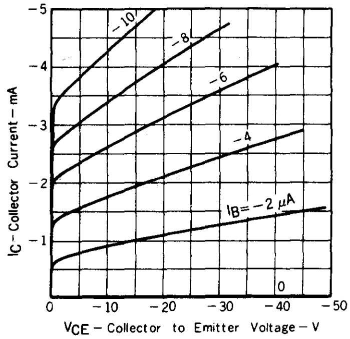
h_{FE} Test Conditions : V_{CE} = −6.0 V, I_C = −1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

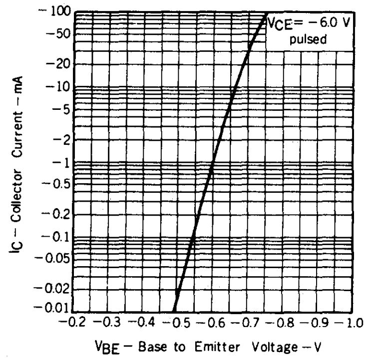
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



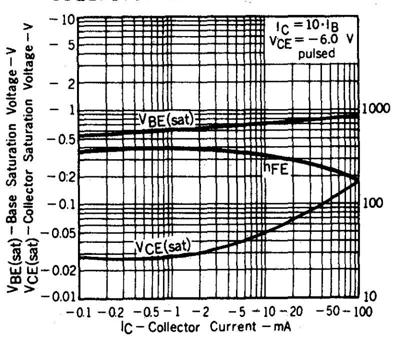
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



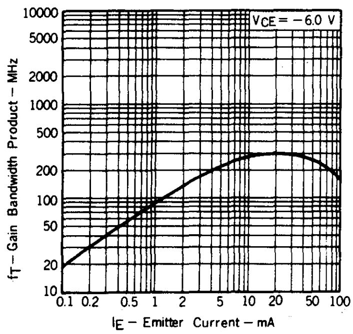
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



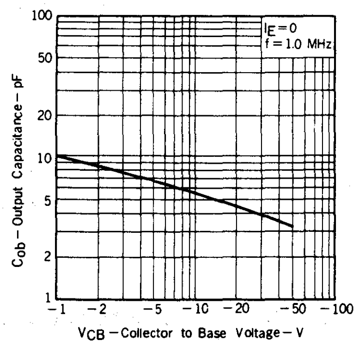
COLLECTOR AND BASE SATURATION VOLTAGE, DC CURRENT GAIN vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

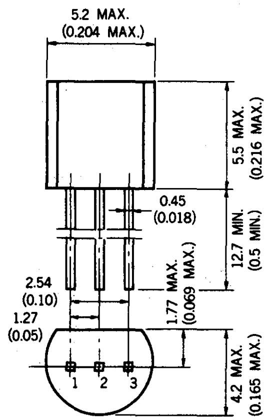
PNP SILICON TRANSISTOR
2SA988

DESCRIPTION The 2SA988 is designed for use in driver stage of AF amplifier.

FEATURES

- High Voltage. V_{CEO} : −120 V
- Low Output Capacitance. C_{ob} : 2.0 pF TYP. (V_{CB} = −30 V)
- High h_{FE}. h_{FE} : 500 TYP. (V_{CE} = −6.0 V, I_C = −1.0 mA)

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. COLLECTOR JEDEC : TO-92
3. BASE IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −55 to +125 °C

Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation . . . . 500 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO} Collector to Base Voltage . . . . −120 V

V_{CEO} Collector to Emitter Voltage . . . . −120 V

V_{EBO} Emitter to Base Voltage . . . . −5.0 V

I_C Collector Current . . . . −50 mA

I_B Base Current . . . . −10 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	150	500		−	V_{CE} = −6.0 V, I_C = −0.1 mA
h_{FE2}	DC Current Gain	200	500	800	−	V_{CE} = −6.0 V, I_C = −1.0 mA
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE} = −6.0 V, I_C = −1.0 mA
Cob	Output Capacitance		2.0	3.0	pF	V_{CB} = −30 V, I_E = 0, f = 1.0 MHz
I_{CBO}	Collector Cutoff Current			−50	nA	V_{CB} = −120 V, I_E = 0
I_{CEO}	Collector Cutoff Current			−1.0	μA	V_{CE} = −100 V, R_{BE} = ∞
I_{EBO}	Emitter Cutoff Current			−50	nA	V_{EB} = −5.0 V, I_C = 0
V_{BE}	Base to Emitter Voltage	−0.55	−0.61	−0.65	V	V_{CE} = −6.0 V, I_C = −1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.09	−0.30	V	I_C = −10 mA, I_B = −1.0 mA

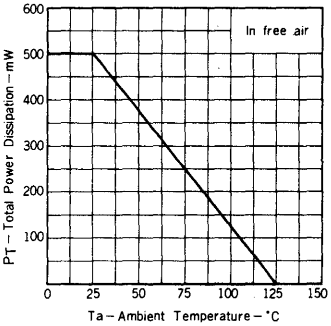
Classification of h_{FE2}

Rank	P	F	E
Range	200 − 400	300 − 600	400 − 800

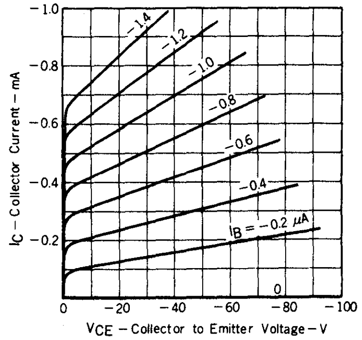
h_{FE} Test Conditions : V_{CE} = −6.0 V, I_C = −1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

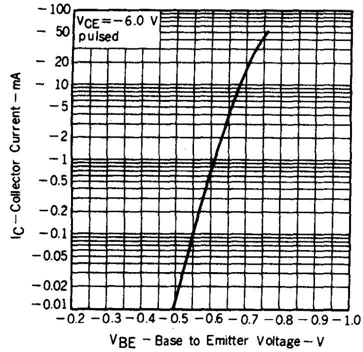
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



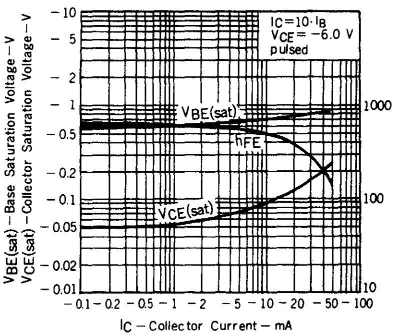
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



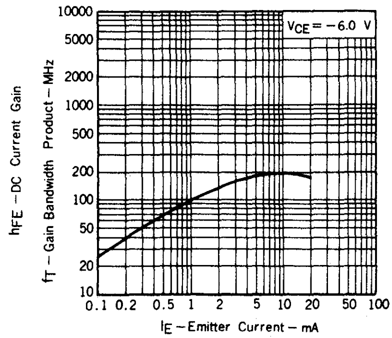
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



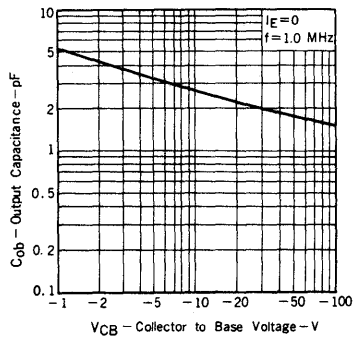
COLLECTOR AND BASE SATURATION VOLTAGE, DC CURRENT GAIN vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

PNP SILICON TRANSISTOR
2SA990

DESCRIPTION The 2SA990 is designed for use in driver stage of AF amplifier.

FEATURE • High h_{FE}. h_{FE} : 400 TYP. (V_{CE} = −6.0 V, I_C = −1.0 mA)

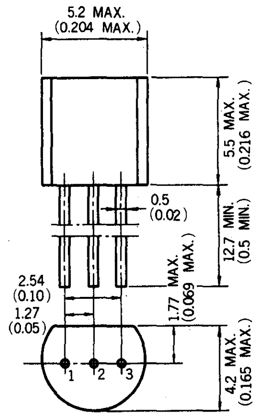
ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures
- Storage Temperature . . . . −55 to +125 °C
- Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents (Ta = 25 °C)
- V_{CBO} Collector to Base Voltage . . . . −60 V
- V_{CEO} Collector to Emitter Voltage . . . . −50 V
- V_{EBO} Emitter to Base Voltage . . . . −5.0 V
- I_C Collector Current . . . . −100 mA
- I_B Base Current . . . . −20 mA

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. COLLECTOR JEDEC : TO-92
3. BASE IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	150	380		–	V_{CE} = −6.0 V, I_C = −0.1 mA
h_{FE2}	DC Current Gain	200	400	800	–	V_{CE} = −6.0 V, I_C = −1.0 mA
f_T	Gain Bandwidth Product	50	180		MHz	V_{CE} = −6.0 V, I_C = −1.0 mA
Cob	Output Capacitance		4.5	6.0	pF	V_{CB} = −10 V, I_E = 0, f = 1.0 MHz
NV	Noise Voltage		25	40	mV	V_{CE} = −5.0 V, I_C = −1.0 mA, R_G = 100 kΩ, G_V = 80 dB, f = 10 Hz to 1.0 kHz
I_{CBO}	Collector Cutoff Current			−100	nA	V_{CB} = −60 V, I_E = 0
I_{CEO}	Collector Cutoff Current			−1.0	μA	V_{CE} = −40 V, R_{BE} = ∞
I_{EBO}	Emitter Cutoff Current			−100	nA	V_{EB} = −5.0 V, I_C = 0
V_{BE}	Base to Emitter Voltage	−0.55	−0.62	−0.65	V	V_{CE} = −6.0 V, I_C = −1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.18	−0.30	V	I_C = −100 mA, I_B = −10 mA

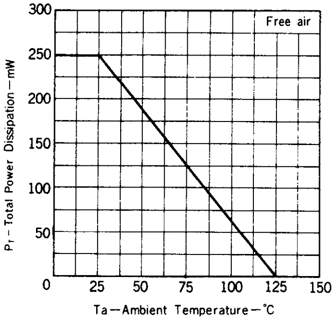
Classification of h_{FE2}

Rank	P	F	E
Range	200 – 400	300 – 600	400 – 800

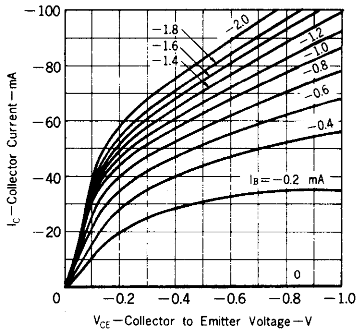
h_{FE2} Test Conditions : V_{CE} = −6.0 V, I_C = −1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

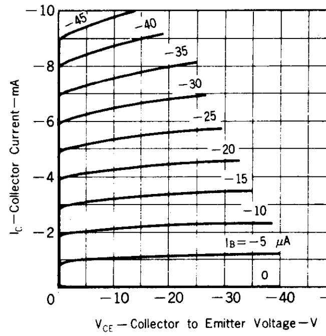
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



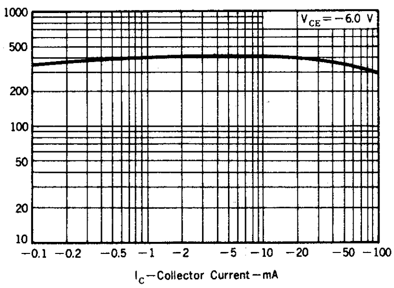
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



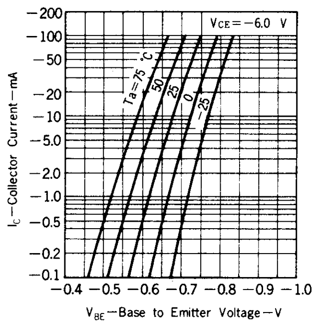
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



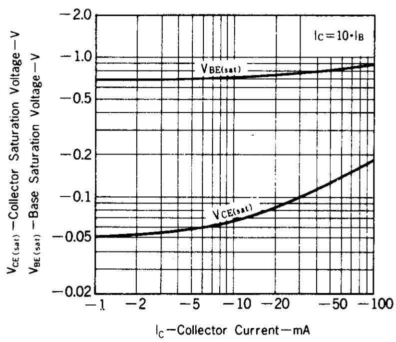
DC CURRENT GAIN vs. COLLECTOR CURRENT



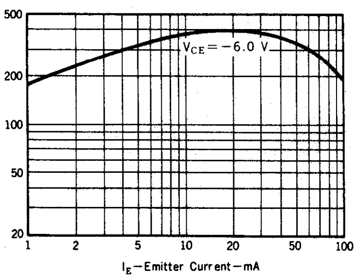
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



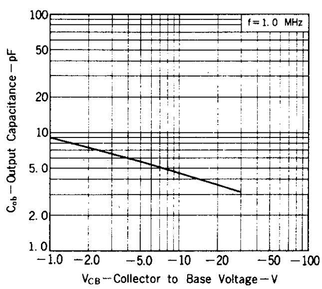
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



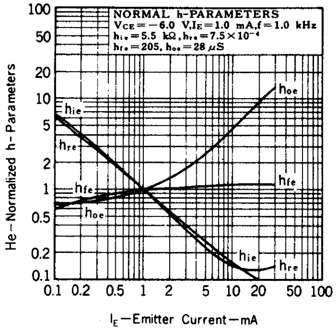
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



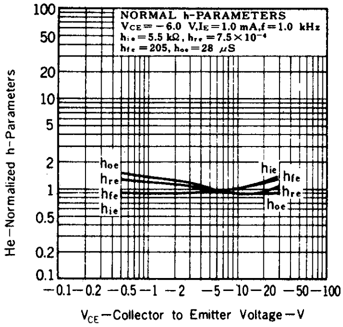
OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



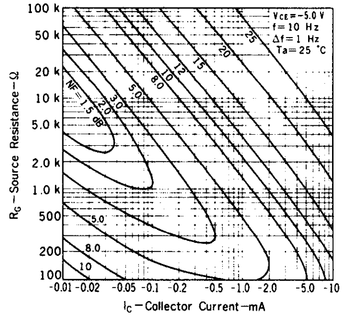
NORMALIZED h-PARAMETERS vs. EMITTER CURRENT



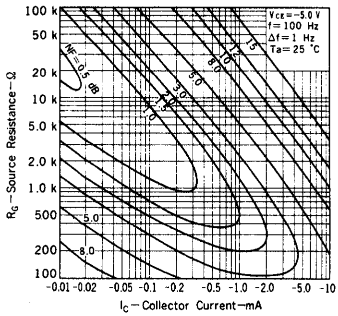
NORMALIZED h-PARAMETERS vs. COLLECTOR TO EMITTER VOLTAGE



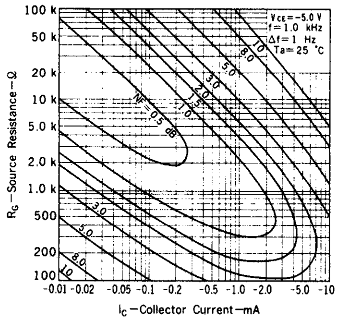
NOISE FIGURE MAP 1



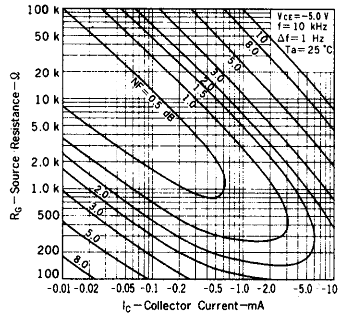
NOISE FIGURE MAP 2



NOISE FIGURE MAP 3



NOISE FIGURE MAP 4



NEC
ELECTRON DEVICE

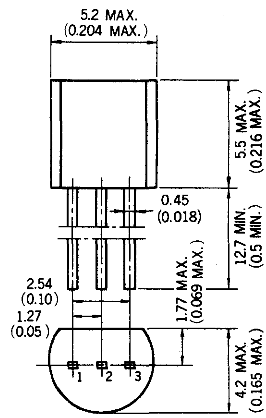
PNP SILICON TRANSISTOR
2SA991

DESCRIPTION The 2SA991 is best for the head amplifier of tape recorders, the equalizer of moving coil type record players, and etc.

FEATURES

- Super Low Noise. NV : 30 mV TYP. (See test circuit.)
- High h_{FE}. h_{FE} : 400 TYP. (V_{CE}=−6.0 V, I_C=−1.0 mA)
- Complementary to 2SC1844.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −55 to +125 °C

Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta=25 °C)

Total Power Dissipation . . . . 500 mW

Maximum Voltages and Currents (Ta=25 °C)

V_{CBO}	Collector to Base Voltage	−60 V
V_{CEO}	Collector to Emitter Voltage	−60 V
V_{EBO}	Emitter to Base Voltage	−5.0 V
I_C	Collector Current	−100 mA
I_B	Base Current	−20 mA

ELECTRICAL CHARACTERISTICS (Ta=25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	150	380		–	V_{CE}=−6.0 V, I_C=−0.1 mA
h_{FE2}	DC Current Gain	200	400	800	–	V_{CE}=−6.0 V, I_C=−1.0 mA
f_T	Gain Bandwidth Product	50	90		MHz	V_{CE}=−6.0 V, I_C=−1.0 mA
C_{ob}	Output Capacitance		5.5	10	pF	V_{CB}=−10 V, I_E=0, f=1.0 MHz
NV	Noise Voltage		30	45	mV	V_{CE}=−5.0 V, I_C=−1.0 mA, R_G=100 kΩ G_v=80 dB, f=10 Hz to 1.0 kHz
I_{CBO}	Collector Cutoff Current			−50	nA	V_{CB}=−60 V, I_E=0
I_{CEO}	Collector Cutoff Current			−1.0	μA	V_{CE}=−50 V, R_{BE}=∞
I_{EBO}	Emitter Cutoff Current			−50	nA	V_{EB}=−5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	−0.55	−0.60	−0.65	V	V_{CE}=−6.0 V, I_C=−1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.18	−0.50	V	I_C=−100 mA, I_B=−10 mA

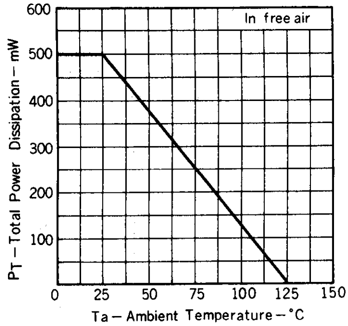
Classification of h_{FE2}

Rank	P	F	E
Range	200 – 400	300 – 600	400 – 800

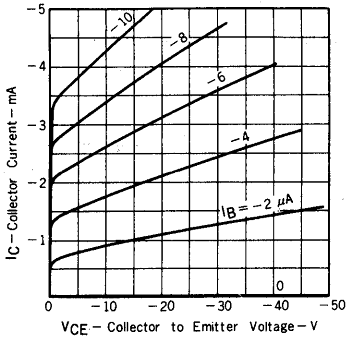
h_{FE} Test Conditions : V_{CE}=−6.0 V, I_C=−1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

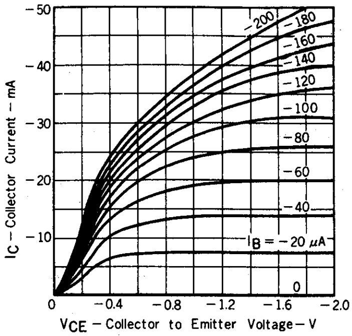
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



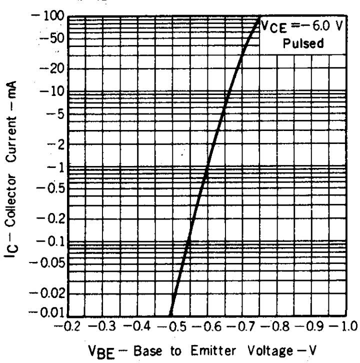
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



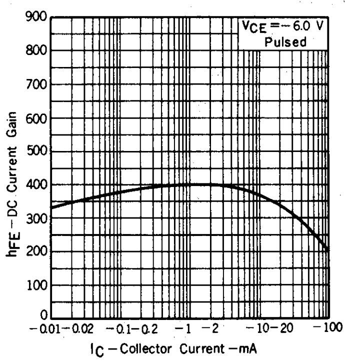
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



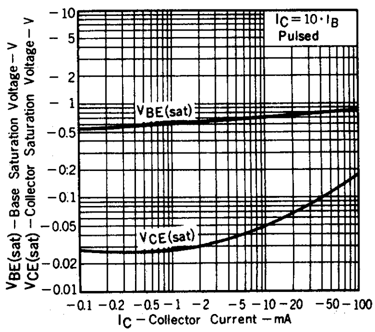
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



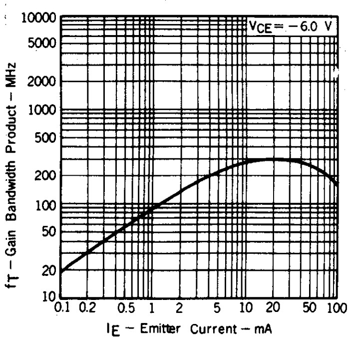
DC CURRENT GAIN vs. COLLECTOR CURRENT



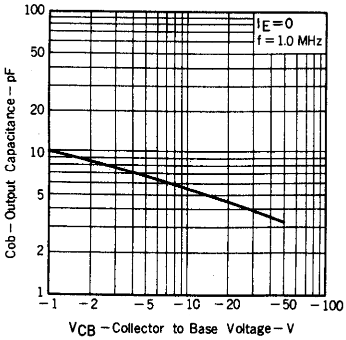
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



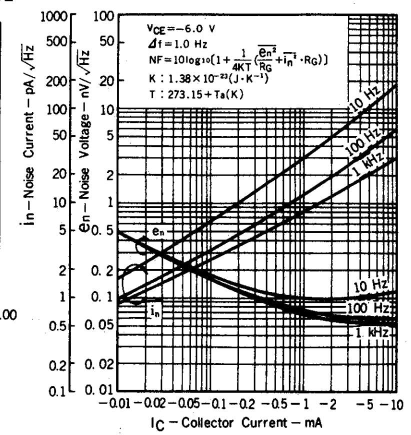
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



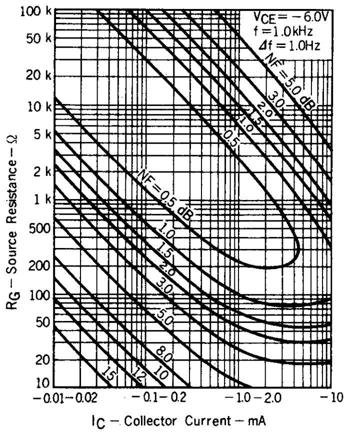
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



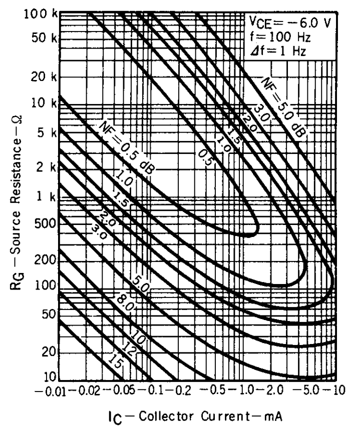
e_n AND i_n vs. COLLECTOR CURRENT



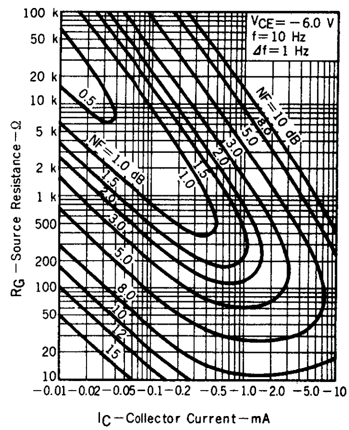
NOISE FIGURE MAP1



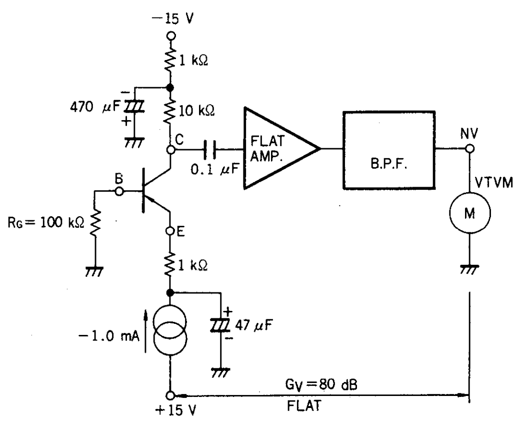
NOISE FIGURE MAP2



NOISE FIGURE MAP3



NOISE VOLTAGE TEST CIRCUIT



$V_{CE} \doteqdot -5$ V, $I_C = -1.0$ mA, $R_G = 100$ kΩ, $G_V = 80$ dB, FLAT (f = 10 Hz to 1.0 kHz)

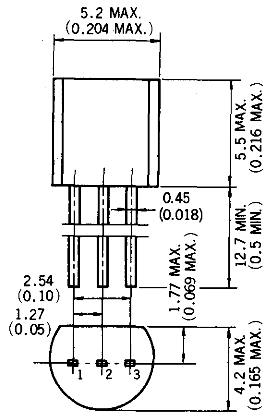
NEC
ELECTRON DEVICE

PNP SILICON TRANSISTOR
2SA992

DESCRIPTION The 2SA992 is best for use as the middle range amplifier in Hi-Fi stereo control amplifiers, power amplifiers, and etc.

FEATURES
- High Voltage. V_{CEO} : −120 V
- Low Output Capacitance. C_{ob} : 2.0 pF TYP. (V_{CB} = −30 V)
- High h_{FE}. h_{FE} : 500 TYP. (V_{CE} = −6.0 V, I_C = −1.0 mA)
- Super Low Noise. NV : 25 mV TYP. (See test circuit.)
- Complementary to 2SC1845.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. COLLECTOR JEDEC : TO-92
3. BASE IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature . . . . −55 to +125 °C
- Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation . . . . 500 mW

Maximum Voltages and Currents (Ta = 25 °C)
- V_{CBO} Collector to Base Voltage . . . . −120 V
- V_{CEO} Collector to Emitter Voltage . . . . −120 V
- V_{EBO} Emitter to Base Voltage . . . . −5.0 V
- I_C Collector Current . . . . −50 mA
- I_B Base Current . . . . −10 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	150	500		−	V_{CE} = −6.0 V, I_C = −0.1 mA
h_{FE2}	DC Current Gain	200	500	800	−	V_{CE} = −6.0 V, I_C = −1.0 mA
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE} = −6.0 V, I_C = −1.0 mA
Cob	Output Capacitance		2.0	3.0	pF	V_{CB} = −30 V, I_E = 0, f = 1.0 MHz
NV	Noise Voltage		25	40	mV	V_{CE} = −5.0 V, I_C = −1.0 mA, R_G = 100 kΩ G_V = 80 dB, f = 10 Hz to 1.0 kHz
I_{CBO}	Collector Cutoff Current			−50	nA	V_{CB} = −120 V, I_E = 0
I_{CEO}	Collector Cutoff Current			−1.0	μA	V_{CE} = −100 V, R_{BE} = ∞
I_{EBO}	Emitter Cutoff Current			−50	nA	V_{EB} = −5.0 V, I_C = 0
V_{BE}	Base to Emitter Voltage	−0.55	−0.61	−0.65	V	V_{CE} = −6.0 V, I_C = −1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.09	−0.30	V	I_C = −10 mA, I_B = −1.0 mA

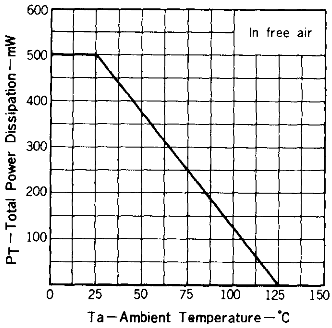
Classification of h_{FE2}

Rank	P	F	E
Range	200 − 400	300 − 600	400 − 800

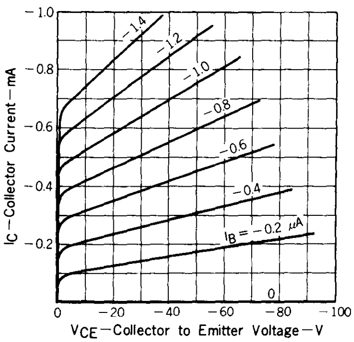
h_{FE} Test Conditions : V_{CE} = −6.0 V, I_C = −1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

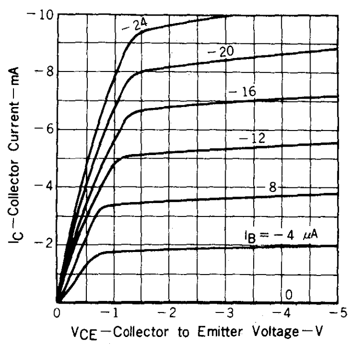
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



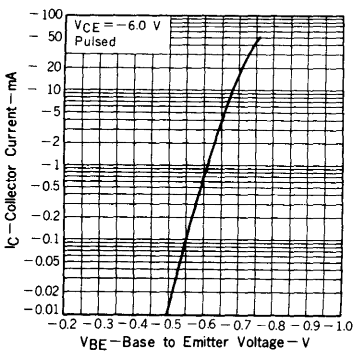
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



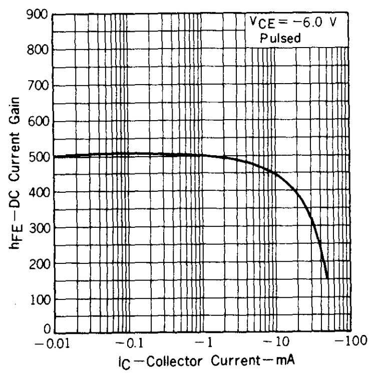
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



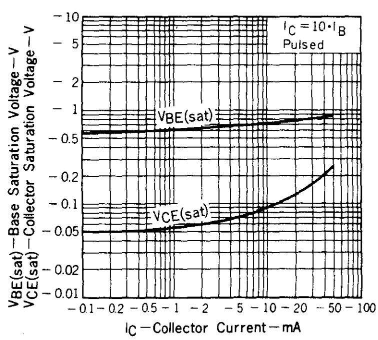
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



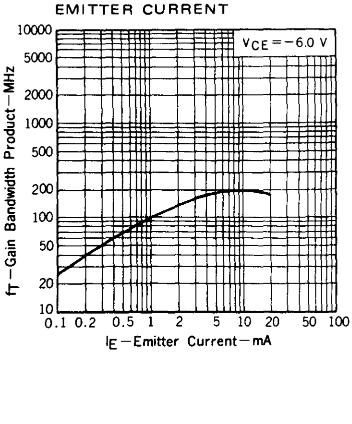
DC CURRENT GAIN vs. COLLECTOR CURRENT



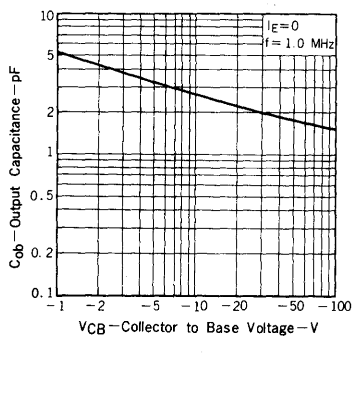
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



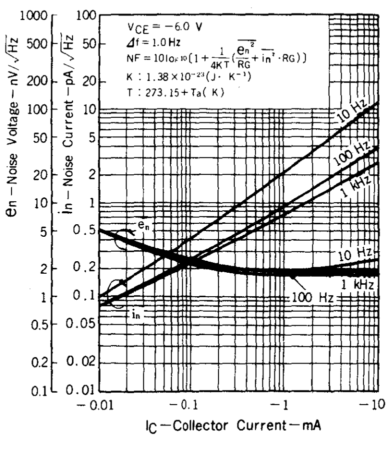
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



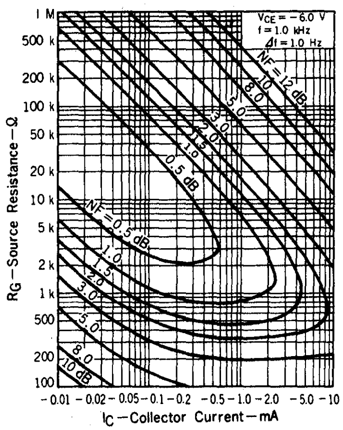
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



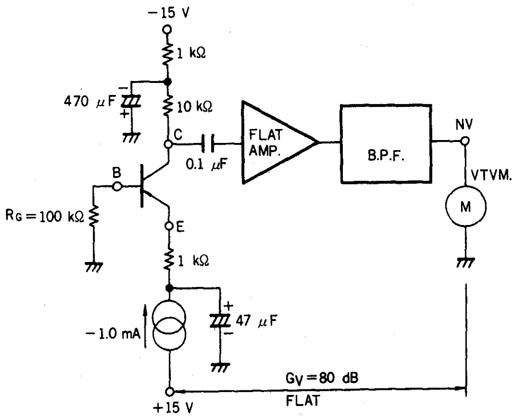
e_n AND i_n vs. COLLECTOR CURRENT



NOISE FIGURE MAP.



NOISE VOLTAGE TEST CIRCUIT



$V_{CE} \doteqdot -5$ V, $I_C = -1.0$ mA, $R_G = 100$ kΩ, $G_V = 80$ dB, FLAT(f = 10 Hz to 1.0 kHz)

NEC
ELECTRON DEVICE

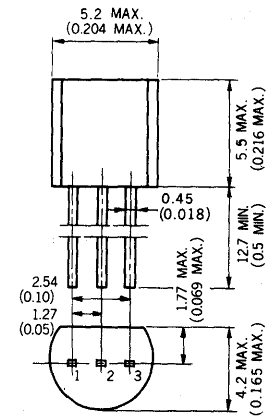
PNP SILICON TRANSISTOR
2SA1005

DESCRIPTION The 2SA1005 is designed for use in RF amplifier, conv., and oscillator of FM tuner.

FEATURES

- High gain bandwidth product: $f_T = 400$ MHz TYP. @$V_{CE} = -10$ V, $I_E = 1.0$ mA
- Small output capacitance: $C_{ob} = 1.1$ pF TYP. @$V_{CB} = -10$ V, f = 1.0 MHz
- Low noise figure: NF = 3.5 dB TYP.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. COLLECTOR JEDEC : TO-92
3. BASE IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature . . . . −55 to +125 °C
- Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO}	Collector to Base Voltage	−40	V
V_{CEO}	Collector to Emitter Voltage	−40	V
V_{EBO}	Emitter to Base Voltage	−5.0	V
I_C	Collector Current	−30	mA
I_B	Base Current	−20	mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{CBO}	Collector Cutoff Current			−100	nA	$V_{CB} = -40$ V, $I_E = 0$
I_{EBO}	Emitter Cutoff Current			−100	nA	$V_{EB} = -4.0$ V, $I_C = 0$
h_{FE}	DC Current Gain	40	90	180	–	$V_{CE} = -10$ V, $I_C = -1.0$ mA
V_{BE}	Base to Emitter Voltage	−0.67	−0.72		V	$V_{CE} = -10$ V, $I_C = -1.0$ mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.09	−0.3	V	$I_C = -10$ mA, $I_B = -1.0$ mA
f_T	Gain Bandwidth Product	250	400		MHz	$V_{CE} = -10$ V, $I_E = 1.0$ mA
C_{ob}	Output Capacitance		1.1	2.0	pF	$V_{CB} = -10$ V, $I_E = 0$, f = 1.0 MHz
$C_{c} r_{b'b}$	Collector to Base Time Constant			20	ps	$V_{CE} = -10$ V, $I_E = 1.0$ mA, f = 31.9 MHz
NF	Noise Figure		3.5		dB	$V_{CE} = -10$ V, $I_C = -1.0$ mA, $R_G = 500\ \Omega$, f = 1.0 MHz

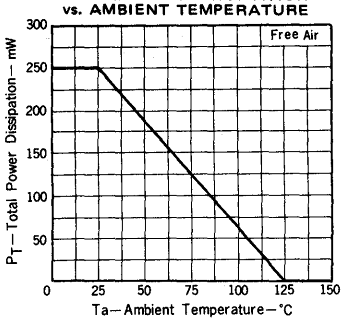
Classification of h_{FE}

Rank	M	L	K
Range	40 – 80	60 – 120	90 – 180

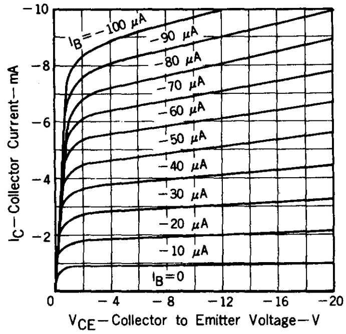
h_{FE} Test Conditions : $V_{CE} = -10$ V, $I_C = -1.0$ mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

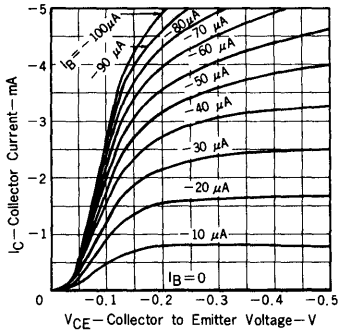
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



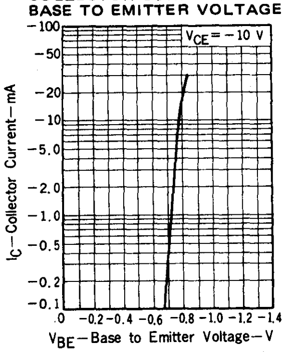
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



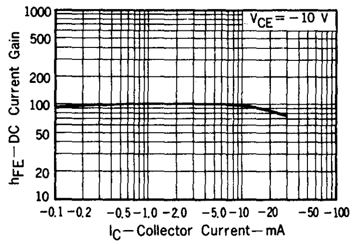
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



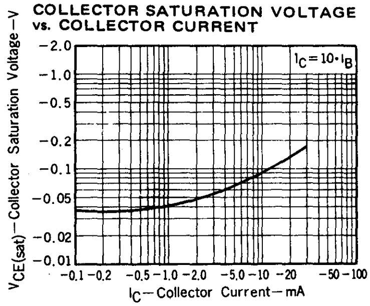
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



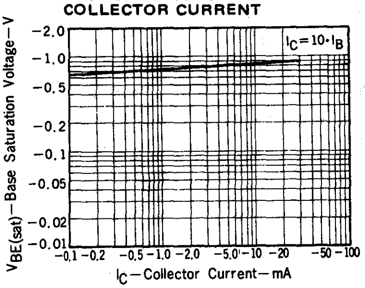
DC CURRENT GAIN vs. COLLECTOR CURRENT



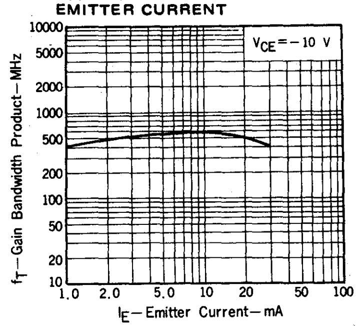
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



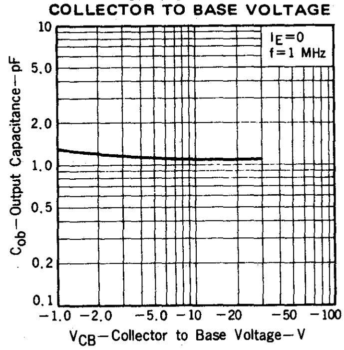
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



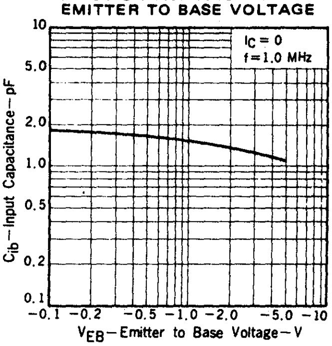
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



INPUT CAPACITANCE vs.
EMITTER TO BASE VOLTAGE



NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SB564

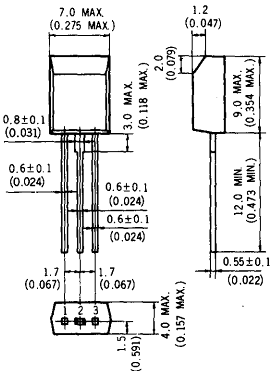
AUDIO FREQUENCY POWER AMPLIFIER
PNP SILICON EPITAXIAL TRANSISTOR

DESCRIPTION

The 2SB564 is designed for use in driver and output stages of audio frequency amplifiers.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Emitter
2. Collector
3. Base

FEATURES

- High total power dissipation:
  1.0 W at 25 °C ambient temperature.
- Complementary to the NEC 2SD471 NPN transistor.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25 °C)			
Collector to Base Voltage ($R_{BE} = \infty$)	V_{CBO}	−30	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	−25	V
Emitter to Base Voltage	V_{EBO}	−5.0	V
Continuous Collector Current	$I_{C(DC)}$	−1.0	A
Peak Collector Current*	$I_{C(peak)}$	−1.5	A
Maximum Power Dissipation			
Total Power Dissipation			
at 25 °C Ambient Temperature	P_T	1.0	W
Maximum Temperatures			
Storage Temperature	T_{stg}	−55 to +150	°C
Operating Junction Temperature	T_j	150	°C

*Pulse test : PW ≦ 10 ms, duty cycle ≦ 50 %

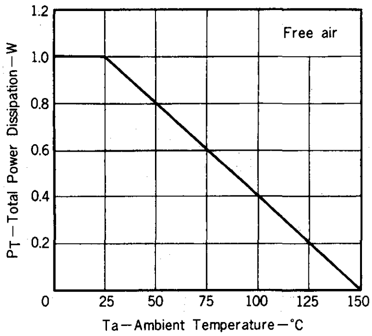
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−100	nA	V_{CB} = −30 V, I_E = 0
Emitter Cutoff Current	I_{EBO}			−100	nA	V_{EB} = −5.0 V, I_C = 0
DC Current Gain	h_{FE1}	90	200	400		V_{CE} = −1.0 V, I_C = −0.1 A *
DC Current Gain	h_{FE2}	50	100			V_{CE} = −1.0 V, I_C = −1.0 A *
Base to Emitter Voltage	V_{BE}	−600	−640	−700	mV	V_{CE} = −6.0 V, I_C = −10 mA *
Collector Saturation Voltage	$V_{CE(sat)}$		−0.25	−0.35	V	I_C = −1.0 A, I_B = −0.1 A *
Base Saturation Voltage	$V_{BE(sat)}$		−1.0	−1.2	V	I_C = −1.0 A, I_B = −0.1 A *
Output Capacitance	C_{ob}		36		pF	V_{CB} = −6.0 V, I_E = 0, f = 1.0 MHz
Gain Bandwidth Product	f_T		110		MHz	V_{CE} = −6.0 V, I_E = 10 mA

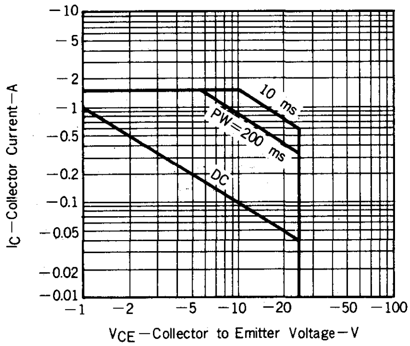
*Pulse test : pulse width ≦ 350 μs, duty cycle ≦ 2 %

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

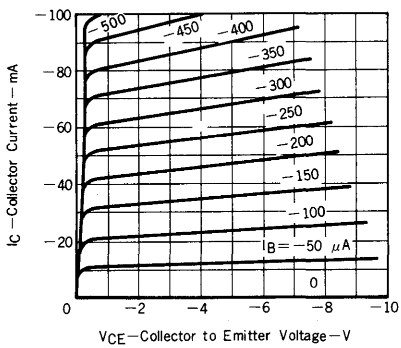
TOTAL POWER DISSIPATION
vs. AMBIENT TEMPERATURE



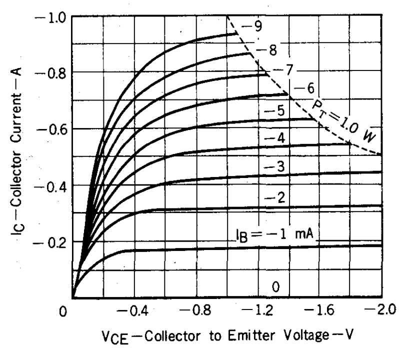
SAFE OPERATING AREAS
(TRANSIENT THERMAL RESISTANCE)



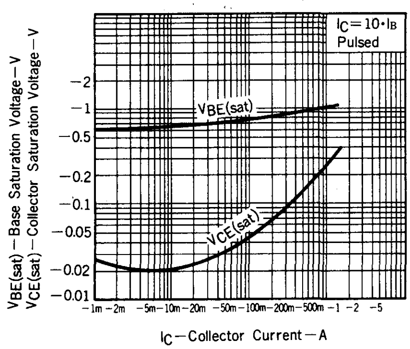
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



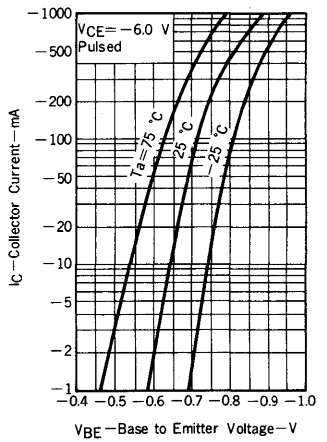
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



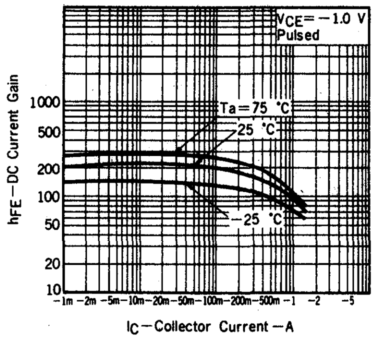
BASE AND COLLECTOR SATURATION
VOLTAGE vs. COLLECTOR CURRENT



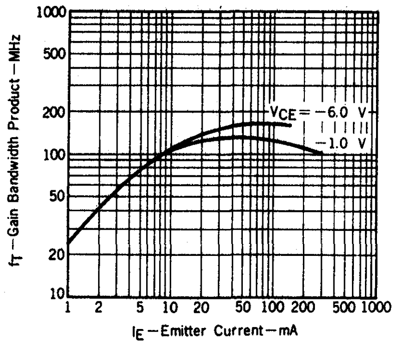
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



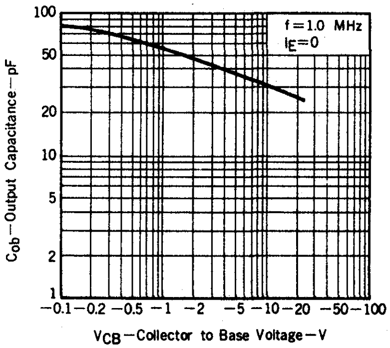
DC CURRENT GAIN vs.
COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT
vs. EMITTER CURRENT



OUTPUT CAPACITANCE vs.
COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SB605

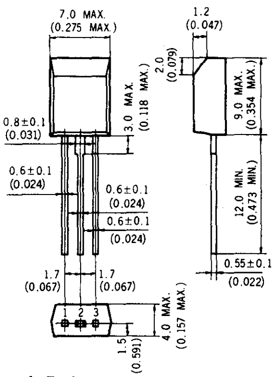
AUDIO FREQUENCY POWER AMPLIFIER
PNP SILICON EPITAXIAL TRANSISTOR

DESCRIPTION

The 2SB605 is designed for use in driver output stages of audio frequency amplifiers.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Emitter
2. Collector
3. Base

FEATURES

- High total power dissipation and high breakdown voltage: 1.0 W at ambient temperature / V_{CEO} = -50 V
- Complementary to the NEC 2SD571 NPN transistor.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25 °C)			
Collector to Base Voltage ($R_{BE}=\infty$)	V_{CBO}	-60	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	-50	V
Emitter to Base Voltage	V_{EBO}	-5.0	V
Continuous Collector Current	$I_{C(DC)}$	-0.7	A
Peak Collector Current*	$I_{C(peak)}$	-1.0	A
Maximum Power Dissipation			
Total Power Dissipation			
at 25 °C Ambient Temperature	P_T	1.0	W
Maximum Temperatures			
Storage Temperature	T_{stg}	-55 to +150	°C
Operating Junction Temperature	T_j	150	°C

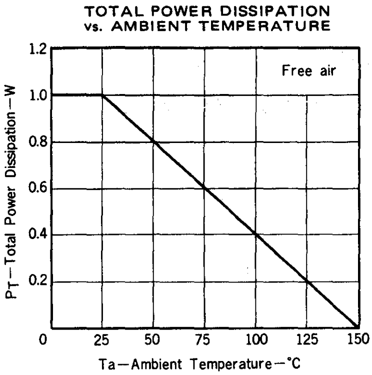
*Pulse test : PW ≦ 10 ms, duty cycle ≦ 50 %

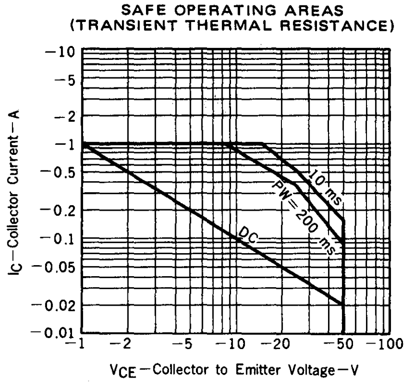
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

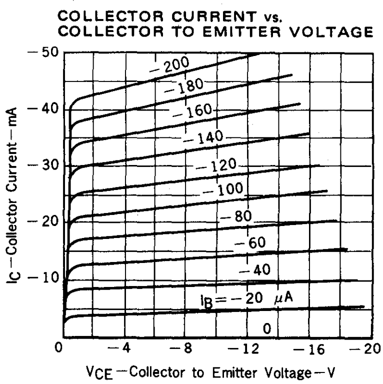
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS	
Collector Cutoff Current	I_{CBO}			-100	nA	V_{CB} = -60 V, I_E = 0	
Emitter Cutoff Current	I_{EBO}			-100	nA	V_{EB} = -5.0 V, I_C = 0	
DC Current Gain	h_{FE1}	90	200	400		V_{CE} = -1.0 V, I_C = -0.1 A	*
DC Current Gain	h_{FE2}	50	120			V_{CE} = -1.0 V, I_C = -0.5 A	*
Base to Emitter Voltage	V_{BE}	-600	-630	-700	mV	V_{CE} = -6.0 V, I_C = -10 mA	*
Collector Saturation Voltage	$V_{CE(sat)}$		-0.16	-0.35	V	I_C = -0.5 A, I_B = -50 mA	*
Base Saturation Voltage	$V_{BE(sat)}$		-0.90	-1.2	V	I_C = -0.5 A, I_B = -50 mA	*
Output Capacitance	C_{ob}		25		pF	V_{CB} = -6.0 V, I_E = 0, f = 1.0 MHz	
Gain Bandwidth Product	f_T		120		MHz	V_{CE} = -6.0 V, I_E = 10 mA	

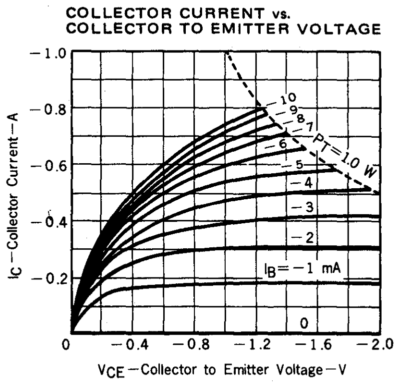
*Pulse test : pulse width ≦ 350 μs, duty cycle ≦ 2 %

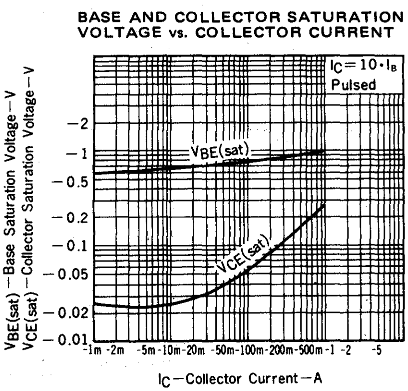
TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

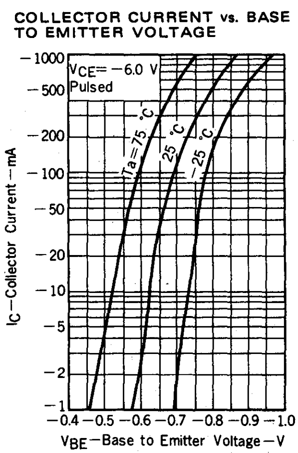






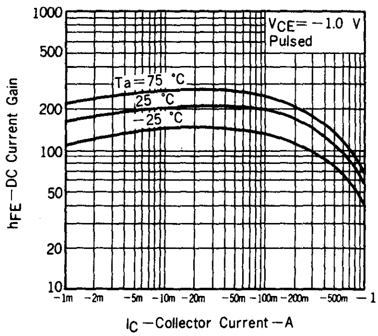




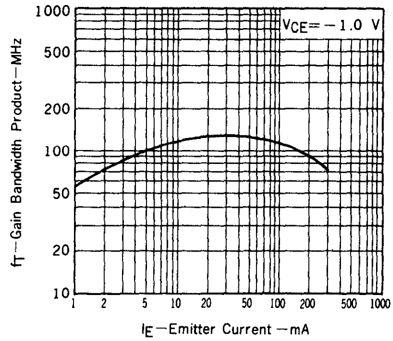


2

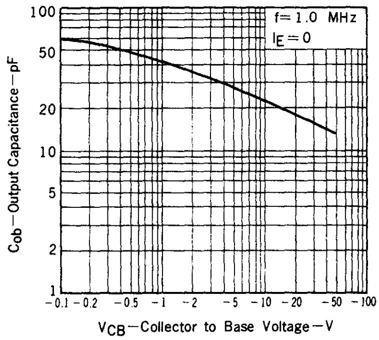
DC CURRENT GAIN vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

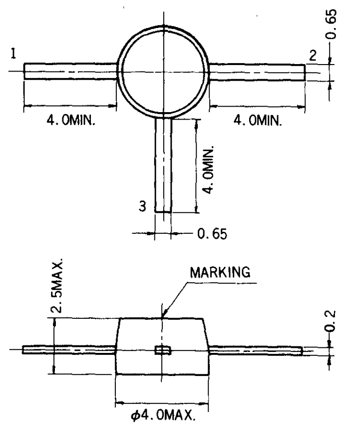
SILICON TRANSISTOR
2SC287A(B)

VHF OSCILLATOR
NPN SILICON EPITAXIAL TRANSISTOR
"DISK MOLD"

DESCRIPTION

The 2SC287A(B) is an NPN silicon epitaxial transistor intended for use as VHF oscillator in a tuner of a TV receiver.
The device features stable oscillation and small frequency drift against any change of the supply voltage and the ambient temperature.

PACKAGE DIMENSIONS (Unit : mm)



1. Base
2. Emitter
3. Collector

FEATURES

- High gain bandwidth product; f_T = 1100MHz TYP.
- Low collector to base time constant; $C_c \cdot r_{b'b}$ = 10 ps TYP.
- Low output capacitance; C_{ob} = 1.0pF MAX.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Voltages and Current			
Collector to Base Voltage	V_{CBO}	35	V
Collector to Emitter Voltage	V_{CEO}	15	V
Emitter to Base Voltage	V_{EBO}	4.0	V
Collector Current	I_C	20	mA
Maximum Power Dissipation			
Total Power Dissipation	P_T	200	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature	T_{stg}	−55 to +125	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

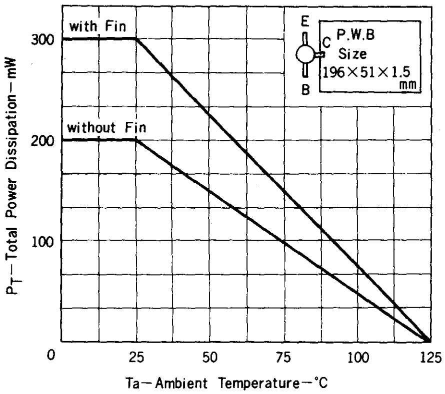
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB}=15V, I_E=0
DC Current Gain	h_{FE}	60	100	200		V_{CE}=10V, I_C=5.0mA *1
Collector Saturation Voltage	$V_{CE(sat)}$		0.1	0.6	V	I_C=10mA, I_B=1.0mA
Gain Bandwidth Product	f_T	600	1100		MHz	V_{CE}=10V, I_E=−5.0mA
Output Capacitance	C_{ob}		0.8	1.0	pF	V_{CB}=10V, I_E=0, f=1.0MHz
Reverse Transfer Capacitance *2	C_{rb}		0.35	0.4	pF	V_{CE}=10V, f=1.0MHz
Collector to Base Time Constant	$C_c \cdot r_{b'b}$		10	20	ps	V_{CE}=10V, I_E=−5.0mA f=31.9MHz

*1 h_{FE} Classification F : 60 – 120 E : 100 – 200
*2 The base terminal should be connected to the guard terminal of the capacitance bridge.

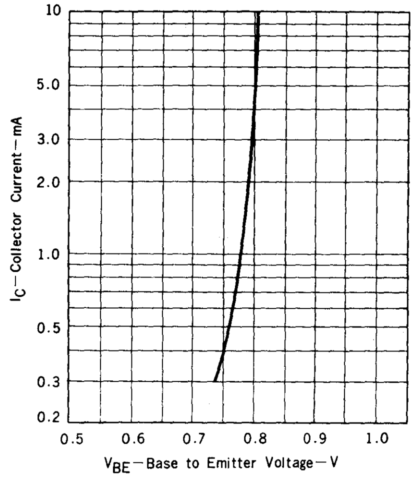
2

TYPICAL CHARACTERISTICS (Ta = 25°C)

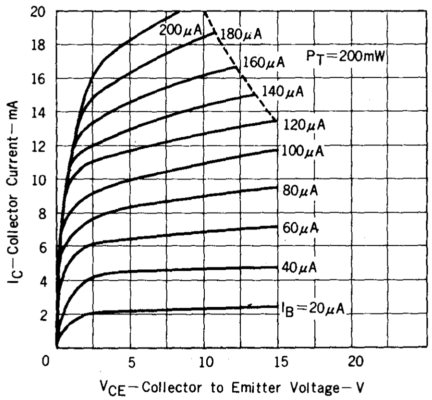
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



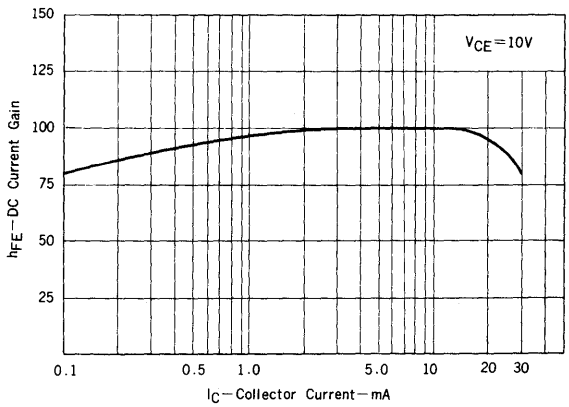
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



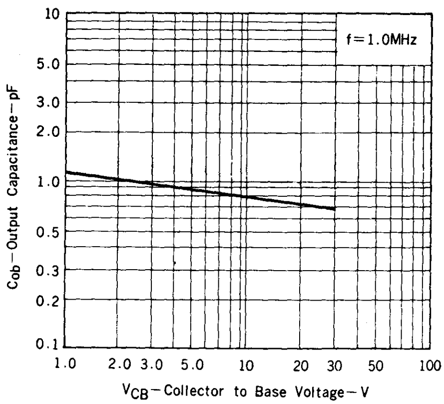
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



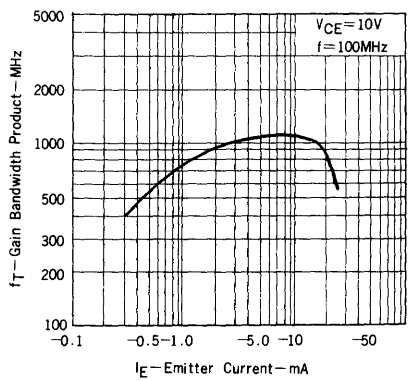
DC CURRENT GAIN vs. COLLECTOR CURRENT



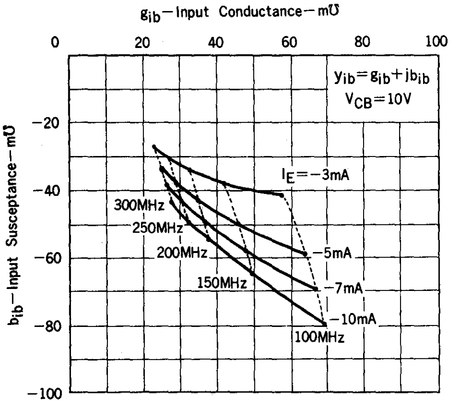
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



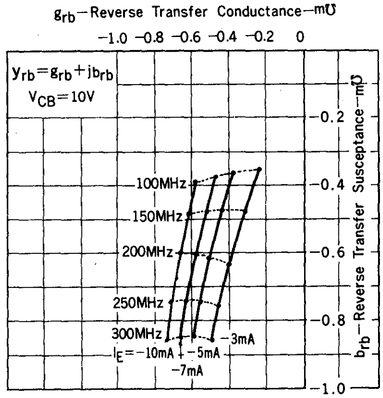
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



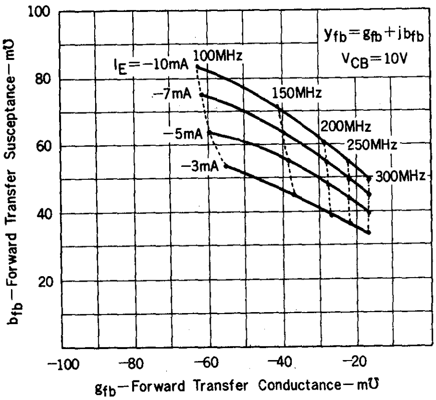
INPUT ADMITTANCE (Yib) vs. FREQUENCY



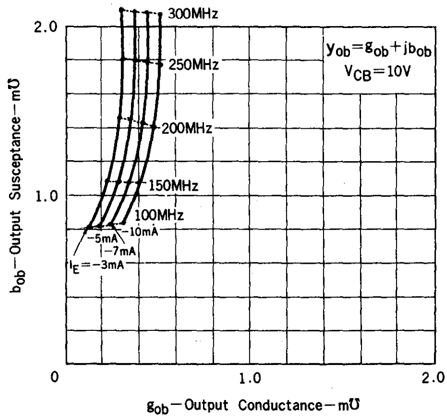
REVERSE TRANSFER ADMITTANCE (Yrb) vs. FREQUENCY



FORWARD TRANSFER ADMITTANCE (Yfb) vs. FREQUENCY



OUTPUT ADMITTANCE (Yob) vs. FREQUENCY



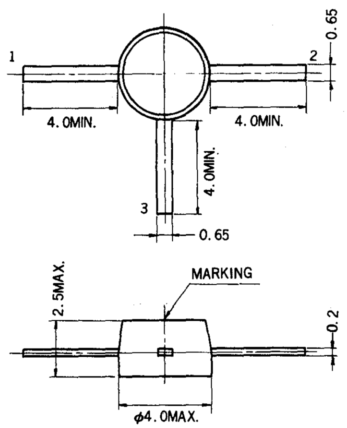
NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SC288A(I·B)

UHF OSCILLATOR
NPN SILICON EPITAXIAL TRANSISTOR
"DISK MOLD"

2

PACKAGE DIMENSIONS (Unit : mm)



1. Base
2. Emitter
3. Collector

DESCRIPTION

The 2SC288A(1·B) is an NPN silicon epitaxial transistor intended for use as UHF oscillator in tuner of a TV receiver.
The device features stable oscillation and small frequency drift against any change of the supply voltage and the ambient temperature.

FEATURES

- High gain bandwidth product; f_T = 1100MHz TYP.
- Low collector to base time constant; $C_c \cdot r_{b'b}$ = 8ps TYP.
- The most suitable capacitance; 1.05 TYP.
- Easy economical mounting realizable with plastic mold package.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Voltages and Current			
Collector to Base Voltage	V_{CBO}	35	V
Collector to Emitter Voltage	V_{CEO}	15	V
Emitter to Base Voltage	V_{EBO}	4.0	V
Collector Current	I_C	20	mA
Maximum Power Dissipation			
Total Power Dissipation	P_T	200	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature	T_{stg}	-55 to +125	°C

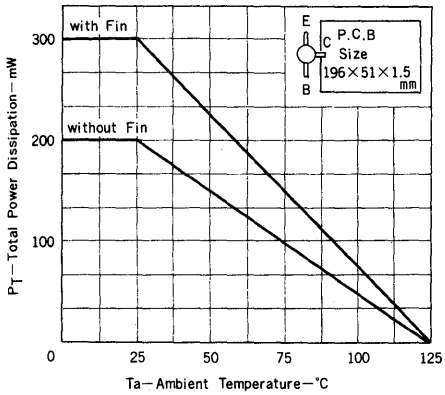
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB} = 15V, I_E = 0
DC Current Gain	h_{FE}	60	100	200		V_{CE} = 10V, I_C = 5.0mA *1
Collector Saturation Voltage	$V_{CE(sat)}$		0.1	0.6	V	I_C = 10mA, I_B = 1.0mA
Gain Bandwidth Product	f_T	850	1100		MHz	V_{CE} = 10V, I_E = -5.0mA
Output Capacitance	C_{ob}		1.05	1.5	pF	V_{CB} = 10V, I_E = 0, f = 1.0MHz
Reverse Transfer Capacitance *2	C_{rb}		0.6	0.7	pF	V_{CE} = 10V, f = 1.0MHz
Collector to Base Time Constant	$C_c \cdot r_{b'b}$		12	20	ps	V_{CE} = 10V, I_E = -5.0mA f = 31.9MHz

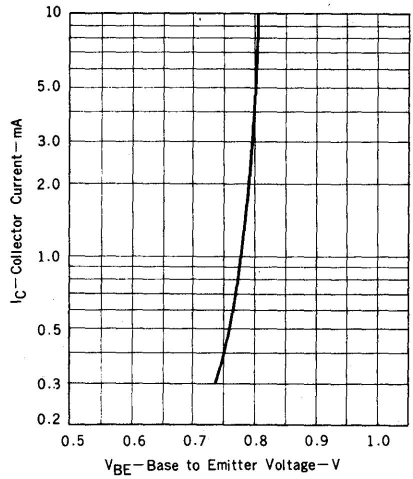
*1 h_{FE} Classification F : 60 – 120 E : 100 – 200
*2 The base terminal should be connected to the guard terminal of the capacitance bridge.

TYPICAL CHARACTERISTICS (Ta=25°C)

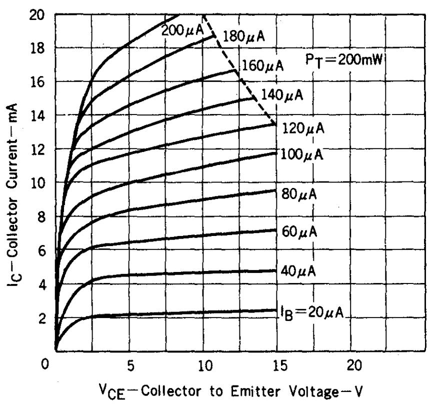
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



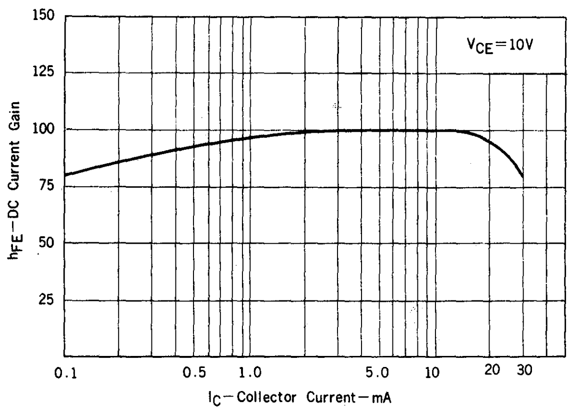
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



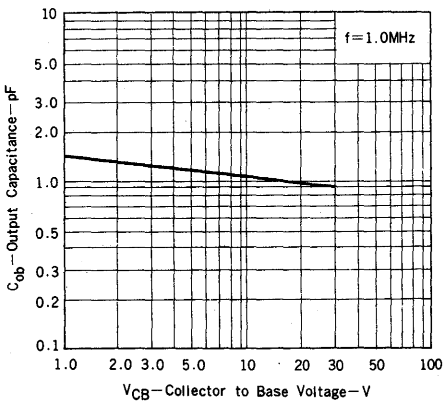
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



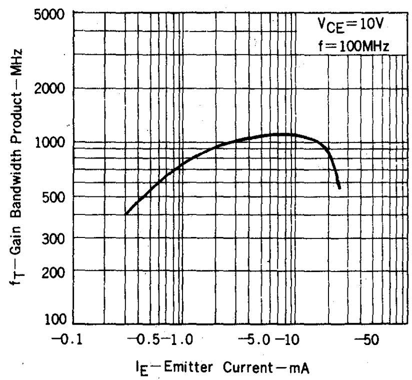
DC CURRENT GAIN vs.
COLLECTOR CURRENT



OUTPUT CAPACITANCE vs.
COLLECTOR TO BASE VOLTAGE

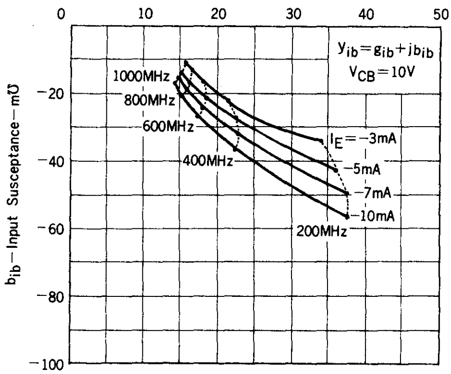


GAIN BANDWIDTH PRODUCT vs.
EMITTER CURRENT

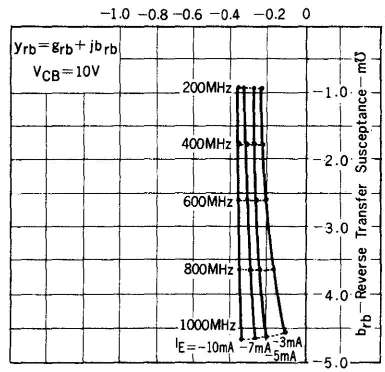


2

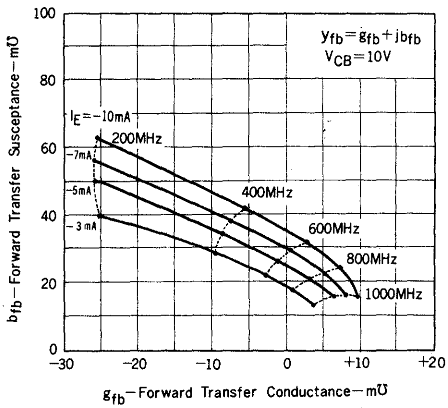
INPUT ADMITTANCE (y_{ib}) vs. FREQUENCY



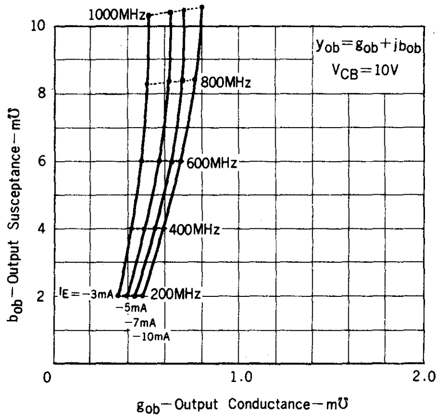
REVERSE TRANSFER ADMITTANCE (y_{rb}) vs. FREQUENCY



FORWARD TRANSFER ADMITTANCE (y_{fb}) vs. FREQUENCY



OUTPUT ADMITTANCE (y_{ob}) vs. FREQUENCY

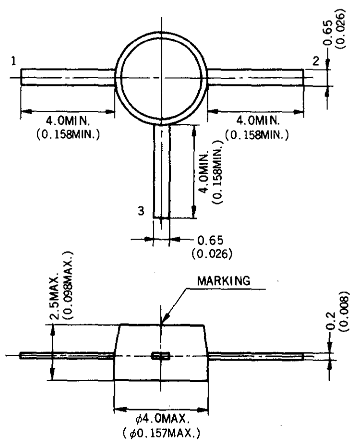


NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SC288A(5·B)

UHF OSCILLATOR
NPN SILICON EPITAXIAL TRANSISTOR
"DISK MOLD"

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector

DESCRIPTION

The 2SC288A(5·B) is an NPN silicon epitaxial transistor intended for use as UHF oscillator in a tuner of a TV receiver.

The device features stable oscillation and small frequency drift against any change of the supply voltage and the ambient temperature.

FEATURES

- High gain bandwidth product; $f_T = 1300$MHz TYP.
- Low collector to base time constant; $C_c \cdot r_{b'b} = 8$ ps TYP.
- Low output capacitance; $C_{ob} = 1.0$pF MAX.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Voltages and Current			
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	15	V
Emitter to Base Voltage	V_{EBO}	4.0	V
Collector Current	I_C	20	mA
Maximum Power Dissipation			
Total Power Dissipation	P_T	200	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature	T_{stg}	-55 to +125	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

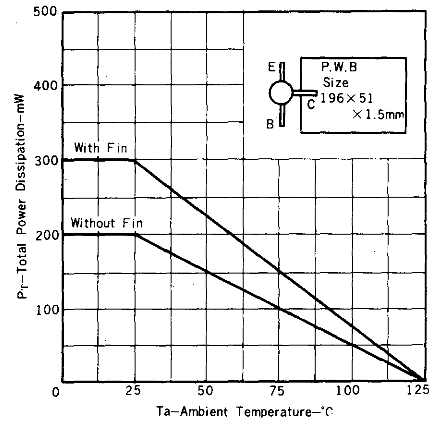
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	$V_{CB} = 15V$, $I_E = 0$
DC Current Gain	h_{FE}	60	100	200		$V_{CE} = 10V$, $I_C = 5.0mA$
Collector Saturation Voltage	$V_{CE(sat)}$		0.1	0.5	V	$I_C = 10mA$, $I_B = 1.0mA$
Gain Bandwidth Product	f_T	1000	1300		MHz	$V_{CE} = 10V$, $I_E = -5.0mA$
Output Capacitance	C_{ob}		0.8	1.0	pF	$V_{CB} = 10V$, $I_E = 0$ f = 1.0MHz
Collector to Base Time Constant	$C_c \cdot r_{b'b}$		8	15	ps	$V_{CE} = 10V$, $I_E = -5.0mA$ f = 31.9MHz

h_{FE} Classification F : 60 – 120 E : 100 – 200

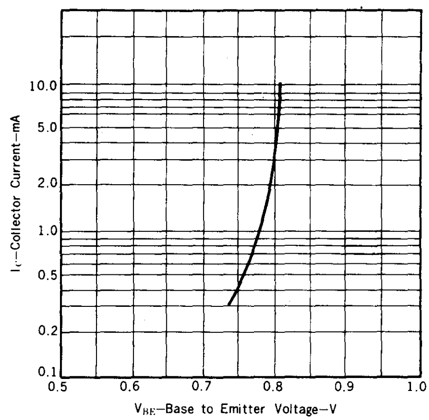
2

TYPICAL CHARACTERISTICS (Ta = 25°C)

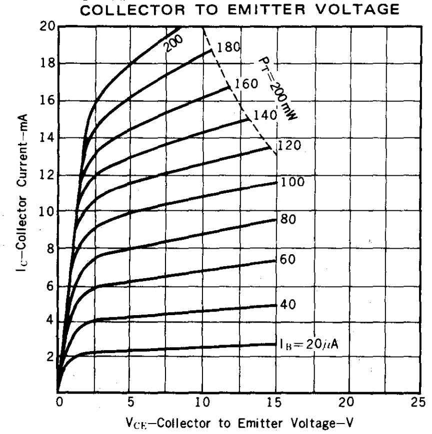
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



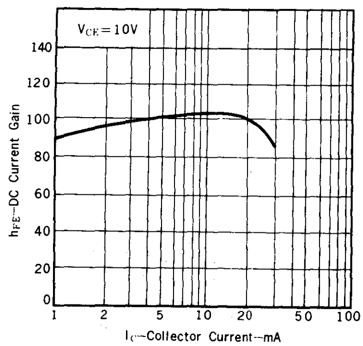
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



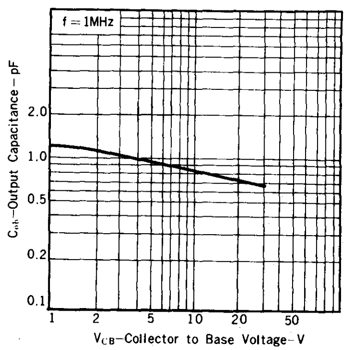
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



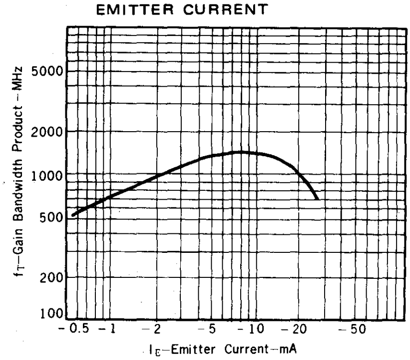
DC CURRENT GAIN vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE

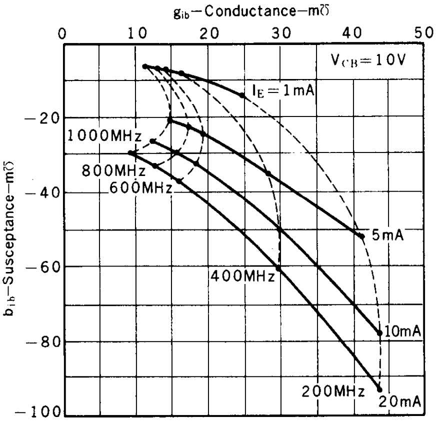


GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT

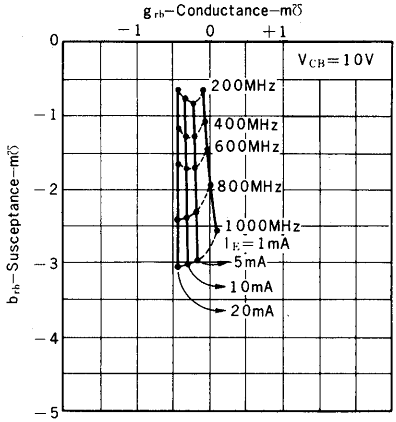


TYPICAL SMALL SIGNAL "Y" PARAMETERS (Common Base)

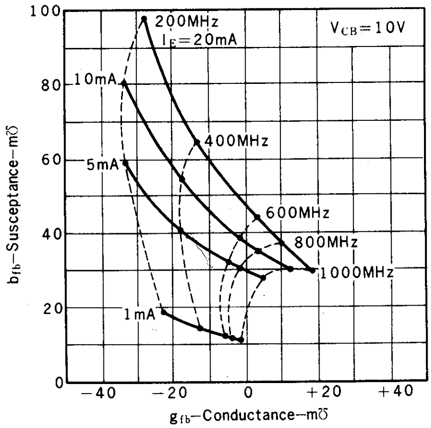
y_{ib} vs. f



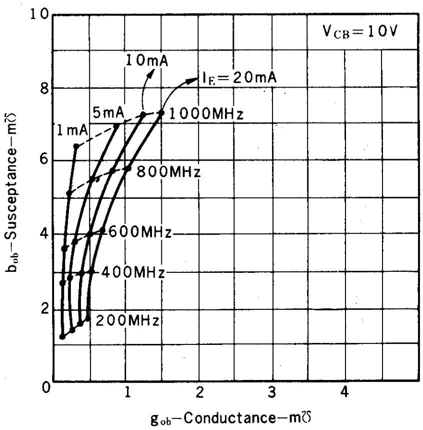
y_{rb} vs. f



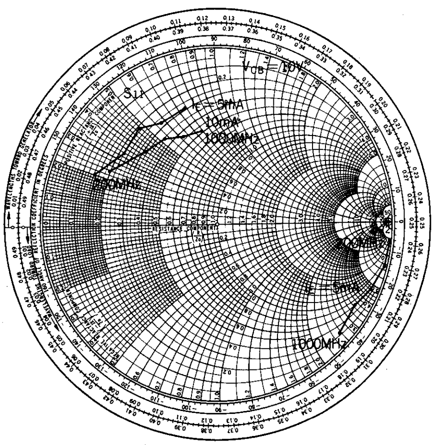
y_{fb} vs. f



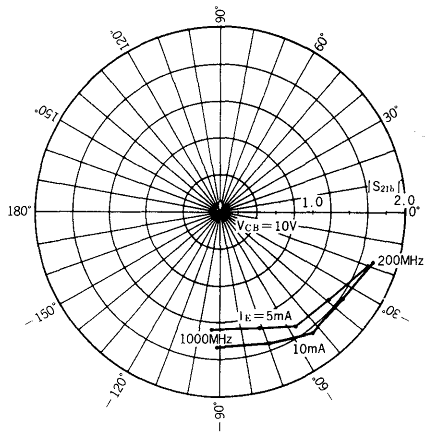
y_{ob} vs. f



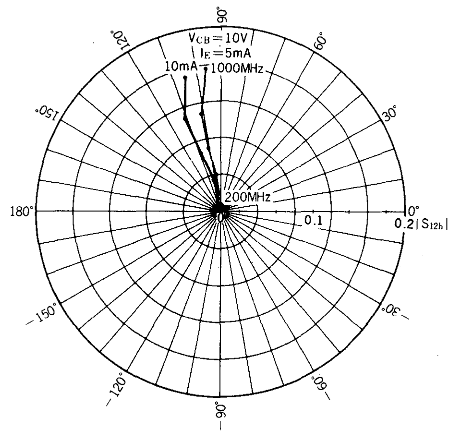
S_{11} vs. f, S_{22} vs. f



S_{21b} vs. f



S_{12b} vs. f



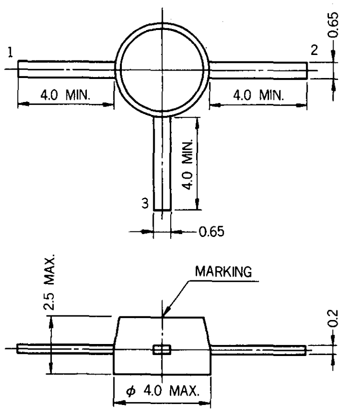
NEC
ELECTRON DEVICE

SILICON TRANSISTORS

2SC605(B), 2SC606(B)

FOR TV TUNER
2SC606(B) : VHF RF AMPLIFIER
2SC605(B) : VHF MIXER
NPN SILICON EPITAXIAL TRANSISTOR

PACKAGE DIMENSIONS (Unit : mm)



1. Base
2. Emitter
3. Collector

FEATURES

- Low NF high G_{pe}.
  NF = 2.0 dB TYP. G_{pe} = 24 dB TYP. (f = 200 MHz)
- Forward AGC capability to 30 dB.
- Low output capacitance; C_{ob} = 0.55 pF TYP.

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	30	V
Emitter to Base Voltage	V_{EBO}	4.0	V
Collector Current (DC)	I_C	20	mA
Total Power Dissipation	P_T	200	mW
Junction Temperature	T_j	125	°C
Storage Temperature	T_{stg}	−55 to +125	°C

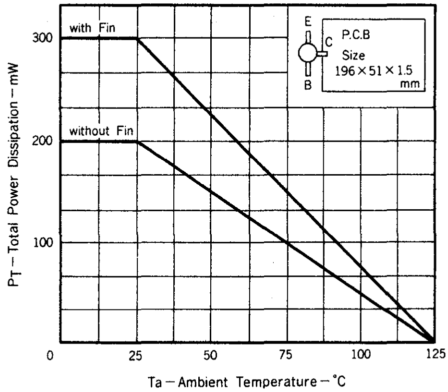
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	2SC605(B)			2SC606(B)			UNIT	TEST CONDITIONS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
Collector Cutoff Current	I_{CBO}			0.2			0.2	μA	V_{CB} = 20 V, I_E = 0
DC Current Gain *1	h_{FE}	40	100	200	60	100	200		V_{CE} = 10 V, I_C = 3.0 mA
Gain Bandwidth Product	f_T	350	530		400	530		MHz	V_{CE} = 10 V, I_E = −3.0 mA
Output Capacitance	C_{ob}		0.55	1.0		0.55	1.0	pF	f = 1.0 MHz, V_{CB} = 10 V, I_E = 0
Power Gain	G_{pe}	18	23		20	23		dB	f = 200 MHz, I_C = 3.0 mA
AGC Current *2	I_{AGC}				−8		−11	mA	f = 200 MHz I_E at gain reduction of 30 dB
Noise Figure	NF		2.0	4.0		2.0	3.3	dB	f = 200 MHz, I_C = 3.0 mA To see test circuit

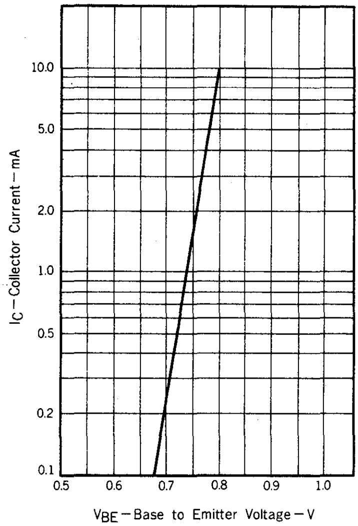
*1 2SC605(B) h_{FE} Classification M : 40 – 80 L : 60 – 120 K : 100 – 200
*2 2SC606(B) I_{AGC} Classification V : −8.0 – −10.5 mA T : −9.3 – −11.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

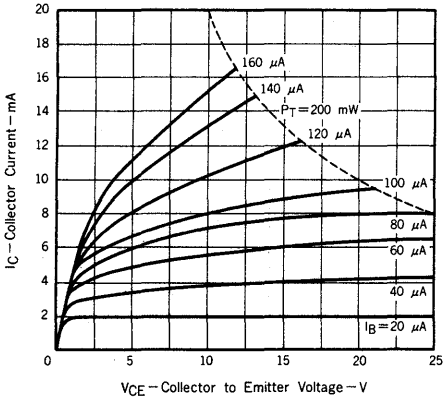
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



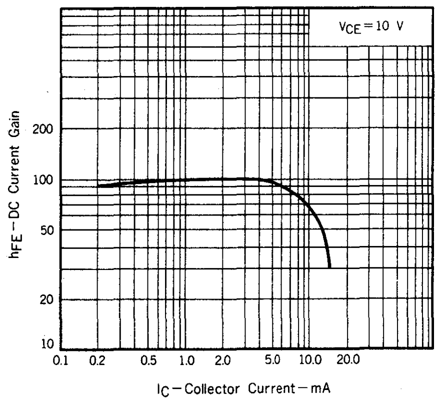
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



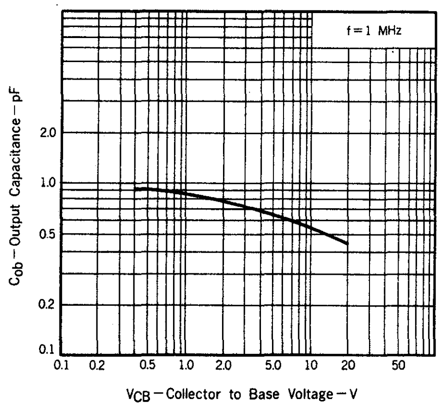
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



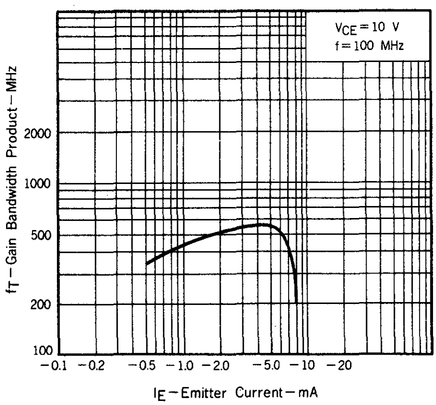
DC CURRENT GAIN vs. COLLECTOR CURRENT



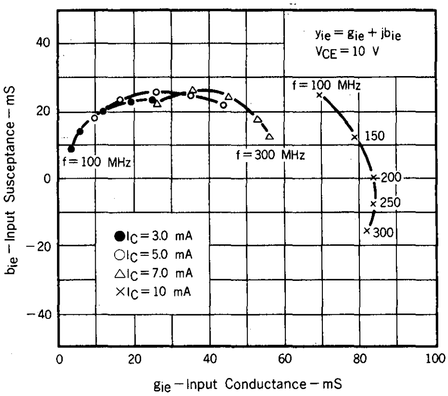
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



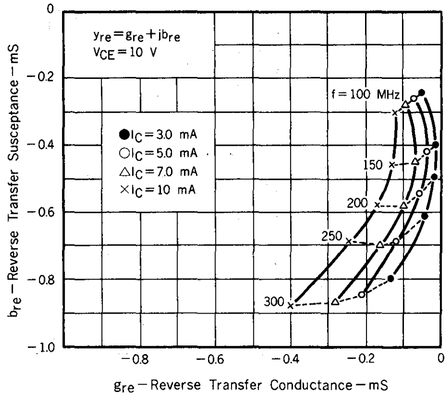
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



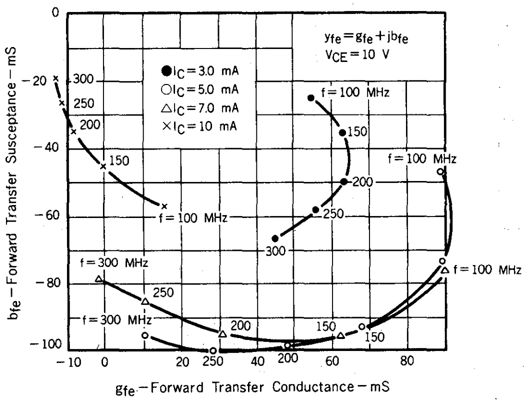
INPUT ADMITTANCE (y_{ie}) vs. FREQUENCY



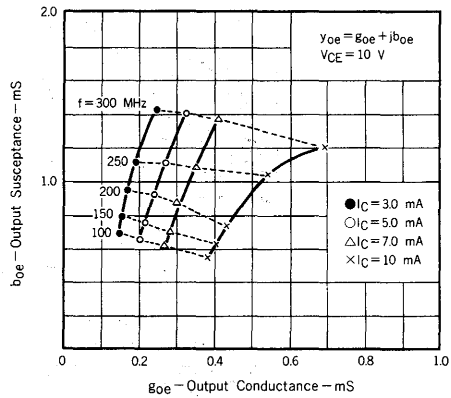
REVERSE TRANSFER ADMITTANCE (y_{re}) vs. FREQUENCY



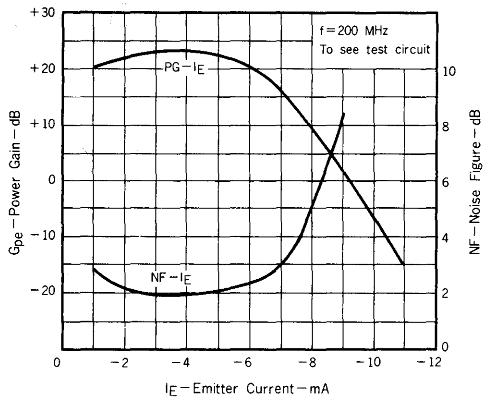
FORWARD TRANSFER ADMITTANCE (y_{fe}) vs. FREQUENCY



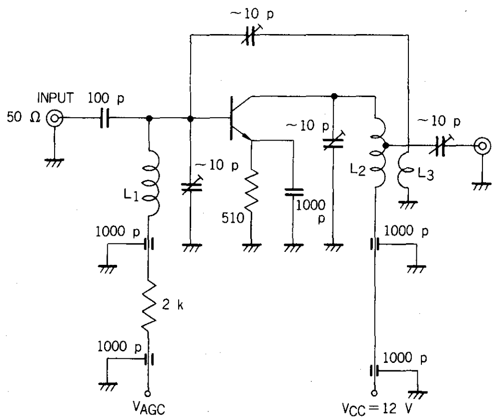
OUTPUT ADMITTANCE (y_{oe}) vs. FREQUENCY



NOISE FIGURE, POWER GAIN vs. EMITTER CURRENT



200 MHz G_{pe}, NF, I_{AGC} TEST CIRCUIT



L_1 ; 0.6 mm Cu wire Plated with Ag 4T 6 mm inter dia.
L_2 ; 0.6 mm Cu wire Plated with Ag 4T 6 mm inter dia., ground with 2.5T from collector, pitch 2.0 mm
L_3 ; 0.6 mm Cu wire plated with Ag 2T 6 mm inter dia.

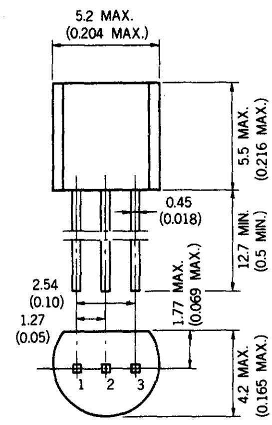
NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC945

DESCRIPTION The 2SC945 is designed for use in driver stage of AF amplifier and low speed switching.

FEATURES
- High Voltage ($V_{CEO} > 50$ V)
- Excellent h_{FE} Linearity
  h_{FE1} (0.1 mA)/h_{FE2} (1.0 mA) : 0.92 TYP.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC 43
JEDEC : TO 92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature . . . . −55 to +125 °C
- Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents (Ta = 25 °C)
- V_{CBO} Collector to Base Voltage . . . . 60 V
- V_{CEO} Collector to Emitter Voltage . . . . 50 V
- V_{EBO} Emitter to Base Voltage . . . . 5.0 V
- I_C Collector Current . . . . 100 mA
- I_B Base Current . . . . 20 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	50	185			V_{CE}=6.0 V, I_C=0.1 mA
h_{FE2}	DC Current Gain	90	200	600		V_{CE}=6.0 V, I_C=1.0 mA
NF	Noise Figure		0.8	15	dB	V_{CE}=6.0 V, I_C=0.1 mA, R_G=2.0 kΩ, f=1.0 kHz
f_T	Gain Bandwidth Product	150	250	450	MHz	V_{CE}=6.0 V, I_E=−10 mA
C_{ob}	Collector to Base Capacitance		3.0	4.0	pF	V_{CB}=6.0 V, I_E=0, f=1.0 MHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB}=60 V, I_E=0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE}=40 V, I_B=0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB}=5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	0.55	0.62	0.65	V	V_{CE}=6.0 V, I_C=1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.15	0.3	V	I_C=100 mA, I_B=10 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.86	1.0	V	I_C=100 mA, I_B=10 mA

Classification of h_{FE2}

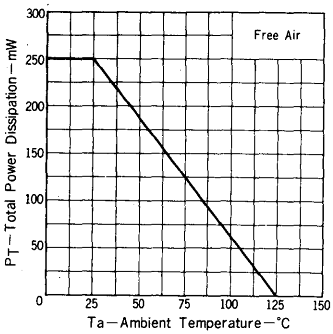
Rank	RA	QA	PA	KA
Range	90 − 180	135 − 270	200 − 400	300 − 600

h_{FE2} Test Conditions : V_{CE} = 6.0 V, I_C = 1.0 mA

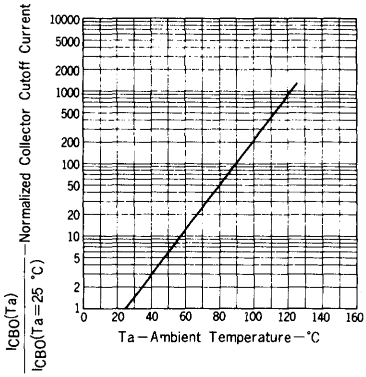
2

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

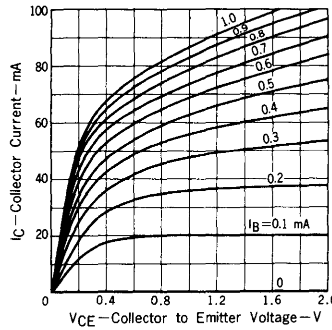
TOTAL POWER DISSIPATION
vs. AMBIENT TEMPERATURE



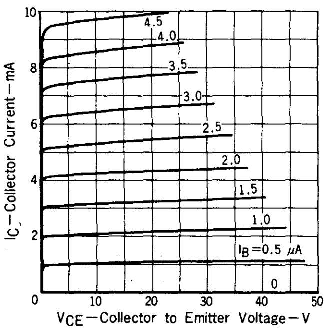
NORMALIZED COLLECTOR CUTOFF
CURRENT vs. AMBIENT TEMPERATURE



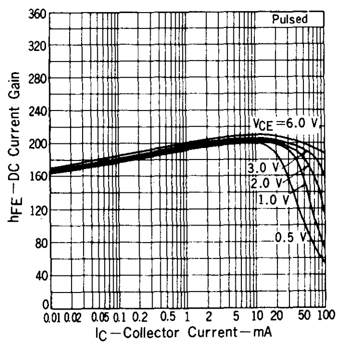
COLLECTOR CURRENT
vs. COLLECTOR TO EMITTER VOLTAGE



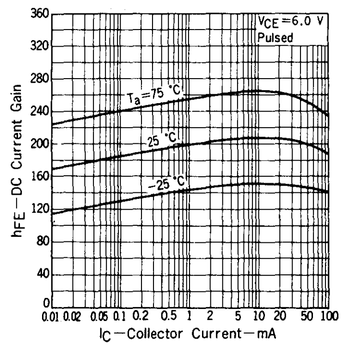
COLLECTOR CURRENT
vs. COLLECTOR TO EMITTER VOLTAGE



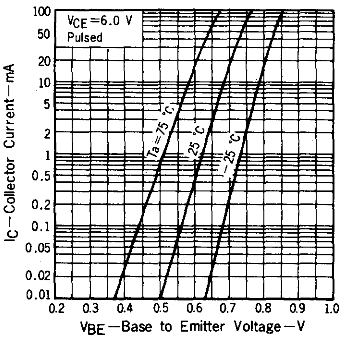
DC CURRENT GAIN
vs. COLLECTOR CURRENT



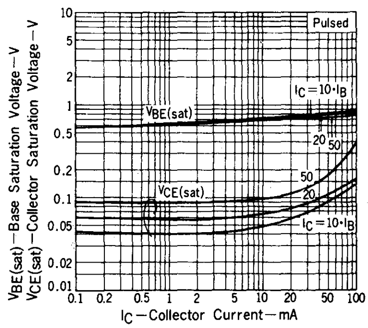
DC CURRENT GAIN
vs. COLLECTOR CURRENT



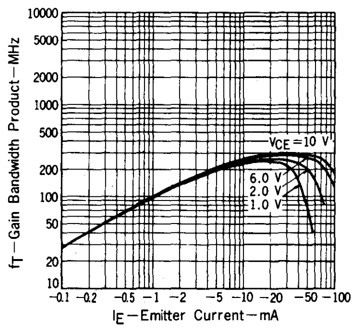
COLLECTOR CURRENT
vs. BASE TO EMITTER VOLTAGE



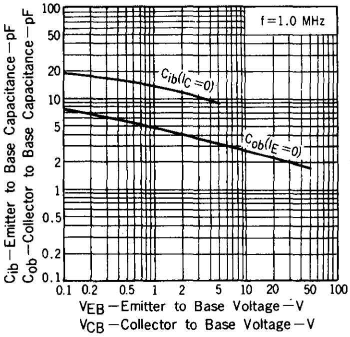
COLLECTOR AND BASE SATURATION
VOLTAGE vs. COLLECTOR CURRENT



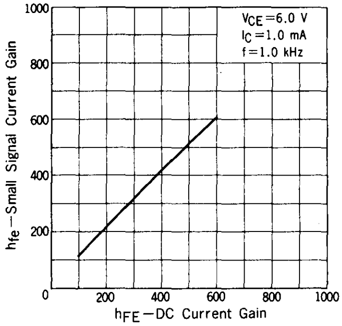
GAIN BANDWIDTH PRODUCT
vs. EMITTER CURRENT



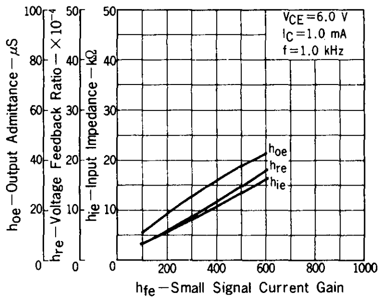
EMITTER TO BASE AND COLLECTOR TO BASE CAPACITANCE vs. REVERSE VOLTAGE



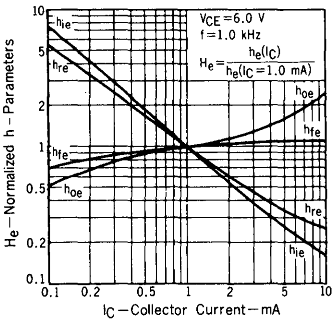
SMALL SIGNAL CURRENT GAIN vs. DC CURRENT GAIN



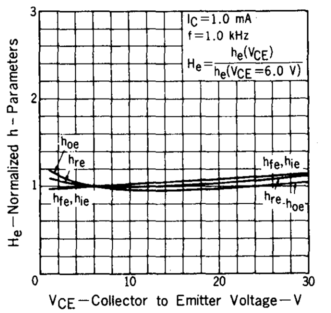
INPUT IMPEDANCE, VOLTAGE FEEDBACK RATIO AND OUTPUT ADMITTANCE vs. SMALL SIGNAL CURRENT GAIN



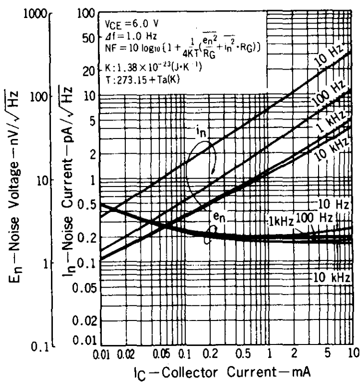
NORMALIZED h-PARAMETERS vs. COLLECTOR CURRENT



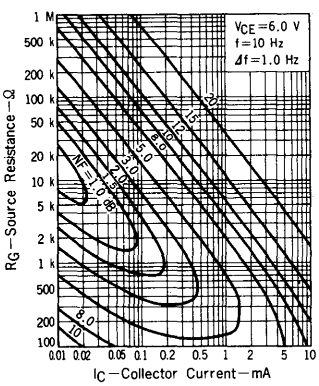
NORMALIZED h-PARAMETERS vs. COLLECTOR TO EMITTER VOLTAGE



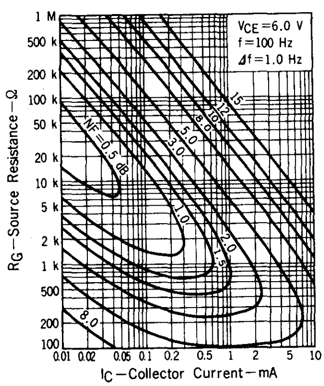
E_n AND I_n vs. COLLECTOR CURRENT



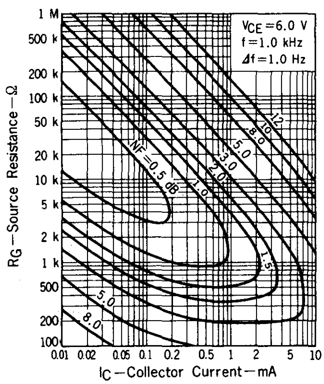
NOISE FIGURE MAP 1



NOISE FIGURE MAP 2



NOISE FIGURE MAP 3



NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC945Ⓛ

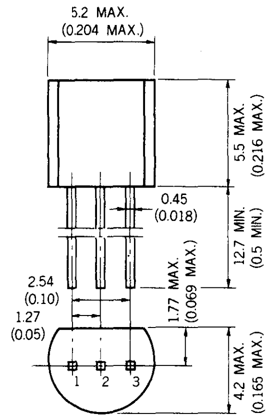
DESCRIPTION

The 2SC945Ⓛ is designed for use in an AF amplifier of low level low noise and general purpose.

FEATURES

- Excellent h_{FE} Linearity (h_{FE1}(0.1 mA)/h_{FE2}(1.0 mA): 0.92 TYP.)
- Low Noise Figure (NF_1: 2.5 dB TYP.)
- High Voltage (V_{CEO} > 50 V)

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. COLLECTOR JEDEC: TO-92
3. BASE IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature . . . . −55 to +125 °C
- Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents (Ta = 25 °C)
- V_{CBO} Collector to Base Voltage . . . . 60 V
- V_{CEO} Collector to Emitter Voltage . . . . . . 50 V
- V_{EBO} Emitter to Base Voltage . . . . 5.0 V
- I_C Collector Current . . . . 100 mA
- I_B Base Current . . . . 20 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	50	185		–	V_{CE}=6.0 V, I_C=0.1 mA
h_{FE2}	DC Current Gain	90	200	600	–	V_{CE}=6.0 V, I_C=1.0 mA
NF_1	Noise Figure (h_{FE2} Rank KA, PA, QA)		2.5	20	dB	V_{CE}=6.0 V, I_C=0.3 mA, R_G=10 kΩ, f=100 Hz
NF_2	Noise Figure		1.2	20	dB	V_{CE}=6.0 V, I_C=0.3 mA, R_G=2.0 kΩ, f=100 Hz
f_T	Gain Bandwidth Product	150	250	450	MHz	V_{CE}=6.0 V, I_E=−10 mA
C_{ob}	Output Capacitance		3.0	4.0	pF	V_{CB}=6.0 V, I_E=0, f=1.0 MHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB}=60 V, I_E=0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE}=40 V, I_B=0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB}=5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	0.55	0.62	0.65	V	V_{CE}=6.0 V, I_C=1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.15	0.30	V	I_C=100 mA, I_B=10 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.86	1.00	V	I_C=100 mA, I_B=10 mA

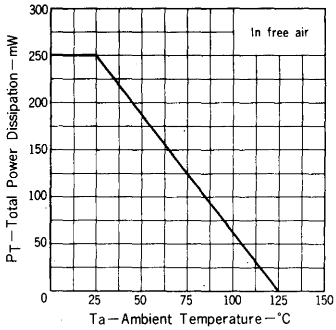
Classification of h_{FE2}

Rank	RA	QA	PA	KA
Range	90 – 180	135 – 270	200 – 400	300 – 600

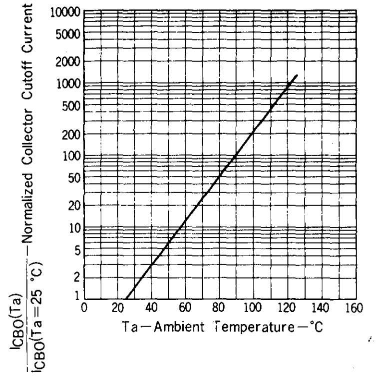
h_{FE2} Test Conditions : V_{CE}=6.0 V, I_C=1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

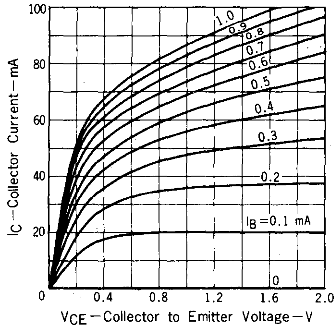
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



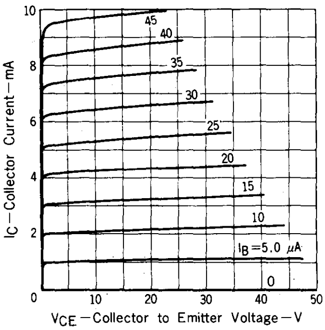
NORMALIZED COLLECTOR CUTOFF CURRENT vs. AMBIENT TEMPERATURE



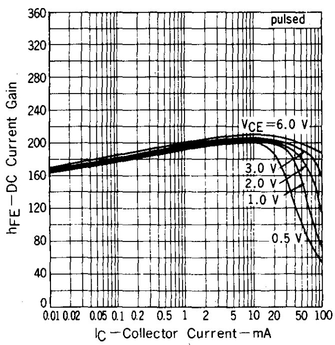
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



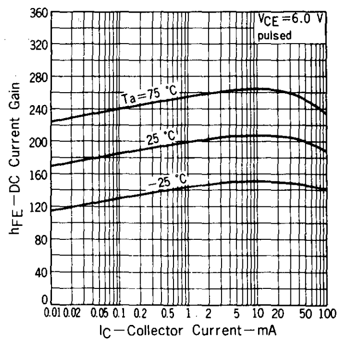
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



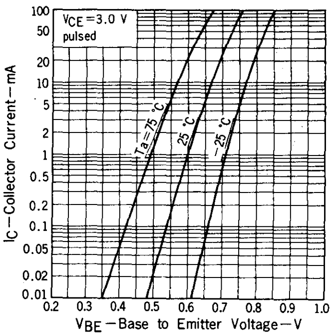
DC CURRENT GAIN vs. COLLECTOR CURRENT



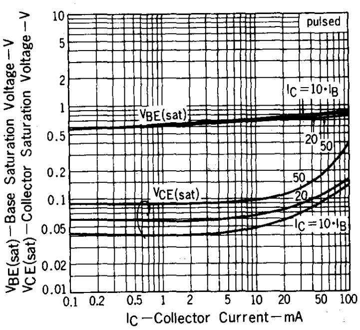
DC CURRENT GAIN vs. COLLECTOR CURRENT



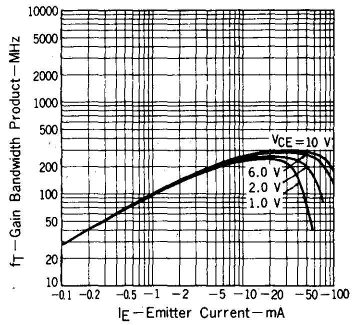
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



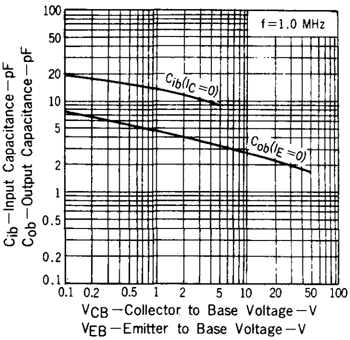
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



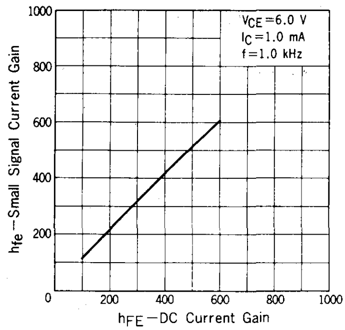
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



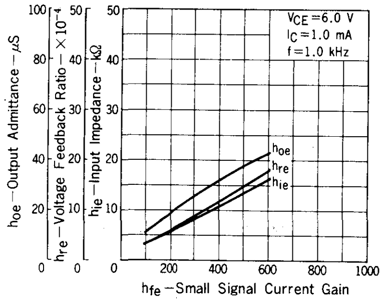
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



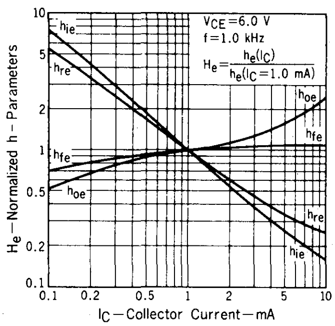
SMALL SIGNAL CURRENT GAIN vs. DC CURRENT GAIN



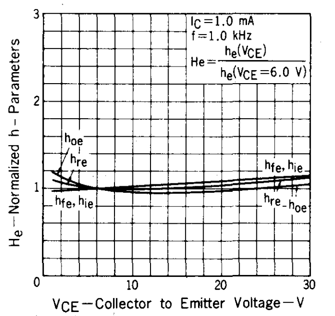
INPUT IMPEDANCE, VOLTAGE FEEDBACK RATIO AND OUTPUT ADMITTANCE vs. SMALL SIGNAL CURRENT GAIN



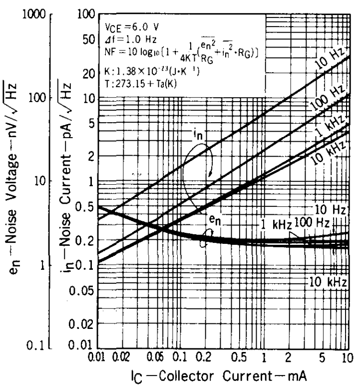
NORMALIZED h-PARAMETERS vs. COLLECTOR CURRENT



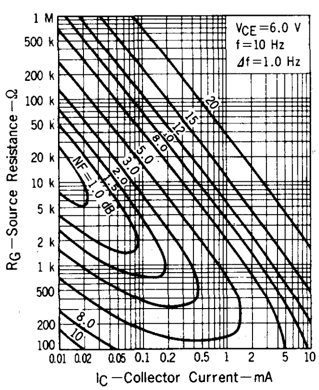
NORMALIZED h-PARAMETERS vs. COLLECTOR TO EMITTER VOLTAGE



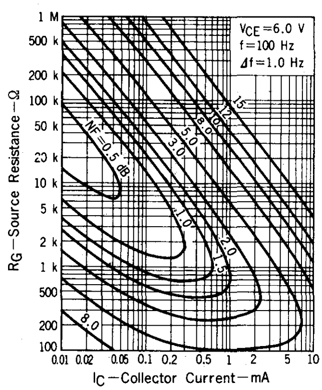
e_n AND i_n vs. COLLECTOR CURRENT



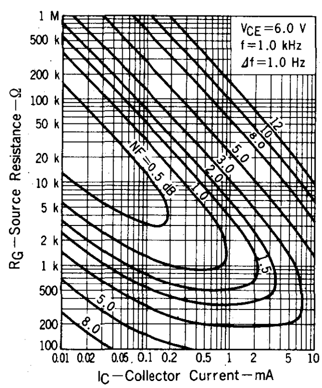
NOISE FIGURE MAP 1



NOISE FIGURE MAP 2



NOISE FIGURE MAP 3



NEC
ELECTRON DEVICE

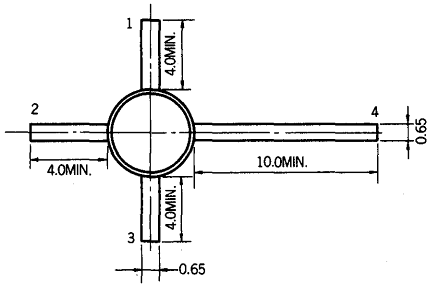
SILICON TRANSISTOR
2SC1070(B)

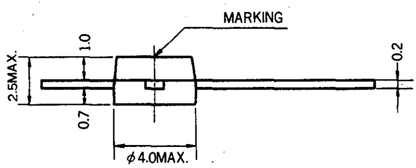
RF AMP. FOR UHF TV TUNER
NPN SILICON TRANSISTOR
DISK MOLD

The 2SC1070(B) is specifically designed for UHF RF amplifier applications. The 2SC1070(B) features high power gain, low noise, and excellent forward AGC characteristics in a tiny four-lead plastic package designed to realize easy and economical mounting.

- Packaged in tiny plastic mold package.
- Easy & economical mounting realizable with plastic mold package.
- Forward AGC characteristic.
- Balanced base.

PACKAGE DIMENSIONS (Unit : mm)





1. Base
2. Emitter
3. Base
4. Collector

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	25	V
Emitter to Base Voltage	V_{EBO}	4.0	V
Collector Current	I_C	20	mA
Total Power Dissipation	P_T	200	mW
Junction Temperature	T_j	125	°C
Storage Temperature	T_{stg}	- 55 to +125	°C

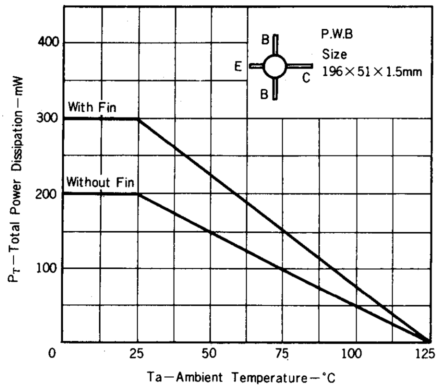
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB} = 25V, I_E = 0
DC Current Gain	h_{FE}	60	100	200		V_{CE} = 10V, I_C = 3.0mA
Gain Bandwidth Product	f_T	750	900		MHz	V_{CE} = 10V, I_E = - 3.0mA
Output Capacitance	C_{ob}		0.6	0.8	pF	V_{CB} = 10V, I_E = 0, f = 1MHz
Noise Figure	NF		4.5	6.0	dB	V_{CB} = 10V, I_E = - 3.0mA, f = 900MHz
Power Gain	G_{pb}	14			dB	V_{CB} = 10V, I_E = - 3.0mA, f = 900MHz
AGC Current	I_{AGC}	- 8	- 10	- 11	mA	I_E for which G_{pbAGC} = G_{pb} -30dB *

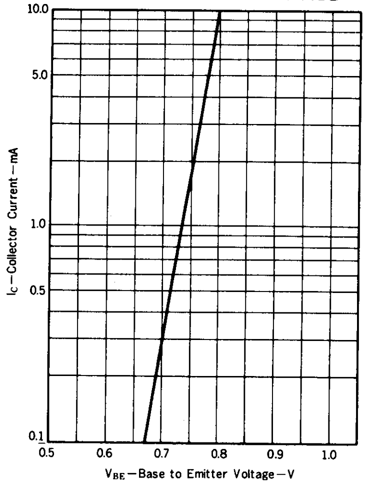
* I_{AGC} Classification L: -8.0 — -10.0mA, K: -9.0 — -11.0mA

TYPICAL CHARACTERISTICS (Ta = 25°C)

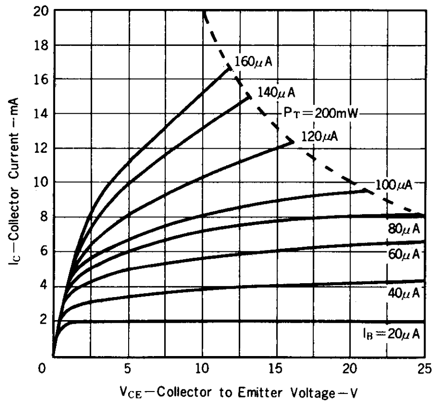
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



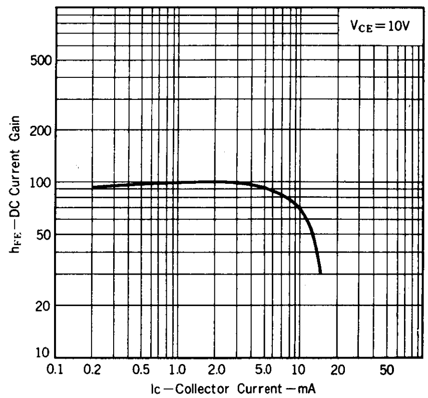
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



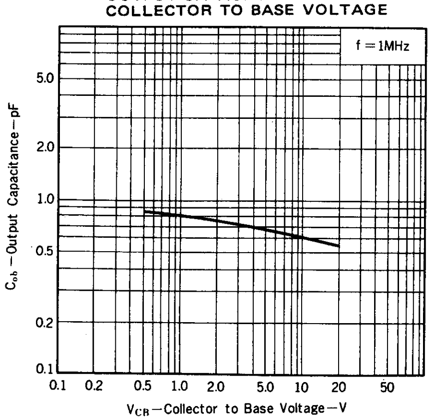
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



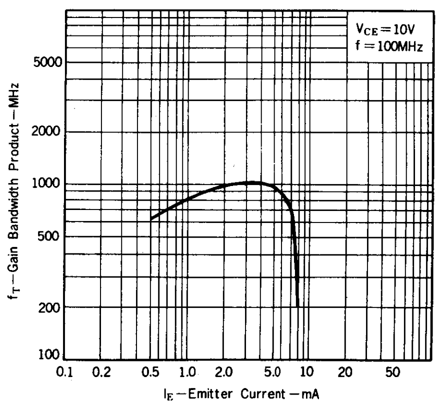
DC CURRENT GAIN vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE

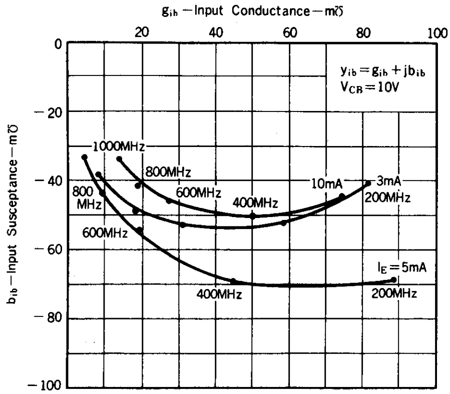


GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT

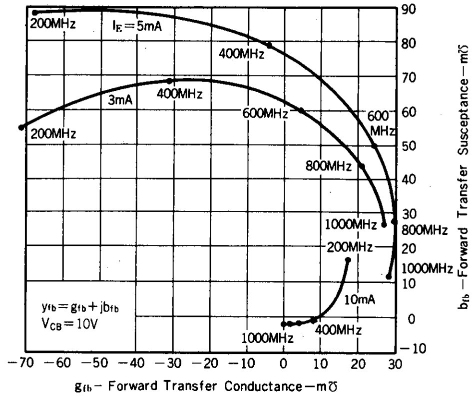


TYPICAL CHARACTERISTICS of "Y" PARAMETERS

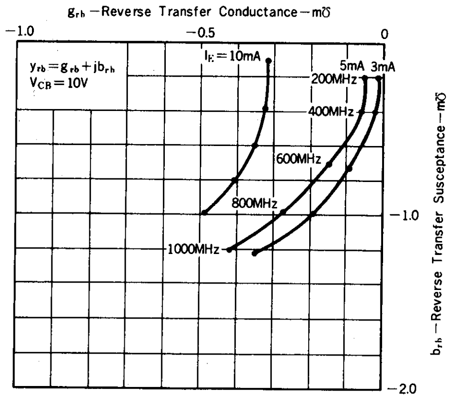
INPUT ADMITTANCE (Yib) vs. FREQUENCY



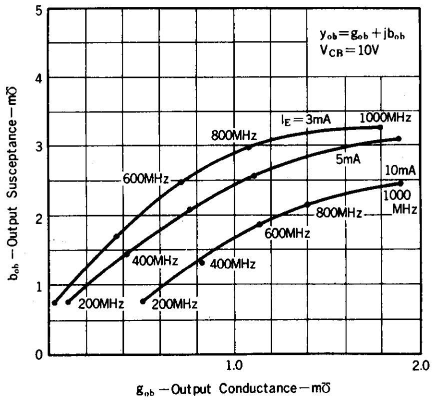
FORWARD TRANSFER ADMITTANCE (Yfb) vs. FREQUENCY



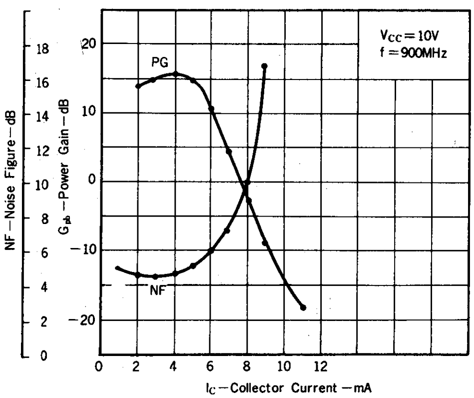
REVERSE TRANSFER ADMITTANCE (Yrb) vs. FREQUENCY



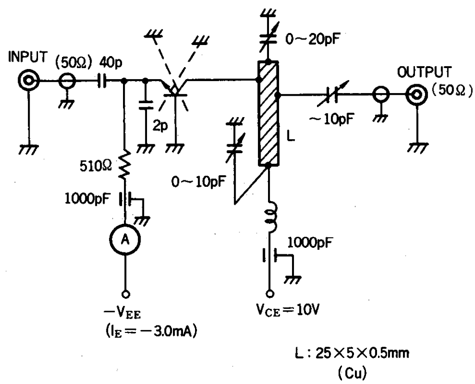
OUTPUT ADMITTANCE (Yob) vs. FREQUENCY



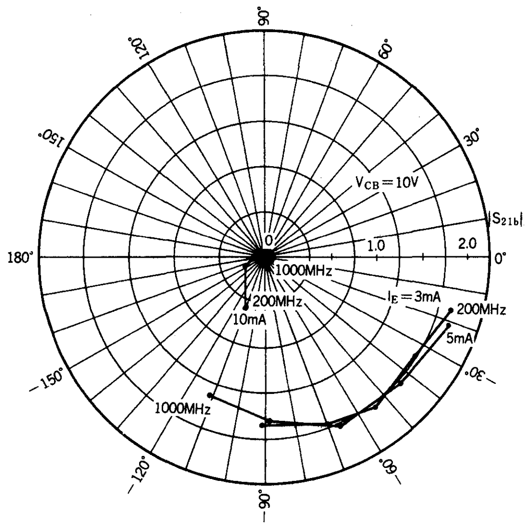
NOISE FIGURE, POWER GAIN vs. COLLECTOR CURRENT



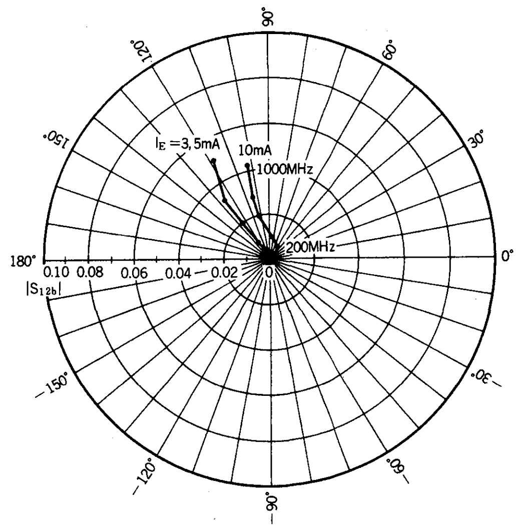
900MHz G_{pb} & NF Test Circuit



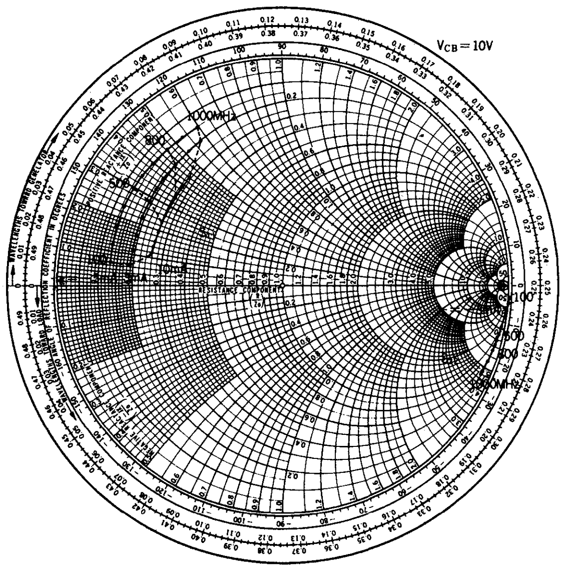
S21b vs. f



S12b vs. f



S11 vs. f, S22 vs. f



NEC
ELECTRON DEVICE

NPN SILICON TRANSISTORS

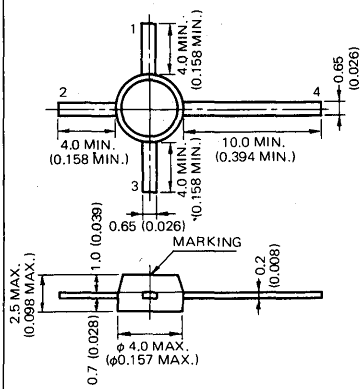
2SC1070(1), 2SC1070(2)

DESCRIPTION The 2SC1070(1) is specifically designed for UHF RF amplifier applications. The 2SC1070(2) is specifically designed for UHF mixer applications. They feature high power gain, low noise figure and excellent forward AGC characteristics in a tiny four-lead plastic package.

FEATURES

- Low NF high G_{pb}.
  NF=2.8 dB TYP. G_{pb}= 18 dB TYP. (f=900 MHz)
- Forward AGC characteristic.
- Balanced base.

PACKAGE DIMENSIONS
in millimeters (inches)



1. BASE
2. EMITTER
3. BASE
4. COLLECTOR

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −55 to +125 °C

Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta=25 °C)

Total Power Dissipation . . . . 200 mW

Maximum Voltages and Currents (Ta=25 °C)

V_{CBO}	Collector to Base Voltage	30 V
V_{CEO}	Collector to Emitter Voltage	25 V
V_{EBO}	Emitter to Base Voltage	3.0 V
I_C	Collector Current	20 mA
I_B	Base Current	10 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	2SC1070(1) MIN.	TYP.	MAX.	2SC1070(2) MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	40	80	200	40	80	200	–	V_{CE}=10 V, I_C=3.0 mA
I_{AGC}	AGC Current	−8.0		−11				mA	f=200 MHz I_E at gain reduction of 30 dB.
f_T	Gain Bandwidth Product	750	1000		750	1000		MHz	V_{CE}=10 V, I_E=−3.0 mA
C_{ob}	Output Capacitance		0.55	0.8		0.55	0.8	pF	V_{CB}=10 V, f=1.0 MHz, I_E=0
G_{pb}	Power Gain	14			14			dB	V_{CB}=10 V, I_E=−3.0 mA, f=900 MHz See Test Circuit
NF	Noise Figure		2.8	4.0		2.8	4.0	dB	V_{CB}=10 V, I_E=−3.0 mA, f=900 MHz
I_{CBO}	Collector Cutoff Current			0.1			0.1	μA	V_{CB}=25 V, I_E=0

2SC1070(1) Classification of I_{AGC}

Rank	Q	P
Range (mA)	−8.0 – −10	−9.0 – −11

I_{AGC} Test Conditions : I_E for which G_{pbAGC}=G_{pb} −30 dB

2SC1070(2) Classification of h_{FE}

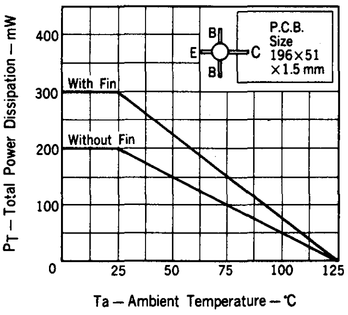
Rank	F
Range	40 – 200

h_{FE} Test Conditions : V_{CE}=10 V, I_C=3.0 mA

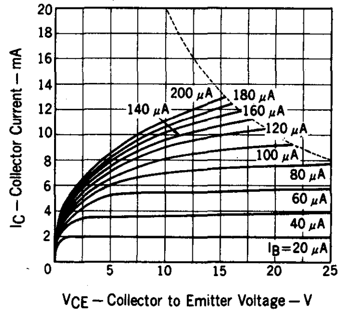
2

TYPICAL CHARACTERISTICS (Ta=25 °C)

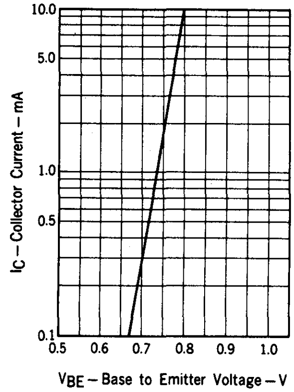
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



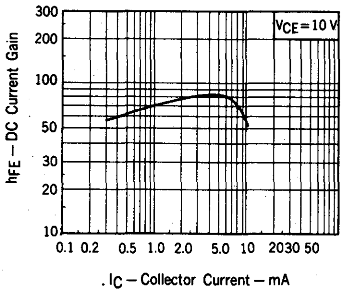
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



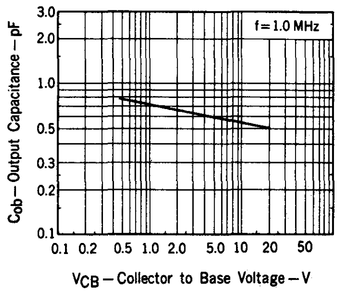
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



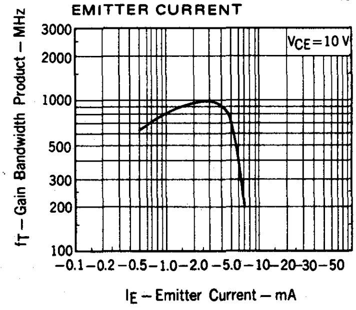
DC CURRENT GAIN vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE

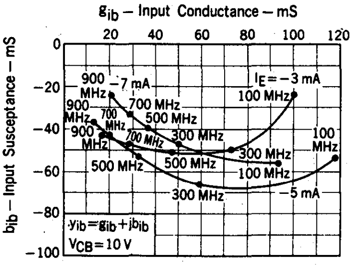


GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT

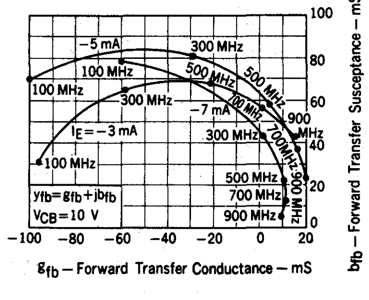


TYPICAL CHARACTERISTICS of "Y" PARAMETERS

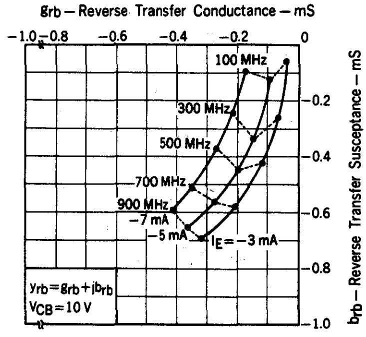
INPUT ADMITTANCE (y_{ib}) vs. FREQUENCY

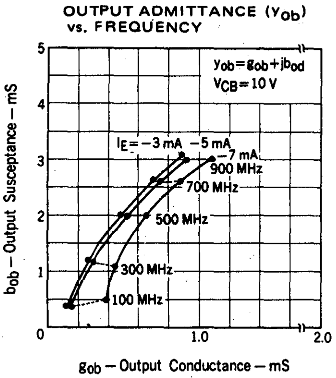


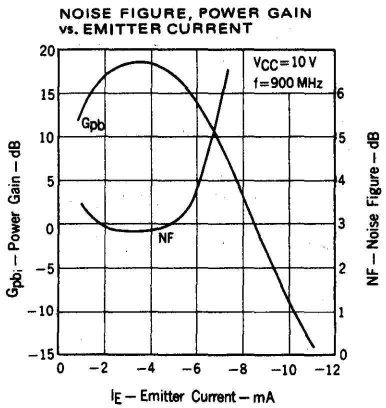
FORWARD TRANSFER ADMITTANCE (y_{fb}) vs. FREQUENCY

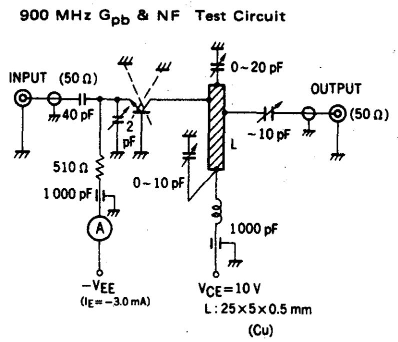


REVERSE TRANSFER ADMITTANCE (y_{rb}) vs. FREQUENCY

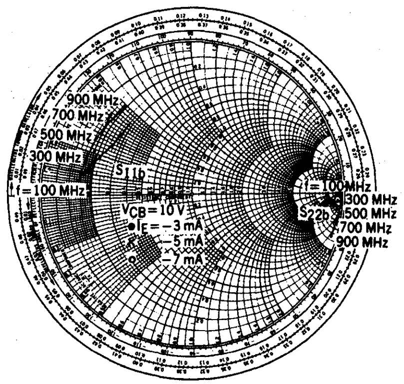


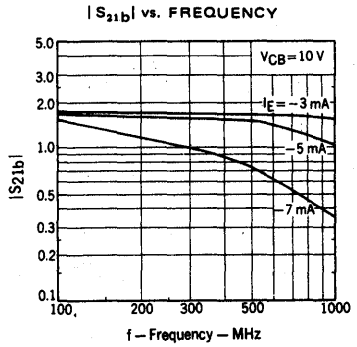


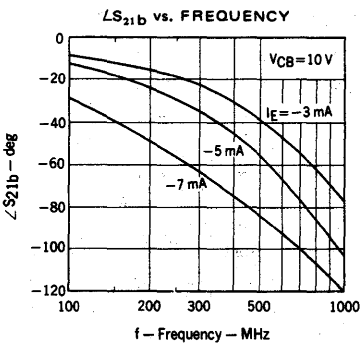


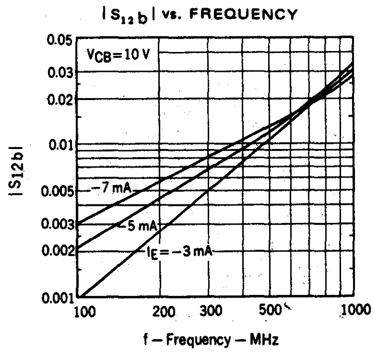


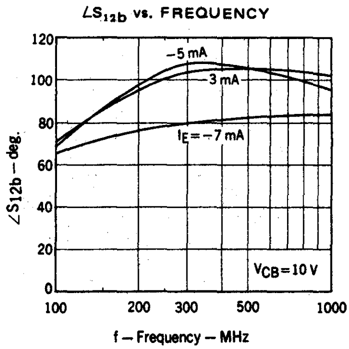
TYPICAL CHARACTERISTICS of "S" PARAMETERS











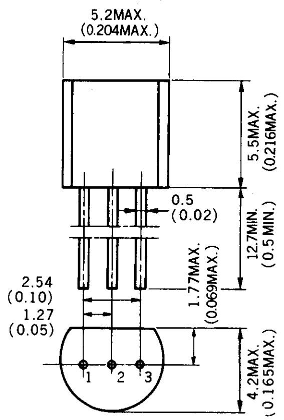
NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC1222

DESCRIPTION The 2SC1222 is designed for use in AF low noise amplifier of a high-class STEREO SET, RADIO and TAPE RECORDER.

FEATURES
- High h_{FE} and Excellent h_{FE} Linearity
  - h_{FE} (I_C = 0.5mA, V_{CE} = 3V) : 500 TYP.
  - h_{FE1} (0.1mA) / h_{FE2} (1.0mA) (V_{CE} = 3V) : 0.92 TYP.
- Low Noise Voltage
  - NV : 22 mV TYP.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Temperatures
- Storage Temperature . . . . -55 to +125°C
- Junction Temperature . . . . +125°C Maximum

Maximum Power Dissipation (Ta = 25°C)
- Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents
- V_{CBO} Collector to Base Voltage . . . . 60 V
- V_{CEO} Collector to Emitter Voltage . . . . 50 V
- V_{EBO} Emitter to Base Voltage . . . . 5.0 V
- I_C Collector Current . . . . 100 mA
- I_B Base Current . . . . 20 mA

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	170	470		–	V_{CE}=3.0V, I_C=0.1mA
h_{FE2}	DC Current Gain	225	500	1000	–	V_{CE}=3.0V, I_C=0.5mA
NF_1	Noise Figure		2.8	10	dB	V_{CE}=6.0V, I_C=0.3mA, R_G=10kΩ, f=10Hz
NF_2	Noise Figure		0.8	3.0	dB	V_{CE}=6.0V, I_C=0.3mA, R_G=10kΩ, f=100Hz
NV	Noise Voltage		22	30	mV	See test circuit
I_{CBO}	Collector Cutoff Current			50	nA	V_{CB}=60V, I_E=0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE}=40V, I_B=0
I_{EBO}	Emitter Cutoff Current			50	nA	V_{EB}=5.0V, I_C=0
V_{BE}	Base to Emitter Voltage	0.55	0.58	0.65	V	V_{CE}=3.0V, I_C=0.5mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.13	0.3	V	I_C=100mA, I_B=10mA
$V_{BE(sat)}$	Base Saturation Voltage		0.86	1.0	V	I_C=100mA, I_B=10mA
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE}=6.0V, I_E=-1.0mA
C_{ob}	Output Capacitance		3.5	5.0	pF	V_{CB}=6.0V, I_E=0, f=1.0MHz

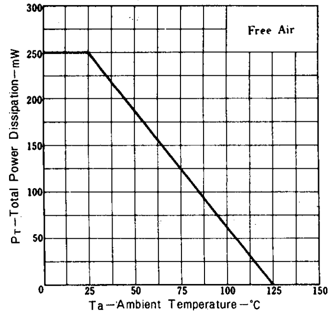
Classification of h_{FE}

Rank	F	E	U
Range	225 – 450	350 – 700	500 – 1000

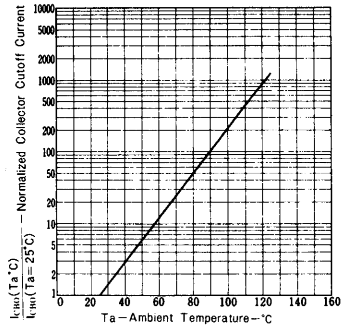
h_{FE} Test Conditions : V_{CE} = 3.0V, I_C = 0.5mA

TYPICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

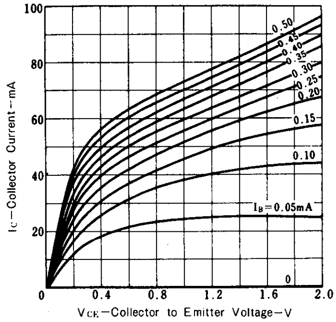
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



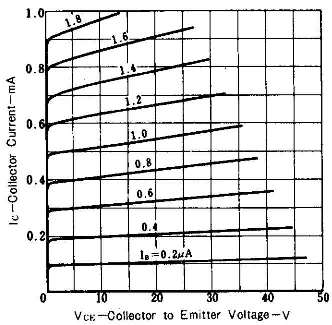
NORMALIZED COLLECTOR CUTOFF CURRENT vs. AMBIENT TEMPERATURE



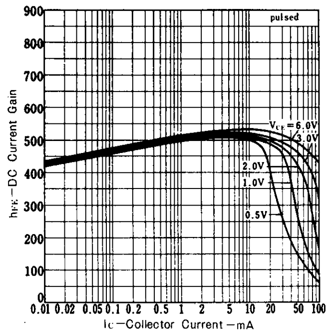
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



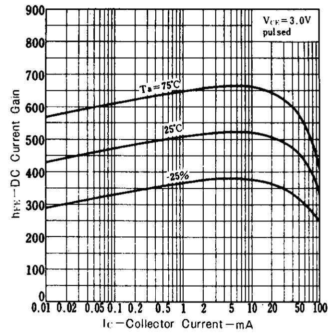
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



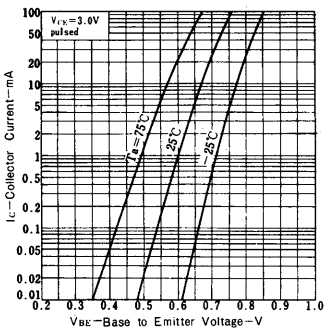
DC CURRENT GAIN vs. COLLECTOR CURRENT



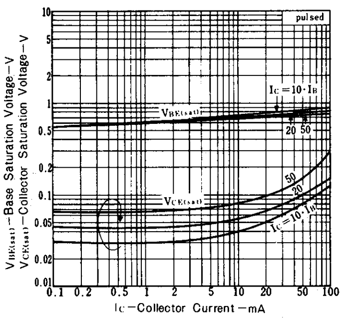
DC CURRENT GAIN vs. COLLECTOR CURRENT



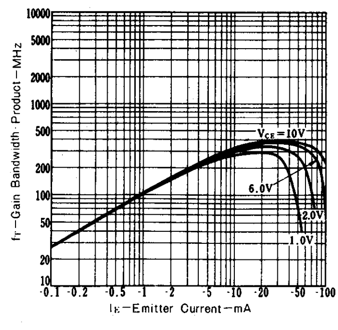
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



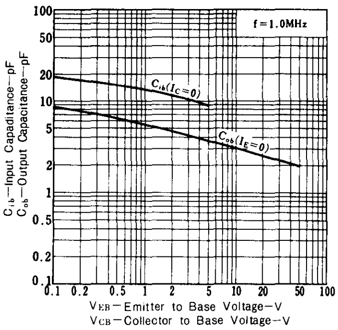
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



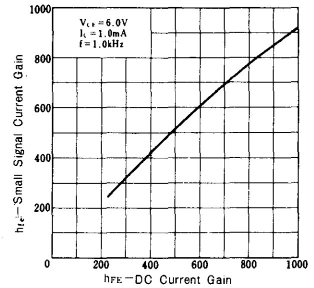
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



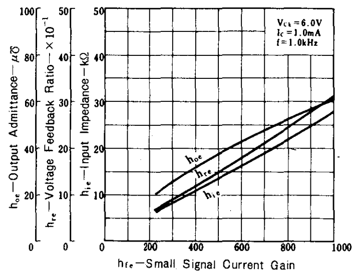
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



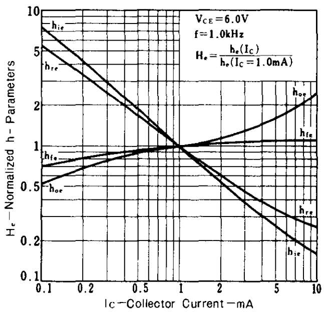
SMALL SIGNAL CURRENT GAIN vs. DC CURRENT GAIN



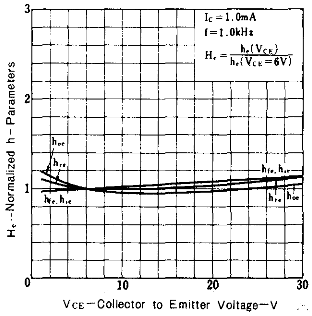
INPUT IMPEDANCE, VOLTAGE FEEDBACK RATIO AND OUTPUT ADMITTANCE vs. SMALL SIGNAL CURRENT GAIN



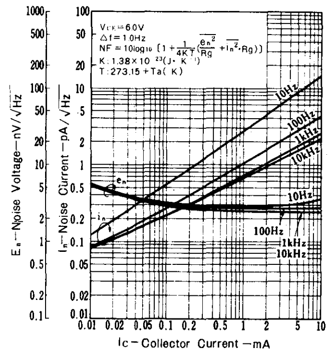
NORMALIZED h-PARAMETERS vs. COLLECTOR CURRENT



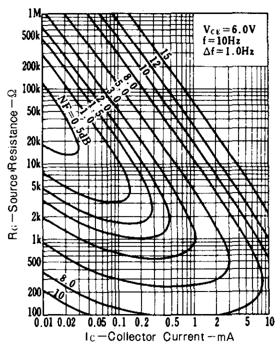
NORMALIZED h-PARAMETERS vs. COLLECTOR TO EMITTER VOLTAGE



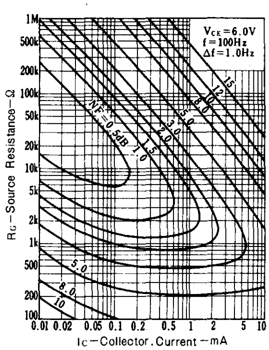
E_n AND I_n vs. COLLECTOR CURRENT



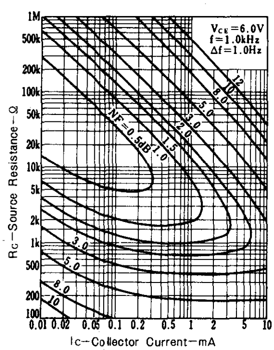
NOISE FIGURE MAP 1



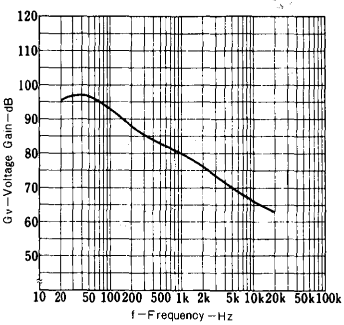
NOISE FIGURE MAP 2



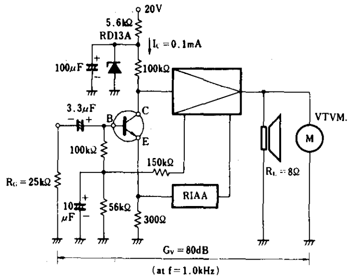
NOISE FIGURE MAP 3



VOLTAGE GAIN vs. FREQUENCY



NOISE VOLTAGE TEST CIRCUIT



$V_{CE} \doteqdot 3V$, $I_C = 0.1mA$, $R_G = 25k\Omega$, $G_V = 80dB$ (at $f = 1.0kHz$) RIAA

NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC1279Ⓢ

DESCRIPTION The 2SC1279Ⓢ is designed for use high voltage switching application.

FEATURES • High Breakdown Voltage BV_{CBO}: 180 V

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −55 to +125 °C

Junction Temperature . . . . 125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation . . . . 250 mW

Maximum Voltages and Current (Ta = 25 °C)

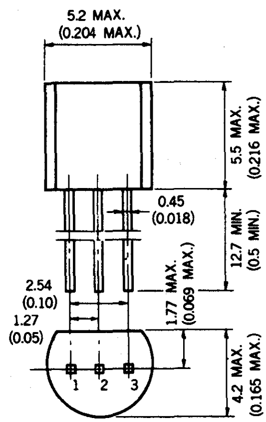
V_{CBO} Collector to Base Voltage . . . . 180 V

V_{CEO} Collector to Emitter Voltage . . . . . . 160 V

V_{EBO} Emitter to Base Voltage . . . . 5.0 V

I_C Collector Current . . . . 50 mA

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. COLLECTOR JEDEC : TO-92
3. BASE IEC : PA33

2

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
f_T	Gain Bandwidth Product		150		MHz	V_{CE} = 10 V, I_E = −10 mA
C_{ob}	Output Capacitance		4.5		pF	V_{CB} = 10 V, I_E = 0, f = 1.0 MHz
h_{FE1}	DC Current Gain	40	90		–	V_{CE} = 3.0 V, I_C = 1.0 mA
h_{FE2}	DC Current Gain	50	100	330	–	V_{CE} = 3.0 V, I_C = 15 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.1	0.5	V	I_C = 10 mA, I_B = 1.0 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.73	1.0	V	I_C = 10 mA, I_B = 1.0 mA
I_{CBO}	Collector Cutoff Current			0.1	μA	V_{CB} = 100 V, I_E = 0
I_{EBO}	Emitter Cutoff Current			0.1	μA	V_{EB} = 5.0 V, I_C = 0

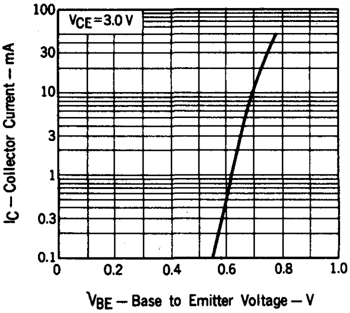
Classification of h_{FE2}

Rank	R	Q	P
Range	50 – 130	100 – 200	150 – 330

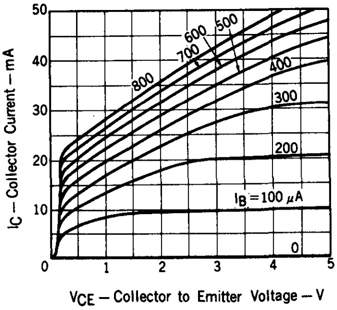
Test Conditions: V_{CE} = 3.0 V, I_C = 15 mA

TYPICAL CHARACTERISTICS (Ta=25 °C)

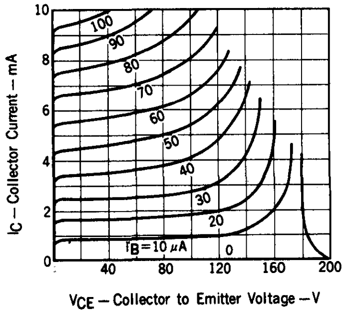
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



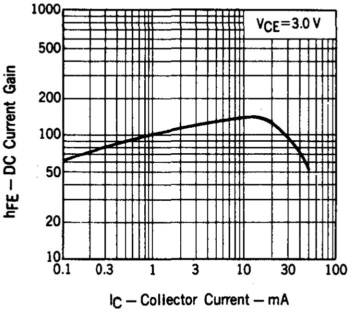
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



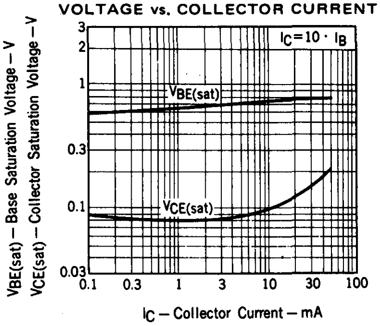
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



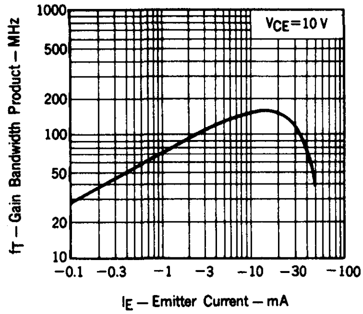
DC CURRENT GAIN vs.
COLLECTOR CURRENT



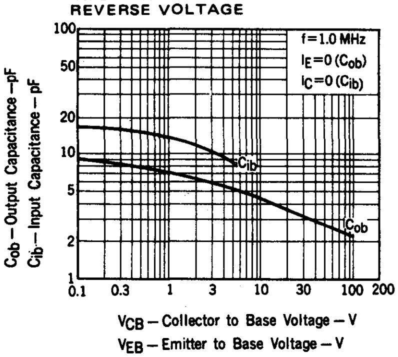
BASE AND COLLECTOR SATURATION
VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs.
EMITTER CURRENT



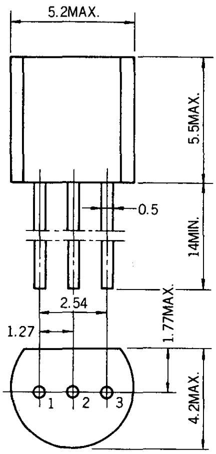
INPUT AND OUTPUT CAPACITANCE vs.
REVERSE VOLTAGE



SILICON TRANSISTORS
2SC1393,2SC1394

NPN SILICON EPITAXIAL TRANSISTOR
2SC1393 : VHF RF AMPLIFIER
2SC1394 : VHF MIXER
FOR TV TUNER

PACKAGE DIMENSIONS
(Unit : mm)



1. Base
2. Emitter
3. Collector

FEATURES

- Low NF high G_{pe}.
  NF = 2.0dB TYP. G_{pe} = 24dB TYP. (f = 200MHz)
- Forward AGC capability to 30dB.
- Low feedback capacity. C_{re} = 0.35pF TYP.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

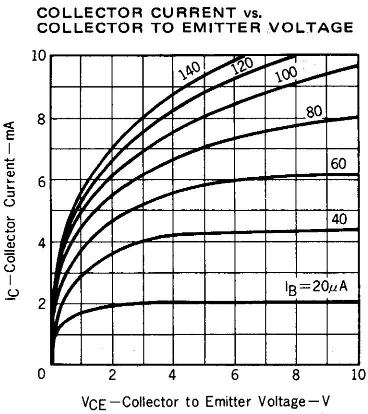
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	30	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current (DC)	I_C	20	mA
Total Power Dissipation	P_T	250	mW
Junction Temperature	T_j	125	°C
Storage Temperature	T_{stg}	-55 to +125	°C

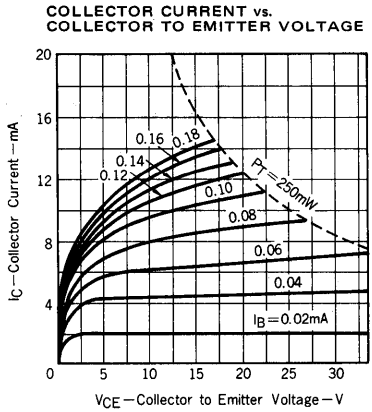
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

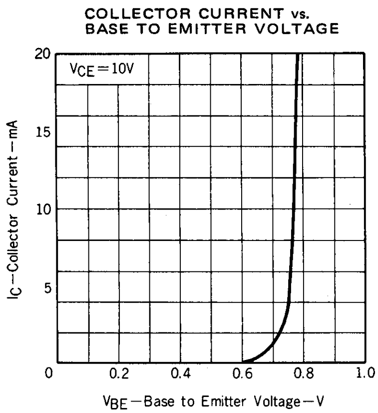
CHARACTERISTIC	SYMBOL	2SC1393			2SC1394			UNIT	TEST CONDITIONS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
Collector Cutoff Current	I_{CBO}			0.1			0.1	μA	V_{CB}=20V, I_E=0
DC Current Gain	h_{FE}	40	100	180	40	100	180		V_{CE}=10V, I_C=2.0mA
Gain Bandwidth Product	f_T	400	700		400	700		MHz	V_{CE}=10V, I_E=-3.0mA
Feed-back Capacitance	C_{re}		0.35	0.5		0.35	0.5	pF	f=1.0MHz, V_{CB}=10V, I_E=0
Power Gain	G_{pe}	20	24		20			dB	f=200MHz, I_C=3.0mA
AGC Current	I_{AGC}		-10	-12				mA	f=200MHz, I_E at gain reduction of 30dB.
Noise Figure	NF		2.0	3.0			3.5	dB	f=200MHz, I_C=3.0mA

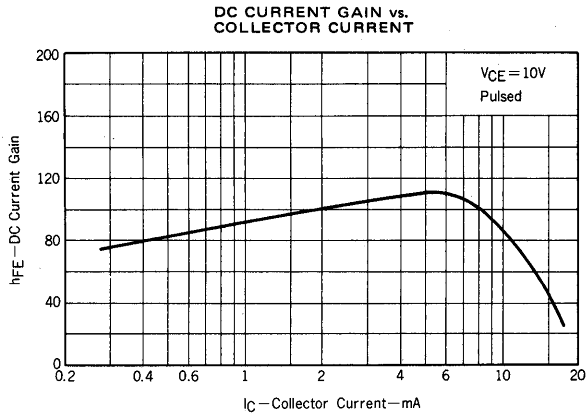
h_{FE} Classification
M : 40 – 80 L : 60 – 120 K : 90 – 180

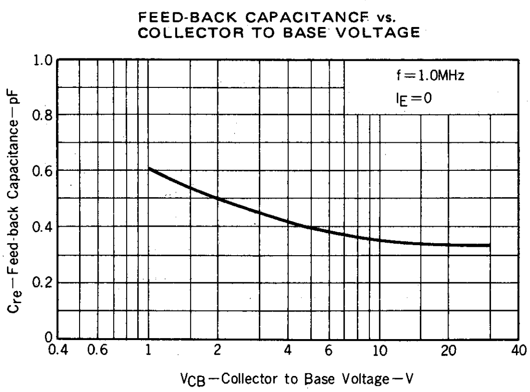
TYPICAL CHARACTERISTICS (Ta = 25°C)

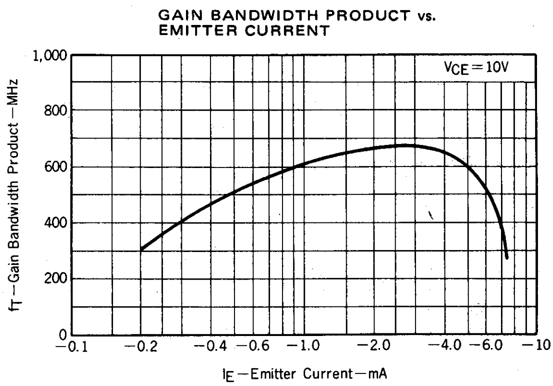




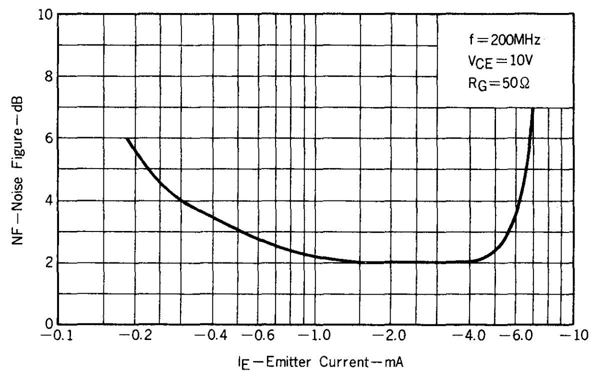




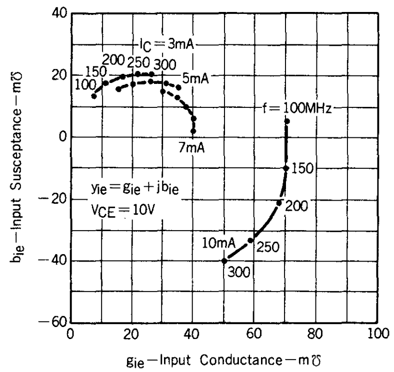




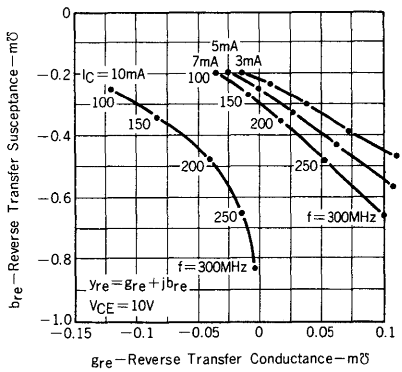
NOISE FIGURE vs. EMITTER CURRENT



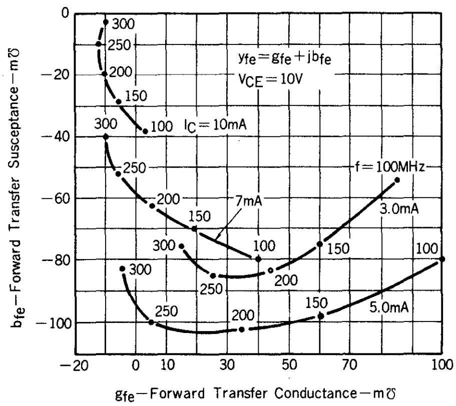
INPUT ADMITTANCE (yie) vs. FREQUENCY



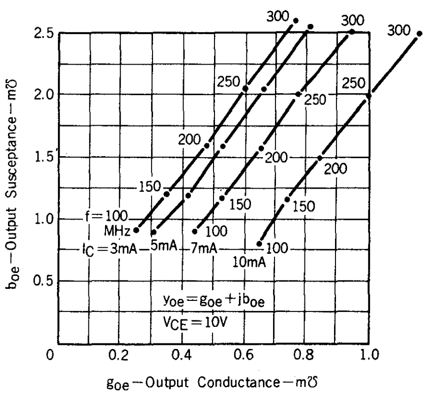
REVERSE TRANSFER ADMITTANCE (yre) vs. FREQUENCY



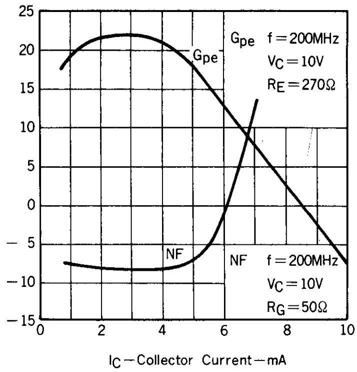
FORWARD TRANSFER ADMITTANCE (yfe) vs. FREQUENCY



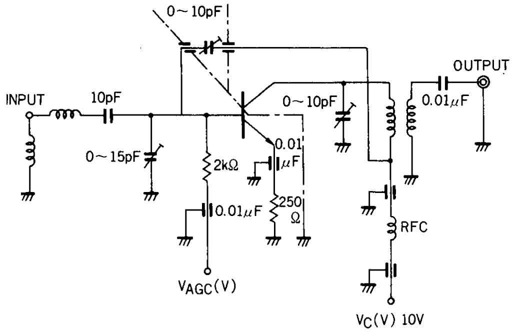
OUTPUT ADMITTANCE (yoe) vs. FREQUENCY



POWER GAIN AND NOISE FIGURE vs. COLLECTOR CURRENT



POWER GAIN AND NOISE FIGURE TEST CIRCUIT
f = 200MHz, B.W = 6.0MHz



NEC
ELECTRON DEVICE

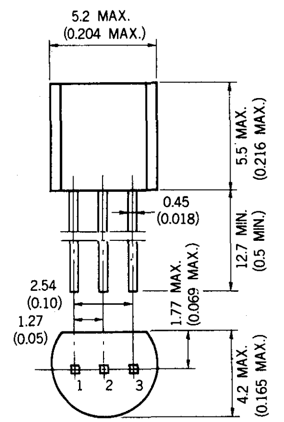
NPN SILICON TRANSISTOR
2SC1399

DESCRIPTION The 2SC1399 is designed for use in driver stage of AF amplifier, and low speed swiching.

FEATURES

- High Voltage
  - V_{CEO} : 80 V
- High h_{FE} and Excellent h_{FE} Linearity
  - h_{FE} (I_C = 0.5 mA, V_{CE} = 3 V) : 600 TYP.
  - h_{FE1} (0.1 mA)/h_{FE2} (1.0 mA)(V_{CE} = 3 V) : 0.92 TYP.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER	EIAJ : SC-43
2. COLLECTOR	JEDEC : TO-92
3. BASE	IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −55 to +125 °C

Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO} Collector to Base Voltage . . . . 100 V

V_{CEO} Collector to Emitter Voltage . . . . 80 V

V_{EBO} Emitter to Base Voltage . . . . 5.0 V

I_C Collector Current . . . . 50 mA

I_B Base Current . . . . 10 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	170	560		–	V_{CE}=3.0 V, I_C=0.1 mA
h_{FE2}	DC Current Gain	225	600	1000	–	V_{CE}=3.0 V, I_C=0.5 mA
NF	Noise Figure			20	dB	V_{CE}=6.0 V, I_C=0.3 mA, R_G=2.0 kΩ, f=100 Hz
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE}=6.0 V, I_E=−1.0 mA
C_{ob}	Collector to Base Capacitance		2.7	5.0	pF	V_{CB}=6.0 V, I_E=0, f=1.0 MHz
I_{CBO}	Collector Cutoff Current			50	nA	V_{CB}=100 V, I_E=0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE}=60 V, I_B=0
I_{EBO}	Emitter Cutoff Current			50	nA	V_{EB}=5.0 V, I_C=0
$V_{CE(sat)}$	Collector Saturation Voltage		0.09	0.3	V	I_C=50 mA, I_B=5.0 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.81	1.0	V	I_C=50 mA, I_B=5.0 mA

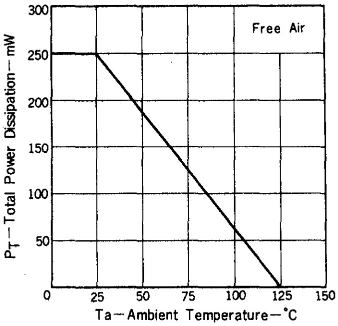
Classification of h_{FE2}

Rank	F	E	U
Range	225 − 450	350 − 700	500 − 1000

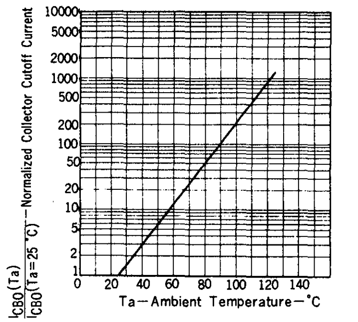
h_{FE} Test Conditions : V_{CE} = 3.0 V, I_C = 0.5 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

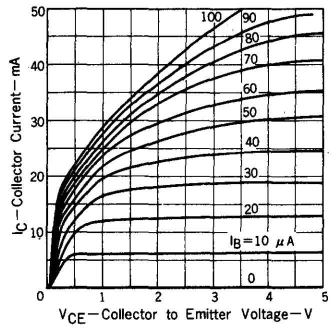
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



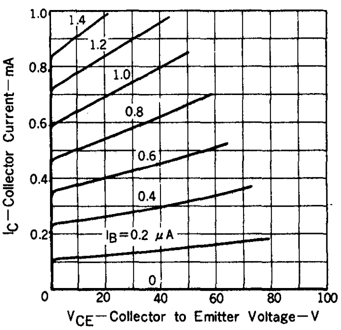
NORMALIZED COLLECTOR CUTOFF CURRENT vs. AMBIENT TEMPERATURE



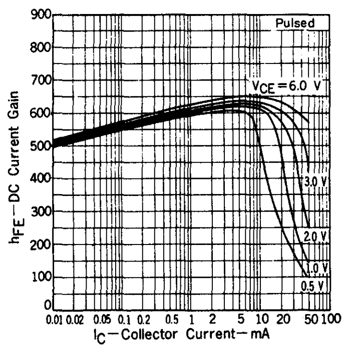
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



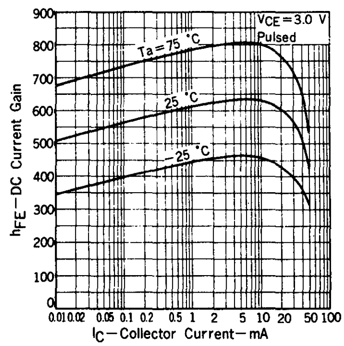
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



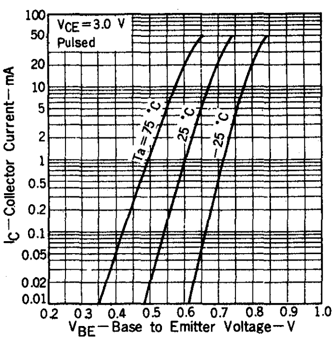
DC CURRENT GAIN vs. COLLECTOR CURRENT



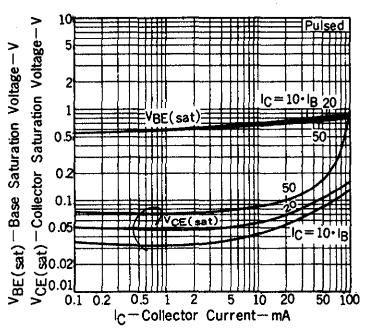
DC CURRENT GAIN vs. COLLECTOR CURRENT



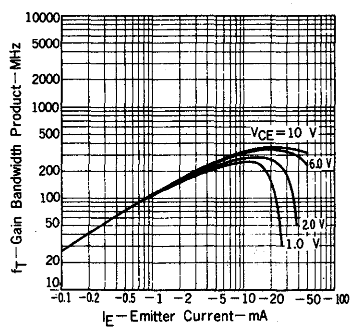
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT

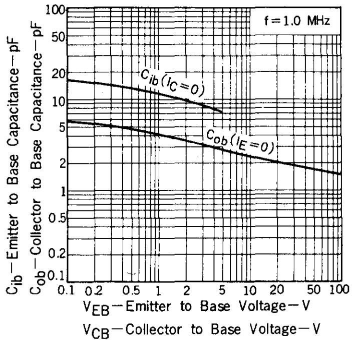


GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT

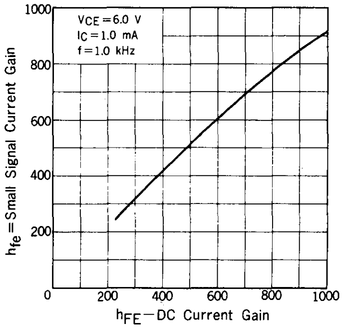


2

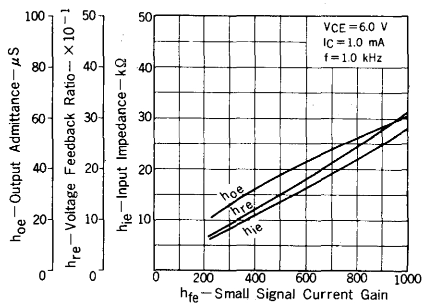
COLLECTOR TO BASE AND EMITTER TO BASE CAPACITANCE vs. REVERSE VOLTAGE



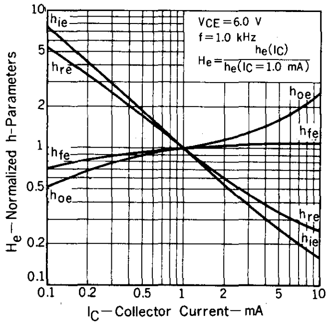
SMALL SIGNAL CURRENT GAIN vs. DC CURRENT GAIN



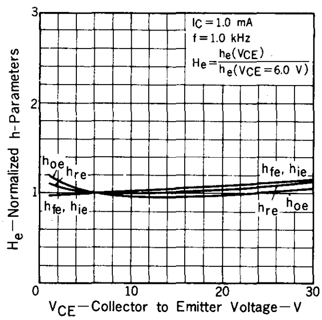
INPUT IMPEDANCE, VOLTAGE FEEDBACK RATIO AND OUTPUT ADMITTANCE vs. SMALL SIGNAL CURRENT GAIN



NORMALIZED h-PARAMETERS vs. COLLECTOR CURRENT



NORMALIZED h-PARAMETERS vs. COLLECTOR TO EMITTER VOLTAGE



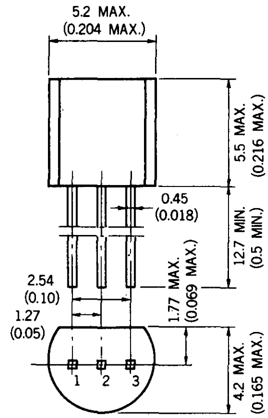
NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC1400

DESCRIPTION The 2SC1400 is designed for use in AF low noise amplifier of a high-class STEREO SET.

FEATURES
- High Voltage : 80 V
- High h_{FE} and excellent h_{FE} linearity.
  - h_{FE} (I_C = 0.5 mA)(V_{CE} = 3 V) : 600 TYP.
  - h_{FE1} (0.1 mA)/h_{FE2} (1.0 mA)(V_{CE} = 3 V) : 0.92 TYP.
- Low noise voltage : 22 mV TYP.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature . . . . −55 to +125 °C
- Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents (Ta = 25 °C)
- V_{CBO} Collector to Base Voltage . . . . 100 V
- V_{CEO} Collector to Emitter Voltage . . . . 80 V
- V_{EBO} Emitter to Base Voltage . . . . 5.0 V
- I_C Collector Current . . . . 50 mA
- I_B Base Current . . . . 10 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	170	560		–	V_{CE}=3.0 V, I_C=0.1 mA
h_{FE2}	DC Current Gain	225	600	1000	–	V_{CE}=3.0 V, I_C=0.5 mA
NF_1	Noise Figure		2.8	10	dB	V_{CE}=6.0 V, I_C=0.3 mA, R_G=10 kΩ, f=10 Hz
NF_2	Noise Figure		0.8	3.0	dB	V_{CE}=6.0 V, I_C=0.3 mA, R_G=10 kΩ, f=100 Hz
NV	Noise Voltage		22	30	mV	See test circuit
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE}=6.0 V, I_E=−1.0 mA
C_{ob}	Output Capacitance		2.7	5.0	pF	V_{CB}=6.0 V, I_E=0, f=1.0 MHz
I_{CBO}	Collector Cutoff Current			50	nA	V_{CB}=100 V, I_E=0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE}=60 V, I_B=0
I_{EBO}	Emitter Cutoff Current			50	nA	V_{EB}=5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	0.55	0.58	0.65	V	V_{CE}=3.0 V, I_C=0.5 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.09	0.3	V	I_C=50 mA, I_B=5.0 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.81	1.0	V	I_C=50 mA, I_B=5.0 mA

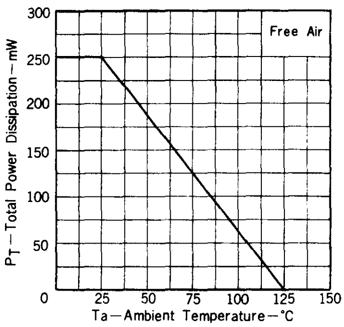
Classification of h_{FE2}

Rank	F	E	U
Range	225 – 450	350 – 700	500 – 1000

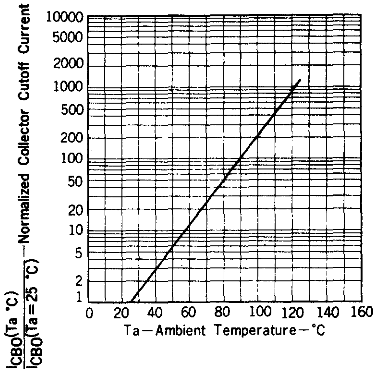
h_{FE} Test Conditions : V_{CE} = 3.0 V, I_C = 0.5 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

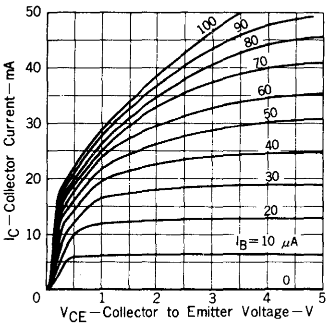
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



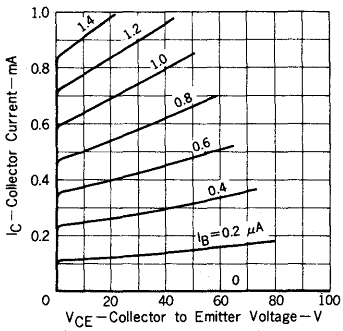
NORMALIZED COLLECTOR CUTOFF CURRENT vs. AMBIENT TEMPERATURE



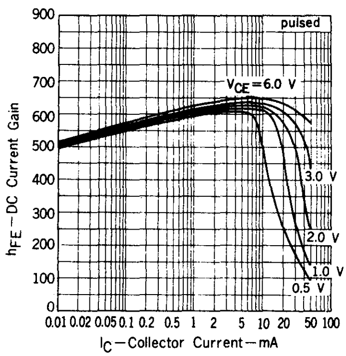
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



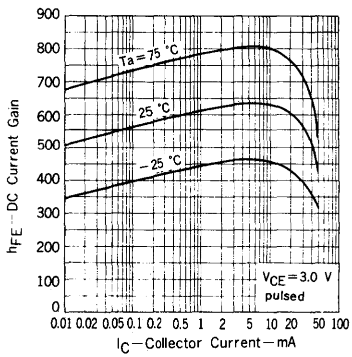
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



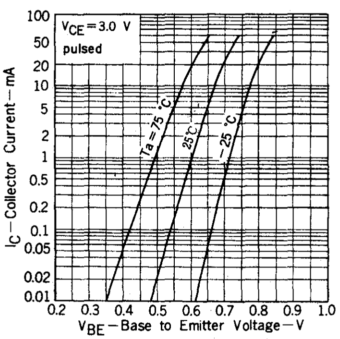
DC CURRENT GAIN vs. COLLECTOR CURRENT



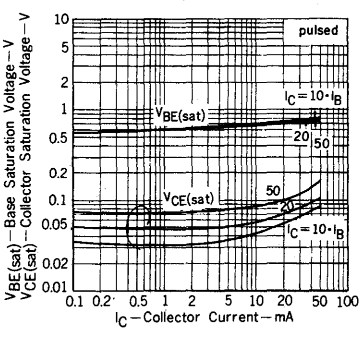
DC CURRENT GAIN vs. COLLECTOR CURRENT



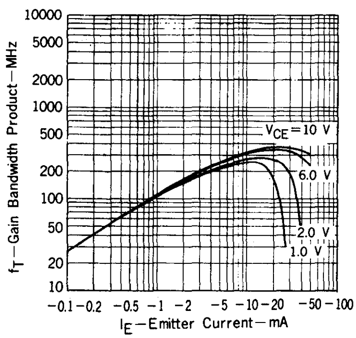
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT

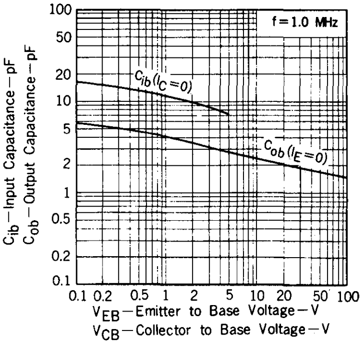


GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT

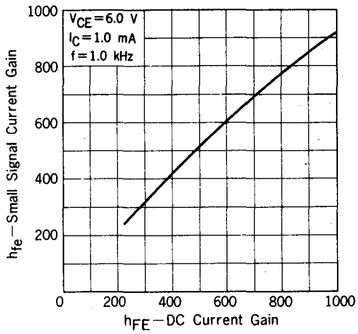


2

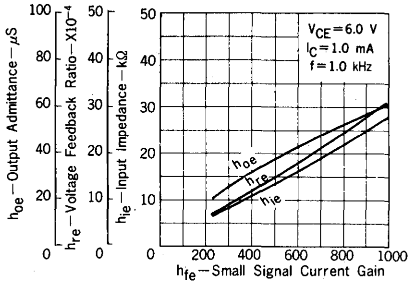
OUTPUT AND INPUT CAPACITANCE vs. REVERSE VOLTAGE



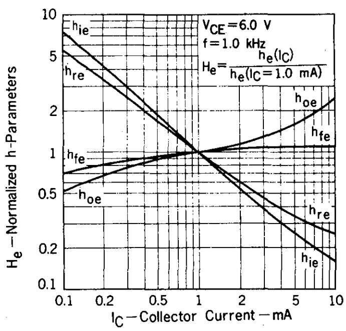
SMALL SIGNAL CURRENT GAIN vs. DC CURRENT GAIN



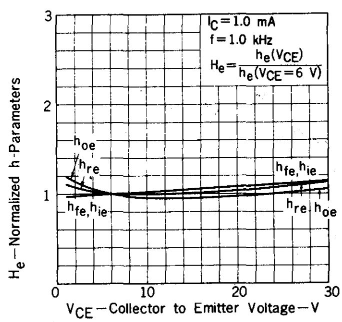
INPUT IMPEDANCE, VOLTAGE FEEDBACK RATIO AND OUTPUT ADMITTANCE vs. SMALL SIGNAL CURRENT GAIN



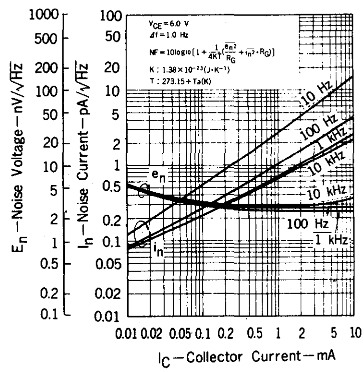
NORMALIZED h-PARAMETERS vs. COLLECTOR CURRENT



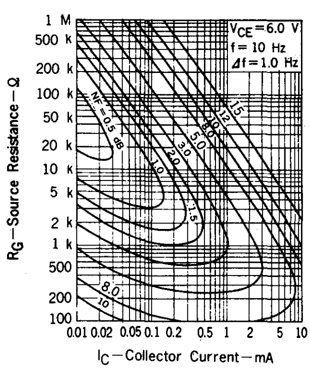
NORMALIZED h-PARAMETERS vs. COLLECTOR TO EMITTER VOLTAGE



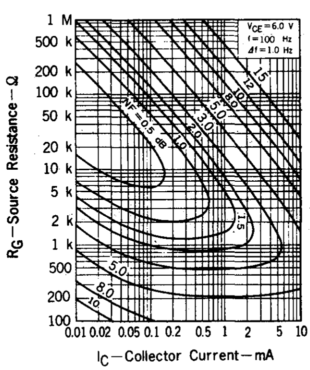
E_n AND I_n vs. COLLECTOR CURRENT



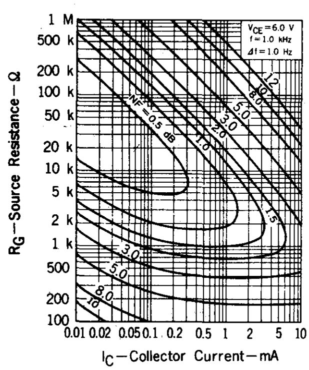
NOISE FIGURE MAP 1



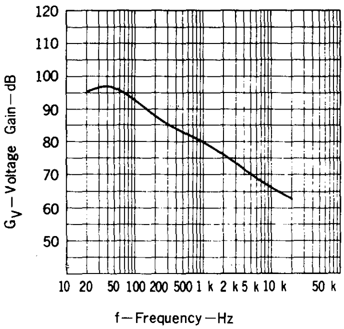
NOISE FIGURE MAP 2



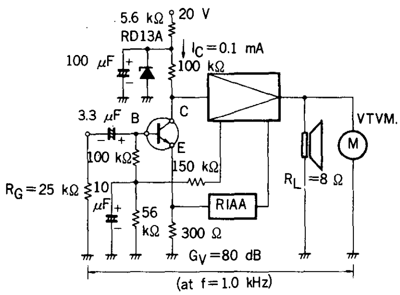
NOISE FIGURE MAP 3



VOLTAGE GAIN vs. FREQUENCY



NOISE VOLTAGE TEST CIRCUIT



$V_{CE} \fallingdotseq 3$ V, I_C=0.1 mA, R_G=25 kΩ, G_V=80 dB(at f=1 kHz)RIAA

NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC1674

DESCRIPTION The 2SC1674 is designed for use in FM RF amplifier and local oscillator of FM tuner.

FEATURES

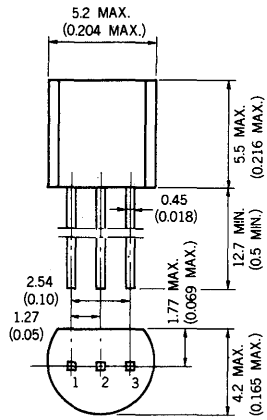
- High gain bandwidth product (f_T = 600 MHz TYP.)
- Small output capacitance (C_{ob} = 1.0 pF TYP.)
- Low noise figure (NF = 3.0 dB TYP. @100 MHz)

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
Storage Temperature . . . . −55 to +125 °C
Junction Temperature . . . . +125 °C Maximum
Maximum Power Dissipation (Ta = 25 °C)
Total Power Dissipation . . . . 250 mW
Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO}	Collector to Base Voltage	[illegible]	V
V_{CEO}	Collector to Emitter Voltage	20	V
V_{EBO}	Emitter to Base Voltage	4.0	V
I_C	Collector Current	20	mA
I_B	Base Current	20	mA

PACKAGE DIMENSIONS
in millimeters (inches)



1.EMITTER EIAJ : SC-43
2.COLLECTOR JEDEC : TO-92
3.BASE IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	40	90	180	–	V_{CE} = 6.0 V, I_C = 1.0 mA
C_{ob}	Output Capacitance		1.0	1.3	pF	V_{CB} = 6.0 V, I_E = 0, f = 1.0 MHz
NF	Noise Figure		3.0	5.0	dB	V_{CE} = 6.0 V, I_E = −1.0 mA, R_G = 50 Ω, f = 100 MHz See test circuit
f_T	Gain Bandwidth Product	400	600		MHz	V_{CE} = 6.0 V, I_E = −1.0 mA
G_{pe}	Power Gain	18	22		dB	V_{CE} = 6.0 V, I_E = −1.0 mA, R_G = 50 Ω, f = 100 MHz See test circuit
$C_c \cdot r_{b'b}$	Collector to Base Time Constant		12	15	ps	V_{CE} = 6.0 V, I_E = −1.0 mA, f = 31.9 MHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB} = 30 V, I_E = 0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB} = 4.0 V, I_C = 0
V_{BE}	Base to Emitter Voltage		0.72		V	V_{CE} = 6.0 V, I_C = 1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.1	0.3	V	I_C = 10 mA, I_B = 1.0 mA

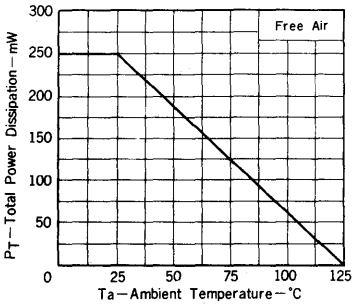
Classification of h_{FE}

Rank	M	L	K
Range	40 – 80	60 – 120	90 – 180

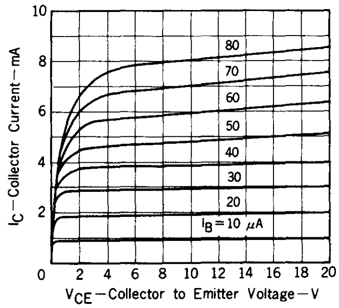
h_{FE} Test Conditions : V_{CE} = 6.0 V, I_C = 1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

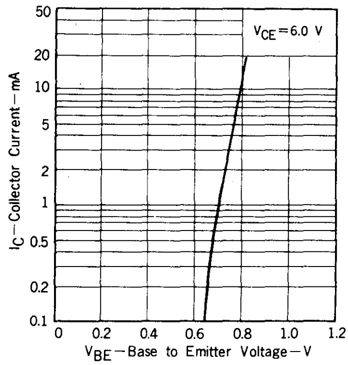
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



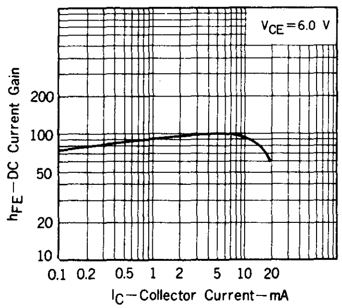
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



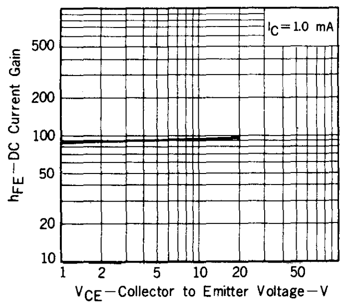
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



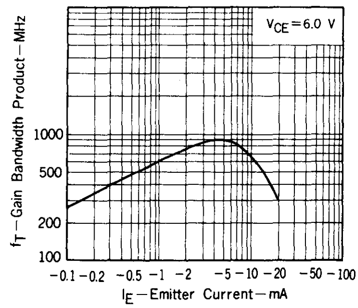
DC CURRENT GAIN vs. COLLECTOR CURRENT



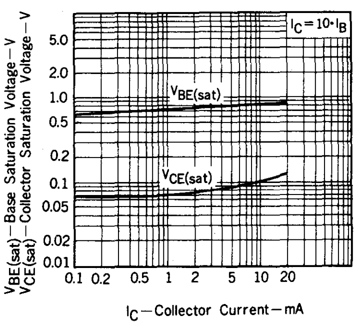
DC CURRENT GAIN vs. COLLECTOR TO EMITTER VOLTAGE



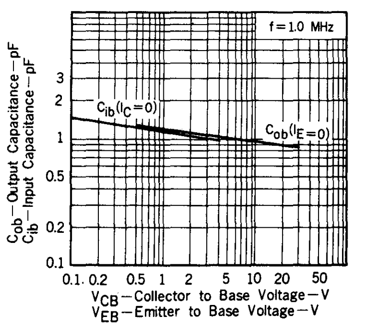
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



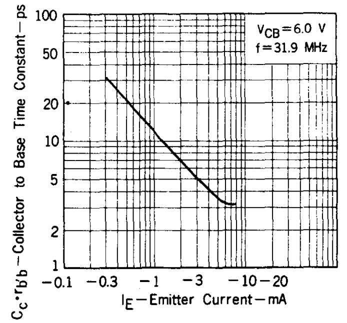
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



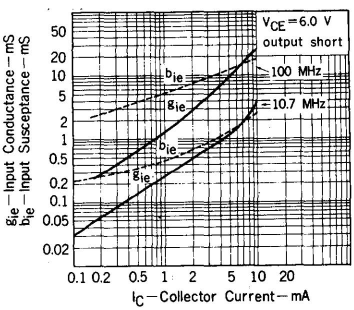
INPUT CAPACITANCE vs. EMITTER TO BASE VOLTAGE, OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



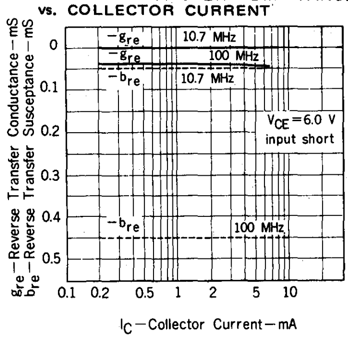
COLLECTOR TO BASE TIME CONSTANT vs. EMITTER CURRENT



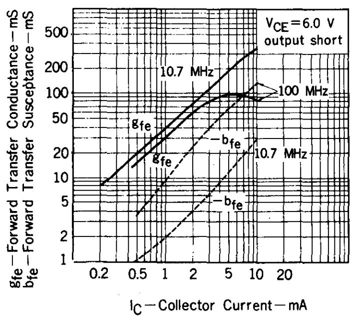
INPUT ADMITTANCE vs. COLLECTOR CURRENT



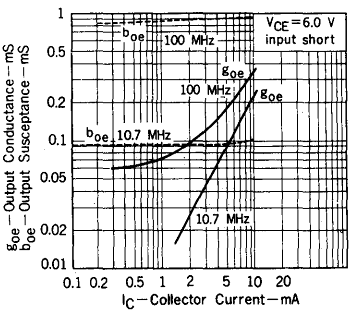
REVERSE TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



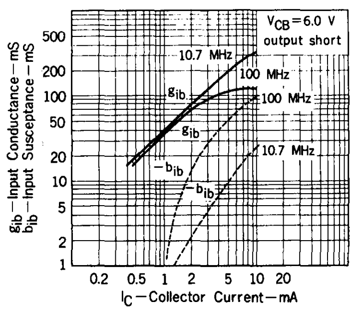
FORWARD TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



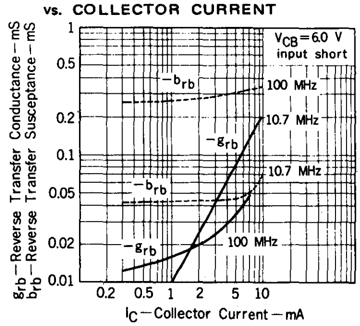
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



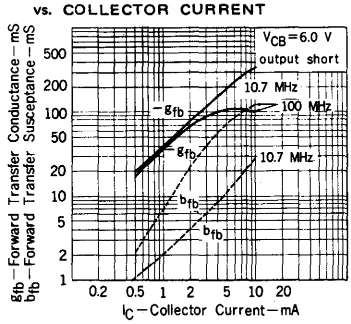
INPUT ADMITTANCE vs. COLLECTOR CURRENT



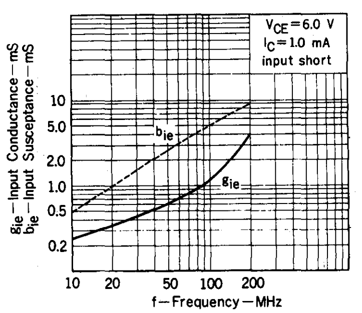
REVERSE TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



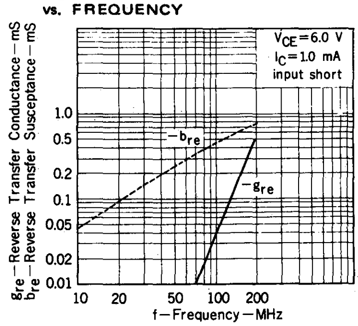
FORWARD TRANSFER ADMITTANCE vs. COLLECTOR CURRENT

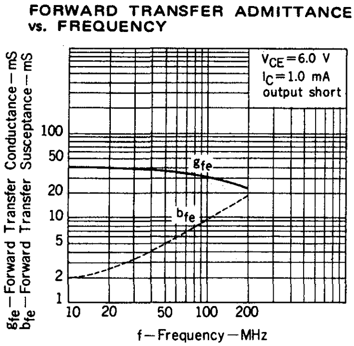


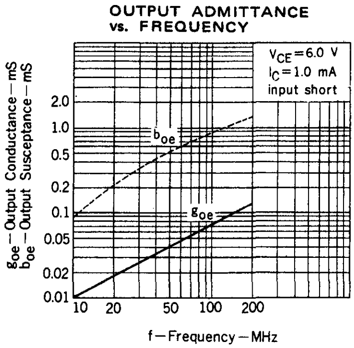
INPUT ADMITTANCE vs. FREQUENCY

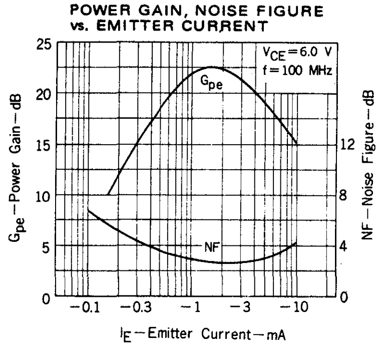


REVERSE TRANSFER ADMITTANCE vs. FREQUENCY

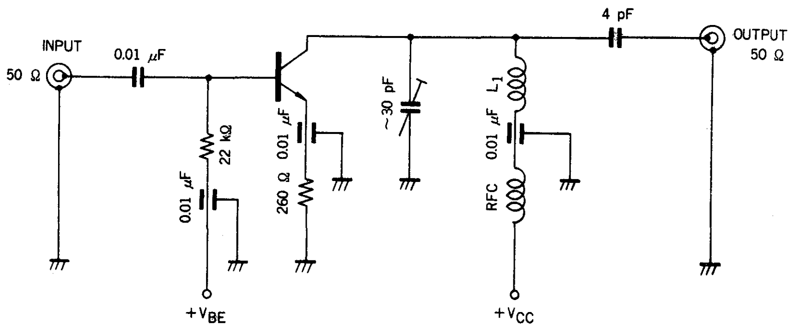








100 MHz G_{pe}, NF TEST CIRCUIT



NPN SILICON TRANSISTOR
2SC1675

DESCRIPTION

The 2SC1675 is designed for use in AM converter, AM/FM IF amplifier and local oscillator of AM/FM tuner.

FEATURES

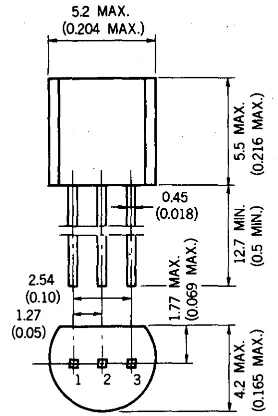
- Small output capacitance (C_{ob} = 1.9 pF TYP.)
- Low noise figure (NF = 2.0 dB TYP. @1.0 MHz)

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
Storage Temperature . . . . −55 to +125 °C
Junction Temperature . . . . +125 °C Maximum
Maximum Power Dissipation (Ta = 25 °C)
Total Power Dissipation . . . . 250 mW
Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO}	Collector to Base Voltage	50	V
V_{CEO}	Collector to Emitter Voltage	30	V
V_{EBO}	Emitter to Base Voltage	5.0	V
I_C	Collector Current	30	mA
I_B	Base Current	30	mA

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC: TO-92
IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	40	90	180	–	V_{CE}=6.0 V, I_C=1.0 mA
C_{ob}	Output Capacitance		1.9	2.2	pF	V_{CB}=6.0 V, I_E=0, f=1.0 MHz
NF	Noise Figure		2.0	4.0	dB	V_{CE}=6.0 V, I_E=−1.0 mA, R_G=500 Ω, f=1.0 MHz
f_T	Gain Bandwidth Product	150	250		MHz	V_{CE}=6.0 V, I_E=−1.0 mA
$C_c \cdot r_{b'b}$	Collector to Base Time Constant		10	15	ps	V_{CE}=6.0 V, I_E=−10 mA, f=31.9 MHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB}=50 V, I_E=0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB}=5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	0.65	0.70	0.75	V	V_{CE}=6.0 V, I_C=1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.08	0.30	V	I_C=10 mA, I_B=1.0 mA

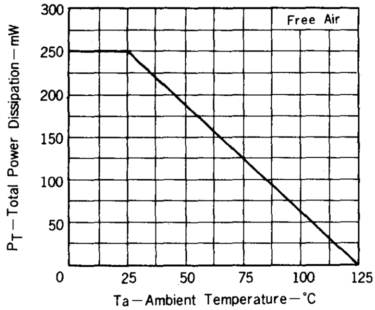
Classification of h_{FE}

Rank	M	L	K
Range	40−80	60−120	90−180

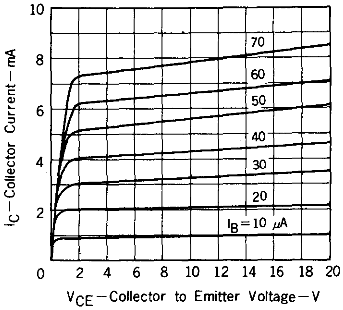
h_{FE} Test Conditions : V_{CE} = 6.0 V, I_C = 1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

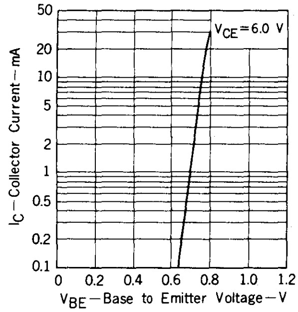
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



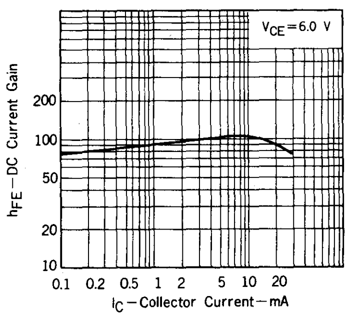
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



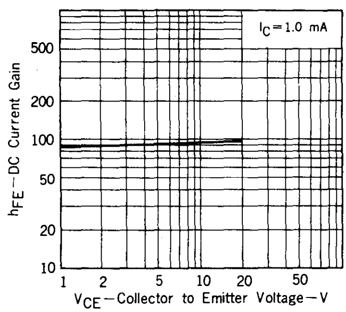
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



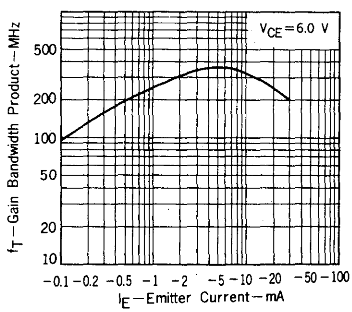
DC CURRENT GAIN vs. COLLECTOR CURRENT



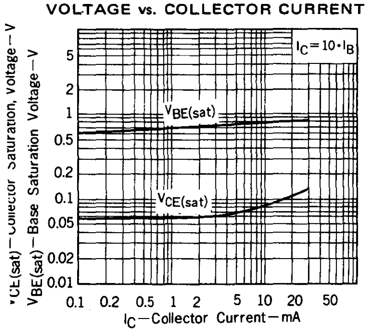
DC CURRENT GAIN vs. COLLECTOR TO EMITTER VOLTAGE



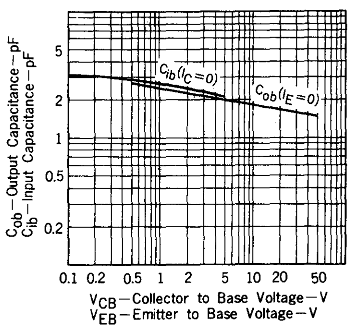
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



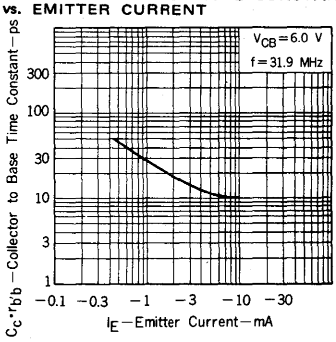
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



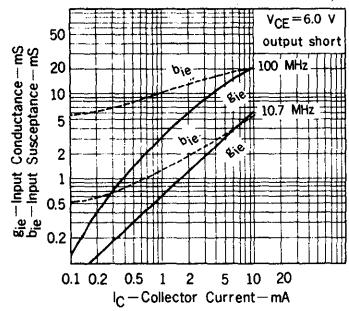
INPUT CAPACITANCE vs. EMITTER TO BASE VOLTAGE, OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



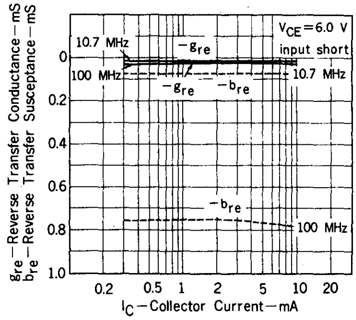
COLLECTOR TO BASE TIME CONSTANT vs. EMITTER CURRENT



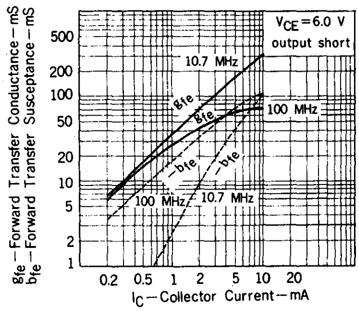
INPUT ADMITTANCE vs. COLLECTOR CURRENT



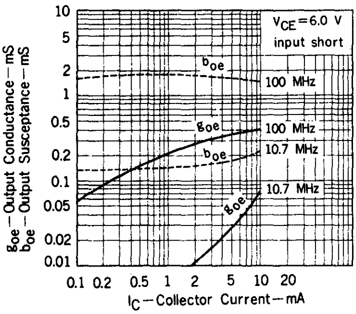
REVERSE TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



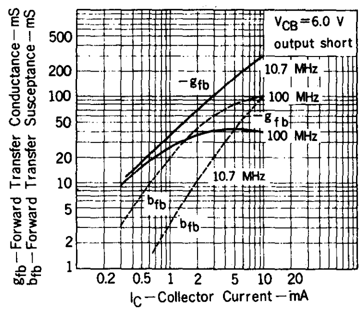
FORWARD TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



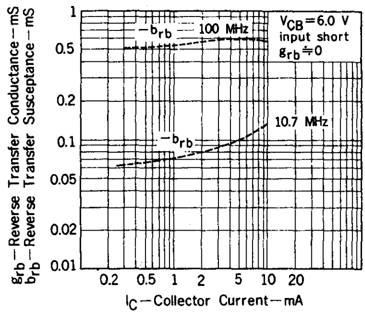
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



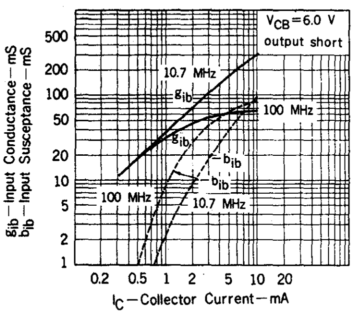
FORWARD TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



REVERSE TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



INPUT ADMITTANCE vs. COLLECTOR CURRENT



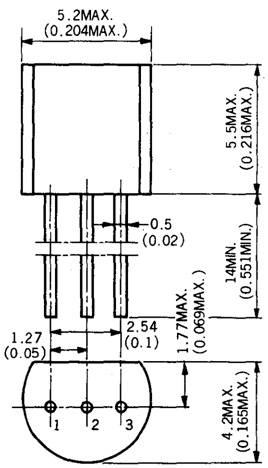
NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SC1730

UHF/VHF OSCILLATOR AND VHF MIXER
NPN SILICON EPITAXIAL TRANSISTOR

2

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Collector
3. Base

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

DESCRIPTION

The 2SC1730 is an NPN silicon epitaxial transistor intended for use as VHF and UHF oscillators and a VHF mixer in a tuner of a TV receiver.

The device features stable oscillation and small frequency drift against any change of the supply voltage and the ambient temperature.

FEATURES

- High Gain Bandwidth Product; f_T = 1100MHz TYP.
- Low Collector to Base Time Constant; $C_c \cdot r_{b'b}$ = 10ps TYP.
- Low Output Capacitance; C_{ob} = 1.5pF MAX.

ABSOLUTE MAXIMUM RATINGS (Ta=25°C)

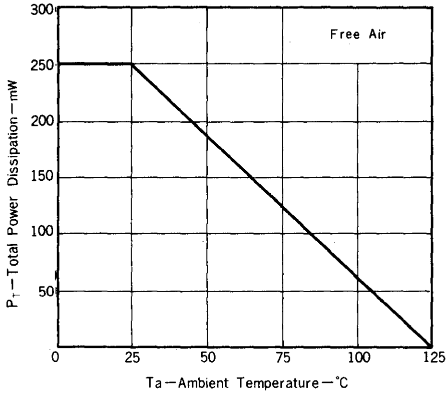
Maximum Voltages and Current		
Collector to Base Voltage	V_{CBO}	30V
Collector to Emitter Voltage	V_{CEO}	15V
Emitter to Base Voltage	V_{EBO}	5.0V
Collector Current	I_C	50mA
Maximum Power Dissipation		
Total Power Dissipation	P_T	250mW
Maximum Temperatures		
Junction Temperature	T_j	125°C
Storage Temperature	T_{stg}	-55 to +125°C

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

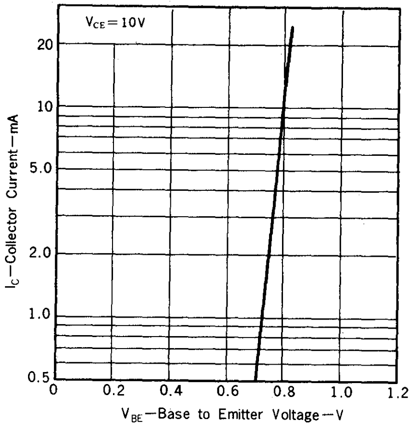
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB} = 12V, I_E = 0
DC Current Gain	h_{FE}	40	100	180		V_{CE} = 10V, I_C = 5.0mA
Collector Saturation Voltage	$V_{CE(sat)}$			0.5	V	I_C = 10mA, I_B = 1.0mA
Gain Bandwidth Product	f_T	800	1100		MHz	V_{CE} = 10V, I_E = -5.0mA
Output Capacitance	C_{ob}			1.5	pF	V_{CB} = 10V, I_E = 0 f = 1.0MHz
Collector to Base Time Constant	$C_c \cdot r_{b'b}$		10	15	ps	V_{CE} = 10V, I_E = -5.0mA f = 31.9MHz

TYPICAL CHARACTERISTICS (Ta = 25 °C)

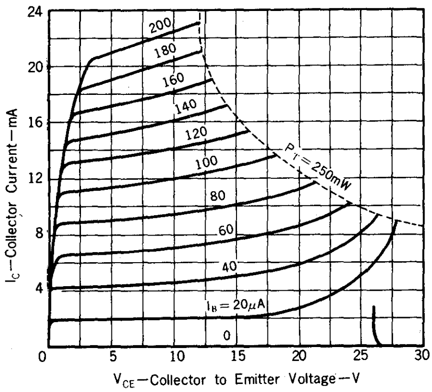
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



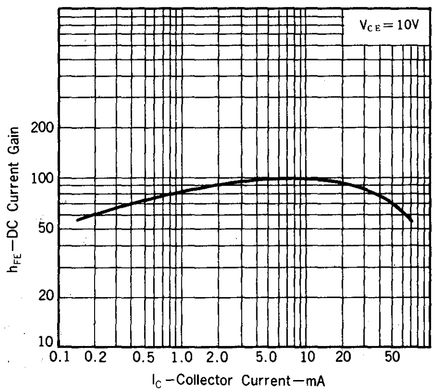
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



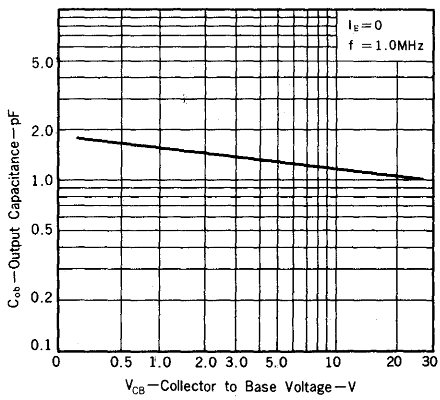
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



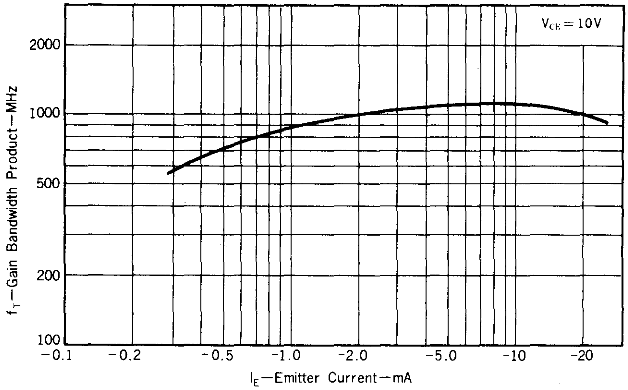
DC CURRENT GAIN vs.
COLLECTOR CURRENT



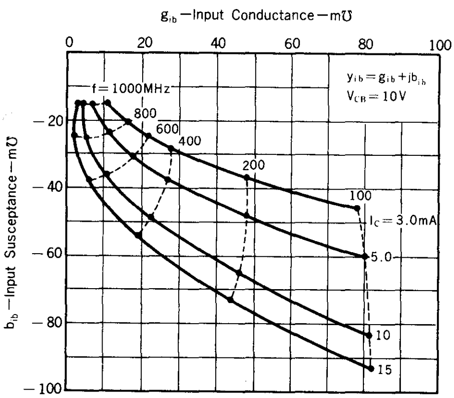
OUTPUT CAPACITANCE vs.
COLLECTOR TO BASE VOLTAGE



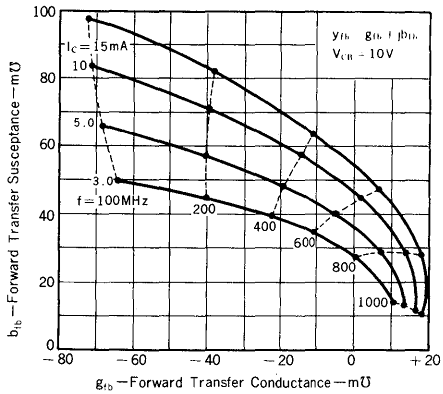
GAIN BANDWIDTH PRODUCT
vs. EMITTER CURRENT



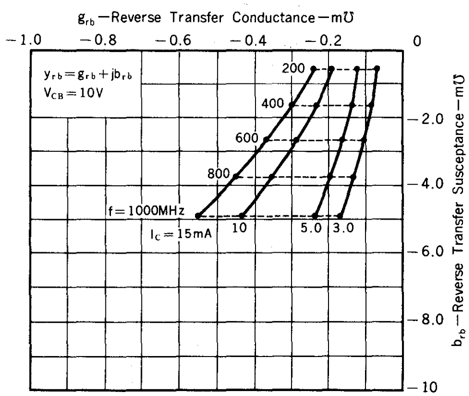
INPUT ADMITTANCE (y_{ib})
vs. FREQUENCY



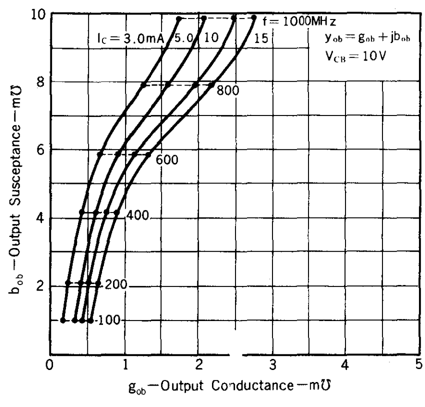
FORWARD TRANSFER ADMITTANCE (y_{fb})
vs. FREQUENCY



REVERSE TRANSFER ADMITTANCE (y_{rb})
vs. FREQUENCY



OUTPUT ADMITTANCE (y_{ob})
vs. FREQUENCY



NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC1840

DESCRIPTION The 2SC1840 is designed for use in AF amplifier, driver and low speed switching.

FEATURES
- High h_{FE} h_{FE} : 400 TYP. (V_{CE} = 6.0 V, I_C = 1.0 mA)

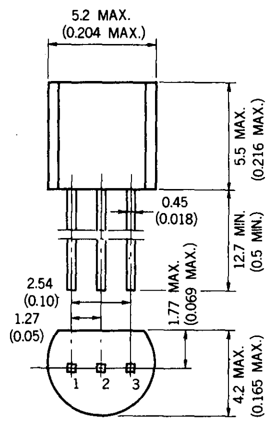
ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature . . . . −55 to +125 °C
- Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation . . . . 500 mW

Maximum Voltages and Currents (Ta = 25 °C)
- V_{CBO} Collector to Base Voltage . . . . 40 V
- V_{CEO} Collector to Emitter Voltage . . . . 35 V
- V_{EBO} Emitter to Base Voltage . . . . 5.0 V
- I_C Collector Current . . . . 100 mA
- I_B Base Current . . . . 20 mA

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. COLLECTOR JEDEC : TO-92
3. BASE IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	150	370		–	V_{CE} = 6.0 V, I_C = 0.1 mA
h_{FE2}	DC Current Gain	200	400	800	–	V_{CE} = 6.0 V, I_C = 1.0 mA
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE} = 6.0 V, I_C = 1.0 mA
Cob	Output Capacitance			8.0	pF	V_{CB} = 10 V, I_E = 0, f = 1.0 MHz
I_{CBO}	Collector Cutoff Current			50	nA	V_{CB} = 40 V, I_E = 0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE} = 30 V, R_{BE} = ∞
I_{EBO}	Emitter Cutoff Current			50	nA	V_{EB} = 5.0 V, I_C = 0
V_{BE}	Base to Emitter Voltage	0.55	0.59	0.65	V	V_{CE} = 6.0 V, I_C = 1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.13	0.30	V	I_C = 100 mA, I_B = 10 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.84	1.00	V	I_C = 100 mA, I_B = 10 mA

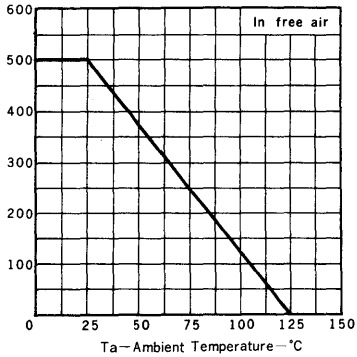
Classification of h_{FE2}

Rank	P	F	E
Range	200 – 400	300 – 600	400 – 800

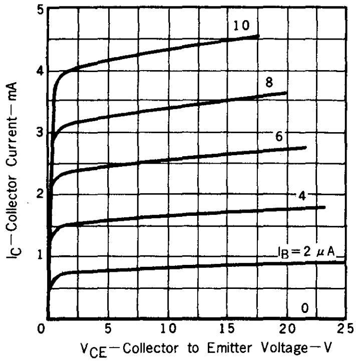
h_{FE} Test Conditions : V_{CE} = 6.0 V, I_C = 1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

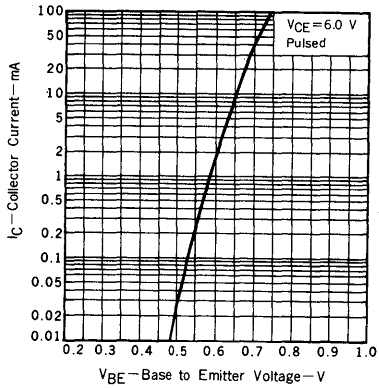
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



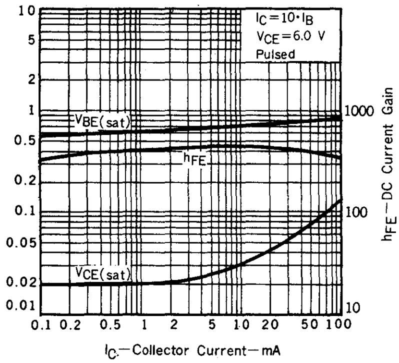
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



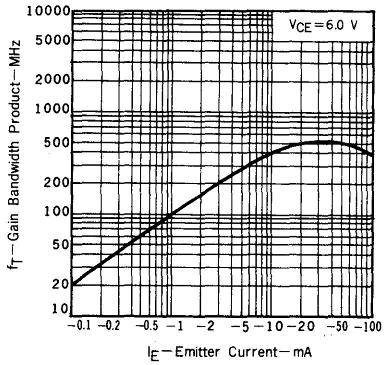
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



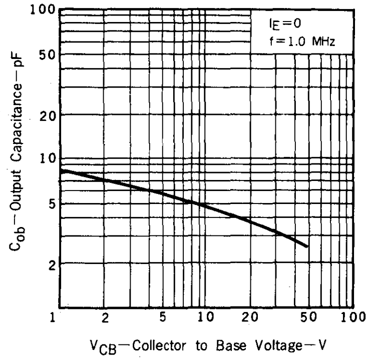
DC CURRENT GAIN, COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC1841

DESCRIPTION The 2SC1841 is designed for use in AF amplifier, driver and low speed switching.

FEATURES

- High Voltage V_{CEO} : 120 V
- High h_{FE} h_{FE} : 600 TYP. (V_{CE} = 6.0 V, I_C = 1.0 mA)

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −55 to +125 °C

Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation . . . . 500 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO} Collector to Base Voltage . . . . 120 V

V_{CEO} Collector to Emitter Voltage . . . . . . 120 V

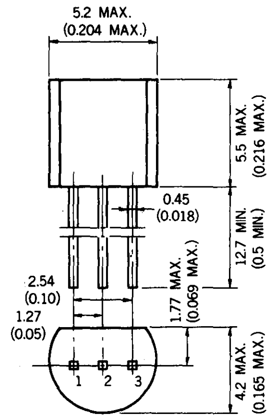
V_{EBO} Emitter to Base Voltage . . . . 5.0 V

I_C Collector Current . . . . 50 mA

I_B Base Current . . . . 10 mA

PACKAGE DIMENSIONS

in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. COLLECTOR JEDEC : TO-92
3. BASE IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	150	580			V_{CE} = 6.0 V, I_C = 0.1 mA
h_{FE2}	DC Current Gain	200	600	1200		V_{CE} = 6.0 V, I_C = 1.0 mA
f_T	Gain Bandwidth Product	50	110		MHz	V_{CE} = 6.0 V, I_E = −1.0 mA
C_{ob}	Output Capacitance		1.6	2.5	pF	V_{CB} = 30 V, I_E = 0, f = 1.0 MHz
I_{CBO}	Collector Cutoff Current			50	nA	V_{CB} = 120 V, I_E = 0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE} = 100 V, R_{BE} = ∞
I_{EBO}	Emitter Cutoff Current			50	nA	V_{EB} = 5.0 V, I_C = 0
V_{BE}	Base to Emitter Voltage	550	590	650	mV	V_{CE} = 6.0 V, I_C = 1.0 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.73	1.0	V	I_C = 10 mA, I_B = 1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		70	300	mV	I_C = 10 mA, I_B = 1.0 mA

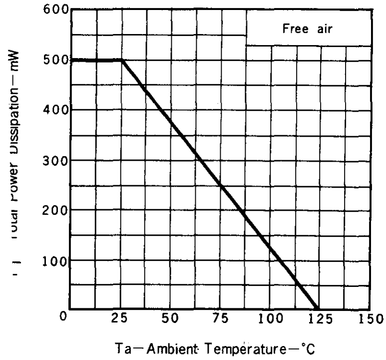
Classification of h_{FE2}

Rank	P	F	E	U
Range	200 – 400	300 – 600	400 – 800	600 – 1200

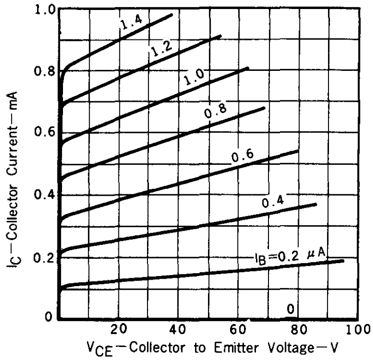
h_{FE} Test Conditions : V_{CE} = 6.0 V, I_C = 1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

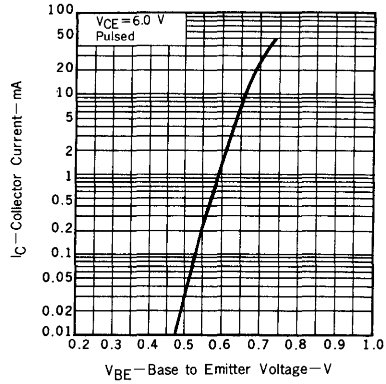
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



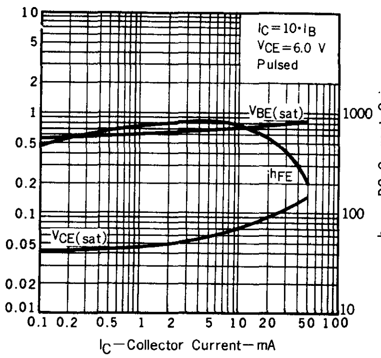
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



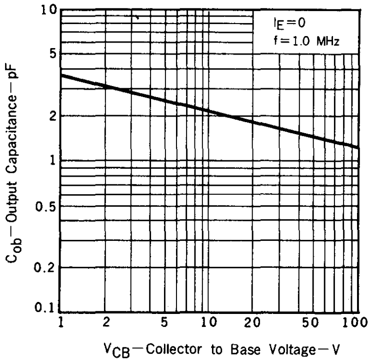
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



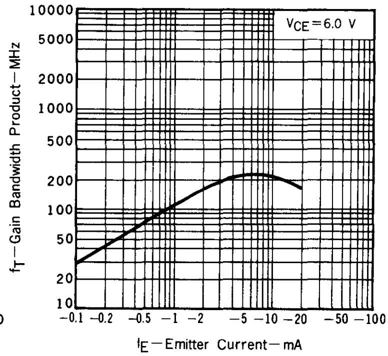
DC CURRENT GAIN, COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR

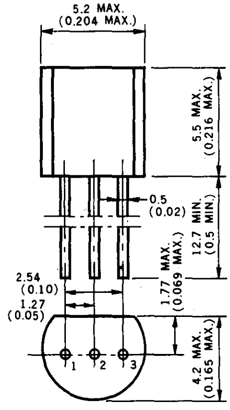
2SC1842

DESCRIPTION The 2SC1842 is designed for use in an AF amplifier and general purpose.

FEATURES

- High h_{FE}. h_{FE} : 600 TYP. (V_{CE} = 6.0 V, I_C = 1.0 mA)
- Low Noise Voltage. NV : 30 mV TYP. (V_{CE} = 6.0 V, I_C = 1.0 mA, R_G = 100 kΩ, G_V = 80 dB, f = 10 Hz to 1.0 kHz)

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. COLLECTOR JEDEC : TO-92
3. BASE IEC : PA33

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures

Storage Temperature		−55 to +125 °C
Junction Temperature		+125 °C Maximum
Maximum Power Dissipation (Ta = 25 °C)		
Total Power Dissipation		250 mW
Maximum Voltages and Currents (Ta = 25 °C)		
V_{CBO}	Collector to Base Voltage	40 V
V_{CEO}	Collector to Emitter Voltage	35 V
V_{EBO}	Emitter to Base Voltage	5.0 V
I_C	Collector Current	100 mA
I_B	Base Current	20 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	150	580		–	V_{CE} = 6.0 V, I_C = 0.1 mA
h_{FE2}	DC Current Gain	200	600	1200	–	V_{CE} = 6.0 V, I_C = 1.0 mA
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE} = 6.0 V, I_C = 1.0 mA
Cob	Output Capacitance		3.0	4.0	pF	V_{CB} = 6.0 V, I_E = 0, f = 1.0 MHz
NV	Noise Voltage		30	50	mV	V_{CE} = 5.0 V, I_C = 1.0 mA, R_G = 100 kΩ, G_V = 80 dB, f = 10 Hz to 1.0 kHz
I_{CBO}	Collector Cutoff Current			50	nA	V_{CB} = 40 V, I_E = 0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE} = 30 V, R_{BE} = ∞
I_{EBO}	Emitter Cutoff Current			50	nA	V_{EB} = 5.0 V, I_C = 0
$V_{BE(sat)}$	Base Saturation Voltage		0.86	1.0	V	I_C = 100 mA, I_B = 10 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.15	0.3	V	I_C = 100 mA, I_B = 10 mA
V_{BE}	Base to Emitter Voltage	0.55	0.60	0.65	V	V_{CE} = 6.0 V, I_C = 1.0 mA

Classification of h_{FE2}

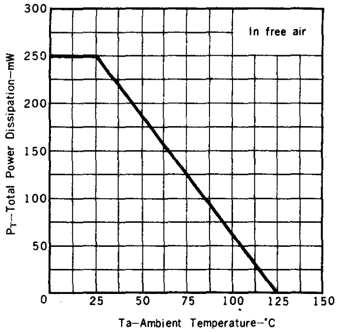
Rank	P	F	E	U
Range	200 – 400	300 – 600	400 – 800	600 – 1200

h_{FE} Test Conditions : V_{CE} = 6.0 V, I_C = 1.0 mA

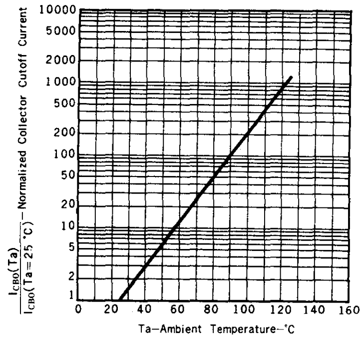
2

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

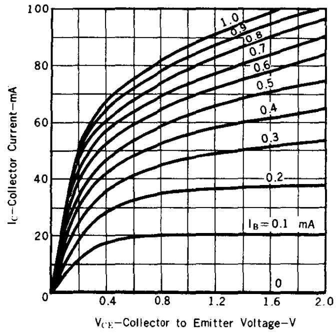
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



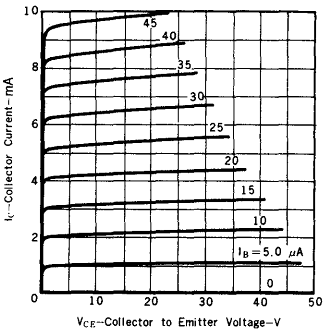
NORMALIZED COLLECTOR CUTOFF CURRENT vs. AMBIENT TEMPERATURE



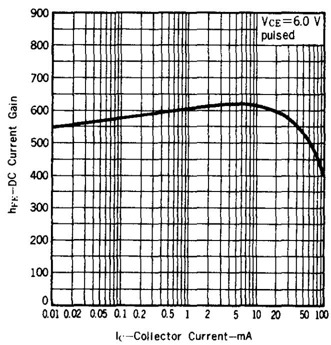
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



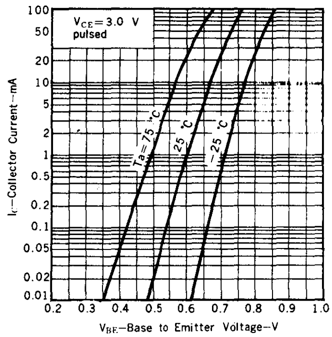
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



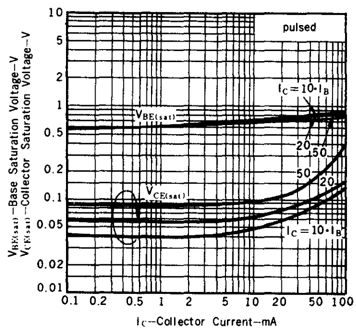
DC CURRENT GAIN vs. COLLECTOR CURRENT



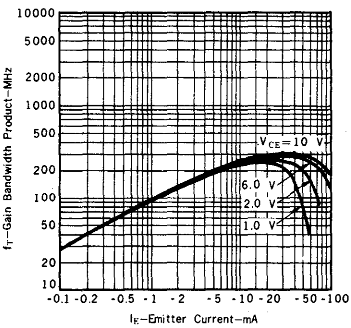
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



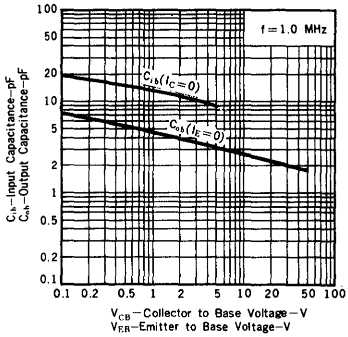
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



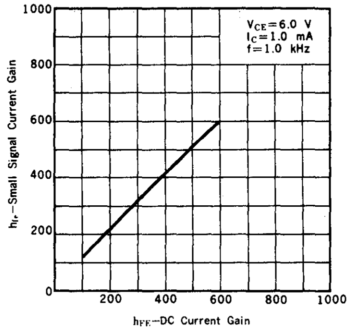
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



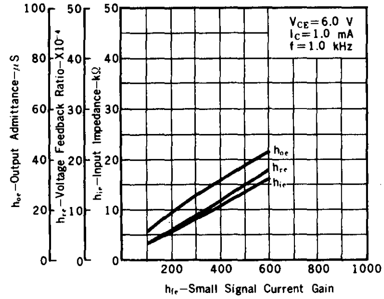
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



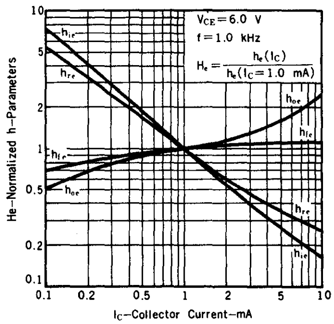
SMALL SIGNAL CURRENT GAIN vs. DC CURRENT GAIN



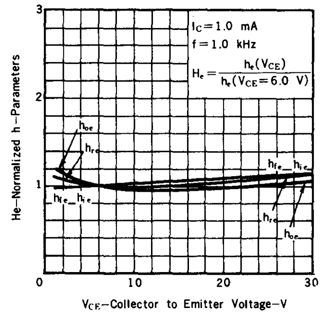
INPUT IMPEDANCE, VOLTAGE FEEDBACK RATIO AND OUTPUT ADMITTANCE vs. SMALL SIGNAL CURRENT GAIN



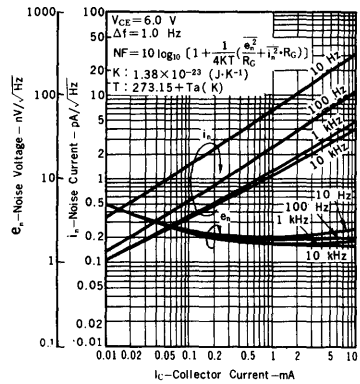
NORMALIZED h-PARAMETERS vs. COLLECTOR CURRENT



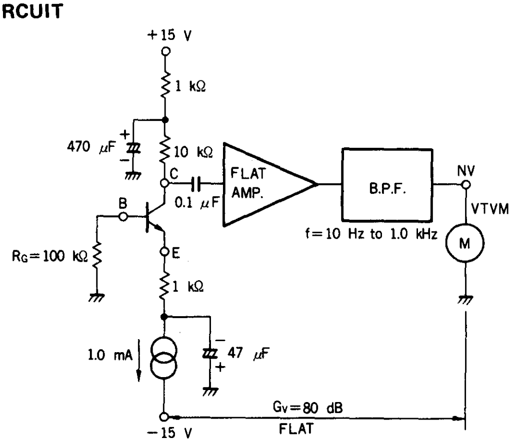
NORMALIZED h-PARAMETERS vs. COLLECTOR TO EMITTER VOLTAGE



e_n AND i_n vs. COLLECTOR CURRENT



NOISE VOLTAGE TEST CIRCUIT



$V_{CE}≒5$ V, I_C=1.0 mA, R_G=100 kΩ, Gv=80 dB, FLAT(f=10 Hz to 1.0 kHz)

NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC1843

2

DESCRIPTION The 2SC1843 is designed for use in an AF amplifier of low level low noise and general purpose.

FEATURES

- High h_{FE}. h_{FE} : 400 TYP. (V_{CE} = 6.0 V, I_C = 1.0 mA)
- Low Noise Voltage. NV : 30 mV TYP. (V_{CE} = 5.0 V, I_C = 1.0 mA, R_G = 100 kΩ, G_v = 80 dB, f = 10 Hz to 1.0 kHz)

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures

Storage Temperature . . . . −55 to +125 °C

Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO} Collector to Base Voltage . . . . 60 V

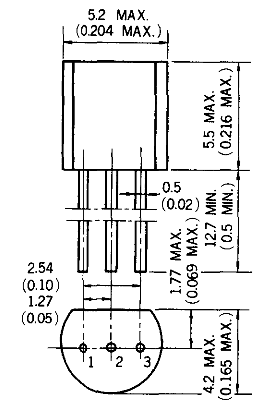
V_{CEO} Collector to Emitter Voltage . . . . 50 V

V_{EBO} Emitter to Base Voltage . . . . 5.0 V

I_C Collector Current . . . . 100 mA

I_B Base Current . . . . 20 mA

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. COLLECTOR JEDEC : TO-92
3. BASE IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	150	370		–	V_{CE} = 6.0 V, I_C = 0.1 mA
h_{FE2}	DC Current Gain	200	400	800	–	V_{CE} = 6.0 V, I_C = 1.0 mA
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE} = 6.0 V, I_C = 1.0 mA
C_{ob}	Output Capacitance		3.0	4.0	pF	V_{CB} = 6.0 V, I_E = 0, f = 1.0 MHz
NV	Noise Voltage		30	40	mV	V_{CE} = 5.0 V, I_C = 1.0 mA, R_G = 100 kΩ, G_v = 80 dB, f = 10 Hz to 1.0 kHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB} = 60 V, I_E = 0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE} = 40 V, R_{BE} = ∞
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB} = 5.0 V, I_C = 0
V_{BE}	Base to Emitter Voltage	0.55	0.60	0.65	V	V_{CE} = 6.0 V, I_C = 1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.15	0.30	V	I_C = 100 mA, I_B = 10 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.86	1.0	V	I_C = 100 mA, I_B = 10 mA

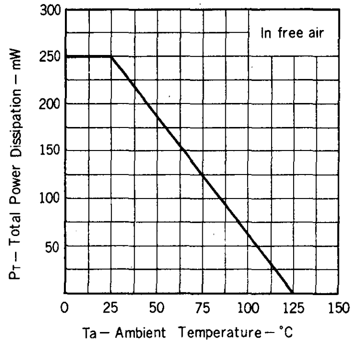
Classification of h_{FE2}

Rank	P	F	E
Range	200 – 400	300 – 600	400 – 800

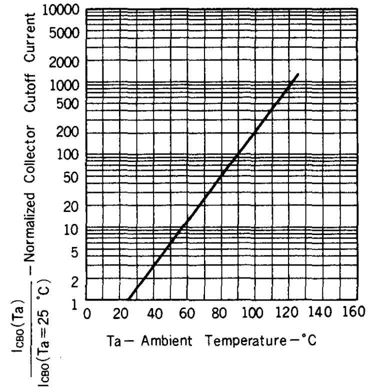
h_{FE} Test Conditions : V_{CE} = 6.0 V, I_C = 1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

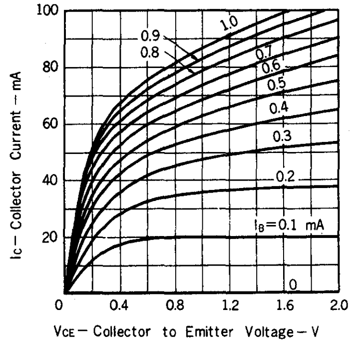
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



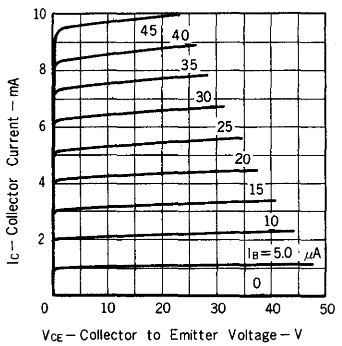
NORMALIZED COLLECTOR CUTOFF CURRENT vs. AMBIENT TEMPERATURE



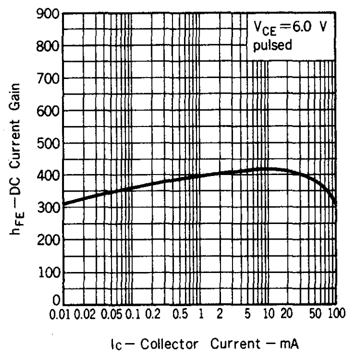
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



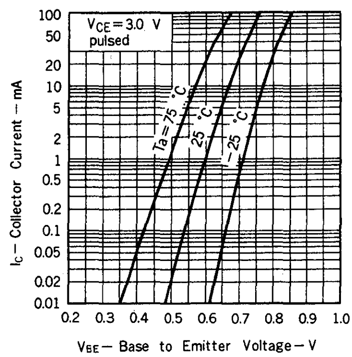
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



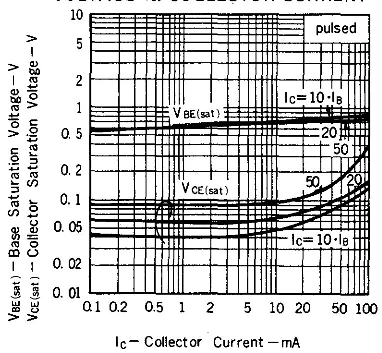
DC CURRENT GAIN vs. COLLECTOR CURRENT



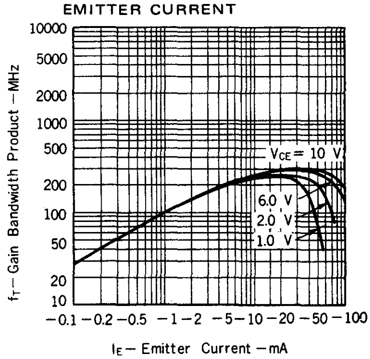
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



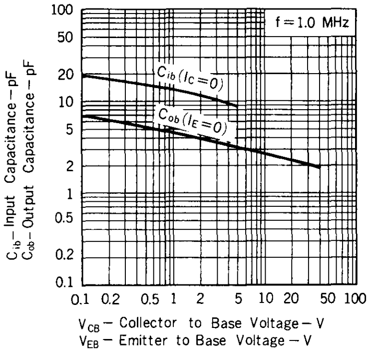
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



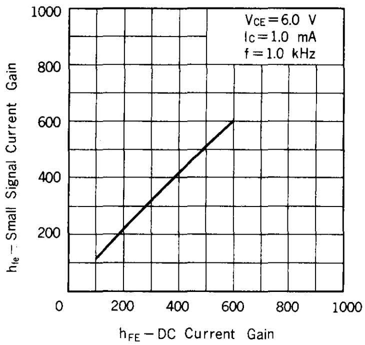
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



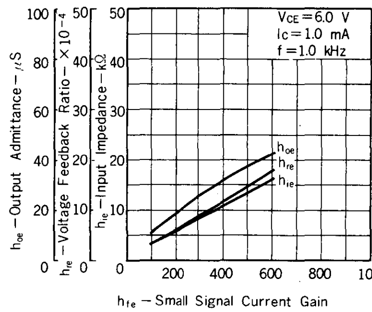
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



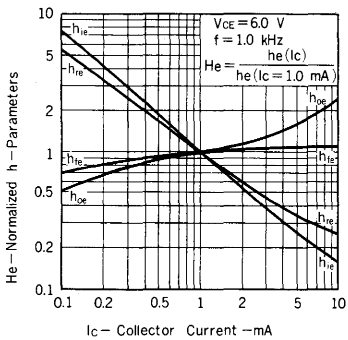
SMALL SIGNAL CURRENT GAIN vs. DC CURRENT GAIN



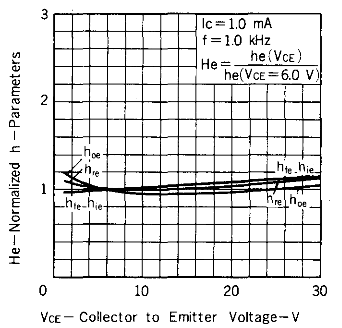
INPUT IMPEDANCE, VOLTAGE FEEDBACK RATIO AND OUTPUT ADMITTANCE vs. SMALL SIGNAL CURRENT GAIN



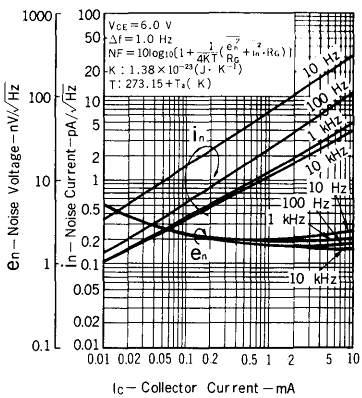
NORMALIZED h-PARAMETERS vs. COLLECTOR CURRENT



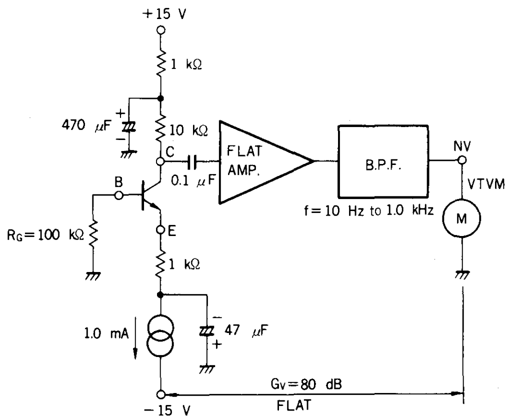
NORMALIZED h-PARAMETERS vs. COLLECTOR TO EMITTER VOLTAGE



e_n AND i_n vs. COLLECTOR CURRENT



NOISE VOLTAGE TEST CIRCUIT



V_{CE} ≒ 5 V, I_C = 1.0 mA, R_G = 100 kΩ, Gv = 80 dB, FLAT (f = 10 Hz to 1.0 kHz)

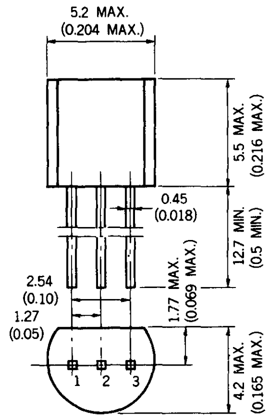
NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC1844

DESCRIPTION The 2SC1844 is the best for the head amplifier of tape recorders, the equalizer of moving coil type record players, and etc.

FEATURES
- Super Low Noise. NV : 30 mV TYP. (See test circuit.)
- High h_{FE}. h_{FE} : 400 TYP. (V_{CE} = 6.0 V, I_C = 1.0 mA)
- Complementary to 2SA991.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER EIAJ : SC-43
2. COLLECTOR JEDEC : TO-92
3. BASE IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −55 to +125 °C

Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation . . . . 500 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO}	Collector to Base Voltage	60	V
V_{CEO}	Collector to Emitter Voltage	60	V
V_{EBO}	Emitter to Base Voltage	5.0	V
I_C	Collector Current	100	mA
I_B	Base Current	20	mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	150	370		–	V_{CE} = 6.0 V, I_C = 0.1 mA
h_{FE2}	DC Current Gain	200	400	800	–	V_{CE} = 6.0 V, I_C = 1.0 mA
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE} = 6.0 V, I_C = 1.0 mA
Cob	Output Capacitance		4.8	8.0	pF	V_{CB} = 10 V, I_E = 0, f = 1.0 MHz
NV	Noise Voltage		30	45	mV	V_{CE} = 5.0 V, I_C = 1.0 mA, R_G = 100 kΩ G_V = 80 dB, f = 10 Hz to 1.0 kHz
I_{CBO}	Collector Cutoff Current			50	nA	V_{CB} = 60 V, I_E = 0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE} = 50 V, R_{BE} = ∞
I_{EBO}	Emitter Cutoff Current			50	nA	V_{EB} = 5.0 V, I_C = 0
V_{BE}	Base to Emitter Voltage	0.55	0.59	0.65	V	V_{CE} = 6.0 V, I_C = 1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.13	0.30	V	I_C = 100 mA, I_B = 10 mA

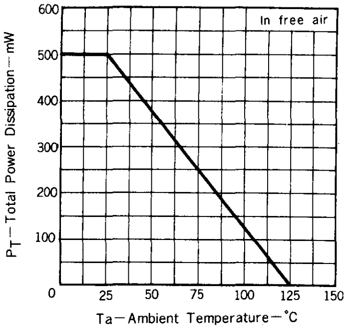
Classification of h_{FE2}

Rank	P	F	E
Range	200 – 400	300 – 600	400 – 800

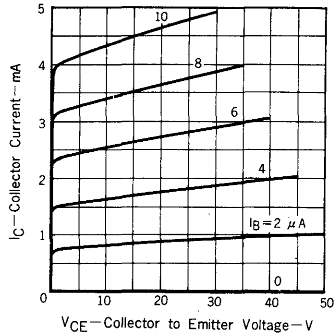
h_{FE} Test Conditions : V_{CE} = 6.0 V, I_C = 1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

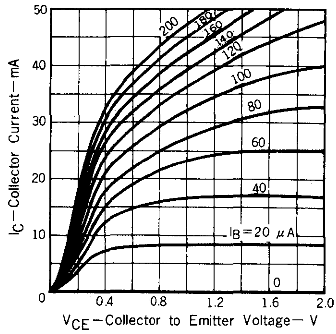
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



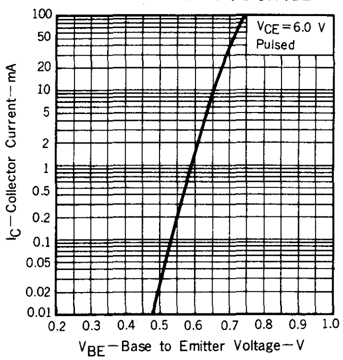
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



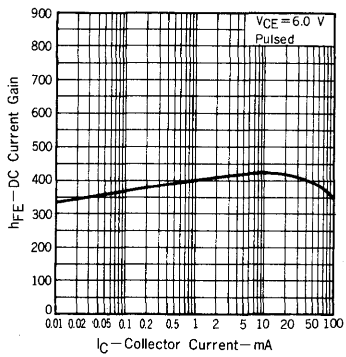
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



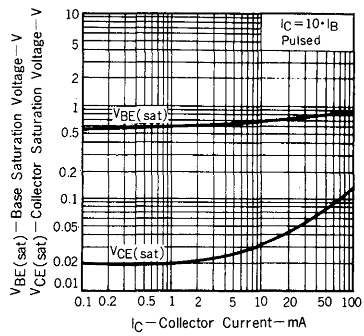
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



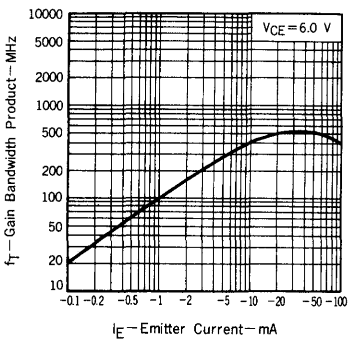
DC CURRENT GAIN vs. COLLECTOR CURRENT



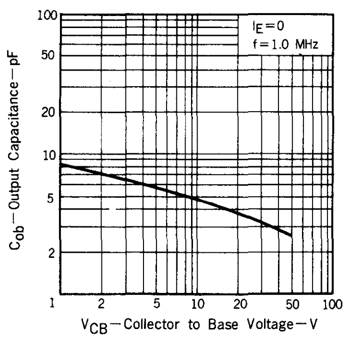
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



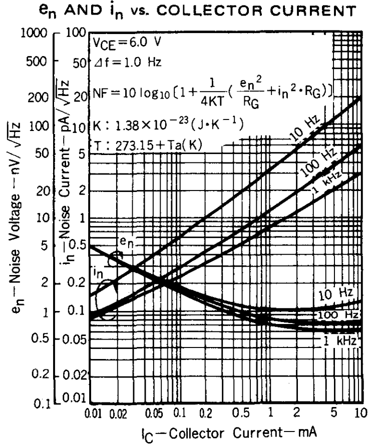
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



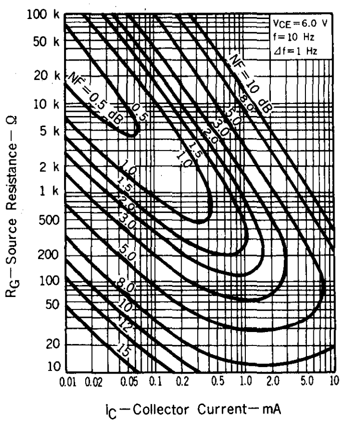
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



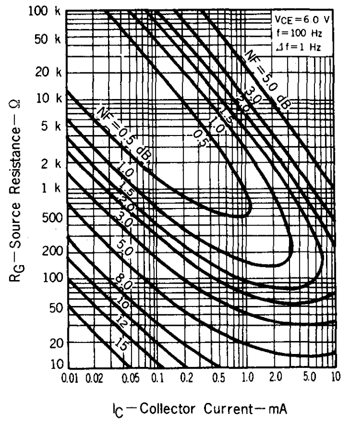
e_n AND i_n vs. COLLECTOR CURRENT



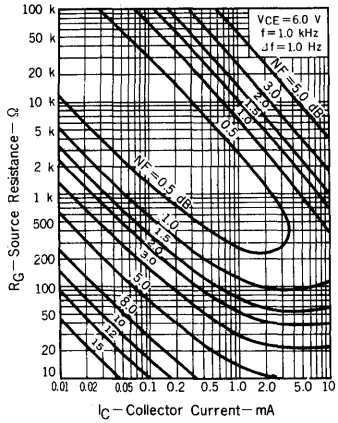
NOISE FIGURE MAP



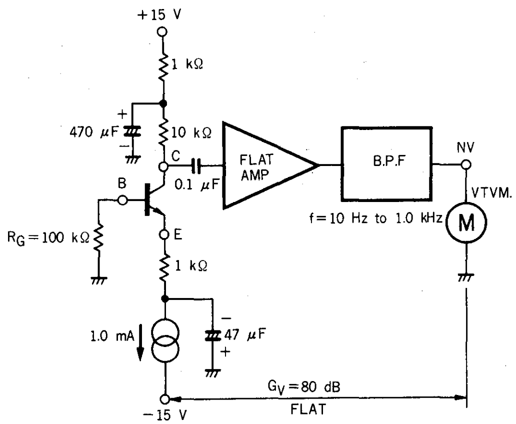
NOISE FIGURE MAP 2



NOISE FIGURE MAP 3



NOISE VOLTAGE TEST CIRCUIT



$V_{CE} \doteqdot 5$ V, $I_C = 1.0$ mA, $R_G = 100$ kΩ, $G_V = 80$ dB FLAT(f=10 Hz to 1.0 kHz)

NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC1845

DESCRIPTION The 2SC1845 is the best for use as the middle range amplifier in Hi-Fi stereo control amplifiers, power amplifiers, and etc.

FEATURES

- High Voltage. V_{CEO} : 120 V
- Low Output Capacitance. C_{ob} : 1.6 pF TYP. (V_{CB} = 30 V)
- High h_{FE}. h_{FE} : 600 TYP. (V_{CE} = 6.0 V, I_C = 1.0 mA)
- Super Low Noise. NV : 25 mV TYP. (See test Circuit.)

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −55 to +125 °C

Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation . . . . 500 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO} Collector to Base Voltage . . . . 120 V

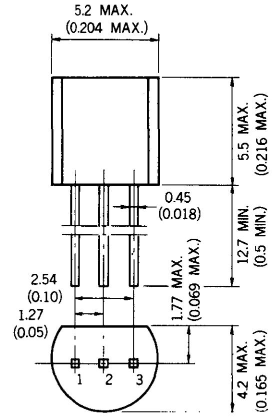
V_{CEO} Collector to Emitter Voltage . . . . 120 V

V_{EBO} Emitter to Base Voltage . . . . 5.0 V

I_C Collector Current . . . . 50 mA

I_B Base Current . . . . 10 mA

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	150	580		–	V_{CE} = 6.0 V, I_C = 0.1 mA
h_{FE2}	DC Current Gain	200	600	1200	–	V_{CE} = 6.0 V, I_C = 1.0 mA
f_T	Gain Bandwidth Product	50	110		MHz	V_{CE} = 6.0 V, I_C = 1.0 mA
C_{ob}	Output Capacitance		1.6	2.5	pF	V_{CB} = 30 V, I_E = 0, f = 1.0 MHz
NV	Noise Voltage		25	40	mV	V_{CE} = 5.0 V, I_C = 1.0 mA, R_G = 100 kΩ G_v = 80 dB, f = 10 Hz to 1.0 kHz
I_{CBO}	Collector Cutoff Current			50	nA	V_{CB} = 120 V, I_E = 0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE} = 100 V, R_{BE} = ∞
I_{EBO}	Emitter Cutoff Current			50	nA	V_{EB} = 5.0 V, I_C = 0
V_{BE}	Base to Emitter Voltage	0.55	0.59	0.65	V	V_{CE} = 6.0 V, I_C = 1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.07	0.30	V	I_C = 10 mA, I_B = 1.0 mA

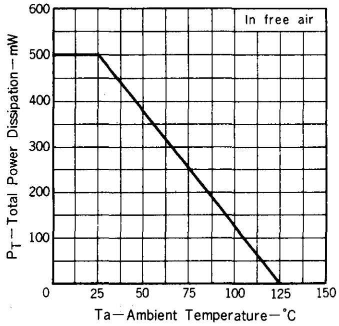
Classification of h_{FE2}

Rank	P	F	E	U
Range	200 – 400	300 – 600	400 – 800	600 – 1200

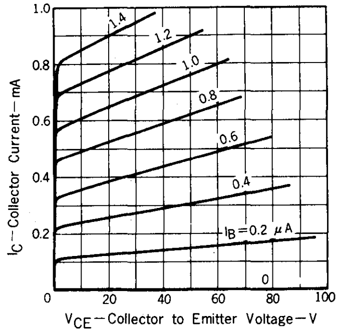
h_{FE} Test Conditions : V_{CE} = 6.0 V, I_C = 1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

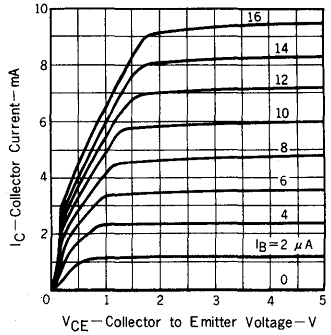
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



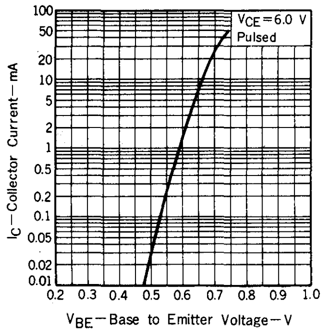
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



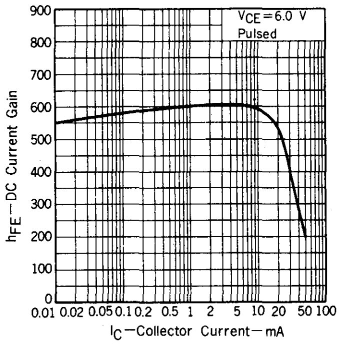
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



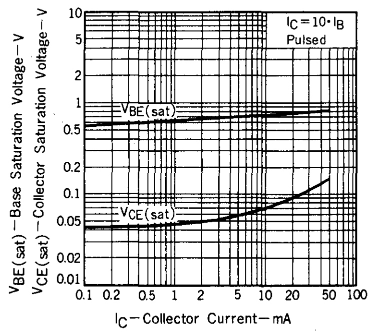
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



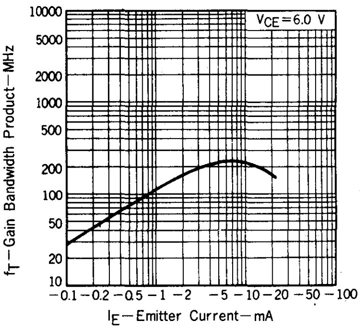
DC CURRENT GAIN vs. COLLECTOR CURRENT



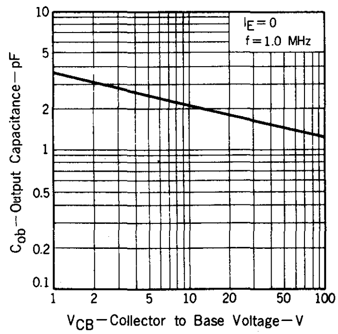
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



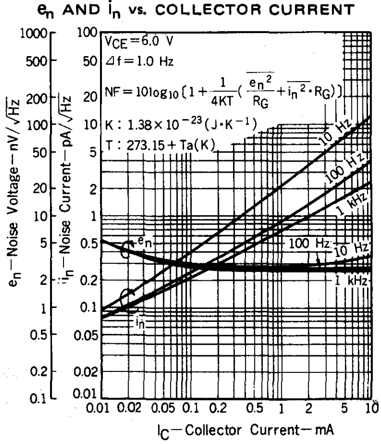
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE

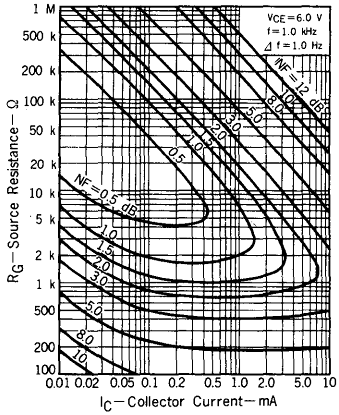


e_n AND i_n vs. COLLECTOR CURRENT

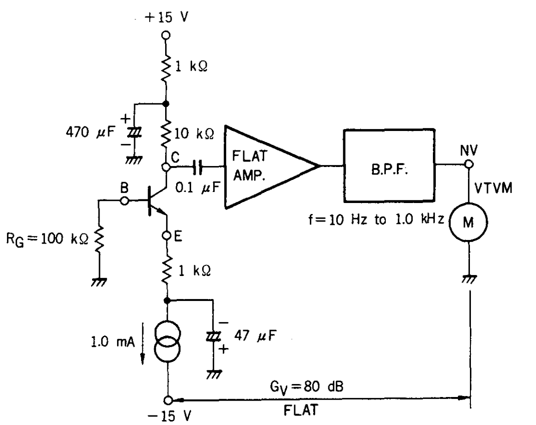


2

NOISE FIGURE MAP.



NOISE VOLTAGE TEST CIRCUIT



$V_{CE} \doteqdot 5$ V, $I_C = 1.0$ mA, $R_G = 100$ kΩ, $G_V = 80$ dB, FLAT(f=10 Hz to 1.0 kHz)

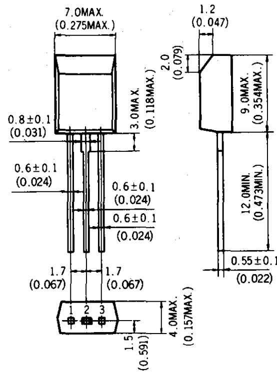
NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC1940

DESCRIPTION The 2SC1940 is designed for use in driver stages of audio frequency amplifiers.

FEATURES
- High total power dissipation and high breakdown voltage: 1.0W at 25°C ambient temperature/V_{CEO} = 120V
- Complementary to the NEC 2SA915 PNP transistor.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Collector
3. Base

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature .... –55 to +150°C
- Junction Temperature .... +150°C Maximum

Maximum Power Dissipation (Ta = 25°C)
- Total Power Dissipation 1.0W
- Thermal Resistance(Junction to Ambient) ..... 125°C/W

Maximum Voltages and Currents (Ta = 25°C)

V_{CBO}	Collector to Base Voltage	120	V
V_{CEO}	Collector to Emitter Voltage	120	V
V_{EBO}	Emitter to Base Voltage	5.0	V
I_C	Collector Current	50	mA
I_B	Base Current	10	mA

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	90	200	400	–	V_{CE} = 10V, I_C = 10mA
h_{FE2}	DC Current Gain	50	180		–	V_{CE} = 10V, I_C = 1.0mA
f_T	Gain Bandwidth Product	50	120		MHz	V_{CE} = 10V, I_E = –10mA
C_{ob}	Output Capacitance		2.3	3.0	pF	V_{CB} = 10V, I_E = 0, f = 1.0MHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB} = 120V, I_E = 0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB} = 5.0V, I_C = 0
V_{BE}	Base to Emitter Voltage	650	685	750	mV	V_{CE} = 10V, I_C = 10mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.07	0.6	V	I_C = 20mA, I_B = 2.0mA
$V_{BE(sat)}$	Base Saturation Voltage		0.75	1.0	V	I_C = 20mA, I_B = 2.0mA

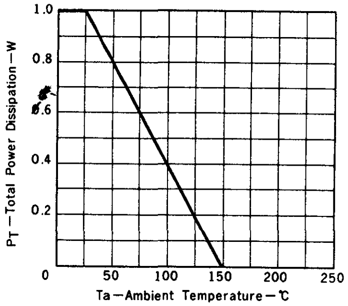
Classification of h_{FE1}

Rank	M	L	K
Range	90 – 180	135 – 270	200 – 400

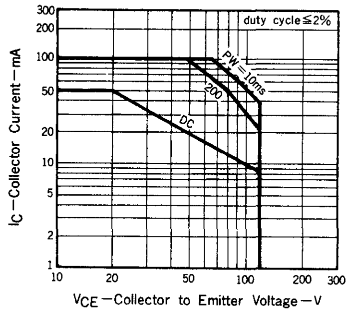
h_{FE1} Test Conditions: V_{CE} = 10V, I_C = 10mA

TYPICAL CHARACTERISTICS (Ta=25°C unless otherwise noted)

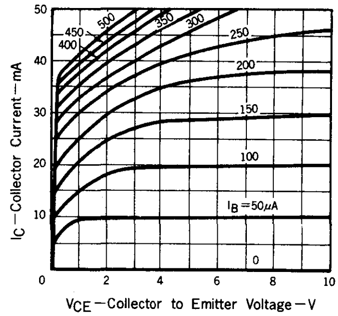
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



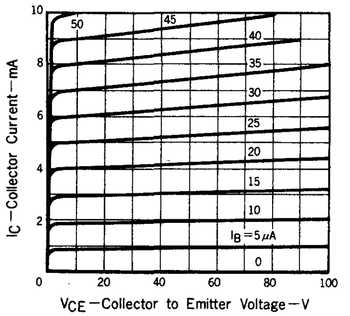
SAFE OPERATING AREAS (TRANSIENT THERMAL RESISTANCE METHOD)



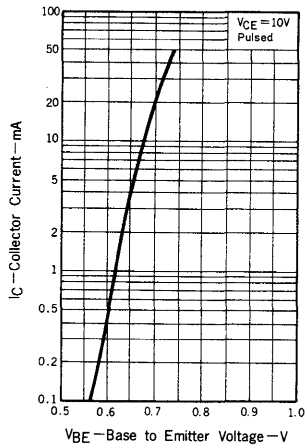
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



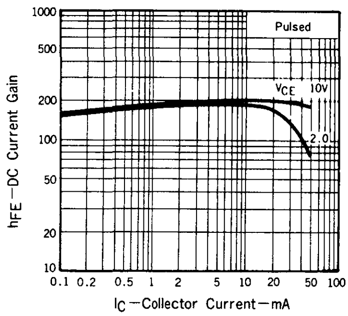
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



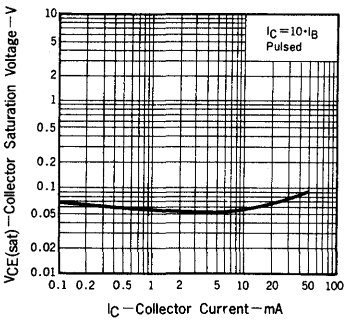
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



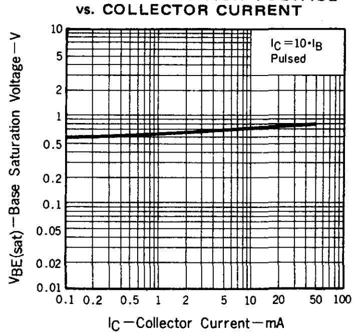
DC CURRENT GAIN vs. COLLECTOR CURRENT



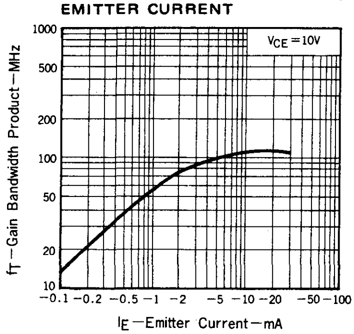
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT

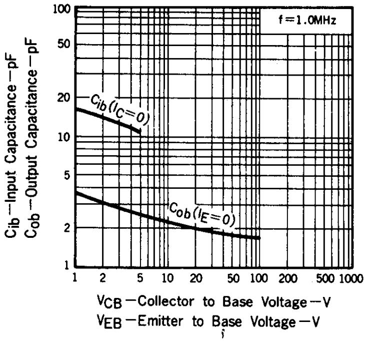


GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



2

INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

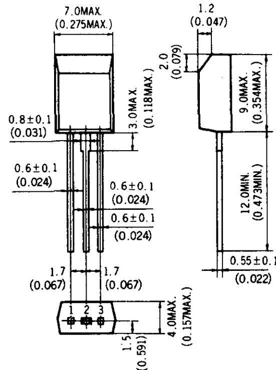
NPN SILICON TRANSISTOR
2SC1941

DESCRIPTION The 2SC1941 is designed for use in driver stages of audio frequency amplifiers.

FEATURES

- High total power dissipation and high breakdown voltage: 1.0W at 25°C ambient temperature/V_{CEO} = 160V
- Complementary to the NEC 2SA916 PNP transistor.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Collector
3. Base

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature .... –55 to +150°C

Junction Temperature .... +150°C Maximum

Maximum Power Dissipation (Ta = 25°C)

Total Power Dissipation 1.0W

Thermal Resistance(junction to Ambient) ... 125°C/W

Maximum Voltages and Currents (Ta = 25°C)

V_{CBO}	Collector to Base Voltage	160 V
V_{CEO}	Collector to Emitter Voltage	160 V
V_{EBO}	Emitter to Base Voltage	5.0 V
I_C	Collector Current	50 mA
I_B	Base Current	10 mA

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	90	200	400	–	V_{CE}=10V, I_C=10mA
h_{FE2}	DC Current Gain	50	180		–	V_{CE}=10V, I_C=1.0mA
f_T	Gain Bandwidth Product	50	120		MHz	V_{CE}=10V, I_E= –10mA
C_{ob}	Output Capacitance		2.3	3.0	pF	V_{CB}=10V, I_E=0, f=1.0MHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB}=160V, I_E=0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB}=5.0V, I_C=0
V_{BE}	Base to Emitter Voltage	650	685	750	mV	V_{CE}=10V, I_C=10mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.07	0.6	V	I_C=20mA, I_B=2.0mA
$V_{BE(sat)}$	Base Saturation Voltage		0.75	1.0	V	I_C=20mA, I_B=2.0mA

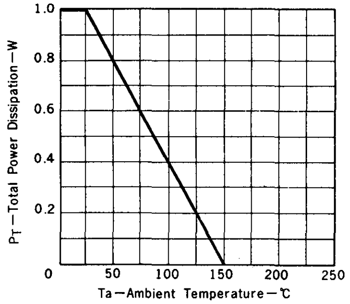
Classification of h_{FE1}

Rank	M	L	K
Range	90 – 180	135 – 270	200 – 400

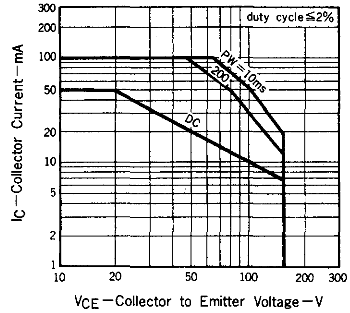
h_{FE1} Test Conditions: V_{CE} = 10V, I_C = 10mA

TYPICAL CHARACTERISTICS (Ta=25°C unless otherwise noted)

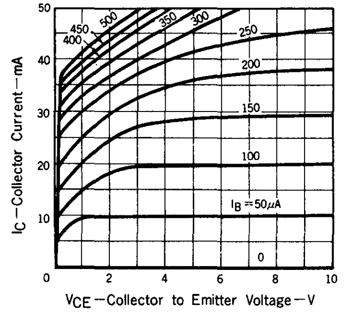
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



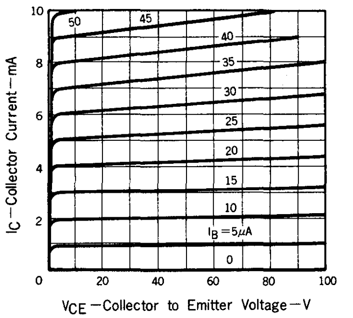
SAFE OPERATING AREAS (TRANSIENT THERMAL RESISTANCE METHOD)



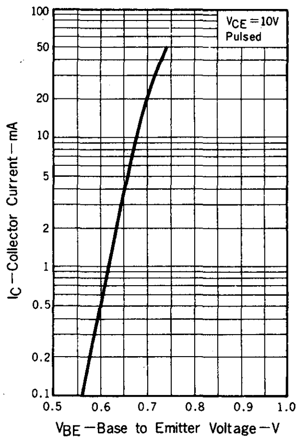
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



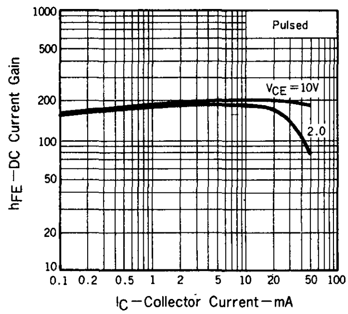
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



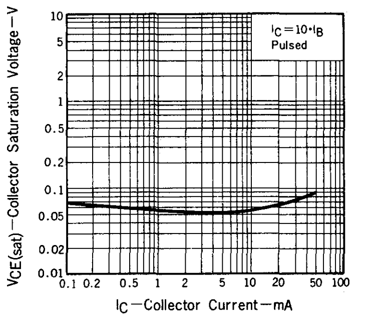
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



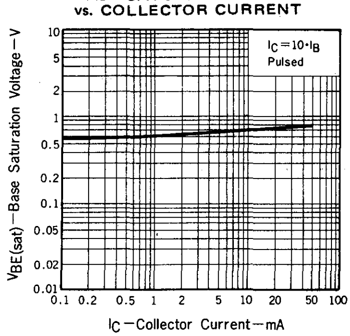
DC CURRENT GAIN vs. COLLECTOR CURRENT



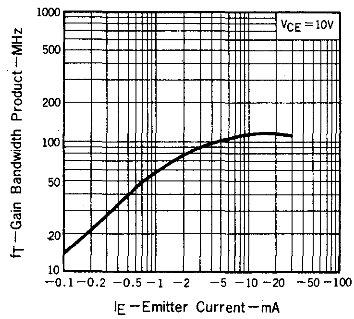
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT

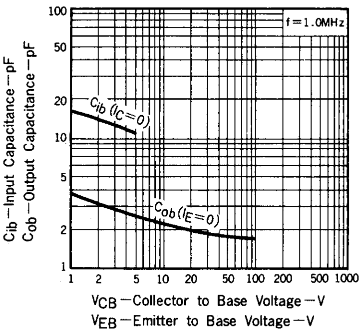


GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



2

INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

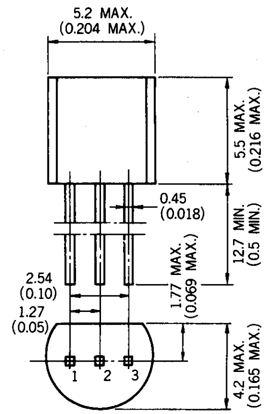
NPN SILICON TRANSISTOR
2SC2000

DESCRIPTION The 2SC2000 is designed for use in AM/RF stage of CAR RADIO and general purpose applications.

FEATURES

- High Electrostatic-Discharge-Strength (E-B reverse bias)
  - Vd1: TYP. 500 V (C=1 000 pF)
  - Vd2: TYP. 1 600 V (C=100 pF)
- Low f_T, $C_c \cdot r_{b'b}$ and NF.
  - f_T: TYP. 70 MHz (V_{CE}=6.0 V, I_E=−1.0 mA)
  - $C_c \cdot r_{b'b}$: TYP. 6.0 ps (V_{CB}=6.0 V, I_E=−10 mA, f=31.9 MHz)
  - NF: TYP. 3.0 dB (V_{CE}=6.0 V, I_C=1.0 mA, f=1.0 MHz, R_G=500 Ω)

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC: TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature . . . . −55 to +150 °C
- Junction Temperature . . . . +150 °C Maximum

Maximum Power Dissipation (Ta=25 °C)
- Total Power Dissipation . . . . 600 mW

Maximum Voltages and Currents (Ta=25 °C)

V_{CBO}	Collector to Base Voltage	60	V
V_{CEO}	Collector to Emitter Voltage	50	V
V_{EBO}	Emitter to Base Voltage	5.0	V
I_C	Collector Current	200	mA
I_B	Base Current	20	mA

ELECTRICAL CHARACTERISTICS (Ta=25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	40	90	180	−	V_{CE}=6.0 V, I_C=1.0 mA
C_{ob}	Output Capacitance		3.7	4.5	pF	V_{CB}=6.0 V, I_E=0, f=1.0 MHz
f_T	Gain Bandwidth Product	40	70		MHz	V_{CE}=6.0 V, I_E=−1.0 mA
NF	Noise Figure		3.0		dB	V_{CE}=6.0 V, I_C=1.0 mA R_G=500 Ω, f=1.0 MHz
Vd	Electrostatic-Discharge-Strength		500		V	See Test Circuit
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB}=60 V, I_E=0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB}=5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	600	650	700	mV	V_{CE}=6.0 V, I_C=1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		110	300	mV	I_C=100 mA, I_B=10 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.85	1.5	V	I_C=100 mA, I_B=10 mA
$C_c \cdot r_{b'b}$	Collector to Base Time Constant		6.0	15	ps	V_{CB}=6.0 V, I_E=−10 mA f=31.9 MHz

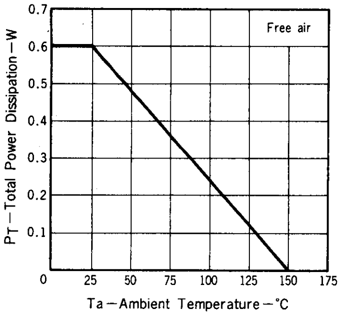
Classification of h_{FE}

Rank	M	L	K
Range	40 − 80	60 − 120	90 − 180

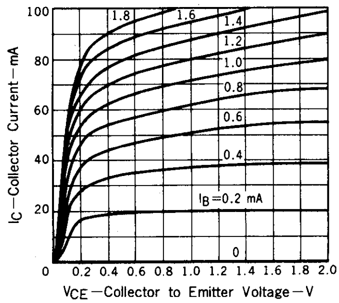
h_{FE} Test Conditions : V_{CE}=6.0 V, I_C=1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

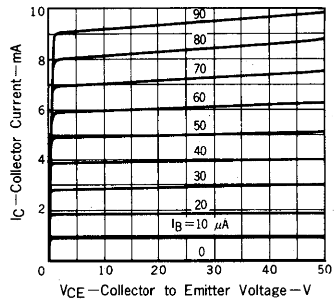
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



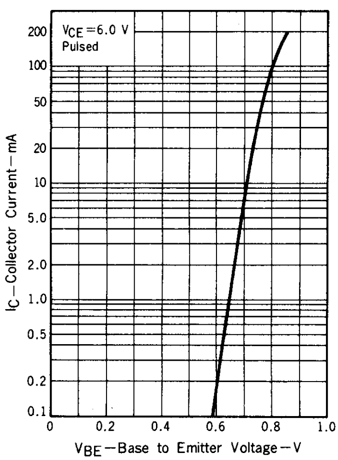
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



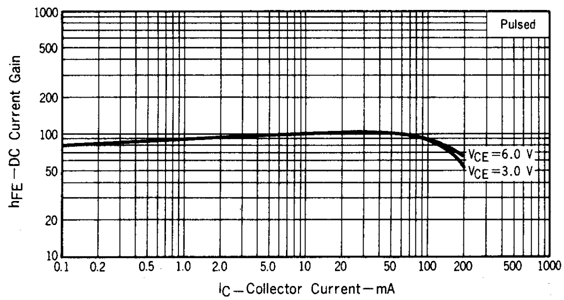
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



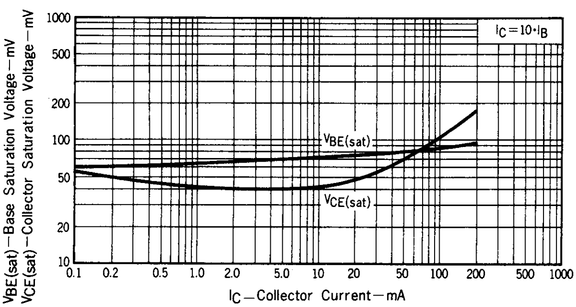
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



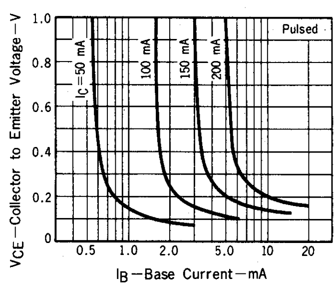
DC CURRENT GAIN vs.
COLLECTOR CURRENT



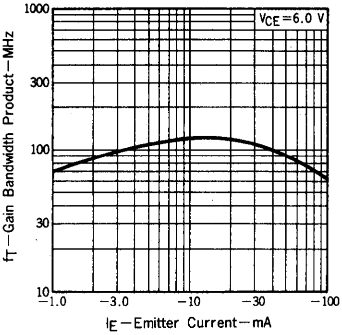
BASE AND COLLECTOR SATURATION VOLTAGE vs.
COLLECTOR CURRENT



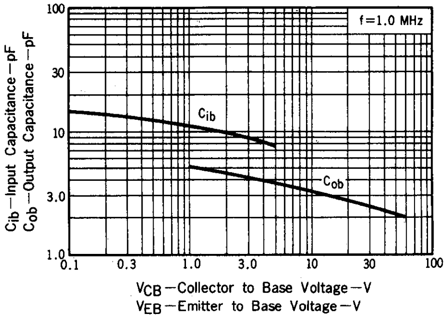
COLLECTOR TO EMITTER VOLTAGE vs.
BASE CURRENT



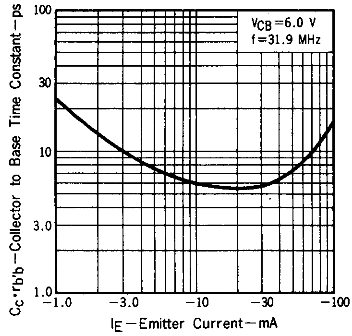
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



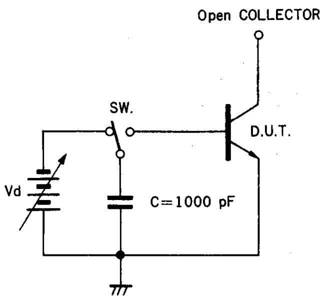
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



COLLECTOR TO BASE TIME CONSTANT vs. EMITTER CURRENT



ELECTROSTATIC-DISCHARGE-STRENGTH TEST CIRCUIT



TEST CONDITION

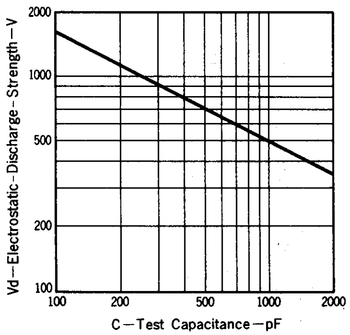
1) E-B reverse bias
2) C = 1 000 pF
3) Apply one shot pulse to D.U.T. (Device Under the Test) by SW.

JUDGEMENT

REJECT: BV_{EBO} waveform defect

As a result if D.U.T. is not rejected, apply higher voltage to capacitor and test again.

ELECTROSTATIC-DISCHARGE-STRENGTH vs. CAPACITANCE



NEC
ELECTRON DEVICE

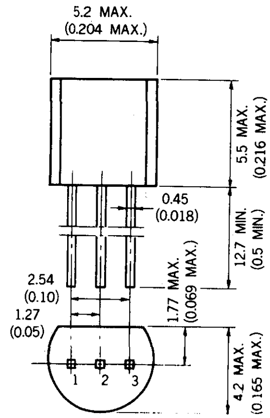
NPN SILICON TRANSISTOR
2SC2001

DESCRIPTION The 2SC2001 is designed for use in output stage of portable RADIO and cassette type tape recorder, general purpose applications.

FEATURES

- High total power dissipation.
  P_T : 600 mW
- High h_{FE} and low $V_{CE(sat)}$
  h_{FE} (I_C = 100 mA) : 200 TYP.
  $V_{CE(sat)}$ (700 mA) : 0.20 V TYP.

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature .... −55 to +150 °C

Junction Temperature .... +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation .... 600 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO}	Collector to Base Voltage	30	V
V_{CEO}	Collector to Emitter Voltage	25	V
V_{EBO}	Emitter to Base Voltage	5.0	V
I_C	Collector Current	700	mA
I_B	Base Current	150	mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}*	DC Current Gain	90	200	400	–	V_{CE} = 1.0 V, I_C = 100 mA
h_{FE2}*	DC Current Gain	50	140		–	V_{CE} = 1.0 V, I_C = 700 mA
C_{ob}	Collector to Base Capacitance		13	25	pF	V_{CB} = 6.0 V, I_E = 0 f = 1.0 MHz
f_T	Gain Bandwidth Product	50	170		MHz	V_{CE} = 6.0 V, I_E = −10 mA
V_{BE}*	Base to Emitter Voltage	600	640	700	mV	V_{CE} = 6.0 V, I_C = 10 mA
$V_{CE(sat)}$*	Collector Saturation Voltage		0.2	0.6	V	I_C = 700 mA, I_B = 70 mA
$V_{BE(sat)}$*	Base Saturation Voltage		0.95	1.2	V	I_C = 700 mA, I_B = 70 mA
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB} = 30 V, I_E = 0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB} = 5.0 V, I_C = 0

* Pulsed PW ≦ 350 μs, duty cycle ≦ 2.0 %

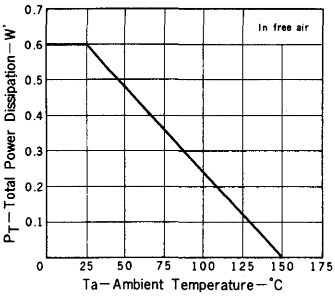
Classification of h_{FE1}

Rank	M	L	K
Range	90 – 180	135 – 270	200 – 400

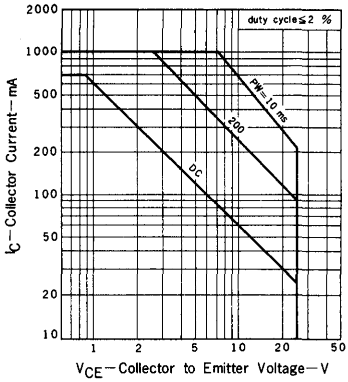
h_{FE} Test Conditions : V_{CE} = 1.0 V, I_C = 100 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

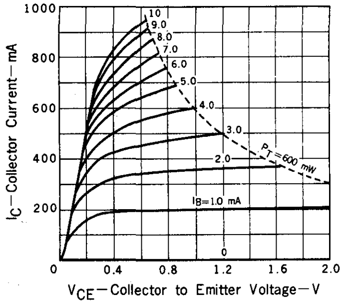
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



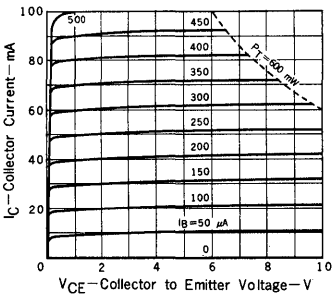
SAFE OPERATING AREAS (TRANSIENT THERMAL RESISTANCE)



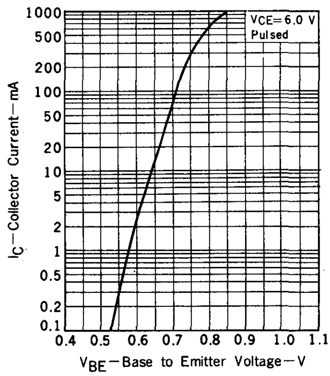
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



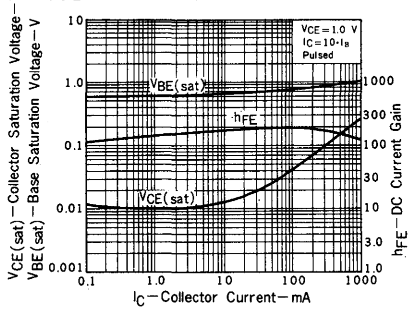
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



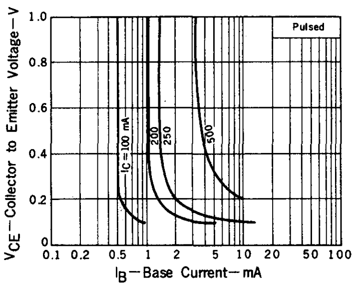
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



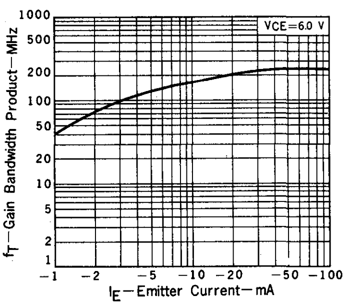
DC CURRENT GAIN, BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



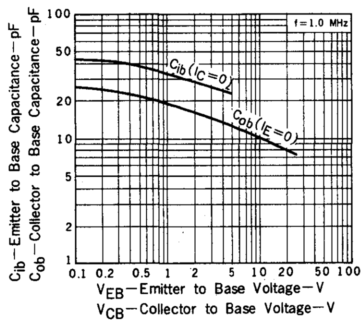
COLLECTOR TO EMITTER VOLTAGE vs. BASE CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



EMITTER TO BASE AND COLLECTOR TO BASE CAPACITANCE vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

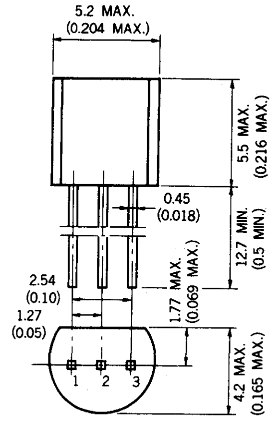
NPN SILICON TRANSISTOR
2SC2002

DESCRIPTION The 2SC2002 is designed for use in driver stage of high voltage audio equipments.

FEATURES

- High total power dissipation.
  P_T : 600 mW
- High h_{FE} and high voltage.
  h_{FE} (I_C = 50 mA) : 200 TYP.
  V_{CEO} : 60 V

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC: TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
Storage Temperature .... −55 to +150 °C
Junction Temperature .... +150 °C Maximum
Maximum Power Dissipation (Ta = 25 °C)
Total Power Dissipation .... 600 mW
Maximum Voltages and Currents (Ta = 25 °C)
V_{CBO} Collector to Base Voltage .... 60 V
V_{CEO} Collector to Emitter Voltage .... 60 V
V_{EBO} Emitter to Base Voltage .... 5.0 V
I_C Collector Current .... 300 mA
I_B Base Current .... 60 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}*	DC Current Gain	90	200	400	–	V_{CE} = 1.0 V, I_C = 50 mA
h_{FE2}*	DC Current Gain	30	80		–	V_{CE} = 2.0 V, I_C = 300 mA
C_{ob}	Collector to Base Capacitance		7.0	15	pF	V_{CB} = 6.0 V, I_E = 0 f = 1.0 MHz
f_T	Gain Bandwidth Product	50	140		MHz	V_{CE} = 6.0 V, I_E = −10 mA
V_{BE}*	Base to Emitter Voltage	600	645	700	mV	V_{CE} = 6.0 V, I_C = 10 mA
$V_{CE(sat)}$*	Collector Saturation Voltage		0.15	0.6	V	I_C = 300 mA, I_B = 30 mA
$V_{BE(sat)}$*	Base Saturation Voltage		0.86	1.2	V	I_C = 300 mA, I_B = 30 mA
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB} = 60 V, I_E = 0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB} = 5.0 V, I_E = 0

*Pulsed PW ≦ 350 μs, duty cycle ≦ 2.0 %.

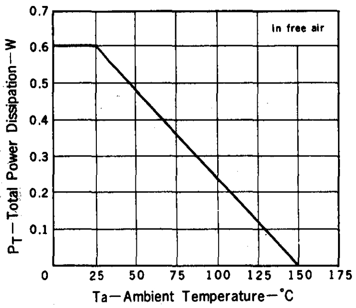
Classification of h_{FE1}

Rank	M	L	K
Range	90 – 180	135 – 270	200 – 400

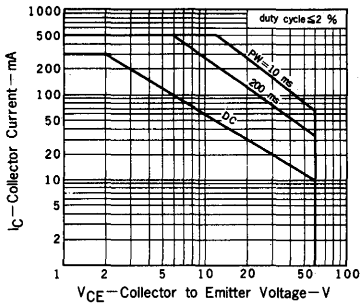
h_{FE} Test Conditions : V_{CE} = 1.0 V, I_C = 50 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

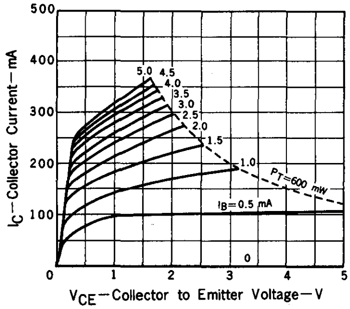
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



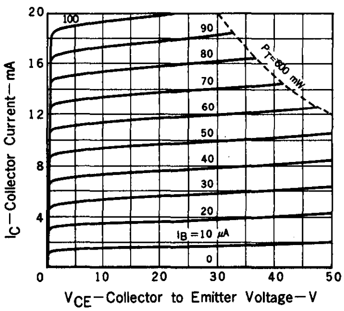
SAFE OPERATING AREAS (TRANSIENT THERMAL RESISTANCE)



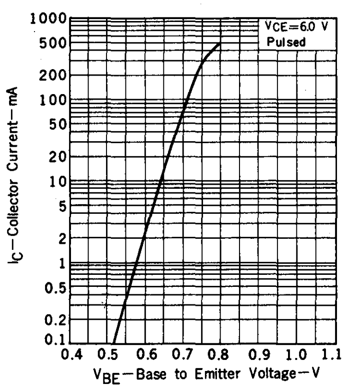
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



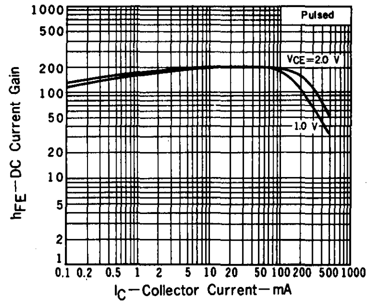
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



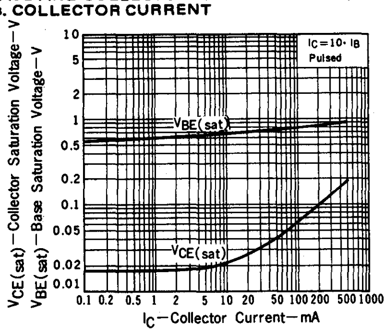
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



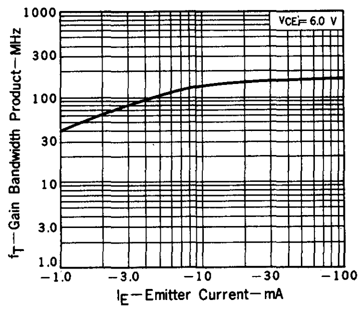
DC CURRENT GAIN vs. COLLECTOR CURRENT



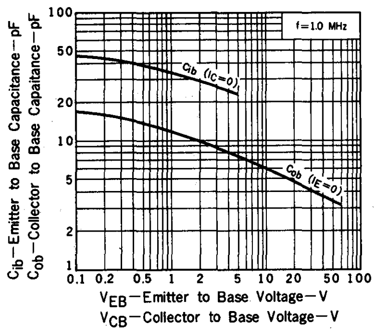
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



EMITTER TO BASE AND COLLECTOR TO BASE CAPACITANCE vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC2003

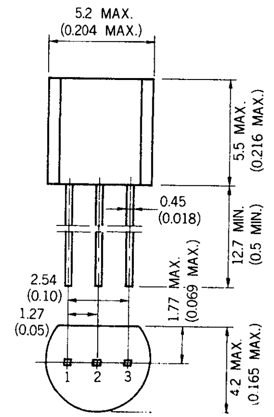
2

DESCRIPTION The 2SC2003 is designed for use in driver stage of high voltage audio equipments.

FEATURES

- High total power dissipation.
  P_T : 600 mW
- High h_{FE} and high voltage.
  h_{FE} (I_C = 50 mA) : 200 TYP.
  V_{CEO} : 80 V

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. COLLECTOR
3. BASE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature .... −55 to +150 °C

Junction Temperature .... +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation .... 600 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{CBO}	Collector to Base Voltage	80	V
V_{CEO}	Collector to Emitter Voltage	80	V
V_{EBO}	Emitter to Base Voltage	5.0	V
I_C	Collector Current	300	mA
I_B	Base Current	60	mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}*	DC Current Gain	90	200	400	–	V_{CE} = 1.0 V, I_C = 50 mA
h_{FE2}*	DC Current Gain	30	80		–	V_{CE} = 2.0 V, I_C = 300 mA
C_{ob}	Collector to Base Capacitance		7.0	15	pF	V_{CB} = 6.0 V, I_E = 0 f = 1.0 MHz
f_T	Gain Bandwidth Product	50	140		MHz	V_{CE} = 6.0 V, I_E = −10 mA
V_{BE}*	Base to Emitter Voltage	600	645	700	mV	V_{CE} = 6.0 V, I_C = 10 mA
$V_{CE(sat)}$*	Collector Saturation Voltage		0.15	0.6	V	I_C = 300 mA, I_B = 30 mA
$V_{BE(sat)}$*	Base Saturation Voltage		0.86	1.2	V	I_C = 300 mA, I_B = 30 mA
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB} = 80 V, I_E = 0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB} = 5.0 V, I_E = 0

*Pulsed PW ≦ 350 μs, duty cycle ≦ 2.0 %.

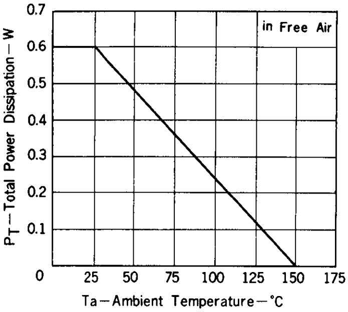
Classification of h_{FE1}

Rank	M	L	K
Range	90 – 180	135 – 270	200 – 400

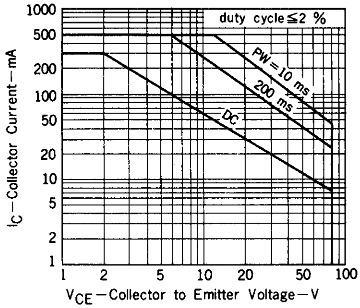
h_{FE} Test Conditions : V_{CE} = 1.0 V, I_C = 50 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

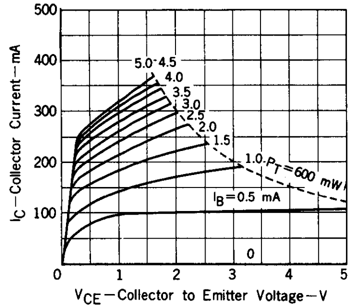
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



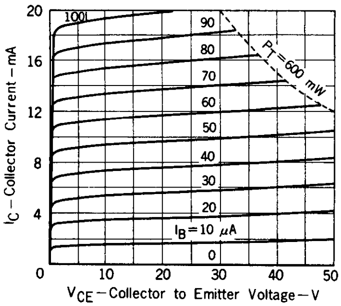
SAFE OPERATING AREAS (TRANSIENT THERMAL RESISTANCE)



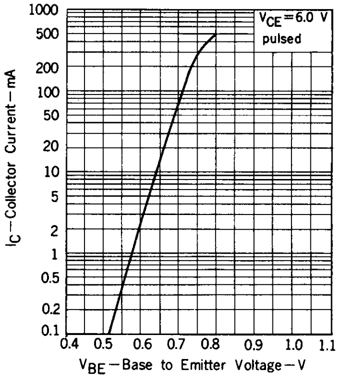
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



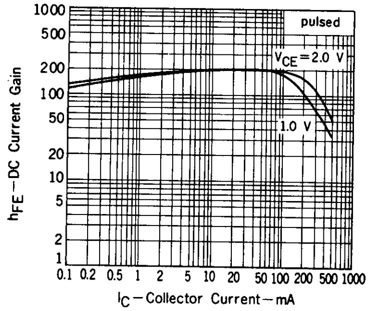
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



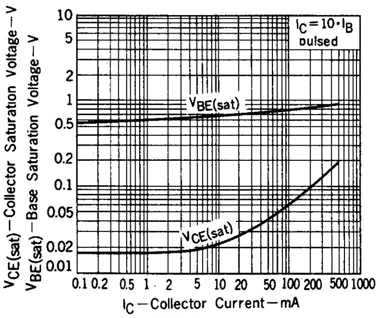
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



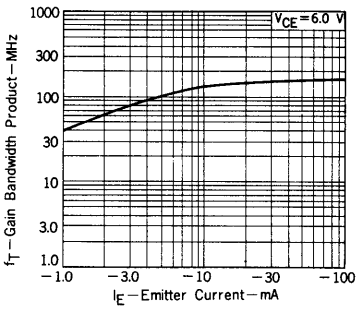
DC CURRENT GAIN vs. COLLECTOR CURRENT



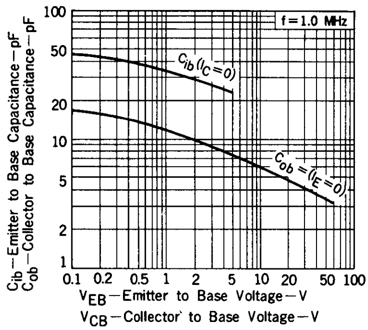
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



EMITTER TO BASE AND COLLECTOR TO BASE CAPACITANCE vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SC2026

RF LOW NOISE AMPLIFIER
NPN SILICON EPITAXIAL TRANSISTOR

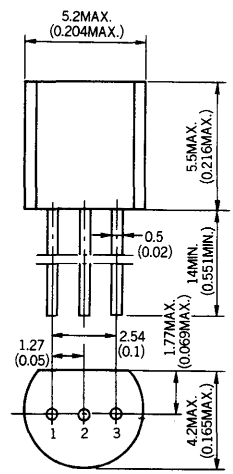
DESCRIPTION

Suitable for low noise amplifier in the VHF to UHF band.

FEATURES

NF	3.0dB TYP. @f = 500MHz	
G_{pe}	15dB TYP. @f = 500MHz	
f_T	2.0GHz TYP.	

PACKAGE DIMENSIONS
in millimeter (inches)



1. Base	EIAJ	: SC-43
2. Emitter	JEDEC	: TO-92
3. Collector	IEC	: PA33

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Voltages and Current			
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	14	V
Emitter to Base Voltage	V_{EBO}	3.0	V
Collector Current	I_C	50	mA
Maximum Power Dissipation			
Total Power Dissipation	P_T	250	mW
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	-55 to +150	°C

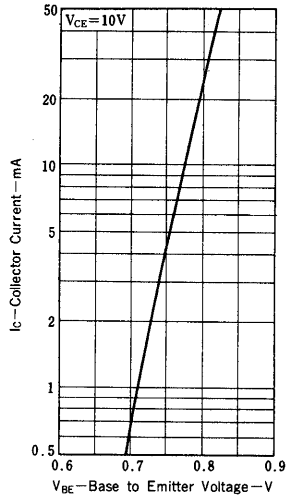
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB} = 15V, I_E = 0
Emitter Cutoff Current	I_{EBO}			0.1	μA	V_{EB} = 2.0V, I_C = 0
DC Current Gain	h_{FE}	25	80	200		V_{CE} = 10V, I_C = 10mA
Gain Bandwidth Product	f_T	1.5	2.0		GHz	V_{CE} = 10V, I_C = 10mA
Output Capacitance *	Cob		0.75	1.1	pF	V_{CB} = 10V, I_E = 0, f = 1.0MHz
Power Gain	Gpe	13	15		dB	V_{CE} = 10V, I_C = 10mA, f = 500MHz
Noise Figure	NF		3.0	4.0	dB	V_{CE} = 10V, I_C = 3.0mA, f = 500MHz, R_G = 50Ω

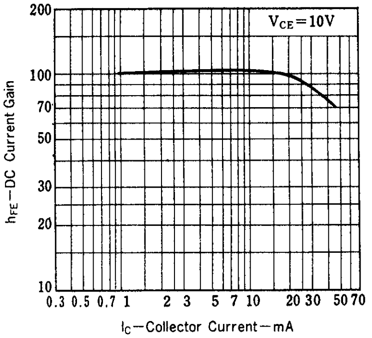
* The emitter terminal should be connected to the guard terminal of the three-terminal capacitance bridge.

TYPICAL CHARACTERISTICS (Ta = 25°C)

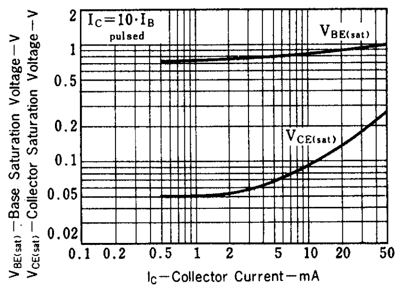
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



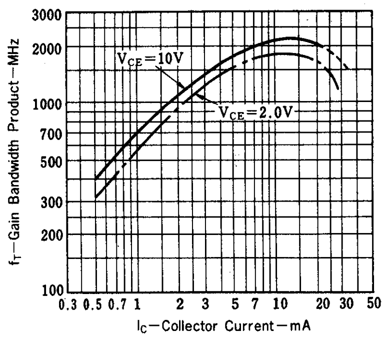
DC CURRENT GAIN vs.
COLLECTOR CURRENT



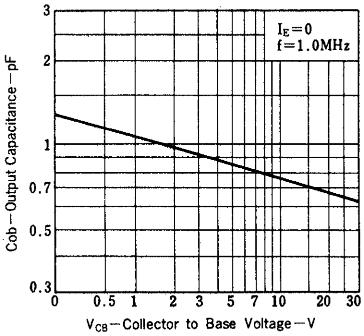
BASE AND COLLECTOR SATURATION
VOLTAGE vs.
COLLECTOR CURRENT



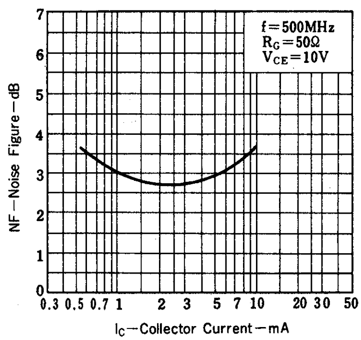
GAIN BANDWIDTH PRODUCT vs.
COLLECTOR CURRENT



OUTPUT CAPACITANCE vs.
COLLECTOR TO BASE VOLTAGE



NOISE FIGURE vs.
COLLECTOR CURRENT



TYPICAL S-PARAMETER

$Z_O = 50\Omega$

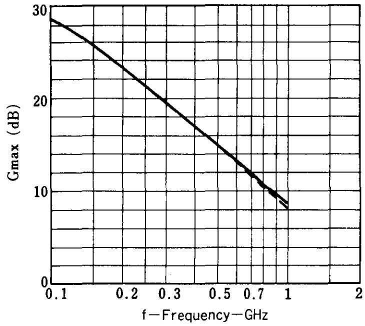
$V_{CE} = 10V$

——— $I_C = 10mA$

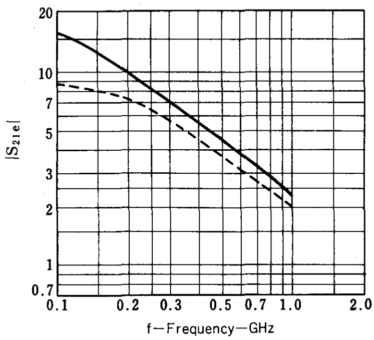
– – – – $I_C = 3.0mA$

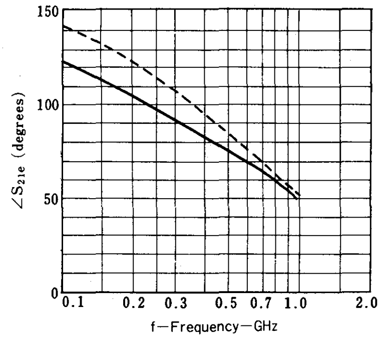
$$G_{max} = |S_{21}|^2 \cdot \frac{1}{1 - |S_{11}|^2} \cdot \frac{1}{1 - |S_{22}|^2}$$

Gmax vs. FREQUENCY

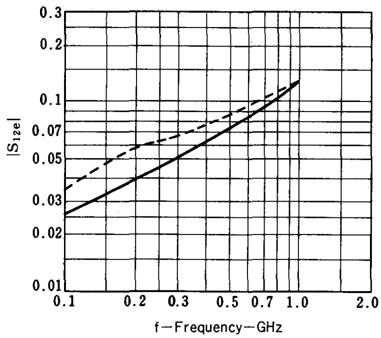


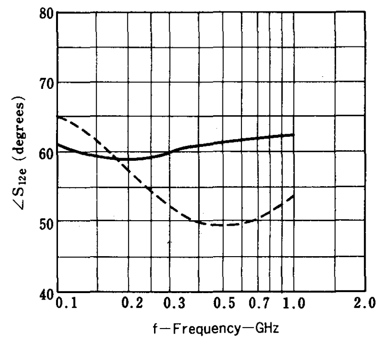
FORWARD TRANSFER COEFFICIENT vs. FREQUENCY





REVERSE TRANSFER COEFFICIENT vs. FREQUENCY





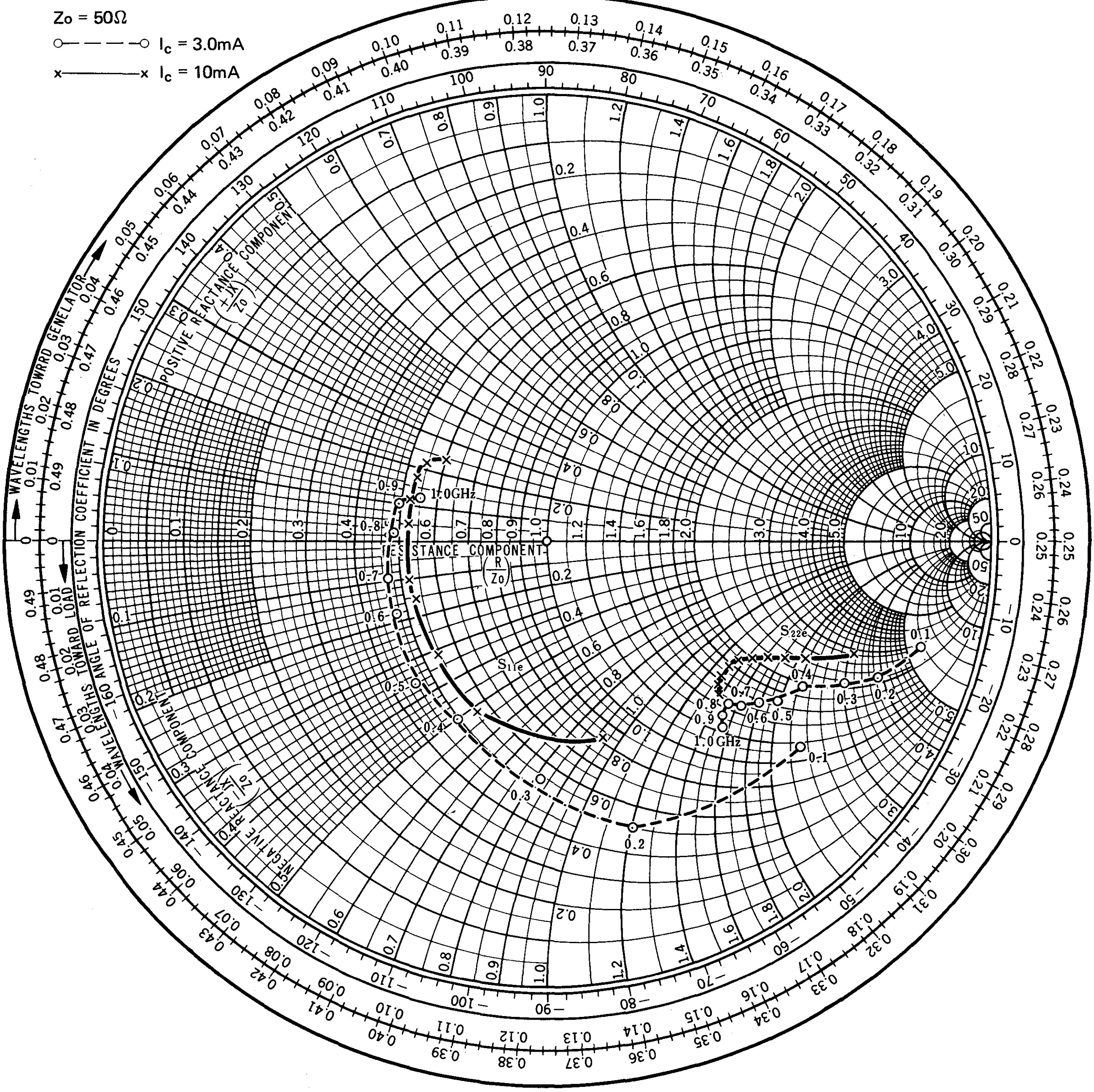
S_{11e}, S_{22e}

V_{CE} = 10V

Zo = 50Ω

○– – – –○ I_c = 3.0mA

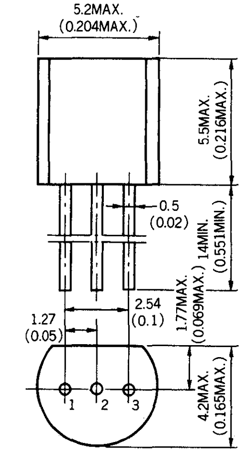
x———x I_c = 10mA



SILICON TRANSISTOR
2SC2037

RF LOW NOISE AMPLIFIER
NPN SILICON EPITAXIAL TRANSISTOR

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter — EIAJ : SC-43
2. Base — JEDEC : TO-92
3. Collector — IEC : PA33

DESCRIPTION

Suitable for low noise amplifier in the VHF to UHF band.

FEATURES

NF	3.0dB TYP. @f = 500MHz
G_{pe}	13dB TYP. @f = 500MHz
f_T	2.0GHz TYP.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Voltages and Current			
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	14	V
Emitter to Base Voltage	V_{EBO}	3.0	V
Collector Current	I_C	50	mA
Maximum Power Dissipation			
Total Power Dissipation	P_T	250	mW
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−55 to +150	°C

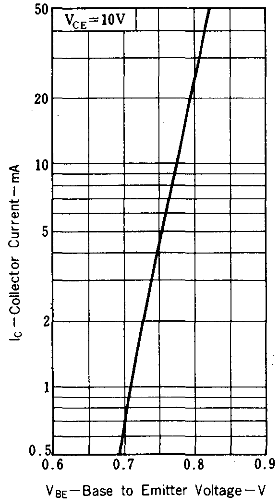
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB} = 15V, I_E = 0
Emitter Cutoff Current	I_{EBO}			0.1	μA	V_{EB} = 2.0V, I_C = 0
DC Current Gain	h_{FE}	25	80	200		V_{CE} = 10V, I_C = 10mA
Gain Bandwidth Product	f_T	1.5	2.0		GHz	V_{CE} = 10V, I_C = 10mA
Output Capacitance	Cob		0.9	1.3	pF	V_{CB} = 10V, I_E = 0, f = 1.0MHz*
Power Gain	Gpe	11	13		dB	V_{CE} = 10V, I_C = 10mA, f = 500MHz
Noise Figure	NF		3.0	4.0	dB	V_{CE} = 10V, I_C = 3.0mA, f = 500MHz, R_G = 50Ω

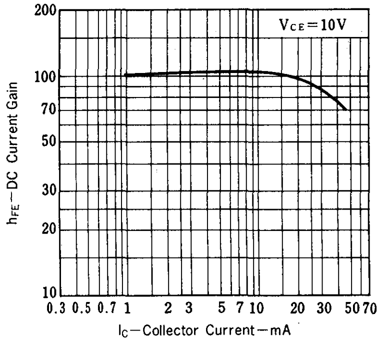
* The emitter terminal should be connected to the gurad terminal of the three-terminal capacitance bridge.

TYPICAL CHARACTERISTICS (Ta = 25°C)

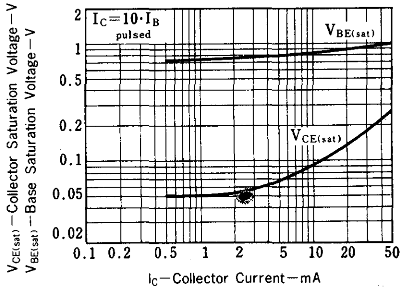
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



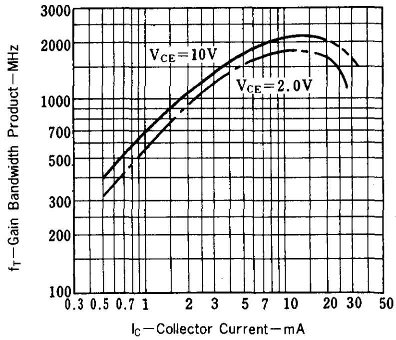
DC CURRENT GAIN vs.
COLLECTOR CURRENT



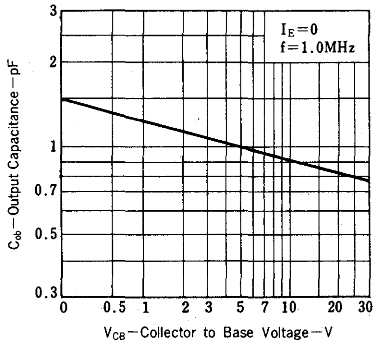
BASE AND COLLECTOR
SATURATION VOLTAGE vs.
COLLECTOR CURRENT



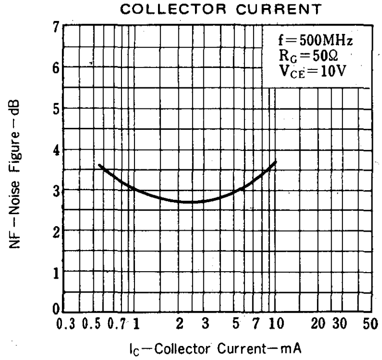
GAIN BANDWIDTH PRODUCT vs.
COLLECTOR CURRENT



OUTPUT CAPACITANCE vs.
COLLECTOR TO BASE VOLTAGE



NOISE FIGURE vs.
COLLECTOR CURRENT



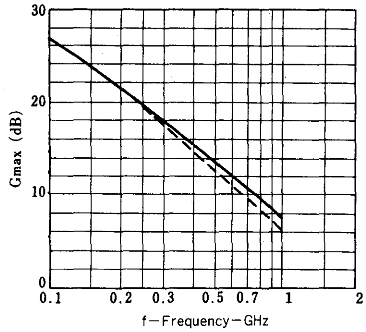
2

TYPICAL S-PARAMETER

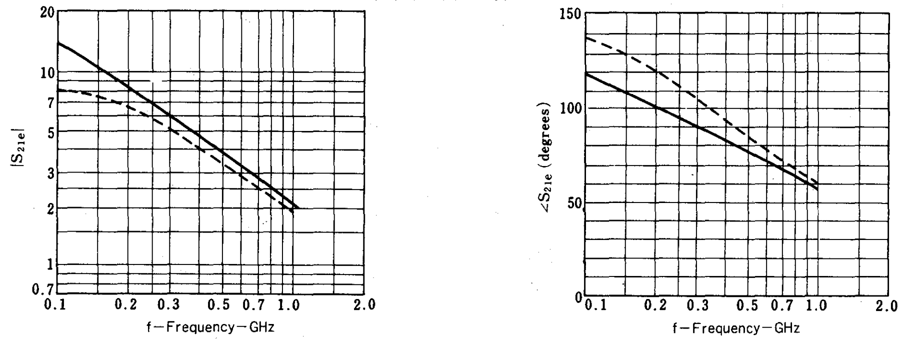
$Z_O = 50\Omega$
$V_{CE} = 10V$
———— $I_C = 10mA$
– – – – $I_C = 3.0mA$

$$G_{max} = |S_{21}|^2 \cdot \frac{1}{1 - |S_{11}|^2} \cdot \frac{1}{1 - |S_{22}|^2}$$

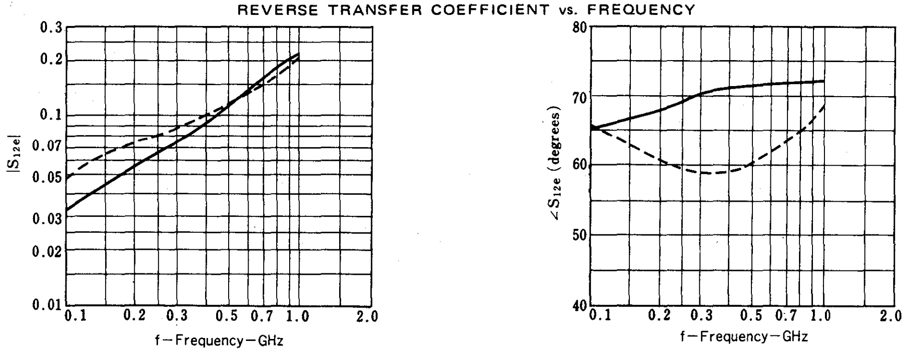
G_{max} vs. FREQUENCY



FORWARD TRANSFER COEFFICIENT vs. FREQUENCY

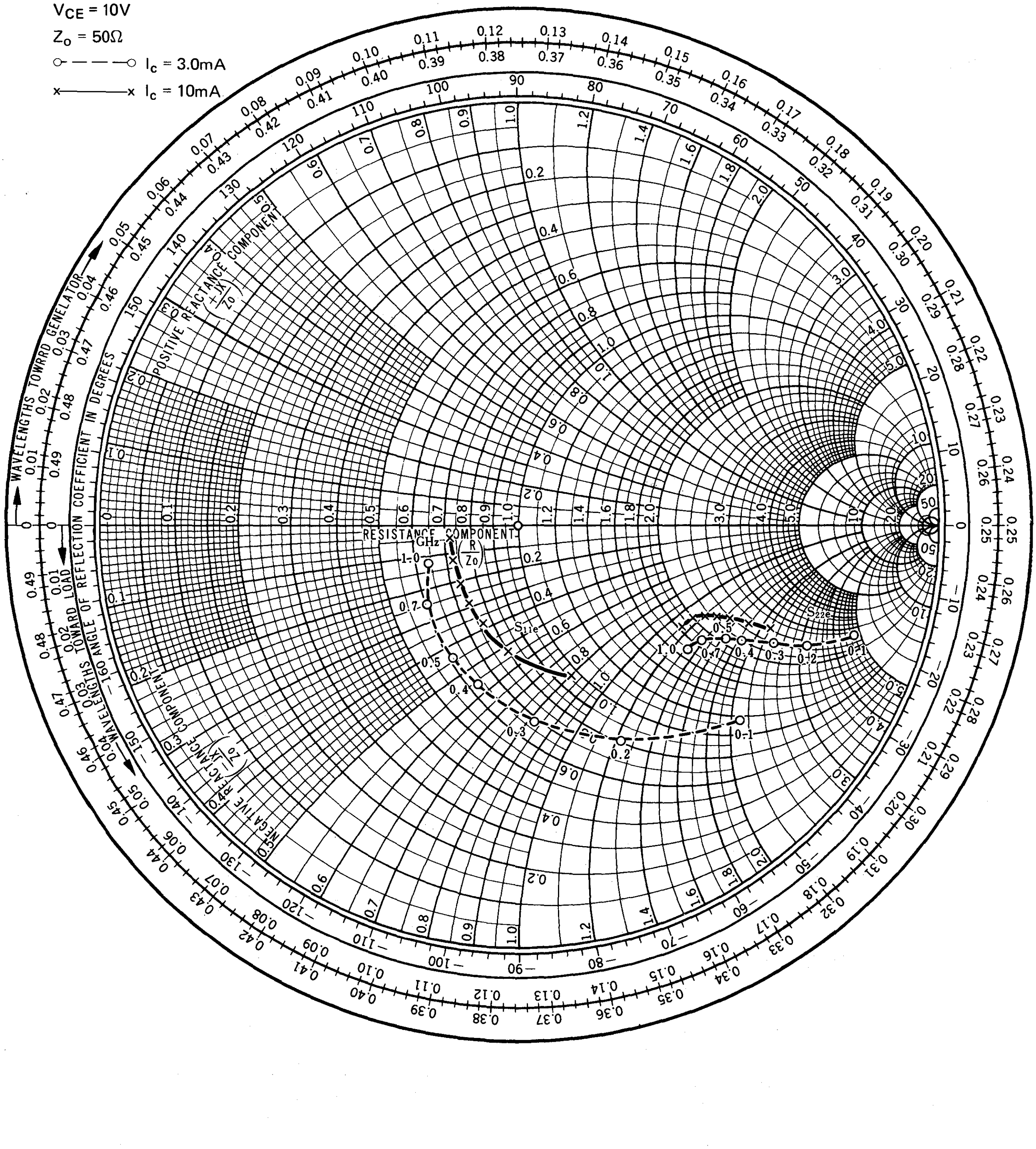


REVERSE TRANSFER COEFFICIENT vs. FREQUENCY



S_{11e}, S_{22e}

V_{CE} = 10V
Z_o = 50Ω
o– – – –o I_c = 3.0mA
x———x I_c = 10mA



NEC
ELECTRON DEVICE

SILICON TRANSISTOR 2SC2352

VHF MIXER
NPN SILICON EPITAXIAL TRANSISTOR

2

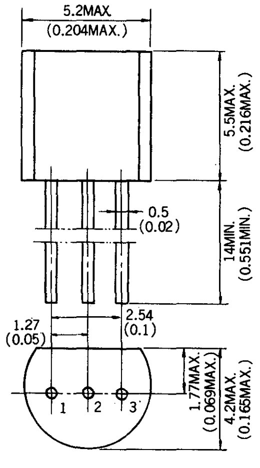
DESCRIPTION

The 2SC2352 is an NPN silicon epitaxial transistor intended for use as a VHF mixer in a tuner of a TV receiver.
The device features are high conversion gain and low distortion.

FEATURES

- Low C_{re}. : 0.4pF TYP.
- High conversion gain. : 15dB TYP.
- Excellent h_{FE} linearity.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base   EIAJ : SC-43
2. Emitter   IEC : PA33
3. Collector   JEDEC : TO-92

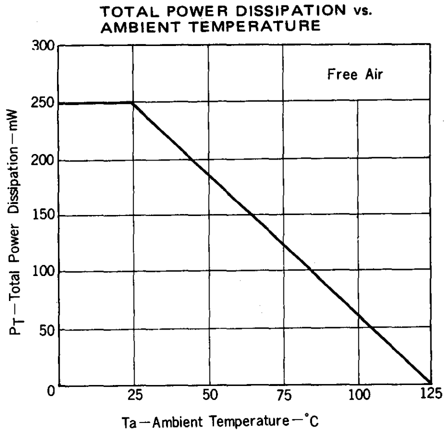
ABSOLUTE MAXIMUM RATINGS (Ta=25°C)

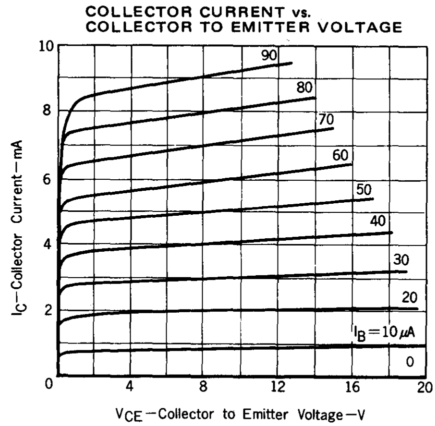
Maximum Voltages and Current			
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	20	V
Emitter to Base Voltage	V_{EBO}	4.0	V
Collector Current	I_C	30	mA
Maximum Power Dissipation			
Total Power Dissipation	P_T	250	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature	T_{stg}	-55 to +125	°C

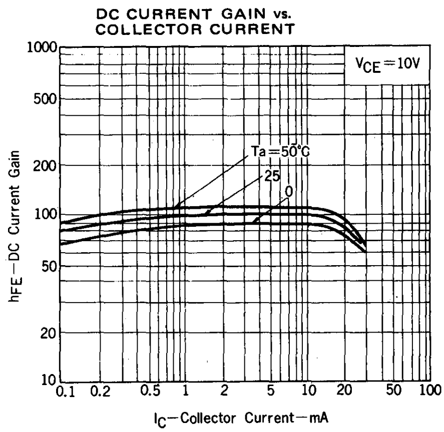
ELECTRICAL CHARACTERISTICS (Ta=25°C)

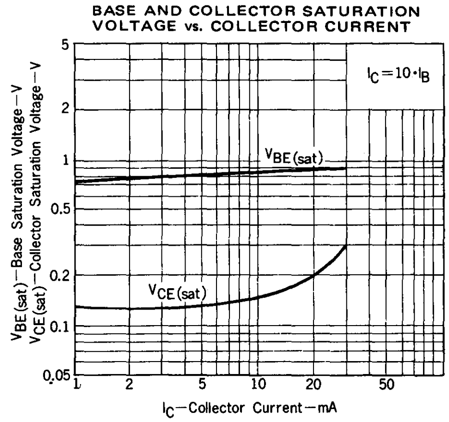
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB}=20V, I_E=0
DC Current Gain	h_{FE}	60	100	200		V_{CE}=10V, I_C=5.0mA
Collector Saturation Voltage	$V_{CE(sat)}$			0.5	V	I_C=10mA, I_B=1.0mA
Gain Bandwidth Product	f_T	500	850		MHz	V_{CE}=10V, I_E=-5.0mA
Feed Back Capacitance	C_{re}		0.4	0.7	pF	V_{CB}=10V, I_E=0, f=1.0MHz
Conversion Gain	G_c	12			dB	V_{CE}=10V, I_E=-5.0mA f=200MHz, f_L=258MHz

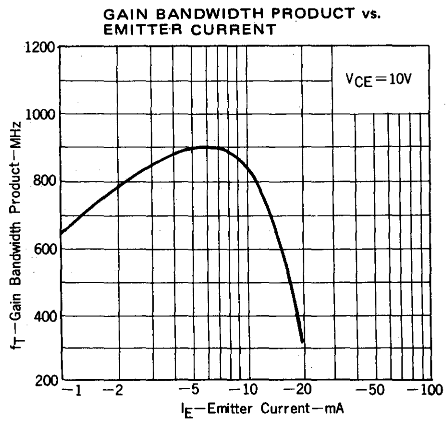
TYPICAL CHARACTERISTICS (Ta=25°C)

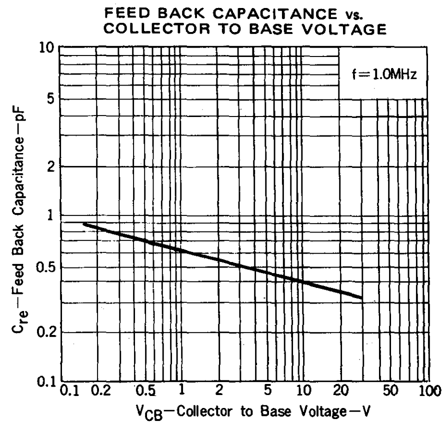




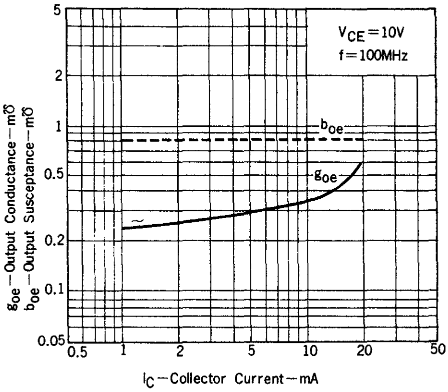




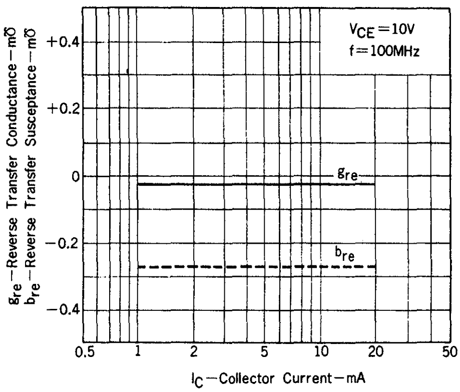




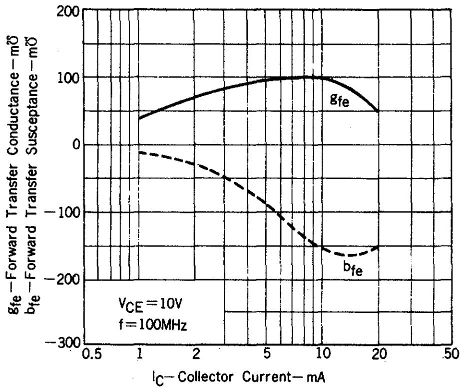
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



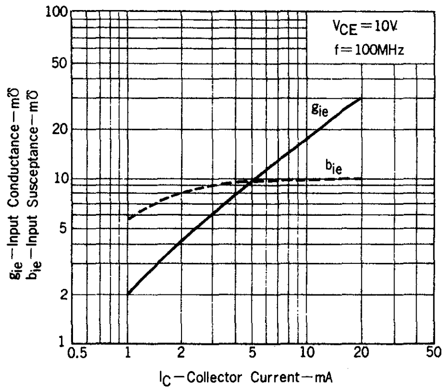
REVERSE TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



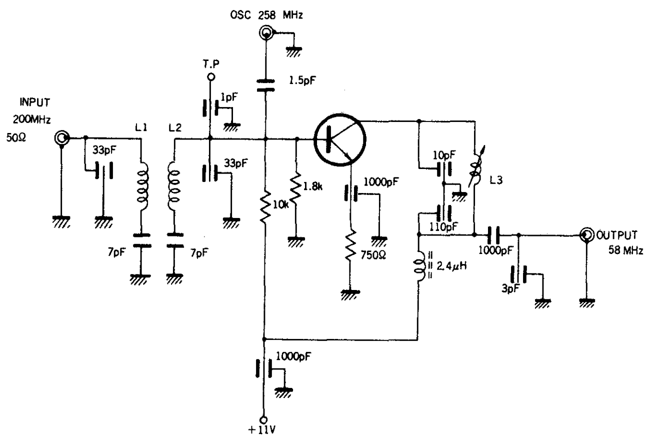
FORWARD TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



INPUT ADMITTANCE vs. COLLECTOR CURRENT



CONVERSION GAIN TEST CIRCUIT



L1. 0.6mm U.E.W 5.0φ 4T
L2. 0.6mm U.E.W 5.0φ 4T
L3. 0.3mm U.E.W 6.0φ 11T

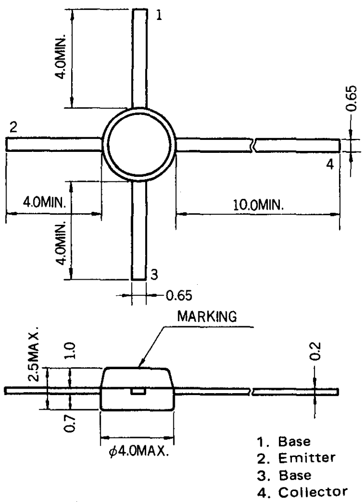
NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SC2353

NPN SILICON EPITAXIAL TRANSISTOR
UHF/VHF MIXER
" DISK MOLD "

The 2SC2353 is specially designed for use as VHF and UHF mixer in a tuner of TV receiver. The influence of mirror effect is little by balanced base.

PACKAGE DIMENSIONS (Unit : mm)



- Packaged in tiny plastic mold package.
- Low noise. NF : 4.0 dB (TYP.)
- High conversion gain. G_{cb} : 12.5 dB (TYP.)
- Balanced base.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	14	V
Emitter to Base Voltage	V_{EBO}	3.0	V
Collector Current	I_C	50	mA
Total Power Dissipation	P_T	200	mW
Junction Temperature	T_j	125	°C
Storage Temperature	T_{stg}	-55 to +125	°C

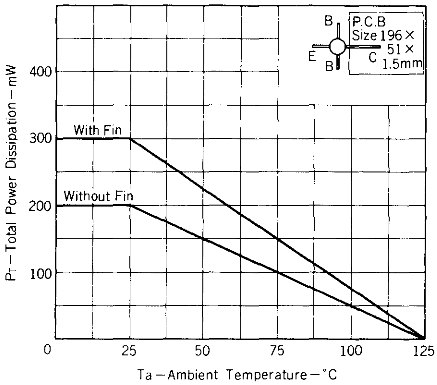
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB} = 15V, I_E = 0
DC Current Gain	h_{FE}	60	100	180		V_{CE} = 10V, I_C = 5.0mA
Gain Bandwidth Product	f_T	1.5	2.3		GHz	V_{CE} = 10V, I_E = -5.0mA
Output Capacitance	C_{ob}		0.85	1.0	pF	V_{CB} = 10V, I_E = 0, f = 1MHz
Noise Figure	NF		4.0	5.0	dB	V_{CB} = 10V, I_E = -5.0mA, f = 900MHz
Power Gain	G_{pb}	14	16		dB	V_{CB} = 10V, I_E = -5.0mA, f = 900MHz
Conversion Gain	G_{cb}	10	12.5		dB	f_{RF} = 900MHz, f_{LOC} = 930MHz V_{CB} = 10V, I_E = -5.0mA Local level = 110mV

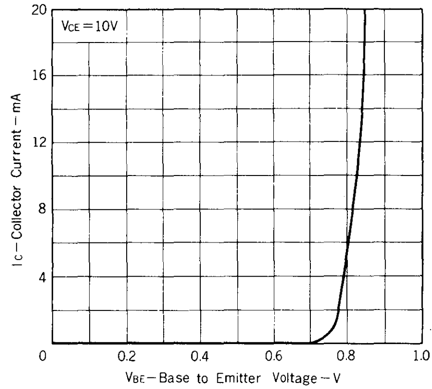
h_{FE} Classification L : 60 – 120 K : 90 – 180

TYPICAL CHARACTERISTICS (Ta = 25°C)

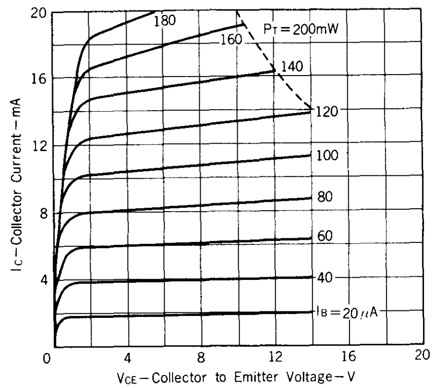
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



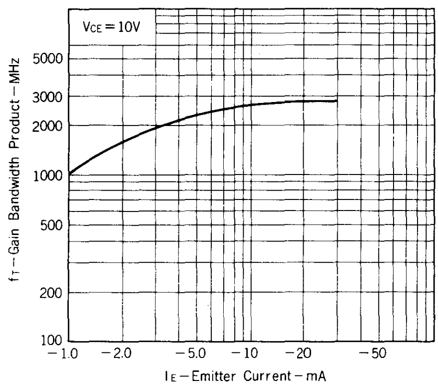
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



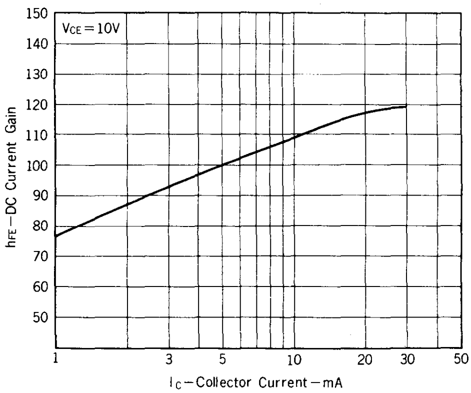
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



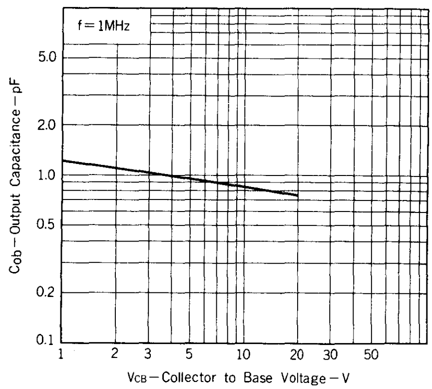
GAIN BANDWIDTH PRODUCT vs.
EMITTER CURRENT



DC CURRENT GAIN vs.
COLLECTOR CURRENT

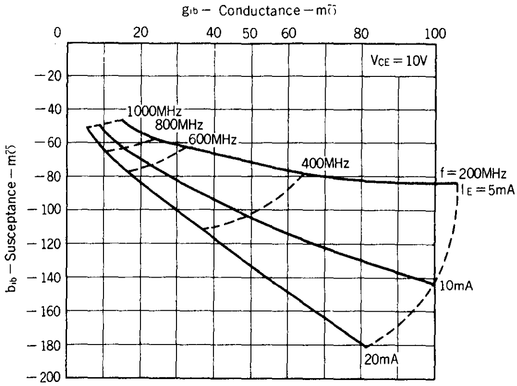


OUTPUT CAPACITANCE vs.
COLLECTOR TO BASE VOLTAGE

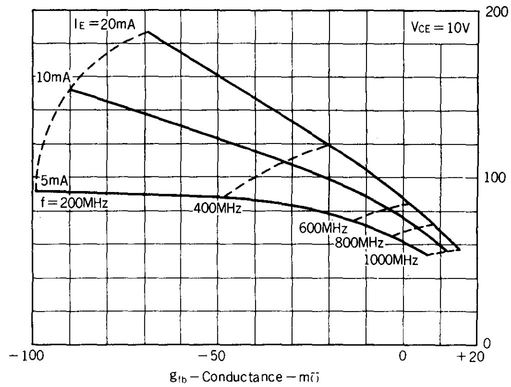


TYPICAL SMALL SIGNAL "Y" PARAMETERS (Common Base)

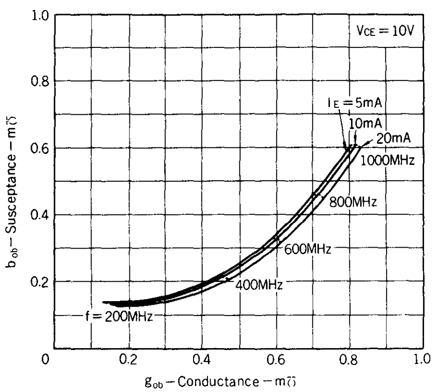
y_{ib} vs. f



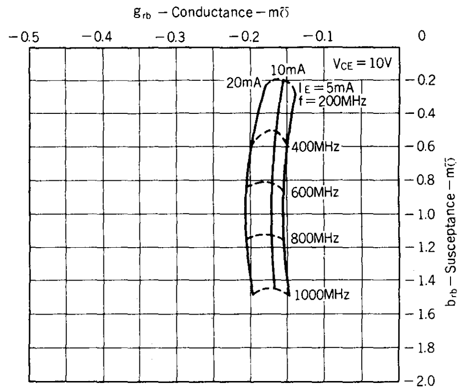
y_{fb} vs. f



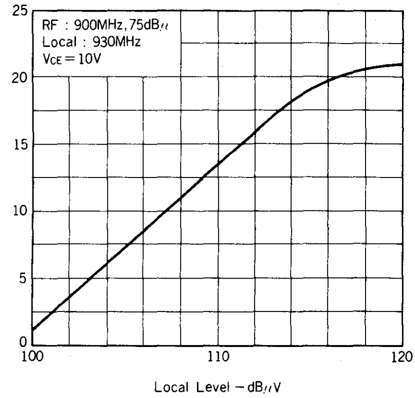
y_{ob} vs. f



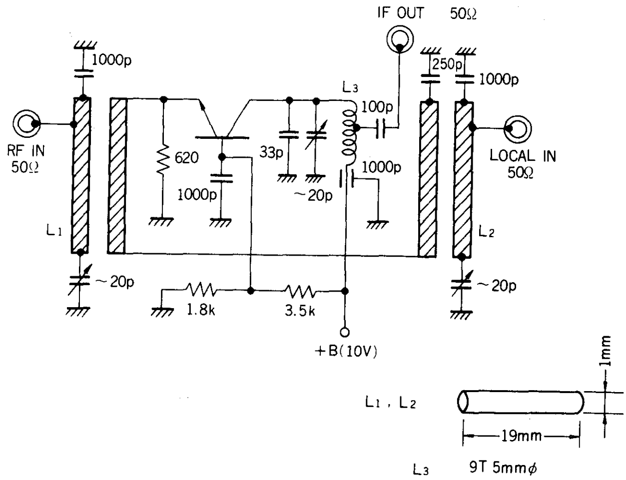
y_{rb} vs. f



CONVERSION GAIN vs. LOCAL OSCILLATOR LEVEL



900MHz G_{cb} Test Circuit

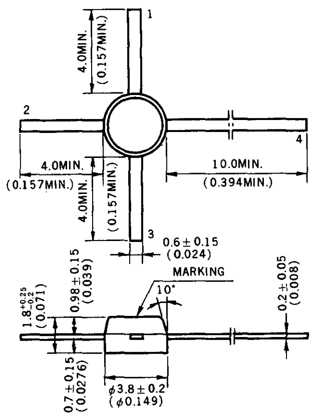


NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SC2368

MICROWAVE LOW NOISE AMPLIFIER
NPN SILICON EPITAXIAL TRANSISTOR

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Base
3. Emitter
4. Collector

NF	2.3 dB	TYP.	@ 500 MHz
MAG	17 dB	TYP.	@ 500 MHz

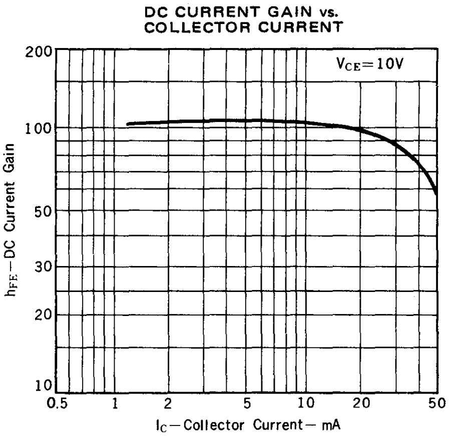
ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

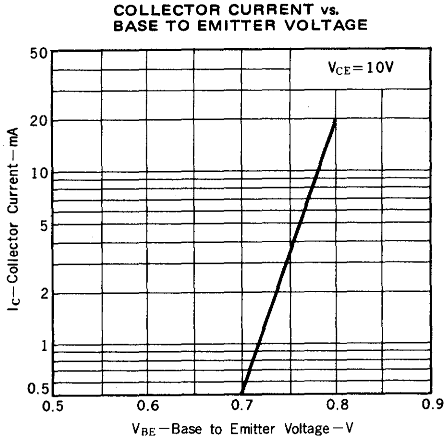
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	14	V
Emitter to Base Voltage	V_{EBO}	3.0	V
Collector Current	I_C	50	mA
Total Power Dissipation	P_T	250	mW
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	-65 to +150	°C

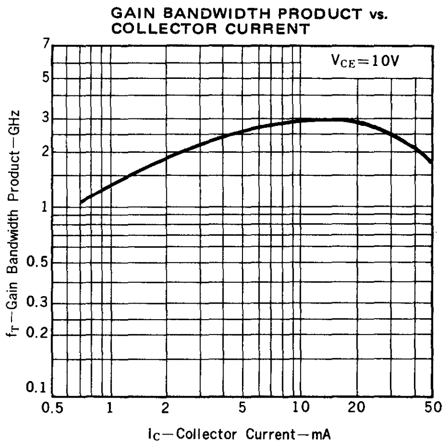
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

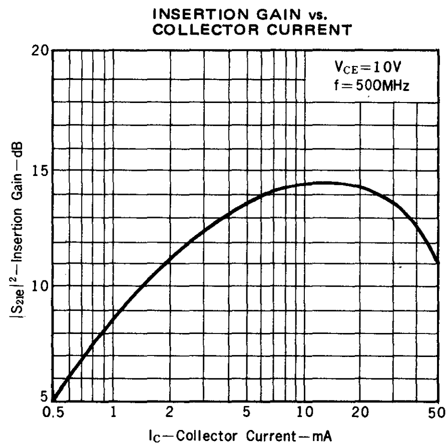
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB} = 15V, I_E = 0
Emitter Cutoff Current	I_{EBO}			0.1	μA	V_{EB} = 2.0V, I_C = 0
DC Current Gain	h_{FE}	40		200		V_{CE} = 10V, I_C = 10mA
Gain Bandwidth Product	f_T		2.8		GHz	V_{CE} = 10V, I_C = 10mA
Output Capacitance	C_{ob}		0.7	1.0	pF	V_{CB} = 10V, I_E = 0, f = 1.0MHz
Insertion Power Gain	$\|S_{21e}\|^2$	13	14.5		dB	V_{CE} = 10V, I_C = 10mA, f = 500MHz
Noise Figure	NF		2.3	3.5	dB	V_{CE} = 10V, I_C = 3mA, f = 500MHz
Maximum Available Gain	MAG		17		dB	V_{CE} = 10V, I_C = 10mA, f = 500MHz

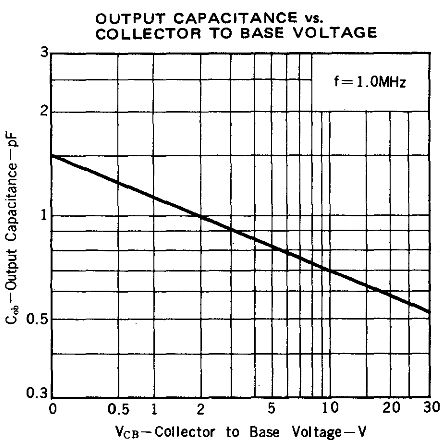
TYPICAL CHARACTERISTICS (Ta = 25°C)

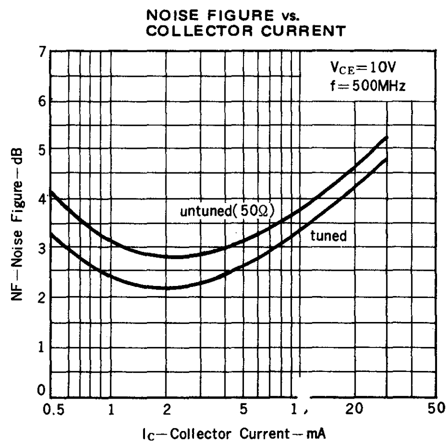




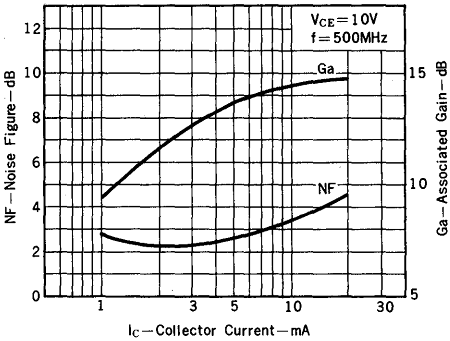








NF, Ga vs. COLLECTOR CURRENT



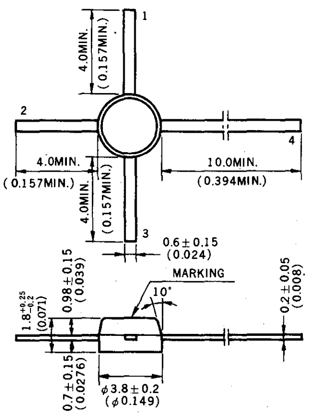
NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SC2369

MICROWAVE LOW NOISE AMPLIFIER
NPN SILICON EPITAXIAL TRANSISTOR

2

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Base
3. Emitter
4. Collector

NF	1.5 dB	TYP.	@ f = 1.0 GHz
MAG	14 dB	TYP.	@ f = 1.0 GHz

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

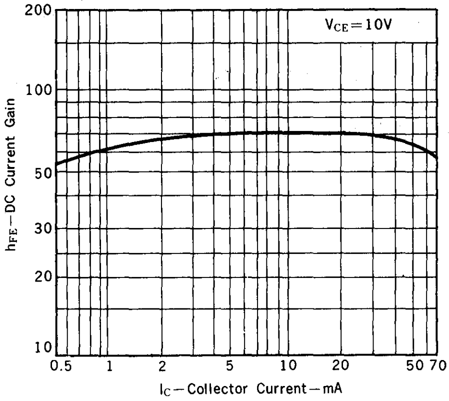
Collector to Base Voltage	V_{CBO}	25	V
Collector to Emitter Voltage	V_{CEO}	12	V
Emitter to Base Voltage	V_{EBO}	3.0	V
Collector Current	I_C	70	mA
Total Power Dissipation	P_T	250	mW
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−65 to +150	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

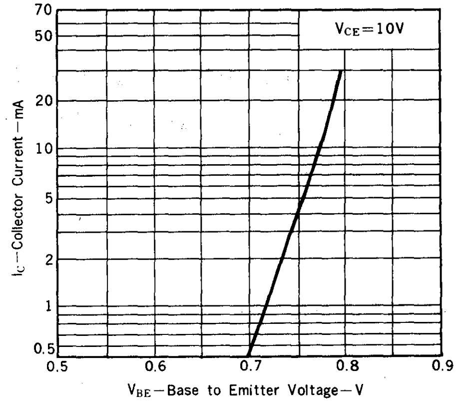
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB} = 15V, I_E = 0
Emitter Cutoff Current	I_{EBO}			0.1	μA	V_{EB} = 2.0V, I_C = 0
DC Current Gain	h_{FE}	40		200		V_{CE} = 10V, I_C = 20mA
Gain Bandwidth Product	f_T		4.5		GHz	V_{CE} = 10V, I_C = 20mA
Output Capacitance	C_{ob}		0.75	1.0	pF	V_{CB} = 10V, I_E = 0, f = 1.0MHz
Insertion Power Gain	$\|S_{21e}\|^2$	9	11		dB	V_{CE} = 10V, I_C = 20mA, f = 1.0GHz
Noise Figure	NF		1.5	3.0	dB	V_{CE} = 10V, I_C = 5mA, f = 1.0GHz
Maximum Available Gain	MAG		14		dB	V_{CE} = 10V, I_C = 20mA, f = 1.0GHz

TYPICAL CHARACTERISTICS (Ta = 25°C)

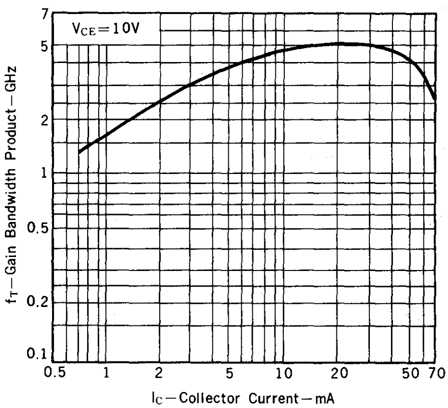
DC CURRENT GAIN vs. COLLECTOR CURRENT



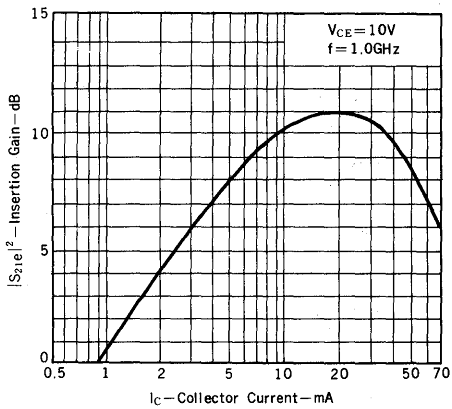
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



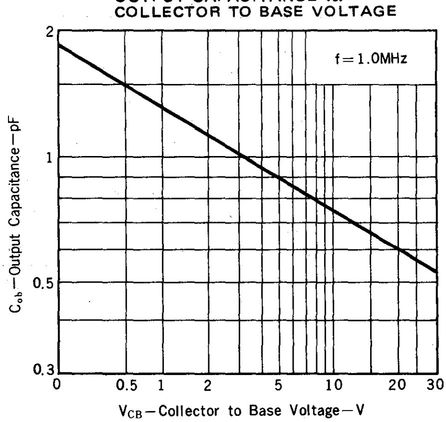
GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



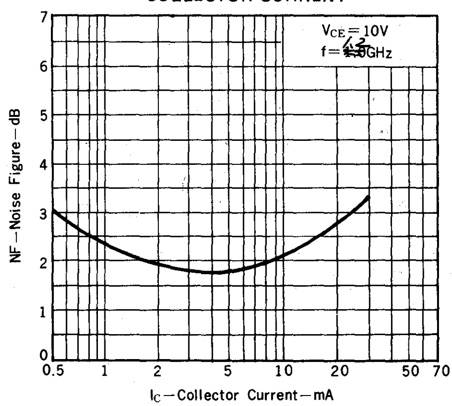
INSERTION GAIN vs. COLLECTOR CURRENT



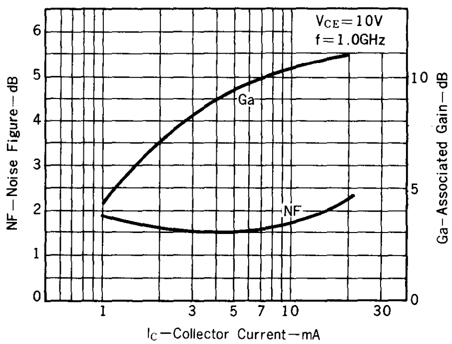
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



NOISE FIGURE vs. COLLECTOR CURRENT



NF, Ga vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

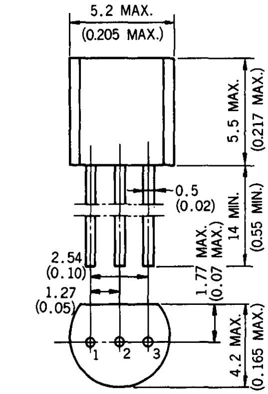
NPN SILICON TRANSISTOR
2SC2407

DESCRIPTION The 2SC2407 is designed for UHF and VHF amplifier.

FEATURES

- P_{out}: 160 mW TYP. @ f=500 MHz, V_{CC}=12.6 V
  P_i=5 mW (Class B)

PACKAGE DIMENSIONS
in millimeters (inches)



1. BASE
2. EMITTER
3. COLLECTOR

EIAJ : SC-43
JEDEC: TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature . . . . −65 to +150 °C
- Junction Temperature . . . . +150 °C Maximum

Maximum Power Dissipation (Ta=25 °C)
- Total Power Dissipation . . . . 600 mW

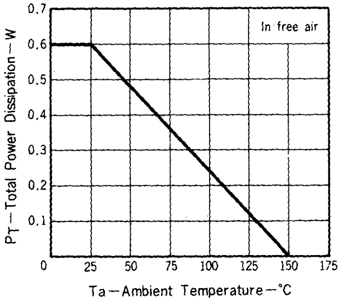
Maximum Voltages and Currents (Ta=25 °C)
- V_{CBO} Collector to Base Voltage . . . . 35 V
- V_{CEO} Collector to Emitter Voltage . . . . 18 V
- V_{EBO} Emitter to Base Voltage . . . . 3.0 V
- I_C Collector Current . . . . 150 mA
- I_B Base Current . . . . 50 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

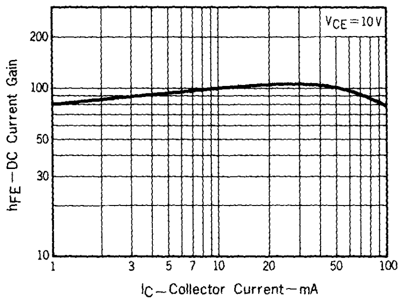
SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	20	60	200		V_{CE}=10 V, I_C=50 mA
C_{ob}	Output Capacitance		1.0	2.0	pF	V_{CB}=10 V, I_E=0, f=1.0 MHz
P_{out}	Output Power	20	22		dBm	V_{CC}=12.6 V, P_{in}=7 dBm, f=500 MHz (Class B)
I_{CBO}	Collector Cutoff Current			0.5	μA	V_{CB}=20 V, I_E=0
I_{EBO}	Emitter Cutoff Current			0.5	μA	V_{EB}=2.0 V, I_C=0

TYPICAL CHARACTERISTICS (Ta = 25 °C)

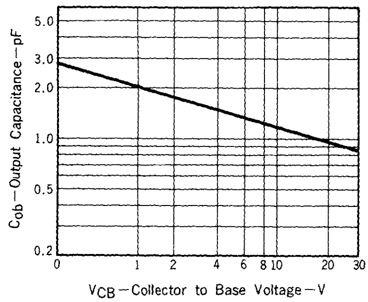
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



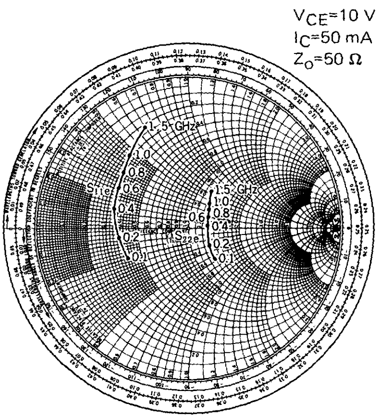
DC CURRENT GAIN vs. COLLECTOR CURRENT



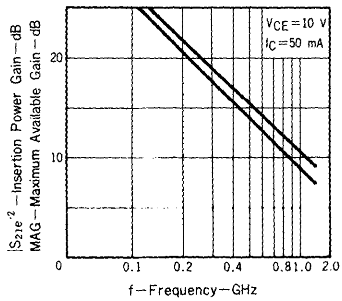
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



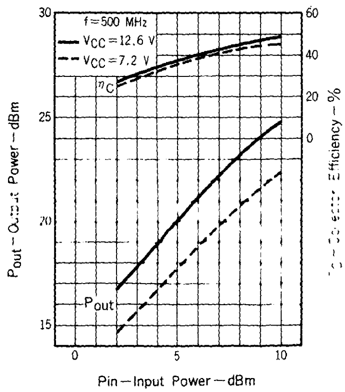
TYPICAL "S" PARAMETERS



INSERTION POWER GAIN AND MAXIMUM AVAILABLE GAIN vs. FREQUENCY



OUTPUT POWER AND COLLECTOR EFFICIENCY vs. INPUT POWER



2

NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC2408

DESCRIPTION 2SC2408 is designed for High frequency Wide Band Amplifier.

FEATURES
- $|S_{21e}|^2$: 21 dB TYP. @200 MHz
- NF : 2.4 dB TYP. @200 MHz

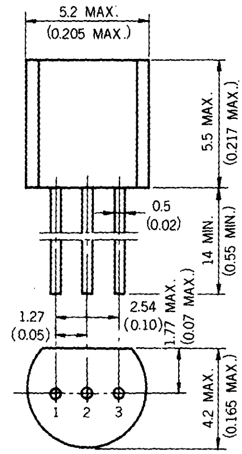
ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature .... −65 to +150 °C
- Junction Temperature .... +150 °C Maximum

Maximum Power Dissipation (Ta=25 °C)
- Total Power Dissipation .... 600 mW

Maximum Voltages and Current (Ta=25 °C)
- V_{CBO} Collector to Base Voltage .... 35 V
- V_{CEO} Collector to Emitter Voltage ...... 18 V
- V_{EBO} Emitter to Base Voltage .... 3.0 V
- I_C Collector Current .... 150 mA

PACKAGE DIMENSIONS
in millimeters (inches)



1. BASE
2. EMITTER
3. COLLECTOR

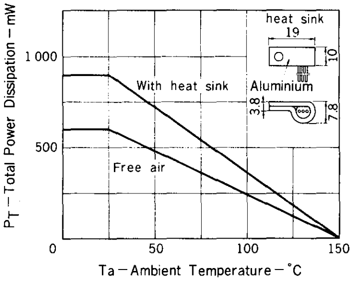
EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

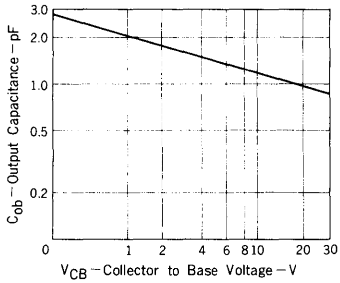
SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	30	100	200		V_{CE}=10 V, I_C=50 mA
f_T	Gain Bandwidth Product		3.5		GHz	V_{CE}=10 V, I_C=50 mA
C_{ob}	Output Capacitance		1.25	2.0	pF	V_{CB}=10 V, I_E=0, f=200 MHz
$\lvert S_{21e}\rvert^2$	Insertion Power Gain	18	21		dB	V_{CE}=10 V, I_C=50 mA, f=200 MHz, R_G=50 Ω
NF	Noise Figure		2.4	4.0	dB	V_{CE}=10 V, I_C=30 mA, f=200 MHz, R_G=50 Ω
I_{CBO}	Collector Cutoff Current			0.5	μA	V_{CB}=20 V, I_E=0
I_{EBO}	Emitter Cutoff Current			0.5	μA	V_{EB}=2.0 V, I_C=0

TYPICAL CHARACTERISTICS (Ta=25 °C)

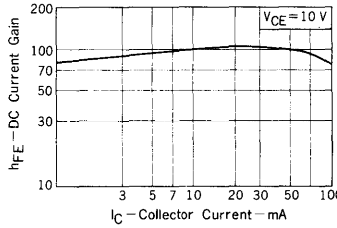
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



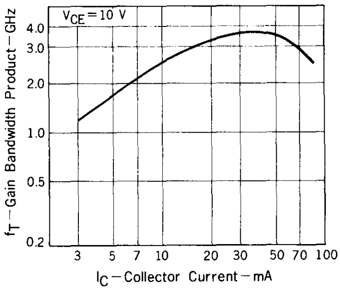
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



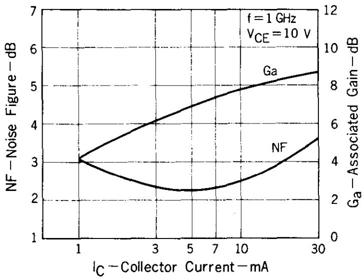
DC CURRENT GAIN vs. COLLECTOR CURRENT



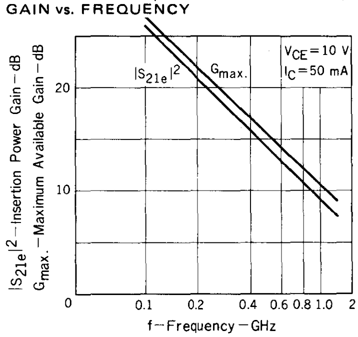
GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



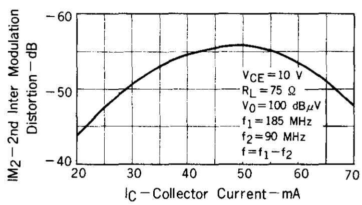
NOISE FIGURE, ASSOCIATED GAIN vs. COLLECTOR CURRENT



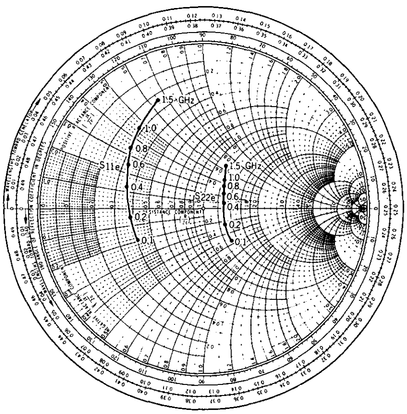
INSERTION GAIN, MAXIMUM AVAILABLE GAIN vs. FREQUENCY



INTER MODULATION DISTORTION vs. COLLECTOR CURRENT

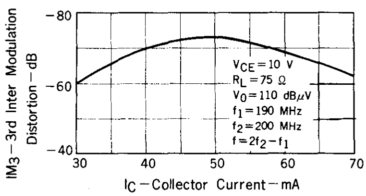


TYPICAL "S" PARAMETER



V_{CE} = 10 V
I_C = 50 mA
Z_O = 50 Ω

INTER MODULATION DISTORTION vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

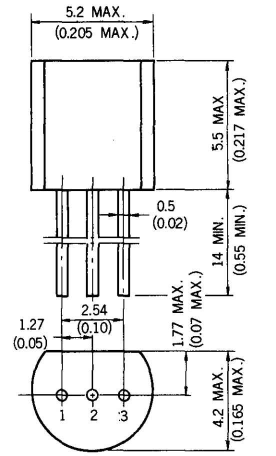
NPN SILICON TRANSISTOR
2SC2570A

DESCRIPTION The 2SC2570A is designed for use in Low Noise Amplifier of VHF & UHF stages.

FEATURES

- Low Noise and High Gain.
  NF=1.5 dB TYP.
  Ga= 8 dB TYP. @V_{CE}=10 V, I_C=5.0 mA, f=1.0 GHz
- Wide Dynamic Range.
  NF=1.9 dB
  Ga= 9 dB @f=1 GHz, V_{CE}=10 V, I_C=15 mA

PACKAGE DIMENSIONS
in millimeters (inches)



1. BASE	EIAJ	: SC-43
2. EMITTER	JEDEC	: TO-92
3. COLLECTOR	IEC	: PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature . . . . −65 to +150 °C
- Junction Temperature . . . . +150 °C Maximum

Maximum Power Dissipation (Ta=25 °C)
- Total Power Dissipation . . . . 600 mW

Maximum Voltages and Current (Ta=25 °C)
- V_{CBO} Collector to Base Voltage . . . . 25 V
- V_{CEO} Collector to Emitter Voltage . . . . . . 12 V
- V_{EBO} Emitter to Base Voltage . . . . 3.0 V
- I_C Collector Current . . . . 70 mA

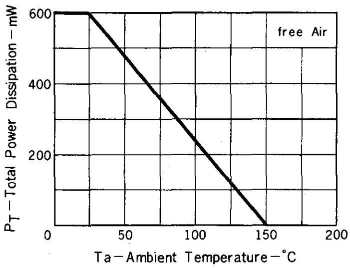
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	40		200		V_{CE}=10 V, I_C=20 mA
f_T	Gain Bandwidth Product		5.0		GHz	V_{CE}=10 V, I_C=20 mA
C_{ob}*	Output Capacitance		0.7	0.9	pF	V_{CB}=10 V, I_E=0, f=1.0 MHz
$\|S_{21e}\|^2$	Insertion Power Gain	8	10		dB	V_{CE}=10 V, I_C=20 mA, f=1.0 GHz
NF	Noise Figure		1.5	3.0	dB	V_{CE}=10 V, I_C=5 mA, f=1.0 GHz
MAG	Maximum Available Gain		11.5		dB	V_{CE}=10 V, I_C=20 mA, f=1.0 GHz
I_{CBO}	Collector Cutoff Current			0.1	μA	V_{CB}=15 V, I_E=0
I_{EBO}	Emitter Cutoff Current			0.1	μA	V_{EB}=2.0 V, I_C=0

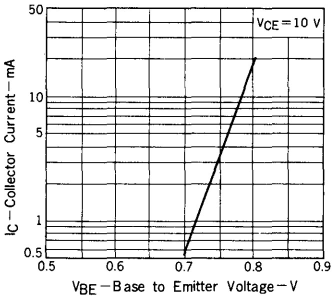
* The emitter and case terminal should be connected to the guard terminal of the capacitance bridge.

TYPICAL CHARACTERISTICS (Ta=25 °C)

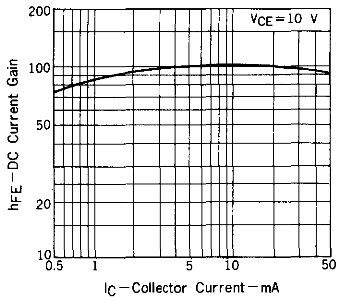
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE

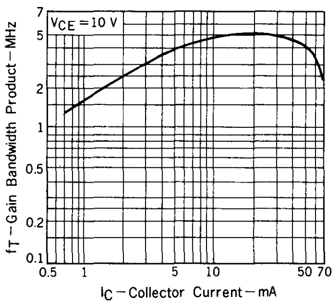


DC CURRENT GAIN vs. COLLECTOR CURRENT

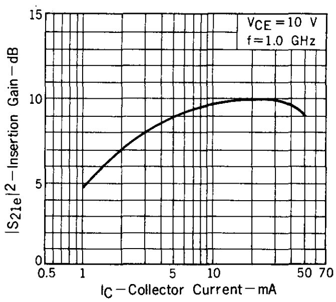


2

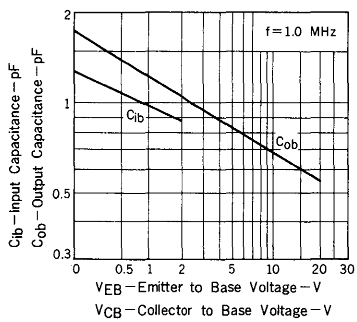
GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



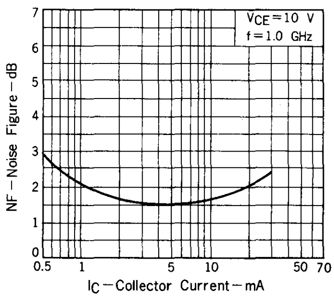
INSERTION GAIN vs. COLLECTOR CURRENT



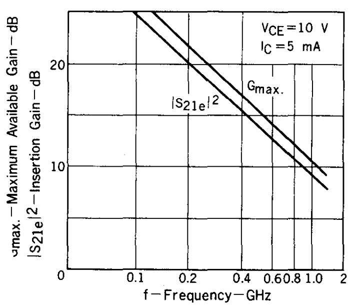
OUTPUT AND INPUT CAPACITANCE vs. REVERSE VOLTAGE



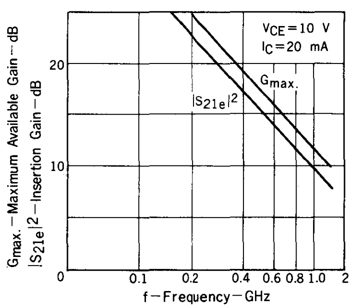
NOISE FIGURE vs. COLLECTOR CURRENT



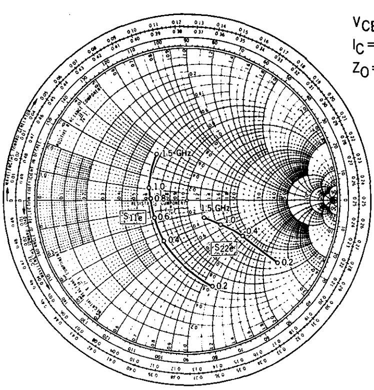
INSERTION GAIN, MAXIMUM AVAILABLE GAIN vs. FREQUENCY



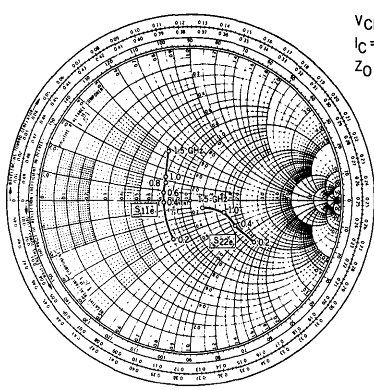
INSERTION GAIN, MAXIMUM AVAILABLE GAIN vs. FREQUENCY



TYPICAL "S" PARAMETERS



$V_{CE} = 10$ V
$I_C = 5$ mA
$Z_O = 50\ \Omega$



$V_{CE} = 10$ V
$I_C = 20$ mA
$Z_O = 50\ \Omega$

PRELIMINARY SPECIFICATION

NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR

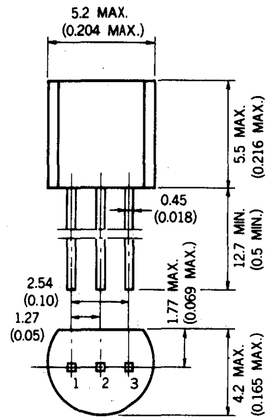
2SC2737

DESCRIPTION The 2SC2737 is designed for Low Noise Amplifier of VHF & UHF band.

FEATURES

- Low Noise and High Gain
  NF = 1.2 dB TYP.
  Ga = 9.0 dB TYP. $V_{CE} = 8$ V, $I_C = 5$ mA, f = 1.0 GHz
- Wide Dynamic Range
  NF = 1.65 dB
  Ga = 10 dB $V_{CE} = 8$ V, $I_C = 20$ mA, f = 1.0 GHz

PACKAGE DIMENSIONS
in millimeters (inches)



1. BASE
2. EMITTER
3. COLLECTOR

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature .... −65 to +150 °C

Junction Temperature .... 150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation .... 600 mW

Maximum Voltages and Current (Ta = 25 °C)

V_{CBO} Collector to Base Voltage .... 20 V

V_{CEO} Collector to Emitter Voltage .... 10 V

V_{EBO} Emitter to Base Voltage .... 3.0 V

I_C Collector Current .... 80 mA

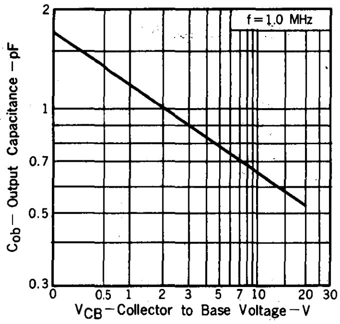
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	30	80	300	–	$V_{CE} = 8$ V, $I_C = 20$ mA
f_T	Gain Bandwidth Product		8		GHz	$V_{CE} = 8$ V, $I_C = 20$ mA
C_{ob}*	Output Capacitance		0.65	1.0	pF	$V_{CB} = 10$ V, $I_E = 0$, f = 1.0 MHz
$\|S_{21e}\|^2$	Insertion Power Gain	9	11		dB	$V_{CE} = 8$ V, $I_C = 20$ mA, f = 1.0 GHz
NF	Noise Figure		1.2	2.5	dB	$V_{CE} = 8$ V, $I_C = 5$ mA, f = 1.0 GHz
I_{CBO}	Collector Cutoff Current			1.0	μA	$V_{CB} = 10$ V, $I_E = 0$
I_{EBO}	Emitter Cutoff Current			1.0	μA	$V_{EB} = 1$ V, $I_C = 0$

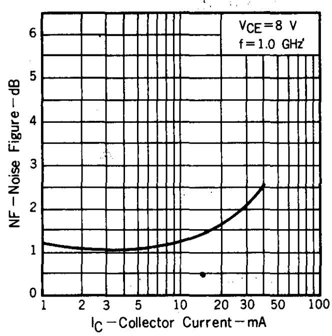
*The emitter should be connected to the guard terminal of the capacitance bridge.

TYPICAL CHARACTERISTICS (Ta = 25 °C)

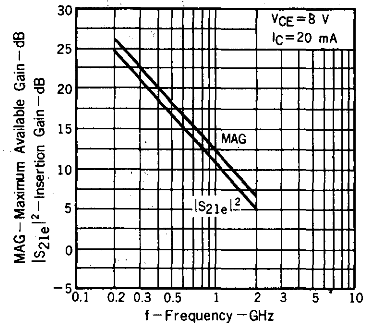
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



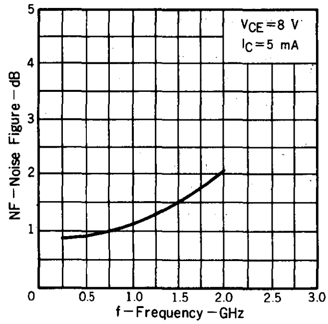
NOISE FIGURE vs. COLLECTOR CURRENT



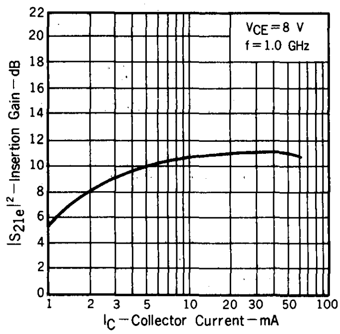
GAIN vs. FREQUENCY



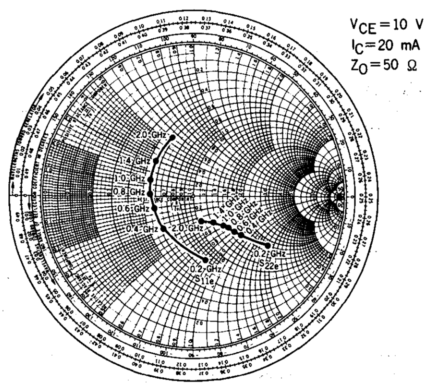
NOISE FIGURE vs. FREQUENCY



INSERTION GAIN vs. COLLECTOR CURRENT



S PARAMETER



NEC
ELECTRON DEVICE

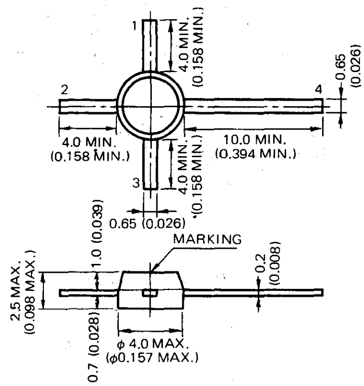
NPN SILICON TRANSISTOR
2SC2869

DESCRIPTION The 2SC2869 is designed for Low Noise Amplifier of VHF & UHF band.

FEATURES

- Low Noise and High Gain
  NF = 1.2 dB TYP.
  Ga = 10.5 dB TYP. V_{CE} = 8 V, I_C = 5 mA, f = 1.0 GHz
- High Power Gain
  MAG = 16.5 dB TYP.
  V_{CE} = 8 V, I_C = 20 mA, f = 1.0 GHz

PACKAGE DIMENSIONS
in millimeters (inches)



1. EMITTER
2. BASE
3. EMITTER
4. COLLECTOR

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature	−65 to +150 °C
Junction Temperature	150 °C Maximum

Maximum Power Dissipation (Tc = 130 °C)

Total Power Dissipation	400 mW

Maximum Voltages and Current (Ta = 25 °C)

V_{CBO}	Collector to Base Voltage	20 V
V_{CEO}	Collector to Emitter Voltage	10 V
V_{EBO}	Emitter to Base Voltage	3.0 V
I_C	Collector Current	80 mA

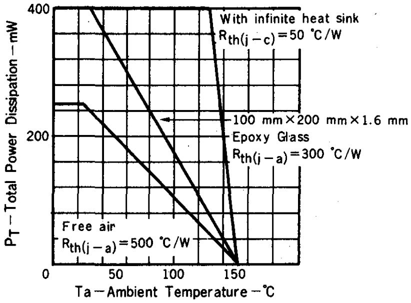
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	30	80	300	—	V_{CE} = 8 V, I_C = 20 mA
f_T	Gain Bandwidth Product		8		GHz	V_{CE} = 8 V, I_C = 20 mA
C_{ob}*	Output Capacitance		0.7	1.0	pF	V_{CB} = 10 V, I_E = 0, f = 1.0 MHz
$\|S_{21e}\|^2$	Insertion Power Gain	11.5	13		dB	V_{CE} = 8 V, I_C = 20 mA, f = 1.0 GHz
NF	Noise Figure		1.2	2.5	dB	V_{CE} = 8 V, I_C = 5 mA, f = 1.0 GHz
I_{CBO}	Collector Cutoff Current			1.0	μA	V_{CB} = 10 V, I_E = 0
I_{EBO}	Emitter Cutoff Current			1.0	μA	V_{EB} = 1.0 V, I_C = 0

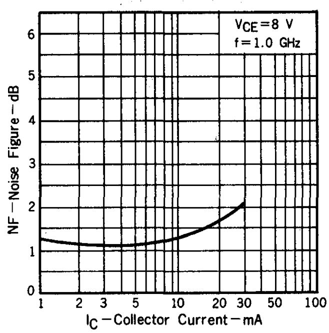
*The emitter should be connected to the guard terminal of the capacitance bridge.

TYPICAL CHARACTERISTICS (Ta = 25 °C)

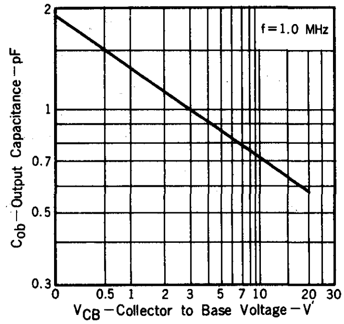
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



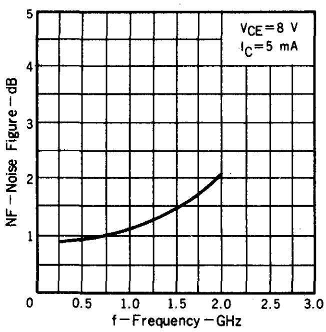
NOISE FIGURE vs. COLLECTOR CURRENT



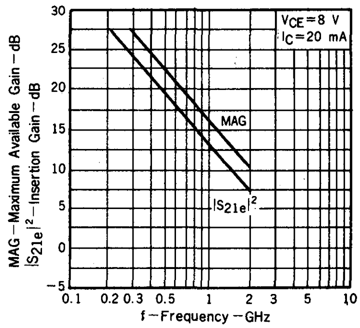
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



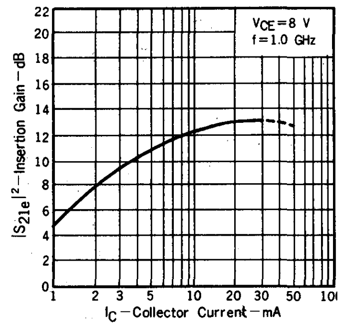
NOISE FIGURE vs. FREQUENCY



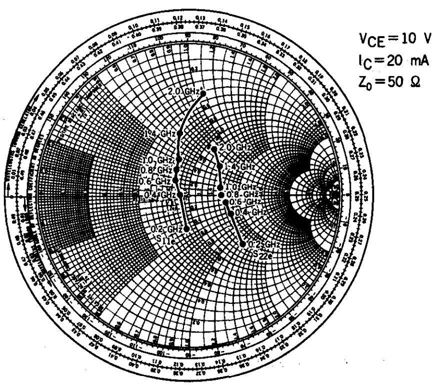
GAIN vs. FREQUENCY



INSERTION GAIN vs. COLLECTOR CURRENT



S PARAMETER



Contents

NEC
ELECTRON DEVICE

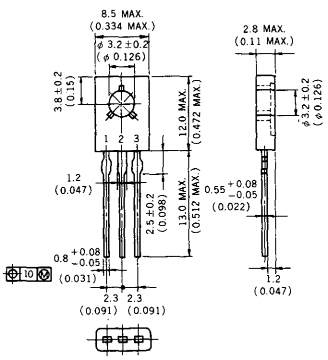
SILICON POWER TRANSISTOR
NT340

HIGH VOLTAGE MEDIUM POWER
NPN SILICON TRIPLE DIFFUSED TRANSISTOR

DESCRIPTION

Suitable for line-operated switching regulators and DC-DC converters.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter (E)
2. Collector (C)
3. Base (B)
4. Fin (Collector)

FEATURES

- High Collector-Emitter Sustaining Voltage.
- High Power Dissipation Capability in Small Package.
- Equivalent to MJE340.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25 °C)			
Collector to Emitter Voltage	V_{CEO}	300	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Continuous Collector Current	$I_{C(DC)}$	500	mA
Peak Collector Current	$I_{C(pulse)}$*	1000	mA
Continuous Base Current	$I_{B(DC)}$	250	mA
Maximum Power Dissipations			
Total Power Dissipation (Ta = 25 °C)	P_T	1.0	W
Total Power Dissipation (T_C = 25 °C)	P_T	20.8	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−65 to +150	°C
Thermal Resistance			
Junction to Case	$R_{th(j-c)}$	6.0	°C/W

*Pulsed PW ≦ 300 μs, duty cycle ≦ 10 %

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	300			V	I_C = 1.0 mA, I_B = 0
Collector Cutoff Current	I_{CBO}			100	μA	V_{CB} = 300 V, I_E = 0
Emitter Cutoff Current	I_{EBO}			100	μA	V_{EB} = 3.0 V, I_C = 0
DC Current Gain	h_{FE}	30		240		V_{CE} = 10 V, I_C = 50 mA*
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C = 100 mA, I_B = 10 mA*
Base Saturation Voltage	$V_{BE(sat)}$			1.0	V	
Turn On Time	t_{on}		0.5		μs	I_C = 0.3 A, I_{VL} = I_{B2} = 60 mA, V_{CC} = 150 V, R_L = 500 Ω, PW = 50 μs, duty cycle ≦ 2 %
Storage Time	t_{stg}		2.3		μs	
Fall Time	t_f		0.35		μs	

* Pulsed PW ≦ 350 μs, duty cycle ≦ 2 %

TENTATIVE SPECIFICATION

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NT350

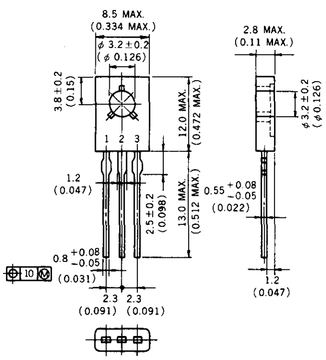
HIGH VOLTAGE MEDIUM POWER
PNP SILICON TRIPLE DIFFUSED TRANSISTOR

3

DESCRIPTION

Suitable for DC-DC converters, line-operated Switching regulators and PDP.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter (E)
2. Collector (C)
3. Base (B)
4. Fin (Collector)

FEATURES

- High Collector-Emitter Sustaining Voltage.
- High Power Dissipation Capability in Small Package.
- Equivalent to MJE350.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25 °C)			
Collector to Emitter Voltage	V_{CEO}	−300	V
Emitter to Base Voltage	V_{EBO}	−5.0	V
Continuous Collector Current	$I_{C(DC)}$	−500	mA
Peak Collector Current	$I_{C(pulse)}$*	−1000	mA
Continuous Base Current	$I_{B(DC)}$	−250	mA
Maximum Power Dissipations			
Total Power Dissipation (Ta = 25 °C)	P_T	1.0	W
Total Power Dissipation (T_C = 25 °C)	P_T	20	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−65 to +150	°C
Thermal Resistance			
Junction to Case	$R_{th(j\text{-}c)}$	6.25	°C/W

* Pulsed PW ≦ 300 μs, duty cycle ≦ 10 %

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	−300			V	I_C=−1.0 mA, I_B=0
Collector Cutoff Current	I_{CBO}			−100	μA	V_{CB}=−300 V, I_E=0
Emitter Cutoff Current	I_{EBO}			−100	μA	V_{EB}=−3.0 V, I_C=0
DC Current Gain	h_{FE}	30		240		V_{CE}=−10 V, I_C=−50 mA*
Collector Saturation Voltage	$V_{CE(sat)}$			−1.0	V	I_C=−100 mA, I_B=−10 mA*
Base Saturation Voltage	$V_{BE(sat)}$			−1.2	V	

*Pulsed PW ≦ 350 μs, duty cycle ≦ 2 %

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTA959

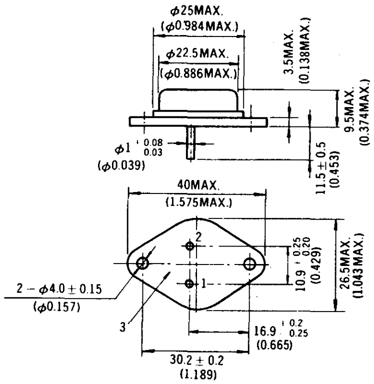
HIGH SPEED HIGH CURRENT SWITCHING PNP EPITAXIAL TRANSISTOR

Industrial Use

DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector (Case)

EIAJ :TC-3,TB-3
JEDEC:TO-3
IEC :C14A,B18

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased S.O.A. with inductive loads.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Emitter Voltage	V_{CEX}	-100	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	-100	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	-100	V
Emitter to Base Voltage	V_{EBO}	-7.0	V
Continuous Collector Current	$I_{C(DC)}$	-15	A
Peak Collector Current*	$I_{C(pulse)}$	-30	A
Continuous Base Current	$I_{B(DC)}$	-5.0	A
Peak Base Current*	$I_{B(pulse)}$	-10	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(Tc=25°C)}$	150	W
Total Power Dissipation	$P_{T(Tc=100°C)}$	86	W
Total Power Dissipation	$P_{T(Ta=25°C)}$	5	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature 1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	1.17	°C/W
Junction to Ambient	$R_{th(j-a)}$	35	°C/W

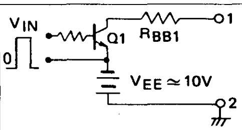
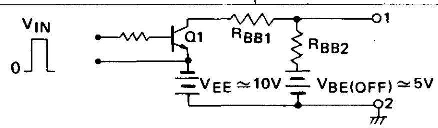
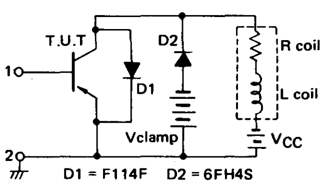
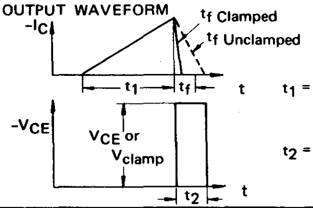
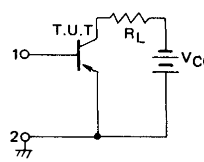
* Pulsed PW ≦ 300 μs, duty cycle ≦ 10%

ELECTRICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	-100			V	Table 1. I_C = -10A, I_{B1} = -1.0A, L = 50 μH
	$V_{CEX(SUS)1}$	-100			V	Table 1. I_C = -10A, I_{B1} = $-I_{B2}$ = -1.0A, V_{clamp} = Rated V_{CEX}, Ta = 125°C
	$V_{CEX(SUS)2}$	-100			V	Table 1. I_C = -20A, I_{B1} = -2A, I_{B2} = -1.0A, V_{clamp} = Rated V_{CEX}, Ta = 125°C
Collector Cutoff Current	I_{CER}			-2.0	mA	V_{CE} = -100V, R_{BE} = 50Ω, Ta = 125°C
	I_{CEX}			-100	μA	V_{CE} = -100V, $V_{BE(OFF)}$ = 1.5V
	I_{CEX}			-1.0	mA	V_{CE} = -100V, $V_{BE(OFF)}$ = 1.5V, Ta = 125°C
Emitter Cutoff Current	I_{EBO}			-10	μA	V_{EB} = -7.0V, I_C = 0
Second Breakdown Collector Current	$I_{S/B}$	-7.5			A	t = 1.0 s, V_{CE} = -20V, Tc = 25°C
Second Breakdown Energy	$E_{S/B}$	2.0			mJ	I_C = -10A, I_{B1} = -1A, $V_{BE(OFF)}$ = 5V
DC Current Gain	h_{FE1}	30		200		V_{CE} = -5V, I_C = -5A **
	h_{FE2}	20				V_{CE} = -5V, I_C = -10A **
Collector Saturation Voltage	$V_{CE(sat)}$			-1.0	V	I_C = -10A, I_B = -1.0A **
	$V_{CE(sat)}$			-1.5	V	I_C = -10A, I_B = -1.0A, Ta = 125°C **
Base Saturation Voltage	$V_{BE(sat)}$			-1.5	V	I_C = -10A, I_B = -1.0A **
	$V_{BE(sat)}$			-1.5	V	I_C = -10A, I_B = -1.0A, Ta = 125°C **
Gain Bandwidth Product	f_T	20			MHz	V_{CE}=-10V, I_C=-500mA, f_o=3.0MHz, Tc=25°C
Output Capacitance	C_{ob}			500	pF	V_{CB} = -10V, f_o = 1.0 MHz
Delay Time	t_d			0.1	μs	Resistive Load (Table 1.)
Rise Time	t_r			0.7	μs	
	t_r			2.1	μs	Ta = 125°C; I_C = -10A, I_{B1} = $-I_{B2}$ = -1.0A
Storage Time	t_{stg}			1.5	μs	R_L = 5.0Ω, V_{CC} ≃ -50V
	t_{stg}			3.0	μs	Ta = 125°C; PW ≃ 50μs, duty cycle ≦ 2%
Fall Time	t_f			0.3	μs	
	t_f			1.2	μs	Ta = 125°C

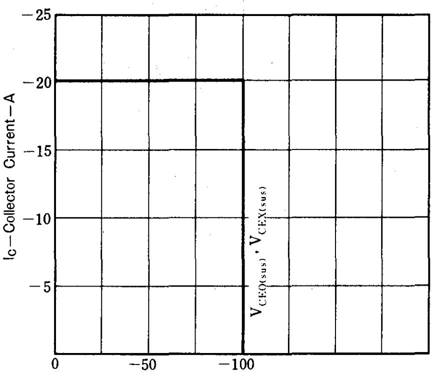
** PW ≦ 350 μs, duty cycle ≦ 2%

TABLE 1. — TEST CONDITIONS FOR DYNAMIC PERFORMANCE

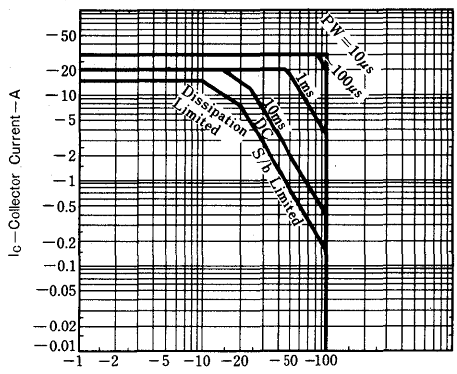
	V_{CEO} (SUS)	V_{CEX} (SUS)	$E_{S/B}$	RESISTIVE SWITCHING
INPUT CONDITIONS	 PW Varied to Attain I_C = -10A	 PW Varied to Attain I_C = -10A duty cycle ≦ 2% Q_1 = 2SC1869		
CIRCUIT VALUES	L_{coil} = 50μH, V_{CC} = -10V R_{coil} = 0.05Ω V_{clamp} (Unclamped)	L_{coil} = 180 μH, V_{CC} = -20V R_{coil} = 0.2Ω V_{clamp} = Rated V_{CEX} Value	L_{coil} = 40 μH, V_{CC} = -10V R_{coil} = 0.05Ω, R_{BB2} = 50Ω V_{clamp} (Unclamped)	R_L = 5.5Ω, V_{CC} ≃ -50V
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT  D1 = F114F D2 = 6FH4S	OUTPUT WAVEFORM 	t_1 Adjust to Obtain IC $t_1 = \frac{L_{coil}(I_{C\,pk})}{V_{CC}}$ $t_2 = \frac{L_{coil}(I_{C\,pk})}{V_{clamp}}$	RESISTIVE TEST CIRCUIT 

TYPICAL CHARACTERISTICS (Ta=25°C)

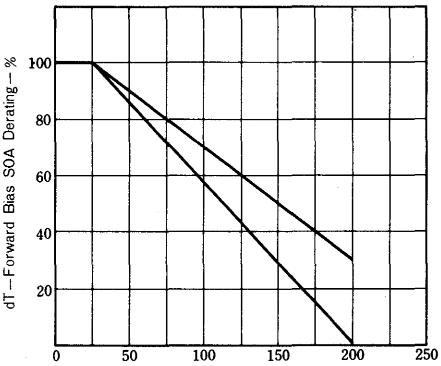
REVERSE BIAS SAFE OPERATING AREA



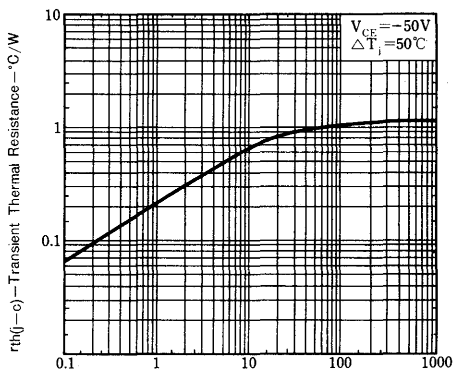
FORWARD BIAS SAFE OPERATING AREAS



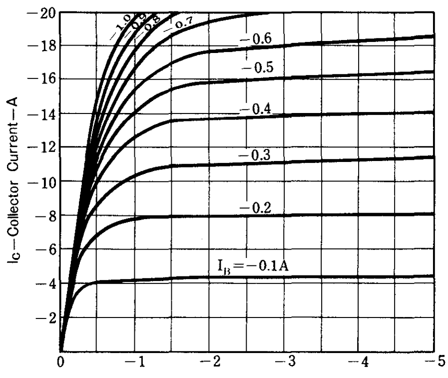
DERATING CURVE OF FORWARD BIAS SAFE OPERATING AREA



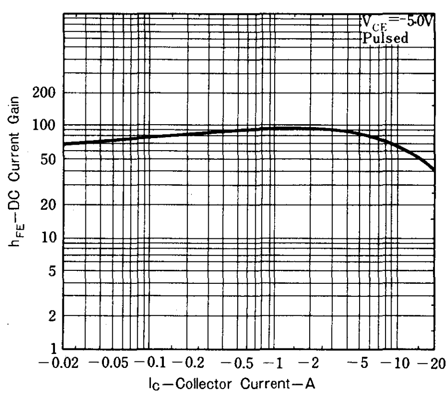
TRANSIENT THERMAL RESISTANCE



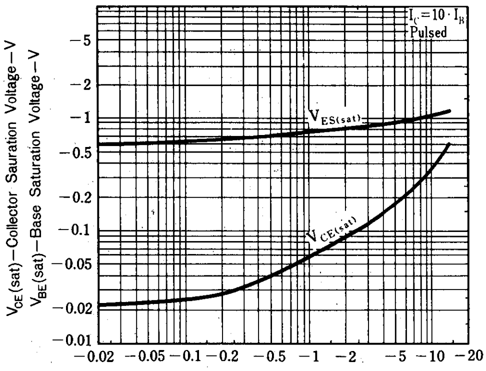
COLLECTOR CURRENT vs. COLLECTOR TO EMTTER VOLTAGE



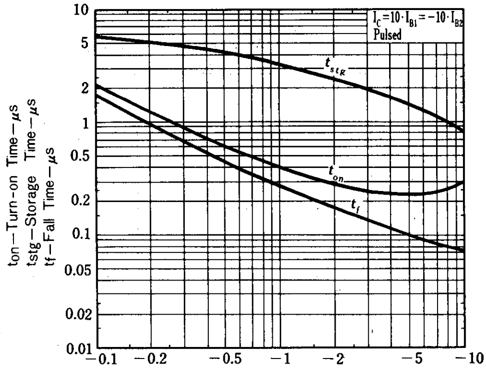
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTA1008

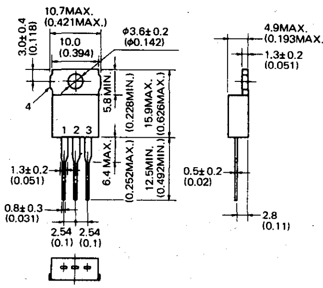
HIGH SPEED HIGH CURRENT SWITCHING
PNP SILICON EPITAXIAL TRANSISTOR

Industrial Use

DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base (B)
2. Collector (C)
3. Emitter (E)
4. Fin (Collector)

JEDEC: TO-220AB

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased SOA with inductive loads.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta=25°C)			
Collector to Emitter Voltage	V_{CEX}	−100	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	−100	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	−100	V
Emitter to Base Voltage	V_{EBO}	−7.0	V
Continuous Collector Current	$I_{C(DC)}$	−2.0	A
Peak Collector Current	$I_{C(pulse)}$ *	−4.0	A
Continuous Base Current	$I_{B(DC)}$	−1.0	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T}(Tc=25°C)$	40	W
Total Power Dissipation	$P_{T}(Tc=100°C)$	16	W
Total Power Dissipation	$P_{T}(Ta=25°C)$	2.0	W
Maximum Temperatures			
Junction Temperature	Tj	150	°C
Storage Temperature	Tstg	−55 to +150	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	3.13	°C/W
Junction to Ambient	$R_{th(j-a)}$	62.5	°C/W

* Pulsed PW $\leq$ 300 μs, duty cycle $\leq$ 10%

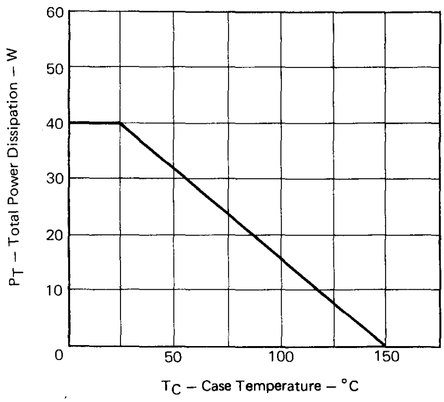
ELECTRICAL CHARACTERISTICS (Ta=25°C unless otherwise noted.)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	−100			V	I_C=−1.0A, I_B=−0.10A, L=1mH
	$V_{CEX(SUS)1}$	−100			V	I_C=−1.0A, I_{B1}=−I_{B2}=−0.1A, $V_{BE(OFF)}$=5V, L=180μH *1 Ta=125°C
	$V_{CEX(SUS)2}$	−100			V	I_C=−2A, I_{B1}=−0.2A, I_{B2}=0.10A, $V_{BE(OFF)}$=5V, L=180μH *2 Ta=125°C
Collector Cutoff Current	I_{CEX1}			−10	μA	V_{CE}=−100V, $V_{BE(OFF)}$=1.5V
	I_{CEX2}			−1.0	mA	V_{CE}=−100V, $V_{BE(OFF)}$=1.5V Ta=125°C
	I_{CER}			−1.0	mA	V_{CE}=−100V, R_{BE}=100Ω, Ta=125°C
Emitter Cutoff Current	I_{EBO}			−10	μA	V_{EB}=−5.0V, I_C=0
Second Breakdown Collector Current	$I_{S/B}$	−0.75			A	V_{CE}=−20V, t=1sec, Tc=25°C
Second Breakdown Energy	$E_{S/B}$	80			μJ	I_C=−1.0A, I_{B1}=−0.1A, V_{BE} (OFF) = 5V, R_{BB} = 50Ω, L=80μH
DC Current Gain	h_{FE1}	30				V_{CE}=−5.0V, I_C=−0.1A *3
	h_{FE2}	40		200		V_{CE}=−5.0V, I_C=−1.0A *3
Collector Saturation Voltage	$V_{CE(sat)}$			−1.0	V	I_C=−1.0A, I_B=−0.10A *3
Base Saturation Voltage	$V_{BE(sat)}$			−1.5	V	
Gain Bandwidth Product	f_T	50			MHz	V_{CE}=−10V, I_C=−50mA, f=3MHz
Output Capacitance	Cob			60	pF	V_{CB}=−10V, I_E=0, f=1MHz
Turn On Time	t_{on}			0.5	μs	I_C=−1.0A, I_{B1}=−I_{B2}=−0.1A $V_{BE(OFF)}$=5.0V, R_L = 50 Ω
Storage Time	t_{stg}			1.5	μs	
Fall Time	t_f			0.3	μs	

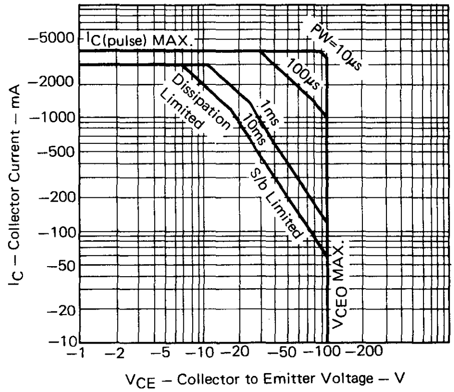
*1 V_{CE} clamped Vclamp = −100V
*2 V_{CE} clamped Vclamp = −100V
*3 Pulsed PW≤350μs, duty cycle≤2%

TYPICAL CHARACTERISTICS (Ta=25°C)

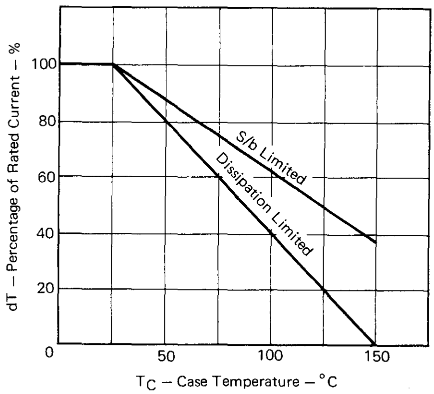
TOTAL POWER DISSIPATION vs. CASE TEMPERATURE



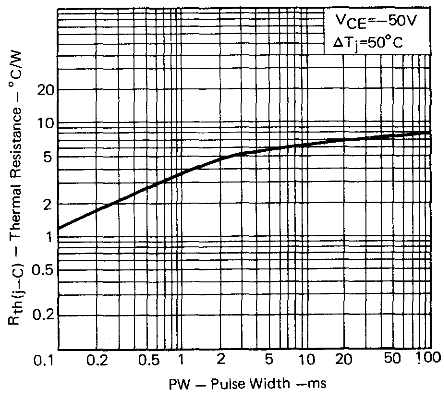
FORWARD BIAS SAFE OPERATING AREAS



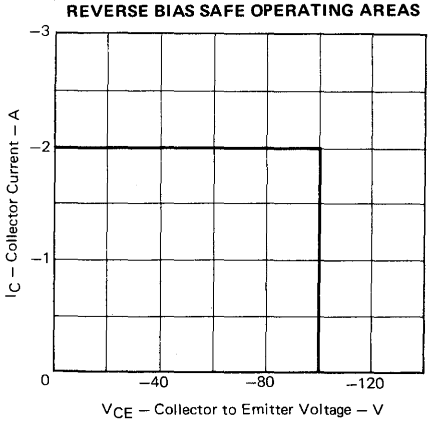
DERATING CURVE OF SAFE OPERATING AREAS



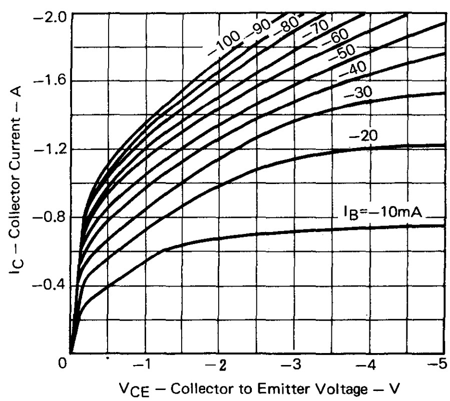
TRANSIENT THERMAL RESISTANCE



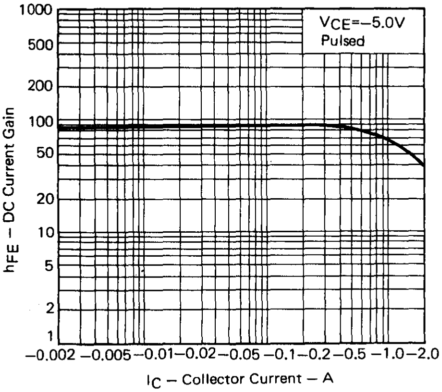
REVERSE BIAS SAFE OPERATING AREAS



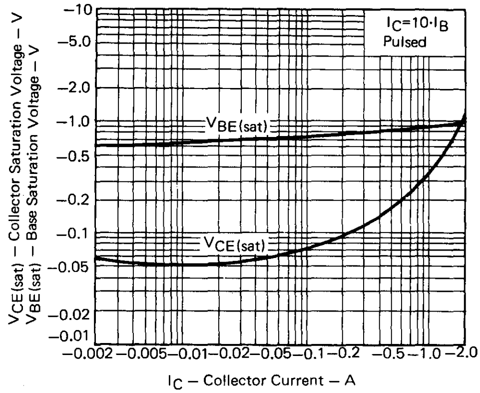
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



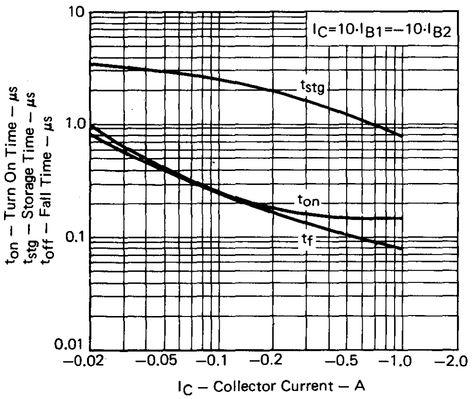
DC CURRENT GAIN vs. COLLECTOR CURRENT



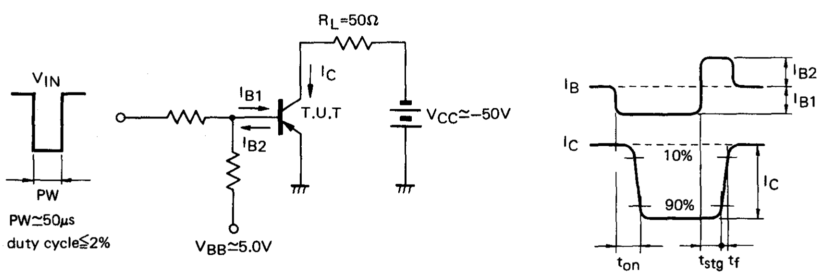
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT



SWITCHING TIME (t_{on}, t_{stg}, t_f) TEST CIRCUIT



NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTA1010

HIGH SPEED HIGH CURRENT SWITCHING
PNP SILICON EPITAXIAL TRANSISTOR

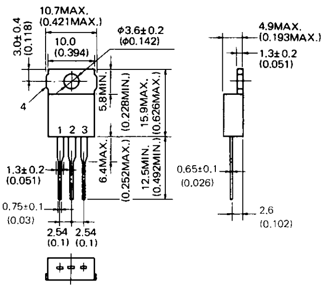
Industrial Use

3

DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base (B)
2. Collector (C)
3. Emitter (E)
4. Fin (Collector)

JEDEC: TO-220AB

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased SOA with inductive loads.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta=25°C)			
Collector to Emitter Voltage	V_{CEX}	−100	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	−100	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	−100	V
Emitter to Base Voltage	V_{EBO}	−7.0	V
Continuous Collector Current	$I_{C(DC)}$	−7.0	A
Peak Collector Current	$I_{C(pulse)}$*	−15	A
Continuous Base Current	$I_{B(DC)}$	−3.0	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(Tc=25°C)}$	65	W
Total Power Dissipation	$P_{T(Tc=100°C)}$	26	W
Total Power Dissipation	$P_{T(Ta=25°C)}$	2.0	W
Maximum Temperatures			
Junction Temperature	Tj	150	°C
Storage Temperature	Tstg	−55 to +150	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	1.92	°C/W
Junction to Ambient	$R_{th(j-a)}$	62.5	°C/W

* Pulsed PW ≤ 300 μs, duty cycle ≤ 10%

ELECTRICAL CHARACTERISTICS (Ta=25 °C unless otherwise noted.)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	−100			V	I_C=−5.0A, I_B=−0.5A, L=100μH
	$V_{CEX(SUS)1}$	−100			V	I_C=−5.0A, I_{B1}=−I_{B2}=−0.5A, $V_{BE(OFF)}$=5V, L=180μH, Ta=125°C *1
	$V_{CEX(SUS)2}$	−100			V	I_C=−10A, I_{B1}=−1.0A, I_{B2}=0.5A, $V_{BE(OFF)}$=5V, L=180μH, *2 Ta=125°C
Collector Cutoff Current	I_{CEX1}			−10	μA	V_{CE}=−100V, $V_{BE(OFF)}$=1.5V
	I_{CEX2}			−1.0	mA	V_{CE}=−100V, $V_{BE(OFF)}$=1.5V, Ta=125°C
	I_{CER}			−1.0	mA	V_{CE}=−100V, R_{BE}=100Ω, Ta=125°C
Emitter Cutoff Current	I_{EBO}			−10	μA	V_{EB}=−5.0V, I_C=0
Second Breakdown Collector Current	$I_{S/B}$	−2.0			A	V_{CE}=−20V, t=1sec Tc=25°C
Second Breakdown Energy	$E_{S/B}$	125			μJ	I_C=−5A, I_{B1}=−0.5A, $V_{BE(OFF)}$=5V, R_{BB}=50Ω, L=10μH
DC Current Gain	h_{FE1}	40				V_{CE}=−5.0V, I_C=−3.0A, *3
	h_{FE2}	20				V_{CE}=−5.0V, I_C=−5.0A *3
Collector Saturation Voltage	$V_{CE(sat)}$			−0.6	V	I_C=−5.0A, I_B=−0.5A *3
Base Saturation Voltage	$V_{BE(sat)}$			−1.5	V	
Gain Bandwidth Product	f_T	20			MHz	V_{CE}=−10V, I_C=−0.2A, f=3MHz
Output Capacitance	Cob			250	pF	V_{CB}=−10V, I_E=0, f=1MHz
Turn On Time	ton			0.5	μs	I_C=−5.0A, I_{B1}=−I_{B2}=−0.5A, $V_{BE(OFF)}$=5V, R_L=10Ω, Vcc≈−50V
Storage Time	tstg			1.5	μs	
Fall Time	t_f			0.3	μs	

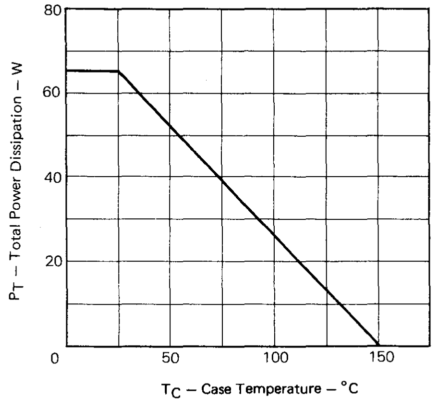
*1 V_{CE} clamped Vclamp = −100V

*2 V_{CE} clamped Vclamp = −100V

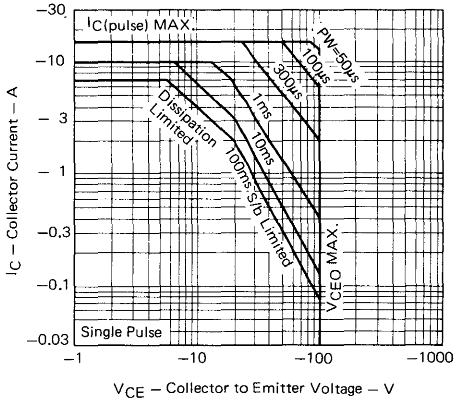
*3 Pulsed PW ≦350μs, duty cycle≦2%

TYPICAL CHARACTERISTICS (Ta=25°C)

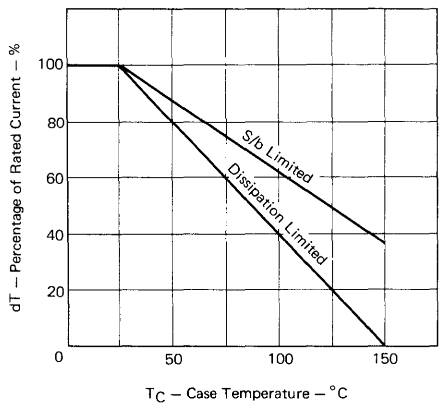
TOTAL POWER DISSIPATION vs. CASE TEMPERATURE



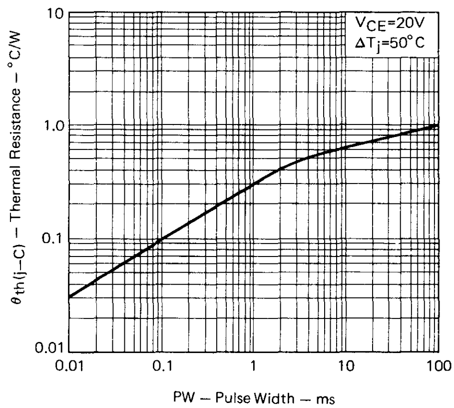
SAFE OPERATING AREA



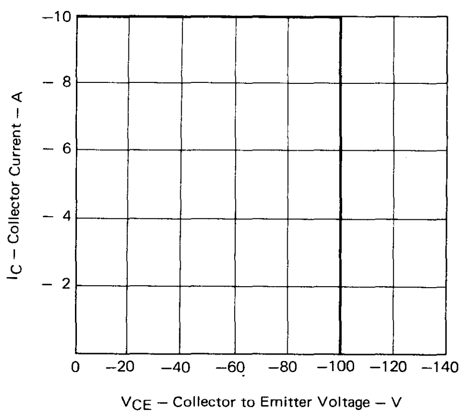
DERATING CURVE OF SAFE OPERATING AREAS



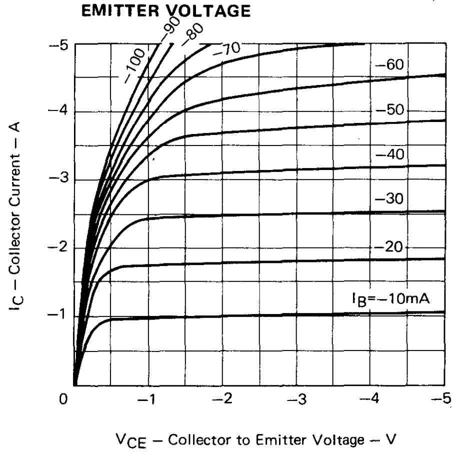
TRANSIENT THERMAL RESISTANCE



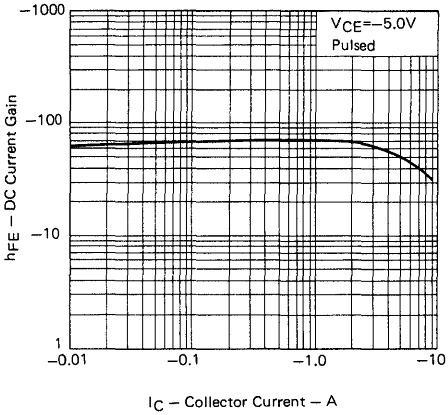
REVERSE BIAS SAFE OPERATING AREAS



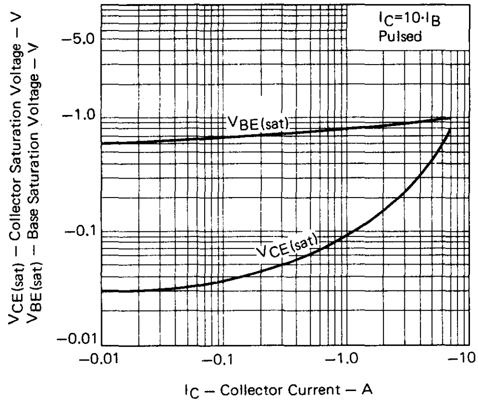
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



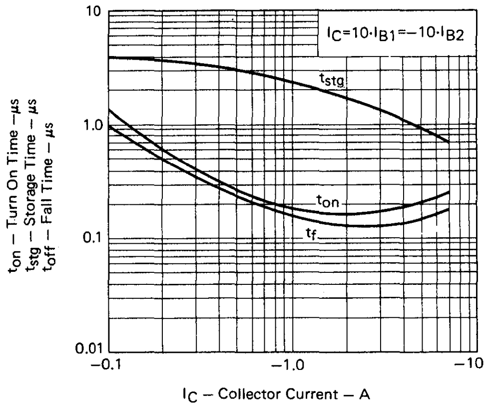
DC CURRENT GAIN vs. COLLECTOR CURRENT



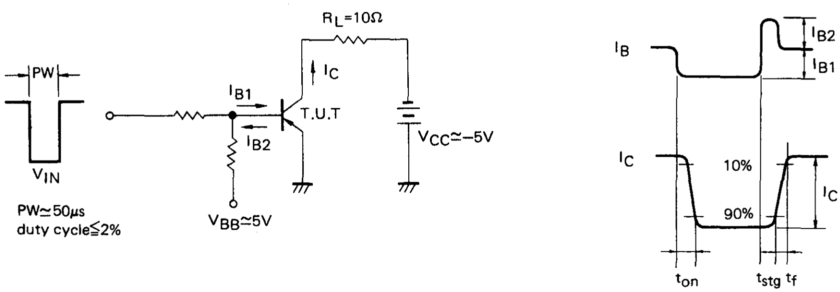
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORAGE AND FALL TIME vs. COLLECTOR CURRENT



SWITCHING TIME (t_{on}, t_{stg}, t_f) TEST CIRCUIT



NEC
ELECTRON DEVICE

SILICON POWER TRANSISTORS
NTA1069, NTA1069A

HIGH SPEED HIGH CURRENT SWITCHING
PNP SILICON EPITAXIAL TRANSISTOR

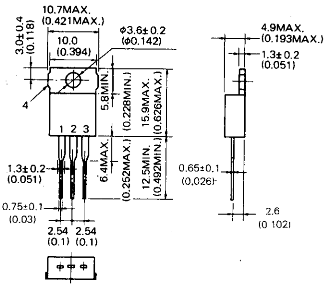
Industrial Use

3

DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base (B)
2. Collector (C)
3. Emitter (E)
4. Fin (Collector)

JEDEC: TO-220AB

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased SOA with inductive loads.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (T_a=25°C)		NTA1069	NTA1069A	
Collector to Emitter Voltage	V_{CEX}	−80	−80	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	−60	−80	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	−60	−80	V
Emitter to Base Voltage	V_{EBO}	−12	−12	V
Continuous Collector Current	$I_{C(DC)}$	−5.0	−5.0	A
Peak Collector Current	$I_{C(pulse)}$*	−10	−10	A
Continuous Base Current	$I_{B(DC)}$	−2.5	−2.5	A
Maximum Power Dissipations				
Total Power Dissipation	$P_{T(Tc=25°C)}$	50		W
Total Power Dissipation	$P_{T(Ta=25°C)}$	2.0		W
Maximum Temperatures				
Junction Temperature	T_j	150		°C
Storage Temperature	T_{stg}	−55 to +150		°C
Lead Temperature 1/8 inch from case for 10 seconds	T_L	260		°C
Thermal Resistances				
Junction to Case	$R_{th(j-c)}$	2.5		°C/W
Junction to Ambient	$R_{th(j-a)}$	62.5		°C/W

* Pulsed PW ≦ 300μs, duty cycle ≦ 10%

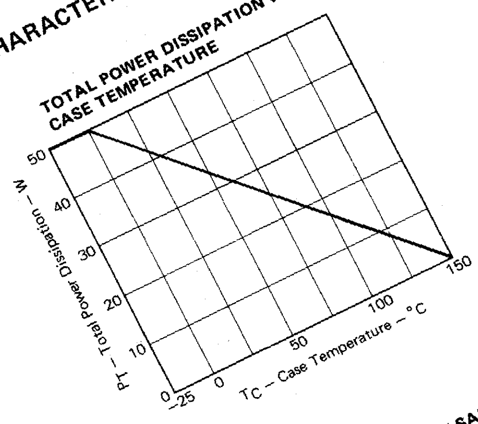
ELECTRICAL CHARACTERISTICS (Ta=25°C unless otherwise noted.) NTA1069 / NTA1069A

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	−60/−80			V	I_C=−1.0A, I_B=−0.10A, L=1mH
	$V_{CEX(SUS)1}$	−60/−80			V	I_C=−3.0A, I_{B1}=−I_{B2}=−0.3A, $V_{BE(OFF)}$=5V, L=180μH *1 Ta=125°C
	$V_{CEX(SUS)2}$	−60/−80			V	I_C=−6.0A, I_{B1}=−0.6A, I_{B2}=0.3A, $V_{BE(OFF)}$=5V, L=180μH*2 Ta=125°C
Collector Cutoff Current	I_{CEX1}			−10	μA	V_{CE}=−60/−80V, $V_{BE(OFF)}$=1.5V
	I_{CEX2}			−1.0	mA	V_{CE}=−60/−80V, $V_{BE(OFF)}$=1.5V Ta=125°C
	I_{CER}			−1.0	mA	V_{CE}=−60/−80V, R_{BE}=51Ω, Ta=125°C
Emitter Cutoff Current	I_{EBO}			−10	μA	V_{EB}=−5.0V, I_C=0
Second Breakdown Collector Current	$I_{S/B}$	−1.5			A	V_{CE}=−20V, t=1sec, Tc=25°C
Second Breakdown Energy	$E_{S/B}$	180			μJ	I_C=−3.0A, I_{B1}=−0.3A, V_{BE} (OFF) = 5V, R_{BB} = 50Ω, L=40μH
DC Current Gain	h_{FE1}	40				V_{CE}=−5.0V, I_C=−0.3A *3
	h_{FE2}	40		200		V_{CE}=−5.0V, I_C=−3.0A *3
Collector Saturation Voltage	$V_{CE(sat)}$			−0.6	V	I_C=−3.0A, I_B=−0.3A *3
Base Saturation Voltage	$V_{BE(sat)}$			−1.5	V	
Gain Bandwidth Product	f_T	20			MHz	V_{CE}=−10V, I_C=−50mA, f=3MHz
Output Capacitance	Cob			200	pF	V_{CB}=−10V, I_E=0, f=1MHz
Turn On Time	t_{on}			0.5	μs	I_C=−3.0A, I_{B1}=−I_{B2}=−0.3A $V_{BE(OFF)}$=5.0V, R_L = 17Ω Vcc≈−50V
Storage Time	t_{stg}			1.5	μs	
Fall Time	t_f			0.5	μs	

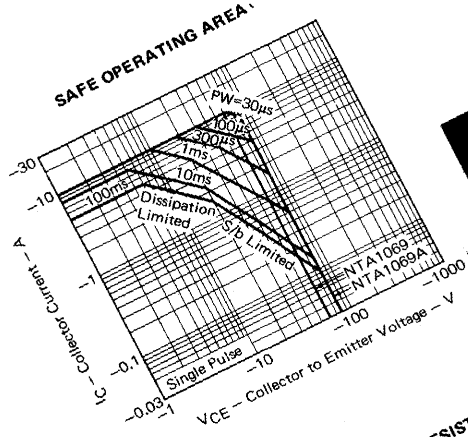
*1 V_{CE} clamped Vclamp = −60/−80V
*2 V_{CE} clamped Vclamp = −60/−80V
*3 Pulsed PW≦350μs, duty cycle≦2%

...ICAL CHARACTERISTICS (Ta=25°C)

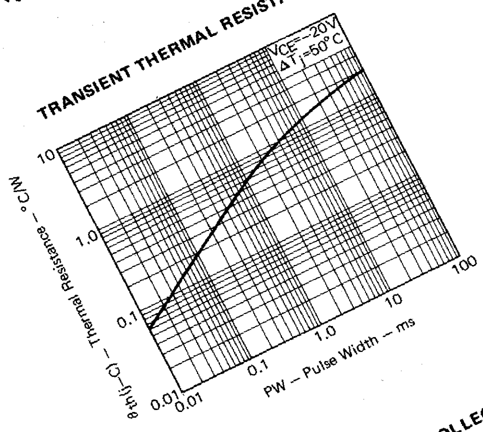
TOTAL POWER DISSIPATION vs. CASE TEMPERATURE



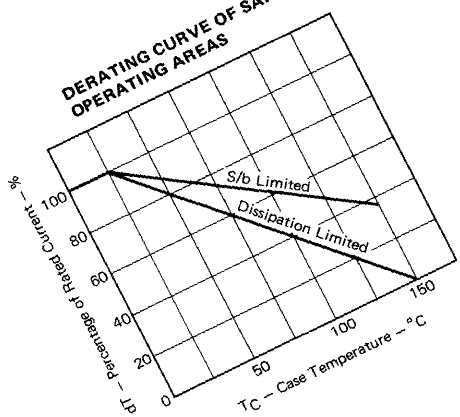
SAFE OPERATING AREA



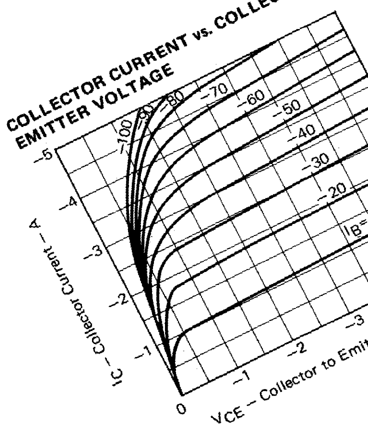
TRANSIENT THERMAL RESISTANCE



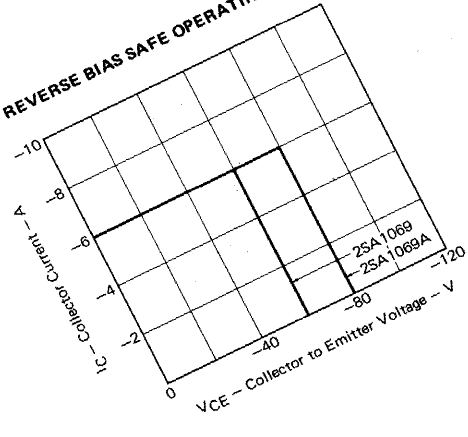
DERATING CURVE OF SAFE OPERATING AREAS



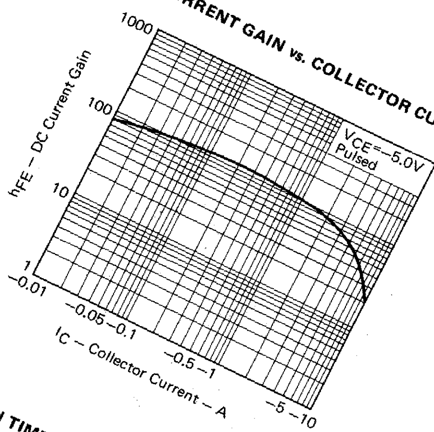
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



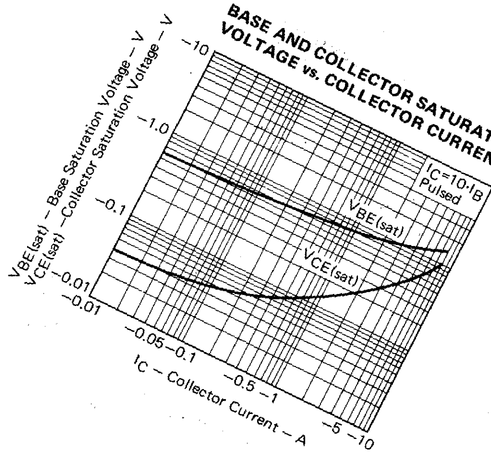
REVERSE BIAS SAFE OPERATING AREAS



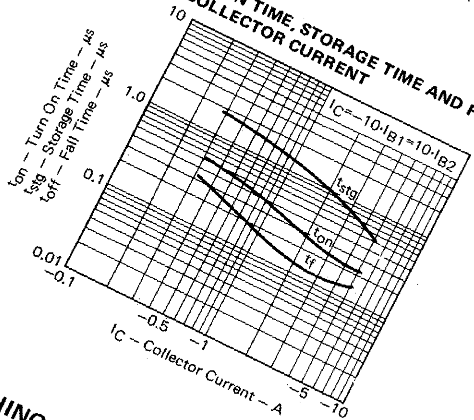
DC CURRENT GAIN vs. COLLECTOR CURRENT



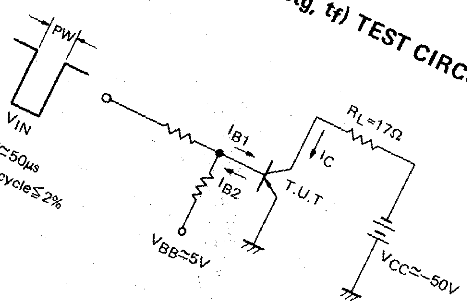
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

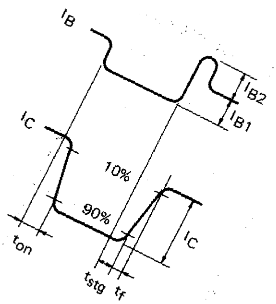


TURN ON TIME, STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT



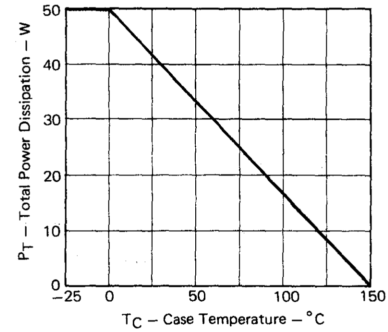
SWITCHING TIME (ton, tstg, tf) TEST CIRCUIT



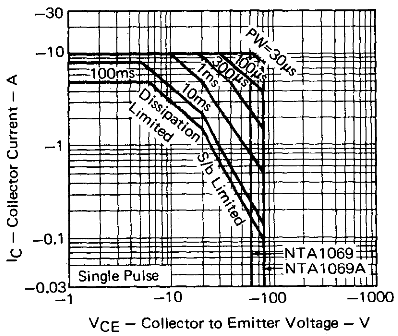


TYPICAL CHARACTERISTICS (Ta=25°C)

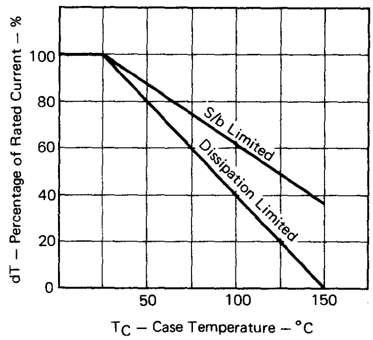
TOTAL POWER DISSIPATION vs. CASE TEMPERATURE



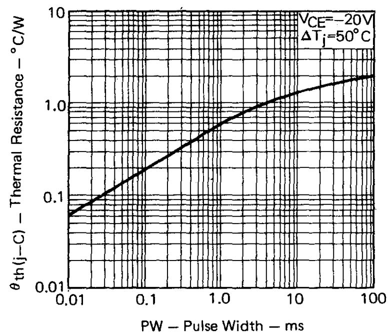
SAFE OPERATING AREA



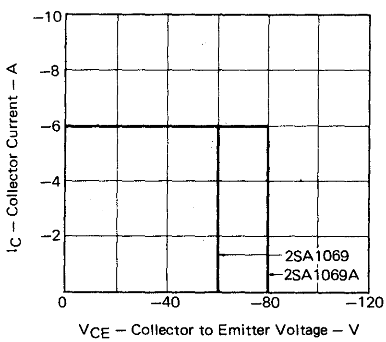
DERATING CURVE OF SAFE OPERATING AREAS



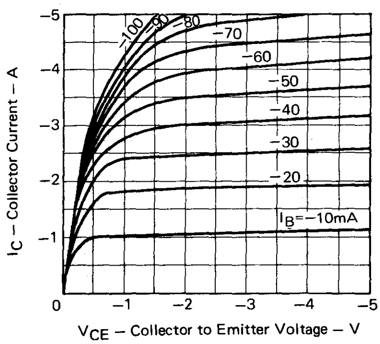
TRANSIENT THERMAL RESISTANCE



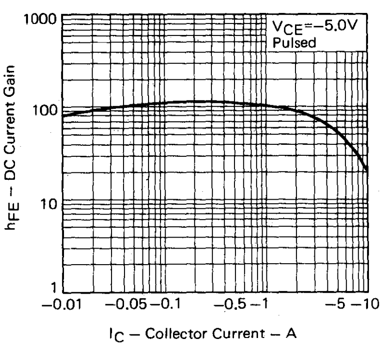
REVERSE BIAS SAFE OPERATING AREAS



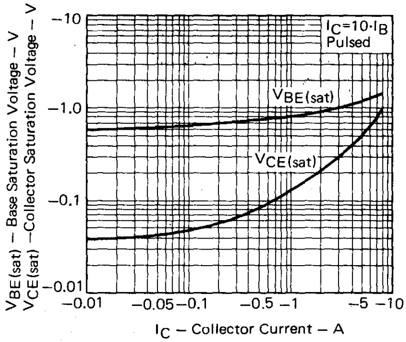
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



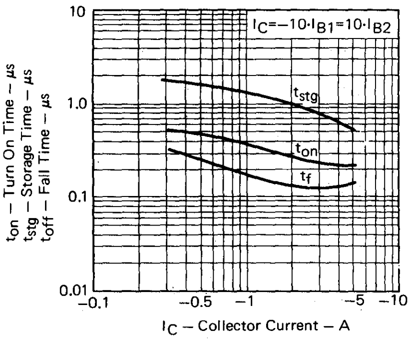
DC CURRENT GAIN vs. COLLECTOR CURRENT



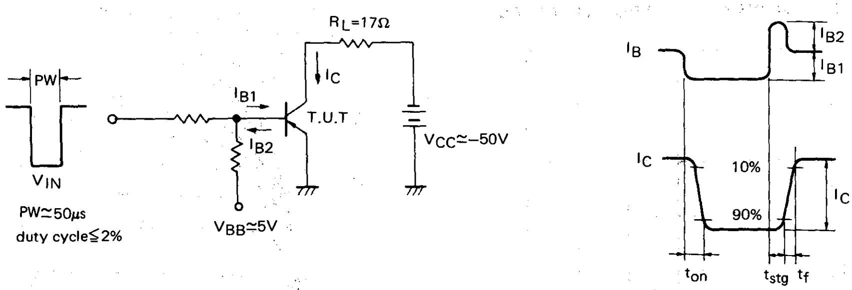
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT



SWITCHING TIME (t_{on}, t_{stg}, t_f) TEST CIRCUIT



NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTA1071(V126)

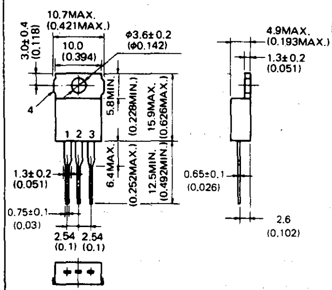
HIGH SPEED HIGH CURRENT SWITCHING
PNP SILICON TRIPLE DIFFUSED TRANSISTOR

Industrial Use

DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base (B)
2. Collector (C)
3. Emitter (E)
4. Fin (Collector)

JEDEC: TO-220AB

FEATURES

- High speed, high voltage switching.
- Low collector saturation voltage.
- Specified of reverse biased SOA with inductive loads.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (T_a=25°C)			
Collector to Emitter Voltage	V_{CEX}	−400	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	−400	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	−400	V
Emitter to Base Voltage	V_{EBO}	−8.0	V
Continuous Collector Current	$I_{C(DC)}$	−5.0	A
Peak Collector Current	$I_{C(pulse)}$*	−10	A
Continuous Base Current	$I_{B(DC)}$	−2.5	A
Maximum Power Dissipations			
Total Power Dissipation	P_T(T_c=25°C)	50	W
Total Power Dissipation	P_T(T_a=25°C)	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−55 to +150	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	2.5	°C/W
Junction to Ambient	$R_{th(j-a)}$	62.5	°C/W

*Pulsed PW ≦ 300μs, duty cycle ≦ 10%

ELECTRICAL CHARACTERISTICS (Ta=25 °C unless otherwise noted.)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	−400			V	I_C=−2.0A, I_B=−0.4A, L=100μH
	$V_{CEX(SUS)1}$	−400			V	I_C=−2.0A, I_{B1}=−I_{B2}=−0.4A, $V_{BE(OFF)}$=5V, L=180μH, Ta=125°C *1
	$V_{CEX(SUS)2}$	−400			V	I_C=−4A, I_{B1}=−1.6A, I_{B2}=0.4A, $V_{BE(OFF)}$=5V, L=180μH, Ta=125°C *2
Collector Cutoff Current	I_{CEX1}			−10	μA	V_{CE}=−400V, $V_{BE(OFF)}$=1.5V
	I_{CEX2}			−1.0	mA	V_{CE}=−400V, $V_{BE(OFF)}$=1.5V, Ta=125°C
	I_{CER}			−1.0	mA	V_{CE}=−400V, R_{BE}=51Ω, Ta=125°C
Emitter Cutoff Current	I_{EBO}			−10	μA	V_{EB}=−5.0V, I_C=0
Second Breakdown Collector Current	$I_{S/B}$	−1.0			A	V_{CE}=−30V, t=1sec, Tc=25°C
Second Breakdown Energy	$E_{S/B}$	180			μJ	I_C=−2.0A, I_{B1}=−0.4A, $V_{BE(OFF)}$=5V, R_{BB}=50Ω, L=40μH
DC Current Gain	h_{FE1}	20				V_{CE}=−5V, I_C=−0.5A *3
	h_{FE2}	10				V_{CE}=−5V, I_C=−2.0A *3
Collector Saturation Voltage	$V_{CE(sat)}$			−1.0	V	I_C=−2.0A, I_B=−0.4A *3
Base Saturation Voltage	$V_{BE(sat)}$			−1.5	V	
Gain Bandwidth Product	f_T	10			MHz	V_{CE}=−10V, I_C=−0.2A, f=3MHz
Output Capacitance	Cob			150	pF	V_{CB}=−10V, I_E=0, f=1MHz
Turn On Time	t_{on}			1.0	μs	I_C=−2.0A, I_{B1}=−I_{B2}=−0.4A, V_{CC}≃−150V, $V_{BE(OFF)}$=5V, R_L=75Ω
Storage Time	t_{stg}			2.5	μs	
Fall Time	t_f			1.0	μs	

*1 V_{CE} clamped Vclamp = 400V
*2 V_{CE} clamped Vclamp = 400V
*3 Pulsed PW ≦350μs, duty cycle≦2%

SILICON POWER TRANSISTORS
NTB707,NTB708

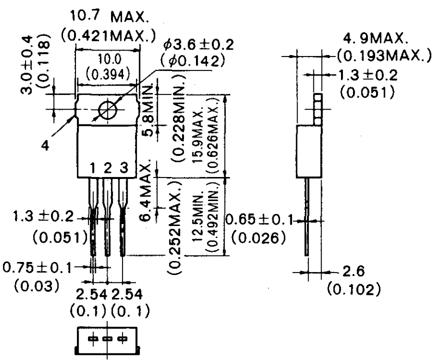
LOW FREQUENCY AMPLIFIER AND LOW SPEED SWITCHING PNP SILICON EPITAXIAL TRANSISTOR

Industrial Use

DESCRIPTION

Suitable for lamp driver and inductive load driver.

PACKAGE DIMENSIONS
in millimeters(inches)



1. Base(B)
2. Collector(C)
3. Emitter(E)
4. Fin(Collector)

FEATURES

- High current switching capability.
- Low collector saturation voltage.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents(Ta=25°C)		NTB707	NTB708	
Collector to Base Voltage	V_{CBO}	−80	−80	V
Collector to Emitter Voltage	V_{CEO}	−60	−80	V
Emitter to Base Voltage	V_{EBO}	−7.0	−7.0	V
Continuous Collector Current	$I_{C(DC)}$	−7.0	−7.0	A
Peak Collector Current	$I_{C(pulse)}$*	−15	−15	A
Continuous Base Current	$I_{B(DC)}$	−3.5	−3.5	A
Maximum Power Dissipations				
Total Power Dissipations				
at 25°C Ambient Temperature	P_T	2.0		W
at 25°C Case Temperature	P_T	65		W
Maximum Temperatures				
Junction Temperature	T_j	150		°C
Storage Temperature	T_{stg}	−55 to +150		°C

*Pulsed PW≦300μs, duty cycle≦10%

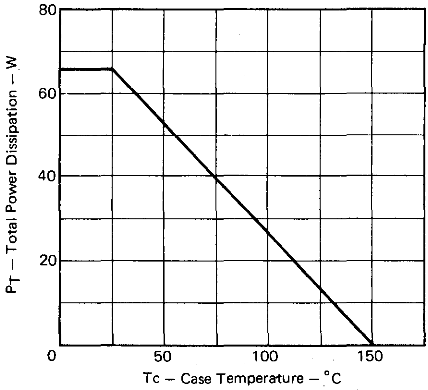
ELECTRICAL CHARACTERISTICS (Ta=25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−10	μA	V_{CB}=−60V, I_E=0
DC Current Gain	h_{FE1}	40				V_{CE}=−1.0V, I_C=−3.0A *
DC Current Gain	h_{FE2}	20				V_{CE}=−1.0V, I_C=−5.0A *
Collector Saturation Voltage	$V_{CE(sat)}$			−0.5	V	I_C=−5.0A *
Base Saturation Voltage	$V_{BE(sat)}$			−1.5	V	I_B=−0.5A

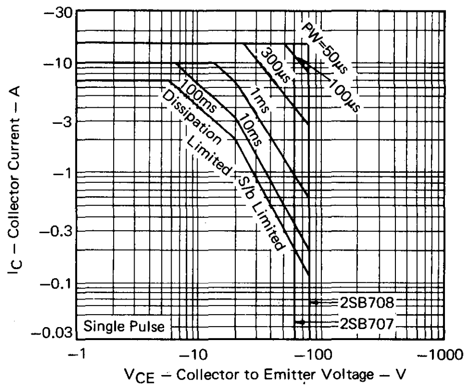
*Pulsed PW≦350μs, duty cycle≦2%

TYPICAL CHARACTERISTICS (Ta=25°C)

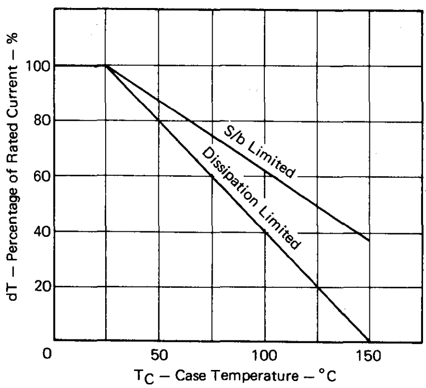
TOTAL POWER DISSIPATION vs. CASE TEMPERATURE



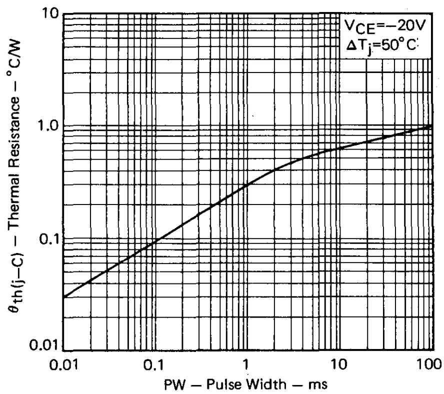
FORWARD BIAS SAFE OPERATING AREAS



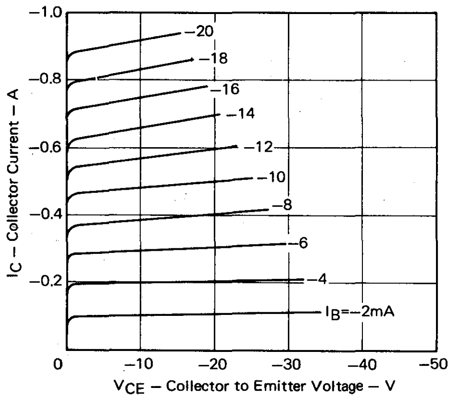
DERATING CURVE OF SAFE OPERATING AREAS



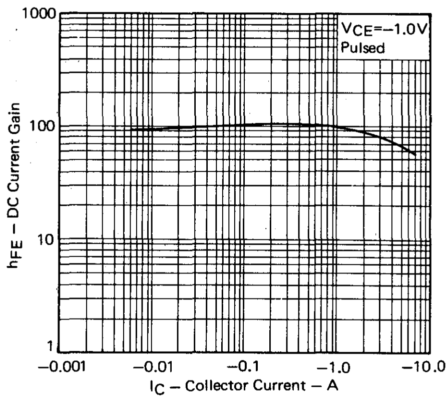
TRANSIENT THERMAL RESISTANCE



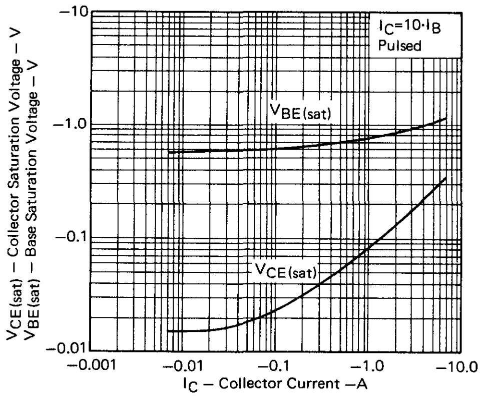
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

SILICON DARLINGTON POWER TRANSISTORS
NTB794, NTB795

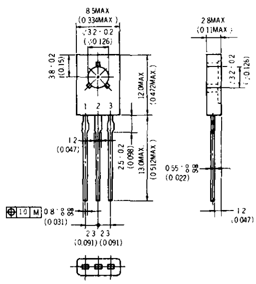
LOW FREQUENCY AMPLIFIER AND LOW SPEED SWITCHING
PNP SILICON EPITAXIAL DARLINGTON TRANSISTOR

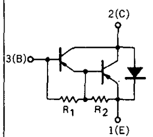
Industrial Use

DESCRIPTION

Suitable for hummer driver, pulse motor driver and relay driver applications.

PACKAGE DIMENSIONS in millimeters (inches)





1. Emitter (E)
2. Collector (C)
3. Base (B)
4. Fin (Collector)

$R_1 \fallingdotseq 10k\Omega$

$R_2 \fallingdotseq 500\Omega$

FEATURES

- Operates from IC without predriver.
- Low collector saturation voltage.
- For complementary use with type NTD985, NTD986.
- Similar to MJE700 ~ 703.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)		NTB794	NTB795	
Collector to Base Voltage	V_{CBO}	−60	−80	V
Collector to Emitter Voltage	$V_{CER(SUS)}$	−60	−80	V
	$V_{CEX(SUS)}$	−60	−80	V
	$V_{CEO(SUS)}$	−60	−80	V
Emitter to Base Voltage	V_{EBO}	−8.0		V
Continuous Collector Current	$I_{C(DC)}$	−2.0		A
Peak Collector Current	$I_{C(pulse)}$*	−4.0		A
Continuous Base Current	$I_{B(DC)}$	−0.2		A
Maximum Power Dissipations				
Total Power Dissipation (Ta=25°C)	P_T	1.0		W
(Tc=25°C)	P_T	10		W
Maximum Temperatures				
Junction Temperature	T_j	150		°C
Storage Temperature	T_{stg}	−55 to +150		°C
Lead Temperature				
1/8 inch from case for 10 seconds	T_L	260		°C
Thermal Resistances				
Junction to Ambient	$R_{th(j-a)}$	125		°C/W
Junction to Case	$R_{th(j-c)}$	12.5		°C/W

* Pulsed PW ≤ 300 μs, duty cycle ≤ 10%.

ELECTRICAL CHARACTERISTICS (Ta = 25 °C) **(NTB794/795)**

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	−60/ −80			V	I_C=−0.2A, I_B=0
	$V_{CER(SUS)}$	−60/ −80			V	I_C=−0.2A
	$V_{CEX(SUS)}$	−60/ −80			V	I_C=−0.2A, I_B=−I_B=−2mA
Collector Cutoff Current	I_{CBO}			−10	μA	V_{CB}=−60/−80V, I_E=0
				−1.0	mA	V_{CB}=−60/−80V, I_E=0, Tc=125°C
Collector Cutoff Current	I_{CEO}			−10	μA	V_{CE}=−60/−80V, I_B=0
Emitter Cutoff Current	I_{EBO}			−1.0	mA	V_{EB}=−5.0V, I_C=0
DC Current Gain	h_{FE}	2000	4000			V_{CE}=−2.0V, I_C=−1.0A*
Collector Saturation Voltage	$V_{CE(sat)}$			−1.5	V	I_C=−1.0A, I_B=−1.0mA
Base Saturation Voltage	$V_{BE(sat)}$			−2.0	V	

*Pulsed PW ≦ 350 μs, duty cycle ≦ 2%

3

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC1863

HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON EPITAXIAL MESA TRANSISTOR

Industrial Use

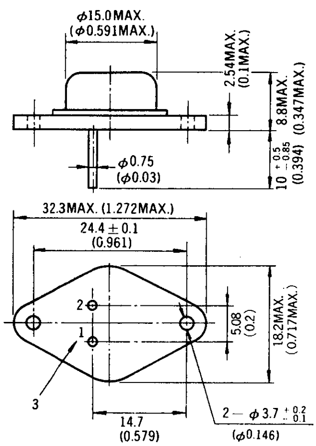
DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased S.O.A. with inductive loads.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector (Case)

EIAJ :TC-16,TB-23
JEDEC:TO-66
IEC :C13

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents ($T_a = 25°C$)			
Collector to Emitter Voltage	V_{CEX}	150	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	100	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	150	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	7.0	A
Peak Collector Current*	$I_{C(pulse)}$	15	A
Continuous Base Current	$I_{B(DC)}$	4.0	A
Peak Base Current*	$I_{B(pulse)}$	8.0	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(Tc=25°C)}$	50	W
Total Power Dissipation	$P_{T(Tc=100°C)}$	29	W
Total Power Dissipation	$P_{T(Ta=25°C)}$	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature 1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	3.50	°C/W
Junction to Ambient	$R_{th(j-a)}$	87.5	°C/W

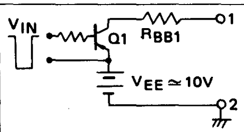
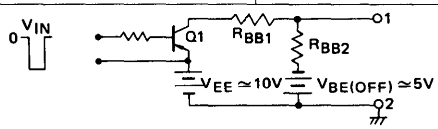
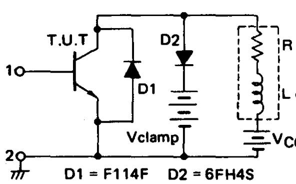
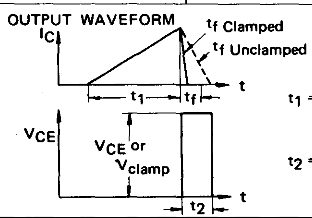
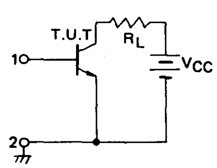
* Pulsed PW ≦ 300 μs, duty cycle ≦ 10%

ELECTRICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	100			V	Table 1. I_C = 5A, I_{B1} = 0.5A, L = 100µH
	$V_{CEX(SUS)1}$	150			V	Table 1. I_C = 5A, I_{B1} = $-I_{B2}$ = 0.5A V_{clamp} = Rated V_{CEX}, Ta = 125°C
	$V_{CEX(SUS)2}$	100			V	Table 1. I_C = 10A, I_{B1} = 1.0A, I_{B2} = −0.5A V_{clamp} = Rated V_{CEX}, Ta = 125°C
Collector Cutoff Current	I_{CER}			1.0	mA	V_{CE} = 150V, R_{BE} = 50Ω, Ta = 125°C
	I_{CEX}			100	µA	V_{CE} = 150V, $V_{BE(OFF)}$ = −1.5V
	I_{CEX}			500	µA	V_{CE} = 150V, $V_{BE(OFF)}$ = −1.5V Ta = 125°C
Emitter Cutoff Current	I_{EBO}			10	µA	V_{EB} = 7.0V, I_C = 0
Second Breakdown Collector Current	$I_{S/B}$	2.5			A	t = 1.0 s, V_{CE} = 20V, Tc = 25°C
Second Breakdown Energy	$E_{S/B}$	500			µJ	I_C = 5A, I_{B1} = 0.5A, $V_{BE(OFF)}$ = −5V
DC Current Gain	h_{FE1}	20		160		V_{CE} = 5V, I_C = 3A **
	h_{FE2}	15				V_{CE} = 5V, I_C = 5A **
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C = 5A, I_B = 0.5A **
	$V_{CE(sat)}$			1.5	V	I_C = 5A, I_B = 0.5A, Ta = 125°C **
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	I_C = 5A, I_B = 0.5A **
	$V_{BE(sat)}$			1.5	V	I_C = 7A, I_B = 0.7A, Ta = 125°C **
Gain Bandwidth Product	f_T	20			MHz	V_{CE}=10V, I_C=50mA, f_o=3.0MHz, Tc=25°C
Output Capacitance	C_{ob}			300	pF	V_{CB} = 10V, f_o = 1.0 MHz
Delay Time	t_d			0.1	µs	Resistive Load (Table 1.)
Rise Time	t_r			0.7	µs	
	t_r			2.1	µs	Ta = 125°C I_C = 5A, I_{B1} = $-I_{B2}$ = 0.5A
Storage Time	t_{stg}			1.0	µs	R_L = 10Ω, V_{CC} ≃ 50V
	t_{stg}			1.5	µs	Ta = 125°C PW ≃ 50µs, duty cycle ≦ 2%
Fall Time	t_f			3.0	µs	
	t_f			1.2	µs	Ta = 125°C

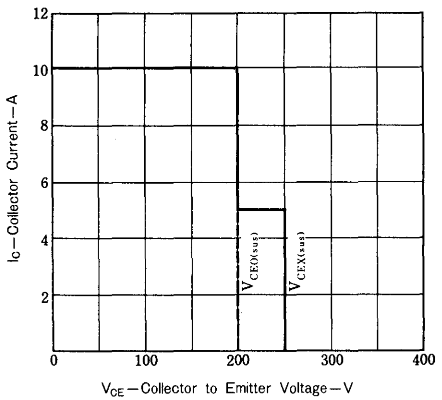
** PW ≦ 350 µs, duty cycle ≦ 2%

TABLE 1. – TEST CONDITIONS FOR DYNAMIC PERFORMANCE

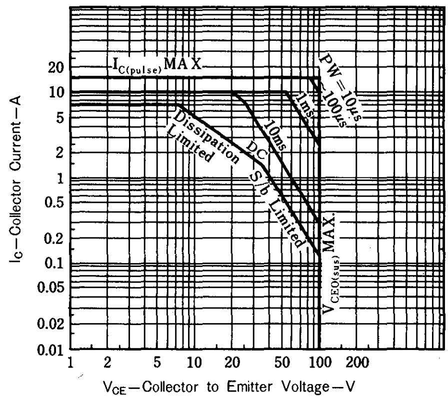
	VCEO (SUS)	VCEX (SUS)	$E_{S/B}$	RESISTIVE SWITCHING
INPUT CONDITIONS	 PW Varied to Attain I_C = 5A	 PW Varied to Attain I_C = 5A duty cycle ≦ 2% Q_1 = 2SA959		
CIRCUIT VALUES	L_{coil} = 100µH, V_{CC} = 10V R_{coil} = 0.05Ω V_{clamp} (Unclamped)	L_{coil} = 180 µH, V_{CC} = 20V R_{coil} = 0.05Ω V_{clamp} = Rated V_{CEX} Value	L_{coil} = 40 µH, V_{CC} = 10V R_{coil} = 0.05Ω, R_{BB2} = 50Ω V_{clamp} (Unclamped)	R_L = 10Ω, V_{CC} ≃ 50V
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT  D1 = F114F D2 = 6FH4S	OUTPUT WAVEFORM 	t_1 Adjust to Obtain IC $t_1 = \frac{L_{coil}(I_{C\,pk})}{V_{CC}}$ $t_2 = \frac{L_{coil}(I_{C\,pk})}{V_{clamp}}$	RESISTIVE TEST CIRCUIT 

TYPICAL CHARACTERISTICS (Ta=25°C)

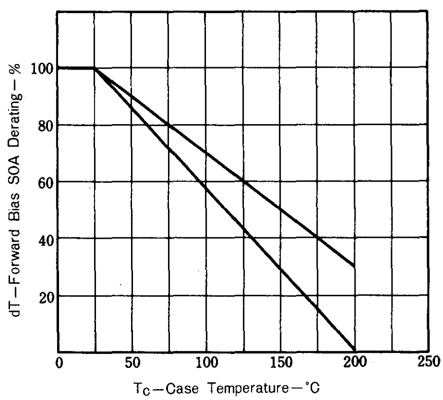
REVERSE BIAS SAFE OPERATING AREA



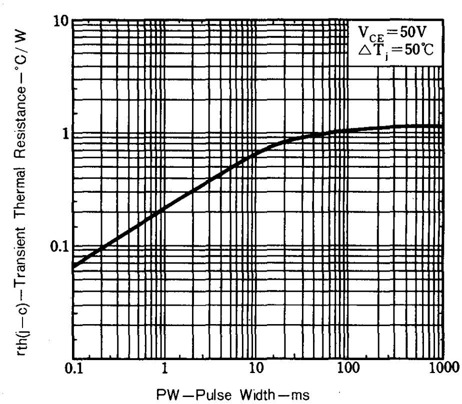
FORWARD BIAS SAFE OPERATING AREAS



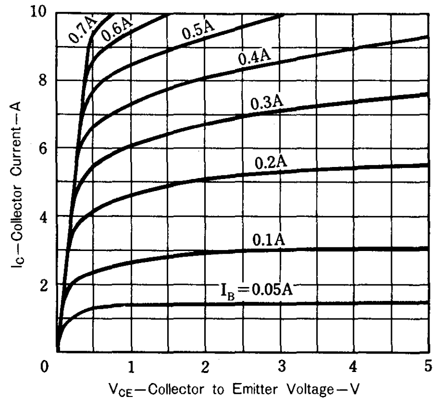
DERATING CURVE OF FORWARD BIAS SAFE OPERATING AREA



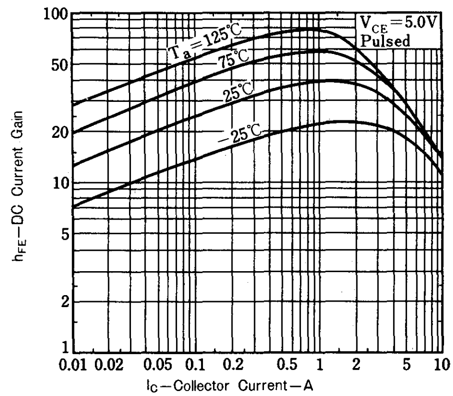
TRANSIENT THERMAL RESISTANCE



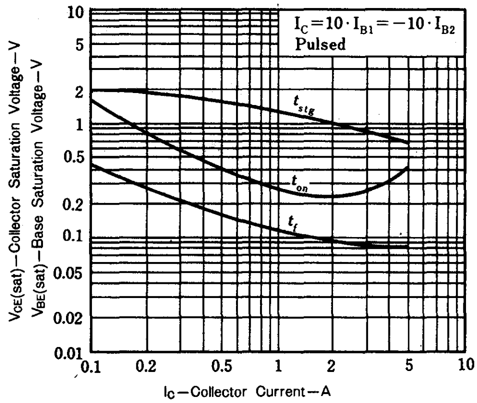
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



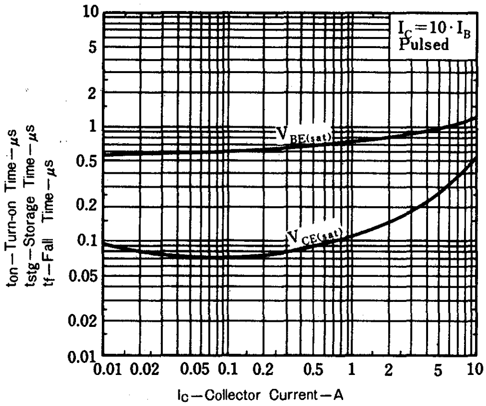
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC1864

HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON EPITAXIAL MESA TRANSISTOR

Industrial Use

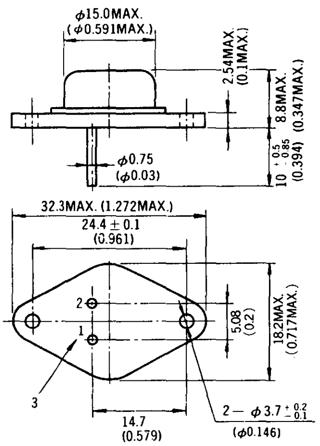
DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased S.O.A. with inductive loads.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector (Case)

EIAJ :TC-16,TB-23
JEDEC:TO-66
IEC :C13

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Emitter Voltage	V_{CEX}	300	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	200	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	250	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	7.0	A
Peak Collector Current*	$I_{C(pulse)}$	15	A
Continuous Base Current	$I_{B(DC)}$	4.0	A
Peak Base Current*	$I_{B(pulse)}$	8.0	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(Tc=25°C)}$	50	W
Total Power Dissipation	$P_{T(Tc=100°C)}$	29	W
Total Power Dissipation	$P_{T(Ta=25°C)}$	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature 1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	3.50	°C/W
Junction to Ambient	$R_{th(j-a)}$	87.5	°C/W

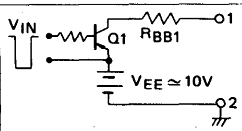
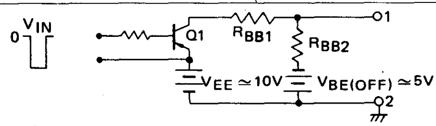
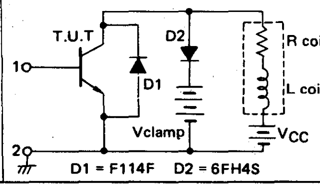
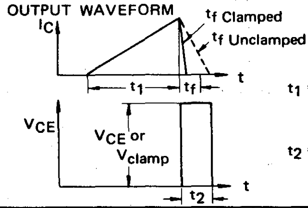
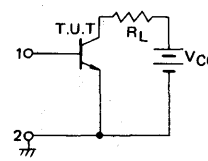
* Pulsed PW ≦ 300 μs, duty cycle ≦ 10%

ELECTRICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	200			V	Table 1. I_C = 5A, I_{B1} = 0.5A, L = 100μH
	$V_{CEX(SUS)1}$	250			V	Table 1. I_C = 5A, I_{B1} = $-I_{B2}$ = 0.5A, V_{clamp} = Rated V_{CEX}, Ta = 125°C
	$V_{CEX(SUS)2}$	200			V	Table 1. I_C = 10A, I_{B1} = 1.0A, I_{B2} = −0.5A, V_{clamp} = Rated V_{CEX}, Ta = 125°C
Collector Cutoff Current	I_{CER}			1.0	mA	V_{CE} = 300V, R_{BE} = 50Ω, Ta = 125°C
	I_{CEX}			100	μA	V_{CE} = 300V, $V_{BE(OFF)}$ = −1.5V
	I_{CEX}			500	μA	V_{CE} = 300V, $V_{BE(OFF)}$ = −1.5V, Ta = 125°C
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB} = 7.0V, I_C = 0
Second Breakdown Collector Current	$I_{S/B}$	2.5			A	t = 1.0 s, V_{CE} = 20V, Tc = 25°C
Second Breakdown Energy	$E_{S/B}$	500			μJ	I_C = 5A, I_{B1} = 0.5A, $V_{BE(OFF)}$ = −5V
DC Current Gain	h_{FE1}	20		160		V_{CE} = 5V, I_C = 3A **
	h_{FE2}	15				V_{CE} = 5V, I_C = 5A **
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C = 5A, I_B = 0.5A **
	$V_{CE(sat)}$			1.5	V	I_C = 5A, I_B = 0.5A, Ta = 125°C **
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	I_C = 5A, I_B = 0.5A **
	$V_{BE(sat)}$			1.5	V	I_C = 5A, I_B = 0.5A, Ta = 125°C **
Gain Bandwidth Product	f_T	20			MHz	V_{CE} = 10V, I_C = 300mA, f_o = 3.0 MHz, Tc = 25°C
Output Capacitance	C_{ob}			200	pF	V_{CB} = 10V, f_o = 1.0 MHz
Delay Time	t_d			0.1	μs	Resistive Load (Table 1.)
Rise Time	t_r			0.9	μs	
	t_r			2.7	μs	Ta = 125°C; I_C = 5A, I_{B1} = $-I_{B2}$ = 0.5A
Storage Time	t_{stg}			2.0	μs	R_L = 20Ω, V_{CC} ≃ 100V
	t_{stg}			4.0	μs	Ta = 125°C; PW ≃ 50μs, duty cycle ≦ 2%
Fall Time	t_f			0.5	μs	
	t_f			2.0	μs	Ta = 125°C

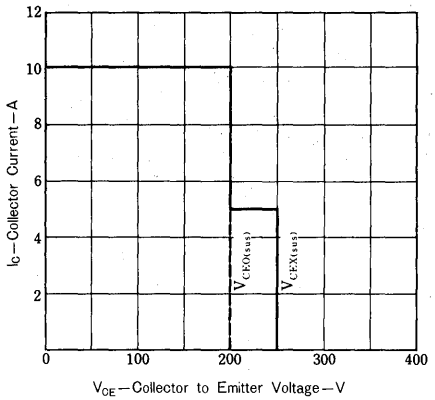
** PW ≦350 μs, duty cycle ≦2%

TABLE 1. — TEST CONDITIONS FOR DYNAMIC PERFORMANCE

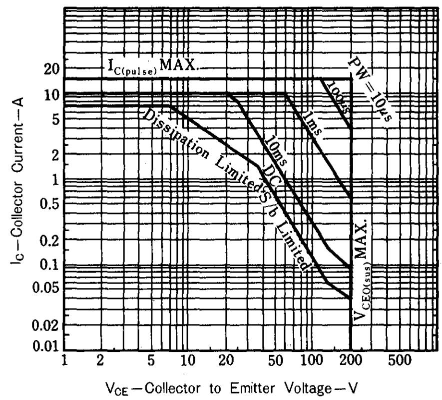
	V_{CEO} (SUS)	V_{CEX} (SUS)	$E_{S/B}$	RESISTIVE SWITCHING
INPUT CONDITIONS	 PW Varied to Attain I_C = 5A	 PW Varied to Attain I_C = 5A duty cycle ≦2% Q_1 = 2SA959		
CIRCUIT VALUES	L_{coil} = 100μH, V_{CC} = 10V R_{coil} = 0.05Ω V_{clamp} (Unclamped)	L_{coil} = 180 μH, V_{CC} = 20V R_{coil} = 0.05Ω V_{clamp} = Rated V_{CEX} Value	L_{coil} = 40 μH, V_{CC} = 10V R_{coil} = 0.05Ω, R_{BB2} = 50Ω V_{clamp} (Unclamped)	R_L = 0.2Ω V_{CC} ≃ 100V
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT  D1 = F114F D2 = 6FH4S	OUTPUT WAVEFORM 	t_1 Adjust to Obtain IC $t_1 = \frac{L_{coil}(I_{C\,pk})}{V_{CC}}$ $t_2 = \frac{L_{coil}(I_{C\,pk})}{V_{clamp}}$	RESISTIVE TEST CIRCUIT 

TYPICAL CHARACTERISTICS (Ta=25°C)

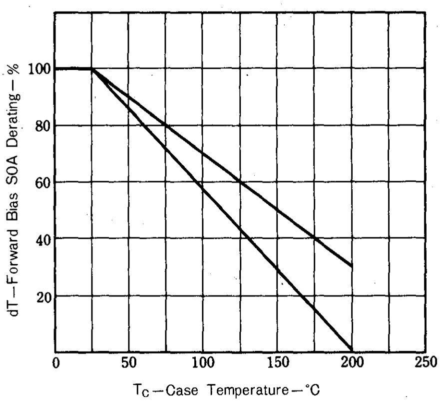
REVERSE BIAS SAFE OPERATING AREA



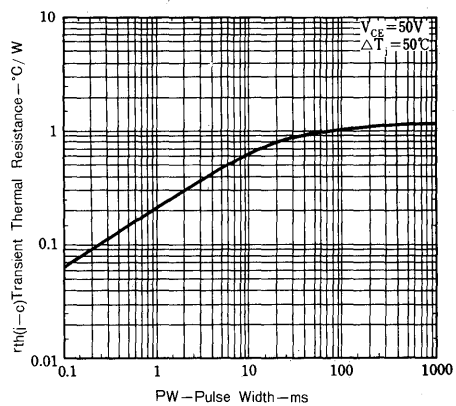
REVERSE BIAS SAFE OPERATING AREAS



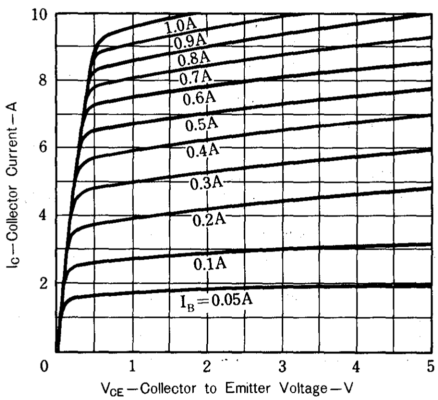
DEATING CURVE OF FORWARD BIAS SAFE OPERATING AREA



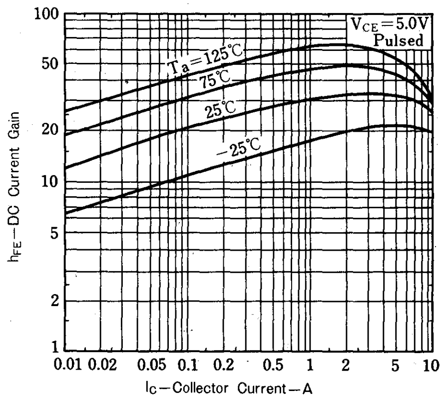
TRANSIENT THERMAL RESISTANCE



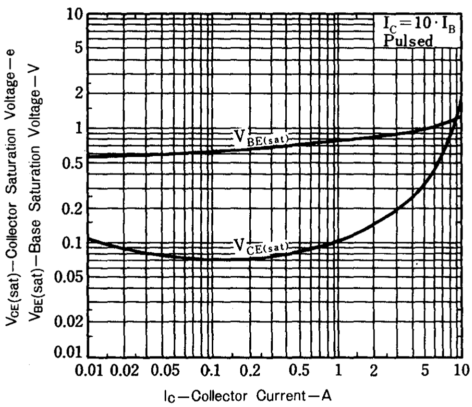
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



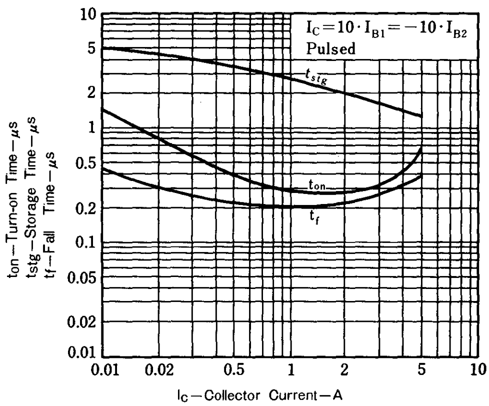
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORGE TIME AND FALL TIME vs. COLLECTOR CURRENT



3

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC1865

HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON TRIPLE DIFFUSED MESA TRANSISTOR

Industrial Use

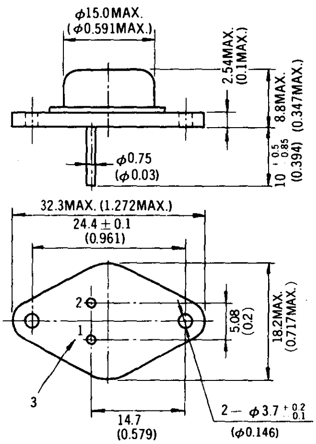
DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased S.O.A. with inductive loads.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector (Case)

EIAJ :TC-16,TB-23
JEDEC:TO-66
IEC :C13

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Emitter Voltage	V_{CEX}	500	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	450	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	7.0	A
Peak Collector Current*	$I_{C(pulse)}$	15	A
Continuous Base Current	$I_{B(DC)}$	4.0	A
Peak Base Current*	$I_{B(pulse)}$	8.0	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(Tc=25°C)}$	50	W
Total Power Dissipation	$P_{T(Tc=100°C)}$	29	W
Total Power Dissipation	$P_{T(Ta=25°C)}$	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature 1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	3.50	°C/W
Junction to Ambient	$R_{th(j-a)}$	87.5	°C/W

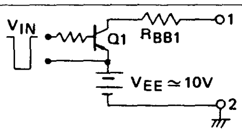
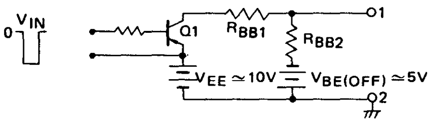
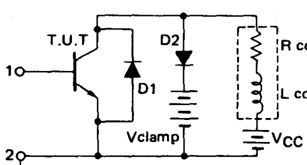
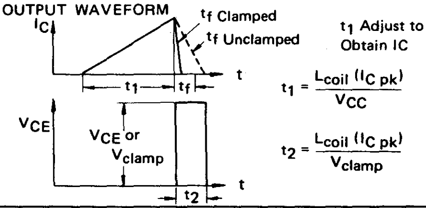
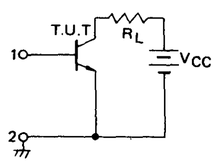
* Pulsed PW ≦ 300 μs, duty cycle ≦ 10%

ELECTRICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400			V	Table 1. I_C = 5A, I_{B1} = 1A, L = 100μH
	$V_{CEX(SUS)1}$	450			V	Table 1. I_C = 5A, I_{B1} = $-I_{B2}$ = 1A, V_{clamp} = Rated V_{CEX}, Ta = 125°C
	$V_{CEX(SUS)2}$	400			V	Table 1. I_C = 10A, I_{B1} = 2A, I_{B2} = -1A, V_{clamp} = Rated V_{CEX}, Ta = 125°C
Collector Cutoff Current	I_{CER}			1.0	mA	V_{CE} = 500V, R_{BE} = 50Ω, Ta = 125°C
	I_{CEX}			100	μA	V_{CE} = 500V, $V_{BE(OFF)}$ = -1.5V
	I_{CEX}			500	μA	V_{CE} = 500V, $V_{BE(OFF)}$ = -1.5V, Ta = 125°C
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB} = 7.0V, I_C = 0
Second Breakdown Collector Current	$I_{S/B}$	1			A	t = 1.0 s, V_{CE} = 40V, Tc = 25°C
Second Breakdown Energy	$E_{S/B}$	500			μJ	I_C = 5A, I_{B1} = 1A, $V_{BE(OFF)}$ = -5V
DC Current Gain	h_{FE1}	15		100		V_{CE} = 5V, I_C = 3A **
	h_{FE2}	10				V_{CE} = 5V, I_C = 5A **
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C = 5A, I_B = 1A **
	$V_{CE(sat)}$			1.5	V	I_C = 5A, I_B = 1A, Ta = 125°C **
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	I_C = 5A, I_B = 1A **
	$V_{BE(sat)}$			1.5	V	I_C = 5A, I_B = 1A, Ta = 125°C **
Gain Bandwidth Product	f_T	10			MHz	V_{CE}=10V, I_C=300mA, f_o=3.0 MHz, Tc=25°C
Output Capacitance	C_{ob}			200	pF	V_{CB} = 10V, f_o = 1.0 MHz
Delay Time	t_d			0.1	μs	Resistive Load (Table 1.)
Rise Time	t_r			0.9	μs	
	t_r			2.7	μs	Ta = 125°C; I_C = 5A, I_{B1} = $-I_{B2}$ = 1A
Storage Time	t_{stg}			2.0	μs	R_L = 30Ω, V_{CC} ≃ 150V
	t_{stg}			4.0	μs	Ta = 125°C; PW ≃ 50μs, duty cycle ≦ 2%
Fall Time	t_f			0.7	μs	
	t_f			2.8	μs	Ta = 125°C

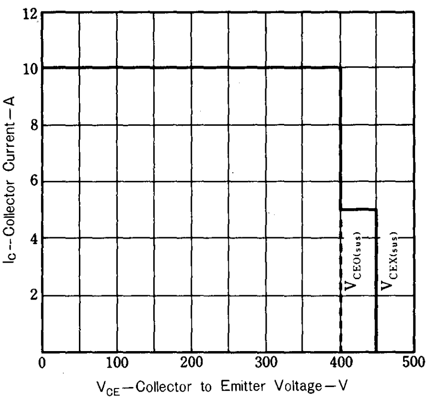
** PW ≦350 μs, duty cycle ≦2%

TABLE 1. — TEST CONDITIONS FOR DYNAMIC PERFORMANCE

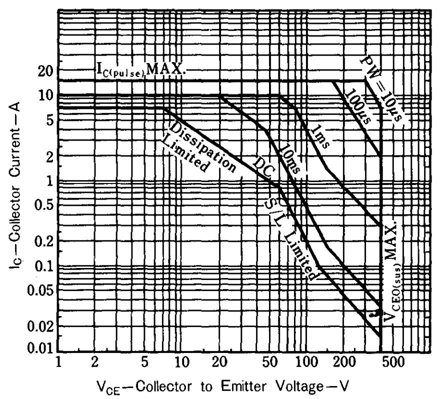
	V_{CEO} (SUS)	V_{CEX} (SUS)	$E_{S/B}$	RESISTIVE SWITCHING
INPUT CONDITIONS	 PW Varied to Attain I_C = 5A	 PW Varied to Attain I_C = 5A duty cycle ≦ 2% Q_1 = 2SA959		
CIRCUIT VALUES	L_{coil} = 100μH, V_{CC} = 10V R_{coil} = 0.05Ω V_{clamp} (Unclamped)	L_{coil} = 180 μH, V_{CC} = 20V R_{coil} = 0.05Ω V_{clamp} = Rated V_{CEX} Value	L_{coil} = 40 μH, V_{CC} = 10V R_{coil} = 0.05Ω, R_{BB2} = 50Ω V_{clamp} (Unclamped)	R_L = 30Ω, V_{CC}≃150V
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT  D1 = F114F D2 = 6FH4S	OUTPUT WAVEFORM 		RESISTIVE TEST CIRCUIT 

TYPICAL CHARACTERISTICS (Ta=25°C)

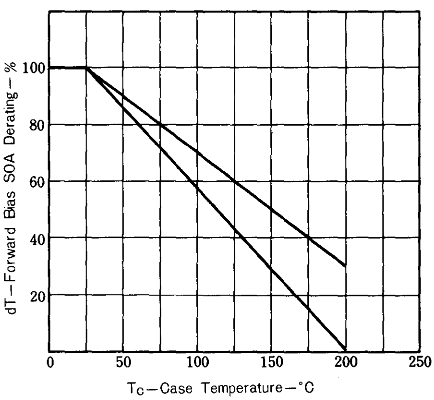
REVERSE BIAS SAFE OPERATING AREA



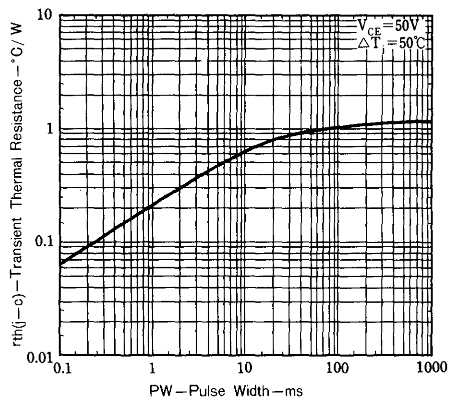
FORWARD BIAS SAFE OPERATING AREAS



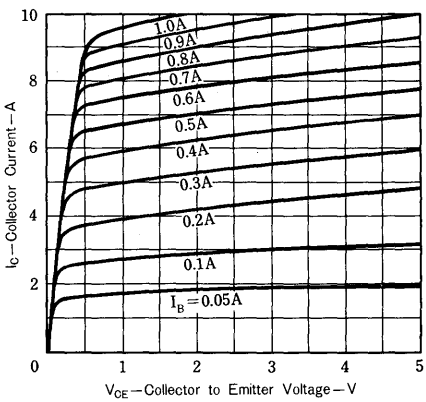
DERATING CURVE OF FORWARD BIAS SAFE OPERATING AREA



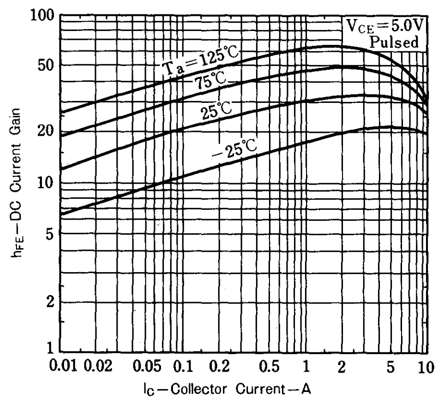
TRANSIENT THERMAL RESISTANCE



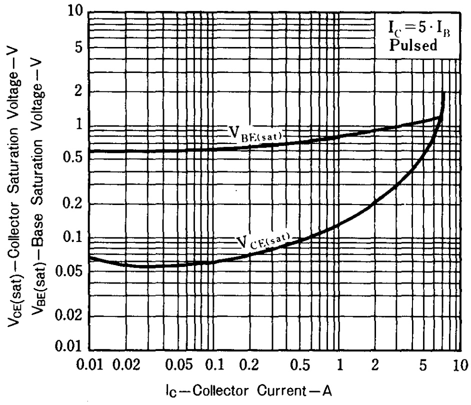
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



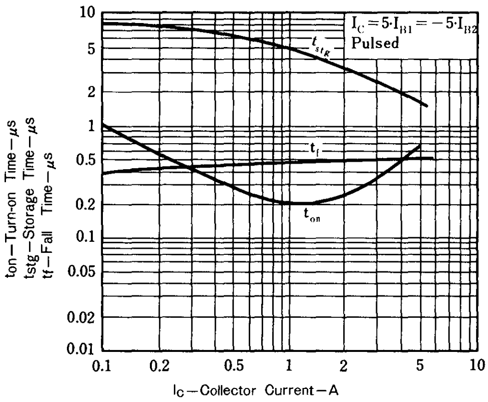
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORGE TIME AND FALL TIME vs. COLLECTOR CURRENT



3

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC1866

HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON EPITAXIAL MESA TRANSISTOR

Industrial Use

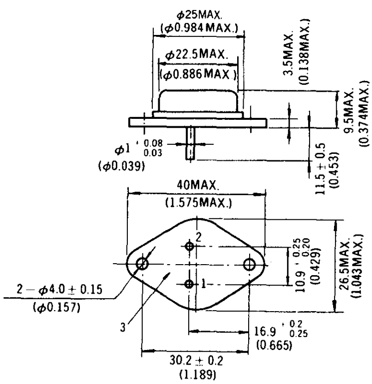
DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased S.O.A. with inductive loads.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector (Case)

EIAJ :TC-3,TB-3
JEDEC:TO-3
IEC :C14A,B18

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Emitter Voltage	V_{CEX}	150	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	100	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	150	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	7.0	A
Peak Collector Current*	$I_{C(pulse)}$	15	A
Continuous Base Current	$I_{B(DC)}$	4.0	A
Peak Base Current*	$I_{B(pulse)}$	8.0	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(Tc=25°C)}$	100	W
Total Power Dissipation	$P_{T(Tc=100°C)}$	57	W
Total Power Dissipation	$P_{T(Ta=25°C)}$	5	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature 1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	1.75	°C/W
Junction to Ambient	$R_{th(j-a)}$	35	°C/W

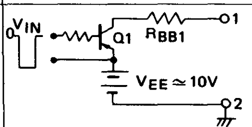
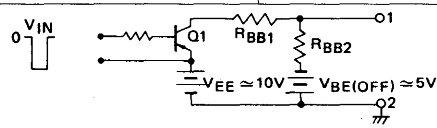
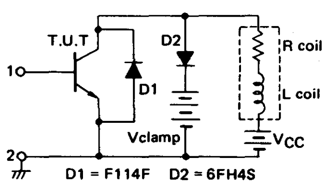
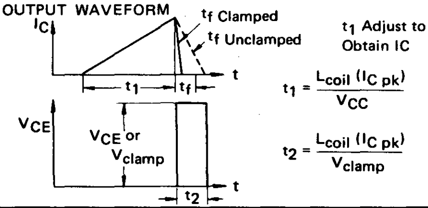
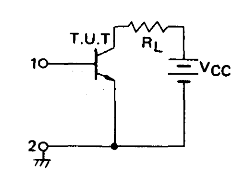
* Pulsed PW ≦ 300 μs, duty cycle ≦ 10%

ELECTRICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	100			V	Table 1. I_C = 5A, I_{B1} = 0.5A, L = 100μH
	$V_{CEX(SUS)1}$	150			V	Table 1. I_C = 5A, I_{B1} = $-I_{B2}$ = 0.5A V_{clamp} = Rated V_{CEX}, Ta = 125°C
	$V_{CEX(SUS)2}$	100			V	Table 1. I_C = 10A, I_{B1} = 1.0A, I_{B2} = −0.5A V_{clamp} = Rated V_{CEX}, Ta = 125°C
Collector Cutoff Current	I_{CER}			1.0	mA	V_{CE} = 150V, R_{BE} = 50Ω, Ta = 125°C
	I_{CEX}			100	μA	V_{CE} = 150V, $V_{BE(OFF)}$ = −1.5V
	I_{CEX}			500	μA	V_{CE} = 150V, $V_{BE(OFF)}$ = −1.5V, Ta = 125°C
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB} = 7.0V, I_C = 0
Second Breakdown Collector Current	$I_{S/B}$	5.0			A	t = 1.0 s, V_{CE} = 20V, Tc = 25°C
Second Breakdown Energy	$E_{S/B}$	500			μJ	I_C = 5A, I_{B1} = 0.5A, $V_{BE(OFF)}$ = −5V
DC Current Gain	h_{FE1}	20		160		V_{CE} = 5V, I_C = 3A **
	h_{FE2}	15				V_{CE} = 5V, I_C = 5A **
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C = 5A, I_B = 0.5A **
	$V_{CE(sat)}$			1.5	V	I_C = 5A, I_B = 0.5A, Ta = 125°C **
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	I_C = 5A, I_B = 0.5A **
	$V_{BE(sat)}$			1.5	V	I_C = 5A, I_B = 0.5A, Ta = 125°C **
Gain Bandwidth Product	f_T	20			MHz	V_{CE}=10V, I_C=300mA, f_o=3.0 MHz, Tc=25°C
Output Capacitance	C_{ob}			300	pF	V_{CB} = 10V, f_o = 1.0 MHz
Delay Time	t_d			0.1	μs	Resistive Load (Table 1.)
Rise Time	t_r			0.7	μs	
	t_r			2.1	μs	Ta = 125°C I_C = 5A, I_{B1} = $-I_{B2}$ = 0.5A
Storage Time	t_{stg}			1.5	μs	R_L = 10Ω, V_{CC} ≃ 50V
	t_{stg}			3.0	μs	Ta = 125°C PW ≃ 50μs, duty cycle ≦ 2%
Fall Time	t_f			0.3	μs	
	t_f			1.2	μs	Ta = 125°C

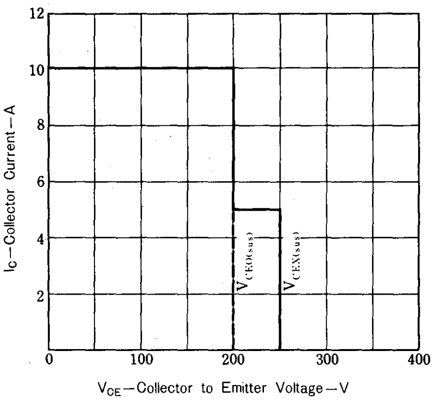
** PW ≦ 350 μs, duty cycle ≦ 2%

TABLE 1. – TEST CONDITIONS FOR DYNAMIC PERFORMANCE

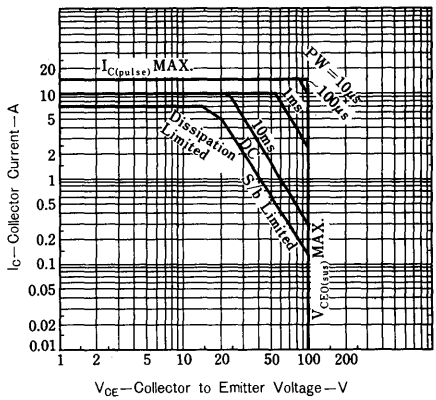
	V_{CEO} (SUS)	V_{CEX} (SUS)	$E_{S/B}$	RESISTIVE SWITCHING
INPUT CONDITIONS	 PW Varied to Attain I_C = 5A	 PW Varied to Attain I_C = 5A duty cycle ≦ 2% Q_1 = 2SA959		
CIRCUIT VALUES	L_{coil} = 100μH, V_{CC} = 10V R_{coil} = 0.05Ω V_{clamp} (Unclamped)	L_{coil} = 180 μH, V_{CC} = 20V R_{coil} = 0.05Ω V_{clamp} = Rated V_{CEX} Value	L_{coil} = 40 μH, V_{CC} = 10V R_{coil} = 0.05Ω, R_{BB2} = 50Ω V_{clamp} (Unclamped)	R_L = 10Ω, V_{CC} ≃ 50V
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT 	OUTPUT WAVEFORM 		RESISTIVE TEST CIRCUIT 

TYPICAL CHARACTERISTICS (Ta=25°C)

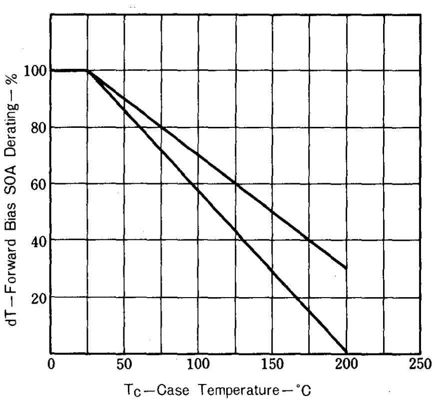
REVERSE BIAS SAFE OPERATING AREA



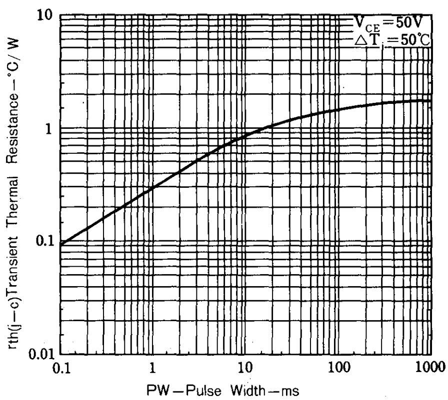
FORWARD BIAS SAFE OPERATING AREA



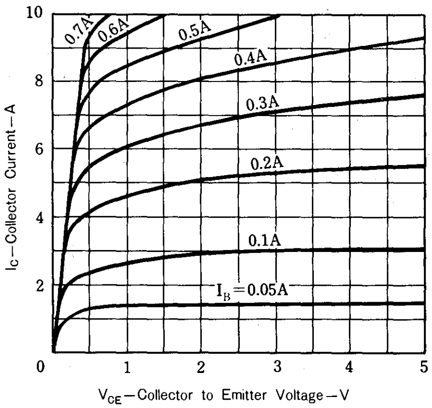
DERATING CURVE OF FORWARD BIAS SAFE OPERATING AREA



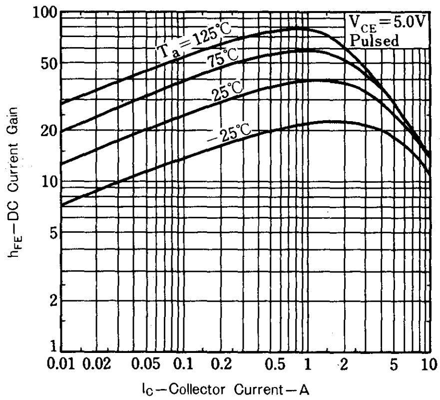
TRASIENT THERMAL RESISTANCE



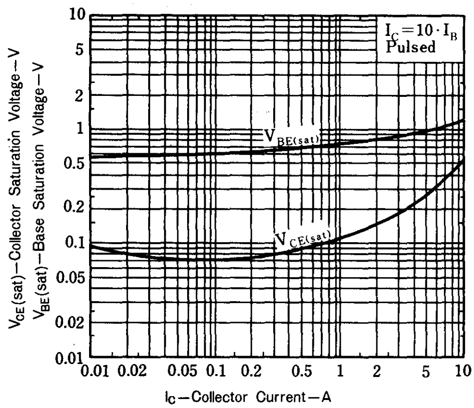
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



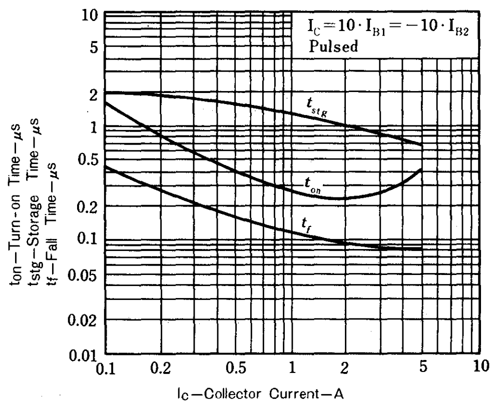
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORGE TIME AND FALL TIME vs. COLLECTOR CURRENT



3

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC1867

HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON EPITAXIAL MESA TRANSISTOR

Industrial Use

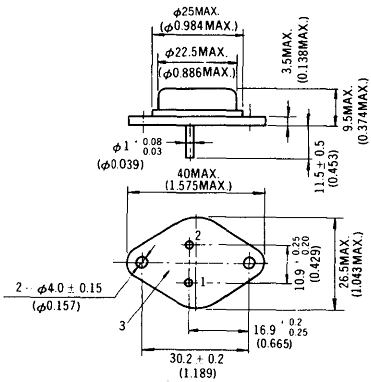
DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased S.O.A. with inductive loads.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector (Case)

EIAJ : TC-3, TB-3
JEDEC : TO-3
IEC : C14A, B18

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (T_a = 25°C)			
Collector to Emitter Voltage	V_{CEX}	300	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	250	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	300	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	7.0	A
Peak Collector Current*	$I_{C(pulse)}$	15	A
Continuous Base Current	$I_{B(DC)}$	4.0	A
Peak Base Current*	$I_{B(pulse)}$	8.0	A
Maximum Power Dissipations			
Total Power Dissipation	$P_T(T_c=25°C)$	100	W
Total Power Dissipation	$P_T(T_c=100°C)$	57	W
Total Power Dissipation	$P_T(T_a=25°C)$	5	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature 1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	1.75	°C/W
Junction to Ambient	$R_{th(j-a)}$	35	°C/W

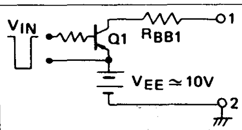
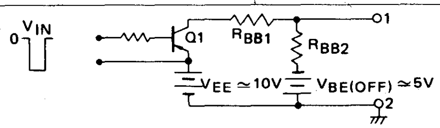
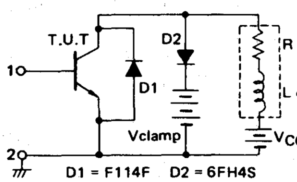
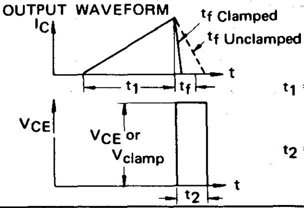
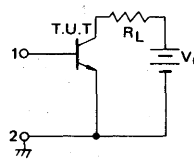
* Pulsed PW ≦ 300 μs, duty cycle ≦ 10%

ELECTRICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	200			V	Table 1. I_C = 5A, I_{B1} = 0.5A, L = 100μH
	$V_{CEX(SUS)1}$	250			V	Table 1. I_C = 5A, I_{B1} = $-I_{B2}$ = 0.5A V_{clamp} = Rated V_{CEX}, Ta = 125°C
	$V_{CEX(SUS)2}$	200			V	Table 1. I_C = 10A, I_{B1} = 1.0A, I_{B2} = −0.5A, V_{clamp} = Rated V_{CEX}, Ta = 125°C
Collector Cutoff Current	I_{CER}			1.0	mA	V_{CE} = 300V, R_{BE} = 50Ω, Ta = 125°C
	I_{CEX}			100	μA	V_{CE} = 300V, $V_{BE(OFF)}$ = −1.5V
	I_{CEX}			500	μA	V_{CE} = 300V, $V_{BE(OFF)}$ = −1.5V, Ta = 125°C
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB} = 7.0V, I_C = 0
Second Breakdown Collector Current	$I_{S/B}$	5.0			A	t = 1.0 s, V_{CE} = 20V, Tc = 25°C
Second Breakdown Energy	$E_{S/B}$	500			μJ	I_C = 5A, I_{B1} = 0.5A, $V_{BE(OFF)}$ = −5V
DC Current Gain	h_{FE1}	20		160		V_{CE} = 5V, I_C = 3A **
	h_{FE2}	15				V_{CE} = 5V, I_C = 5A **
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C = 5A, I_B = 0.5A **
	$V_{CE(sat)}$			1.5	V	I_C = 5A, I_B = 0.5A, Ta = 125°C **
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	I_C = 5A, I_B = 0.5A **
	$V_{BE(sat)}$			1.5	V	I_C = 5A, I_B = 0.5A, Ta = 125°C**
Gain Bandwidth Product	f_T	20			MHz	V_{CE}=10V, I_C=300mA, f_o=3.0 MHz, Tc=25°C
Output Capacitance	C_{ob}			200	pF	V_{CB} = 10V, f_o = 1.0 MHz
Delay Time	t_d			0.1	μs	Resistive Load (Table 1.)
Rise Time	t_r			0.9	μs	
	t_r			2.7	μs	Ta = 125°C; I_C = 5A, I_{B1} = $-I_{B2}$ = 0.5A
Storage Time	t_{stg}			2.0	μs	R_L = 20Ω, V_{CC} ≃ 100V
	t_{stg}			4.0	μs	Ta = 125°C; PW ≃ 50μs, duty cycle ≦ 2%
Fall Time	t_f			0.5	μs	
	t_f			2.0	μs	Ta = 125°C

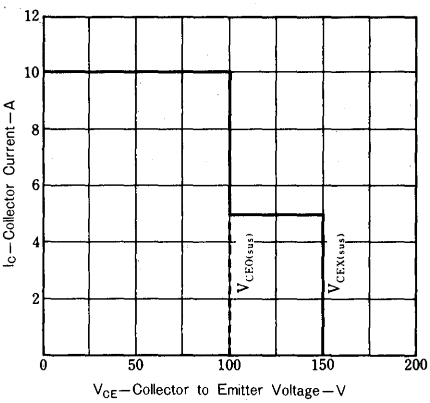
** PW ≦ 350 μs, duty cycle ≦ 2%

TABLE 1. — TEST CONDITIONS FOR DYNAMIC PERFORMANCE

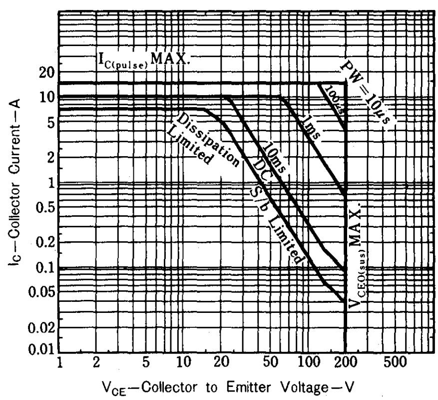
	V_{CEO} (SUS)	V_{CEX} (SUS)	$E_{S/B}$	RESISTIVE SWITCHING
INPUT CONDITIONS	 PW Varied to Attain I_C = 5A	 PW Varied to Attain I_C = 5A duty cycle ≦ 2% Q_1 = 2SA959		
CIRCUIT VALUES	L_{coil} = 100μH, V_{CC} = 10V R_{coil} = 0.05Ω V_{clamp} (Unclamped)	L_{coil} = 180 μH, V_{CC} = 20V R_{coil} = 0.05Ω V_{clamp} = Rated V_{CEX} Value	L_{coil} = 40 μH, V_{CC} = 10V R_{coil} = 0.05Ω, R_{BB2} = 50Ω V_{clamp} (Unclamped)	R_L = 20Ω, V_{CC} ≃ 100V
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT  D1 = F114F D2 = 6FH4S	OUTPUT WAVEFORM 	t_1 Adjust to Obtain IC $t_1 = \frac{L_{coil}(I_{C\,pk})}{V_{CC}}$ $t_2 = \frac{L_{coil}(I_{C\,pk})}{V_{clamp}}$	RESISTIVE TEST CIRCUIT 

TYPICAL CHARACTERISTICS (Ta = 25°C)

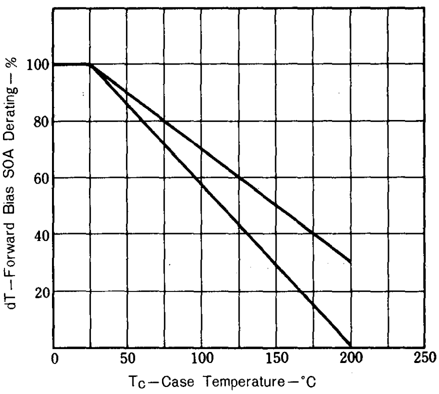
REVERES BIAS SAFE OPERATING AREA



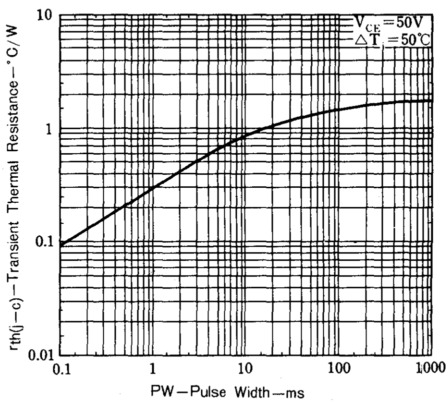
FORWARD BIAS SAFE OPERATING AREAS



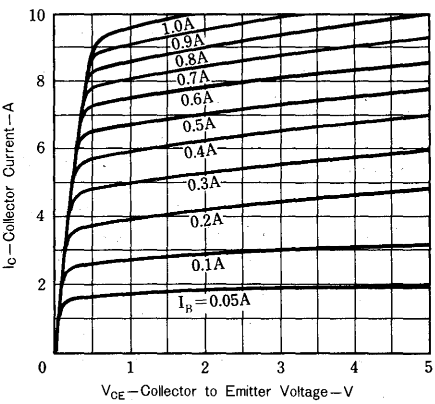
DERATING CURVE OF FORWARD BIAS SAFE OPERATING AREA



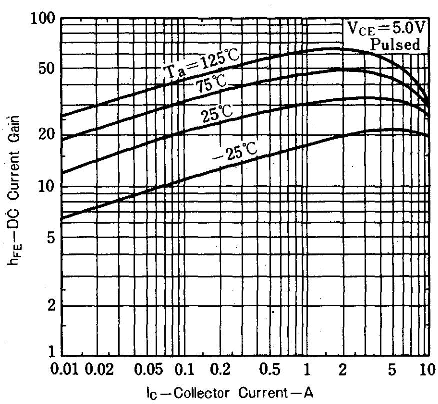
TRANSIENT THERMAL RESISTANCE

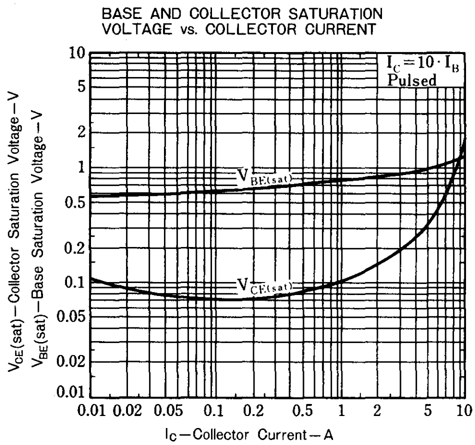


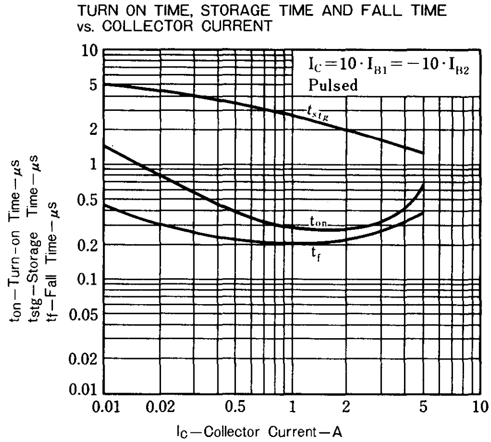
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT




BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT
IC=10·IB
Pulsed
VBE(sat)
VCE(sat)
VCE(sat)—Collector Saturation Voltage—V
VBE(sat)—Base Saturation Voltage—V
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
0.01 0.02 0.05 0.1 0.2 0.5 1 2 5 10
IC—Collector Current—A


TURN ON TIME, STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT
IC=10·IB1=−10·IB2
Pulsed
tstg
ton
tf
ton—Turn-on Time—μs
tstg—Storage Time—μs
tf—Fall Time—μs
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
0.01 0.02 0.5 1 2 5 10
IC—Collector Current—A

3

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC1868

HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON TRIPLE DIFFUSED MESA TRANSISTOR

Industrial Use

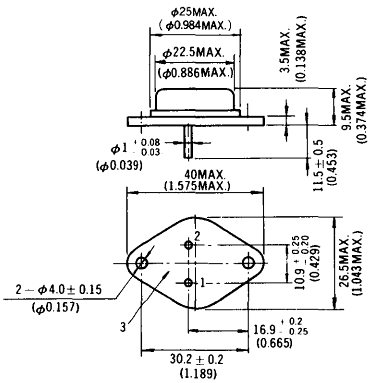
DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased S.O.A. with inductive loads.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector (Case)

EIAJ :TC-3,TB-3
JEDEC:TO-3
IEC :C14A,B18

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Emitter Voltage	V_{CEX}	500	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	450	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	7.0	A
Peak Collector Current*	$I_{C(pulse)}$	15	A
Continuous Base Current	$I_{B(DC)}$	4.0	A
Peak Base Current*	$I_{B(pulse)}$	8.0	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(Tc=25°C)}$	100	W
Total Power Dissipation	$P_{T(Tc=100°C)}$	57	W
Total Power Dissipation	$P_{T(Ta=25°C)}$	5	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature 1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	1.75	°C/W
Junction to Ambient	$R_{th(j-a)}$	35	°C/W

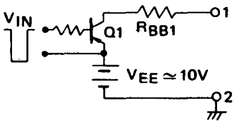
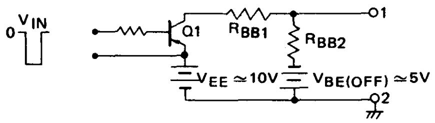
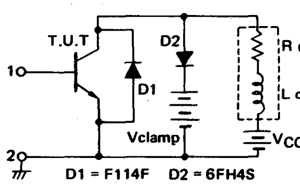
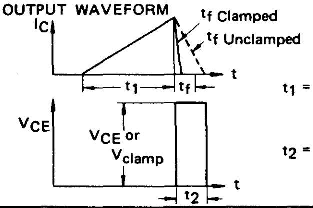
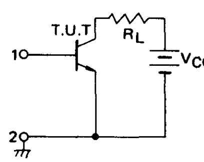
* Pulsed PW ≦ 300 μs, duty cycle ≦ 10%

ELECTRICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400			V	Table 1. I_C = 5A, I_{B1} = 1A, L = 100μH
	$V_{CEX(SUS)1}$	450			V	Table 1. I_C = 5A, I_{B1} = $-I_{B2}$ = 1A V_{clamp} = Rated V_{CEX}, Ta = 125°C
	$V_{CEX(SUS)2}$	400			V	Table 1. I_C = 10A, I_{B1} = 2A, I_{B2} = -1A, V_{clamp} = Rated V_{CEX}, Ta = 125°C
Collector Cutoff Current	I_{CER}			1.0	mA	V_{CE} = 500V, R_{BE} = 50Ω, Ta = 125°C
	I_{CEX}			100	μA	V_{CE} = 500V, $V_{BE(OFF)}$ = -1.5V
	I_{CEX}			500	μA	V_{CE} = 500V, $V_{BE(OFF)}$ = -1.5V, Ta = 125°C
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB} = 7.0V, I_C = 0
Second Breakdown Collector Current	$I_{S/B}$	2.5			A	t = 1.0 s, V_{CE} = 40V, Tc = 25°C
Second Breakdown Energy	$E_{S/B}$	500			μJ	I_C = 5A, I_{B1} = 1A, $V_{BE(OFF)}$ = 5V
DC Current Gain	h_{FE1}	15		100		V_{CE} = 5V, I_C = 3A **
	h_{FE2}	10				V_{CE} = 5V, I_C = 5A **
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C = 5A, I_B = 1A **
	$V_{CE(sat)}$			1.5	V	I_C = 5A, I_B = 1A, Ta = 125°C **
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	I_C = 5A, I_B = 1A **
	$V_{BE(sat)}$			1.5	V	I_C = 5A, I_B = 1A, Ta = 125°C **
Gain Bandwidth Product	f_T	10			MHz	V_{CE} = 10V, I_C = 300mA, f_o = 3.0 MHz, Tc = 25°C
Output Capacitance	C_{ob}			200	pF	V_{CB} = 10V, f_o = 1.0 MHz
Delay Time	t_d			0.1	μs	Resistive Load (Table 1.)
Rise Time	t_r			0.9	μs	
	t_r			2.7	μs	Ta = 125°C; I_C = 5A, I_{B1} = $-I_{B2}$ = 1A
Storage Time	t_{stg}			2.0	μs	R_L = 30Ω, V_{CC} ≃ 150V
	t_{stg}			4.0	μs	Ta = 125°C; PW ≃ 50μs, duty cycle ≦ 2%
Fall Time	t_f			0.7	μs	
	tf			2.8	μs	Ta = 125°C

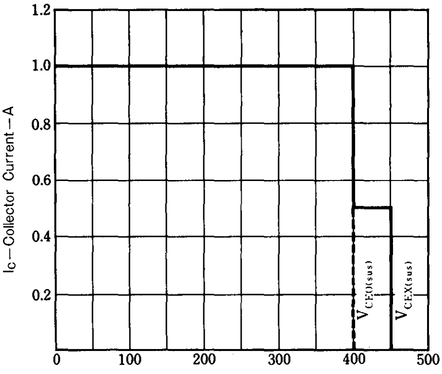
** PW ≦ 350 μs, duty cycle ≦ 2%

TABLE 1. — TEST CONDITIONS FOR DYNAMIC PERFORMANCE

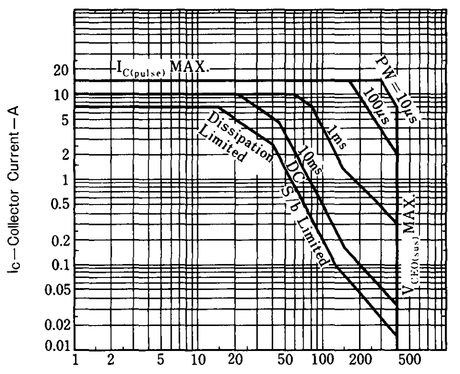
	V_{CEO} (SUS)	V_{CEX} (SUS)	$E_{S/B}$	RESISTIVE SWITCHING
INPUT CONDITIONS	 PW Varied to Attain I_C = 5A	 PW Varied to Attain I_C = 5A duty cycle ≦ 2% Q_1 = 2SA959		
CIRCUIT VALUES	L_{coil} = 100μH, V_{CC} = 10V R_{coil} = 0.05Ω V_{clamp} (Unclamped)	L_{coil} = 180 μH, V_{CC} = 20V R_{coil} = 0.05Ω V_{clamp} = Rated V_{CEX} Value	L_{coil} = 40 μH, V_{CC} = 10V R_{coil} = 0.05Ω, R_{BB2} = 50Ω V_{clamp} (Unclamped)	R_L = 30Ω, V_{CC} ≃ 150V
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT  D1 = F114F D2 = 6FH4S	OUTPUT WAVEFORM 	t_1 Adjust to Obtain IC; $t_1 = \frac{L_{coil}\,(I_{C\,pk})}{V_{CC}}$; $t_2 = \frac{L_{coil}\,(I_{C\,pk})}{V_{clamp}}$	RESISTIVE TEST CIRCUIT 

TYPICAL CHARACTERISTICS (Ta=25°C)

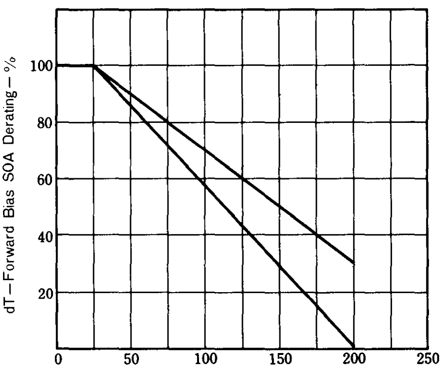
REVERSE BIAS SAFE OPERATING AREA



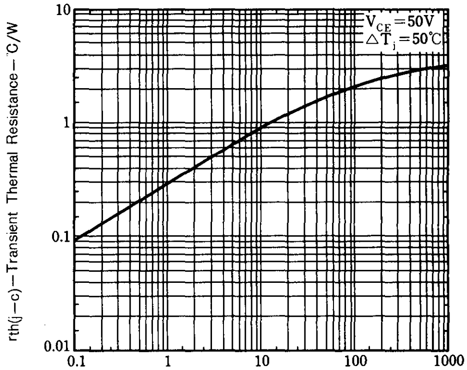
FORWARD BIAS SAFE OPERATING AREA



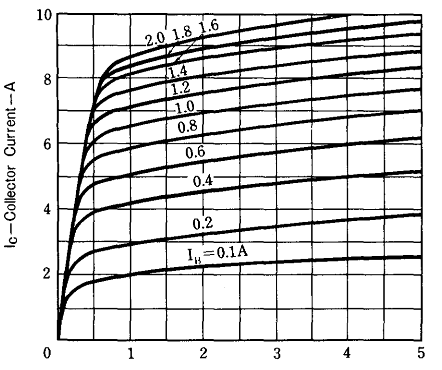
DERATING CURVE OF FORWARD BIAS SAFE OPERATING AREA



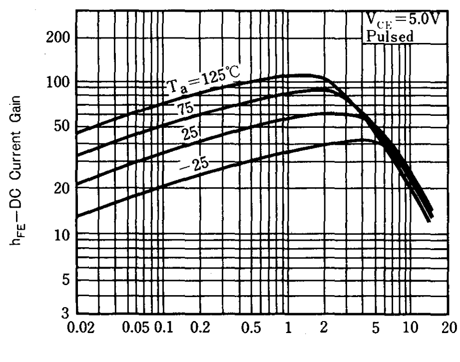
TRANSIENT THERMAL RESISTANCE



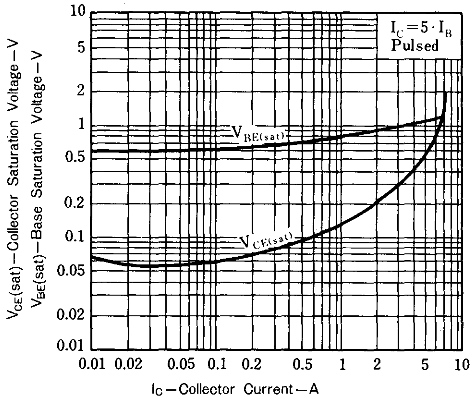
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



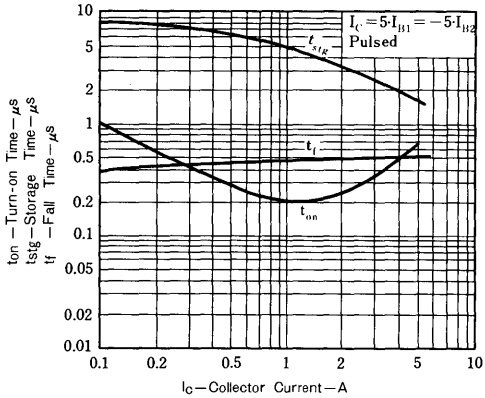
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT



3

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC1869

HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON EPITAXIAL MESA TRANSISTOR

Industrial Use

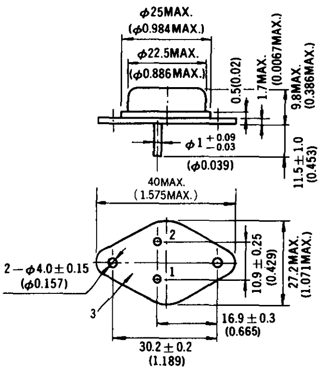
DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased S.O.A. with inductive loads.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector (Case)

EIAJ :TC-3,TB-3
JEDEC:TO-3
IEC :C14A,B18

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Emitter Voltage	V_{CEX}	150	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	100	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	150	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	15	A
Peak Collector Current*	$I_{C(pulse)}$	30	A
Continuous Base Current	$I_{B(DC)}$	5.0	A
Peak Base Current*	$I_{B(pulse)}$	10	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(Tc=25°C)}$	150	W
Total Power Dissipation	$P_{T(Tc=100°C)}$	86	W
Total Power Dissipation	$P_{T(Ta=25°C)}$	5	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature 1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	1.17	°C/W
Junction to Ambient	$R_{th(j-a)}$	35	°C/W

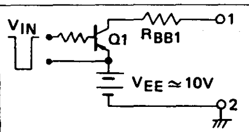
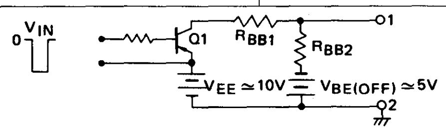
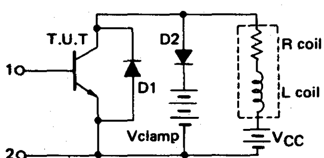
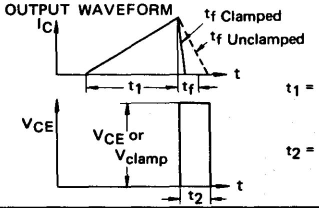
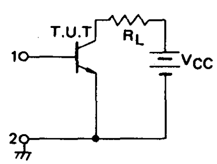
* Pulsed PW $\leqq$ 300 μs, duty cycle $\leqq$ 10%

ELECTRICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	100			V	Table 1. I_C = 10A, I_{B1} = 1A, L = 50μH
	$V_{CEX(SUS)1}$	150			V	Table 1. I_C = 10A, I_{B1} = $-I_{B2}$ = 1A V_{clamp} = Rated V_{CEX}, Ta = 125°C
	$V_{CEX(SUS)2}$	100			V	Table 1. I_C = 20A, I_{B1} = 2A, I_{B2} = −1A V_{clamp} = Rated V_{CEX}, Ta = 125°C
Collector Cutoff Current	I_{CER}			2.0	mA	V_{CE} = 150V, R_{BE} = 50Ω, Ta = 125°C
	I_{CEX}			100	μA	V_{CE} = 150V, $V_{BE(OFF)}$ = −1.5V
	I_{CEX}			1.0	mA	V_{CE} = 150V, $V_{BE(OFF)}$ = −1.5V, Ta = 125°C
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB} = 7.0V, I_C = 0
Second Breakdown Collector Current	$I_{S/B}$	7.5			A	t = 1.0 s, V_{CE} = 20V, Tc = 25°C
Second Breakdown Energy	$E_{S/B}$	2			mJ	I_C = 10A, I_{B1} = 1.5A, $V_{BE(OFF)}$ = 5V
DC Current Gain	h_{FE1}	30		160		V_{CE} = 5V, I_C = 5A **
	h_{FE2}	20				V_{CE} = 5V, I_C = 10A **
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C = 10A, I_B = 1.0A **
	$V_{CE(sat)}$			1.5	V	I_C = 10A, I_B = 1.0A, Ta = 125°C **
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	I_C = 10A, I_B = 1.0A **
	$V_{BE(sat)}$			1.5	V	I_C = 10A, I_B = 1.0A, Ta = 125°C **
Gain Bandwidth Product	f_T	20			MHz	V_{CE} = 10V, I_C = 500mA, f_o = 3.0 MHz, Tc = 25°C
Output Capacitance	C_{ob}			500	pF	V_{CB} = 10V, f_o = 1.0 MHz
Delay Time	t_d			0.1	μs	Resistive Load (Table 1.)
Rise Time	t_r			0.7	μs	
	t_r			2.1	μs	Ta = 125°C I_C = 10A, I_{B1} = $-I_{B2}$ = 1.0A
Storage Time	t_{stg}			1.5	μs	R_L = 3.3Ω, V_{CC} ≃ 50V
	t_{stg}			3.0	μs	Ta = 125°C PW ≃ 50μs, duty cycle ≦ 2%
Fall Time	t_f			0.3	μs	
	t_f			1.2	μs	Ta = 125°C

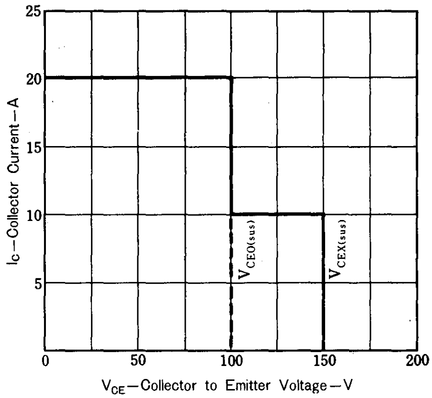
** PW ≦ 350 μs, duty cycle ≦ 2%

TABLE 1. – TEST CONDITIONS FOR DYNAMIC PERFORMANCE

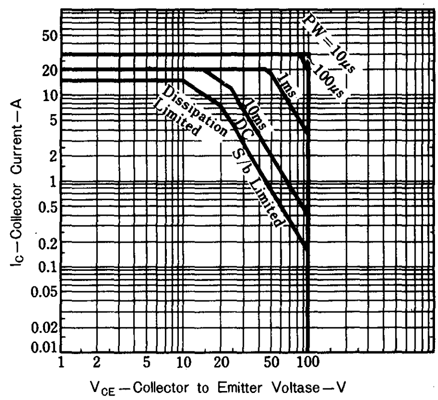
	V_{CEO} (SUS)	V_{CEX} (SUS)	$E_{S/B}$	RESISTIVE SWITCHING
INPUT CONDITIONS	 PW Varied to Attain I_C = 10A	 PW Varied to Attain I_C = 10A duty cycle ≦ 2% Q_1 = 2SA959		
CIRCUIT VALUES	L_{coil} = 50μH, V_{CC} = 10V R_{coil} = 0.05Ω V_{clamp} (Unclamped)	L_{coil} = 180 μH, V_{CC} = 20V R_{coil} = 0.05Ω V_{clamp} = Rated V_{CEX} Value	L_{coil} = 40 μH, V_{CC} = 10V R_{coil} = 0.05Ω, R_{BB2} = 50Ω V_{clamp} (Unclamped)	R_L = 5.0Ω, V_{CC} ≃ 50V
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT  D1 = F114F D2 = 6FH4S	OUTPUT WAVEFORM 	t_1 Adjust to Obtain IC $t_1 = \frac{L_{coil}(I_{C\,pk})}{V_{CC}}$ $t_2 = \frac{L_{coil}(I_{C\,pk})}{V_{clamp}}$	RESISTIVE TEST CIRCUIT 

TYPICAL CHARACTERISTICS (Ta=25°C)

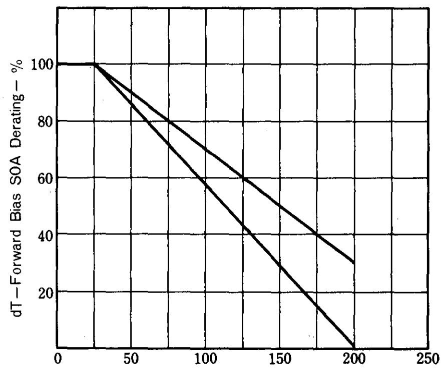
REVERSE BIAS SAFE OPERATING AREA

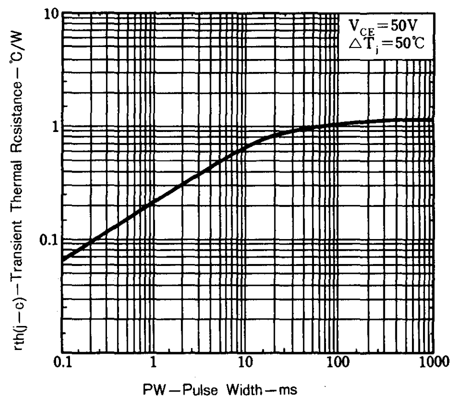


FORWARD BIAS SAFE OPERATING AREA

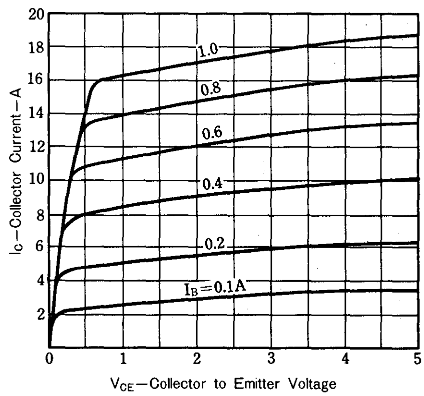


DERATING CURVE OF FORWARD BIAS SAFE OPERATING AREA

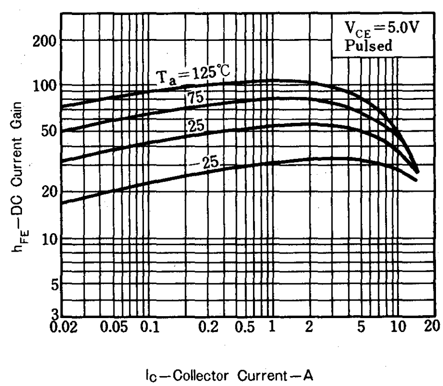




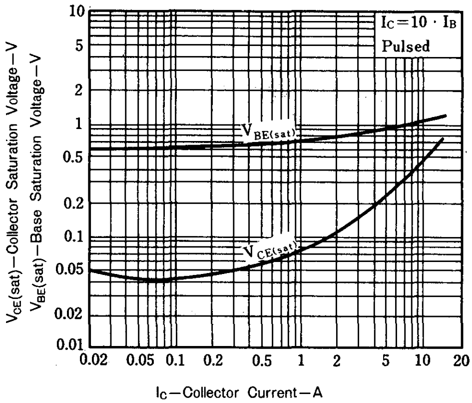
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



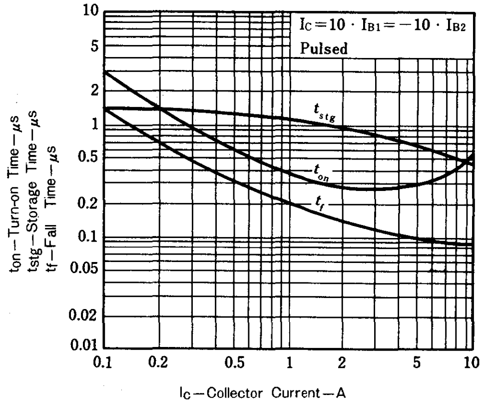
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLETCOR CURRENT



TURN ON TIME, STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT



3

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC1870

HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON EPITAXIAL MESA TRANSISTOR

Industrial Use

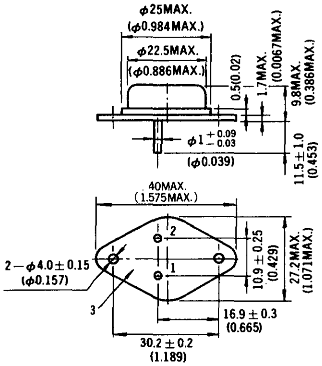
DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased S.O.A. with inductive loads.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector (Case)

EIAJ :TC-3,TB-3
JEDEC:TO-3
IEC :C14A,B18

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Emitter Voltage	V_{CEX}	300	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	200	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	250	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	15	A
Peak Collector Current*	$I_{C(pulse)}$	30	A
Continuous Base Current	$I_{B(DC)}$	5.0	A
Peak Base Current*	$I_{B(pulse)}$	10	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(Tc=25°C)}$	150	W
Total Power Dissipation	$P_{T(Tc=100°C)}$	86	W
Total Power Dissipation	$P_{T(Ta=25°C)}$	5	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature 1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	1.17	°C/W
Junction to Ambient	$R_{th(j-a)}$	35	°C/W

* Pulsed PW ≦ 300 μs, duty cycle ≦ 10%

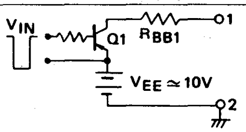
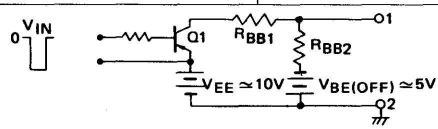
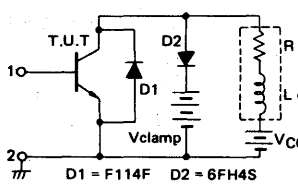
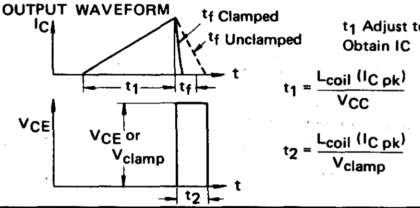
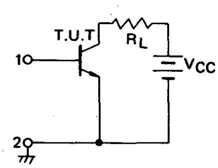
ELECTRICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	200			V	Table 1. I_C = 10A, I_{B1} = 1A, L = 50µH
	$V_{CEX(SUS)1}$	250			V	Table 1. I_C = 10A, I_{B1} = $-I_{B2}$ = 1A V_{clamp} = Rated V_{CEX}, Ta = 125°C
	$V_{CEX(SUS)2}$	200			V	Table 1. I_C = 20A, I_{B1} = 2A, I_{B2} = −1A, V_{clamp} = Rated V_{CEX}, Ta = 125°C
Collector Cutoff Current	I_{CER}			2.0	mA	V_{CE} = 300V, R_{BE} = 50Ω, Ta = 125°C
	I_{CEX}			100	µA	V_{CE} = 300V, $V_{BE(OFF)}$ = −1.5V
	I_{CEX}			1.0	mA	V_{CE} = 300V, $V_{BE(OFF)}$ = −1.5V, Ta = 125°C
Emitter Cutoff Current	I_{EBO}			10	µA	V_{EB} = 7.0V, I_C = 0
Second Breakdown Collector Current	$I_{S/B}$	7.5			A	t = 1.0 s, V_{CE} = 20V, Tc = 25°C
Second Breakdown Energy	$E_{S/B}$	2.0			µJ	I_C = 10A, I_{B1} = 1A, $V_{BE(OFF)}$ = 5V
DC Current Gain	h_{FE1}	20		160		V_{CE} = 5V, I_C = 5A **
	h_{FE2}	15				V_{CE} = 5V, I_C = 10A **
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C = 10A, I_B = 1A **
	$V_{CE(sat)}$			1.5	V	I_C = 10A, I_B = 1A, Ta = 125°C **
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	I_C = 10A, I_B = 1A **
	$V_{BE(sat)}$			1.5	V	I_C = 10A, I_B = 1A, Ta = 125°C **
Gain Bandwidth Product	f_T	20			MHz	V_{CE}=10V, I_C=500mA, f_o=3.0 MHz, Tc=25°C
Output Capacitance	C_{ob}			200	pF	V_{CB} = 10V, f_o = 1.0 MHz
Delay Time	t_d			0.1	µs	Resistive Load (Table 1.)
Rise Time	t_r			0.9	µs	
	t_r			2.7	µs	Ta = 125°C I_C = 10A, I_{B1} = $-I_{B2}$ = 1A
Storage Time	t_{stg}			1.5	µs	R_L = 10Ω, V_{CC} ≃ 100V
	t_{stg}			3.0	µs	Ta = 125°C PW ≃ 50µs, duty cycle ≦ 2%
Fall Time	t_f			0.5	µs	
	tf			2.0	µs	Ta = 125°C

** PW ≦ 350 µs, duty cycle ≦ 2%

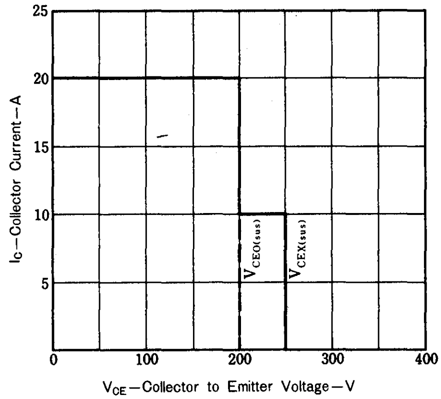
3

TABLE 1. — TEST CONDITIONS FOR DYNAMIC PERFORMANCE

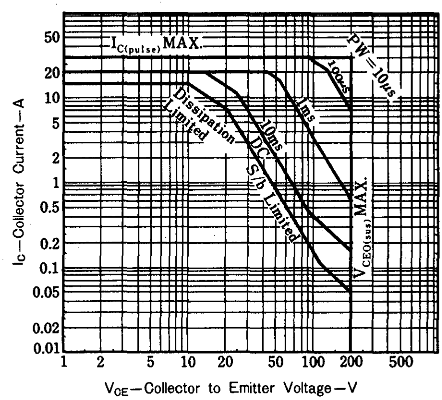
	V_{CEO} (SUS)	V_{CEX} (SUS)	$E_{S/B}$	RESISTIVE SWITCHING
INPUT CONDITIONS	 PW Varied to Attain I_C = 10A	 PW Varied to Attain I_C = 10A duty cycle ≦ 2% Q_1 = 2SA959		
CIRCUIT VALUES	L_{coil} = 50µH, V_{CC} = 10V R_{coil} = 0.05Ω V_{clamp} (Unclamped)	L_{coil} = 180 µH, V_{CC} = 20V R_{coil} = 0.05Ω V_{clamp} = Rated V_{CEX} Value	L_{coil} = 40 µH, V_{CC} = 10V R_{coil} = 0.05Ω, R_{BB2} = 50Ω V_{clamp} (Unclamped)	R_L = 10Ω, V_{CC} ≃ 100V
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT  D1 = F114F D2 = 6FH4S	OUTPUT WAVEFORM 		RESISTIVE TEST CIRCUIT 

TYPICAL CHARACTERISTICS (Ta = 25°C)

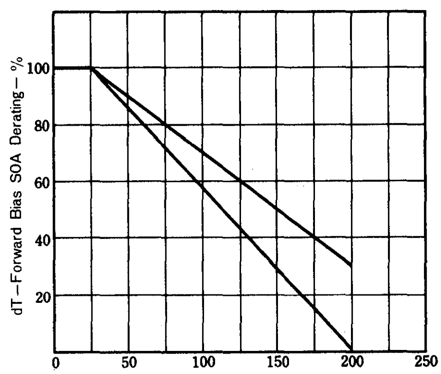
REVERSE BIAS SAFE OPERATING ARAE



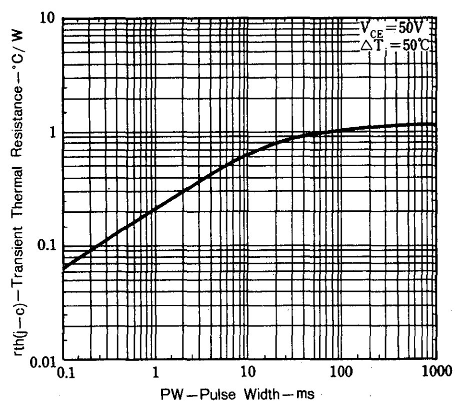
FORWARD BIAS SAFE OPERATING AREA



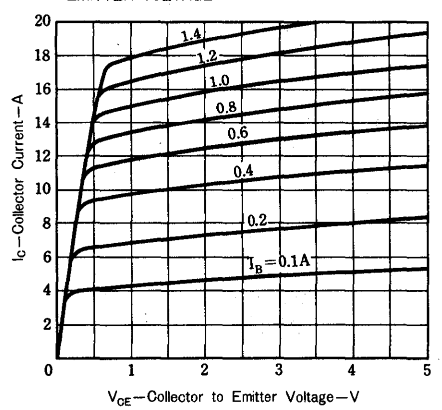
DERATING CURVE OF FORWARD BIAS SAFE OPERATING AREA



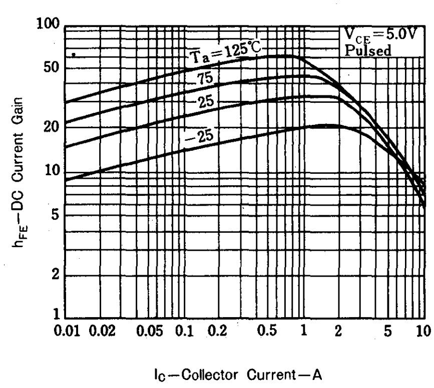
TRANSIENT THERMAL RESISTANCE



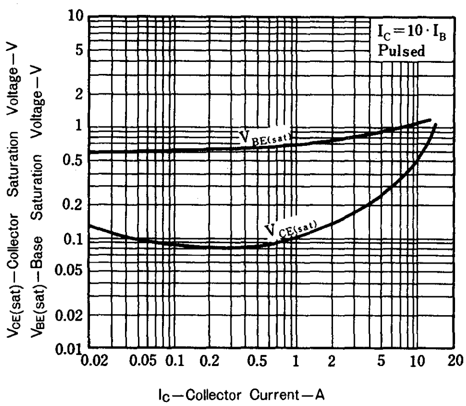
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



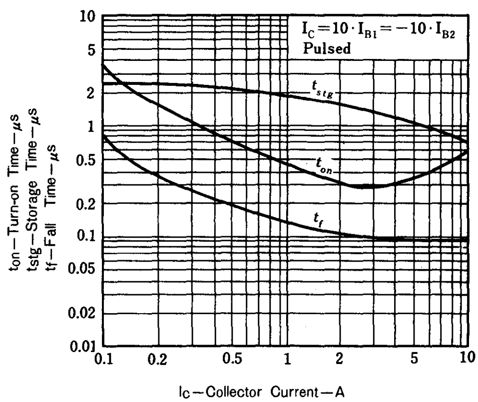
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION
VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORAGE TIME AND FALL TIME
vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC1871A

HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON TRIPLE DIFFUSED MESA TRANSISTOR

Industrial Use

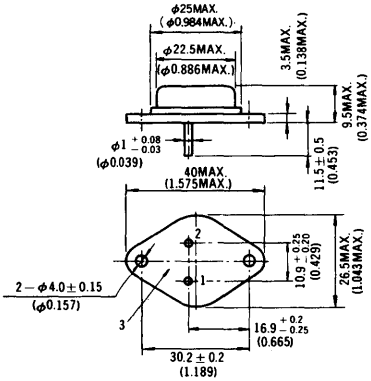
DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased S.O.A. with inductive loads.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector (Case)

EIAJ :TC-3,TB-3
JEDEC:TO-3
IEC :C14A,B18

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (T_a = 25°C)			
Collector to Emitter Voltage	V_{CEX}	500	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	450	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	15	A
Peak Collector Current*	$I_{C(pulse)}$	30	A
Continuous Base Current	$I_{B(DC)}$	5.0	A
Peak Base Current*	$I_{B(pulse)}$	10	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(Tc=25°C)}$	150	W
Total Power Dissipation	$P_{T(Tc=100°C)}$	86	W
Total Power Dissipation	$P_{T(Ta=25°C)}$	5	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature 1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	1.17	°C/W
Junction to Ambient	$R_{th(j-a)}$	35	°C/W

* Pulsed PW ≦ 300 μs, duty cycle ≦ 10%

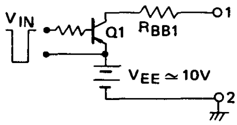
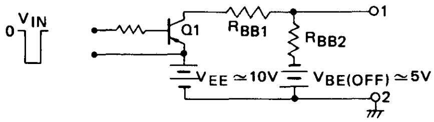
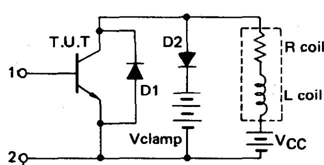
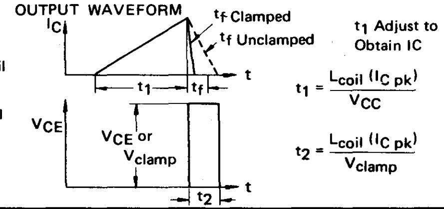
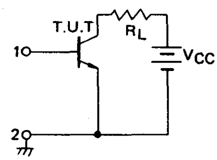
ELECTRICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400			V	Table 1. I_C = 10A, I_{B1} = 2A, L = 50µH
	$V_{CEX(SUS)1}$	450			V	Table 1. I_C = 10A, I_{B1} = $-I_{B2}$ = 2A V_{clamp} = Rated V_{CEX}, Ta = 125°C
	$V_{CEX(SUS)2}$	400			V	Table 1. I_C = 20A, I_{B1} = 4A, I_{B2} = −2A V_{clamp} = Rated V_{CEX}, Ta = 125°C
Collector Cutoff Current	I_{CER}			2.0	mA	V_{CE} = 500V, R_{BE} = 50Ω, Ta = 125°C
	I_{CEX}			100	µA	V_{CE} = 500V, $V_{BE(OFF)}$ = −1.5V
	I_{CEX}			1.0	mA	V_{CE} = 500V, $V_{BE(OFF)}$ = −1.5V, Ta = 125°C
Emitter Cutoff Current	I_{EBO}			10	µA	V_{EB} = 7.0V, I_C = 0
Second Breakdown Collector Current	$I_{S/B}$	3.75			A	t = 1.0 s, V_{CE} = 40V, Tc = 25°C
Second Breakdown Energy	$E_{S/B}$	2.0			mJ	I_C = 10A, I_{B1} = 2.0A, $V_{BE(OFF)}$ = 5V
DC Current Gain	h_{FE1}	15		100		V_{CE} = 5V, I_C = 5A **
	h_{FE2}	10				V_{CE} = 5V, I_C = 10A **
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C = 10A, I_B = 2A **
	$V_{CE(sat)}$			1.5	V	I_C = 10A I_B = 2A, Ta = 125°C **
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	I_C = 10A, I_B = 2A **
	$V_{BE(sat)}$			1.5	V	I_C = 10A, I_B = 2A, Ta = 125°C **
Gain Bandwidth Product	f_T	10			MHz	V_{CE} = 10V, I_C = 500mA, f_o = 3.0 MHz, Tc = 25°C
Output Capacitance	C_{ob}			360	pF	V_{CB} = 10V, f_o = 1.0 MHz
Delay Time	t_d			0.1	µs	Resistive Load (Table 1.)
Rise Time	t_r			0.9	µs	
	t_r			2.7	µs	Ta = 125°C I_C = 10A, I_{B1} = $-I_{B2}$ = 2A
Storage Time	t_{stg}			2.0	µs	R_L = 15Ω, V_{CC} ≃ 150V
	t_{stg}			4.0	µs	Ta = 125°C PW ≃ 50µs, duty cycle ≦ 2%
Fall Time	t_f			0.7	µs	
	t_f			2.8	µs	Ta = 125°C

** PW ≦ 350 µs, duty cycle ≦ 2%

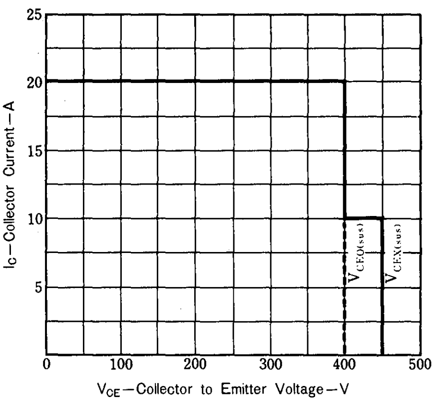
3

TABLE 1. – TEST CONDITIONS FOR DYNAMIC PERFORMANCE

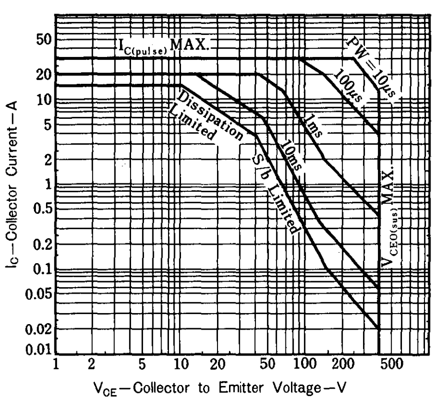
	V_{CEO} (SUS)	V_{CEX} (SUS)	$E_{S/B}$	RESISTIVE SWITCHING
INPUT CONDITIONS	 PW Varied to Attain I_C = 10A	 PW Varied to Attain I_C = 10A duty cycle ≦ 2% Q_1 = 2SA959		
CIRCUIT VALUES	L_{coil} = 50µH, V_{CC} = 10V R_{coil} = 0.05Ω V_{clamp} (Unclamped)	L_{coil} = 180 µH, V_{CC} = 20V R_{coil} = 0.05Ω V_{clamp} = Rated V_{CEX} Value	L_{coil} = 40 µH, V_{CC} = 10V R_{coil} = 0.05Ω, R_{BB2} = 50Ω V_{clamp} (Unclamped)	R_L = 15Ω, V_{CC} ≃ 150V
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT  D1 = F114F D2 = 6FH4S	OUTPUT WAVEFORM 		RESISTIVE TEST CIRCUIT 

TYPICAL CHARACTERISTICS (Ta=25°C)

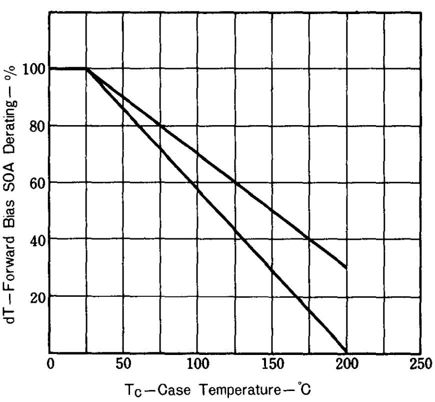
REVERSE BIAS SAFE OPERTING AREA



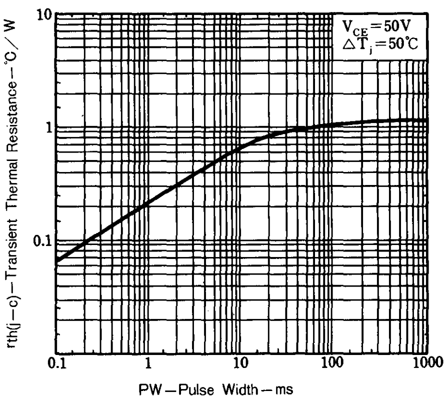
FORWARD BIAS SAFE OPERATING AREA



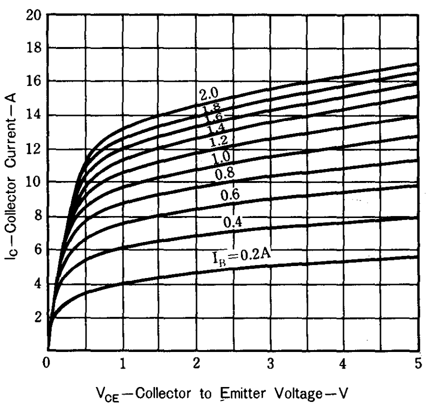
DERATING CURVE OF FORWARD BIAS SAFE OPERATING AREA



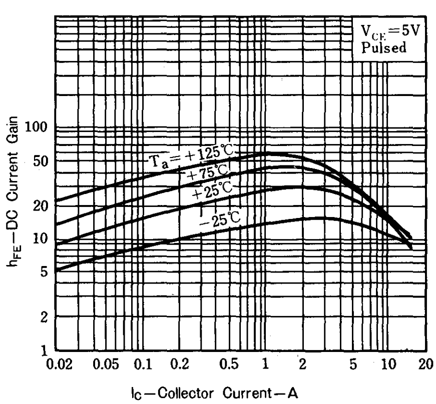
TRANSIENT THERMAL RESISTANCE



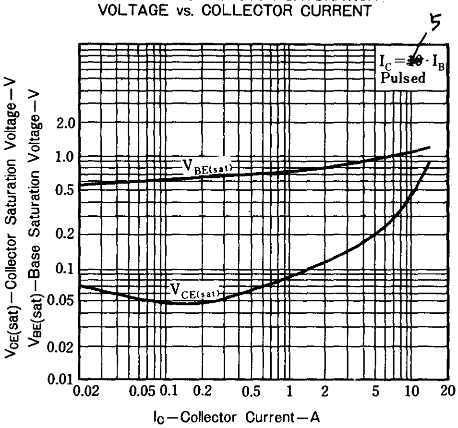
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



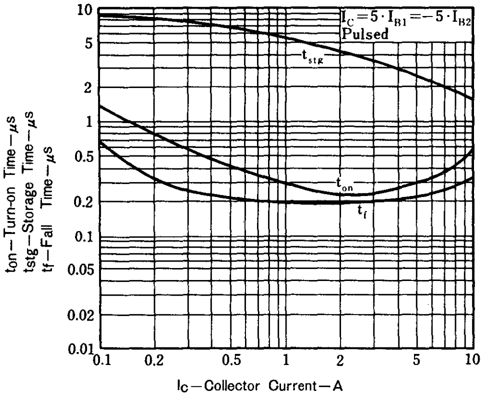
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT



3

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC2331

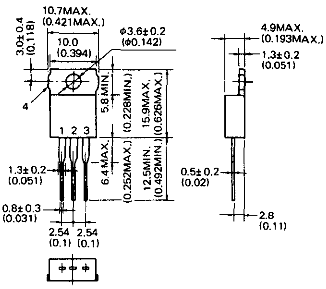
HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON EPITAXIAL TRANSISTOR

Industrial Use

DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base (B)
2. Collector (C)
3. Emitter (E)
4. Fin (Collector)

JEDEC: TO-220AB

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased SOA with inductive loads.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta=25°C)			
Collector to Emitter Voltage	V_{CEX}	200	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	100	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	100	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	2.0	A
Peak Collector Current	$I_{C(pulse)}$*	4.0	A
Continuous Base Current	$I_{B(DC)}$	1.0	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(Tc=25°C)}$	40	W
Total Power Dissipation	$P_{T(Tc=100°C)}$	16	W
Total Power Dissipation	$P_{T(Ta=25°C)}$	2.0	W
Maximum Temperatures			
Junction Temperature	Tj	150	°C
Storage Temperature	Tstg	−55 to +150	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	3.13	°C/W
Junction to Ambient	$R_{th(j-a)}$	62.5	°C/W

* Pulsed PW≦300μs, duty cycle≦10%

ELECTRICAL CHARACTERISTICS (Ta=25°C unless otherwise noted.)

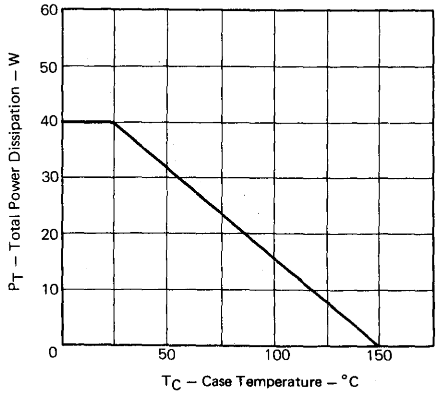
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	100			V	I_C=1.0A, I_B=0.10A, L=1mH
	$V_{CEX(SUS)1}$	100			V	I_C=1.0A, I_{B1}=$-I_{B2}$=0.10A, $V_{BE(OFF)}$=−5V, L=180μH Ta=125°C *1
	$V_{CEX(SUS)2}$	100			V	I_C=2.0A, I_{B1}=0.2A, I_{B2}=−0.1A, $V_{BE(OFF)}$=−5V, L=180μH Ta=125°C *2
Collector Cutoff Current	I_{CEX1}			10	μA	V_{CE}=100V, $V_{BE(OFF)}$=−1.5V
	I_{CEX2}			1.0	mA	V_{CE}=100V, $V_{BE(OFF)}$=−1.5V Ta=125°C
	I_{CER}			1.0	mA	V_{CE}=100V, R_{BE}=100Ω, Ta=125°C
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB}=5.0V, I_C=0
Second Breakdown Collector Current	$I_{S/B}$	0.75			A	V_{CE}=20V, t=1sec, Tc=25°C
Second Breakdown Energy	$E_{S/B}$	40			μJ	I_C=1.0A, I_{B1}=0.10A, $V_{BE(OFF)}$=−5V, R_{BB}=50Ω, L=80μH
DC Current Gain	h_{FE1}	40				V_{CE}=5.0V, I_C=0.1A *3
	h_{FE2}	40		200		V_{CE}=5.0V, I_C=1.0A, *3
Collector Saturation Voltage	$V_{CE(sat)}$			0.6	V	I_C=1.0A, I_B=0.10A *3
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	
Gain Bandwidth Product	f_T	50			MHz	V_{CE}=10V, I_C=50mA, f=3MHz
Output Capacitance	Cob			60	pF	V_{CB}=10V, I_E=0, f=1MHz
Turn On Time	ton			0.5	μs	I_C=1.0A, I_{B1}=$-I_{B2}$=0.1A, $V_{BE(OFF)}$=−5.0V, R_L=50Ω
Storage Time	t_{stg}			1.5	μs	
Fall Time	t_f			0.3	μs	

*1 V_{CE} clamped Vclamp = 100V
*2 V_{CE} clamped Vclamp = 100V
*3 Pulsed PW≦350μs, duty cycle≦2%

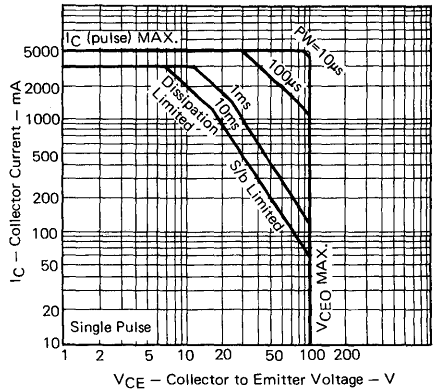
3

TYPICAL CHARACTERISTICS (Ta=25°C)

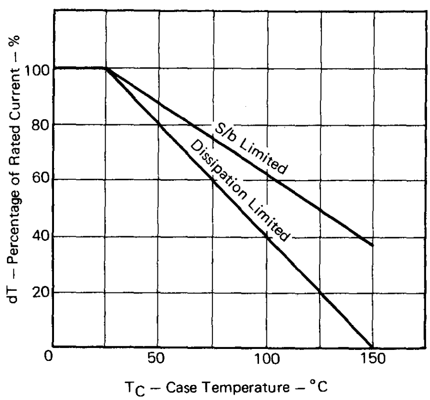
TOTAL POWER DISSIPATION vs. CASE TEMPERATURE



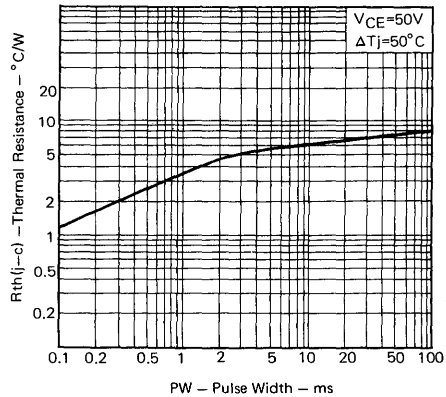
FORWARD BIAS SAFE OPERATING AREAS



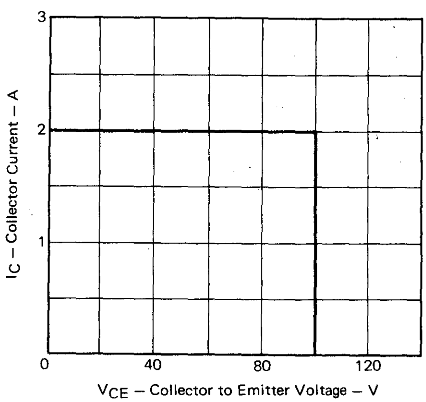
DERATING CURVE SAFE OPERATING AREAS



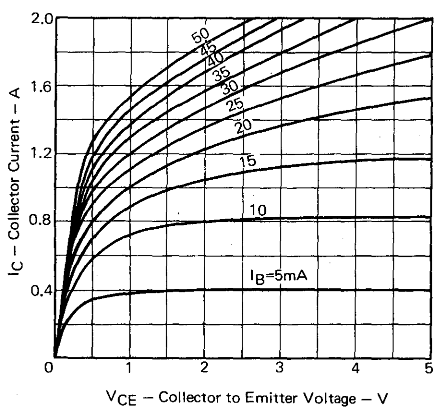
TRANSIENT THERMAL RESISTANCE



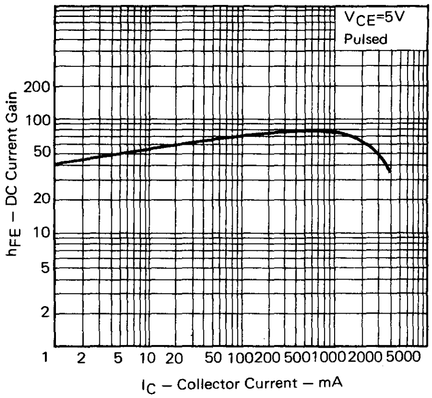
REVERSE BIAS SAFE OPERATING AREAS



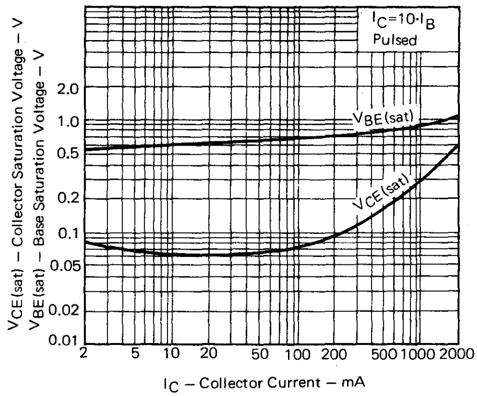
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



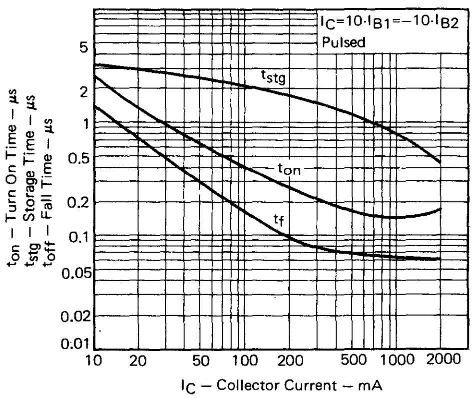
DC CURRENT GAIN vs. COLLECTOR CURRENT



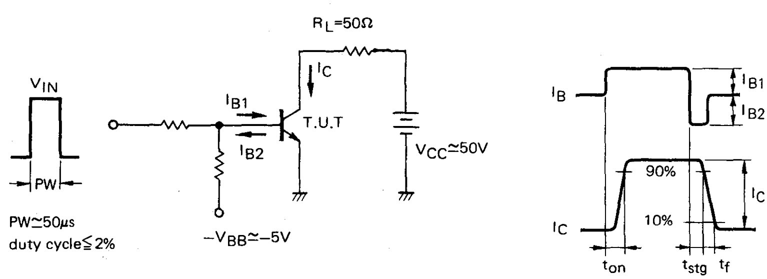
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT



SWITCHING TIME (t_{on}, t_{stg}, t_f) TEST CIRCUIT



3

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC2333

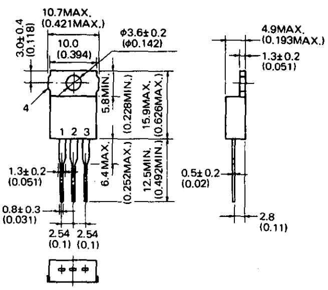
HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON TRIPLE DIFFUSED TRANSISTOR

Industrial Use

DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base (B)
2. Collector (C)
3. Emitter (E)
4. Fin (Collector)

JEDEC: TO-220AB

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased SOA with inductive loads.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta=25°C)			
Collector to Emitter Voltage	V_{CEX}	500	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	450	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	2.0	A
Peak Collector Current	$I_{C(pulse)}$*	4.0	A
Continuous Base Current	$I_{B(DC)}$	1.0	A
Maximum Power Dissipations			
Total Power Dissipation	P_{T}(Tc=25°C)	40	W
Total Power Dissipation	P_{T}(Tc=100°C)	16	W
Total Power Dissipation	P_{T}(Ta=25°C)	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−55 to +150	°C
Lead Temperature 1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	3.13	°C/W
Junction to Ambient	$R_{th(j-a)}$	62.5	°C/W

* Pulsed PW ≦ 300 μs, duty cycle ≦ 10%

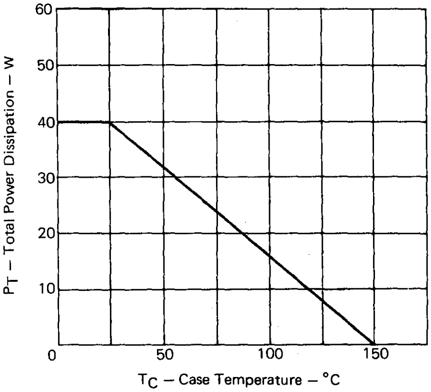
ELECTRICAL CHARACTERISTICS (Ta=25°C unless otherwise noted.)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400			V	I_C=0.5A, I_B=0.1A, I_{B2}=0, L=1.0mH
	$V_{CEX(SUS)1}$	450			V	I_C=0.5A, $I_{B1}=-I_{B2}$ = 0.1A, $V_{BE(OFF)}$ =−5V, L=180μH, Ta=125°C *1
	$V_{CEX(SUS)2}$	400			V	I_C=1A, I_{B1}=0.2A, I_{B2}=−0.1A, $V_{BE(OFF)}$=−5V, L=180μH, *2 Ta=125°C
Collector Cutoff Current	I_{CEX1}			10	μA	V_{CE}=400V, $V_{BE(OFF)}$=−1.5V
	I_{CEX2}			1.0	mA	V_{CE}=400V, $V_{BE(OFF)}$=−1.5V, Ta=125°C
	I_{CER}			1.0	mA	V_{CE}=400V, R_{BE}=100Ω, Ta=125°C
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB}=5.0V, I_C=0
Second Breakdown Collector Current	$I_{S/B}$	0.4			A	V_{CE}=40V, t=1.0sec. Tc=25°C
Second Breakdown Energy	$E_{S/B}$	25			μJ	I_C=0.5A, I_{B1}=0.1A, $V_{BE(OFF)}$=−5V, R_{BB}=50Ω, L=200μH
DC Current Gain	h_{FE1}	20				V_{CE}=5.0V, I_C=0.1A *3
	h_{FE2}	10				V_{CE}=5.0V, I_C=0.5A *3
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C=0.5A, I_B=0.1A *3
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	
Gain Bandwidth Product	f_T	20			MHz	V_{CE}=10V, I_C=50mA, f=3MHz
Output Capacitance	Cob			60	pF	V_{CB}=10V, I_E=0, f=1MHz
Turn On Time	t_{on}			0.9	μs	I_C=0.5A, $I_{B1}=-I_{B2}$ = 0.1A $V_{BE(OFF)}$=−5V, R_L=300Ω
Storage Time	t_{stg}			2.5	μs	
Fall Time	t_f			0.7	μs	

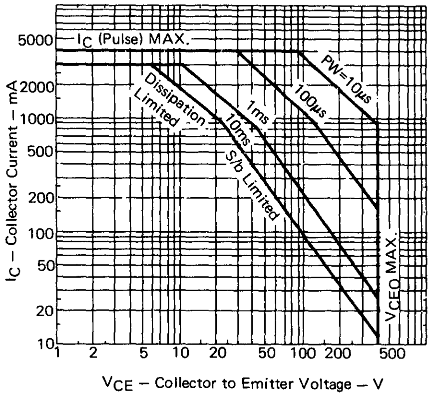
*1 V_{CE} clamped, Vclamp=450V
*2 V_{CE} clamped, Vclamp=400V
*3 Pulsed PW≦350μs, duty cycle≦2%

TYPICAL CHARACTERISTICS (Ta=25°C)

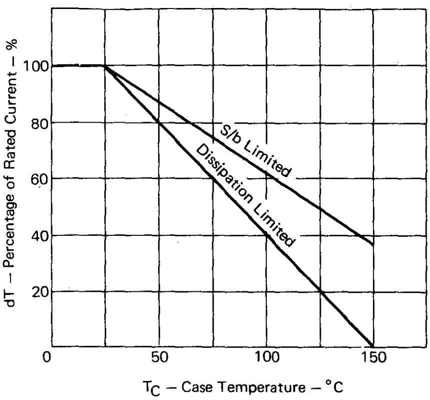
TOTAL POWER DISSIPATION vs. CASE TEMPERATURE



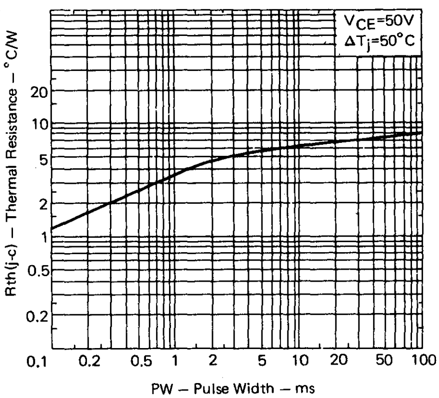
FORWARD BIAS SAFE OPERATING AREAS



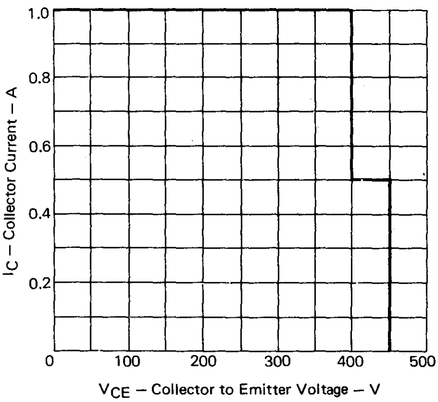
DERATING CURVE OF SAFE OPERATING AREAS



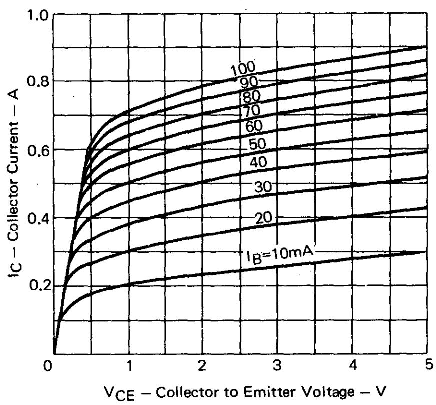
TRANSIENT THERMAL RESISTANCE



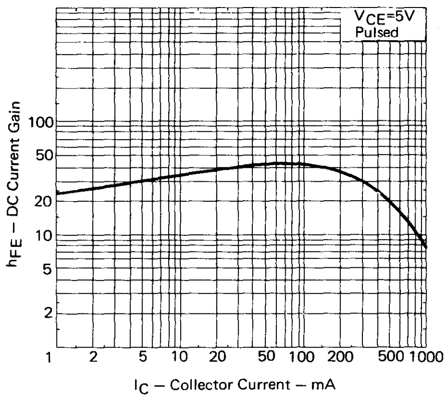
REVERSE BIAS SAFE OPERATING AREA



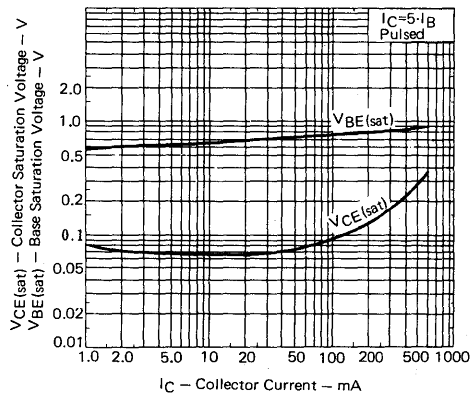
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



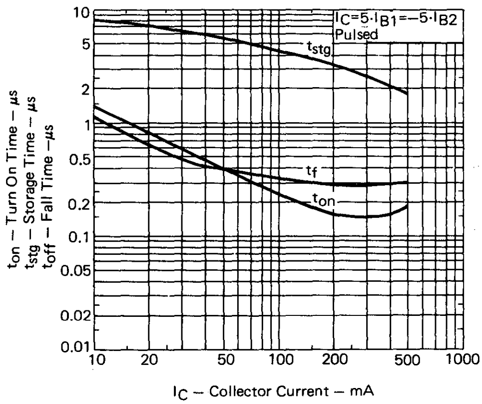
DC CURRENT GAIN vs. COLLECTOR CURRENT



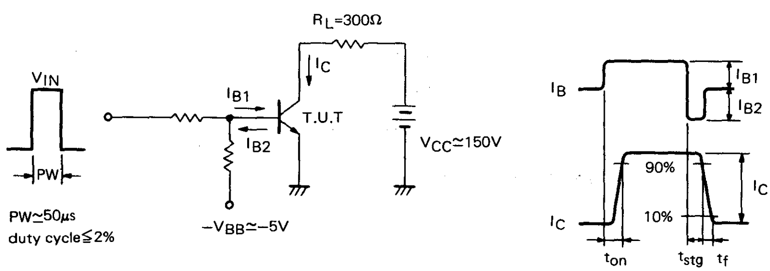
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME. STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT



SWITCHING TIME (t_{on}, t_{stg}, t_f) TEST CIRCUIT



NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC2334

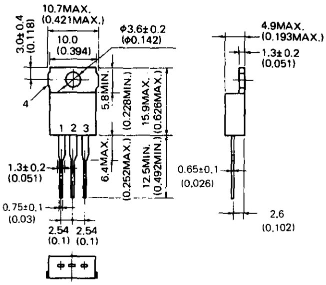
HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON EPITAXIAL TRANSISTOR

Industrial Use

DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base (B)
2. Collector (C)
3. Emitter (E)
4. Fin (Collector)

JEDEC: TO-220AB

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased SOA with inductive loads.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta=25 °C)			
Collector to Emitter Voltage	V_{CEX}	200	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	100	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	100	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	7.0	A
Peak Collector Current	$I_{C(pulse)}$*	15	A
Continuous Base Current	$I_{B(DC)}$	3.5	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(Tc=25°C)}$	65	W
Total Power Dissipation	$P_{T(Tc=100°C)}$	26	W
Total Power Dissipation	$P_{T(Ta=25°C)}$	2.0	W
Maximum Temperatures			
Junction Temperature	Tj	150	°C
Storage Temperature	Tstg	–55 to +150	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	1.92	°C/W
Junction to Ambient	$R_{th(j-a)}$	62.5	°C/W

*Pulsed PW $\leq$ 300 μs, duty cycle $\leq$ 10%

ELECTRICAL CHARACTERISTICS (Ta=25°C unless otherwise noted.)

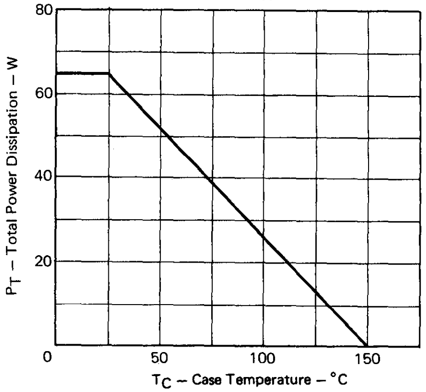
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	100			V	I_C=5.0A, I_B=0.5A, L=100μH
	$V_{CEX(SUS)1}$	100			V	I_C=5.0A, I_{B1}=−I_{B2}=0.5A, $V_{BE(OFF)}$=−5V, L=180μH Ta=125°C *1
	$V_{CEX(SUS)2}$	100			V	I_C=10A, I_{B1}=1.0A, I_{B2}=−0.5A, $V_{BE(OFF)}$=−5V, L=180μH Ta=125°C *2
Collector Cutoff Current	I_{CEX1}			10	μA	V_{CE}=100V, $V_{BE(OFF)}$=−1.5V
	I_{CEX2}			1.0	mA	V_{CE}=100V, $V_{BE(OFF)}$=−1.5V Ta=125°C
	I_{CER}			1.0	mA	V_{CE}=100V, R_{BE}=100Ω, Ta=125°C
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB}=5.0V, I_C=0
Second Breakdown Collector Current	$I_{S/B}$	2.0			A	V_{CE}=20V, t=1sec, Tc=25°C
Second Breakdown Energy	$E_{S/B}$	125			μJ	I_C=5A, I_{B1}=0.5A, $V_{BE(OFF)}$=−5V, R_{BB}=50Ω, L=10μH
DC Current Gain	h_{FE1}	40				V_{CE}=5.0V, I_C=3.0A *3
	h_{FE2}	20				V_{CE}=5.0V, I_C=5.0A *3
Collector Saturation Voltage	$V_{CE(sat)}$			0.6	V	I_C=5.0A, I_B=0.5A *3
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	
Gain Bandwidth Product	f_T	20			MHz	V_{CE}=10V, I_C=0.2A, f=3MHz
Output Capacitance	Cob			250	pF	V_{CB}=10V, I_E=0, f=1MHz
Turn On Time	t_{on}			0.5	μs	I_C=5.0A, I_{B1}=−I_{B2}=0.5A $V_{BE(OFF)}$=−5V, R_L=10Ω, Vcc≈50V
Storage Time	t_{stg}			1.5	μs	
Fall Time	t_f			0.3	μs	

*1 V_{CE} clamped Vclamp = 100V
*2 V_{CE} clamped Vclamp = 100V
*3 Pulsed PW≦350μs, duty cycle≦2%

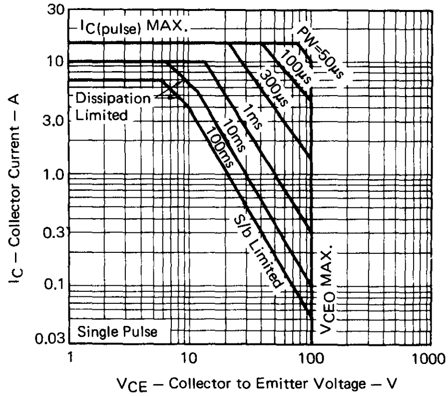
3

TYPICAL CHARACTERISTICS (Ta=25°C)

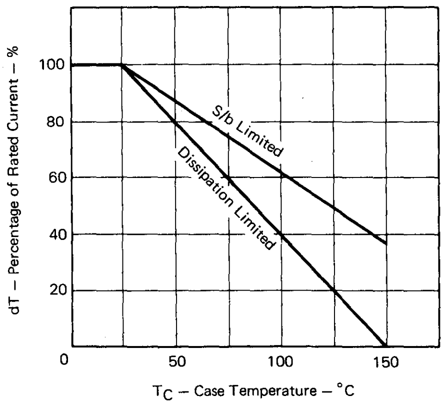
TOTAL POWER DISSIPATION vs. CASE TEMPERATURE



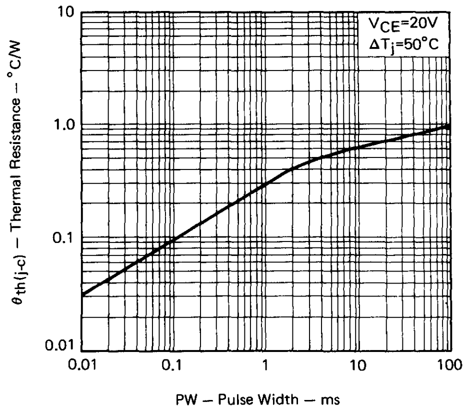
SAFE OPERATING AREAS



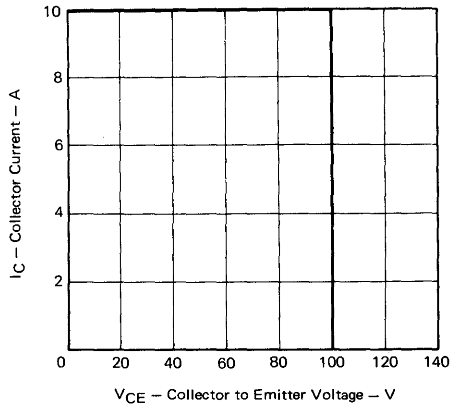
DERATING CURVE OF SAFE OPERATING AREAS



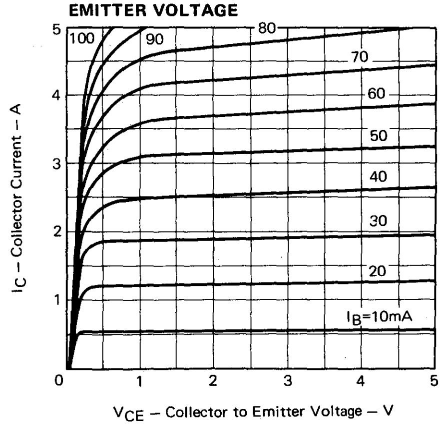
TRANSIENT THERMAL RESISTANCE



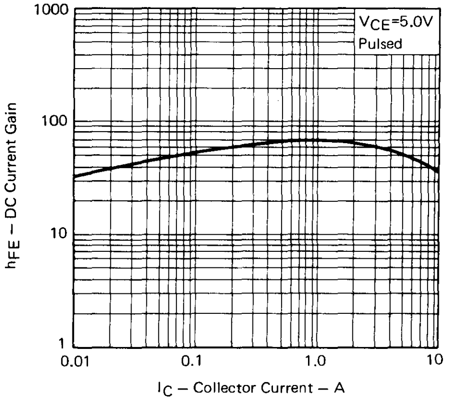
REVERSE BIAS SAFE OPERATING AREAS



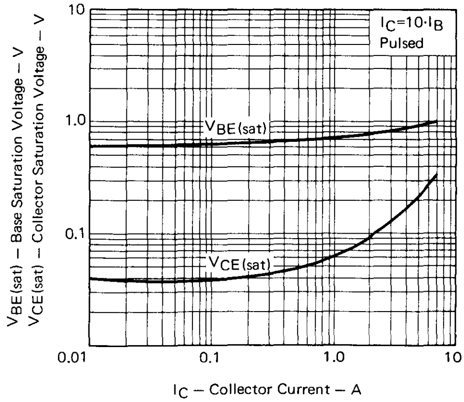
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT

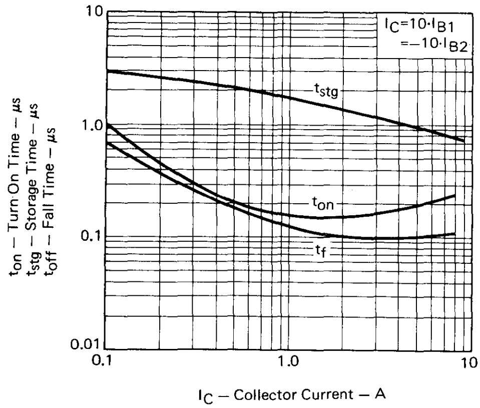


BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

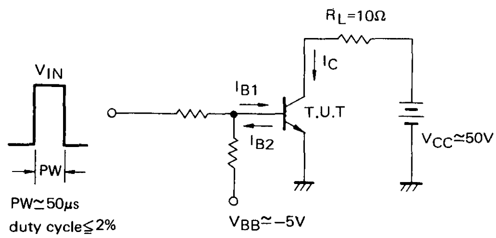


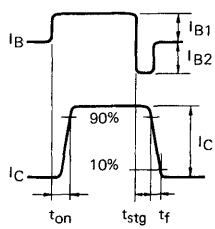
3

TURN ON TIME, STORAGE AND FALL TIME vs. COLLECTOR CURRENT



SWITCHING TIME (t_{on}, t_{stg}, t_f) TEST CIRCUIT





SILICON POWER TRANSISTOR
NTC2335

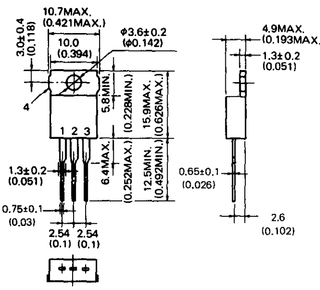
HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON TRIPLE DIFFUSED TRANSISTOR

Industrial Use

DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base (B)
2. Collector (C)
3. Emitter (E)
4. Fin (Collector)

JEDEC: TO-220AB

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased SOA with inductive loads.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta=25°C)

Collector to Emitter Voltage	V_{CEX}	500	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	450	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	7.0	A
Peak Collector Current	$I_{C(pulse)}$ *	15	A
Continuous Base Current	$I_{B(DC)}$	3.5	A

Maximum Power Dissipations

Total Power Dissipation	$P_{T(Tc=25°C)}$	65	W
Total Power Dissipation	$P_{T(Tc=100°C)}$	26	W
Total Power Dissipation	$P_{T(Ta=25°C)}$	2.0	W

Maximum Temperatures

Junction Temperature	Tj	150	°C
Storage Temperature	Tstg	–55 to +150	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C

Thermal Resistances

Junction to Case	$R_{th(j-c)}$	1.92	°C/W
Junction to Ambient	$R_{th(j-a)}$	62.5	°C/W

*Pulsed PW ≦ 300μs, duty cycle ≦ 10%

3

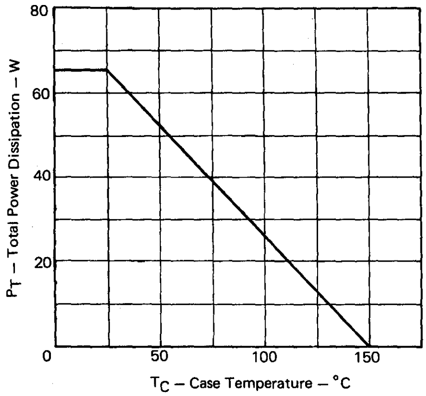
ELECTRICAL CHARACTERISTICS (T_a=25 °C unless otherwise noted.)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400			V	I_C=3A, I_B=0.6A, L=100μH
	$V_{CEX(SUS)1}$	450			V	I_C=3A, I_{B1}=−I_{B2}=0.6A, $V_{BE(OFF)}$=−5V, L=180μH, Ta=125°C *1
	$V_{CEX(SUS)2}$	400			V	I_C=6A, I_{B1}=1.2A, I_{B2}=−0.6A, $V_{BE(OFF)}$=−5V, L=180μH Ta=125°C *2
Collector Cutoff Current	I_{CEX1}			10	μA	V_{CE}=400V, $V_{BE(OFF)}$=−1.5V
	I_{CEX2}			1.0	mA	V_{CE}=400V, $V_{BE(OFF)}$=−1.5V, Ta=125°C
	I_{CER}			1.0	mA	V_{CE}=400V, R_{BE}=100Ω, Ta=125°C
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB}=5.0V, I_C=0
Second Breakdown Collector Current	$I_{S/B}$	1.0			A	V_{CE}=40V, t=1sec, Tc=25°C
Second Breakdown Energy	$E_{S/B}$	180			μJ	I_C=3A, I_{B1}=0.6A, $V_{BE(OFF)}$=−5V, R_{BB}=50Ω, L=40μH
DC Current Gain	h_{FE1}	20				V_{CE}=5V, I_C=1.0A *3
	h_{FE2}	10				V_{CE}=5V, I_C=3A *3
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C=3.0A, I_B=0.6A *3
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	
Gain Bandwidth Product	f_T	10			MHz	V_{CE}=10V, I_C=0.2A, f=3MHz
Output Capacitance	Cob			150	pF	V_{CB}=10V, I_E=0, f=1MHz
Turn On Time	t_{on}			1.0	μs	I_C=3A, I_{B1}=−I_{B2}=0.6A $V_{BE(OFF)}$=−5V, R_L=50Ω
Storage Time	tstg			2.5	μs	
Fall Time	tf			0.7	μs	

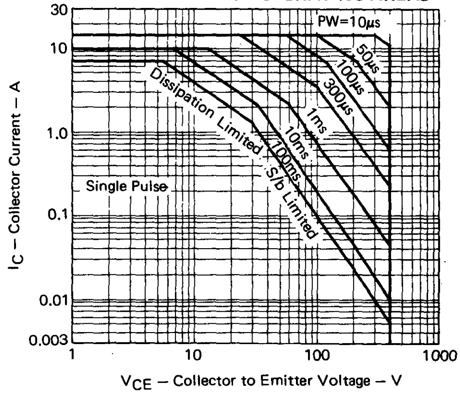
*1 V_{CE} clamped Vclamp = 450V
*2 V_{CE} clamped Vclamp = 400V
*3 Pulsed PW ≦ 350μs, duty cycle ≦ 2%

TYPICAL CHARACTERISTICS (Ta=25°C)

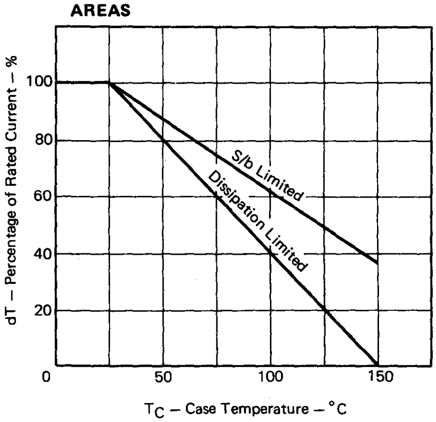
TOTAL POWER DISSIPATION vs. CASE TEMPERATURE



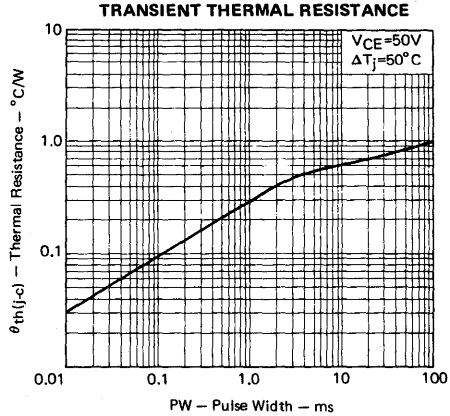
FORWARD BIAS SAFE OPERATING AREAS



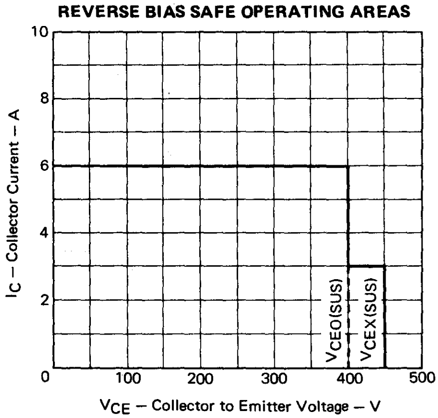
DERATING CURVE OF SAFE OPERATING AREAS



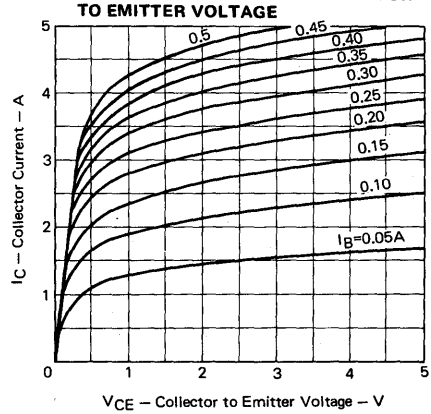
TRANSIENT THERMAL RESISTANCE



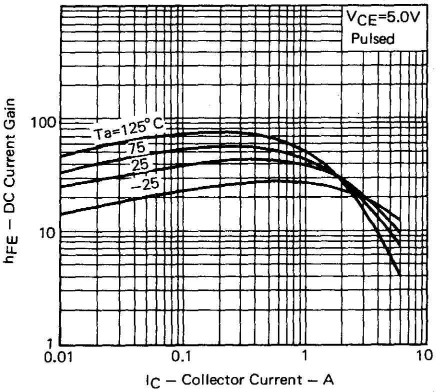
REVERSE BIAS SAFE OPERATING AREAS



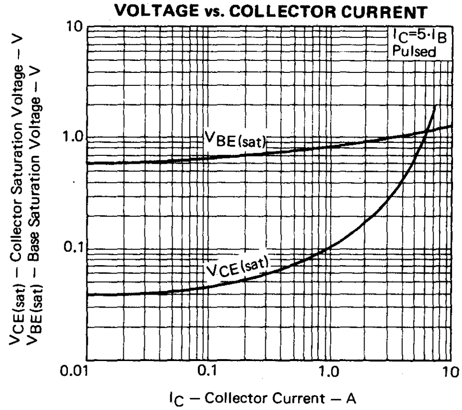
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



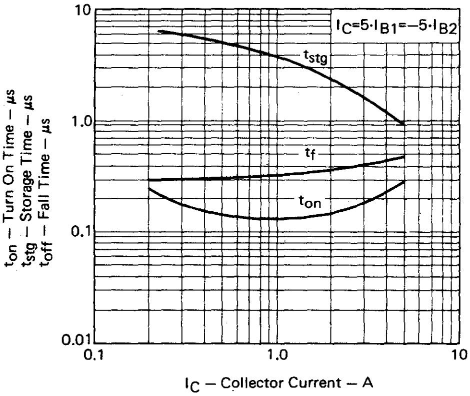
DC CURRENT GAIN vs. COLLECTOR CURRENT



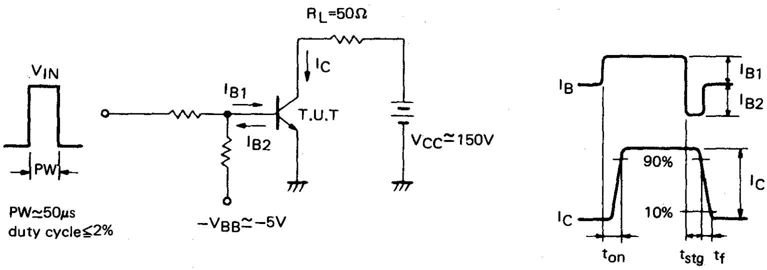
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT



SWITCHING TIME (t_{on}, t_{stg}, t_f) TEST CIRCUIT



NEC
ELECTRON DEVICE

SILICON POWER TRANSISTORS
NTC2516, NTC2516A

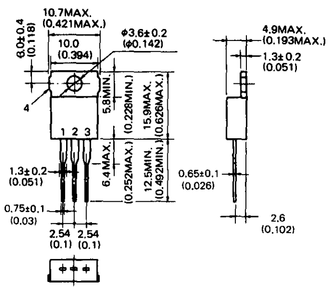
HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON EPITAXIAL TRANSISTOR

Industrial Use

DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base (B)
2. Collector (C)
3. Emitter (E)
4. Fin (Collector)

JEDEC: TO-220AB

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased SOA with inductive loads.

ABSOLUTE MAXIMUM RATINGS

		NTC2516	NTC2516A	
Maximum Voltages and Currents (Ta=25°C)				
Collector to Emitter Voltage	V_{CEX}	150	150	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	60	80	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	150	150	V
Emitter to Base Voltage	V_{EBO}	12	12	V
Continuous Collector Current	$I_{C(DC)}$	5.0	5.0	A
Peak Collector Current	$I_{C(pulse)}$ *	10	10	A
Continuous Base Current	$I_{B(DC)}$	2.5	2.5	A
Maximum Power Dissipations				
Total Power Dissipation	P_T(Tc=25°C)	50	50	W
Total Power Dissipation	P_T(Ta=25°C)	2.0	2.0	W
Maximum Temperatures				
Junction Temperature	Tj	150		°C
Storage Temperature	Tstg	−55 to +150		°C
Lead Temperature				
1/8 inch from case for 10 seconds	T_L	260		°C
Thermal Resistances				
Junction to Case	Rth(j-c)	2.5		°C/W
Junction to Ambient	Rth(j-a)	62.5		°C/W

* Pulsed PW ≤ 300 μs, duty cycle ≤ 10%

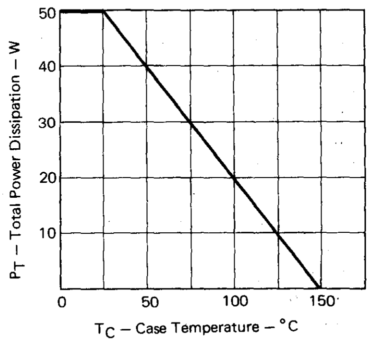
ELECTRICAL CHARACTERISTICS (Ta=25°C unless otherwise noted.) NTC2516/NTC2516A

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	60/80			V	I_C=3.0A, I_B=0.3A, L=1mH
	$V_{CEX(SUS)1}$	150			V	I_C=3.0A, I_{B1}=$-I_{B2}$=0.3A, $V_{BE(OFF)}$=$-$5V, L=180μH Ta=125°C *1
	$V_{CEX(SUS)2}$	60/80			V	I_C=6.0A, I_{B1}=0.6A, I_{B2}=$-$0.3A, $V_{BE(OFF)}$=$-$5V, L=180μH *2 Ta=125°C
Collector Cutoff Current	I_{CEX1}			10	μA	V_{CE}=60/80V, $V_{BE(OFF)}$=$-$1.5V
	I_{CEX2}			1.0	mA	V_{CE}=60/80V, $V_{BE(OFF)}$=$-$1.5V Ta=125°C
	I_{CER}			1.0	mA	V_{CE}=60/80V, R_{BE}=51Ω, Ta=125°C
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB}=5.0V, I_C=0
Second Breakdown Collector Current	$I_{S/B}$	1.5			A	V_{CE}=20V, t=1sec, Tc=25°C
Second Breakdown Energy	$E_{S/B}$	180			μJ	I_C=3.0A, I_{B1}=0.3A, $V_{BE(OFF)}$=$-$5V, R_{BB}=50Ω, L=40μH
DC Current Gain	h_{FE1}	40				V_{CE}=5.0V, I_C=0.3A *3
	h_{FE2}	40		200		V_{CE}=5.0V, I_C=3.0A, *3
Collector Saturation Voltage	$V_{CE(sat)}$			0.6	V	I_C=3.0A, I_B=0.3A, *3
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	
Gain Bandwidth Product	f_T	20			MHz	V_{CE}=10V, I_C=50mA, f=3MHz
Output Capacitance	Cob			200	pF	V_{CB}=10V, I_E=0, f=1MHz
Turn On Time	ton			0.5	μs	I_C=3.0A, I_{B1}=$-I_{B2}$=0.3A $V_{BE(OFF)}$=$-$5.0V, R_L=27Ω Vcc≈50V
Storage Time	tstg			1.5	μs	
Fall Time	t_f			0.5	μs	

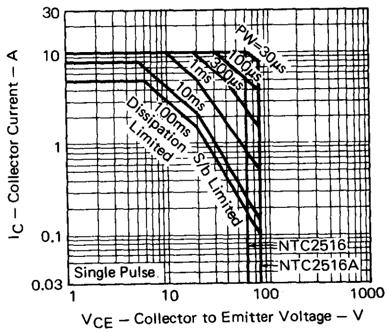
*1 V_{CE} clamped Vclamp = 150V
*2 V_{CE} clamped Vclamp = 60/80V
*3 Pulsed PW ≦ 350μs, duty cycle ≦ 2%

TYPICAL CHARACTERISTICS (Ta=25°C)

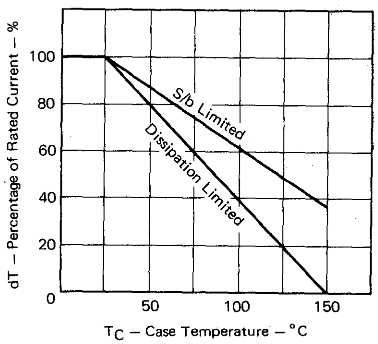
TOTAL POWER DISSIPATION vs. CASE TEMPERATURE



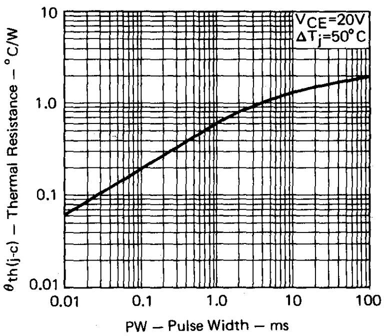
SAFE OPERATING AREA



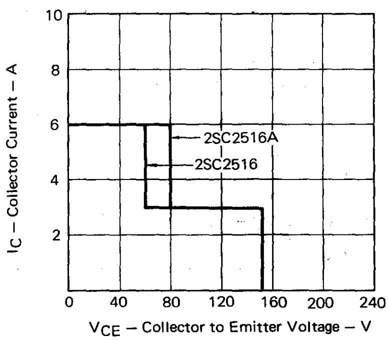
DERATING CURVE OF SAFE OPERATING AREAS



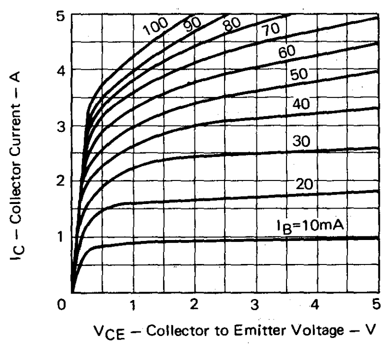
TRANSIENT THERMAL RESISTANCE



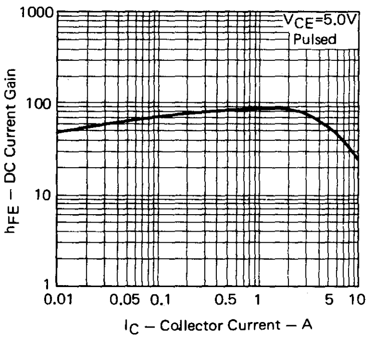
REVERSE BIAS SAFE OPERATING AREAS



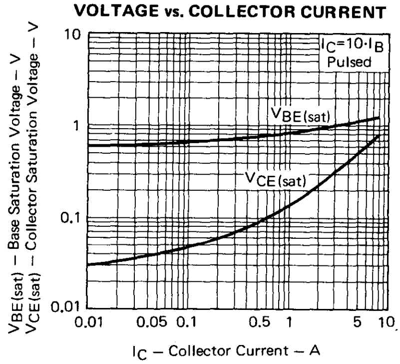
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT

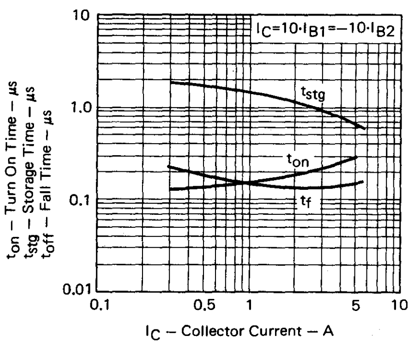


BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

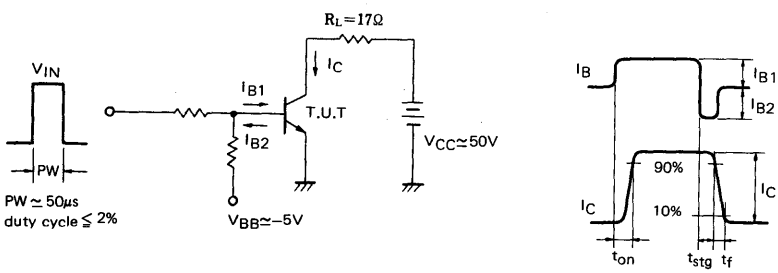


3

TURN ON TIME, STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT



SWITCHING TIME (T_{on}, T_{stg}, t_f) TEST CIRCUIT



NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC2518(V125)

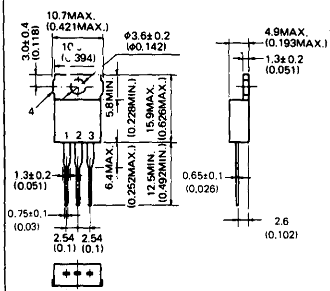
HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON TRIPLE DIFFUSED TRANSISTOR

Industrial Use

DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base (B)
2. Collector (C)
3. Emitter (E)
4. Fin (Collector)

JEDEC: TO-220AB

FEATURES

- High speed, high voltage switching.
- Low collector saturation voltage.
- Specified of reverse biased SOA with inductive loads.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (T_a=25°C)			
Collector to Emitter Voltage	V_{CEX}	500	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	450	V
Emitter to Base Voltage	V_{EBO}	8.0	V
Continuous Collector Current	$I_{C(DC)}$	5.0	A
Peak Collector Current	$I_{C(pulse)}$ *	10	A
Continuous Base Current	$I_{B(DC)}$	2.5	A
Maximum Power Dissipations			
Total Power Dissipation	P_{T}(T_c=25°C)	50	W
Total Power Dissipation	P_{T}(T_a=25°C)	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−55 to +150	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j\text{-}c)}$	2.5	°C/W
Junction to Ambient	$R_{th(j\text{-}a)}$	62.5	°C/W

*Pulsed PW ≦ 300μs, duty cycle ≦ 10%

ELECTRICAL CHARACTERISTICS (Ta=25°C unless otherwise noted.)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400			V	I_C=2.0A, I_B=0.4A, L=100μH
	$V_{CEX(SUS)1}$	450			V	I_C=2.0A, I_{B1}=−I_{B2}=0.4A, $V_{BE(OFF)}$=−5V, L=180μH, Ta=125°C *1
	$V_{CEX(SUS)2}$	400			V	I_C=4.0A, I_{B1}=1.6A, I_{B2}=−0.4A, $V_{BE(OFF)}$=−5V, L=180μH, Ta=125°C *2
Collector Cutoff Current	I_{CEX1}			10	μA	V_{CE}=400V, $V_{BE(OFF)}$=−1.5V
	I_{CEX2}			1.0	mA	V_{CE}=400V, $V_{BE(OFF)}$=−1.5V, Ta=125°C
	I_{CER}			1.0	mA	V_{CE}=400V, R_{BE}=100Ω, Ta=125°C
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB}=5.0V, I_C=0
Second Breakdown Collector Current	$I_{S/B}$	1.0			A	V_{CE}=30V, t=1sec, Tc=25°C
Second Breakdown Energy	$E_{S/B}$	180			μJ	I_C=2.0A, I_{B1}=0.4A, $V_{BE(OFF)}$=−5V, R_{BB}=50Ω, L=40μH
DC Current Gain	h_{FE1}	20				V_{CE}=5V, I_C=0.5A *3
	h_{FE2}	10				V_{CE}=5V, I_C=2.0A *3
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C=2.0A, I_B=0.4A *3
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	
Gain Bandwidth Product	f_T	10			MHz	V_{CE}=10V, I_C=0.2A, f=3MHz
Output Capacitance	Cob			150	pF	V_{CB}=10V, I_E=0, f=1MHz
Turn On Time	t_{on}			1.0	μs	I_C=2.0A, I_{B1}=−I_{B2}=0.4A, V_{CC}≃150V, $V_{BE(OFF)}$=−5V, R_L=75Ω
Storage Time	t_{stg}			2.5	μs	
Fall Time	t_f			1.0	μs	

*1 V_{CE} clamped Vclamp = 450V
*2 V_{CE} clamped Vclamp = 400V
*3 Pulsed PW ≦ 350μs, duty cycle ≦ 2%

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC2749

HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON TRIPLE DIFFUSED TRANSISTOR

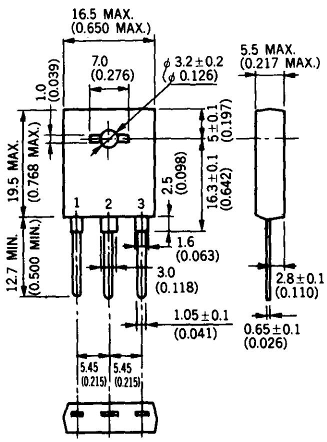
Industrial Use

DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Base
2. Collector (Fin)
3. Emitter

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased S.O.A. with inductive loads.
- Easy assembly (NEC Original Mold Package)

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25 °C)			
Collector to Emitter Voltage	V_{CEX}	500	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	450	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	10	A
Peak Collector Current*	$I_{C(pulse)}$	20	A
Continuous Base Current	$I_{B(DC)}$	5.0	A
Peak Base Current*	$I_{B(pulse)}$	10	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(Tc = 25\,°C)}$	100	W
Total Power Dissipation	$P_{T(Tc = 100\,°C)}$	40	W
Total Power Dissipation	$P_{T(Ta = 25\,°C)}$	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−55 to +150	°C
Lead Temperature 3.18 mm (1/8 inch) from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	1.25	°C/W
Junction to Ambient	$R_{th(j-a)}$	62.5	°C/W

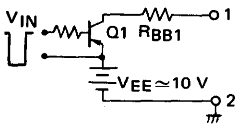
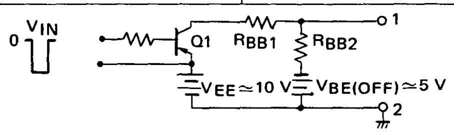
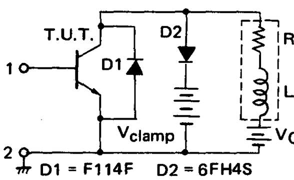
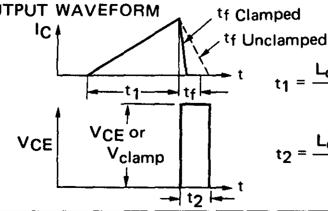
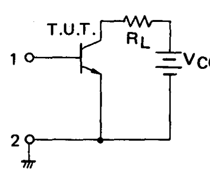
* Pulsed PW ≦ 300 μs, duty cycle ≦ 10 %

ELECTRICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400			V	Table 1. I_C = 6.0 A, I_{B1} = 2 A, L = 100 μH
	$V_{CEX(SUS)1}$	450			V	Table 1. I_C = 6.0 A, I_{B1} = $-I_{B2}$ = 1.2 A, V_{clamp} = Rated V_{CEX}, Ta = 125 °C
	$V_{CEX(SUS)2}$	400			V	Table 1. I_C = 12 A, I_{B1} = 2.4 A, I_{B2} = −1.2 A, V_{clamp} = Rated V_{CEX}, Ta = 125 °C
Collector Cutoff Current	I_{CER}			2.0	mA	V_{CE} = 500 V, R_{BE} = 50 Ω, Ta = 125 °C
	I_{CEX1}			100	μA	V_{CE} = 500 V, $V_{BE(OFF)}$ = −1.5 V
	I_{CEX2}			1.0	mA	V_{CE} = 500 V, $V_{BE(OFF)}$ = −1.5 V, Ta = 125 °C
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB} = 7.0 V, I_C = 0
Second Breakdown Collector Current	$I_{S/B}$	6.0			A	t = 1.0 s, V_{CE} = 16.7 V, T_C = 25 °C
Second Breakdown Energy	$E_{S/B}$	720			μJ	I_C = 6.0 A, I_{B1} = 1.2 A, $V_{BE(OFF)}$ = −5 V
DC Current Gain	h_{FE1}	15		80		V_{CE} = 5 V, I_C = 1 A **
	h_{FE2}	10				V_{CE} = 5 V, I_C = 3 A **
	h_{FE3}	7.0				V_{CE} = 5 V, I_C = 6 A **
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C = 6 A, I_B = 1.2 A **
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	I_C = 6 A, I_B = 1.2 A **
Gain Bandwidth Product	f_T	10			MHz	V_{CE} = 10 V, I_C = 300 mA, f_o = 3.0 MHz, T_C = 25 °C
Output Capacitance	C_{ob}			200	pF	V_{CB} = 10 V, f_o = 1.0 MHz
Turn On Time	t_{on}			1.0	μs	I_C = 6 A, I_{B1} = $-I_{B2}$ = 1.2 A, PW ≃ 50 μs, R_L = 25 Ω, V_{CC} ≈ 150 V
Storage Time	t_{stg}			2.5	μs	
Fall Time	t_f			0.7	μs	

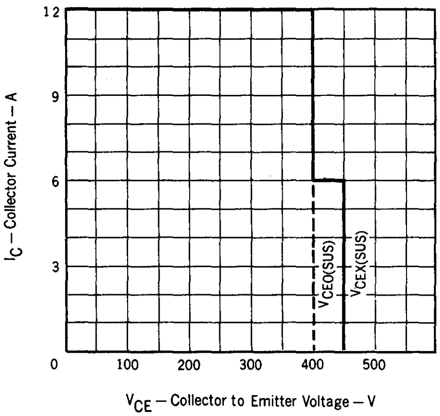
** PW ≦ 350 μs, duty cycle ≦ 2 %

TABLE 1. — TEST CONDITIONS FOR DYNAMIC PERFORMANCE

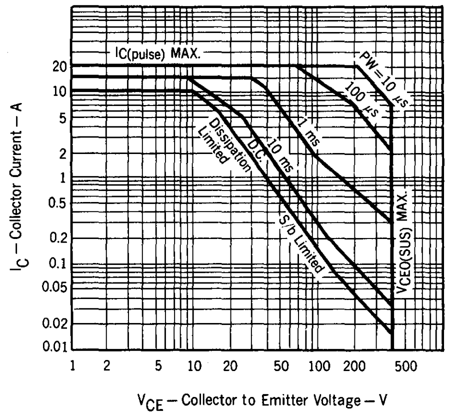
	V_{CEO} (SUS)	V_{CEX} (SUS)	$E_{S/B}$	RESISTIVE SWITCHING
INPUT CONDITIONS	 PW Varied to Attain I_C = 10 A	 PW Varied to Attain I_C = 10 A	duty cycle ≦ 2%	Q_1 = 2SA959
CIRCUIT VALUES	L_{coil} = 100 μH, V_{CC} = 10 V R_{coil} = 0.05 Ω V_{clamp} (Unclamped)	L_{coil} = 180 μH, V_{CC} = 20 V R_{coil} = 0.05 Ω V_{clamp} = Rated V_{CEX} Value	L_{coil} = 40 μH, V_{CC} = 10 V R_{coil} = 0.05 Ω, R_{BB2} = 50 Ω V_{clamp} (Unclamped)	R_L = 25 Ω, V_{CC} ≃ 150 V
TEST CIRCUITS	INDUCTIVE TEST CIRCUIT  D1 = F114F D2 = 6FH4S	OUTPUT WAVEFORM 	t_1 Adjust to Obtain I_C $t_1 = \frac{L_{coil}\,(I_C\,pk)}{V_{CC}}$ $t_2 = \frac{L_{coil}\,(I_C\,pk)}{V_{clamp}}$	RESISTIVE TEST CIRCUIT 

TYPICAL CHARACTERISTICS (Ta = 25 °C)

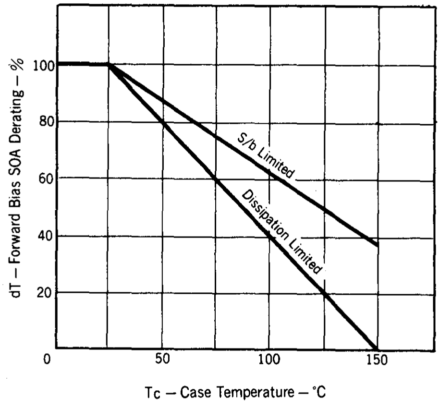
REVERSE BIAS SAFE OPERATING AREA



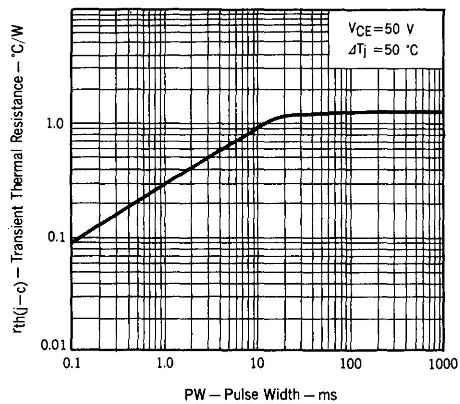
FORWARD BIAS SAFE OPERATING AREAS



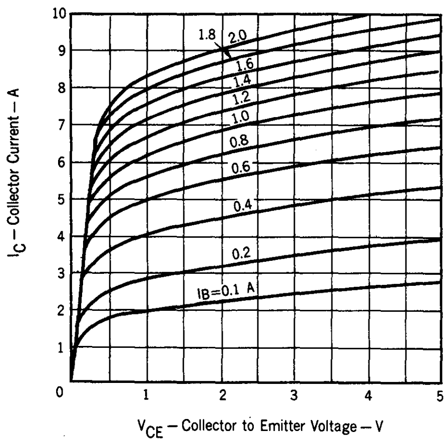
DERATING CURVE OF SAFE OPERATING AREAS



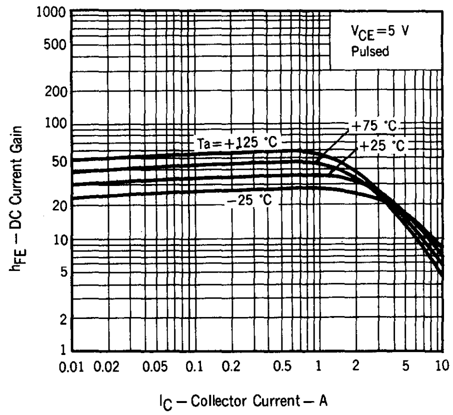
TRANSIENT THERMAL RESISTANCE



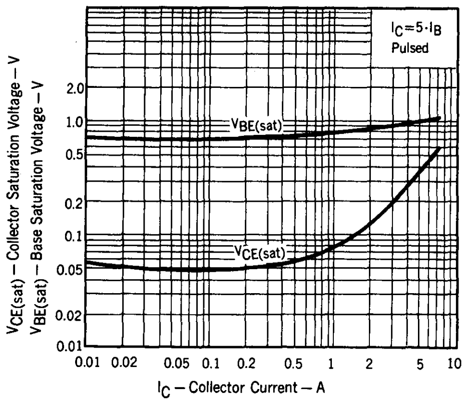
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



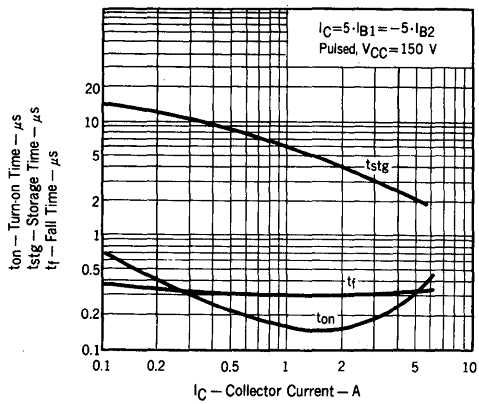
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT



3

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
NTC2908

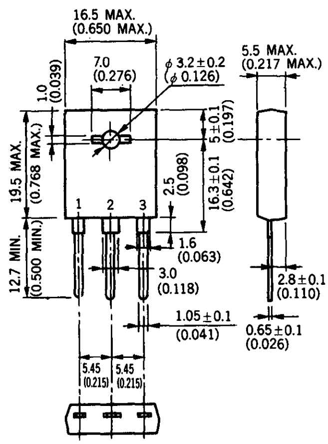
HIGH SPEED HIGH CURRENT SWITCHING
NPN SILICON EPITAXIAL TRANSISTOR

DESCRIPTION

Suitable for switching regulator, DC-DC converter and ultrasonic appliance applications.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Base
2. Collector (Fin)
3. Emitter

FEATURES

- High speed switching.
- Low collector saturation voltage.
- Specified of reverse biased S.O.A. with inductive loads.
- Easy assembly (NEC Original Mold Package)

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25 °C)			
Collector to Emitter Voltage	V_{CEX}	200	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	100	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	150	V
Emitter to Base Voltage	V_{EBO}	12	V
Continuous Collector Current	$I_{C(DC)}$	5.0	A
Peak Collector Current*	$I_{C(pulse)}$	10	A
Continuous Base Current	$I_{B(DC)}$	2.5	A
Peak Base Current*	$I_{B(pulse)}$	5.0	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(Tc = 25\,°C)}$	50	W
Total Power Dissipation	$P_{T(Tc = 100\,°C)}$	20	W
Total Power Dissipation	$P_{T(Ta = 25\,°C)}$	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−55 to +150	°C
Lead Temperature 3.18 mm (1/8 inch) from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	2.5	°C/W
Junction to Ambient	$R_{th(j-a)}$	62.5	°C/W

* Pulsed PW ≦ 300 μs, duty cycle ≦ 10 %

ELECTRICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	100			V	Table 1. I_C = 3 A, I_{B1} = 0.3 A, L = 1 mH
	$V_{CEX(SUS)1}$	150			V	Table 1. I_C = 3 A, I_{B1} = $-I_{B2}$ = 0.3 A V_{clamp} = Rated V_{CEX}, Ta = 125 °C
	$V_{CEX(SUS)2}$	100			V	Table 1. I_C = 6 A, I_{B1} = 0.6 A, I_{B2} = −0.3 A V_{clamp} = Rated V_{CEX}, Ta = 125 °C
Collector Cutoff Current	I_{CER}			1.0	mA	V_{CE} = 200 V, R_{BE} = 50 Ω, Ta = 125 °C
	I_{CEX1}			10	μA	V_{CE} = 200V, $V_{BE(OFF)}$ = −1.5 V
	I_{CEX2}			500	μA	V_{CE} = 200V, $V_{BE(OFF)}$ = −1.5 V, Ta = 125 °C
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB} = 7.0 V, I_C = 0
Second Breakdown Collector Current	$I_{S/B}$	4.0			A	t = 1.0 s, V_{CE} = 12.5 V, T_C = 25 °C
Second Breakdown Energy	$E_{S/B}$	180			μJ	I_C = 3 A, I_{B1} = 0.3 A, $V_{BE(OFF)}$ = −5 V
DC Current Gain	h_{FE1}	60		320		V_{CE} = 5 V, I_C = 0.3 A **
	h_{FE2}	40				V_{CE} = 5 V, I_C = 3 A **
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C = 3 A, I_B = 0.3 A **
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	I_C = 3 A, I_B = 0.3 A **
Gain Bandwidth Product	f_T	20			MHz	V_{CE} = 10 V, I_C = 300 mA, f_o = 3.0 MHz, Tc = 25 °C
Output Capacitance	C_{ob}			200	pF	V_{CB} = 10 V, f_o = 1.0 MHz
Turn On Time	t_{on}			0.5	μs	I_C = 3.0 A, I_{B1} = $-I_{B2}$ = 0.3 A, PW ≃ 50 μs R_L = 16.7 Ω, V_{CC} ≈ 50 V Resistive Load (Table 1.)
Storage Time	t_{stg}			2.0	μs	
Fall Time	t_f			1.0	μs	

** PW ≦ 350 μs, duty cycle ≦ 2%

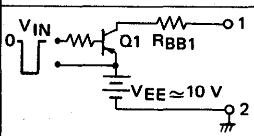
3

TABLE 1. — TEST CONDITIONS FOR DYNAMIC PERFORMANCE

Columns: V_{CEO} (SUS) | V_{CEX} (SUS) | $E_{S/B}$ | RESISTIVE SWITCHING

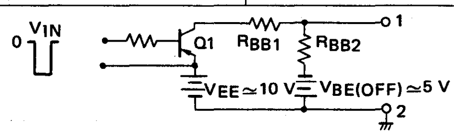
INPUT CONDITIONS

V_{CEO} (SUS):



PW Varied to Attain I_C = 5 A

V_{CEX} (SUS) / $E_{S/B}$ / Resistive switching:



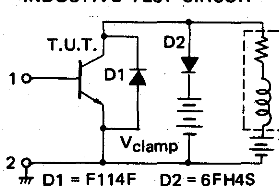
PW Varied to Attain I_C = 5 A duty cycle ≦ 2% Q_1 = NTA959

CIRCUIT VALUES

V_{CEO} (SUS)	V_{CEX} (SUS)	$E_{S/B}$	RESISTIVE SWITCHING
L_{coil} = 1 mH, V_{CC} = 10 V R_{coil} = 0.5 Ω V_{clamp} (Unclamped)	L_{coil} = 180 μH, V_{CC} = 20 V R_{coil} = 0.05 Ω V_{clamp} = Rated V_{CEX} Value	L_{coil} = 40 μH, V_{CC} = 10 V R_{coil} = 0.05 Ω, R_{BB2} = 50 Ω V_{clamp} (Unclamped)	R_L = 16.7 Ω, V_{CC} ≃ 50 V

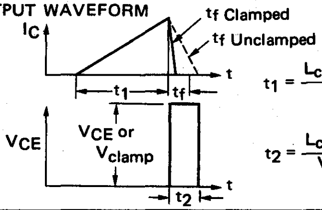
TEST CIRCUITS

INDUCTIVE TEST CIRCUIT



D1 = F114F D2 = 6FH4S

OUTPUT WAVEFORM

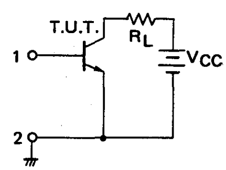


t_1 Adjust to Obtain I_C

$$t_1 = \frac{L_{coil}\,(I_{C\,pk})}{V_{CC}}$$

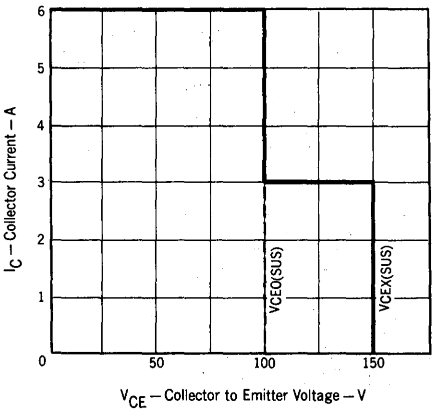
$$t_2 = \frac{L_{coil}\,(I_{C\,pk})}{V_{clamp}}$$

RESISTIVE TEST CIRCUIT

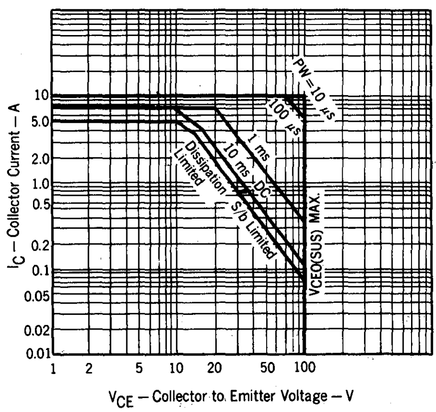


TYPICAL CHARACTERISTICS (Ta = 25 °C)

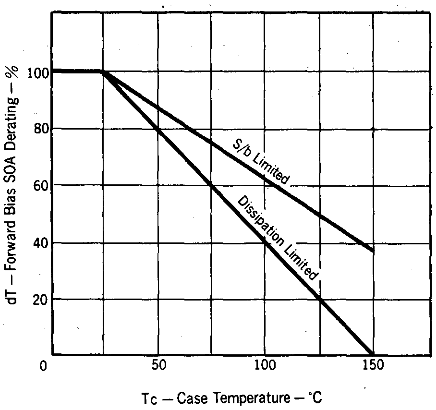
REVERSE BIAS SAFE OPERATING AREA



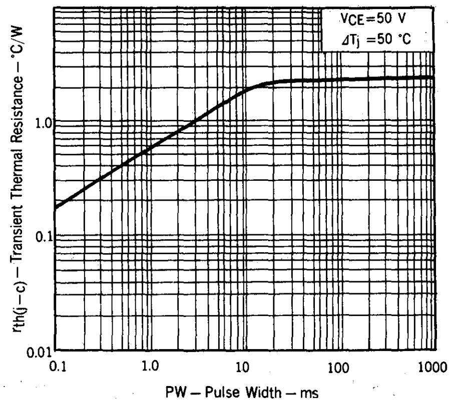
FORWARD BIAS SAFE OPERATING AREAS



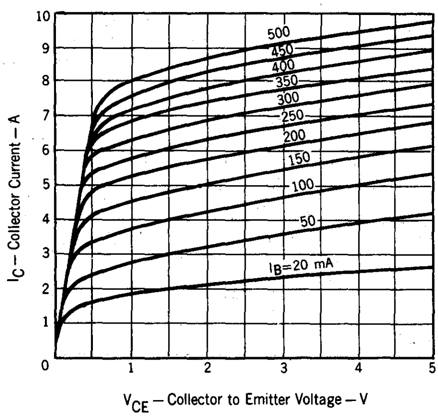
DERATING CURVE OF SAFE OPERATING AREAS



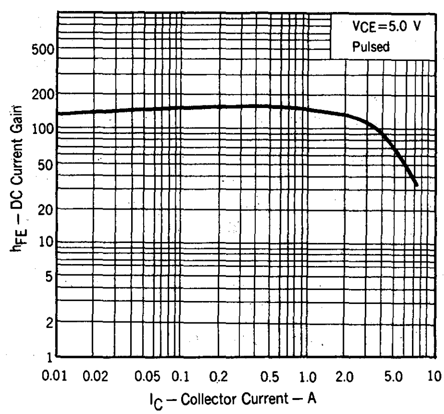
TRANSIENT THERMAL RESISTANCE



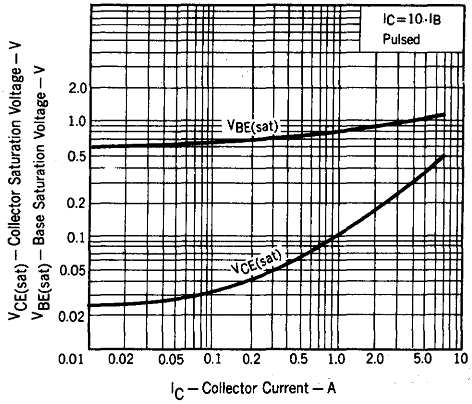
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



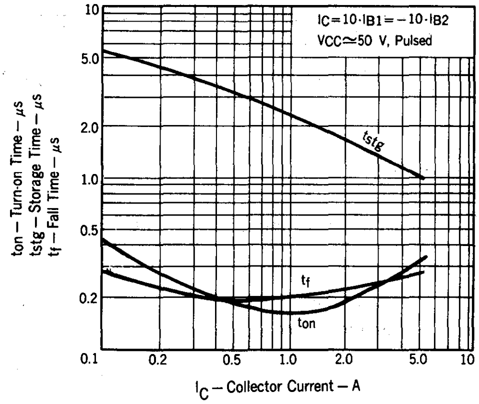
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



TURN ON TIME, STORAGE TIME AND FALL TIME vs. COLLECTOR CURRENT



3

NEC
ELECTRON DEVICE

SILICON DARLINGTON POWER TRANSISTOR
NTD405

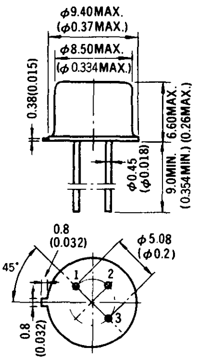
LOW FREQUENCY AMPLIFIER AND LOW SPEED SWITCHING
NPN SILICON EPITAXIAL DARLINGTON TRANSISTOR

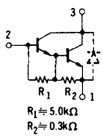
Industrial Use

DESCRIPTION

Suitable for hummer driver, pulse motor driver and relay driver applications.

PACKAGE DIMENSIONS
in millimeters (inches)





1. Emitter
2. Base
3. Collector (Case)

EIAJ :TC-5,TB-5B
JEDEC:TO-205MD (TO-39)
IEC :C4,B4B

FEATURES

- Operates from IC without predriver.
- Low collector saturation voltage.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Base Voltage	V_{CBO}	70	V
Collector to Emitter Voltage	$V_{CER(SUS)}$	70	V
	$V_{CEX(SUS)}$	70	V
	$V_{CEO(SUS)}$	70	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	2.0	A
Peak Collector Current	$I_{C(pulse)}$*	3.0	A
Continuous Base Current	$I_{B(DC)}$	0.2	A
Maximum Power Dissipations			
Total Power Dissipation (Ta = 25°C)	P_T	1.0	W
(Tc = 25°C)	P_T	15	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature 1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Ambient	θ_{Ja}	175	°C/W
Junction to Case	θ_{Jc}	11.7	°C/W

* Pulsed PW ≦ 10 ms, duty cycle ≦ 50%

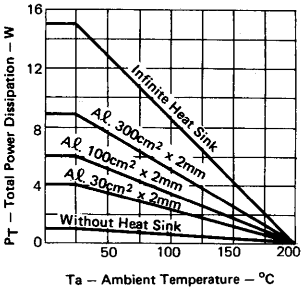
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	70			V	$I_C = 0.2A$, $I_B = 0$
	$V_{CER(SUS)}$	70			V	$I_C = 0.2A$, $R_{BE} = 100\Omega$
	$V_{CEX(SUS)}$	70			V	$I_C = 0.2A$, $I_B = -I_B = 2$ mA
Collector Cutoff Current	I_{CBO}			1.0	μA	$V_{CB} = 50V$, $I_E = 0$
				500	μA	$V_{CB} = 50V$, $I_E = 0$, Tc = 125°C
Collector Cutoff Current	I_{CEO}			10	μA	$V_{CE} = 50V$, $I_B = 0$
Emitter Cutoff Current	I_{EBO}			1.9	mA	$V_{EB} = 5.0V$, $I_C = 0$
DC Current Gain	h_{FE}	2000	4000	12000		$V_{CE} = 2.0V$, $I_C = 1.0A$ *
		2000				$V_{CE} = 2.0V$, $I_C = 2.0A$ *
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	$I_C = 1.0A$, $I_B = 1.0$ mA *
Base Saturation Voltage	$V_{BE(sat)}$			2.0	V	

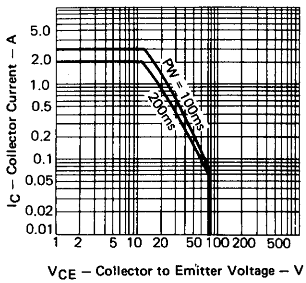
* Pulsed PW ≦ 350 μs, duty cycle ≦ 2%

TYPICAL CHARACTERISTICS (Ta = 25°C)

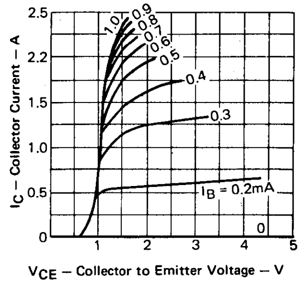
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



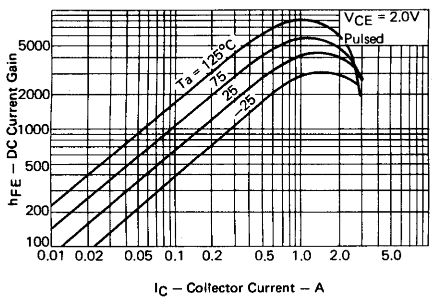
SAFE OPERATING AREA



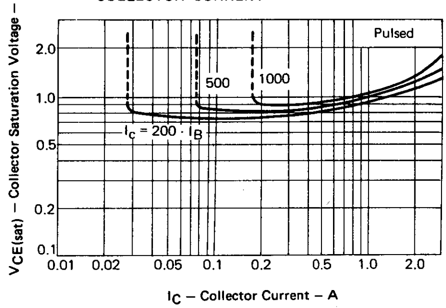
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



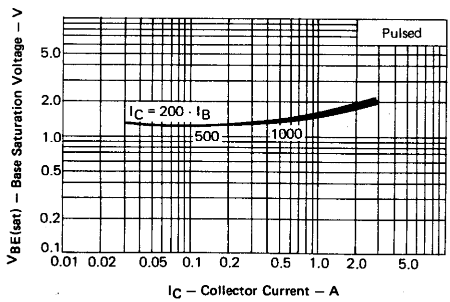
DC CURRENT GAIN vs. COLLECTOR CURRENT



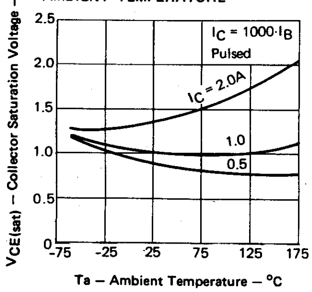
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



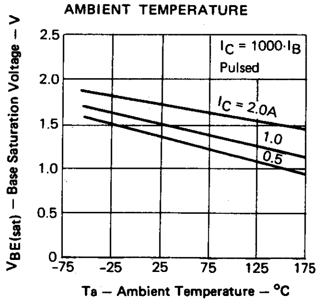
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



COLLECTOR SATURATION VOLTAGE vs. AMBIENT TEMPERATURE



BASE SATURATION VOLTAGE vs. AMBIENT TEMPERATURE



NEC
ELECTRON DEVICE

SILICON DARLINGTON POWER TRANSISTOR
NTD406

LOW FREQUENCY AMPLIFIER AND LOW SPEED SWITCHING NPN SILICON EPITAXIAL DARLINGTON TRANSISTOR

Industrial Use

DESCRIPTION

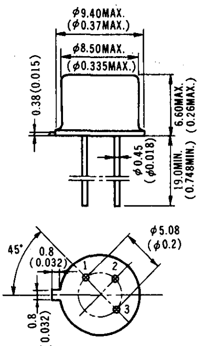
Suitable for hummer driver, pulse motor driver and relay driver applications.

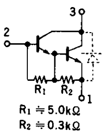
FEATURES

- Operates from IC without predriver.
- Low collector saturation voltage.

PACKAGE DIMENSIONS

in millimeters (inches)





1. Emitter
2. Base
3. Collector (Case)

EIAJ : TC-5, TB-5B
JEDEC : TO-205MD (TO-39)
IEC : C4, B4B

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Base Voltage	V_{CBO}	100	V
Collector to Emitter Voltage	$V_{CER(sus)}$	100	V
	$V_{CEX(sus)}$	100	V
	$V_{CEO(sus)}$	100	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	2.0	A
Peak Collector Current	$I_{C(pulse)}$*	3.0	A
Continuous Base Current	$I_{B(DC)}$	0.2	A
Maximum Power Dissipation			
Total Power Dissipation (Ta = 25°C)	P_T	1.0	W
(Tc = 25°C)	P_T	15	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistance			
Junction to Ambient	$R_{th(j-a)}$	175	°C/W
Junction to Case	$R_{th(j-c)}$	11.7	°C/W

* Pulsed PW ≦ 10 ms, duty cycle ≦ 50%

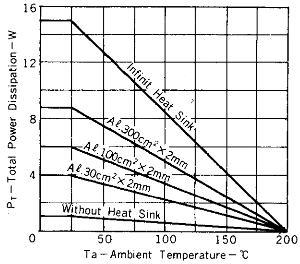
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(sus)}$	100			V	I_C=0.2A, I_B=0
	$V_{CER(sus)}$	100			V	I_C=0.2A, R_{BE}=100Ω
	$V_{CEX(sus)}$	100			V	I_C=0.2A, I_B=$-I_B$=2mA
Collector Cutoff Current	I_{CBO}			1.0	μA	V_{CB}=70V, I_E=0
				100	μA	V_{CB}=70V, I_E=0, T_C=125°C
Collector Cutoff Current	I_{CEO}			10	μA	V_{CE}=70V, I_B=0
Emitter Cutoff Current	I_{EBO}	0.63		1.9	mA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE}	2000	4000	12000		V_{CE}=2.0V, I_C=1.0A*
		2000				V_{CE}=2.0V, I_C=2.0A*
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	I_C=1.0A, I_B=1.0mA*
Base Saturation Voltage	$V_{BE(sat)}$			2.0	V	

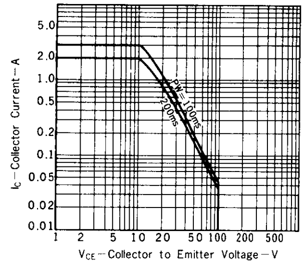
* Pulsed PW ≦ 350 μs, duty cycle ≦ 2%

TYPICAL CHARACTERISTICS (Ta = 25°C)

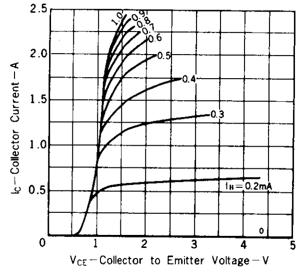
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



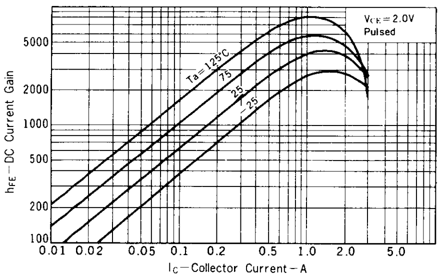
SAFE OPERATING AREA



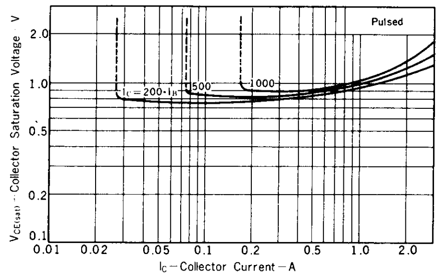
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



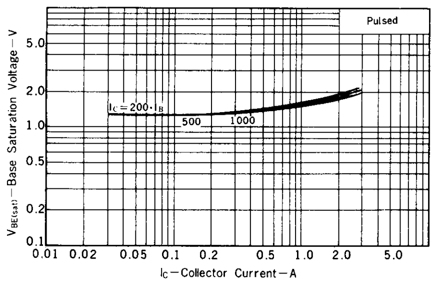
DC CURRENT GAIN vs. COLLECTOR CURRENT



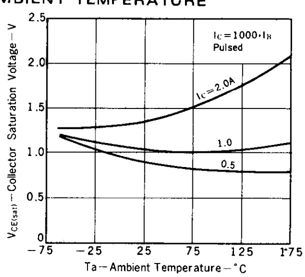
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



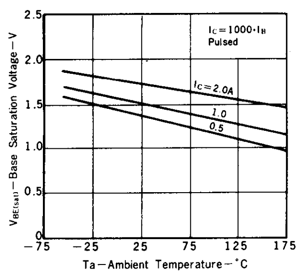
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



COLLECTOR SATURATION VOLTAGE vs. AMBIENT TEMPERATURE



BASE SATURATION VOLTAGE vs. AMBIENT TEMPERATURE



NEC
ELECTRON DEVICE

SILICON DARLINGTON POWER TRANSISTOR
NTD407

LOW FREQUENCY AMPLIFIER AND LOW SPEED SWITCHING NPN SILICON EPITAXIAL MESA DARLINGTON TRANSISTOR

Industrial Use

DESCRIPTION

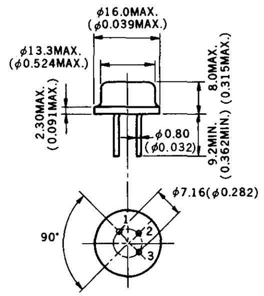
Suitable for hummer driver, pulse motor driver and relay driver applications.

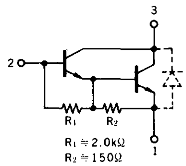
FEATURES

- Operates from IC without predriver.
- Low collector saturation voltage.

PACKAGE DIMENSIONS

in millimeters (inches)





1. Emiter
2. Base
3. Collector (Case)

EIAJ : TC-6, TB-7
JEDEC : TO-8
IEC : C8, B13

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Base Voltage	V_{CBO}	100	V
Collector to Emitter Voltage	$V_{CER(sus)}$	100	V
	$V_{CEX(sus)}$	100	V
	$V_{CEO(sus)}$	100	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	5.0	A
Peak Collector Current	$I_{C(pulse)}$*	8.0	A
Continuous Base Current	$I_{B(DC)}$	0.5	A
Maximum Power Dissipation			
Total Power Dissipation (Ta = 25°C)	P_T	2.0	W
(Tc = 25°C)	P_T	30	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistance			
Junction to Ambient	$R_{th(j-a)}$	87.5	°C/W
Junction to Case	$R_{th(j-c)}$	5.8	°C/W

* Pulsed PW ≦10 ms, duty cycle ≦50%

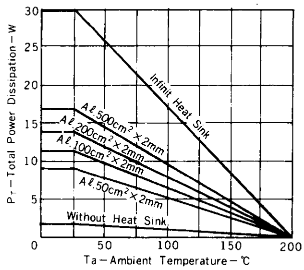
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(sus)}$	100			V	I_C=0.2A, I_B=0
	$V_{CER(sus)}$	100			V	I_C=0.2A, R_{BE}=100Ω
	$V_{CEX(sus)}$	100			V	I_C=0.2A, I_B=$-I_B$=20mA
Collector Cutoff Current	I_{CBO}			10	μA	V_{CB}=80V, I_E=0
				500	μA	V_{CB}=80V, I_E=0, T_C=125°C
Collector Cutoff Current	I_{CEO}			100	μA	V_{CE}=50V, I_B=0
Emitter Cutoff Current	I_{EBO}	1.6		2.3	mA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE}	1500	4000	12000		V_{CE}=2.0V, I_C=5.0A*
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	I_C=5.0A, I_B=5.0mA*
Base Saturation Voltage	$V_{BE(sat)}$			2.0	V	

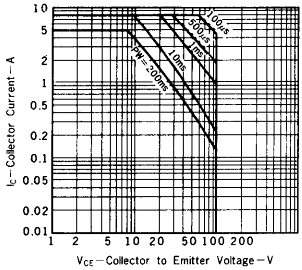
* Pulsed PW ≦ 350 μs, duty cycle ≦2%

TYPICAL CHARACTERISTICS (Ta = 25°C)

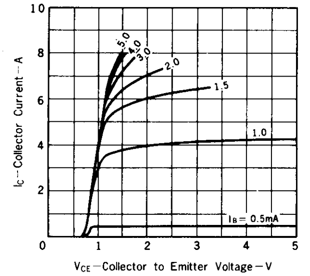
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



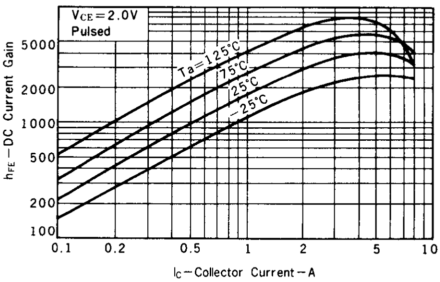
SAFE OPERATING AREA



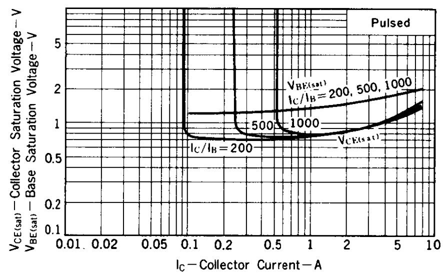
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



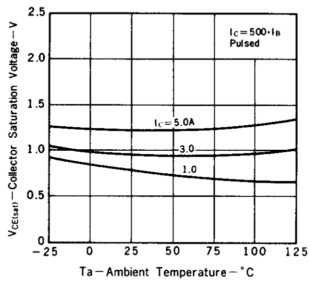
DC CURRENT GAIN vs. COLLECTOR CURRENT



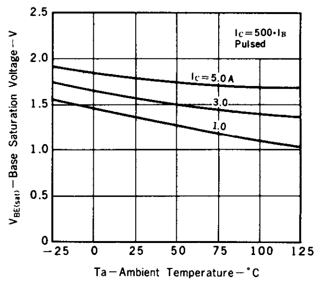
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



COLLECTOR SATURATION VOLTAGE vs. AMBIENT TEMPERATURE



BASE SATURATION VOLTAGE vs. AMBIENT TEMPERATURE



NEC
ELECTRON DEVICE

SILICON DARLINGTON POWER TRANSISTOR
NTD408

LOW FREQUENCY AMPLIFIER AND LOW SPEED SWITCHING NPN SILICON EPITAXIAL MESA DARLINGTON TRANSISTOR

Industrial Use

DESCRIPTION

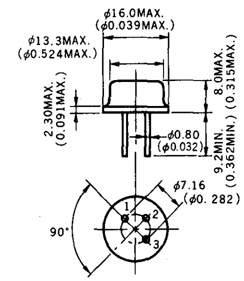
Suitable for hummer driver, pulse motor driver and relay driver applications.

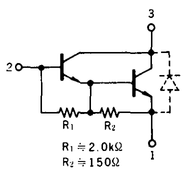
FEATURES

- Operates from IC without predriver.
- Low collector saturation voltage.

PACKAGE DIMENSIONS

in millimeters (inches)





1. Emitter
2. Base
3. Collector (Case)

EIAJ : TC-6, TB-7
JEDEC : TO-8
IEC : C8, B13

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Base Voltage	V_{CBO}	150	V
Collector to Emitter Voltage	$V_{CER(sus)}$	150	V
	$V_{CEX(sus)}$	150	V
	$V_{CEO(sus)}$	150	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	5.0	A
Peak Collector Current	$I_{C(pulse)}$*	8.0	A
Continuous Base Current	$I_{B(DC)}$	0.5	A
Maximum Power Dissipation			
Total Power Dissipation (Ta = 25°C)	P_T	2.0	W
(Tc = 25°C)	P_T	30	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistance			
Junction to Ambient	$R_{th(j-a)}$	87.5	°C/W
Junction to Case	$R_{th(j-c)}$	5.8	°C/W

* Pulsed PW ≦ 10 ms, duty cycle ≦ 50%

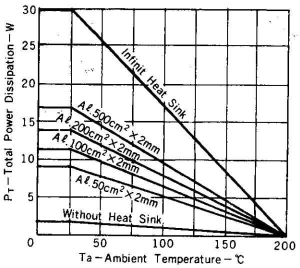
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(sus)}$	150			V	I_C=0.2A, I_B=0
	$V_{CER(sus)}$	150			V	I_C=0.2A, R_{BE}=100Ω
	$V_{CEX(sus)}$	150			V	I_C=0.2A, I_B=$-I_B$=20mA
Collector Cutoff Current	I_{CBO}			10	μA	V_{CB}=100V, I_E=0
				500	μA	V_{CB}=100V, I_E=0, T_C=125°C
Collector Cutoff Current	I_{CEO}			100	μA	V_{CE}=75V, I_B=0
Emitter Cutoff Current	I_{EBO}	1.6		2.3	mA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE}	1500	3000	12000		V_{CE}=2.0V, I_C=5.0A*
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	I_C=5.0A, I_B=5.0mA*
Base Saturation Voltage	$V_{BE(sat)}$			2.0	V	

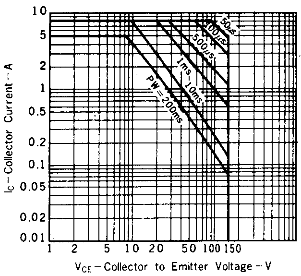
* Pulsed PW ≦ 350 μs, duty cycle ≦ 50%

TYPICAL CHARACTERISTICS (Ta = 25°C)

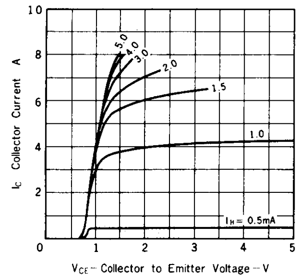
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



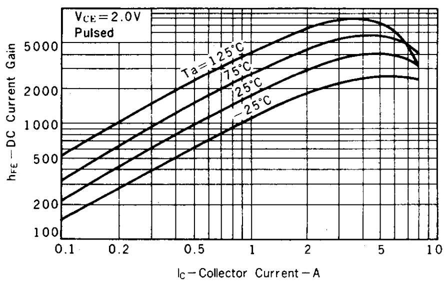
SAFE OPERATING AREA



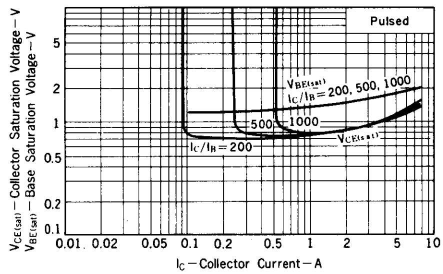
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



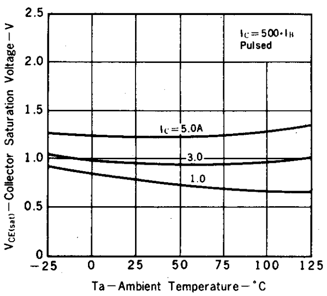
DC CURRENT GAIN vs. COLLECTOR CURRENT



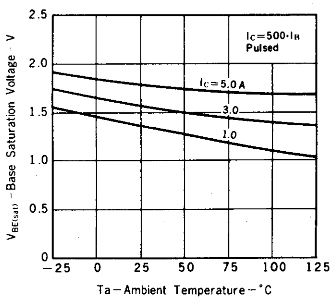
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



COLLECTOR SATURATION VOLTAGE vs. AMBIENT TEMPERATURE



BASE SATURATION VOLTAGE vs. AMBIENT TEMPERATURE



3

NEC
ELECTRON DEVICE

SILICON DARLINGTON POWER TRANSISTOR
NTD409

LOW FREQUENCY AMPLIFIER AND LOW SPEED SWITCHING NPN SILICON EPITAXIAL MESA DARLINGTON TRANSISTOR

Industrial Use

DESCRIPTION

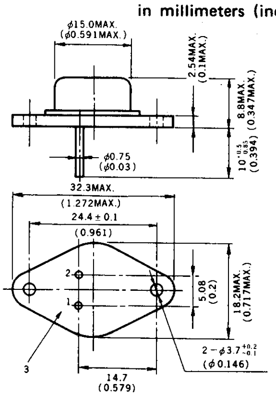
Suitable for hummer driver, pulse motor driver and relay driver applications.

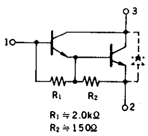
FEATURES

- Operates from IC without predriver.
- Low collector saturation voltage.

PACKAGE DIMENSIONS

in millimeters (inches)





1. Base
2. Emitter
3. Collector (Case)

EIAJ : TC-16, TB-23
JEDEC : TO-66
IEC : C13

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Base Voltage	V_{CBO}	100	V
Collector to Emitter Voltage	$V_{CER(sus)}$	100	V
	$V_{CEX(sus)}$	100	V
	$V_{CEO(sus)}$	100	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	5.0	A
Peak Collector Current	$I_{C(pulse)}$*	8.0	A
Continuous Base Current	$I_{B(DC)}$	0.5	A
Maximum Power Dissipation			
Total Power Dissipation (Ta = 25°C)	P_T	2.0	W
(Tc = 25°C)	P_T	40	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistance			
Junction to Ambient	$R_{th(j-a)}$	87.5	°C/W
Junction to Case	$R_{th(j-c)}$	4.4	°C/W

* Pulsed PW ≦ 10 ms, duty cycle ≦ 50%.

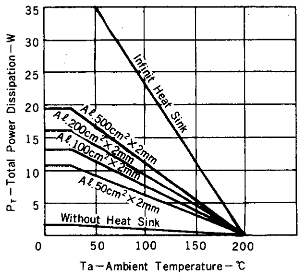
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(sus)}$	100			V	I_C=0.2A, I_B=0
	$V_{CER(sus)}$	100			V	I_C=0.2A, R_{BE}=100Ω
	$V_{CEX(sus)}$	100			V	I_C=0.2A, I_B=$-I_B$=20mA
Collector Cutoff Current	I_{CBO}			10	μA	V_{CB}=80V, I_E=0
				500	μA	V_{CB}=80V, I_E=0, T_C=125°C
Collector Cutoff Current	I_{CEO}			100	μA	V_{CE}=50V, I_B=0
Emitter Cutoff Current	I_{EBO}	1.6		2.3	mA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE}	1500	4000	12000		V_{CE}=2.0V, I_C=5.0A*
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	I_C=5.0A, I_B=5.0mA*
Base Saturation Voltage	$V_{BE(sat)}$			2.0	V	

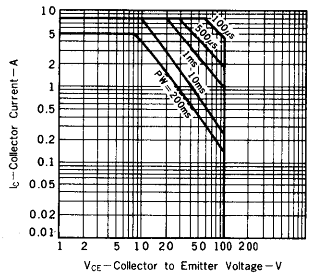
* Pulsed PW ≦ 350 μs, duty cycle ≦ 2%

TYPICAL CHARACTERISTICS (Ta = 25°C)

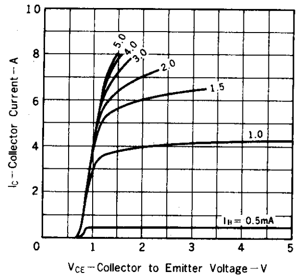
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



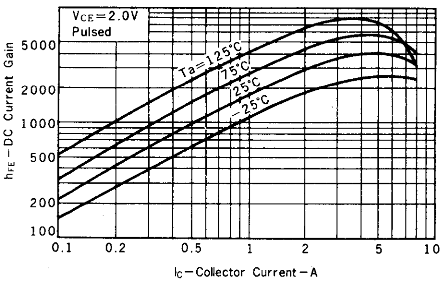
SAFE OPERATING AREA



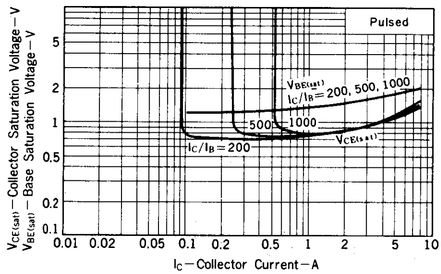
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



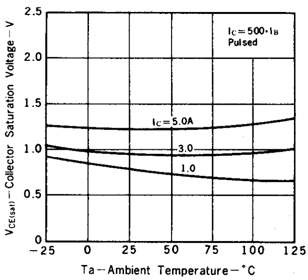
DC CURRENT GAIN vs. COLLECTOR CURRENT



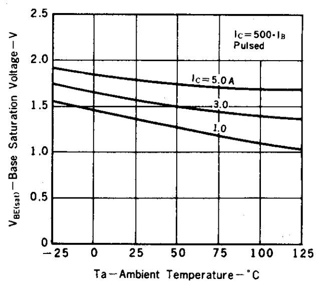
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



COLLECTOR SATURATION VOLTAGE vs. AMBIENT TEMPERATURE



BASE SATURATION VOLTAGE vs. AMBIENT TEMPERATURE



3

NEC
ELECTRON DEVICE

SILICON DARLINGTON POWER TRANSISTOR

NTD410

LOW FREQUENCY AMPLIFIER AND LOW SPEED SWITCHING NPN SILICON EPITAXIAL MESA DARLINGTON TRANSISTOR

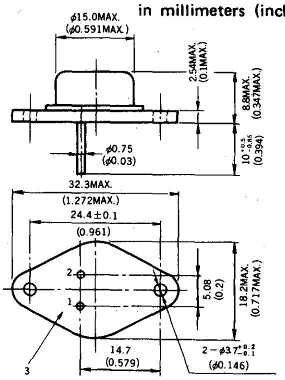
Industrial Use

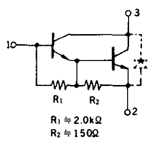
DESCRIPTION

Suitable for hummer driver, pulse motor driver and relay driver applications.

PACKAGE DIMENSIONS

in millimeters (inches)





1. Base
2. Emitter
3. Collector (Case)

EIAJ : TC-16, TB-23
JEDEC : TO-66
IEC : C13

FEATURES

- Operates from IC without predriver.
- Low collector saturation voltage.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (T_a = 25°C)			
Collector to Base Voltage	V_{CBO}	150	V
Collector to Emitter Voltage	$V_{CER(sus)}$	150	V
	$V_{CEX(sus)}$	150	V
	$V_{CEO(sus)}$	150	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	5.0	A
Peak Collector Current	$I_{C(pulse)}$*	8.0	A
Continuous Base Current	$I_{B(DC)}$	0.5	A
Maximum Power Dissipation			
Total Power Dissipation (T_a = 25°C)	P_T	2.0	W
(T_c = 25°C)	P_T	40	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistance			
Junction to Ambient	$R_{th(j-a)}$	87.5	°C/W
Junction to Case	$R_{th(j-c)}$	4.4	°C/W

* Pulsed PW ≦10 ms, duty cycle ≦50%.

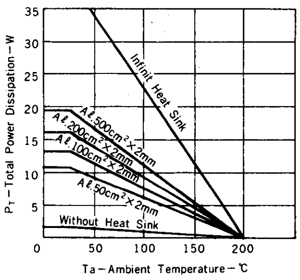
ELECTRICAL CHARACTERISTICS (T_a = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(sus)}$	150			V	I_C=0.2A, I_B=0
	$V_{CER(sus)}$	150			V	I_C=0.2A, R_{BE}=100Ω
	$V_{CEX(sus)}$	150			V	I_C=0.2A, I_B=$-I_B$=20mA
Collector Cutoff Current	I_{CBO}			10	μA	V_{CB}=100V, I_E=0
				500	μA	V_{CB}=100V, I_E=0, T_C=125°C
Collector Cutoff Current	I_{CEO}			100	μA	V_{CE}=75V, I_B=0
Emitter Cutoff Current	I_{EBO}	1.6		2.3	mA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE}	1500	3000	12000		V_{CE}=2.0V, I_C=5.0A*
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	I_C=5.0A, I_B=5.0mA*
Base Saturation Voltage	$V_{BE(sat)}$			2.0	V	

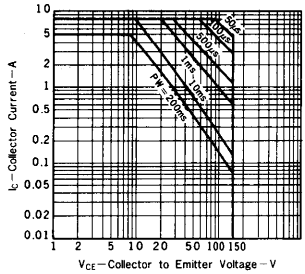
* Pulsed PW ≦350 μs, duty cycle ≦2%

TYPICAL CHARACTERISTICS (Ta = 25°C)

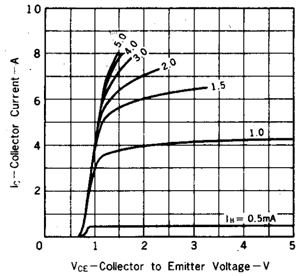
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



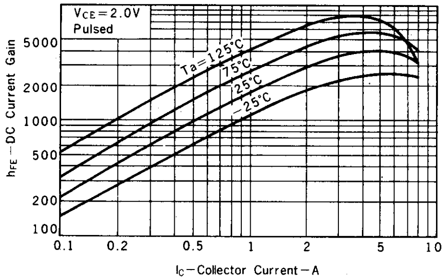
SAFE OPERATING AREA



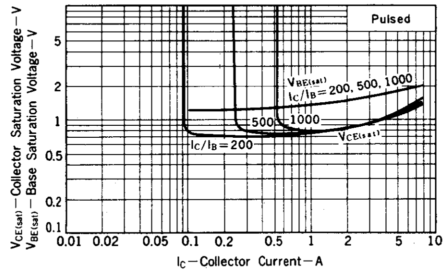
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



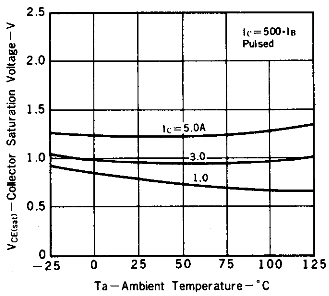
DC CURRENT GAIN vs. COLLECTOR CURRENT



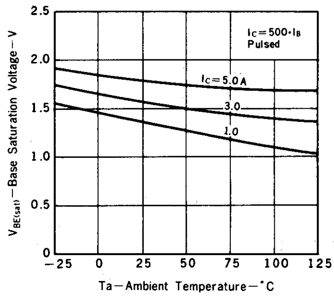
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



COLLECTOR SATURATION VOLTAGE vs. AMBIENT TEMPERATURE



BASE SATURATION VOLTAGE vs. AMBIENT TEMPERATURE



NEC
ELECTRON DEVICE

SILICON DARLINGTON POWER TRANSISTOR
NTD411

LOW FREQUENCY AMPLIFIER AND LOW SPEED SWITCHING NPN SILICON EPITAXIAL MESA DARLINGTON TRANSISTOR

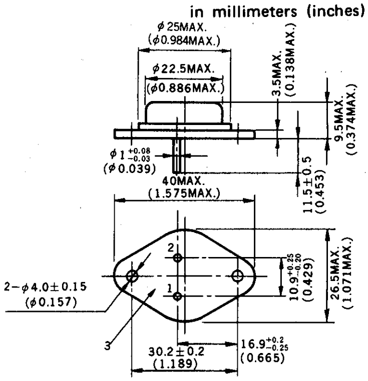
Industrial Use

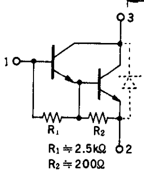
DESCRIPTION

Suitable for hummer driver, pulse motor driver and relay driver applications.

PACKAGE DIMENSIONS

in millimeters (inches)





1. Base
2. Emitter
3. Collector (Case)

EIAJ : TC-3, TB-3
JEDEC : TO-3
IEC : C14A, B18

FEATURES

- Operates from IC without predriver.
- Low collector saturation voltage.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Base Voltage	V_{CBO}	100	V
Collector to Emitter Voltage	$V_{CER(sus)}$	80	V
	$V_{CEX(sus)}$	80	V
	$V_{CEO(sus)}$	80	V
Emitter to Base Voltage	V_{EBO}	8.0	V
Continuous Collector Current	$I_{C(DC)}$	10	A
Peak Collector Current	$I_{C(pulse)}$*	15	A
Continuous Base Current	$I_{B(DC)}$	1.0	A
Maximum Power Dissipation			
Total Power Dissipation (Ta = 25°C)	P_T	5	W
(Tc = 25°C)	P_T	100	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistance			
Junction to Ambient	$R_{th(j-a)}$	35	°C/W
Junction to Case	$R_{th(j-c)}$	1.75	°C/W

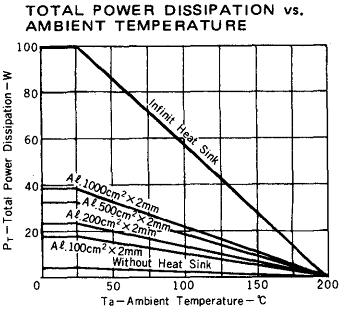
* Pulsed PW ≦ 10 ms, duty cycle ≦ 50%

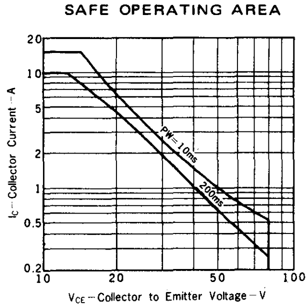
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

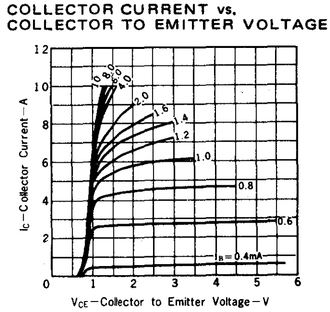
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(sus)}$	80			V	I_C=0.2A, I_B=0
	$V_{CER(sus)}$	80			V	I_C=0.2A, R_{BE}=100Ω
	$V_{CEX(sus)}$	80			V	I_C=0.2A, I_B=$-I_B$=20mA
Collector Cutoff Current	I_{CBO}			100	μA	V_{CB}=80V, I_E=0
				1.0	mA	V_{CB}=80V, I_E=0, T_C=125°C
Collector Cutoff Current	I_{CEO}			100	μA	V_{CE}=40V, I_B=0
Emitter Cutoff Current	I_{EBO}	1.3		3.7	mA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE}	1000	4000	15000		V_{CE}=2.0V, I_C=10A*
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	I_C=10A, I_B=25mA*
Base Saturation Voltage	$V_{BE(sat)}$			2.0	V	

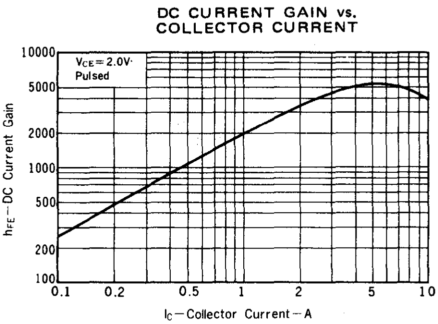
* Pulsed PW ≦ 350 μs, duty cycle ≦ 2%

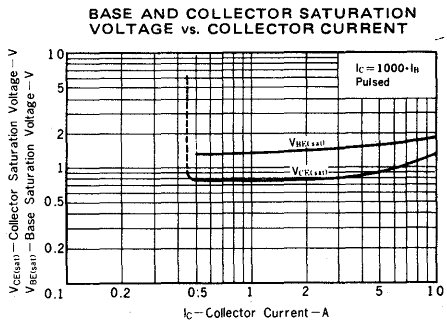
TYPICAL CHARACTERISTICS (Ta = 25°C)











NEC
ELECTRON DEVICE

SILICON DARLINGTON POWER TRANSISTOR
NTD412

LOW FREQUENCY AMPLIFIER AND LOW SPEED SWITCHING NPN SILICON EPITAXIAL MESA DARLINGTON TRANSISTOR

Industrial Use

DESCRIPTION

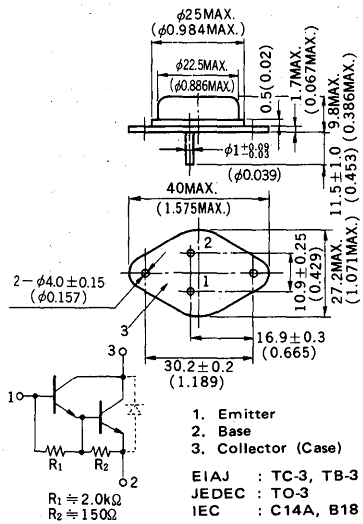
Suitable for hummer driver, pulse motor driver and relay driver applications.

FEATURES

- Operates from IC without predriver.
- Low collector saturation voltage.

PACKAGE DIMENSIONS

in millimeters (inches)



ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Base Voltage	V_{CBO}	150	V
Collector to Emitter Voltage	$V_{CER(sus)}$	100	V
	$V_{CEX(sus)}$	100	V
	$V_{CEO(sus)}$	100	V
Emitter to Base Voltage	V_{EBO}	10	V
Continuous Collector Current	$I_{C(DC)}$	15	A
Peak Collector Current	$I_{C(pulse)}$*	20	A
Continuous Base Current	$I_{B(DC)}$	1.5	A
Maximum Power Dissipation			
Total Power Dissipation (Ta = 25°C)	P_T	5	W
(Tc = 25°C)	P_T	150	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	-65 to +200	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistance			
Junction to Ambient	$R_{th(j-a)}$	35	°C/W
Junction to Case	$R_{th(j-c)}$	1.17	°C/W

* Pulsed PW ≦ 10 ms, duty cycle ≦ 50%

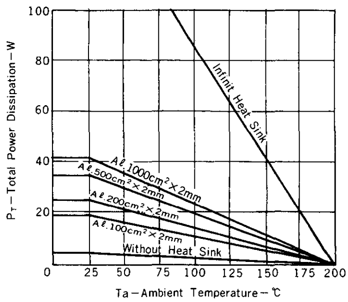
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(sus)}$	100			V	I_C=0.2A, I_B=0
	$V_{CER(sus)}$	100			V	I_C=0.2A, R_{BE}=100Ω
	$V_{CEX(sus)}$	100			V	I_C=0.2A, I_B=−I_B=20mA
Collector Cutoff Current	I_{CBO}			100	μA	V_{CB}=100V, I_E=0
				1.0	mA	V_{CB}=100V, I_E=0, T_C=125°C
Collector Cutoff Current	I_{CEO}			100	μA	V_{CE}=50V, I_B=0
Emitter Cutoff Current	I_{EBO}			4.7	mA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE}	1000	4000	15000		V_{CE}=2.0V, I_C=15A*
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	I_C=15A, I_B=30mA*
Base Saturation Voltage	$V_{BE(sat)}$			2.0	V	

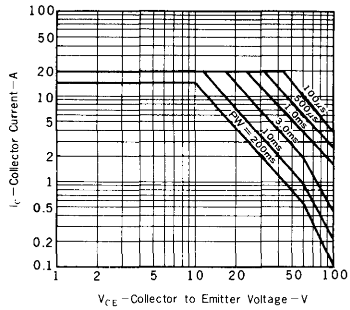
* Pulsed PW ≦ 350 μs, duty cycle ≦ 2%

TYPICAL CHARACTERISTICS (Ta = 25°C)

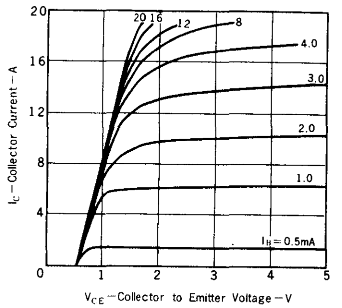
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



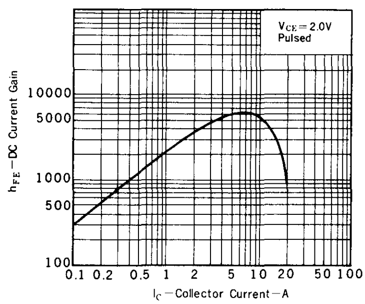
SAFE OPERATING AREA



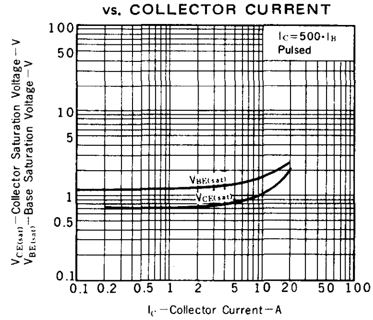
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

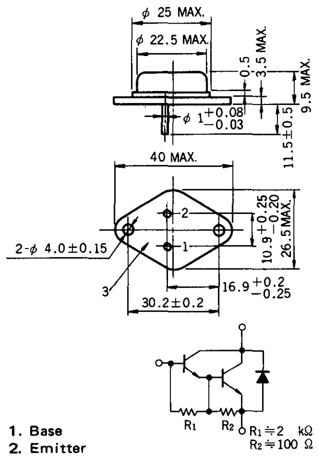


NEC
ELECTRON DEVICE

SILICON DARLINGTON POWER TRANSISTOR
NTD565

LOW FREQUENCY AMPLIFIER AND LOW SPEED HIGH CURRENT SWITCHING NPN SILICON TRIPLE DIFFUSED DARLINGTON TRANSISTOR INDUSTRIAL USE

PACKAGE DIMENSIONS
(Unit : mm)



1. Base
2. Emitter
3. Collector · Case

EIAJ : TC−3, TB−3
JEDEC : TO−204MA(TO−3)
IEC : C14A, B18

DESCRIPTION
Suitable for igniter driver and motor driver applications.

FEATURES
- High Voltage and High Current.
- High Reverse Current.
- Low collector saturation voltage.

ABSOLUTE MAXIMUM RATINGS ($T_a = 25\ ^\circ C$)

Collector to Base Voltage	V_{CBO}	400	V
Collector to Emitter Voltage	V_{CEO}	400	V
Emitter to Base Voltage	V_{EBO}	8	V
Continuous Collector Current	$I_{C(DC)}$	10	A
Peak Collector Current	$I_{C(pulse)}$*	20	A
Maximum Power Dissipation	P_T	100	W
Maximum Junction Temperature	T_j	150	°C
Maximum Storage Temperature	T_{stg}	−65 to +150	°C

*Pulsed PW ≦ 300 μs, duty cycle ≦ 10 %

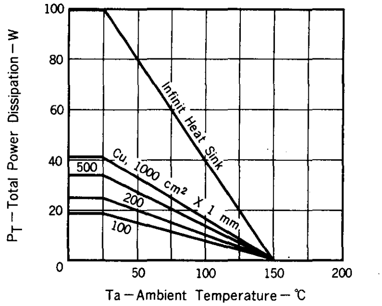
ELECTRICAL CHARACTERISTICS ($T_a = 25\ ^\circ C$)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			100	μA	$V_{CB} = 400$ V, $I_E = 0$
DC Current Gain	h_{FE}	100				$V_{CE} = 1.5$ V, $I_C = 6$ A *
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	$I_C = 6$ A, $I_B = 60$ mA *
Base Saturation Voltage	$V_{BE(sat)}$			2.5	V	

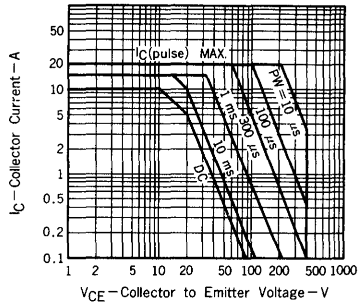
*Pulsed PW ≦ 350 μs, duty cycle ≦ 2 %

TYPICAL CHARACTERISTICS (Ta = 25 °C)

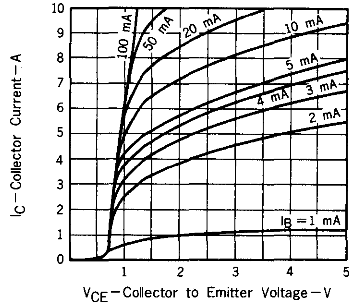
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



SAFE OPERATING AREAS

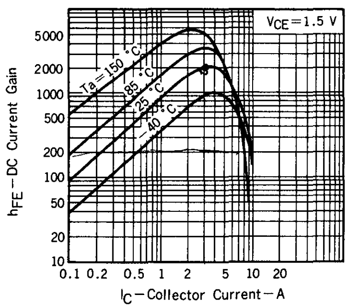


COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

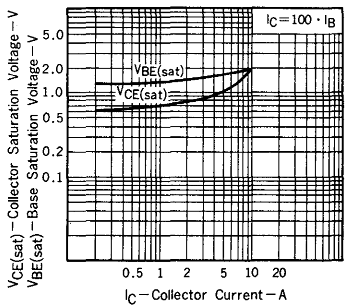


3

DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

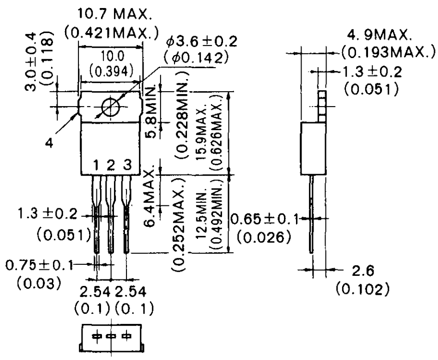
SILICON POWER TRANSISTORS
NTD568, NTD569

LOW FREQUENCY AMPLIFIER AND LOW SPEED SWITCHING NPN SILICON EPITAXIAL TRANSISTOR

Industrial Use

DESCRIPTION
Suitable for lamp driver and inductive load driver.

PACKAGE DIMENSIONS
in millimeters(inches)



1. Base(B)
2. Collector(C)
3. Emitter(E)
4. Fin(Collector)

FEATURES
- High current switching capability.
- Low collector saturation voltage.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents(T_a=25°C)		NTD568	NTD569	
Collector to Base Voltage	V_{CBO}	100	100	V
Collector to Emitter Voltage	V_{CEO}	60	80	V
Emitter to Base Voltage	V_{EBO}	7.0	7.0	V
Continuous Collector Current	$I_{C(DC)}$	7.0	7.0	A
Peak Collector Current	$I_{C(pulse)}$*	15	15	A
Continuous Base Current	$I_{B(DC)}$	3.5	3.5	A
Maximum Power Dissipations				
Total Power Dissipations				
at 25°C Ambient Temperature	P_T	2.0		W
at 25°C Case Temperature	P_T	65		W
Maximum Temperatures				
Junction Temperature	T_j	150		°C
Storage Temperature	T_{stg}	−55 to +150		°C

*Pulsed PW≦300μs, duty cycle≦10%

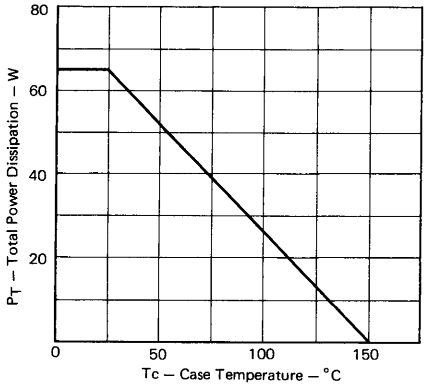
ELECTRICAL CHARACTERISTICS (T_a=25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			10	μA	V_{CB}=80V, I_E=0
DC Current Gain	h_{FE1}	40				V_{CE}=1.0V, I_C=3.0A *
DC Current Gain	h_{FE2}	20				V_{CE}=1.0V, I_C=5.0A *
Collector Saturation Voltage	$V_{CE(sat)}$			0.5	V	I_C=5.0A *
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	I_B=0.5A

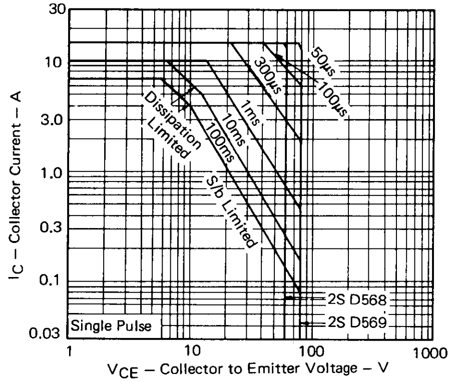
*Pulsed PW≦350μs, duty cycle≦2%

TYPICAL CHARACTERISTICS(Ta=25°C)

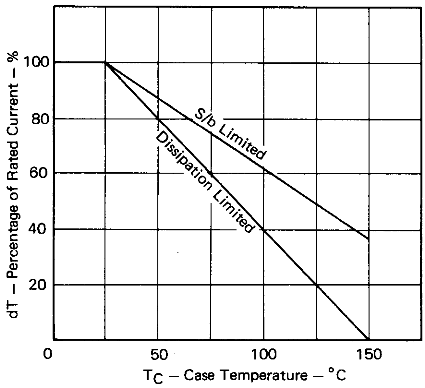
TOTAL POWER DISSIPATION vs. CASE TEMPERATURE



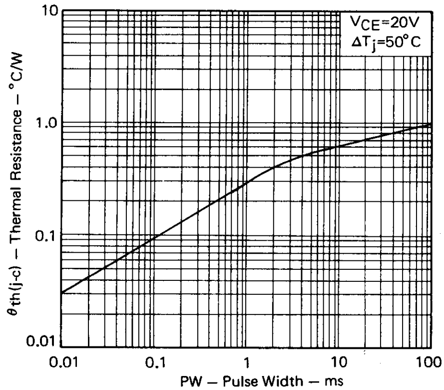
FORWARD BIAS SAFE OPERATING AREAS



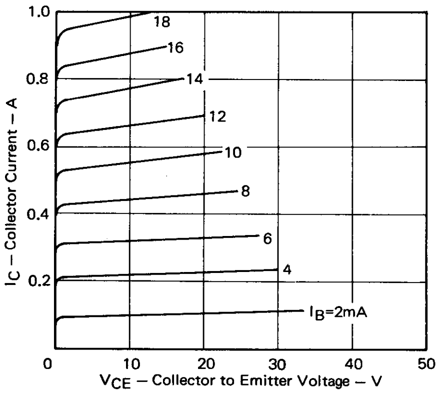
DERATING CURVE SAFE OPERATING AREAS



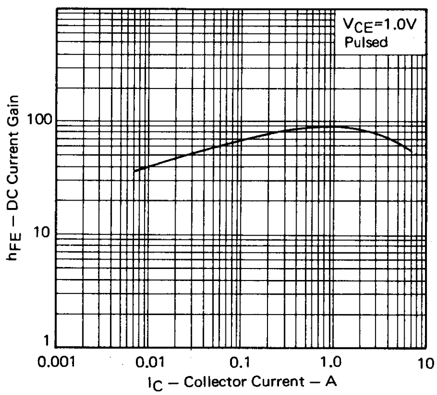
TRANSIENT THERMAL RESISTANCE



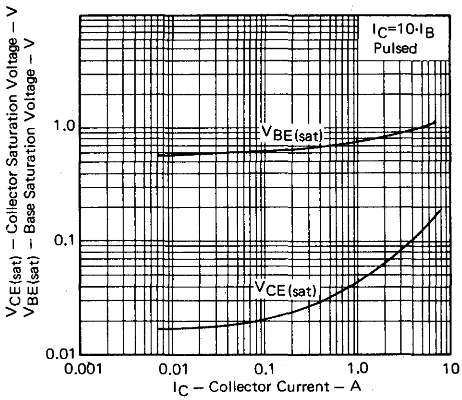
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

SILICON DARLINGTON POWER TRANSISTORS
NTD985,NTD986

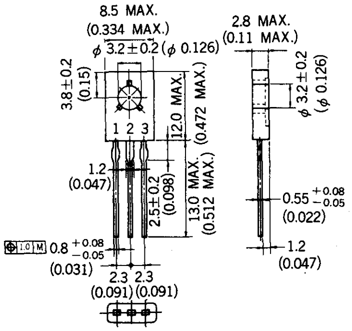
LOW FREQUENCY AMPLIFIER AND LOW SPEED SWITCHING NPN SILICON EPITAXIAL DARLINGTON TRANSISTOR INDUSTRIAL USE

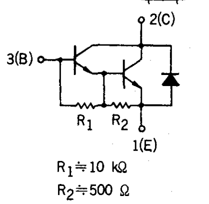
DESCRIPTION

Suitable for hummer driver, pulse motor driver and relay driver applications.

PACKAGE DIMENSIONS

in millimeters (inches)





1. Emitter (E)
2. Collector (C)
3. Base (B)
4. Fin (Collector)

FEATURES

- Operates from IC without predriver.
- Low Collector saturation voltage.
- For complementary use with type NTB794, NTB795.
- Similar to MJE800 to 803.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25 °C)		NTD985	NTD986	
Collector to Base Voltage	V_{CBO}	150	150	V
Collector to Emitter Voltage	$V_{CER(SUS)}$	60	80	V
	$V_{CEX(SUS)}$	60	80	V
	$V_{CEO(SUS)}$	60	80	V
Emitter to Base Voltage	V_{EBO}	8.0		V
Continuous Collector Current	$I_{C(DC)}$	±2.0		A
Peak Collector Current	$I_{C(pulse)}$*	±4.0		A
Continuous Base Current	$I_{B(DC)}$	0.2		A
Maximum Power Dissipations				
Total Power Dissipation (Ta = 25 °C)	P_T	1.0		W
Total Power Dissipation (T_C = 25 °C)	P_T	20		W
Maximum Temperatures				
Junction Temperature	T_j	150		°C
Storage Temperature	T_{stg}	−55 to +150		°C
Lead Temperature				
1/8 inch from case for 10 second	T_L	260		°C
Thermal Resistance				
Junction to Ambient	$R_{th(j-a)}$	125		°C/W
Junction to Case	$R_{th(j-c)}$	6.25		°C/W

*Pulsed PW ≦ 300 μs, duty cycle ≦ 10 %.

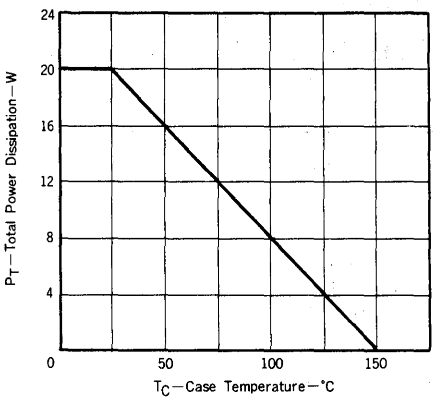
ELECTRICAL CHARACTERISTICS (Ta = 25 °C) NTD985/986

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	60/80			V	I_C = 0.2 A, I_B = 0
	$V_{CER(SUS)}$	60/80			V	I_C = 0.2 A, R_{BE} = 100 Ω
	$V_{CEX(SUS)}$	60/80			V	I_C = 0.2 A, I_B = −I_B = 2.0 mA
Collector Cutoff Current	I_{CBO}			10	μA	V_{CB} = 60/80 V, I_E = 0
				1.0	mA	V_{CB} = 60/80 V, I_E = 0, T_C = 125 °C
Collector Cutoff Current	I_{CEO}			10	μA	V_{CE} = 60/80 V, I_B = 0
Emitter Cutoff Current	I_{EBO}			1.0	mA	V_{EB} = 5.0 V, I_C = 0
DC Current Gain	h_{FE}	2000		30000		V_{CE} = 2.0 V, I_C = 1.0 A*
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	I_C = 1.0 A, I_B = 1.0 mA*
Base Saturation Voltage	$V_{BE(sat)}$			2.0	V	
Turn On Time	t_{on}		0.5		μs	I_C = 1.0 A, I_{B1} = −I_{B2} = 1.0 mA, V_{CC} ≒ 50 V, R_L = 50 Ω
Storage Time	t_{stg}		1.0		μs	
Fall Time	t_f		1.0		μs	

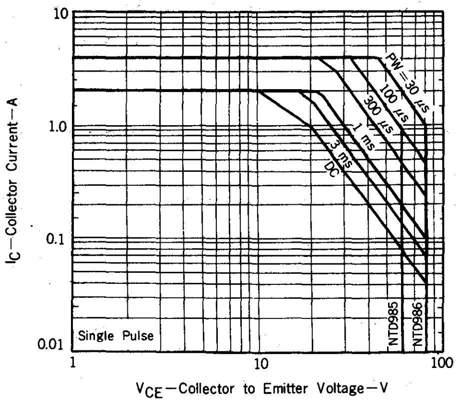
*Pulsed PW ≦ 350 μs, duty cycle ≦ 2 %.

TYPICAL CHARACTERISTICS ($T_a = 25\ ^\circ C$)

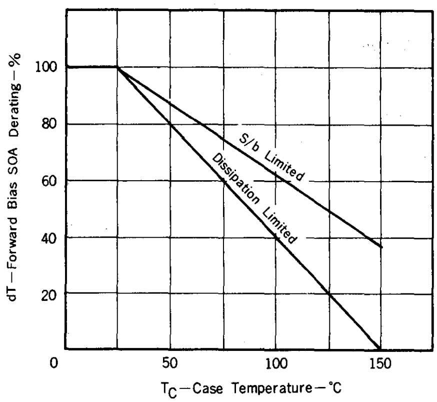
TOTAL POWER DISSIPATION vs. CASE TEMPERATURE



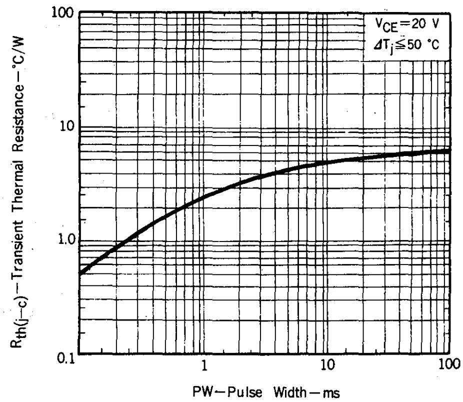
SAFE OPERATING AREAS



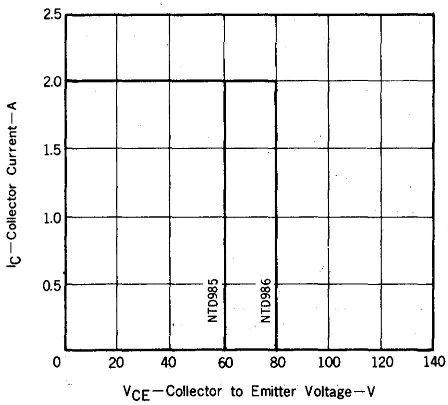
DERATING CURVE OF SAFE OPERATING AREAS



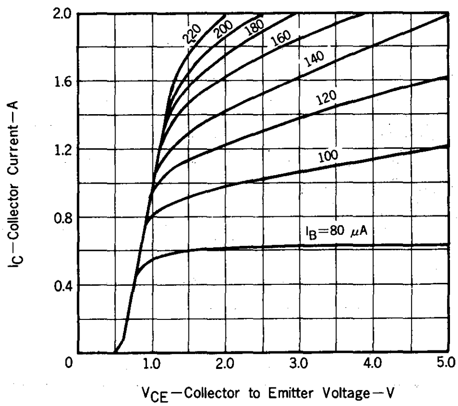
TRANSIENT THERMAL RESISTANCE



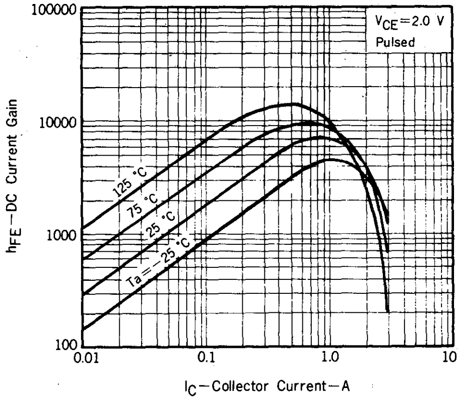
REVERSE BIAS SAFE OPERATING AREAS



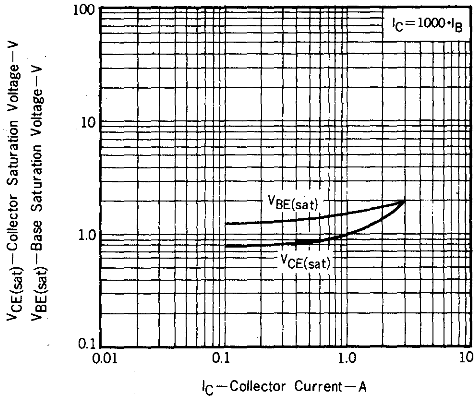
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT

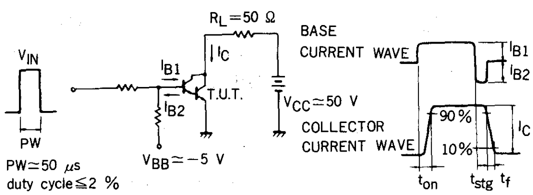


BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



3

SWITCHING TIME (t_{on}, t_{stg}, t_f) TEST CIRCUIT



NEC
ELECTRON DEVICE

SILICON DARLINGTON POWER TRANSISTOR
NTD987

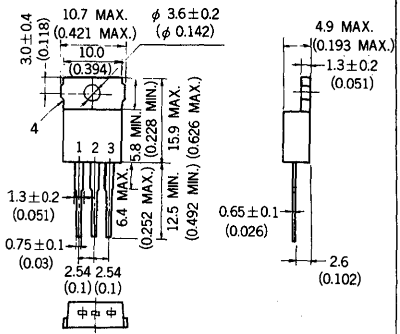
HIGH VOLTAGE HIGH CURRENT SWITCHING
NPN SILICON TRIPLE DIFFUSED DARLINGTON TRANSISTOR
INDUSTRIAL USE

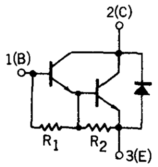
DESCRIPTION

Suitable for transistor ignitor and motor driver applications.

PACKAGE DIMENSIONS

in millimeters (inches)





1. Base (B)
2. Collector (C)
3. Emitter (E)
4. Fin (Collector)

JEDEC : TO−220AB

$R_1 \approx 500\ \Omega$
$R_2 \approx 50\ \Omega$

FEATURES

- High voltage switching.
- Low collector saturation voltage.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta=25 °C)			
Collector to Base Voltage	V_{CBO}	500	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	400	V
Emitter to Base Voltage	V_{EBO}	8.0	V
Continuous Collector Current	$I_{C(DC)}$	±5.0	A
Peak Collector Current	$I_{C(pulse)}$ *	±10	A
Continuous Base Current	$I_{B(DC)}$	0.5	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(T_C=25\ °C)}$	50	W
Total Power Dissipation	$P_{T(Ta=25\ °C)}$	1.85	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−55 to +150	°C
Lead Temperature			
1/8 inch from case for 10 seconds	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-c)}$	2.5	°C/W
Junction to Ambient	$R_{th(j-a)}$	67.8	°C/W

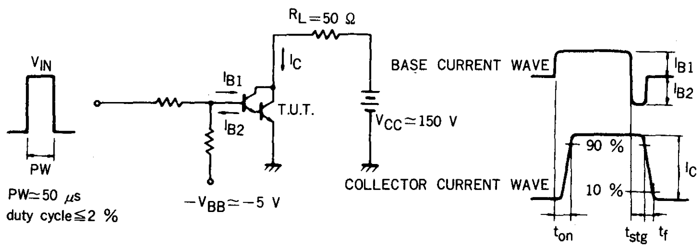
*Pulsed PW ≦ 300 μs, duty cycle ≦ 10 %

ELECTRICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	400			V	I_C=3 A, I_B=30 mA, L=1.0 mH
Collector Cutoff Current	I_{CBO1}			10	μA	V_{CB}=400 V, I_E=0
	I_{CBO2}			1.0	mA	V_{CB}=400 V, I_E=0, Ta=125 °C
Emitter Cutoff Current	I_{EBO}			10	mA	V_{EB}=5.0 V, I_C=0
DC Current Gain	h_{FE1}	200				V_{CE}=2.0 V, I_C=1.0 A *
	h_{FE2}	100				V_{CE}=2.0 V, I_C=3 A *
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	I_C=3.0 A, I_B=30 mA *
Base Saturation Voltage	$V_{BE(sat)}$			2.0	V	
Turn On Time	t_{on}		1.0		μs	I_C=3 A, I_{B1}=−I_{B2}=30 mA, V_{CC}≃150 V, R_L=50 Ω
Storage Time	t_{stg}		9.0		μs	
Fall Time	t_f		4.0		μs	

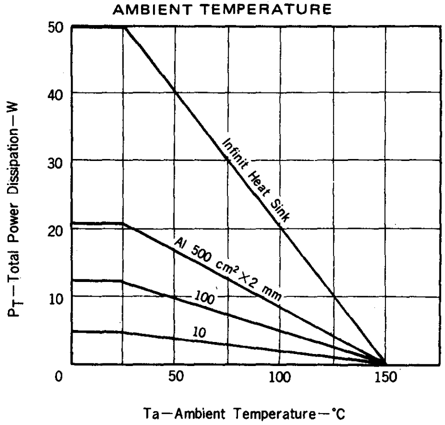
* Pulsed PW ≦ 350 μs, duty cycle ≦ 2 %

SWITCHING TIME (t_{on}, t_{stg}, t_f) TEST CIRCUIT

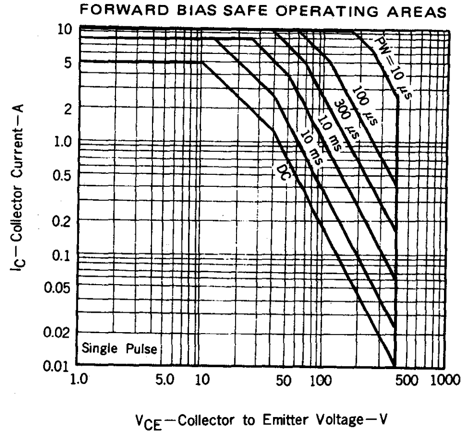


TYPICAL CHARACTERISTICS (Ta = 25 °C)

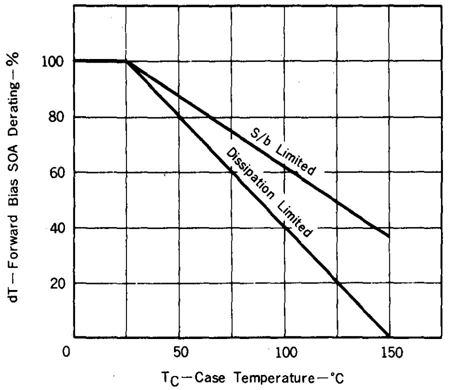
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



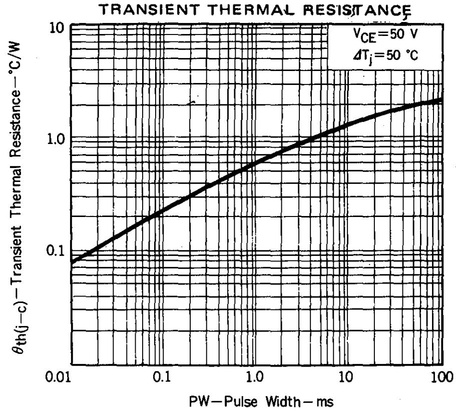
FORWARD BIAS SAFE OPERATING AREAS



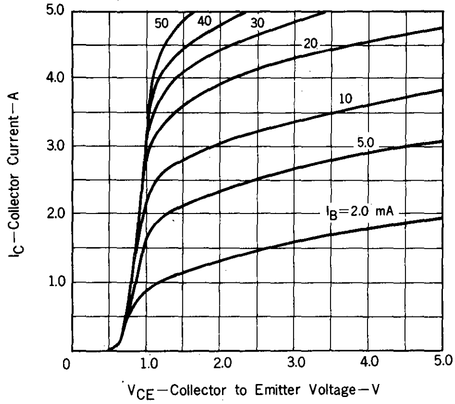
DERATING CURVE OF SAFE OPERATING AREAS



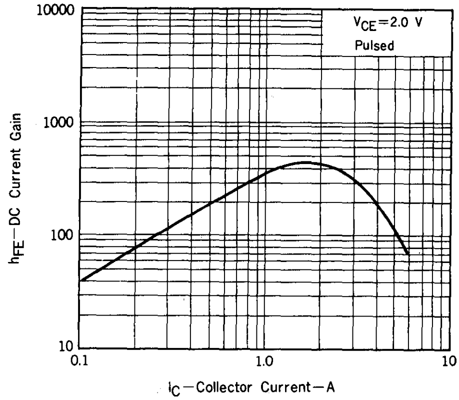
TRANSIENT THERMAL RESISTANCE



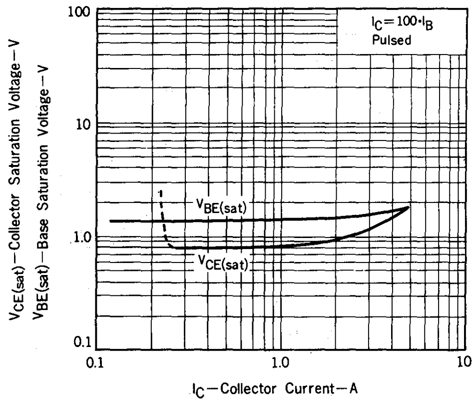
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

SILICON POWER TRANSISTORS

2SA1006,2SA1006A,2SA1006B/2SC2336,2SC2336A,2SC2336B

AUDIO FREQUENCY POWER AMPLIFIER
PNP/NPN SILICON EPITAXIAL TRANSISTOR (BUILT IN EMITTER BALLAST RESISTORS)

DESCRIPTION

The 2SA1006, 2SA1006A, 2SA1006B/2SC2336, 2SC2336A and 2SC2336B are silicon epitaxial transistors suited for use as driver stage of 150 to 500 watts complimentary symmetry audio amplifier.

3

FEATURES

- Wide safe operating area (SOA) because of emitter ballast resistors structure.
- High voltage ratings. V_{CEO} = 180V, 200V, 250V
- High f_T : PNP type, 80MHz, NPN type, 95MHz (at 10V 100mA)
- Excellent h_{FE} linearity.

ABSOLUTE MAXIMUM RATINGS

		2SA1006	2SA1006A	2SA1006B	2SC2336	2SC2336A	2SC2336B	
Maximum Voltages and Currents (Ta = 25°C)								
Collector to Base Voltage	V_{CBO}	-180	-200	-250	180	200	250	V
Collector to Emitter Voltage	V_{CEO}	-180	-200	-250	180	200	250	V
Emitter to Base Voltage	V_{EBO}		-5.0			5.0		V
Collector Current	$I_{C(DC)}$		-1.5			1.5		A
Collector Current	$I_{C(pulse)}$*		-3.0			3.0		A
Maximum Power Dissipations								
Total Power Dissipation	$P_{T(Tc=25°C)}$		25			25		W
Total Power Dissipation	$P_{T(Ta=25°C)}$		1.5			1.5		W
Maximum Temperature								
Junction Temperature	T_j		150			150		°C
Storage Temperature Range	T_{stg}		-55 to +150			-55 to +150		°C

*PW ≦ 10ms, duty cycle ≦ 50%

ELECTRICAL CHARACTERISTICS (Ta = 25°C) 2SA1006, 2SA1006A, 2SA1006B/2SC2336, 2SC2336A, 2SC2336B

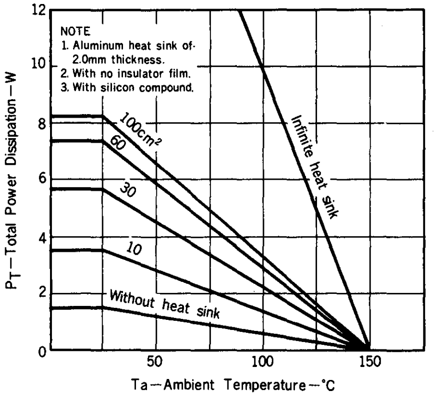
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			-1.0/1.0	μA	V_{CB}=150V, I_E=0
Emitter Cutoff Current	I_{EBO}			-1.0/1.0	μA	V_{EB}=3.0V, I_C=0
DC Current Gain	h_{FE1}	30	120/90			V_{CE}=5.0V, I_C=5.0mA*
	h_{FE2}	60	120	320		V_{CE}=5.0V, I_C=150mA*
Collector Saturation Voltage	$V_{CE(sat)}$		-0.4/0.3	-1.0/1.0	V	I_C=500mA, I_B=50mA*
Base Saturation Voltage	$V_{BE(sat)}$		-1.0/1.0	-1.5/1.5	V	I_C=500mA, I_B=50mA*
Gain Bandwidth Product	f_T		80/95		MHz	V_{CE}=10V, I_C=100mA
Output Capacitance	Cob		45/30		pF	V_{CB}=10V, I_E=0, f=1.0MHz

*Pulse Test PW ≦ 350μs, duty cycle ≦ 2%

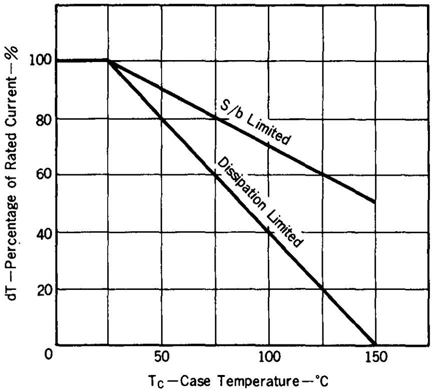
h_{FE2} Classification / R : 60 – 120, Q : 100 – 200, P : 160 – 320

TYPICAL CHARACTERISTICS (Ta=25°C)

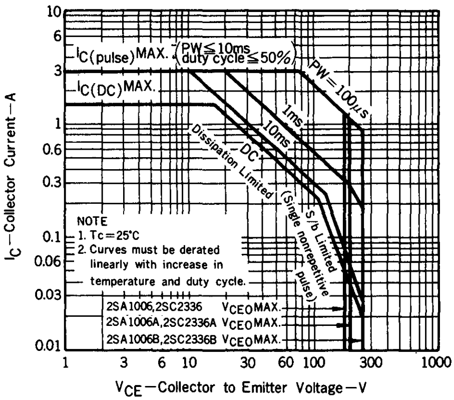
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



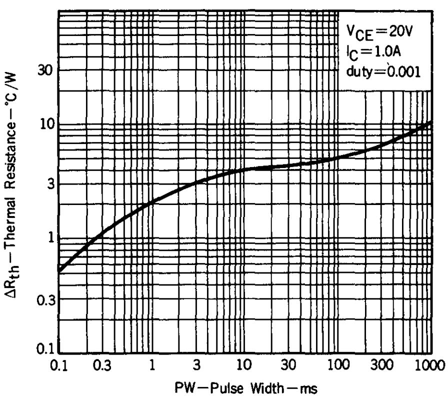
DERATING CURVES FOR ALL TYPES



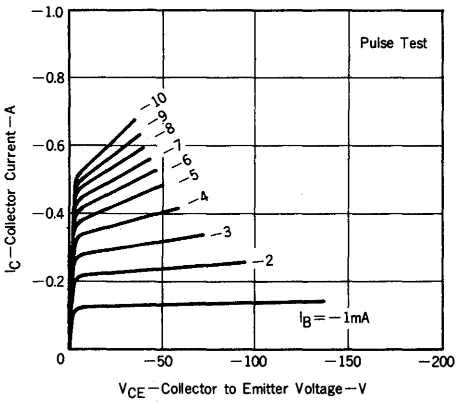
SAFE OPERATING AREA



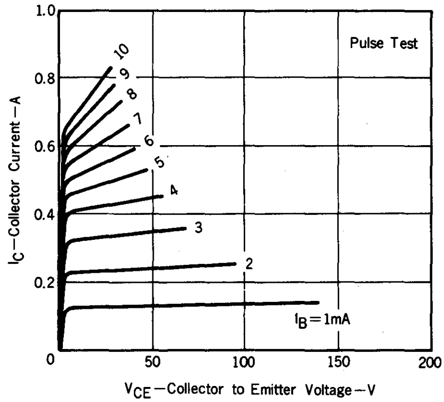
THERMAL RESISTANCE vs. PULSE WIDTH



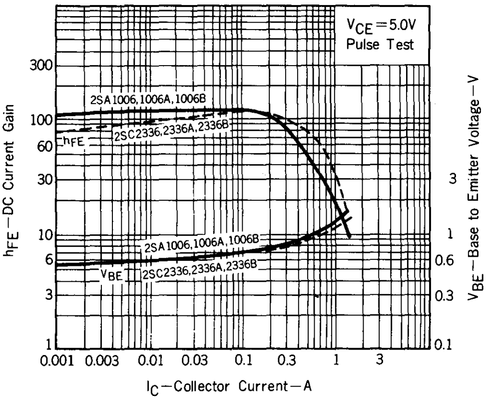
2SA1006, 1006A, 1006B COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



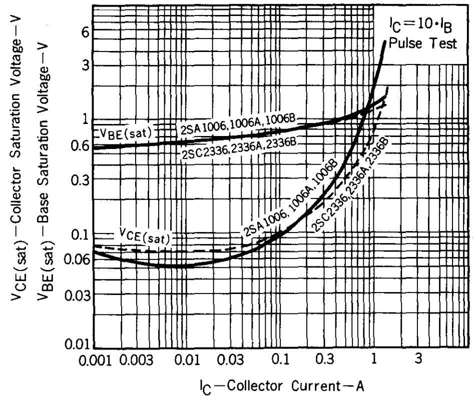
2SC2336, 2336A, 2336B COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



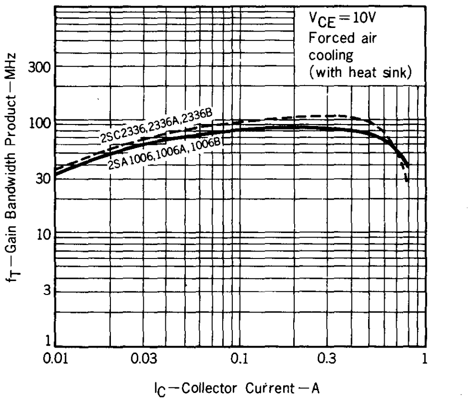
DC CURRENT GAIN, BASE TO EMITTER VOLTAGE vs. COLLECTOR CURRENT



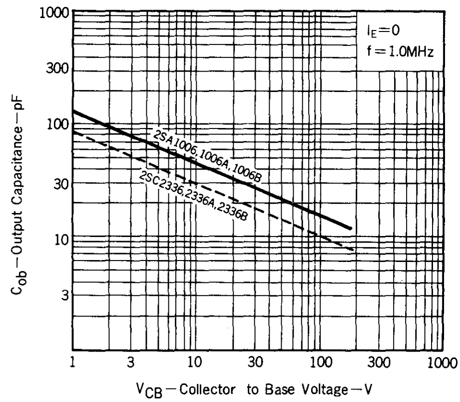
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



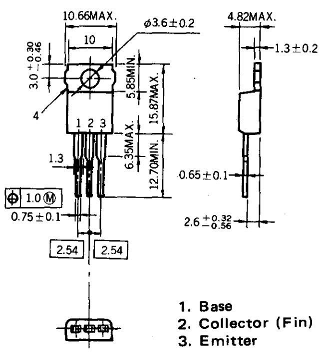
GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE

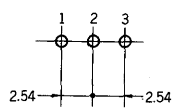


PACKAGE DIMENSIONS (Unit : mm)

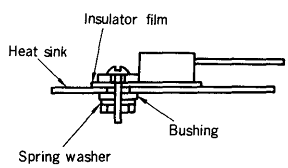


1. Base
2. Collector (Fin)
3. Emitter
4. Fin

Holes for mounting



Mounting instruction

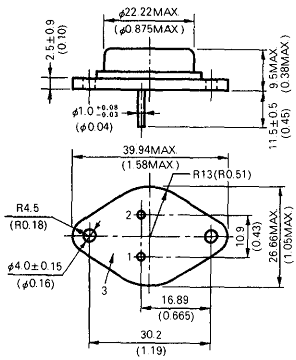


NEC
ELECTRON DEVICE

SILICON POWER TRANSISTORS
2SA1007,2SA1007A/2SC2337,2SC2337A

AUDIO FREQUENCY POWER AMPLIFIER,HIGH FREQUENCY POWER AMPLIFIER AND HIGH CURRENT SWITCHING
PNP/NPN SILICON EPITAXIAL TRANSISTOR (BUILT IN EMITTER BALLAST RESISTORS)

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector (Case)

EIAJ :TC-3, TB-3
JEDEC:TO-204MA(TO-3)
IEC :C14A, B18

DESCRIPTION

The 2SA1007, 2SA1007A/2SC2337, 2SC2337A are epitaxial high power transistors designed for use in high power high fidelity audio amplifier applications.

FEATURES

- Wide safe operating area (SOA) because of buit in emitter ballast resistors structure: 80V, 1A, 1 sec.
- High f_T: PNP type, 60MHz, NPN type, 100MHz (at 5V, 1A)
- Excellent h_{FE} linearity
- Suitable for high fidelity stereo amplifiers, ultra sonic equipments, DC-AC inverters, switching regulators.

ABSOLUTE MAXIMUM RATINGS

		2SA1007/ 2SA1007A	2SC2337/ 2SC2337A	
Maximum Voltages and Currents (Ta=25°C)				
Collector to Base Voltage	V_{CBO}	−150	150	V
Collector to Emitter Voltage	V_{CEO}	−130/−150	130/150	V
Emitter to Base Voltage	V_{EBO}	−4.5	4.5	V
Collector Current	I_C (DC)	−10	10	A
Collector Current *	I_C (pulse)	−15	15	A
Maximum Power Dissipation				
Total Power Dissipation	P_T (Tc=25°C)	100		W
Maximum Temperatures				
Junction Temperature	T_j	150		°C
Storage Temperature	T_{stg}	−65 to +150		°C

*PW ≦ 10 ms, duty cycle ≦ 50%

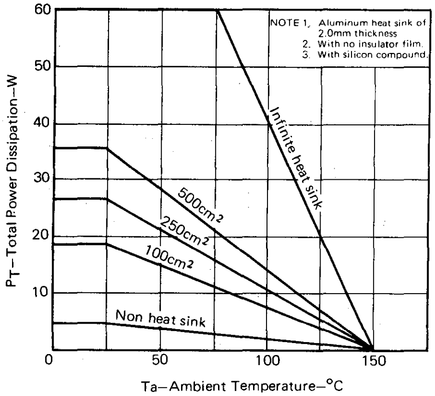
ELECTRICAL CHARACTERISTICS (Ta = 25°C) 2SA1007, 2SA1007A/2SC2337, 2SC2337A

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−50/50	μA	V_{CB}=−150/150V, I_E=0
Emitter Cutoff Current	I_{EBO}			−100/100	μA	V_{EB}=−3.0/3.0V, I_C=0
DC Current Gain	h_{FE1}		165			V_{CE}=−5.0/5.0V, I_C=−50/50mA*
	h_{FE2}	40	150	320		V_{CE}=−5.0/5.0V, I_C=−2.0/2.0A*
Collector Saturation Voltage	$V_{CE(sat)}$		−1.4/0.7	−2.0/2.0	V	I_C=−6.0/6.0A, I_B=−0.6/0.6A*
Base Saturation Voltage	$V_{BE(sat)}$		−1.5/1.5	−2.0/2.0	V	I_C=−6.0/6.0A, I_B=−0.6/0.6A*
Gain Bandwidth Product	f_T		50/70		MHz	V_{CE}=−5.0/5.0V, I_C=−0.2/0.2A
Output Capacitance	C_{ob}		250/150		pF	V_{CB}=−10/10V, I_E=0, f=1.0MHz
Turn On Time	t_{on}		0.2		μs	I_C=−5/5A, I_{B1}=−I_{B2}=−0.5/0.5A R_L=10Ω
Storage Time	t_{stg}		0.7/1.5		μs	
Turn Off Time	t_{off}		1.0/1.8		μs	

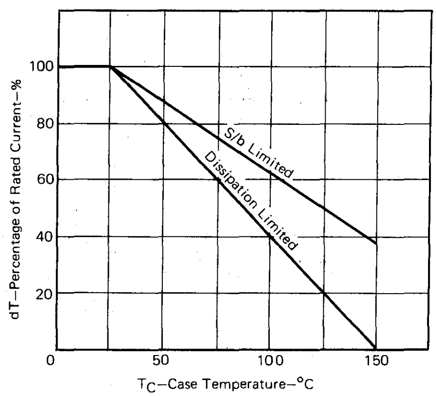
* Pulse Test PW ≦ 350μs, duty cycle ≦ 2%   **h_{FE2} Classification / S: 40to80, R: 60to120, Q: 100to200, P: 160to320**

TYPICAL CHARACTERISTICS (Ta = 25°C)

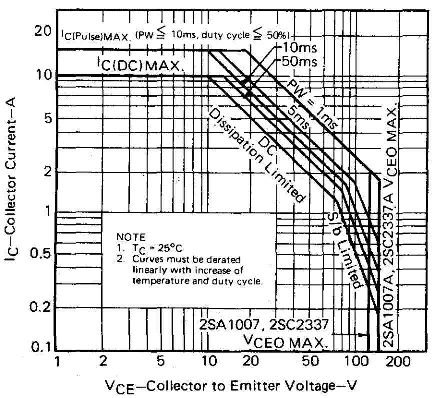
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



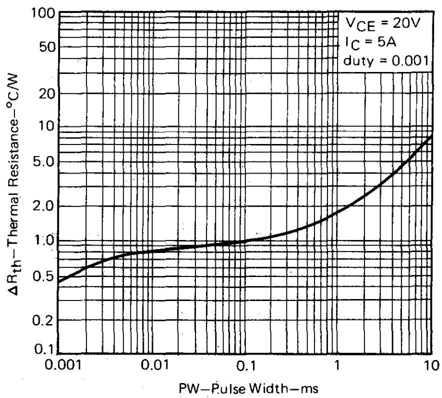
DERATING CURVE OF SAFE OPERATING AREAS



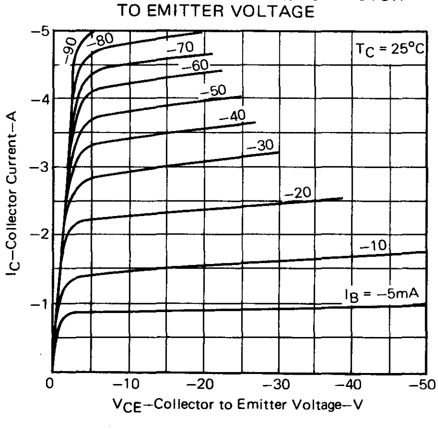
SAFE OPERATING AREAS



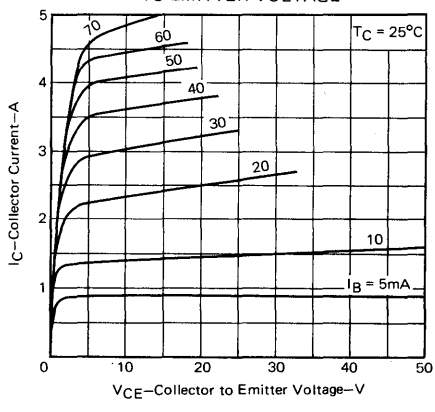
TRANSIENT THERMAL RESISTANCE



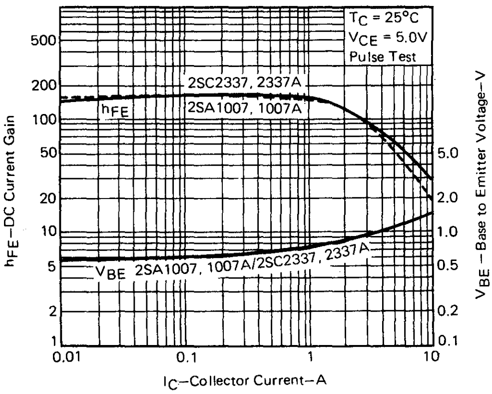
2SA1007, 2SA1007A
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



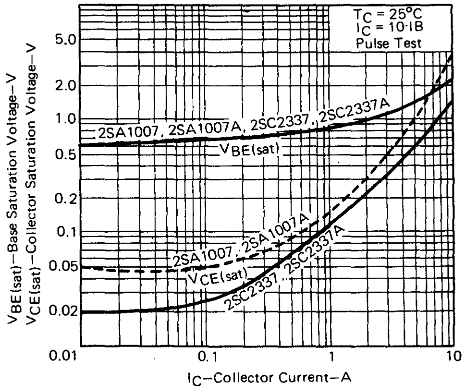
2SC2337, 2SC2337A
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



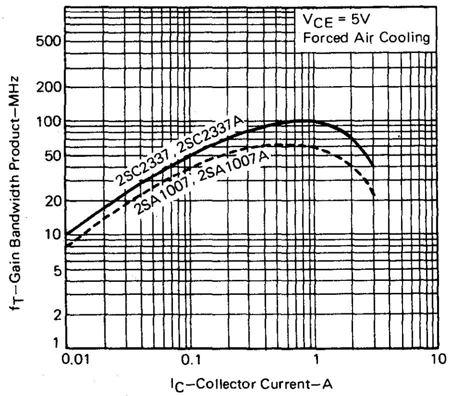
DC CURRENT GAIN AND BASE TO EMITTER VOLTAGE vs. COLLECTOR CURRENT



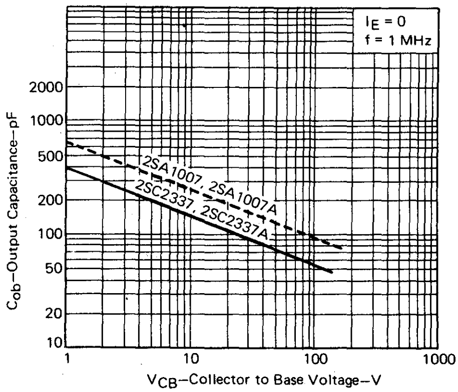
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

SILICON POWER TRANSISTORS
2SB536,2SB537/2SD381,2SD382

AUDIO FREQUENCY POWER AMPLIFIER AND LOW SPEED SWITCHING PNP/NPN SILICON EPITAXIAL TRANSISTOR

3

DESCRIPTION

The 2SB536, 2SB537 and 2SD381, 2SD382 are silicon epitaxial transistors intended for a wide variety of switching and amplifier applications.

These devices are especially suitable for use in the driver stage of 60 to 100 watts complimentary-symmetrical audio amplifier applications.

The 2SB537 and 2SD382 have formed emitter and base leads for easy insertion into TO-66 sockets.

FEATURES

- High breakdown voltage
- High f_T
- Wide safe-operating area

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta=25°C)		2SB536, 2SB537	2SD381, 2SD382	
Collector to Base Voltage	V_{CBO}	−130	130	V
Collector to Emitter Voltage	V_{CEO}	−120	120	V
Emitter to Base Voltage	V_{EBO}	−5.0	5.0	V
Collector Current	$I_{C(DC)}$	−1.5	1.5	A
Collector Current	$I_{C(pulse)}$*	−3.0	3.0	A
Base Current	$I_{B(DC)}$	−0.3	0.3	A
Maximum Power Dissipations				
Total Power Dissipation				
at Case Temperature	P_T(Tc=25°C)	20	20	W
at Ambient Temperature	P_T(Ta=25°C)	1.5	1.5	W
Maximum Temperatures				
Junction Temperature	T_j	150	150	°C
Storage Temperature	T_{stg}	−55 to +150	−55 to +150	°C

* PW ≦10ms, duty cycle ≦50%

ELECTRICAL CHARACTERISTICS (Ta = 25°C) 2SB536, 2SB537/2SD381, 2SD382

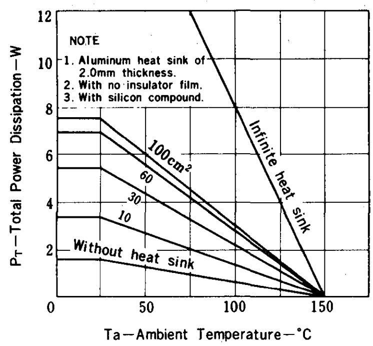
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−1.0/1.0	μA	V_{CB} = 120V, I_B = 0
Emitter Cutoff Current	I_{EBO}			−1.0/1.0	μA	V_{EB} = 3.0V, I_C = 0
DC Current Gain	h_{FE1}	25	100/65			V_{CE} = 5.0V, I_C = 5.0mA*
DC Current Gain	h_{FE2}	40	110	250		V_{CE} = 5.0V, I_C = 0.3A*
Collector Saturation Voltage	$V_{CE(sat)}$		−1.0/0.3	−2.0/2.0	V	I_C = 1.0A, I_B = 0.1A*
Base Saturation Voltage	$V_{BE(sat)}$		−0.9/0.9	−1.5/1.5	V	I_C = 1.0A, I_B = 0.1A*
Gain Bandwidth Product	f_T		40/45		MHz	V_{CE} = 5.0V, I_C = 0.1A
Output Capacitance	C_{ob}		35/25		pF	V_{CB} = 10V, I_E = 0, f = 1.0MHz

* Pulse Test/PW≦350μs, duty cycle≦2%

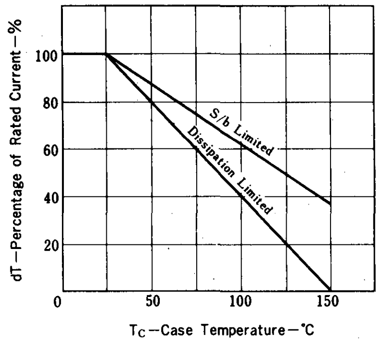
h_{FE} rank (h_{FE2})/N: 40～80, M: 60～120, L: 80～160, K: 120～250

TYPICAL CHARACTERISTICS (Ta=25°C)

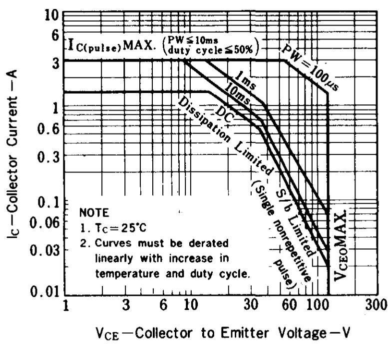
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



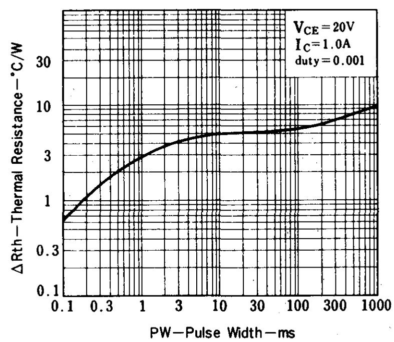
DERATING CURVES FOR ALL TYPES



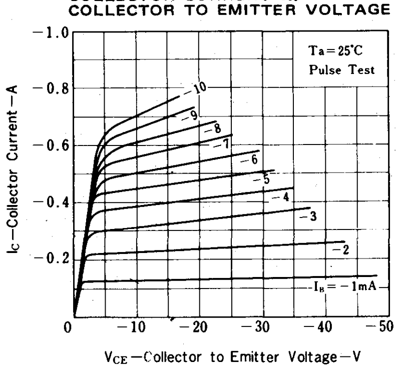
SAFE OPERATING AREAS



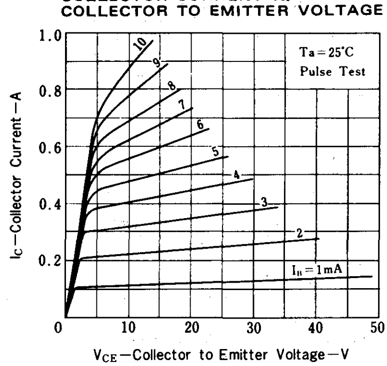
THERMAL RESISTANCE vs. PULSE WIDTH



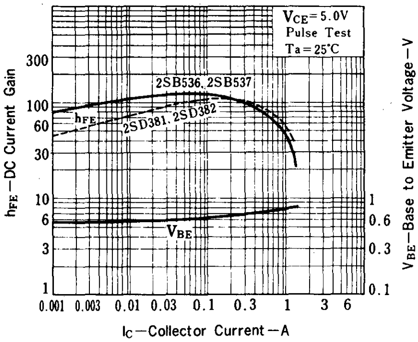
2SB536, 2SB537
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



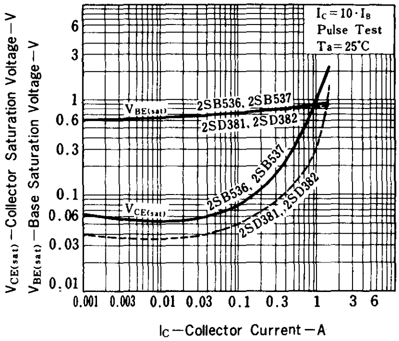
2SD381, 2SD382
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



DC CURRENT GAIN, BASE TO EMITTER VOLTAGE vs. COLLECTOR CURRENT

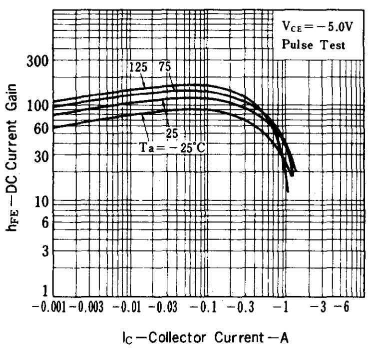


BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

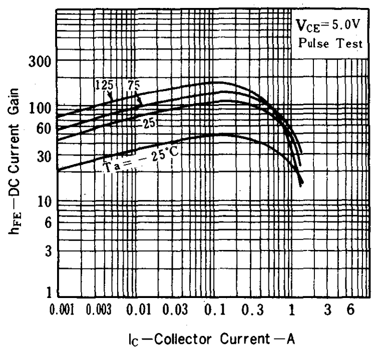


3

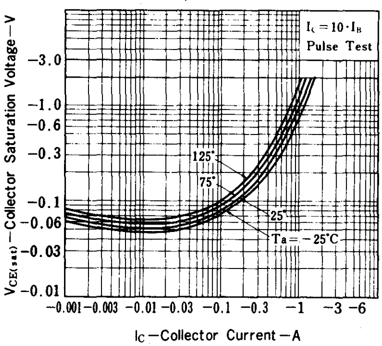
2SB536, 2SB537 DC CURRENT GAIN vs. COLLECTOR CURRENT



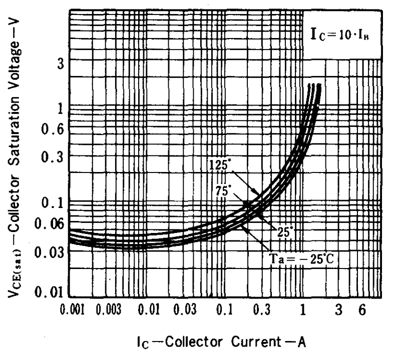
2SD381, 2SD382 DC CURRENT GAIN vs. COLLECTOR CURRENT



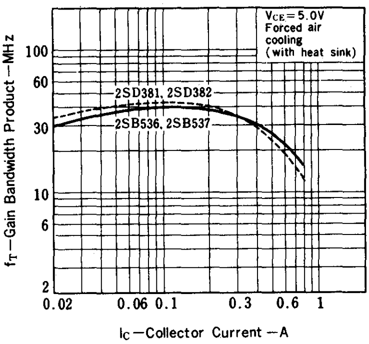
2SB536, 2SB537 COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



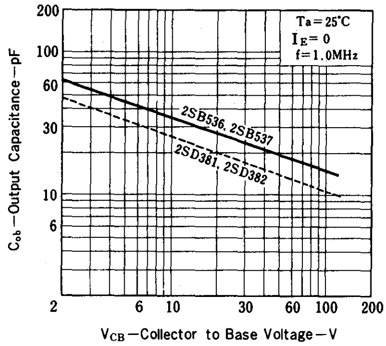
2SD381, 2SD382 COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT

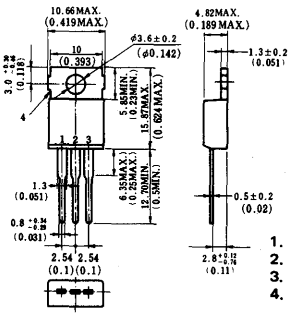


OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



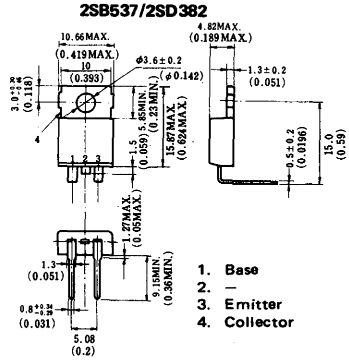
PACKAGE DIMENSIONS In millimeters (inches)

2SB536/2SD381



1. Base
2. Collector
3. Emitter
4. Fin

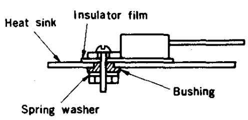
2SB537/2SD382



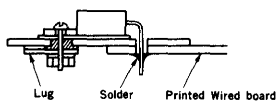
1. Base
2. —
3. Emitter
4. Collector

MOUNTING HARDWARES

2SB536/2SD381

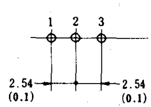


2SB537/2SD382

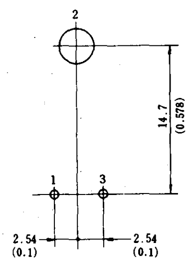


MOUNTING HOLES

2SB536/2SD381



2SB537/2SD382



NEC
ELECTRON DEVICE

SILICON POWER TRANSISTORS
2SB539A,B,C/2SD287A,B,C

AUDIO FREQUENCY POWER AMPLIFIER
PNP/NPN SILICON TRIPLE DIFFUSED MESA TRANSISTOR

DESCRIPTION

The 2SB539A,B,C and 2SD287A,B,C are triple diffused mesa transistors designed for use in audio amplifier applications.

These devices are especially suitable for use in output stage of 70 to 80 watts audio power amplifier.

FEATURES

- High breakdown voltage. V_{CEO}=120, 140, 150V
- High current ratings. $I_{C(pulse)}$=15A
- Wide safe-operating-area.

ABSOLUTE MAXIMUM TATINGS

Maximum Voltages and Currents (Ta=25°C)		2SB539A	2SB539B	2SB539C	2SD287A	2SD287B	2SD287C	
Collector to Base Voltage	V_{CBO}	−130	−150	−160	200	200	200	V
Collector to Emitter Voltage	V_{CEO}	−120	−140	−150	120	140	150	V
Emitter to Base Voltage	V_{EBO}		6.0			7.0		V
Collector Current	$I_{C(DC)}$		10			10		A
Collector Current	$I_{C(pulse)}$*		15			15		A
Maximum Power Dissipation (Tc=25°C)								
Total Power Dissipation	P_T		100			100		W
Maximum Temperatures								
Junction Temperature	T_j		150			150		°C
Storage Temperature Range	T_{stg}		−55 ~ +150			−55 ~ +150		°C

* PW ≦ 10ms, duty cycle ≦ 50%

ELECTRICAL CHARACTERISTICS (Ta = 25°C) 2SB539A, B, C/2SD287A, B, C

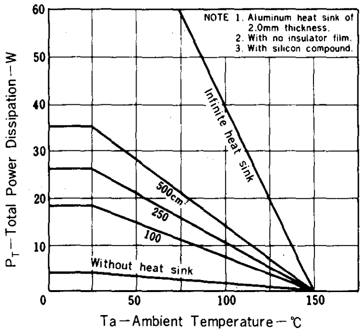
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−100/100	μA	V_{CE} = 120V, I_B = 0
Emitter Cutoff Current	I_{EBO}			−100/100	μA	V_{EB} = 5.0V, I_C = 0
DC. Current Gain	h_{FE1}	40	80	200		V_{CE} = 5.0V, I_C =2.0A*
DC. Current Gain	h_{FE2}	25				V_{CE} = 5.0V, I_C = 5.0A*
Collector Saturation Voltage	$V_{CE(sat)}$		−1.4/0.8	−2.0/2.0	V	I_C = 6.0A, I_B = 0.6A*
Base Saturation Voltage	$V_{BE(sat)}$		−1.1/1.0	−2.0/1.7	V	I_C = 6.0A, I_B = 0.6A*
Gain Bandwidth Product	f_T		7/8		MHz	V_{CE} = 10V, I_C = 0.2A
Output Capacitance	C_{ob}		420/300		pF	V_{CB} = 10V, I_E = 0, f = 1.0 MHz

* Pulse Test PW ≦ 350μs duty cycle ≦ 2%

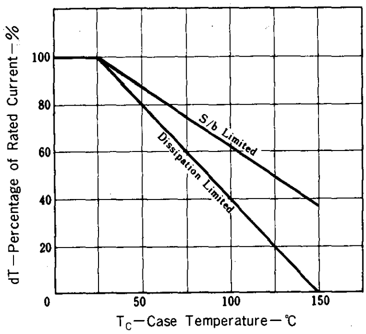
h_{FE1} rank: 40~80, 60~120, 100~200

TYPICAL CHARACTERISTICS (Ta = 25°C)

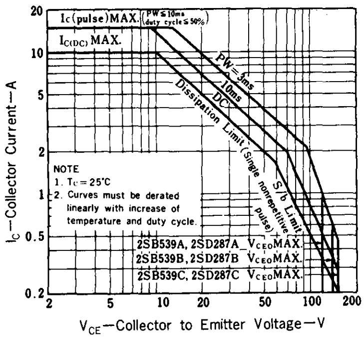
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



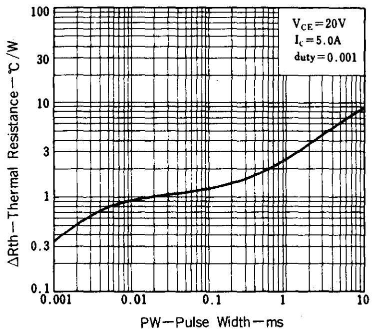
DERATING CURVES FOR ALL TYPES



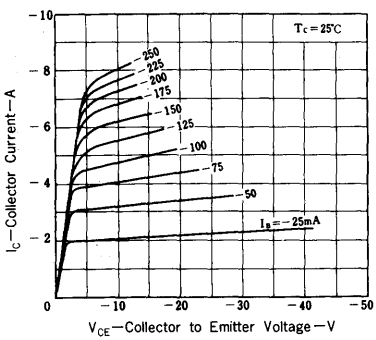
SAFE OPERATING AREAS



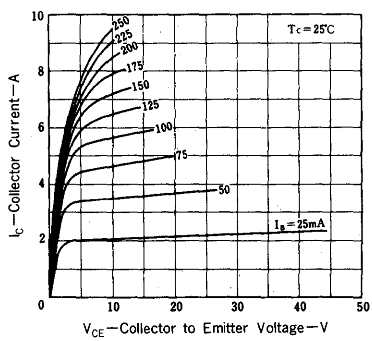
THERMAL RESISTANCE vs. PULSE WIDTH



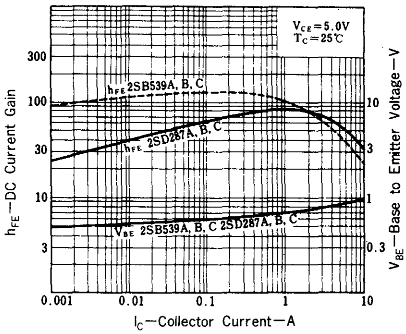
2SB539A, 539B, 539C
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



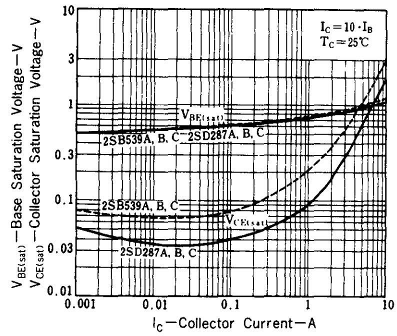
2SD287A, 287B, 287C
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



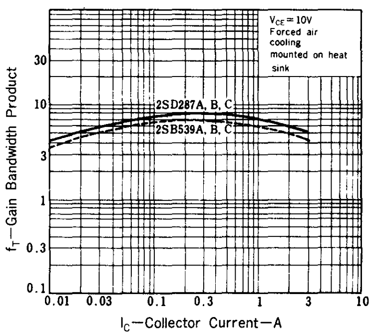
DC CURRENT GAIN AND BASE TO EMITTER VOLTAGE vs. COLLECTOR CURRENT



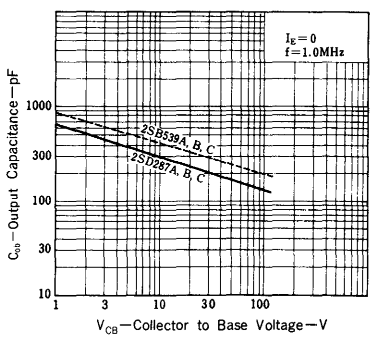
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT

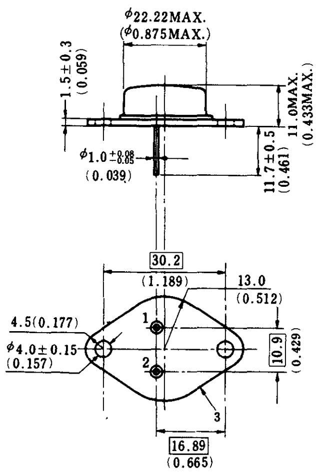


OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



PACKAGE DIMENSIONS

in millimeters (inches)



1. Emitter
2. Base
3. Collector (Case)

EIAJ : TC-3, TB-3
JEDEC: TO-204MA (TO-3)
IEC : C14A, B18

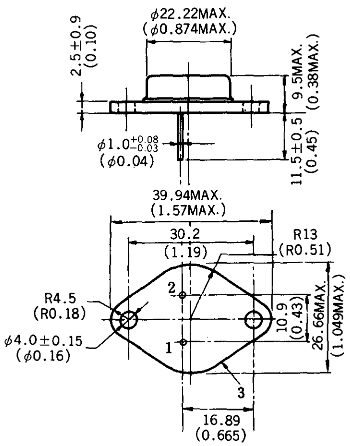
3

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTORS
2SB541/2SD388

AUDIO FREQUENCY POWER AMPLIFIER
PNP/NPN SILICON TRIPLE DIFFUSED MESA TRANSISTOR

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector (Case)

EIAJ : TC-3, TB-3
JEDEC : TO-204MA (TO-3)
IEC : C14A, B18

DESCRIPTION

The 2SB541 and 2SD388 are triple diffused mesa transistors designed for use in **40 to 50 watts complementary-symmetry audio** amplifier applications.

FEATURES

- Excellent h_{FE} linearity
- Low saturation voltages
- Wide Safe Operating Area

ABSOLUTE MAXIMUM RATINGS

		2SB541	2SD388	
Maximum Voltages and Currents (Ta=25°C)				
Collector to Base Voltage	V_{CBO}	−110	150	V
Collector to Emitter Voltage	V_{CEO}	−100	100	V
Emitter to Base Voltage	V_{EBO}	−6.0	7.0	V
Collector Current	$I_{C(DC)}$	−8	8	A
Collector Current	$I_{C(pulse)}$*	−12	12	A
Maximum Power Dissipation				
Total Power Dissipation	$P_{T(Tc=25°C)}$	80		W
Maximum Temperatures				
Junction Temperature	T_j	150		°C
Storage Temperature	T_{stg}	−55 to +150		°C

*PW ≦ 10ms, duty cycle ≦50%

ELECTRICAL CHARACTERISTICS (Ta = 25°C) 2SB541/2SD388

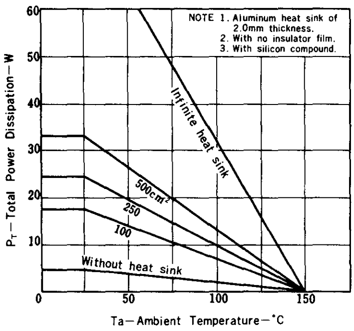
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−100/100	μA	V_{CB} = 100V, I_E = 0
Emitter Cutoff Current	I_{EBO}			−100/100	μA	V_{EB} = −4.0V/5.0V, I_C = 0
DC Current Gain	h_{FE1}	40	80	200		V_{CE} = 5.0 V, I_C = 1.0 A*
	h_{FE2}	20	40			V_{CE} = 5.0 V, I_C = 4.0 A*
Collector Saturation Voltage	$V_{CE(sat)}$		−1.1/1.0	−2.0/2.0	V	I_C = 5.0 A, I_B = 1.0 A*
Base Saturation Voltage	$V_{BE(sat)}$		−1.2/1.1	−2.0/2.0	V	I_C = 5.0 A, I_B = 1.0 A*
Gain Bandwidth Product	f_T		7/9		MHz	V_{CE} = 10 V, I_C = 0.2 A
Output Capacitance	C_{ob}		320/190		pF	V_{CB} = 10 V, I_E = 0, f = 1.0 MHz

*Pulse Test PW ≦ 350μs, duty cycle ≦ 2%
h_{FE1} Classification / S: 40 − 80 R: 60 − 120 Q: 100 − 200

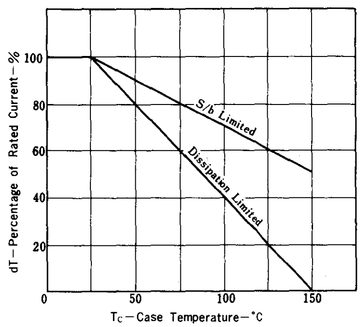
3

TYPICAL CHARACTERISTICS (Ta = 25°C)

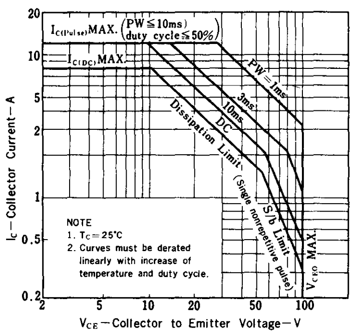
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



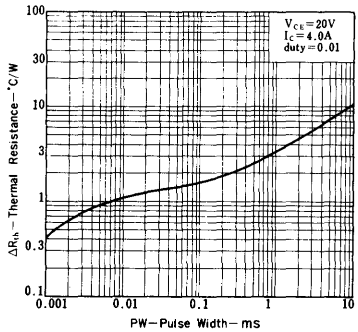
DERATING CURVES FOR ALL TYPES



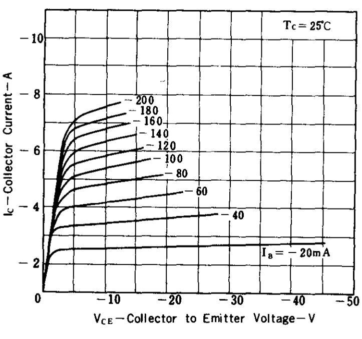
SAFE OPERATING AREA



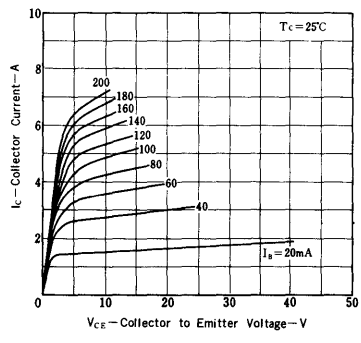
THERMAL RESISTANCE vs. PULSE WIDTH



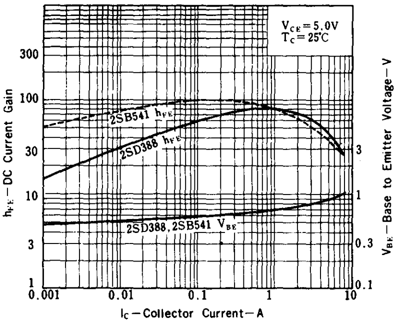
2SB541
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



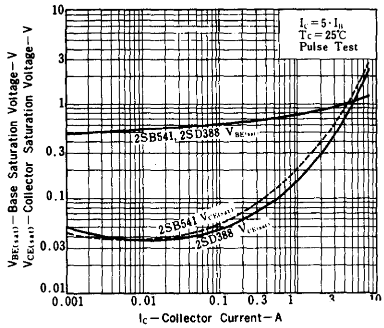
2SD388
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



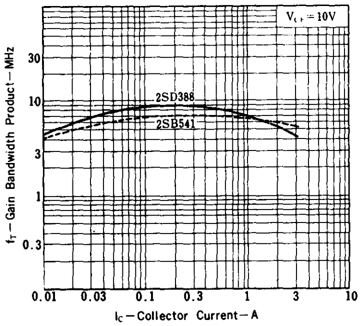
DC CURRENT GAIN,
BASE TO EMITTER VOLTAGE vs.
COLLECTOR CURRENT



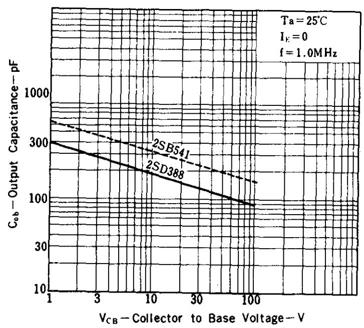
BASE AND COLLECTOR SATURATION
VOLTAGE vs.
COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs.
COLLECTOR CURRENT



OUTPUT CAPACITANCE vs.
COLLECTOR TO BASE VOLTAGE



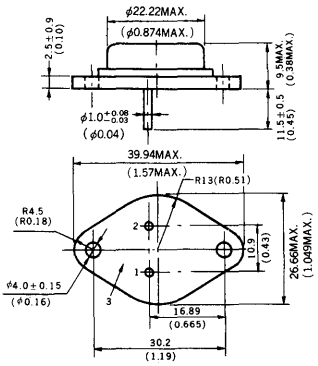
NEC
ELECTRON DEVICE

SILICON POWER TRANSISTORS
2SB600/2SD555

AUDIO FREQUENCY POWER AMPLIFIER
PNP/NPN SILICON TRIPLE DIFFUSED TRANSISTORS

3

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector (Case)

EIAJ : TC-3, TB-3
JEDEC : TO-204MA(TO-3)
IEC : C14A, B18

DESCRIPTION

The 2SB600/2SD555 are triple diffused high power transistors designed for use in high power audio amplifier applications.

FEATURES

- Suitable for use in 200 to 300 watts complementary-symmetry audio amplifier.
- High breakdown voltage V_{CEO} = 200V
- High current ratings $I_{C\ (pulse)}$ = 15A
- Wide Safe Operatıng Area.

ABSOLUTE MAXIMUM RATINGS

		2SB600	2SD555	
Maximum Voltages and Currents (Ta=25°C)				
Collector to Base Voltage	V_{CBO}	−200	250	V
Collector to Emitter Voltage	V_{CEO}	−200	200	V
Emitter to Base Voltage	V_{EBO}	−5	5	V
Collector Current	$I_{C(DC)}$	−10	10	A
Collector Current	$I_{C(pulse)}$*	−15	15	A
Maximum Power Dissipation				
Total Power Dissipation	$P_T(T_C=25°C)$	200		W
Maximum Temperatures				
Junction Temperature	T_j	150		°C
Storage Temperature Range	T_{stg}	−65 to +150		°C

* PW ≦10 ms, duty cycle ≦ 50%

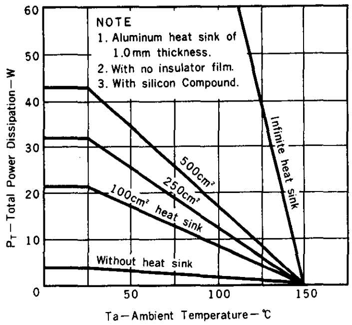
ELECTRICAL CHARACTERISTICS (Ta = 25°C) 2SB600/2SD555

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			-50/50	μA	V_{CB} = -200/200V, I_E = 0
Emitter Cutoff Current	I_{EBO}			-50/50	μA	V_{EB} = -3.0/3.0V, I_C = 0
DC Current Gain	h_{FE1}	20/20	100/55			V_{CE} = -5.0/5.0V, I_C = -50/50 mA*
	h_{FE2}	40/40	70/70	200/200		V_{CE} = -5.0/5.0V, I_C = -2.0/2.0A*
Collector Saturation Voltage	$V_{CE(sat)}$		-1.9/0.9	-3.0/3.0	V	I_C = -10/10A, I_B = -1.0/1.0A*
Base Saturation Voltage	$V_{BE(sat)}$		-2.3/1.6	-3.0/3.0	V	I_C = -10/10A, I_B = -1.0/1.0A*
Gain Bandwidth Product	f_T		14/15		MHz	V_{CE} = -5.0/5.0V, I_C = -0.2/0.2A
Output Capacitance	C_{ob}		450/300		pF	V_{CB} = -10/10V, I_E = 0, f = 1.0 MHz

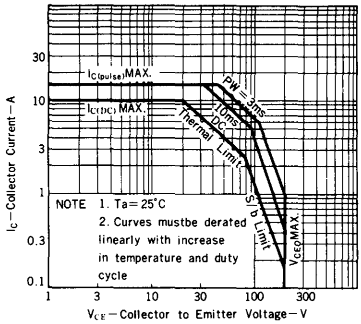
*Pulse Test PW ≦ 350μs, duty cycle ≦ 2%
h_{FE2} Classification / S : 40 – 80, R : 60 – 120, Q : 100 – 200

TYPICAL CHARACTERISTICS (Ta = 25°C)

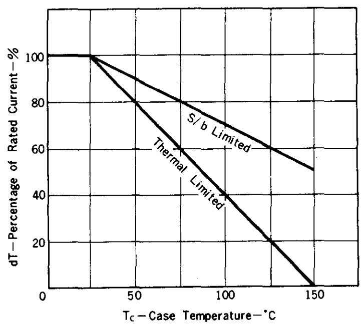
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



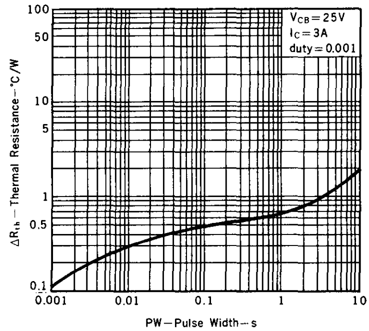
SAFE OPERATING AREAS



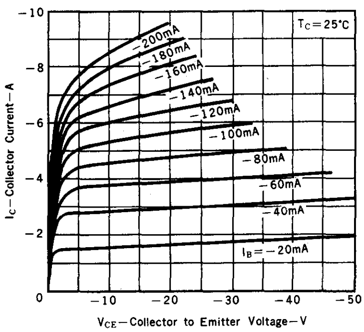
DERATING CURVES OF SAFE OPERATING AREAS



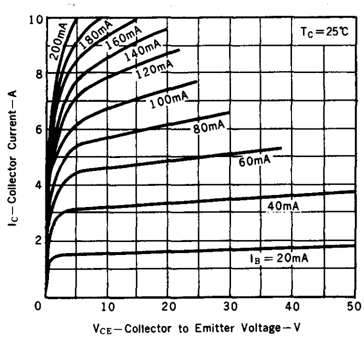
TRANSIENT THERMAL RESISTANCE



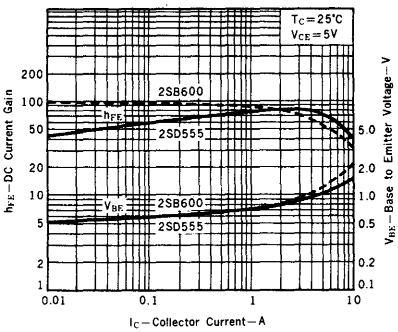
2SB600 COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



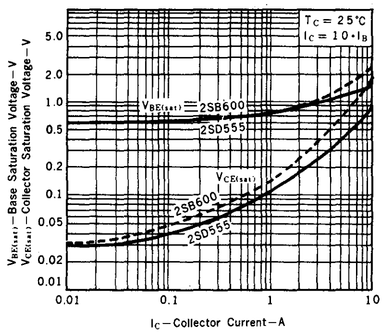
2SD555 COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



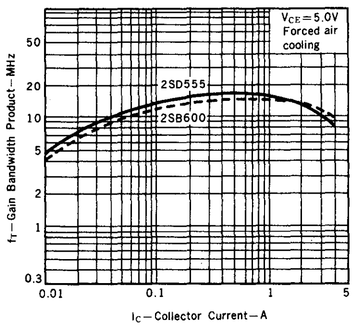
DC CURRENT GAIN AND BASE TO EMITTER VOLTAGE vs. COLLECTOR CURRENT



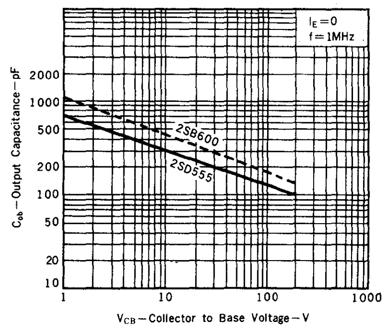
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE

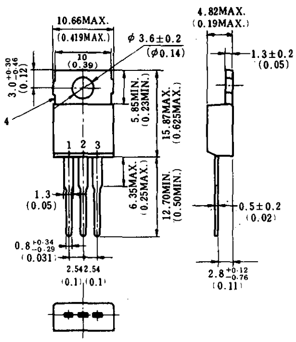


NEC
ELECTRON DEVICE

SILICON POWER TRANSISTORS
2SB628/2SD608

AUDIO FREQUENCY POWER AMPLIFIER AND LOW SPEED SWITCHING PNP/NPN SILICON EPITAXIAL TRANSISTOR

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Collector (Fin)
3. Emitter
4. Fin

DESCRIPTION

The 2SB628/2SD608 are PNP/NPN silicon transistors suited for audio-output use.

FEATURES

- Suitable for use in the driver stage of 100 to 150 watts Hi-Fi amplifier.
- High break-down voltage.
- High gain bandwidth product.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta=25°C)		2SB628	2SD608	
Collector to Base Voltage	V_{CBO}	−160	160	V
Collector to Emitter Voltage	V_{CEO}	−160	160	V
Emitter to Base Voltage	V_{EBO}	−5.0	5.0	V
Collector Current (DC)	$I_{C(DC)}$	−1.5	1.5	A
Collector Current (pulse)	$I_{C(pulse)}$*	−3.0	3.0	A
Base Current (DC)	$I_{B(DC)}$	−0.3	0.3	A
Maximum Power Dissipations				
Total Power Dissipation				
at 25°C Case Temperature	$P_T(T_c=25°C)$	20	20	W
at 25°C Ambient Temperature	$P_T(T_a=25°C)$	1.5	1.5	W
Maximum Temperatures				
Junction Temperature	T_j	150	150	°C
Storage Temperature	T_{stg}	−55 to +150	−55 to +150	°C

* PW ≦ 10ms, duty cycle ≦ 50%

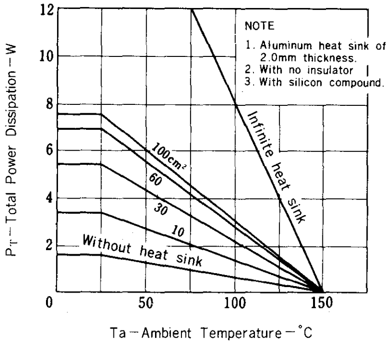
ELECTRICAL CHARACTERISTICS (Ta = 25°C) 2SB628/2SD608

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−1.0/1.0	μA	V_{CB} = 120V, I_E = 0
Emitter Cutoff Current	I_{EBO}			−1.0/1.0	μA	V_{EB} = 3.0V, I_C = 0
DC Current Gain	h_{FE1}	25	70/40			V_{CE} = 5.0V, I_C = 5.0mA*
DC Current Gain	h_{FE2}	40	80	200		V_{CE} = 5.0V, I_C = 0.3A*
Collector Saturation Voltage	$V_{CE(sat)}$		−1.0/0.5	−2.0/2.0	V	I_C = 1.0A, I_B = 0.1A*
Base Saturation Voltage	$V_{BE(sat)}$		−0.9/0.9	−1.5/1.5	V	I_C = 1.0A, I_B = 0.1A*
Gain Bandwidth Product	f_T		40/45		MHz	V_{CE} = 5.0V, I_C = 0.1A
Output Capacitance	C_{ob}		35/25		pF	V_{CB} = 10V, I_E = 0, f = 1.0MHz

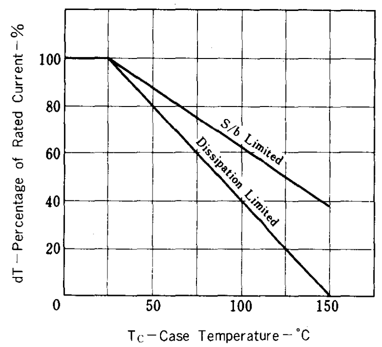
*Pulse Test / PW ≦ 350 μs, duty cycle ≦ 2%
h_{FE} rank (h_{FE2}) / S : 40 ~ 80, R : 60 ~ 120, Q : 100 ~ 200

TYPICAL CHARACTERISTICS (Ta = 25°C)

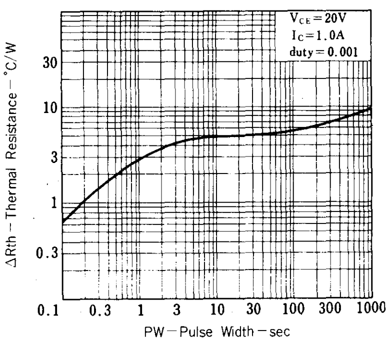
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



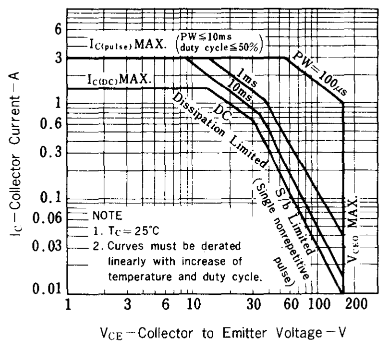
DERATING CURVES FOR ALL TYPES



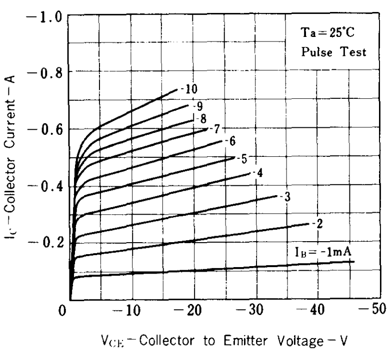
THERMAL RESISTANCE vs. PULSE WIDTH



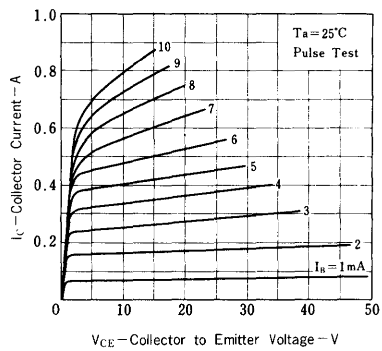
SAFE OPERATING AREAS



2SB628
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

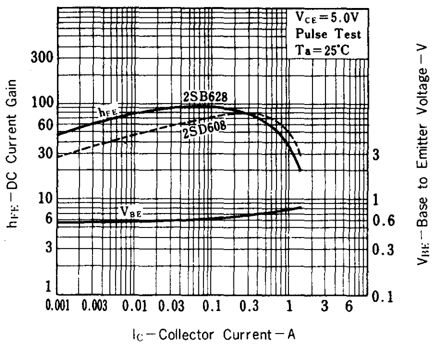


2SD608
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

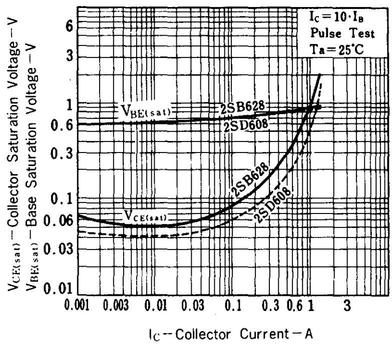


3

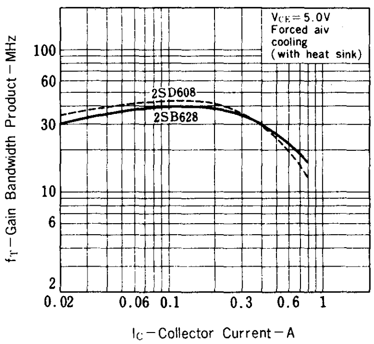
DC CURRENT GAIN AND BASE TO EMITTER VOLTAGE vs. COLLECTOR CURRENT



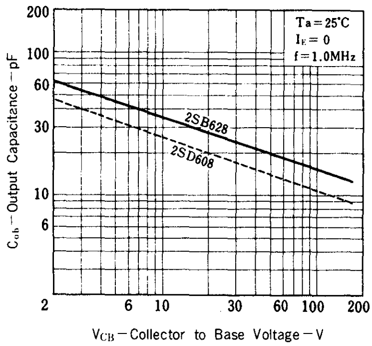
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

SILICON POWER TRANSISTORS
2SB772/2SD882

\UDIO FREQUENCY POWER AMPLIFIER AND LOW SPEED SWITCHING
PNP/NPN SILICON EPITAXIAL TRANSISTOR

3

DESCRIPTION

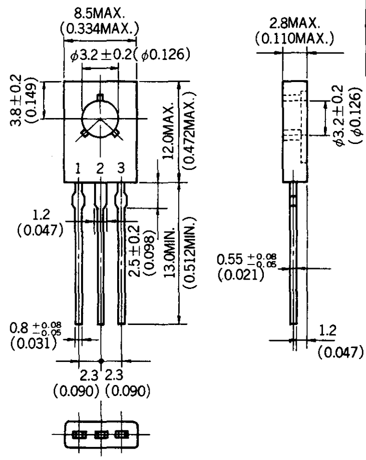
The 2SB772/2SD882 are PNP/NPN silicon transistors suited for the output stage of 3 watts audio amplifier, voltage regulator, DC-DC converter and relay driver.

FEATURES

- Low saturation voltage. ⟶ $V_{CE(sat)} \leqq 0.5V$ (at $I_C = 2A$, $I_B = 0.2A$)
- Excellent h_{FE} linearity and high h_{FE}.
  ⟶ h_{FE} : 60 – 400 (at $V_{CE} = 2V$, $I_C = 1A$)
- Less cramping space required due to small and thin package and reducing. the trouble for attachment to a radiator.
  ⟶ No insulator bushing required

PACKAGE DIMENSIONS

in millimeters (inches)



1. Emitter
2. Collector connected to mounting plane
3. Base

ABSOLUTE MAXIMUM RATINGS

		2SB772	2SD882	
Maximum Voltages and Currents (Ta = 25°C)				
Collector to Base Voltage	V_{CBO}	-40	40	V
Collector to Emitter Voltage	V_{CEO}	-30	30	V
Emitter to Base Voltage	V_{EBO}	-5.0	5.0	V
Collector Current (DC)	$I_{C(DC)}$	-3.0	3.0	A
Collector Current (pulse)	$I_{C(pulse)}$*	-7.0	7.0	A
Base Current (DC)	$I_{B(DC)}$	-0.6	0.6	A
Maximum Power Dissipations				
Total Power Dissipation				
at 25°C Case Temperature	$P_T (T_C = 25°C)$	10	10	W
at 25°C Ambient Temperature	$P_T (Ta = 25°C)$	1.0	1.0	W
Maximum Temperatures				
Junction Temperature	T_j	150	150	°C
Storage Temperature Range	T_{stg}	-55 to +150	-55 to +150	°C

*PW ≦ 10ms, duty cycle ≦ 50%

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

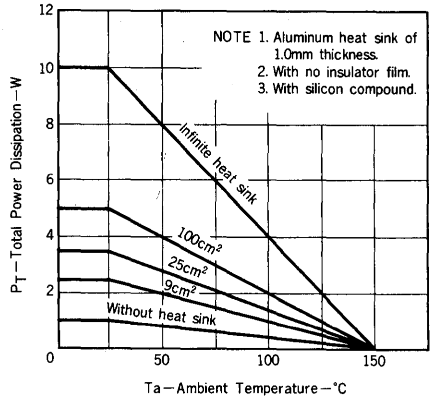
2SB772/2SD882

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			-1.0/1.0	μA	$V_{CB} = 30V$, $I_E = 0$
Emitter Cutoff Current	I_{EBO}			-1.0/1.0	μA	$V_{EB} = 3.0V$, $I_C = 0$
DC Current Gain	h_{FE1}	30	220/150			$V_{CE} = 2.0V$, $I_C = 20mA$*
DC Current Gain	h_{FE2}	60	160	400		$V_{CE} = 2.0V$, $I_C = 1.0A$*
Collector Saturation Voltage	$V_{CE(sat)}$		-0.3/0.3	-0.5/0.5	V	$I_C = 2.0A$, $I_B = 0.2A$*
Base Saturation Voltage	$V_{BE(sat)}$		-1.0/1.0	-2.0/2.0	V	$I_C = 2.0A$, $I_B = 0.2A$*
Gain Bandwidth Product	f_T		80/90		MHz	$V_{CE} = 5.0V$, $I_C = 0.1A$
Output Capacitance	C_{ob}		55/45		pF	$V_{CB} = 10V$, $I_E = 0$, f = 1.0MHz

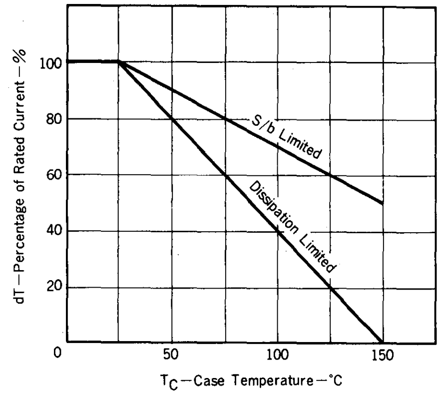
*Pulse Test PW ≦ 350μs, duty cycle ≦ 2%
h_{FE2} Classification / R : 60 – 120 Q : 100 – 200 P : 160 – 320 E : 200 – 400

TYPICAL CHARACTERISTICS (Ta = 25°C)

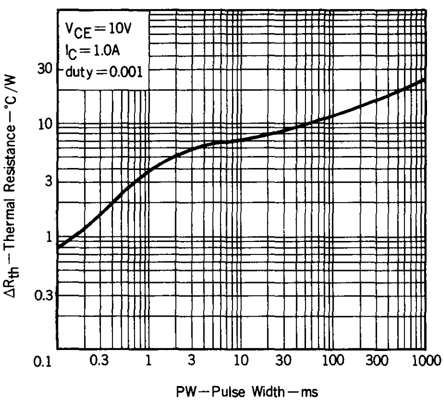
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



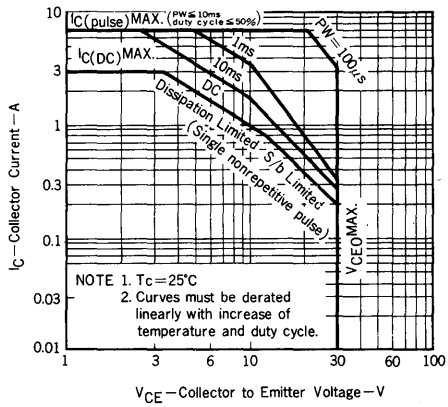
DERATING CURVES FOR ALL TYPES



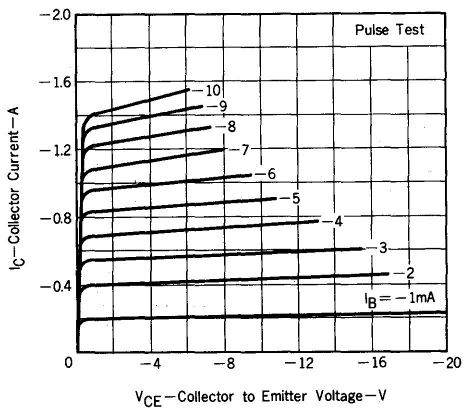
THERMAL RESISTANCE vs.
PULSE WIDTH



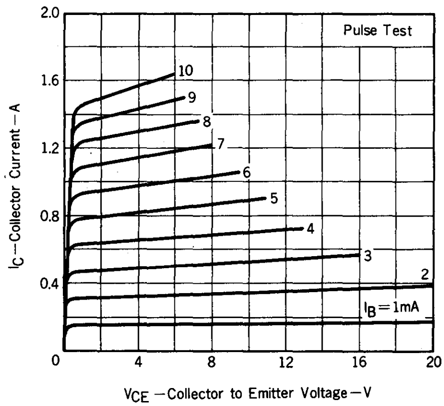
SAFE OPERATING AREA



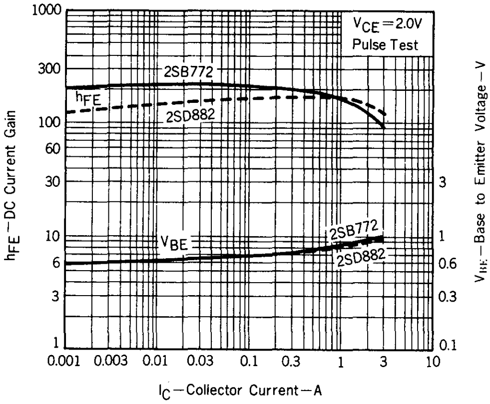
2SB772 COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



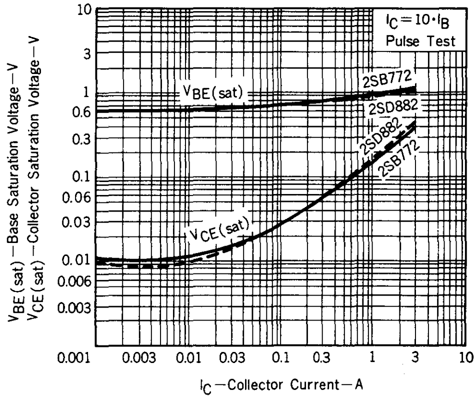
2SD882 COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



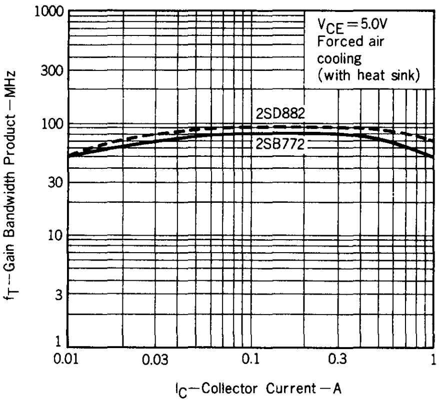
DC CURRENT GAIN, BASE TO EMITTER VOLTAGE vs. COLLECTOR CURRENT



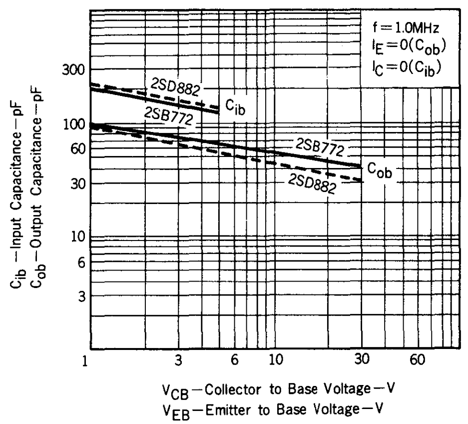
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



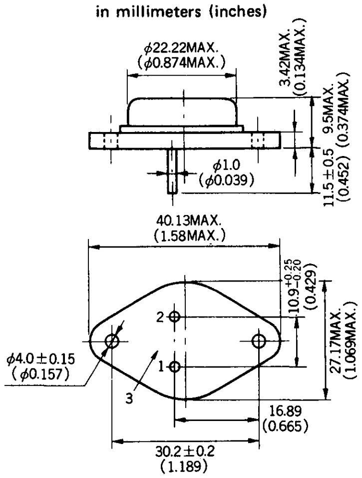
3

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
2SC940

B/W TV HORIZONTAL DEFLECTION OUTPUT NPN SILICON EPITAXIAL MESA TRANSISTOR

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector (Case)

EIAJ : TC-3, TB-3
JEDEC : TO-204MA (TO-3)
IEC : C14A, B18

- Suitable for Horizontal deflection OUTPUT application of 14" B/W TV Receivers.
- Wide Safe operating Area.

ABSOLUTE MAXIMUM RATINGS ($T_a = 25°C$)

Collector to Base Voltage	V_{CBO}	200	V
Collector to Emitter Voltage	V_{CES}	200	V
Collector to Emitter Voltage	V_{CEO}	90	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	7.5	A
Peak Collector Current	$I_{C(pulse)}$*	15	A
Total Power Dissipation	P_T	50	W
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−65 to +150	°C

*Peak current on high Tension discharge

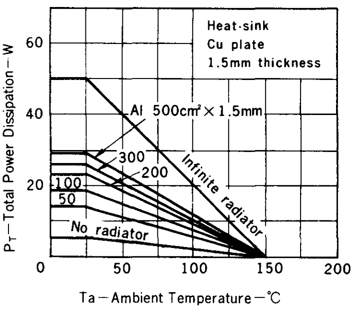
ELECTRICAL CHARACTERISTICS ($T_a = 25°C$)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	CONDITIONS
Collector Cutoff Current	I_{CBO}			2.0	mA	$V_{CB} = 90V$, $I_E = 0$
DC Current Gain	h_{FE}	15	40	70		$V_{CE} = 5V$, $I_C = 5A$*
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	$I_C = 5A$, $I_B = 0.5A$*
Fall Time	t_f			1.0	μs	$I_C = 5.0A$, $I_{B1} = 0.6A$/see test circuit.

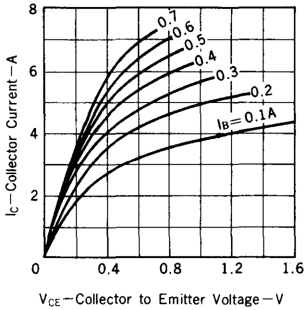
*Pulse condition PW = 350μs. duty cycle = 2%

TYPICAL CHARACTERISTICS (Ta = 25°C)

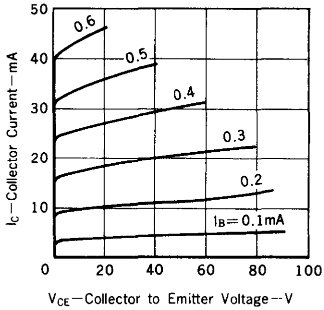
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

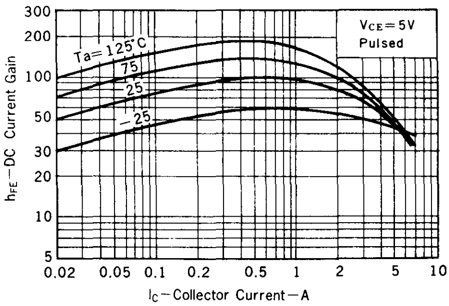


COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

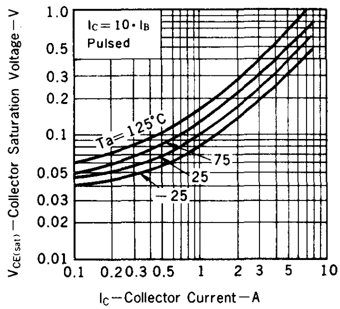


3

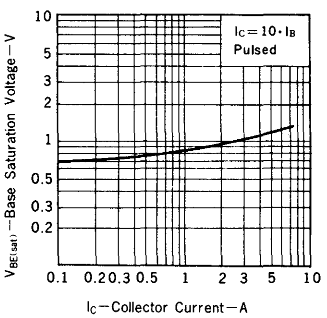
DC CURRENT GAIN vs. COLLECTOR CURRENT



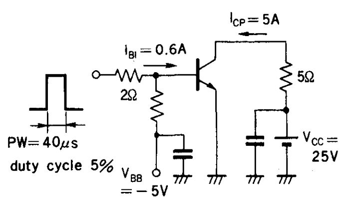
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



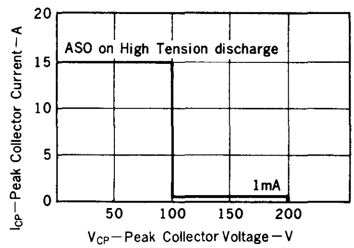
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



Fall Time Test Circuit



ASO on High Tension discharge

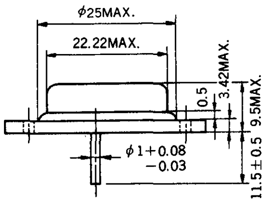


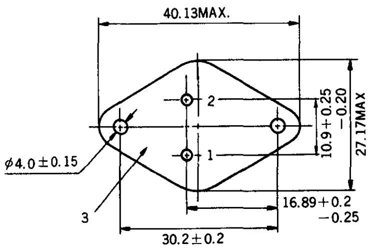
NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
2SC1325A

HORIZONTAL DEFLECTION OUTPUT FOR COLOR TV
NPN SILICON TRIPLE DIFFUSED MESA TRANSISTOR

PACKAGE DIMENSIONS (Unit : mm)





1. Base
2. Emitter
3. Collector connected to case

EIAJ : TC-3, TB-3
JEDEC : TO-204MA (TO-3)
IEC : C14A, B18

- Suitable for horizontal deflection output applications of 20″, 110°color TV receivers.
- High breakdown voltage
- Excellent t_f vs. Ta curve
- Wide safe operating area

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Collector to Base Voltage	V_{CBO}	1500	V
Collector to Emitter Voltage	V_{CEO}	600	V
Emitter to Base Voltage	V_{EBO}	6.0	V
Collector Current	$I_{C\ (DC)}$	6.0	A
Collector Current (pulse)	$I_{C\ (pulse)}$	15	A
Total Power Dissipation	P_T (Tc = 25°C)	80	W
Junction Temperature	Tj	150	°C
Storage Temperature	Tstg	-65 to +150	°C

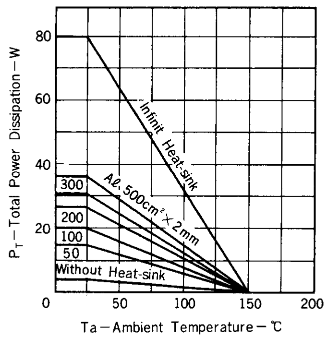
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			20	μA	V_{CB} = 1000V, I_E = 0
Emitter Cutoff Current	I_{EBO}			200	μA	V_{EB} = 5.0V, I_C = 0
DC Current Gain	h_{FE1}	10	19	45		V_{CE} = 15V, I_C = 1.0A *
	h_{FE2}	5.0	16	35		V_{CE} = 15V, I_C = 5.0A *
Collector Saturation Voltage	$V_{CE(sat)}$		1.5	4.0	V	I_C = 5.0A, I_B = 1.2A *
Base Saturation Voltage	$V_{BE(sat)}$	0.9	1.0	1.1	V	I_C = 5.0A, I_B = 1.2A *
Fall Time	t_f			0.8	μs	I_C = 5.0A, I_{B1} = 1.0A, I_{B2} = −1.0A See Application Circuit.
Storage Time	t_s		7.5	10	μs	I_C = 5.0A, I_{B1} = 1.0A, I_{B2} = −1.0A See Application Circuit.

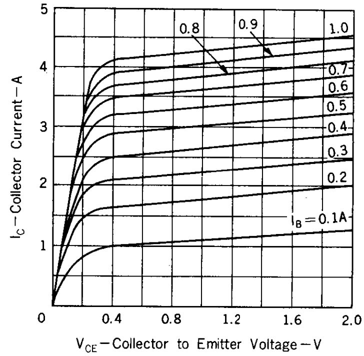
* Pulsed

TYPICAL CHARACTERISTICS (Ta = 25°C)

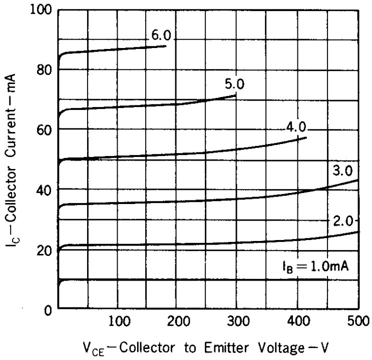
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



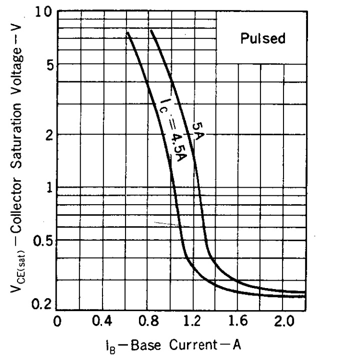
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



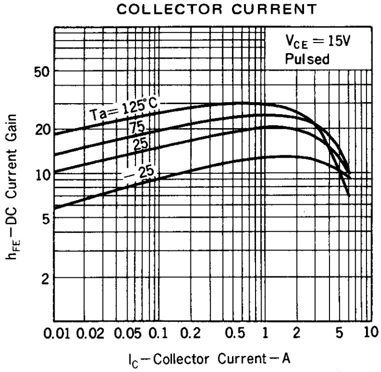
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



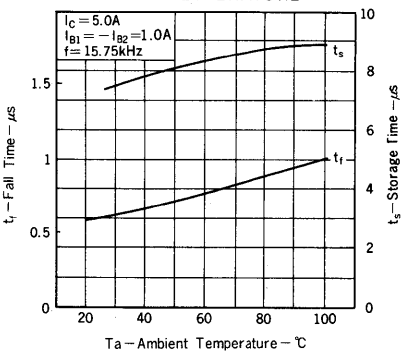
COLLECTOR SATURATION VOLTAGE vs.
BASE CURRENT

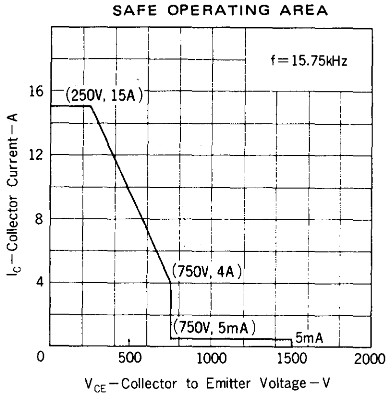


DC CURRENT GAIN vs.
COLLECTOR CURRENT

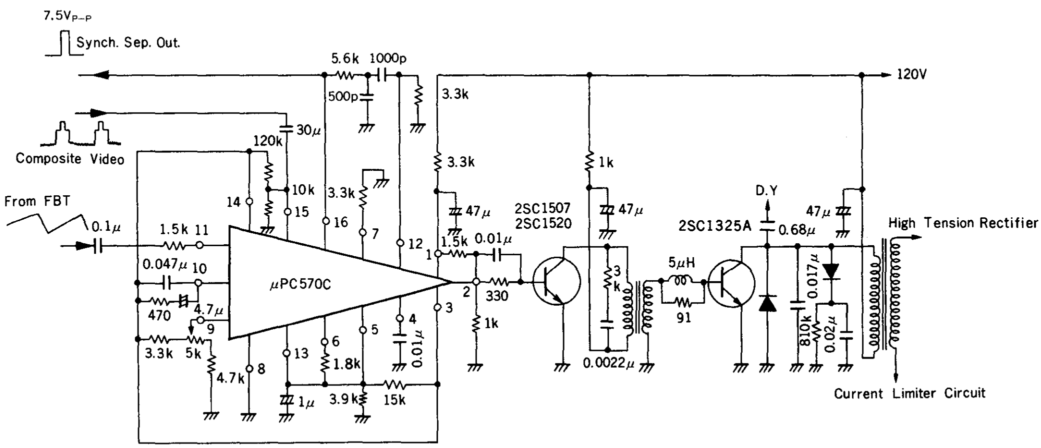


FALL AND STORAGE TIME vs.
AMBIENT TEMPERATURE

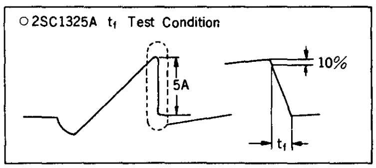




TYPICAL APPLICATION FOR HORIZONTAL OUTPUT OF COLOR TV



○ Drive Transformer
L_1 =25mH 2.4Ω
(0.26φ, 130T)
n_1/n_2=16



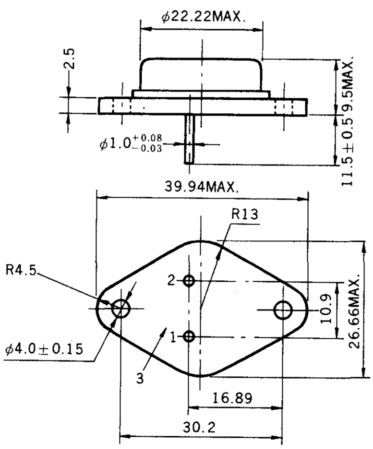
NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
2SC1358

HORIZONTAL DEFLECTION OUTPUT FOR COLOR TV
NPN SILICON TRIPLE DIFFUSED MESA TRANSISTOR

3

PACKAGE DIMENSIONS (Unit : mm)



1. Base
2. Emitter
3. Collector connected to case

EIAJ : TC-3, TB-3
JEDEC : TO-204MA (TO-3)
IEC : C14A, B18

- Suitable for Horizontal Deflection Output Applications of 20", 90° Color TV Receivers.
- High Breakdown Voltage.
- Excellent t_f vs. Ta Curve.
- Wide Safe Operating Area.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Collector to Base Voltage	V_{CBO}	1400	V
Collector to Emitter Voltage	V_{CEO}	500	V
Emitter to Base Voltage	V_{EBO}	6.0	V
Continuous Collector Current	$I_{C\ (DC)}$	4.5	A
Peak Collector Current	$I_{C\ (pulse)}$	10	A
Total Power Dissipation	P_T (Tc = 25°C)	50	W
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−65 to +150	°C

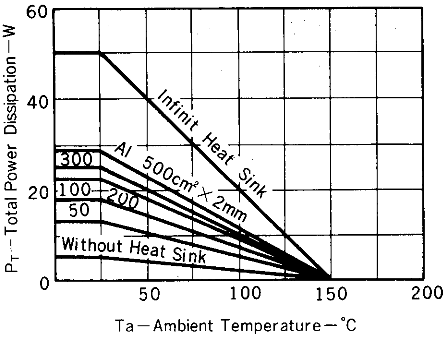
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			20	μA	V_{CB} = 1000V, I_E = 0
Emitter Cutoff Current	I_{EBO}			200	μA	V_{EB} = 5.0V, I_C = 0
DC Current Gain	h_{FE1}	10	19	45		V_{CE} = 15V, I_C = 0.5A *
	h_{FE2}	5	16	35		V_{CE} = 15V, I_C = 3.0A *
Collector Saturation Voltage	$V_{CE(sat)}$		7.0	10	V	I_C = 4.0A, I_B = 0.8A *
Base Saturation Voltage	$V_{BE(sat)}$	0.9	1.0	1.2	V	I_C = 4.0A, I_B = 0.8A *
Fall Time	t_f			1.0	μs	I_C = 4.0A, I_{B1} = 1.0A, I_{B2} = −1.0A See Application Circuit
Storage Time	t_s		7.5	10	μs	I_C = 4.0A, I_{B1} = 1.0A, I_{B2} = −1.0A See Application Circuit

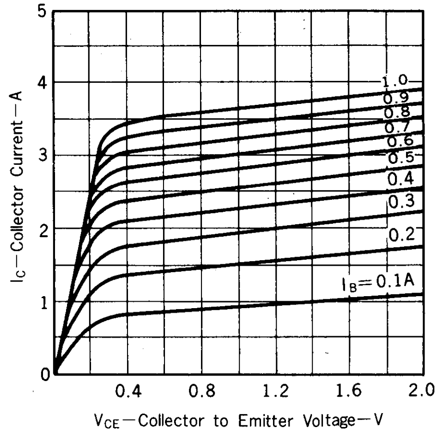
*Pulsed PW ≦ 350μs, duty cycle ≦ 2%

TYPICAL CHARACTERISTICS (Ta = 25°C)

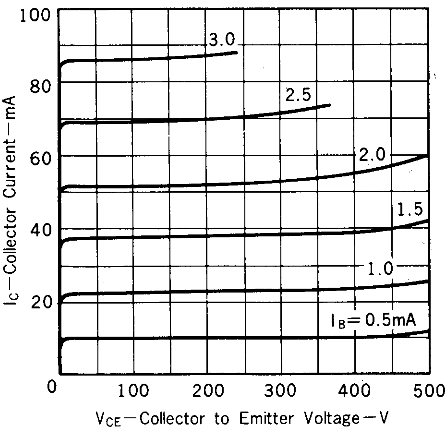
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



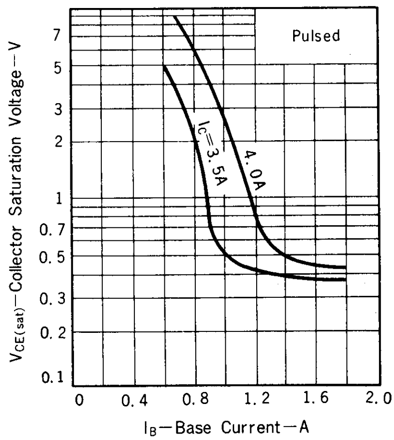
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



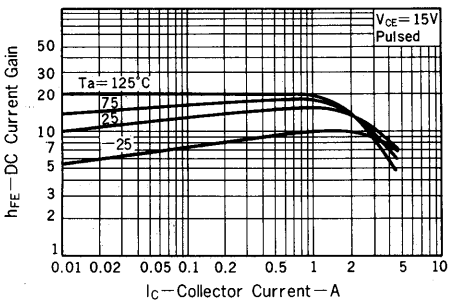
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



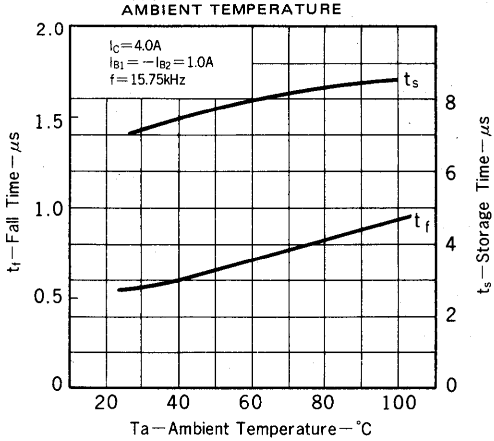
COLLECTOR SATURATION VOLTAGE vs. BASE CURRENT



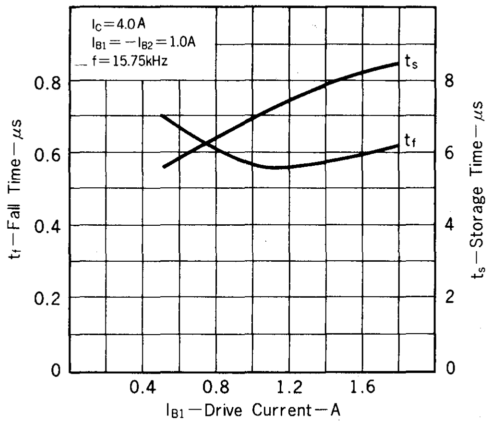
DC CURRENT GAIN vs. COLLECTOR CURRENT



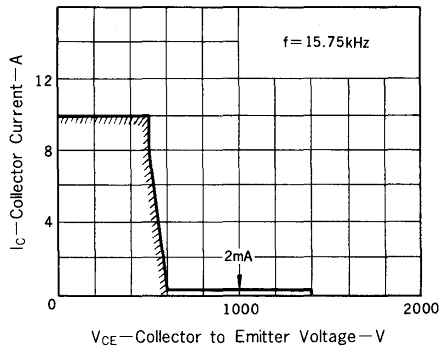
FALL AND STORAGE TIME vs. AMBIENT TEMPERATURE



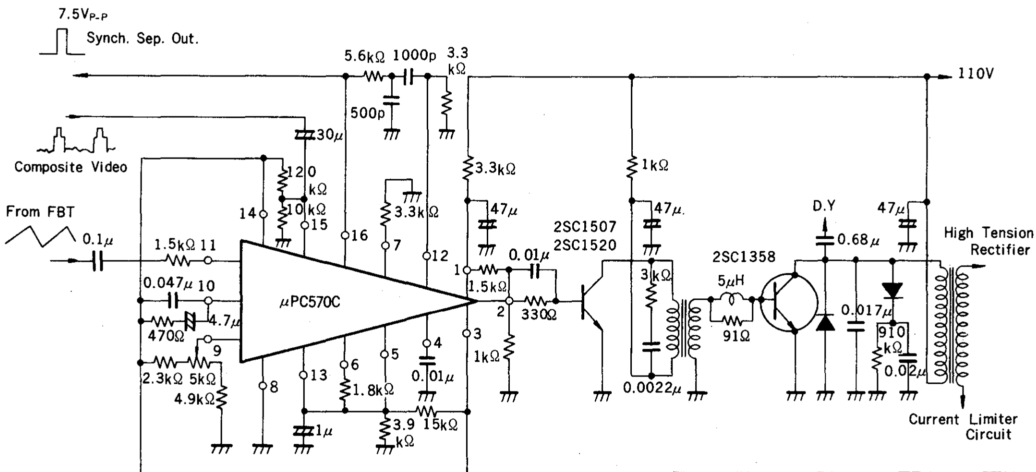
FALL AND STORAGE TIME vs. DRIVE CURRENT



SAFE OPERATING AREA



TYPICAL APPLICATION for HORIZONTAL OUTPUT of COLOR TV

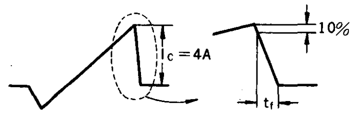


○ OSC Conditions
PW=25μs
f=15.75kHz

○ 2SC1507
2SC1520
I_{B1}=5mA
I_{B2}=−4.5mA
I_C=100mA

○ Drive Transformer
L_1=25mH 2.4Ω(0.26φ 130t)
n_1/n_2=16

○ 2SC1358 t_f Test Condition



NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR
2SC1449

AF POWER AMPLIFIER AND RF POWER AMPLIFIER
NPN SILICON EPITAXIAL TRANSISTOR

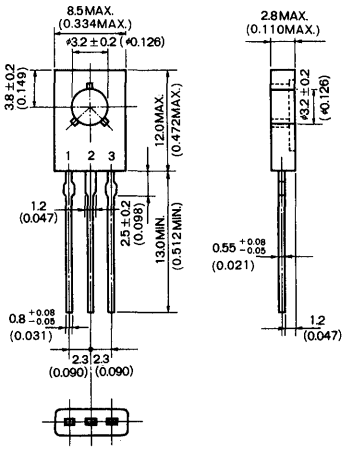
DESCRIPTION

The 2SC1449 is an NPN general purpose transistor designed for use in audio and radio frequency power amplifiers.

FEATURES

- Suitable for use in output stage of 3-watt audio amplifiers.
- High current: I_C: 2.0 A, $I_{C(pulse)}$: 3.0 A
- The smallest package in 3 watt class power transistor.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Collector connected to mounting plane
3. Base

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta=25°C)

Collector to Base Voltage	V_{CBO}	40	V
Collector to Emitter Voltage	V_{CEO}	35	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current (DC)	I_C	2.0	A
Collector Current (pulse)	$I_{C(pulse)}$*	3.0	A

Maximum Power Dissipations

Total Power Dissipation	P_T	1.0	W
Total Power Dissipation (at 25°C case temperature)	P_T	10	W

Maximum Temperatures

Storage Temperature	T_{stg}	−55 to +150	°C
Operating Junction Temperature	T_j	150	°C

* Pulse condition : pulse width≦10ms, duty cycle≦50%.

ELECTRICAL CHARACTERISTICS (Ta=25°C)

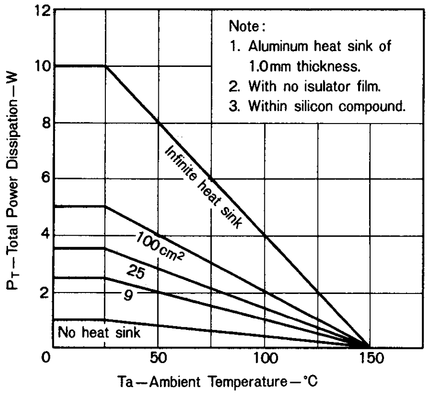
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.5	μA	V_{CB}=35 V, I_E=0
Emitter Cutoff Current	I_{EBO}			0.5	μA	V_{EB}=3.0 V, I_C=0
DC Current Gain	h_{FE}	40	90	250		V_{CE}=2.0 V, I_C=300 mA *
Collector Saturation Voltage	$V_{CE(sat)}$		0.2	0.7	V	I_C=500 mA, I_B=50 mA *
Base Saturation Voltage	$V_{BE(sat)}$		0.9	1.5	V	I_C=500 mA, I_B=50 mA *
Gain Bandwidth Product	f_T		55		MHz	V_{CE}=5.0 V, I_C=100 mA
Output Capacitance	C_{ob}		20		pF	V_{CB}=10 V, I_E=0, f=1 MHz

* Pulse test: pulse width≦350μs, duty cycle≦2%.

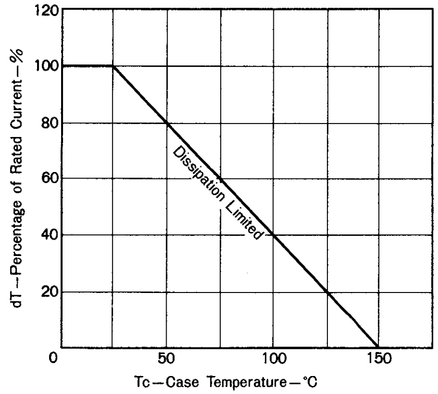
h_{FE} Classification: N; 40—80, M; 60—120, L; 80—160, K; 120—250.

TYPICAL CHARACTERISTICS (Ta=25°C unless otherwise noted)

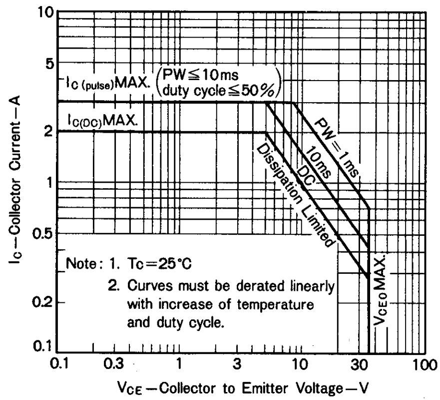
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



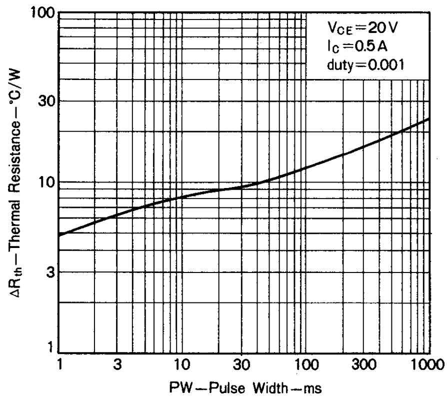
DERATING CURVE OF SAFE OPERATING AREAS



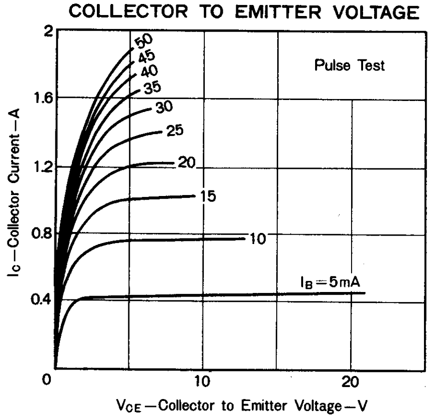
SAFE OPERATING AREAS



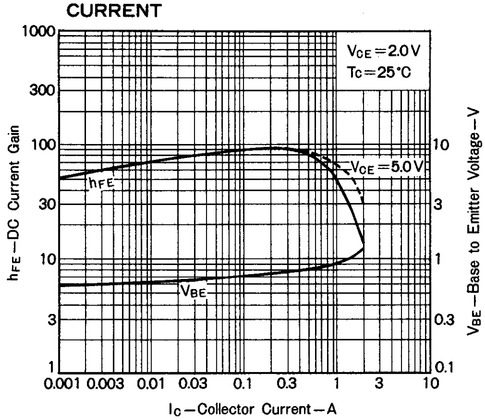
TRANSIENT THERMAL RESISTANCE



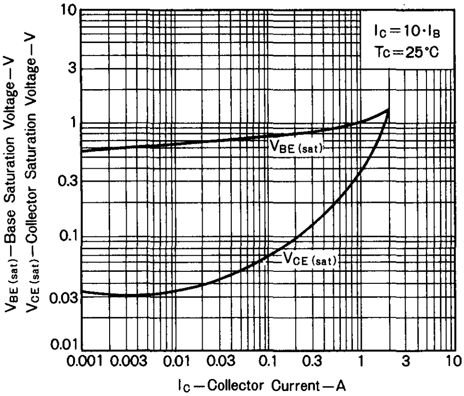
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



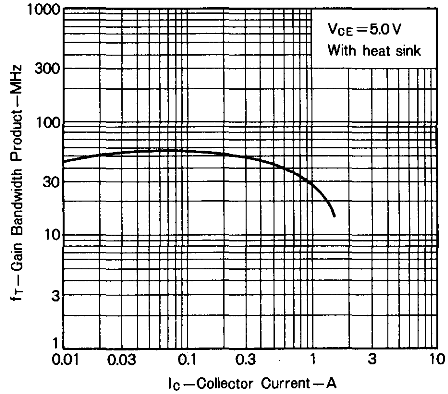
DC CURRENT GAIN AND BASE TO EMITTER VOLTAGE vs. COLLECTOR CURRENT



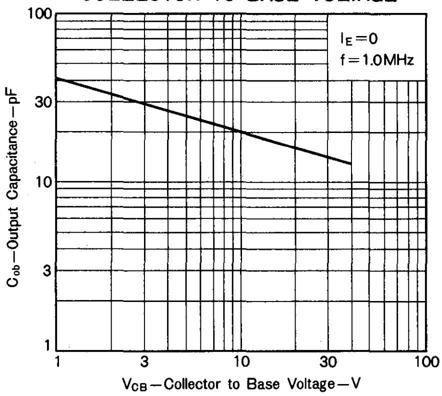
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

SILICON TRANSISTORS
2SC1505,2SC1506,2SC1507

NPN SILICON TRIPLE DIFFUSED TRANSISTORS
COLOR TV CHROMA AND SOUND OUTPUT AMPLIFIERS

3

DESCRIPTION

The 2SC1505, 2SC1506 and 2SC1507 are high voltage triple diffused silicon transistors. These transistors are designed for use in line-operated color TV chroma output circuits and sound output circuits.

Three types of different lead configuration are prepared for designer's convenience.

FEATURES

- Suitable for chroma output circuits and sound output circuits ($P_O = 1.5\,W$) in line-operated color TV receivers.
- High voltage, high f_T and low C_{ob}.
- Three types of different lead configuration available.
  - 2SC1505 . . . . . Standard type
  - 2SC1506 . . . . . TO-66 replacement
  - 2SC1507 . . . . . Upright mounting

ABSOLUTE MAXIMUM RATINGS (Ta=25°C)

Collector to Base Voltage	V_{CBO}	300	V
Collector to Emitter Voltage	V_{CEO}	300	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Collector Current	I_C	200	mA
Total Power Dissipation	$P_T(T_C=25°C)$	15	W
Total Power Dissipation	$P_T(T_a=25°C)$	1.2	W
Junction Temperature	Tj	150	°C
Storage Temperature	Tstg	−55 to +150	°C

ELECTRICAL CHARACTERISTICS (Ta=25°C)

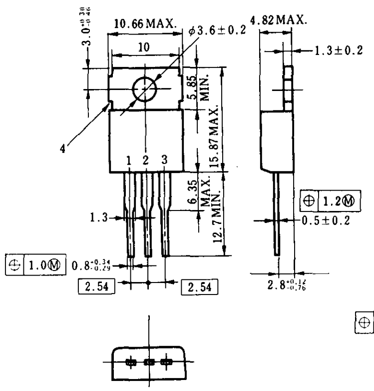
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			100	nA	$V_{CB}=200V, I_E=0$
Emitter Cutoff Current	I_{EBO}			100	nA	$V_{EB}=5.0V, I_C=0$
DC Current Gain	h_{FE}	40	80	200		$V_{CE}=10V, I_C=10mA$ *
Collector Saturation Voltage	$V_{CE(sat)}$			2.0	V	$I_C=50mA, I_B=5.0mA$ *
Gain Bandwidth Product	f_T	50	80		MHz	$V_{CE}=30V, I_E=-10mA$
Collector to Base Capacitance	C_{ob}			4.5	pF	$V_{CB}=50V, I_E=0, f=1.0MHz$

*Pulse test PW ≦ 350 μs, duty cycle ≦ 2.0%

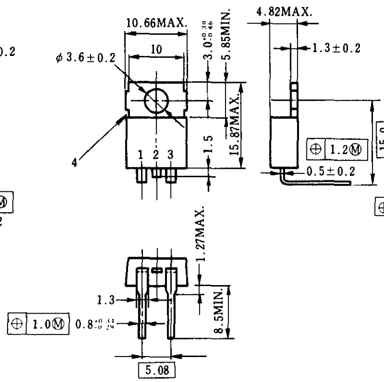
h_{FE} classification /M:40−80 L:60−120 K:100−200

PACKAGE DIMENSIONS (Unit:mm)

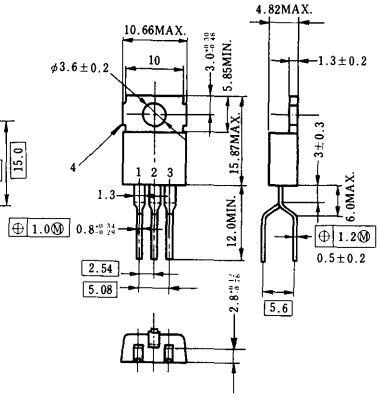
2SC1505



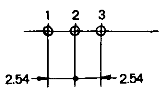
2SC1506

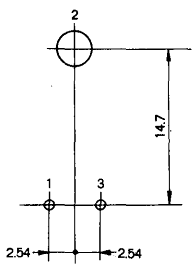


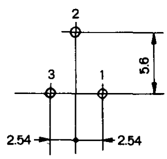
2SC1507



MOUNTING HOLE LAYOUT DIMENSIONS







LEAD CONNECTION

1. Base EIAJ :SC-46
2. Collector(Fin) JEDEC:TO-220AB
3. Emitter IEC :–
4. Fin

As the clearance between collector and Base, Emitter is narrow, care should be taken at high voltage use.

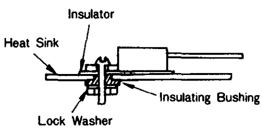
1. Base EIAJ :SC-45
2. – JEDEC:TO-220AA
3. Emitter IEC :–
4. Collector(Fin)

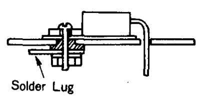
As the collector lead is cut, solder lug is used instead of it.

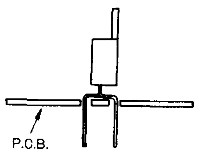
1. Base EIAJ :–
2. Collector(Fin) JEDEC:–
3. Emitter IEC :–
4. Fin

Convenient in case of free-air use.

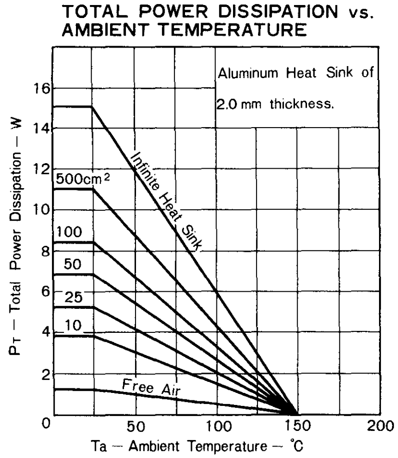
SUGGESTED MOUNTING METHODS

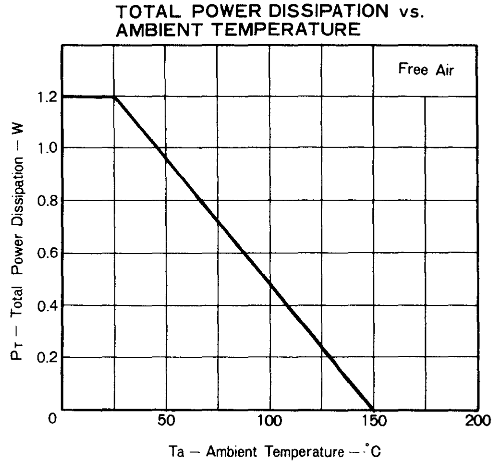




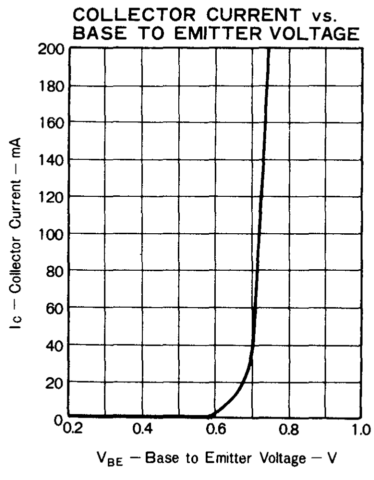


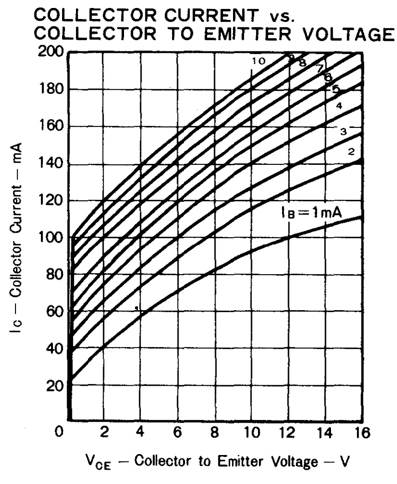
POWER-TEMPERATURE DERATING CURVES

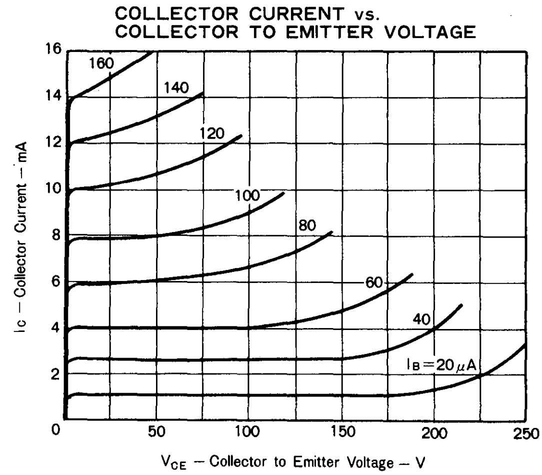


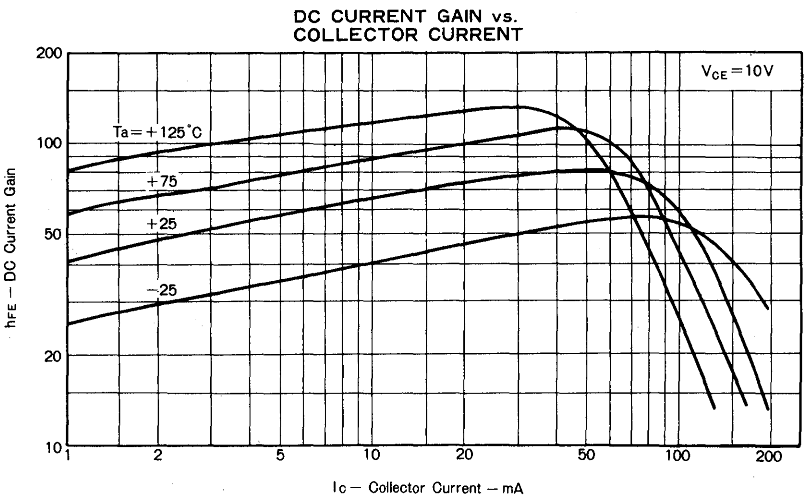


TYPICAL CHARACTERISTICS (Ta=25°C)

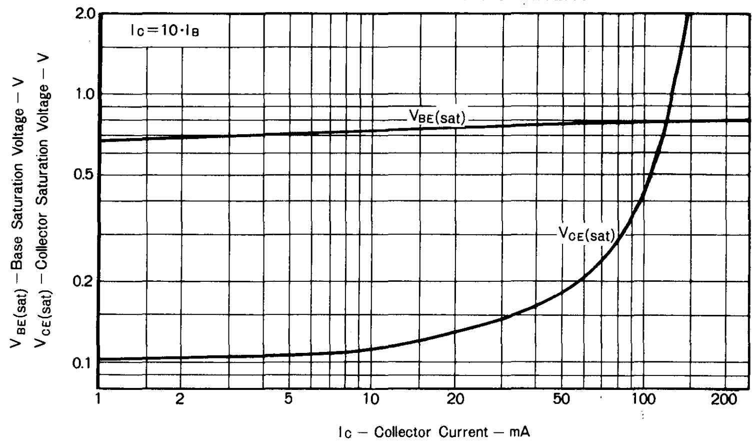




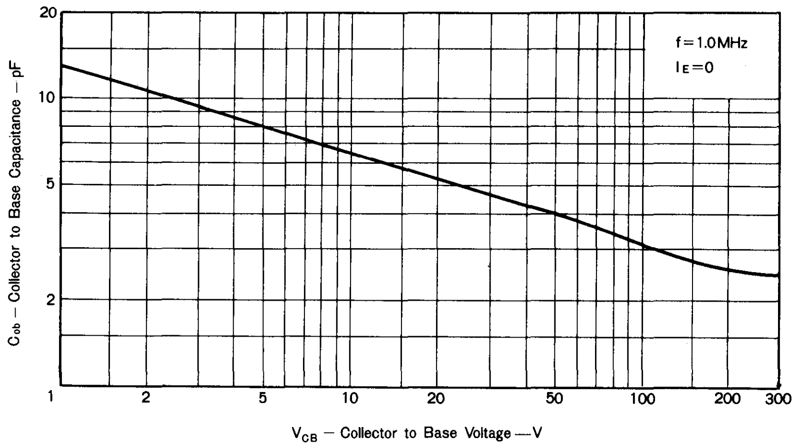

COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE
160
140
120
100
80
60
40
IB=20μA
16
14
12
10
8
6
4
2
0
50
100
150
200
250
Ic – Collector Current – mA
VCE – Collector to Emitter Voltage – V


DC CURRENT GAIN vs.
COLLECTOR CURRENT
VCE=10V
Ta=+125°C
+75
+25
−25
200
100
50
20
10
1
2
5
10
20
50
100
200
hFE – DC Current Gain
Ic – Collector Current – mA

BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

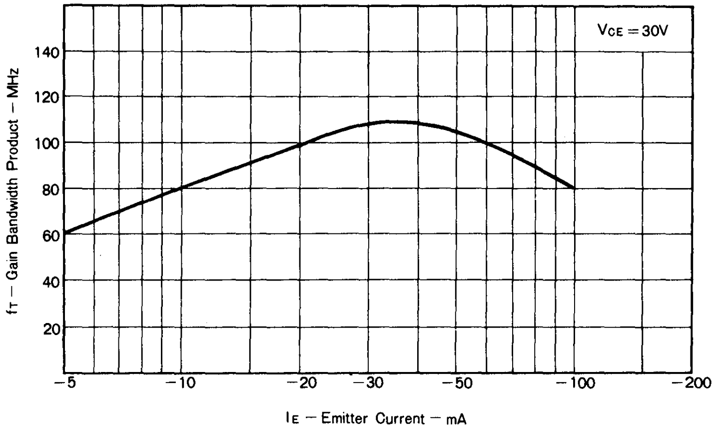


OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



3

GAIN BANDWIDTH PRODUCT vs.
EMITTER CURRENT



NEC
ELECTRON DEVICE

SILICON TRANSISTORS
2SC1520,2SC1521

COLOR TV CHROMA AND VIDEO OUTPUT AMPLIFIERS
NPN SILICON TRIPLE DIFFUSED TRANSISTOR

DESCRIPTION

The 2SC1520 and 2SC1521 are high voltage triple diffused silicon transistors. These transistors are designed for use in line-operated color TV chroma output circuits and video output circuits.

Two types of different lead configuration are prepared for designer's convenience.

3

FEATURES

- Suitable for chroma output circuits and video output circuits in line-operated color TV receivers.
- High voltage, high f_T and low C_{ob}.
- Two types of different lead configuration available.
  - 2SC1520 . . . . . Upright mounting
  - 2SC1521 . . . . . Flat mounting

ABSOLUTE MAXIMUM RATINGS (Ta=25°C)

Collector to Base Voltage	V_{CBO}	250	V
Collector to Emitter Voltage	V_{CEO}	250	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Collector Current	I_C	200	mA
Power Dissipation	P_T(Tc=25°C)	10	W
Power Dissipation	P_T(Ta=25°C)	1.0	W
Junction Temperature	Tj	150	°C
Storage Temperature Range	Tstg	−55 to +150	°C

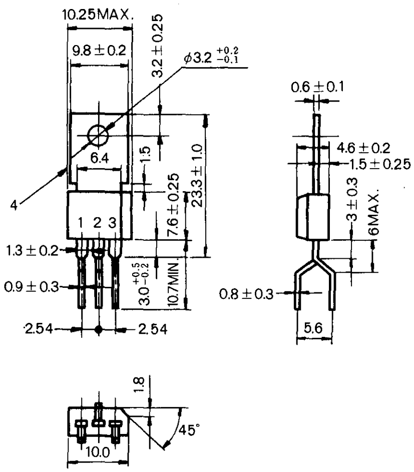
ELECTRICAL CHARACTERISTICS (Ta=25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cut-off Current	I_{CBO}			100	nA	V_{CB}=150V, I_E=0
Emitter Cut-off Current	I_{EBO}			100	nA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE}	40	80	200		V_{CE}=10V, I_C=10mA *
Collector Saturation Voltage	V_{CE}(sat)			2.0	V	I_C=50mA, I_B=5.0mA *
Gain Bandwidth Product	f_T	50	80		MHz	V_{CE}=30V, I_E=−10mA
Collector to Base Capacitance	C_{ob}			4.5	pF	V_{CB}=50V, I_E=0, f=1.0MHz

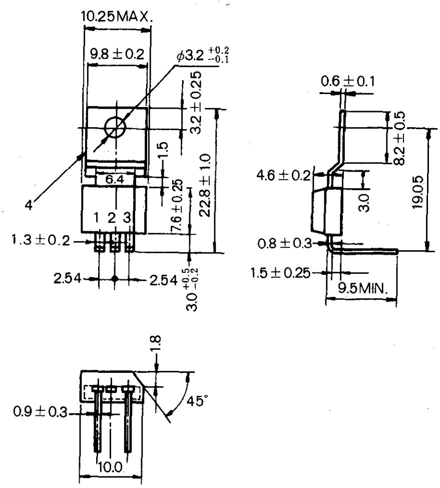
*Pulse test : PW ≦ 350μs, duty cycle≦2%

PACKAGE DIMENSIONS (Unit : mm)

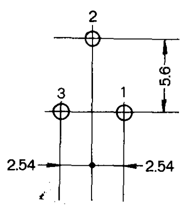
2SC1520

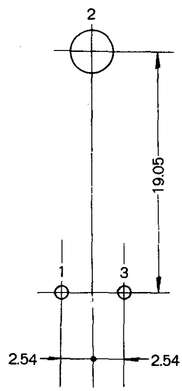


2SC1521



MOUNTING HOLE LAYOUT DIMENSIONS



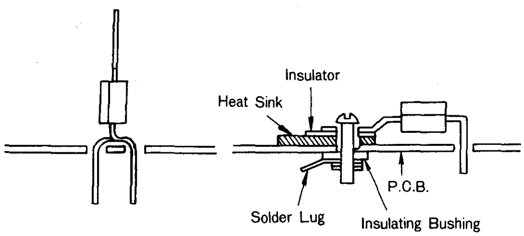


LEAD CONNECTION

1. Base
2. Collector (Fin)
3. Emitter
4. Fin(Collector)

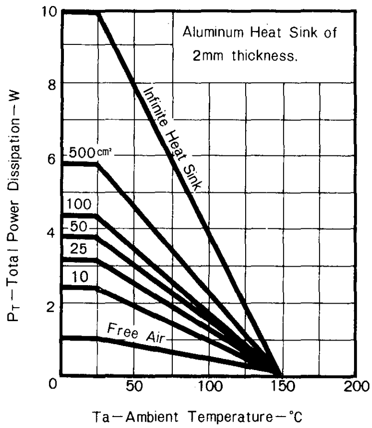
1. Base
2. Collector (Fin)
3. Emitter
4. Fin (Collector)

SUGGESTED MOUNTING METHODS

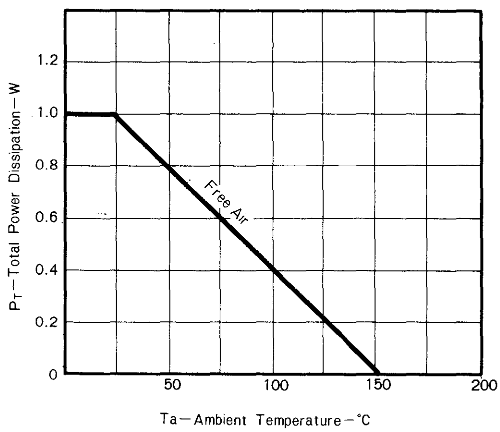


TYPICAL CHARACTERISTICS (Ta=25°C)

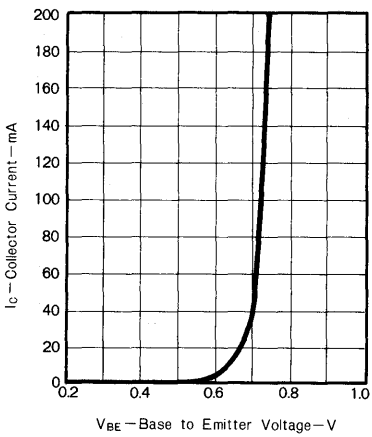
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



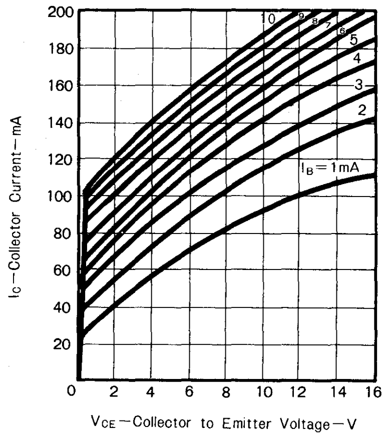
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE

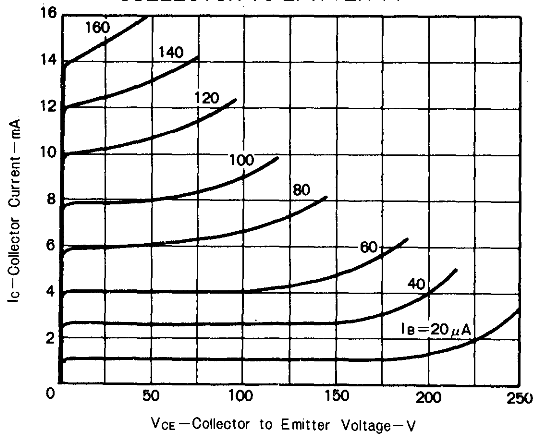


COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

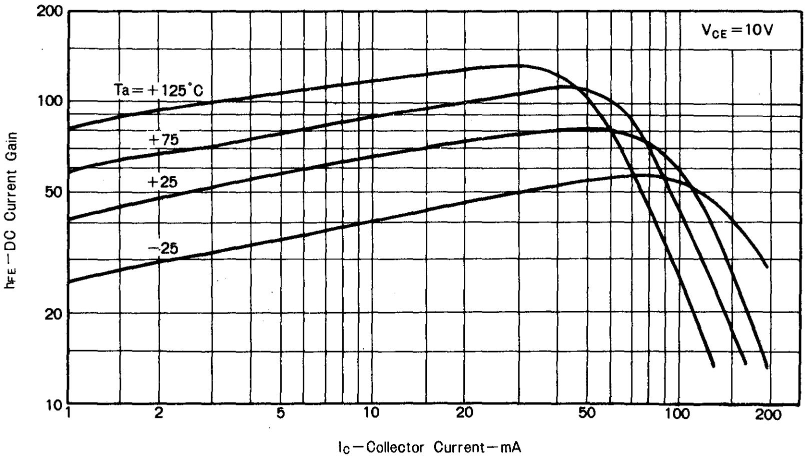


3

COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE

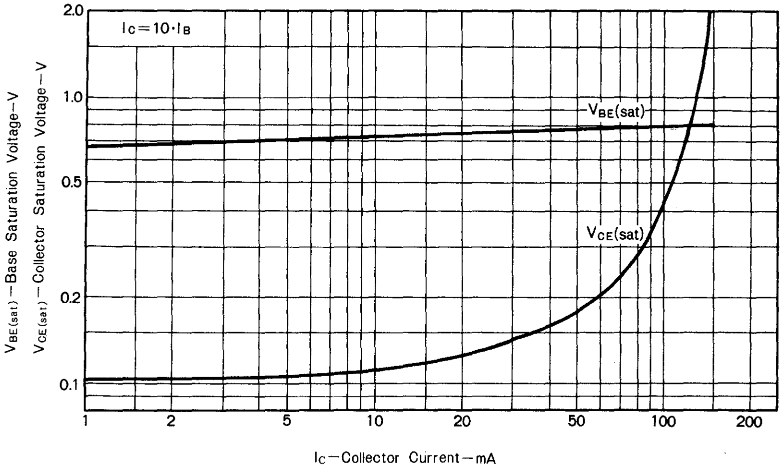


DC CURRENT GAIN vs. COLLECTOR CURRENT

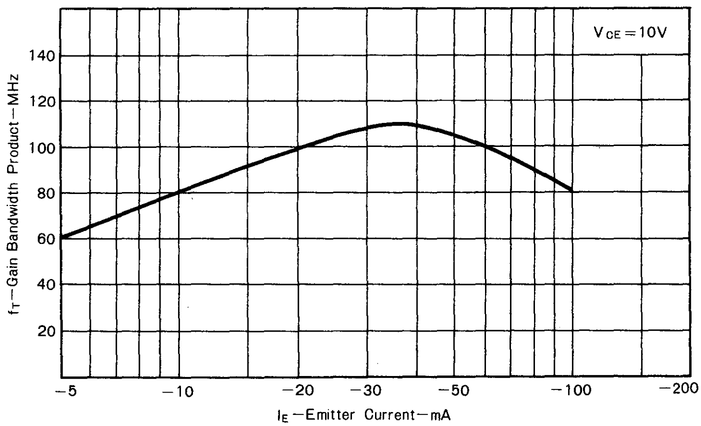


3

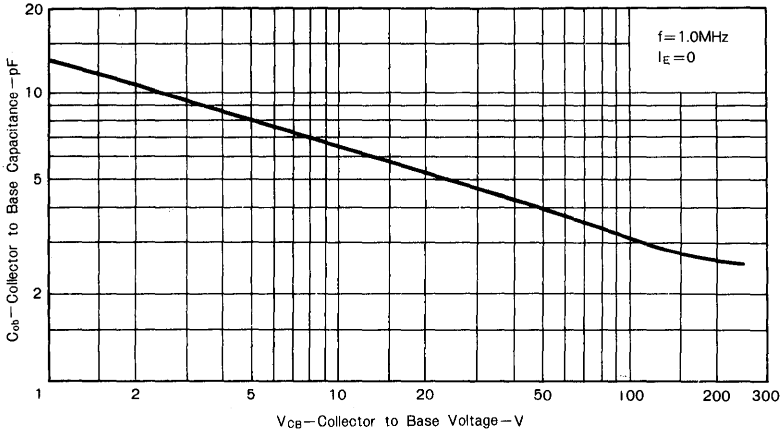
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



COLLECTOR TO BASE CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE

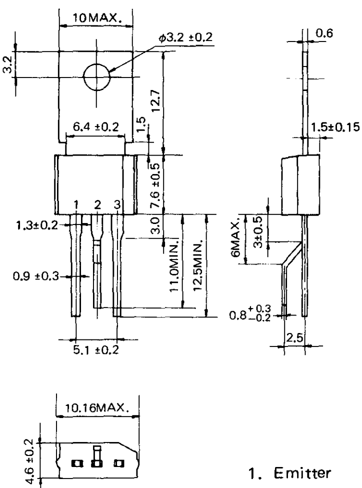


NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SC1758

COLOR TV CHROMA,VIDEO OUTPUT
NPN SILICON TRIPLE DIFFUSED TRANSISTOR

PACKAGE DIMENSIONS
(Unit: mm)



1. Emitter
2. Base
3. Collector

DESCRIPTION
The 2SC1758 is a high voltage silicon transistor intended for use in a color TV receiver and is ideal for video, chroma and RGB output applications.

FEATURES
- High voltage 300V
- Low Cob .... 3.0pF @ 20V
- High power dissipation.

ABSOLUTE MAXIMUM RATINGS (Ta=25°C)

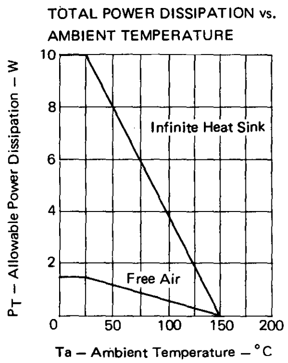
Collector to Base Voltage	V_{CBO}	300	V
Collector to Emitter Voltage	V_{CEO}	300	V
Emitter to Base Voltage	V_{EBO}	7	V
Collector Current	I_C	100	mA
Power Dissipation	P_T(Tc=25°C)	10	W
Power Dissipation	P_T(Tc=70°C)	6.4	W
Power Dissipation	P_T(Ta=50°C)	1.33	W
Thermal Resistance			
Junction to Case	R_θ(J-C)	12.5	°C/W
Junction to Ambient	R_θ(J-a)	75	°C/W
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

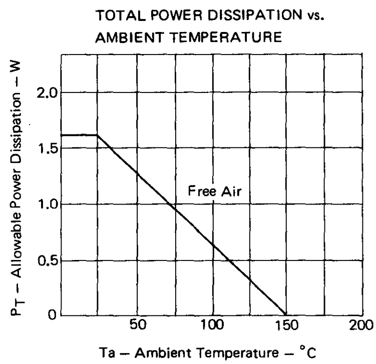
ELECTRICAL CHARACTERISTICS (Ta=25°C)

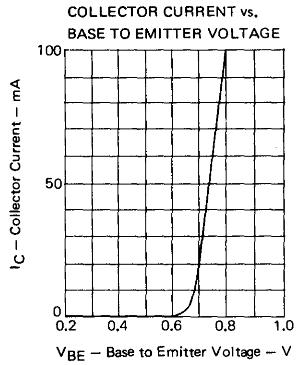
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Voltage	LV_{CEO}	300			V	I_C=1.0mA
Collector Cutoff Current	I_{CBO1}			1.0	μA	V_{CB}=300V, I_E=0
Collector Cutoff Current	I_{CBO2}			100	nA	V_{CB}=200V, I_E=0
Emitter Cutoff Current	I_{EBO}			100	nA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE}	40	120	300		V_{CE}=10V, I_C=20mA *
Collector Saturation Voltage	$V_{CE(sat)}$			0.5	V	I_C=25mA, I_B=2.5mA *
Gain Bandwidth Product	f_T	60	80		MHz	V_{CE}=20V, I_E=−10mA
Collector to Base Capacitance	C_{ob}			3.0	pF	V_{CB}=20V, I_E=0, f=1.0MHz

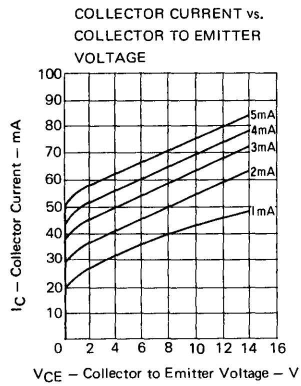
* Pulsed: Pulse Width ≦ 350 μs, duty cycle ≦ 2%

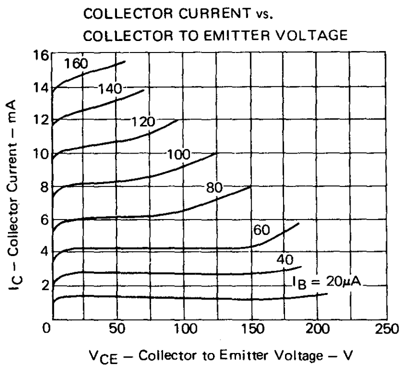
TYPICAL CHARACTERISTICS (Ta=25°C)

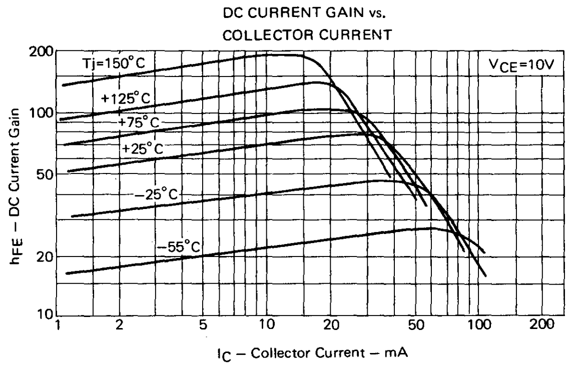




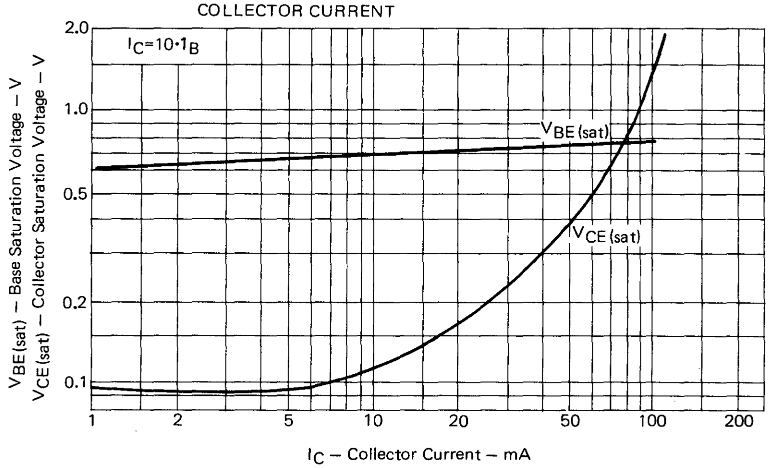




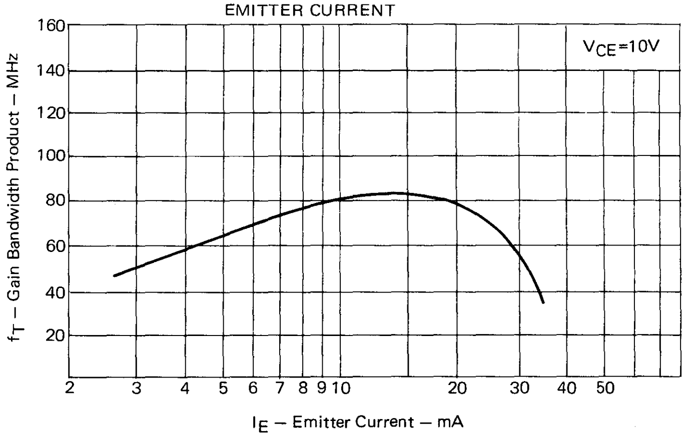




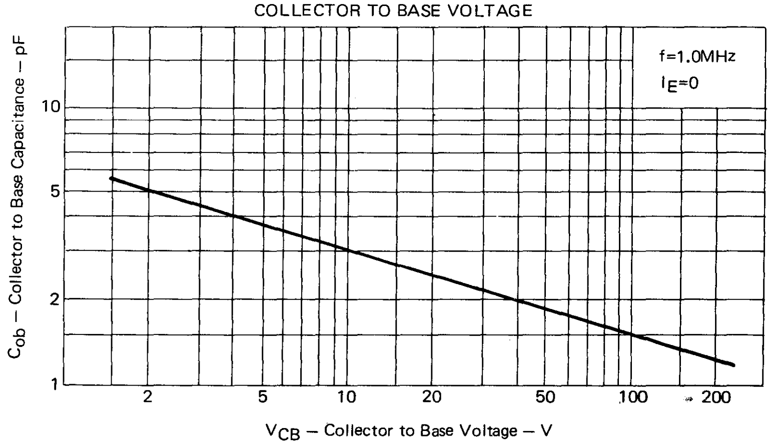
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



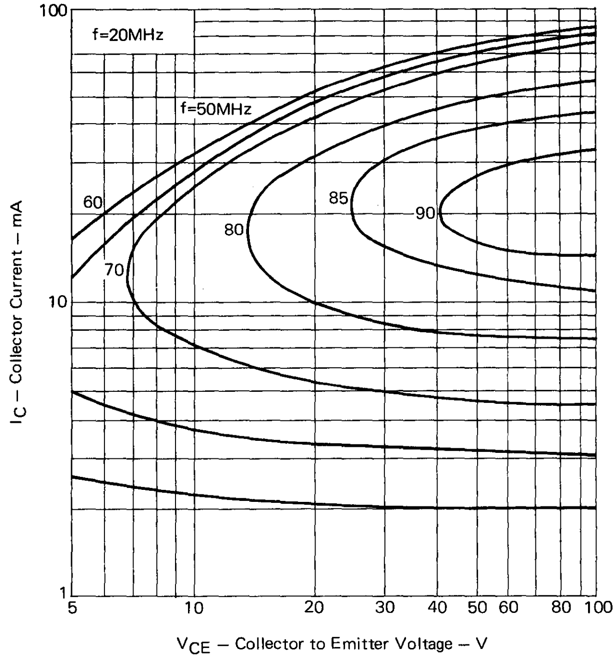
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



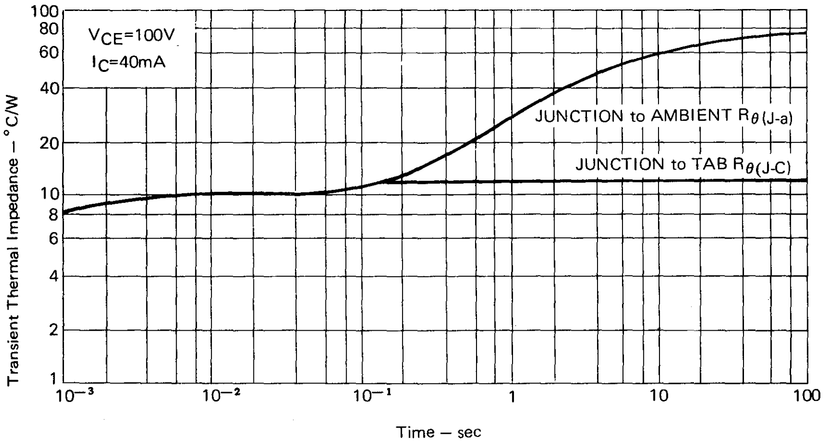
COLLECTOR TO BASE CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



GAIN BANDWIDTH PRODUCT MAP



MAXIMUM TRANSIENT THERMAL IMPEDANCE



NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SC2371

NPN SILICON TRIPLE DIFFUSED TRANSISTOR
VIDEO OUTPUT TRANSISTOR

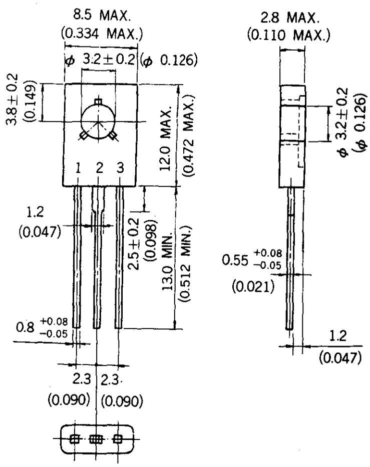
DESCRIPTION

The 2SC2371 is designed for use in Color TV chroma output circuits.

FEATURES

- High Voltage
  $V_{CBO} \geqq 300$ V, $V_{CEO} \geqq 300$ V
- Low C_{re}, High f_T
  $C_{re} \leqq 3.0$ pF ($V_{CB} = 30$ V)
  $f_T \geqq 50$ MHz ($V_{CE} = 30$ V, $I_E = -10$ mA)

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Collector connected to mounting plane
3. Base

3

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Collector to Base Voltage	V_{CBO}	300	V
Collector to Emitter Voltage	V_{CEO}	300	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Collector Current	I_C	100	mA
Total Power Dissipation	$P_{T(T_C=25\ °C)}$	10	W
Total Power Dissipation	$P_{T(Ta=25\ °C)}$	1.25	W
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−55 to +150	°C

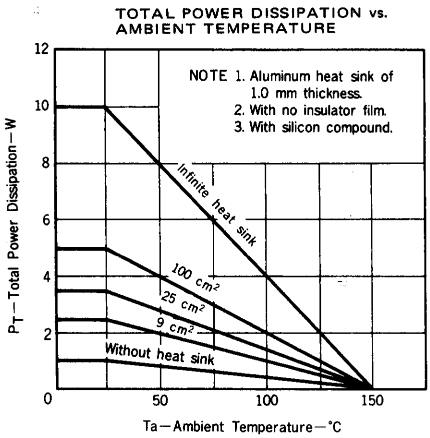
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

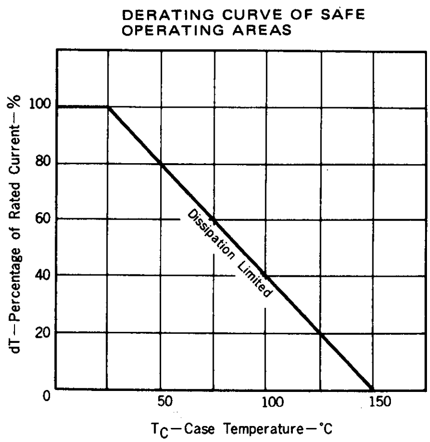
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			100	nA	$V_{CB} = 200$ V, $I_E = 0$
Emitter Cutoff Current	I_{EBO}			100	nA	$V_{EB} = 5.0$ V, $I_C = 0$
DC Current Gain	h_{FE}	40	80	250		$V_{CE} = 10$ V, $I_C = 10$ mA *
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	$I_C = 30$ mA, $I_B = 3.0$ mA *
Gain Bandwidth Product	f_T	50	80		MHz	$V_{CE} = 30$ V, $I_E = -10$ mA
Feedback Capacitance	C_{re}			3.0	pF	$V_{CB} = 20$ V, $I_E = 0$, f = 1.0 MHz

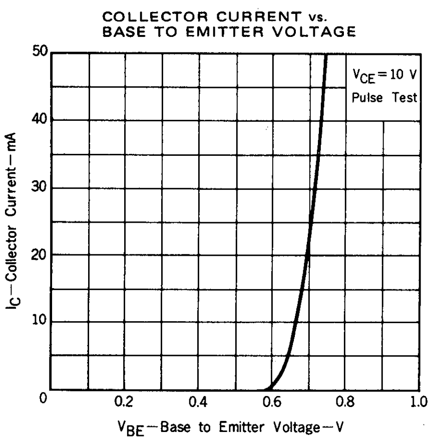
*Pulse test PW ≦ 350 μs, duty cycle ≦ 2.0 %

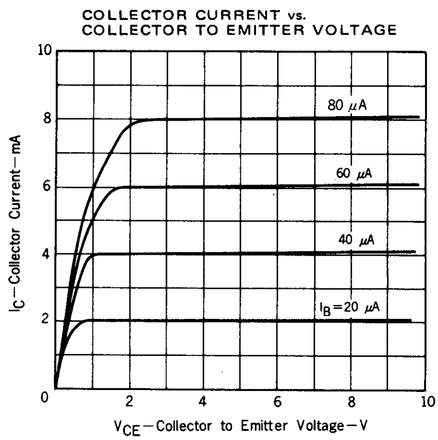
h_{FE} Classification/N : 40 – 80 M : 60 – 120 L : 100 – 200 K : 160 – 250

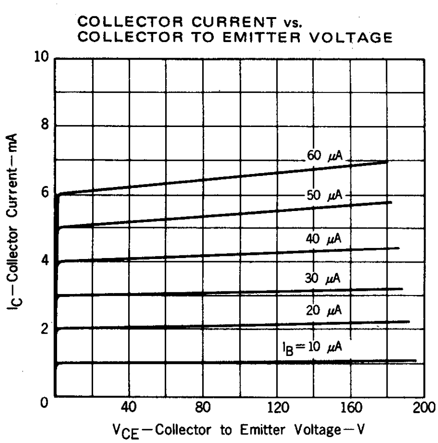
TYPICAL CHARACTERISTICS (Ta = 25 °C)

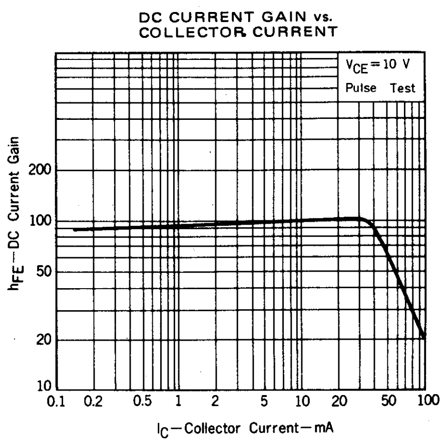




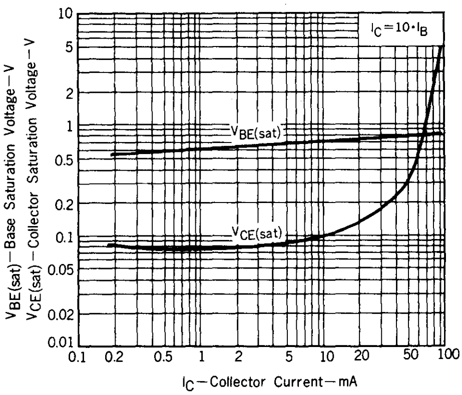




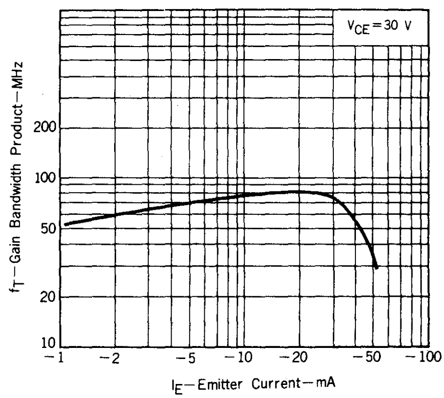




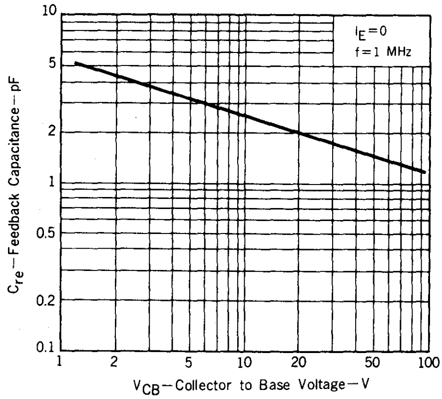
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



FEEDBACK CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SC2373

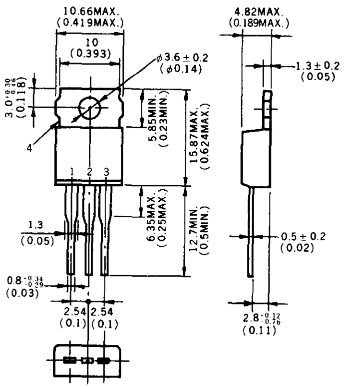
B/W TV HORIZONTAL DEFLECTION OUTPUT
NPN SILICON EPITAXIAL TRANSISTOR

DESCRIPTION

The 2SC2373 is designed for use in B/W TV deflection output circuits.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Base
2. Collector Fin
3. Emitter
4. Fin

EIAJ : SC-46
JEDEC : TO-220AB
IEC : –

FEATURES

- Low saturation voltage. $V_{CE(sat)}$: 0.4V(TYP.) at I_C = 5.0A, I_B = 0.5A
- Very fast speed switching. t_f : 0.3 μs (TYP.) at I_C = 5.0A, I_{B1} = 0.6A

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Collector to Base Voltage (R_{BE} = ∞)	V_{CBO}	200	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	100	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	7.5	A
Peak Collector Current	$I_{C(peak)}$	15	A
Total Power Dissipation (T_C = 25°C)	P_T	40	W
Maximum Temperatures			
Storage Temperature	T_{stg}	-55 to +150	°C
Operating Junction Temperature	T_j	150	°C

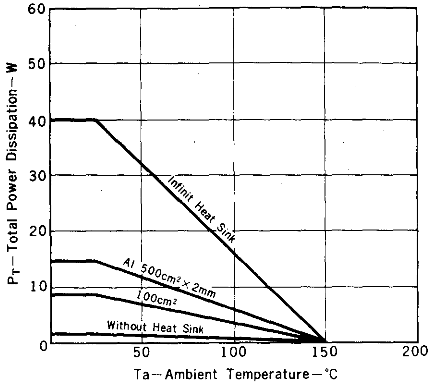
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			10	μA	V_{CB} = 150V, I_E = 0
Emitter Cutoff Current	I_{EBO}			10	μA	V_{EB} = 5.0V, I_C = 0
DC Current Gain	h_{FE}	15	35	75		V_{CE} = 5.0V, I_C = 5.0A*
Collector Saturation Voltage	$V_{CE(sat)}$		0.4	1.5	V	I_C = 5.0A, I_B = 0.5A*
Base Saturation Voltage	$V_{BE(sat)}$		1.0	1.5	V	I_C = 5.0A, I_B = 0.5A*
Fall Time	t_f		0.3	1.0	μs	I_C=5.0A, I_{B1}=0.6A, See Test circuit.
Gain Bandwidth Product	f_T		10		MHz	V_{CE} = 5.0V, I_E = 0.1A

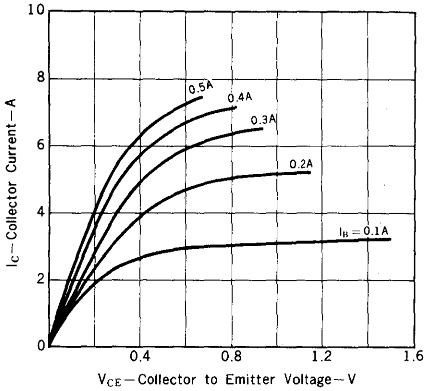
*Pulse Test : PW ≦ 350 μs, duty cycle ≦ 2.0%

TYPICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE

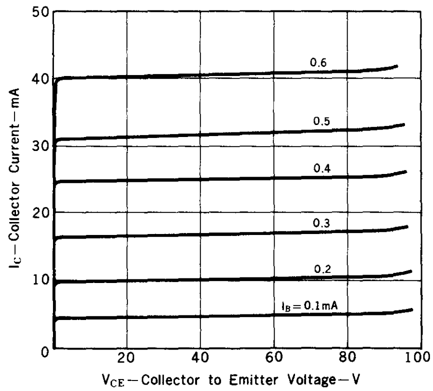


COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

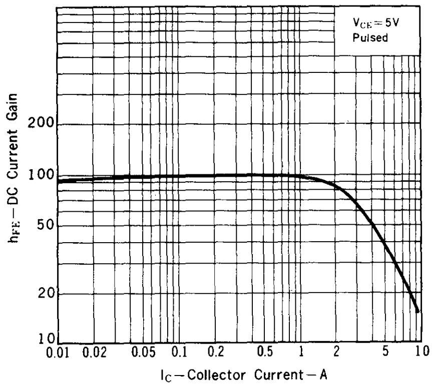


3

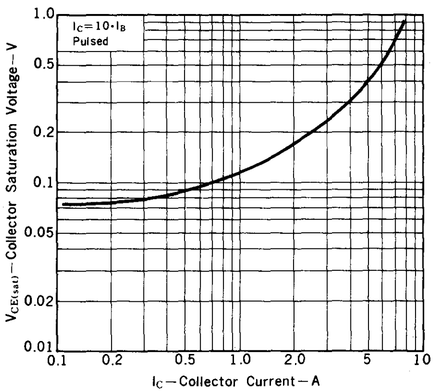
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



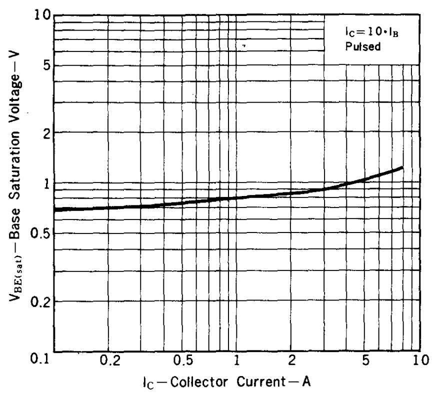
DC CURRENT GAIN vs. COLLECTOR CURRENT



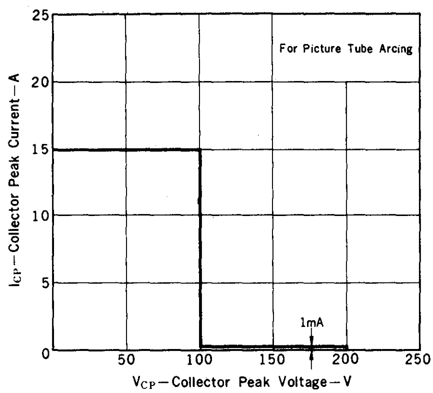
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



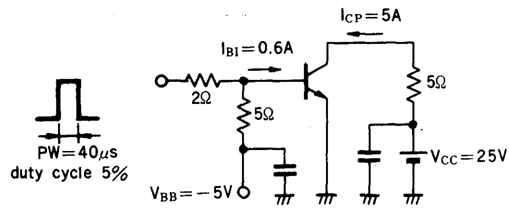
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



SAFE OPERATING AREA



FALL TIME TEST CIRCUIT



NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SC2688

NPN SILICON TRIPLE DIFFUSED TRANSISTOR
VIDEO OUTPUT TRANSISTOR

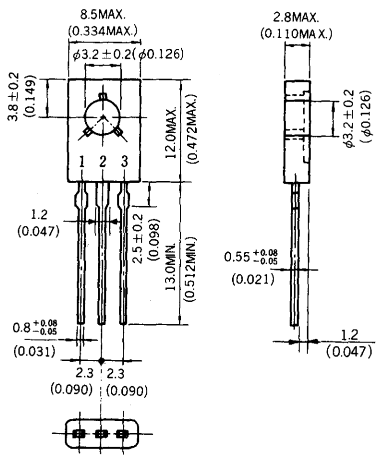
DESCRIPTION

The 2SC2688 is designed for use in Color TV chroma output circuits.

FEATURES

- High Burnout Voltage (E-B reverse bias, C = 2300pF)
  V_d: TYP. 1000V
- Low C_{re}, High f_T
  $C_{re} \leqq 3.0pF$ ($V_{CB} = 30V$)
  $f_T \geqq 50MHz$ ($V_{CE} = 30V$, $I_E = -10mA$)

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Collector connected to mounting plane
3. Base

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Collector to Base Voltage	V_{CBO}	300	V
Collector to Emitter Voltage	V_{CEO}	300	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current	I_C	200	mA
Total Power Dissipation	$P_{T(Tc=25°C)}$	10	W
Total Power Dissipation	$P_{T(Ta=25°C)}$	1.25	W
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−55 to +150	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

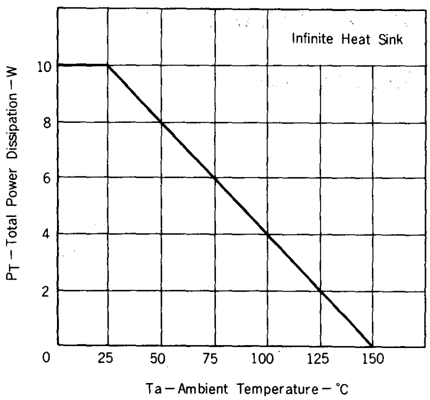
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			100	nA	$V_{CB} = 200V$, $I_E = 0$
Emitter Cutoff Current	I_{EBO}			100	nA	$V_{EB} = 5.0V$, $I_C = 0$
DC Current Gain	h_{FE}	40	80	250		$V_{CE} = 10V$, $I_C = 10mA$ *
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	$I_C = 50mA$, $I_B = 5.0mA$ *
Gain Bandwidth Product	f_T	50	80		MHz	$V_{CE} = 30V$, $I_E = -10mA$
Feedback Capacitance	C_{re}			3.0	pF	$V_{CB} = 30V$, $I_E = 0$, f = 1.0MHz

*Pulse test PW ≦ 350μs, duty cycle ≦ 2.0%
h_{FE} classification/N: 40 − 80 M: 60 − 120 L: 100 − 200 K: 160 − 250

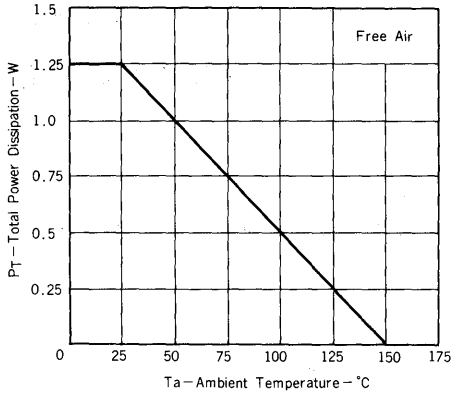
3

TYPICAL CHARACTERISTICS (Ta = 25°C)

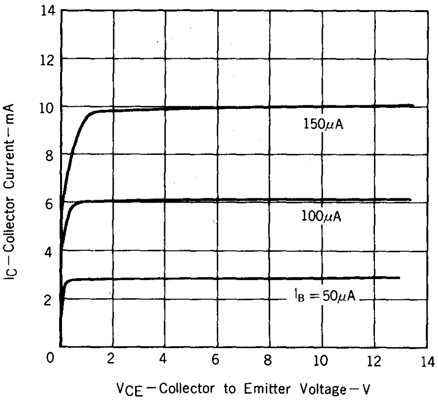
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



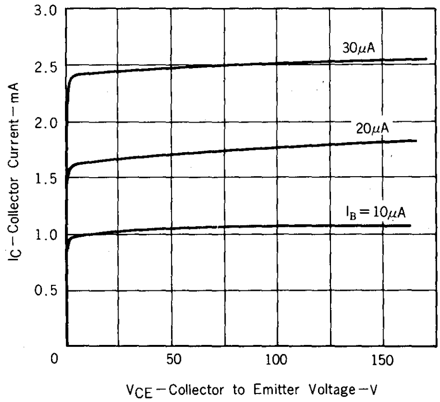
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



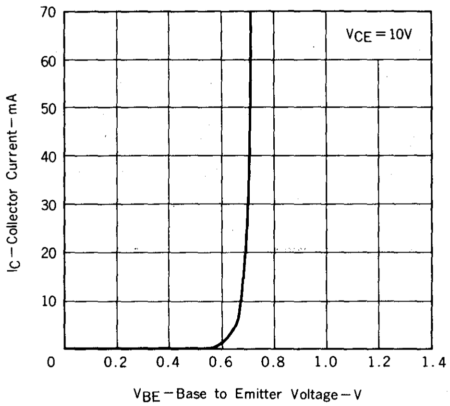
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



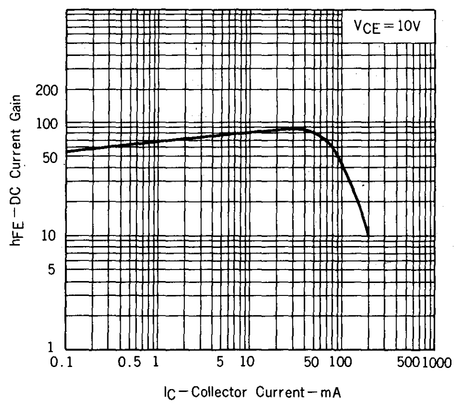
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



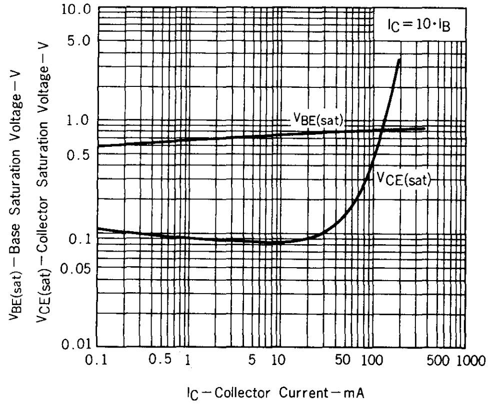
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



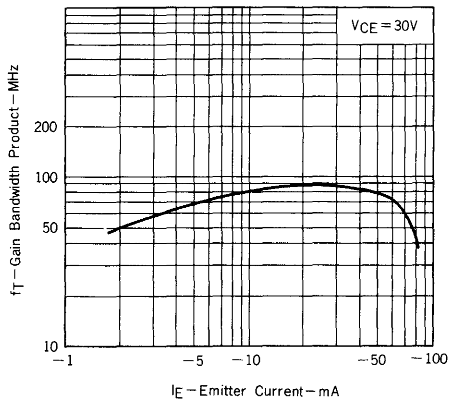
DC CURRENT GAIN vs. COLLECTOR CURRENT



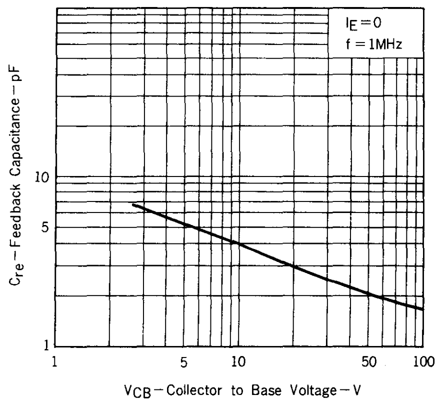
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



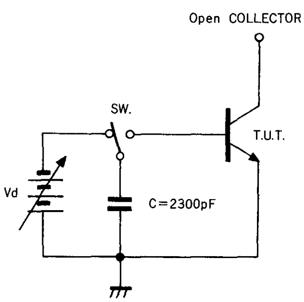
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



FEEDBACK CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



BURNOUT TEST CIRCUIT BY DISCHARGE OF CAPACITOR



TEST CONDITION

1) E-B reverse bias
2) C = 2300pF
3) Apply one shot pluse to T.U.T. (Transistor Under the Test) by SW.

JUDGEMENT

REJECT; BV_{EBO} waveform defect
As a result if T.U.T. is not rejected, apply higher voltage to capacitor and test again.

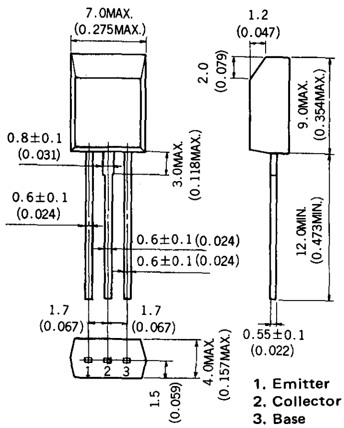
NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SD471

DESCRIPTION The 2SD471 is designed for use in driver and output stages of audio frequency amplifiers.

FEATURES
- High Total Power Dissipation: 1.0W at 25°C Ambient Temperature.
- Complementary to the NEC 2SB564 PNP Transistor.

PACKAGE DIMENSIONS
in millimeters (inches)



ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature . . . . -55 to +150°C
- Junction Temperature . . . . +150°C Maximum

Maximum Power Dissipation (Ta = 25°C)
- Total Power Dissipation . . . . 1.0 W
- Thermal Resistance (Junction to Ambient) . . . . . . 125°C/W

Maximum Voltages and Currents (Ta = 25°C)
- V_{CBO} Collector to Base Voltage . . . . 30 V
- V_{CEO} Collector to Emitter Voltage . . . . 25 V
- V_{EBO} Emitter to Base Voltage . . . . 5.0 V
- I_C Collector Current . . . . 1.0 A
- I_B Base Current . . . . 0.1 A

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	90	200	400		V_{CE}=1.0V, I_C=0.1A
h_{FE2}	DC Current Gain	50	140			V_{CE}=1.0V, I_C=1.0A
f_T	Gain Bandwidth Product		100		MHz	V_{CE}=6.0V, I_C=10mA
C_{ob}	Collector to Base Capacitance		22		pF	V_{CB}=6.0V, I_E=0, f=1.0MHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB}=30V, I_E=0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB}=5.0V, I_C=0
V_{BE}	Base to Emitter Voltage	600	630	700	mV	V_{CE}=6.0V, I_C=10mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.21	0.6	V	I_C=1.0A, I_B=0.1A
$V_{BE(sat)}$	Base Saturation Voltage		1.0	1.2	V	I_C=1.0A, I_B=0.1A

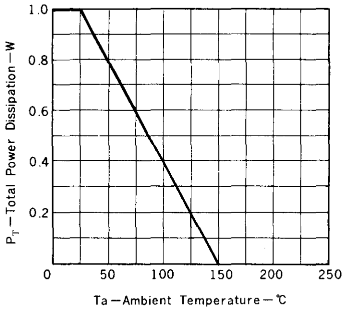
Classification of h_{FE1}

Rank	M	L	K
Range	90 –180	135 – 270	200 – 400

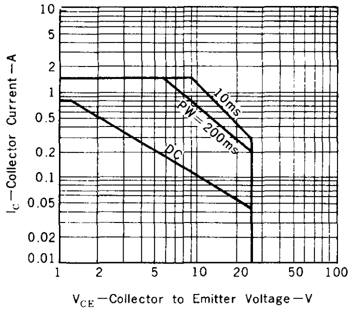
h_{FE1} Test Conditions: V_{CE} = 1.0V, I_C = 0.1A

TYPICAL CHARACTERISTICS (Ta=25°C unless otherwise noted)

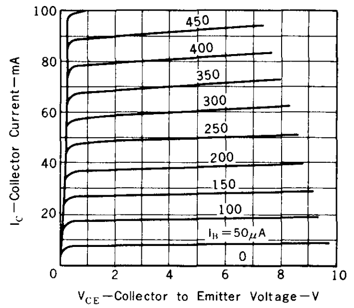
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



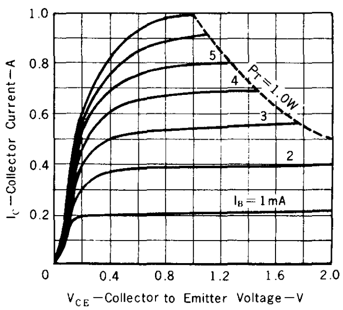
SAFE OPERATING AREAS (TRANSIENT THERMAL RESISTANCE)



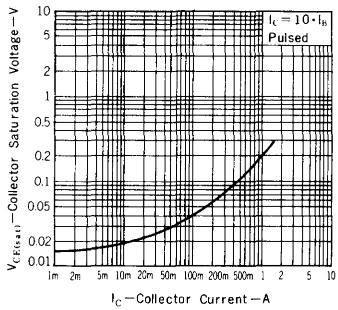
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



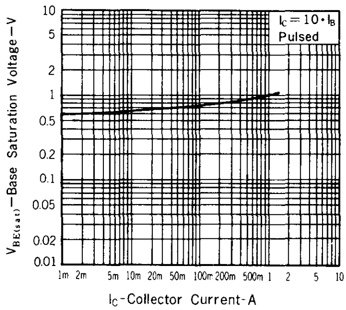
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



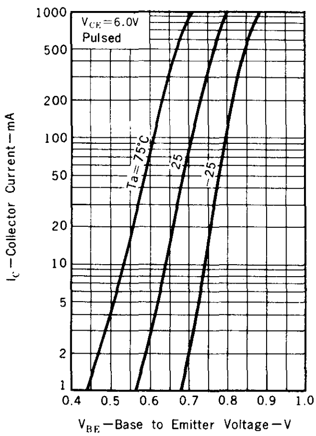
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



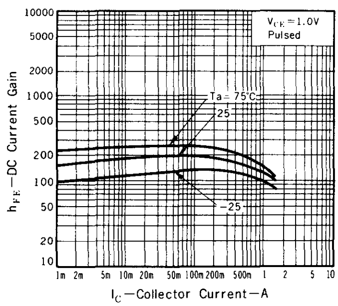
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



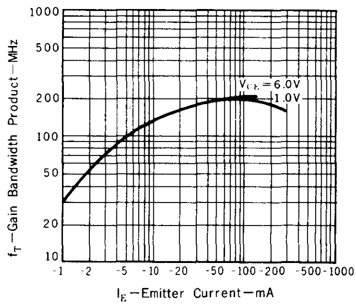
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



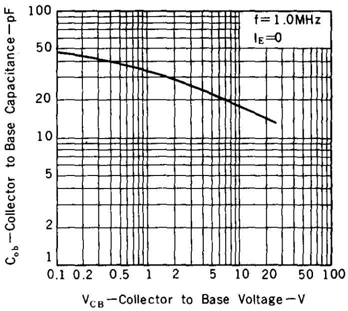
DC CURRENT GAIN vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



COLLECTOR TO BASE CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

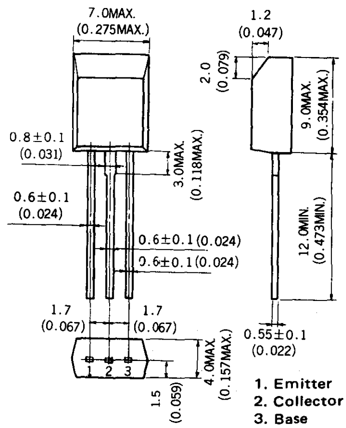
NPN SILICON TRANSISTOR
2SD571

DESCRIPTION The 2SD571 is designed for use in driver and output stages of audio frequency amplifiers.

FEATURES

- High total power dissipation and high breakdown voltage: 1.0W at 25°C ambient temperature/V_{CEO} = 50V
- Complementary to the NEC 2SB605 PNP transistor.

PACKAGE DIMENSIONS
in millimeters (inches)



ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

- Storage Temperature .... –55 to +150°C
- Junction Temperature .... +150°C Maximum

Maximum Power Dissipation (Ta = 25°C)

- Total Power Dissipation 1.0W
- Thermal Resistance (Junction to Ambient) . . 125°C/W

Maximum Voltages and Currents (Ta = 25°C)

V_{CBO}	Collector to Base Voltage	60	V
V_{CEO}	Collector to Emitter Voltage	50	V
V_{EBO}	Emitter to Base Voltage	5.0	V
I_C	Collector Current	0.7	A
I_B	Base Current	0.1	A

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	90	200	400	–	V_{CE}=1.0V, I_C=0.1A
h_{FE2}	DC Current Gain	50	150		–	V_{CE}=1.0V, I_C=0.5A
f_T	Gain Bandwidth Product		110		MHz	V_{CE}=6.0V, I_C=10mA
C_{ob}	Output Capacitance		13		pF	V_{CB}=6.0V, I_E=0, f=1.0MHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB}=60V, I_E=0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB}=5.0V, I_C=0
V_{BE}	Base to Emitter Voltage	600	635	700	mV	V_{CE}=6.0V, I_C=10mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.12	0.6	V	I_C=0.5A, I_B=0.05A
$V_{BE(sat)}$	Base Saturation Voltage		0.90	1.2	V	I_C=0.5A, I_B=0.05A

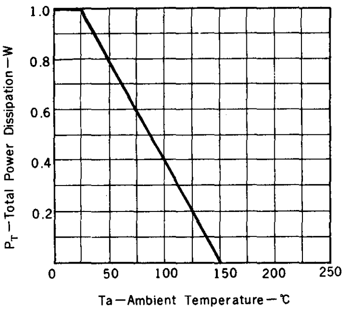
Classification of h_{FE1}

Rank	M	L	K
Range	90 – 180	135 – 270	200 – 400

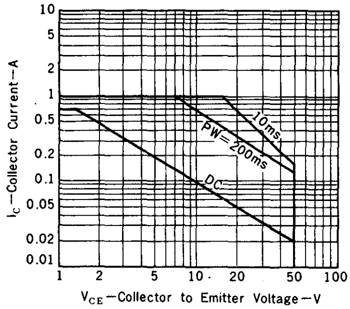
h_{FE1} Test Conditions: V_{CE}=1.0V, I_C=0.1A

TYPICAL CHARACTERISTICS (Ta=25°C unless otherwise noted)

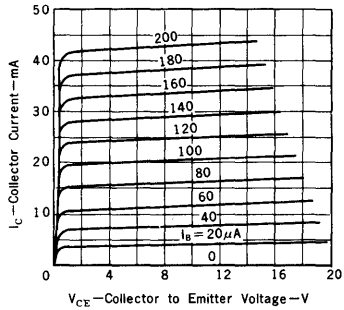
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



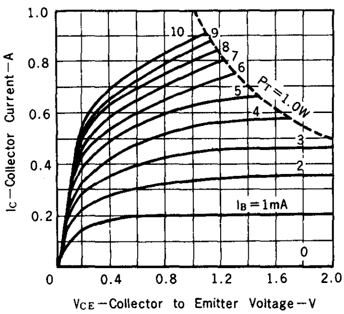
SAFE OPERATING AREAS (TRANSIENT THERMAL RESISTANCE)



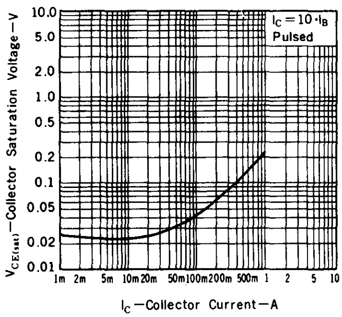
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



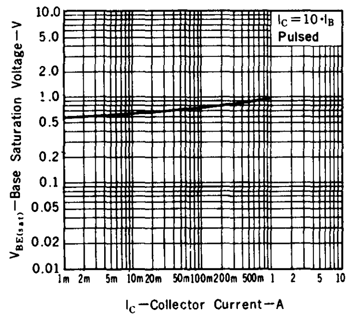
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



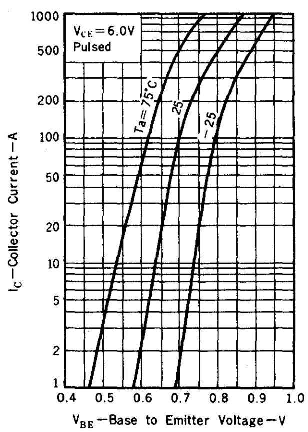
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



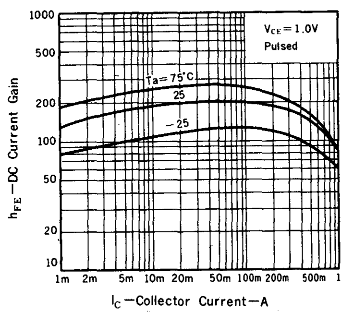
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



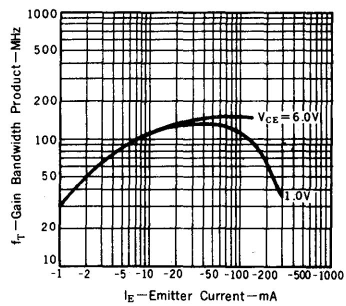
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



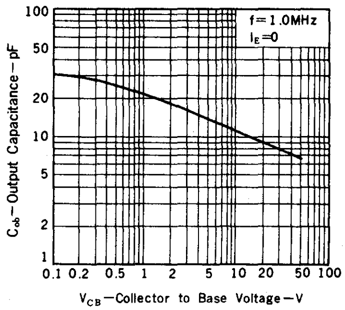
DC CURRENT GAIN vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



OUTPUT CAPACITANCE vs.
COLLECTOR TO BASE VOLTAGE

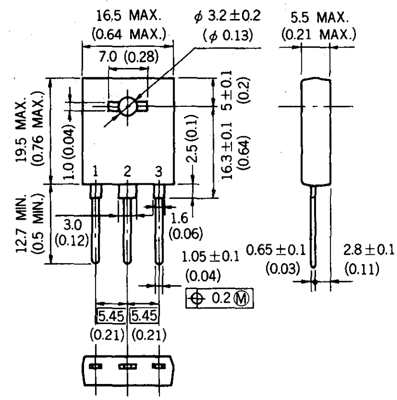


NEC
ELECTRON DEVICE

NPN SILICON POWER TRANSISTOR
2SD1018

DESCRIPTION The 2SD1018 is NPN silicon triple diffused transistor designed for use power supplies of 90° and 110° colour and black and white TV receivers.

PACKAGE DIMENSIONS
in millimeters (inches)



1. BASE
2. COLLECTOR CONNECTED TO HEAT SINK CONTACT AREA
3. EMITTER

FEATURES

- High voltage rating : V_{CEO} = 250 V
- High power dissipation rating : P_T = 80 W, T_C = 25 °C
- Wide safe operating area
- Economy types for DC circuits

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −55 to +150 °C

Junction Temperature . . . . 150 °C Maximum

Maximum Power Dissipation (T_C = 25 °C)

Total Power Dissipation . . . . 80 W

Maximum Voltages and Current (Ta = 25 °C)

V_{CBO} Collector to Base Voltage . . . . 250 V

V_{CEO} Collector to Emitter Voltage . . . . 250 V

V_{EBO} Emitter to Base Voltage . . . . 5.0 V

$I_{C(DC)}$ Collector Current (DC) . . . . 4.0 A

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	40		250	–	V_{CE} = 10 V, I_C = 0.5 A
I_{CBO}	Collector Cutoff Current			100	μA	V_{CB} = 200 V, I_E = 0
I_{EBO}	Emitter Cutoff Current			100	μA	V_{EB} = 4.0 V, I_E = 0
$V_{CE(sat)}$	Collector Saturation Voltage			1.0	V	I_C = 0.5 A, I_B = 0.05 A
$V_{BE(sat)}$	Base Saturation Voltage			1.5	V	I_C = 0.5 A, I_B = 0.05 A
BV_{CBO}	Collector to Base Breakdown Voltage	250			V	I_C = 1.0 mA, I_E = 0
BV_{CEO}	Collector to Emitter Breakdown Voltage	250			V	I_C = 10 mA, I_B = 0
BV_{EBO}	Emitter to Base Breakdown Voltage	5.0			V	I_E = 1.0 mA, I_C = 0

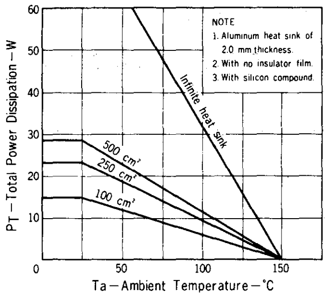
Classification of h_{FE}

Rank	N	M	L	K
Range	40 – 80	60 – 120	100 – 200	160 – 250

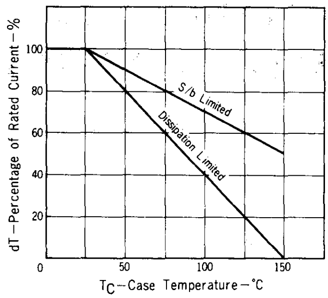
h_{FE} Test Conditions : V_{CE} = 10 V, I_C = 0.5 A

TYPICAL CHARACTERISTICS (Ta = 25 °C)

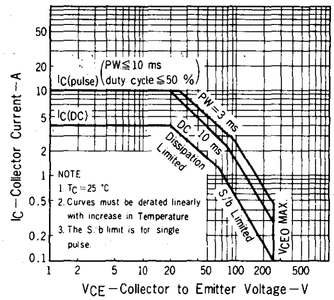
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



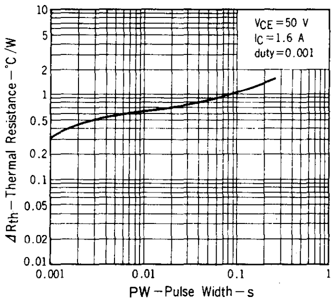
DERATING CURVE OF SAFE OPERATING AREAS



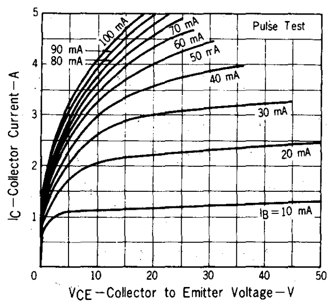
SAFE OPERATING AREAS



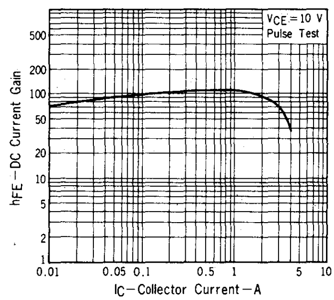
TRANSIENT THERMAL RESISTANCE



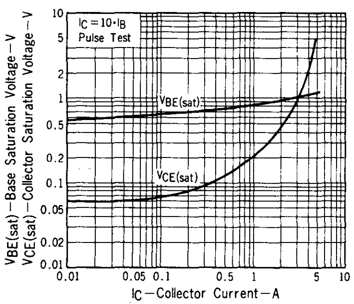
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



3

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTOR

2SD1162 (V443)

HIGH VOLTAGE HIGH CURRENT SWITCHING
NPN SILICON TRIPLE DIFFUSED DARLINGTON TRANSISTOR

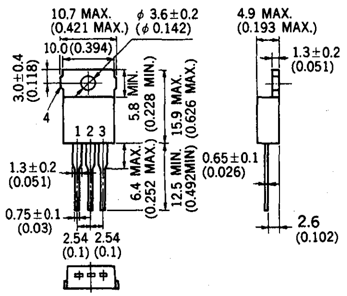
Industrial Use

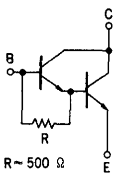
DESCRIPTION

Suitable for transistor ignitor and motor driver applications.

PACKAGE DIMENSIONS

in millimeters (inches)





1. Base (B)
2. Collector (C)
3. Emitter (E)
4. Fin (Collector)

JEDEC : TO-220AB

FEATURES

- High voltage switching.
- Low collector saturation voltage.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents ($T_a = 25\ ^\circ C$)			
Collector to Emitter Voltage	V_{CBO}, V_{CES}	500	V
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	300	V
Collector to Emitter Sustaining Voltage	$V_{CEX(SUS)}$	300	V
Emitter to Base Voltage	V_{EBO}	10	V
Continuous Collector Current	$I_{C(DC)}$	5	A
Peak Collector Current	$I_{C(pulse)}$*	10	A
Continuous Base Current	$I_{B(DC)}$	0.5	A
Maximum Power Dissipations			
Total Power Dissipation	$P_{T(T_c = 25\ ^\circ C)}$	50	W
Total Power Dissipation	$P_{T(T_a = 25\ ^\circ C)}$	1.85	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−55 to +150	°C
Lead Temperature 3.18 mm (1/8 inch) from case for 10 s.	T_L	260	°C
Thermal Resistances			
Junction to Case	$R_{th(j-C)}$	2.5	°C/W
Junction to Ambient	$R_{th(j-a)}$	67.6	°C/W

*Pulsed PW ≦ 1 ms, duty cycle ≦ 10 %

ELECTRICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted.)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Sustaining Voltage	$V_{CEO(SUS)}$	300			V	I_C = 1.5 A, L = 10 mH
Collector Cutoff Current	I_{CBO1}			10	μA	V_{CB} = 400 V, I_E = 0
	I_{CBO2}			1.0	mA	V_{CB} = 400 V, I_E = 0, Ta = 125 °C
Emitter to Collector Voltage	V_{ECO}	10			V	I_C = 1 mA
DC Current Gain	h_{FE1}	400	1000	3000		V_{CE} = 2.0 V, I_C = 2 A *
	h_{FE2}	100				V_{CE} = 2.0 V, I_C = 3 A *
Collector Saturation Voltage	$V_{CE(sat)}$			1.5	V	I_C = 2 A, I_B = 5 mA *
Base Saturation Voltage	$V_{BE(sat)}$			2.0	V	
Turn On Time	t_{on}		1.0		μs	I_C = 3 A, I_{B1} = $-I_{B2}$ = 30 mA V_{CC} ≃ 150 V, R_L = 50 Ω
Storage Time	t_{stg}		12		μs	
Fall Time	t_f		6		μs	

* Pulsed PW ≦ 350 μs, duty cycle ≦ 2 %

3

Contents

NEC
ELECTRON DEVICE

FIELD-EFFECT TRANSISTORS
2N4391,2N4392,2N4393

HIGH SPEED SWITCHING AND CHOPPER
N-CHANNEL SILICON JUNCTION FIELD-EFFECT TRANSISTOR

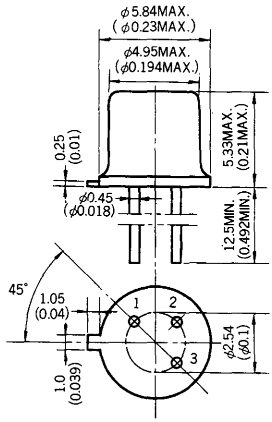
4

DESCRIPTION

The 2N4391, 2N4392, 2N4393 are depletion mode junction field effect transistors, designed for high speed switching and chopper applications.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Source (S)
2. Drain (D)
3. Gate (G), (Case)

EIAJ : TC-7, TB-8C
JEDEC : TO-206MA(TO-18)
IEC : C7, B11

FEATURES

- Low drain source "ON" resistance.
  $r_{DS(on)} = 30\Omega$ MAX. (2N4391)
- Low gate reverse current.
  $I_{GSS} = 0.1nA$ MAX. (at $V_{GS} = 20V$)

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)			
Gate to Drain Voltage	V_{GDO}	-40	V
Gate to Source Voltage	V_{GSO}	-40	V
Drain to Source Voltage	V_{DSX}	40	V
Gate Current	I_G	50	mA
Maximum Power Dissipations (Ta = 25°C)			
Total Power Dissipation	P_T	300	mW
Total Power Dissipation	P_T	1.8*	W
Maximum Temperatures			
Junction Temperature	T_j	200	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

*Case Temperature = 25°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	2N4391 MIN.	2N4391 MAX.	2N4392 MIN.	2N4392 MAX.	2N4393 MIN.	2N4393 MAX.	UNIT	TEST CONDITIONS
Gate-Source Breakdown Voltage	$V_{(BR)GSS}$	-40		-40		-40		V	I_G = -1μA, V_{DS}=0
Gate-Source Forward Voltage	V_{GSF}		1		1		1	V	I_G=1mA, V_{DS}=0
Gate Reverse Current	I_{GSS}		-0.1		-0.1		-0.1	nA	V_{GS}=-20V, V_{DS}=0
			-0.2		-0.2		-0.2	μA	V_{GS}=-20V, V_{DS}=0, Ta=150°C
Drain Cutoff Current	$I_{D(off)}$		0.1					nA	V_{DS}=20V, V_{GS}=-12V
					0.1			nA	V_{DS}=20V, V_{GS}=-7V
							0.1	nA	V_{DS}=20V, V_{GS}=-5V
			0.2					μA	V_{DS}=20V, V_{GS}=-12V, Ta=150°C
					0.2			μA	V_{DS}=20V, V_{GS}=-7V, Ta=150°C
							0.2	μA	V_{DS}=20V, V_{GS}=-5V, Ta=150°C
Gate-Source Cutoff Voltage	$V_{GS(off)}$	-4	-10	-2	-5	-0.5	-3	V	V_{DS}=20V, I_D = 1nA
Zero-Gate-Voltage Drain Current	I_{DSS}	50	150	25	75	5	30	mA	V_{DS}=20V, V_{GS}=0, See Note 1
Drain-Source On-State Voltage	$V_{DS(on)}$		0.4					V	V_{GS}=0, I_D = 12mA
					0.4			V	V_{GS}=0, I_D = 6mA
							0.4	V	V_{GS}=0, I_D = 3mA
Static Drain-Source On-State Resistance	$r_{DS(on)}$		30		60		100	Ω	V_{GS}=0, I_D = 1mA
Small-Signal Drain-Source On-State Resistance	$r_{ds(on)}$		30		60		100	Ω	V_{GS}=0, I_D = 0, f=1kHz
Common-Source Short-Circuit Input Capacitance	C_{iss}		14		14		14	pF	V_{DS}=20V, V_{GS}=0, f=1MHz
Common-Source Short-Circuit Reverse Transfer Capacitance	C_{rss}		3.5					pF	V_{DS}=0, V_{GS}=-12V, f=1MHz
					3.5			pF	V_{DS}=0, V_{GS}=-7V, f=1MHz
							3.5	pF	V_{DS}=0, V_{GS}=-5V, f=1MHz

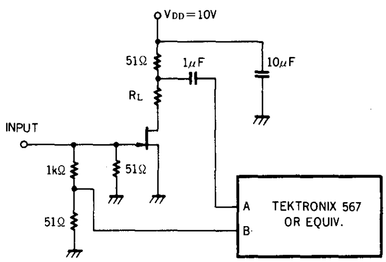
NOTE: This parameter must be measured using pulse techniques. t_W = 1ms, duty cycle ≤1%

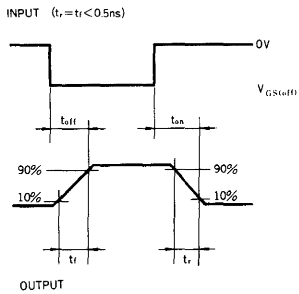
SWITCHING CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	2N4391 MIN.	2N4391 MAX.	2N4392 MIN.	2N4392 MAX.	2N4393 MIN.	2N4393 MAX.	UNIT	TEST CONDITIONS
Rise Time	t_r		5		5		5	ns	V_{DD}=10V, $I_{D(on)}$ = 12mA (2N4391), 6mA (2N4392), 3mA (2N4393)
Turn-On Time	t_{on}		15		15		15	ns	$V_{GS(on)}$=0,
Fall Time	t_f		15		20		30	ns	See test circuit, $V_{GS(off)}$ = -12V (2N4391), -7V (2N4392), -5V (2N4393)
Turn-Off Time	t_{off}		20		35		50	ns	

SWITCHING TIMES TEST CIRCUIT

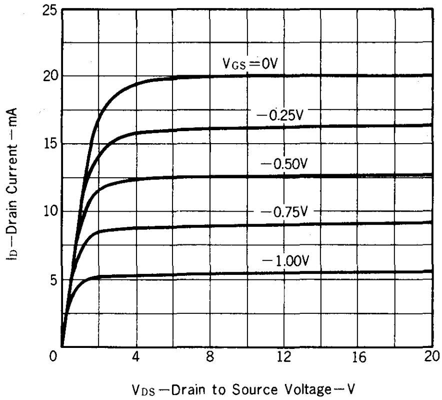
TYPE No.	R_L
2N4391	750Ω
2N4392	1.54kΩ
2N4393	3.16kΩ



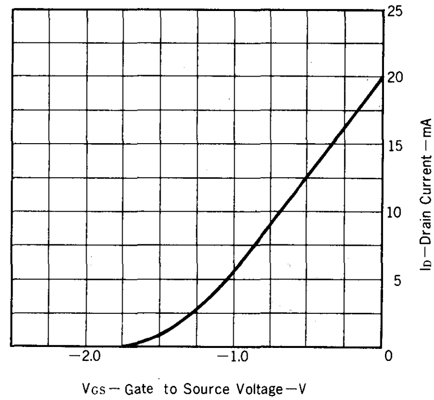


TYPICAL CHARACTERISTICS (Ta = 25°C)

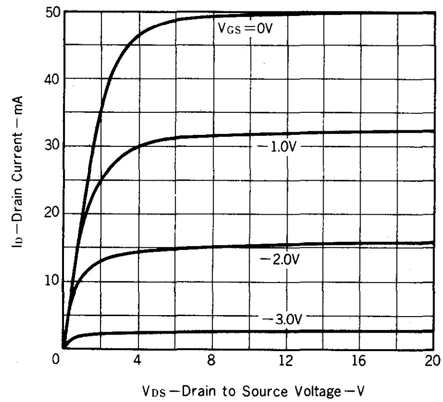
DRAIN CURRENT vs.
DRAIN TO SOURCE VOLTAGE (I_{DSS} = 20mA)



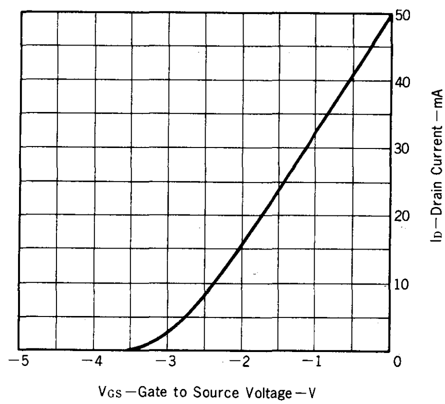
DRAIN CURRENT vs.
GATE TO SOURCE VOLTAGE (I_{DSS} = 20mA)



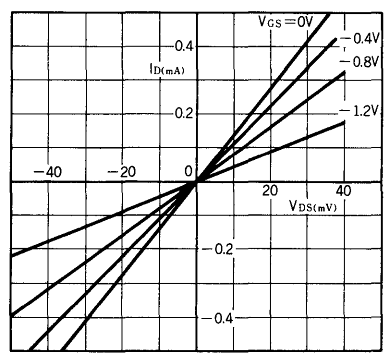
DRAIN CURRENT vs.
DRAIN TO SOURCE VOLTAGE (I_{DSS} = 50mA)



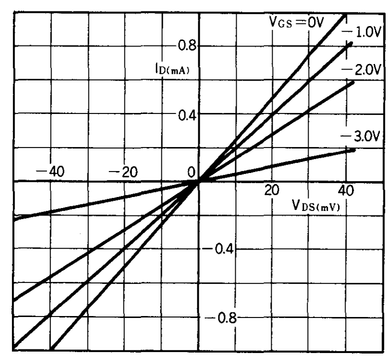
DRAIN CURRENT vs.
GATE TO SOURCE VOLTAGE (I_{DSS} = 50mA)



DRAIN CURRENT vs.
DRAIN TO SOURCE VOLTAGE (I_{DSS} = 20mA)

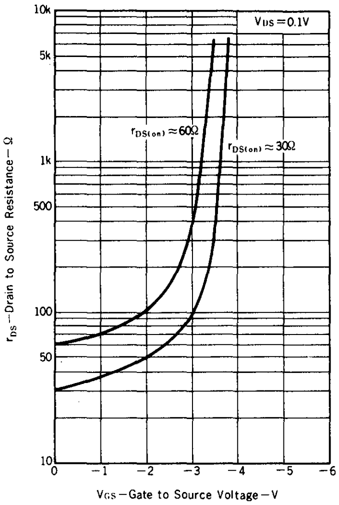


DRAIN CURRENT vs.
DRAIN TO SOURCE VOLTAGE (I_{DSS} = 50mA)

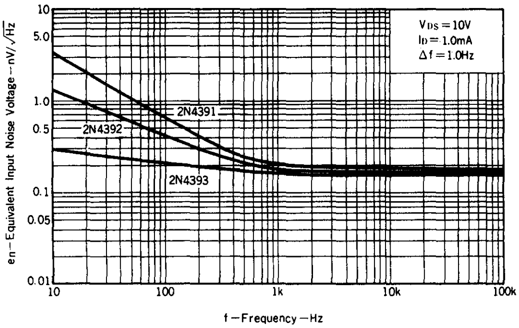


4

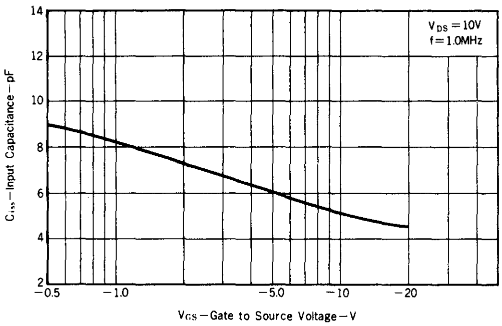
DRAIN TO SOURCE RESISTANCE vs.
GATE TO SOURCE VOLTAGE



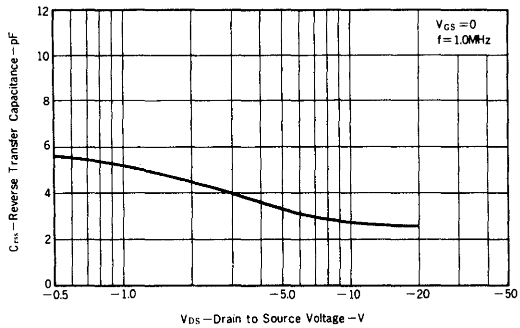
EQUIVALENT INPUT NOISE VOLTAGE
vs. FREQUENCY



INPUT CAPACITANCE vs.
GATE TO SOURCE VOLTAGE



REVERSE TRANSFER CAPACITANCE
vs. DRAIN TO SOURCE VOLTAGE



NEC
ELECTRON DEVICE

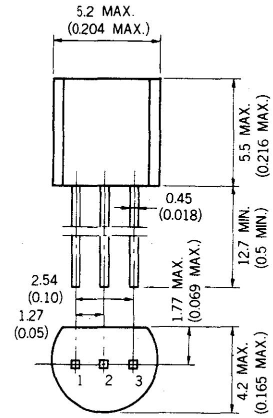
P-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR
2SJ44

DESCRIPTION The 2SJ44 is designed for use in driver stage of AF low noise amplifier.

FEATURES

- Low Noise Figure
  e_n=1.5 nV/$\sqrt{Hz}$ TYP. (V_{DS}=−10 V, I_D=−1.0 mA, f=1.0 kHz)
  NV ≦ 20 mV
- High Voltage, High $|y_{fs}|$, and Wide Dynamic Range
  V_{GDO} ≧ 40 V
  $|y_{fs}|$=9.0 mS TYP. (V_{DS}=−10 V, I_D=−1.0 mA, f=1.0 kHz)
- Complementary to NEC 2SK163

PACKAGE DIMENSIONS
in millimeters (inches)



1. DRAIN
2. GATE
3. SOURCE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −55 to +125 °C

Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation . . . . 400 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{GDO}	Gate to Drain Voltage	40	V
V_{GSO}	Gate to Source Voltage	40	V
V_{DSX}*	Drain to Source Voltage	−40	V
I_D	Drain Current	−30	mA
I_G	Gate Current	−10	mA

* V_{GS} = −2.0 V

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{DSS}	Zero-Gate Voltage Drain Current	−1.0	−9.0	−18	mA	V_{DS} = −10 V, V_{GS} = 0
$\|y_{fs}\|_1$	Forward Transfer Admittance	7.0	9.0		mS	V_{DS} = −10 V, I_D = −1.0 mA, f = 1.0 kHz
$\|y_{fs}\|_2$	Forward Transfer Admittance	7.0			mS	V_{DS} = −10 V, V_{GS} = 0, f = 1.0 kHz
C_{iss}	Input Capacitance		50		pF	V_{DS} = −10 V, V_{GS} = 0, f = 1.0 MHz
C_{rss}	Feedback Capacitance		10		pF	V_{DS} = −10 V, V_{GS} = 0, f = 1.0 MHz
NV	Noise Voltage		16	20	mV	See test circuit
I_{GSS}	Gate Cutoff Current			1.0	nA	V_{GS} = 20 V, V_{DS} = 0
$V_{GS(off)}$	Gate to Source Cutoff Voltage	0.2		1.5	V	V_{DS} = −10 V, I_D = −10 μA

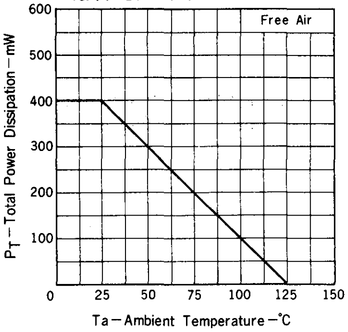
Classification of I_{DSS}

Rank	K	L	M	N
I_{DSS}(mA)	−1.0 – −6.0	−5.0 – −10	−9.0 – −14	−13 – −18

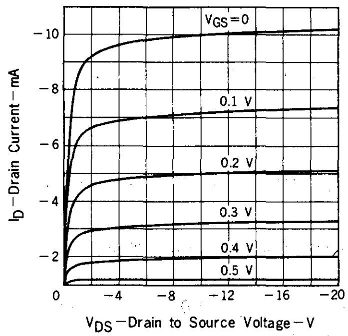
I_{DSS} Test Conditions : V_{DS} = −10 V, V_{GS} = 0

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

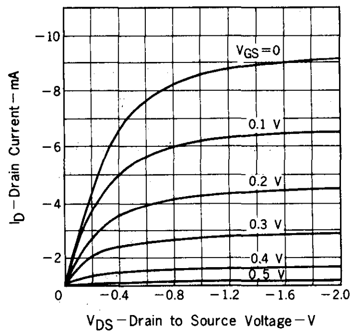
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



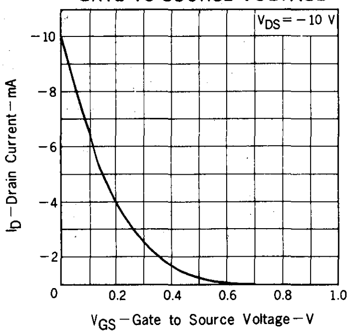
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



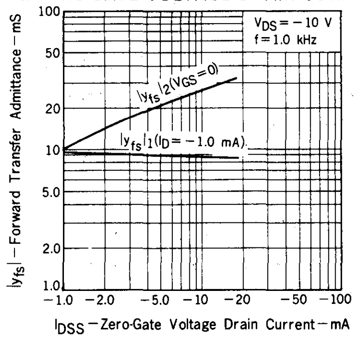
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



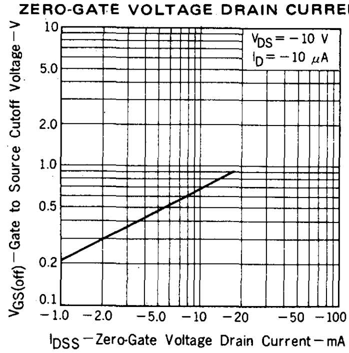
DRAIN CURRENT vs. GATE TO SOURCE VOLTAGE



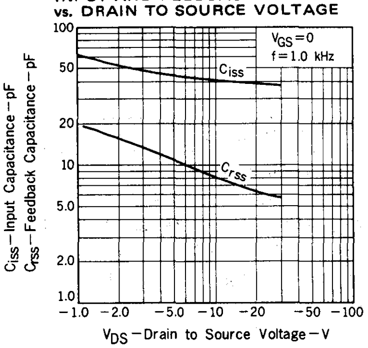
FORWARD TRANSFER ADMITTANCE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



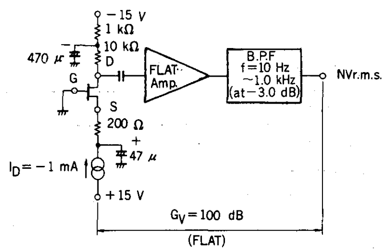
GATE TO SOURCE CUTOFF VOLTAGE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



INPUT AND FEEDBACK CAPACITANCE vs. DRAIN TO SOURCE VOLTAGE



NOISE VOLTAGE TEST CIRCUIT



$V_{DS} \doteqdot -4$ V, $I_D = -1.0$ mA, $R_G = 0$, $G_V = 100$ dB, f = 10 Hz – 1.0 kHz (at −3.0 dB)

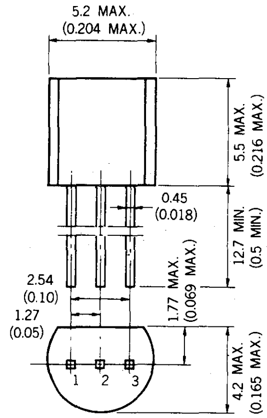
P-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR
2SJ45

DESCRIPTION The 2SJ45 is designed for use in driver stage of AF amplifier and switching circuit.

FEATURES

- High Voltage, High $|y_{fs}|$
  $V_{GDO} \geqq 40$ V
  $|y_{fs}|$=9.0 mS TYP. (V_{DS}=−10 V, I_D=−1.0 mA, f=1.0 kHz)
- High Input impedance
  $I_{GSS} \leqq 1.0$ nA (V_{GS}=20 V, V_{DS}=0)

PACKAGE DIMENSIONS
in millimeters (inches)



1. DRAIN
2. GATE
3. SOURCE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature .... −55 to +125 °C
- Junction Temperature .... +125 °C Maximum

Maximum Power Dissipation (Ta=25 °C)
- Total Power Dissipation .... 400 mW

Maximum Voltages and Currents (Ta=25 °C)

V_{GDO}	Gate to Drain Voltage	40	V
V_{GSO}	Gate to Source Voltage	40	V
V_{DSX}*	Drain to Source Voltage	−40	V
I_D	Drain Current	−30	mA
I_G	Gate Current	−10	mA

* V_{GS}=2.0 V

ELECTRICAL CHARACTERISTICS (Ta=25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{DSS}	Zero-Gate Voltage Drain Current	−1.0	−9.0	−18	mA	V_{DS}=−10 V, V_{GS}=0
$\|y_{fs}\|_1$	Forward Transfer Admittance	7.0	9.0		mS	V_{DS}=−10 V, I_D=−1.0 mA, f=1.0 kHz
$\|y_{fs}\|_2$	Forward Transfer Admittance	7.0			mS	V_{DS}=−10 V, V_{GS}=0, f=1.0 kHz
C_{iss}	Input Capacitance		50		pF	V_{DS}=−10 V, V_{GS}=0, f=1.0 MHz
C_{rss}	Feedback Capacitance		10		pF	V_{DS}=−10 V, V_{GS}=0, f=1.0 MHz
NV	Noise Voltage			50	mV	See test circuit
I_{GSS}	Gate Cutoff Current			1.0	nA	V_{GS}=20 V, V_{DS}=0
$V_{GS(off)}$	Gate to Source Cutoff Voltage	0.2		1.5	V	V_{DS}=−10 V, I_D=−10 μA

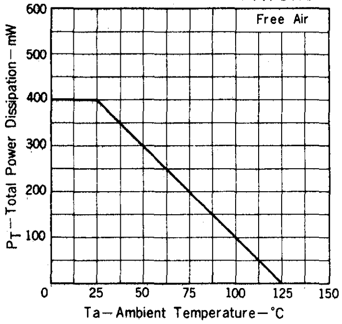
Classification of I_{DSS}

Rank	K	L	M	N
$I_{DSS(mA)}$	−1.0 – −6.0	−5.0 – −10	−9.0 – −14	−13 – −18

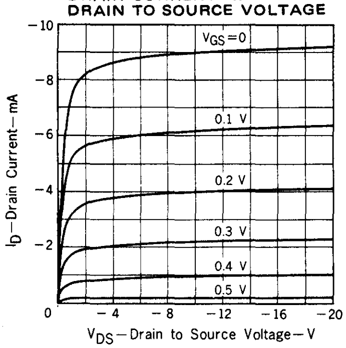
I_{DSS} Test Conditions : V_{DS}=−10 V, V_{GS}=0

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

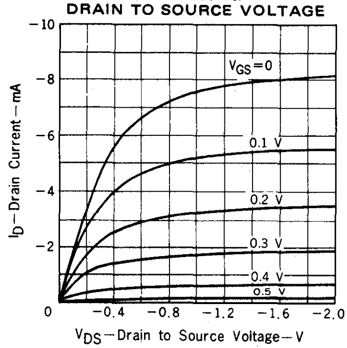
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



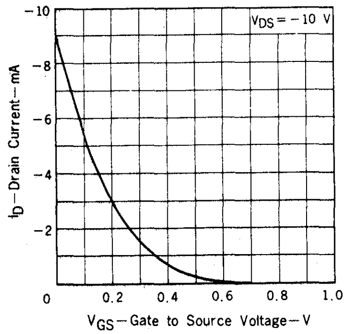
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



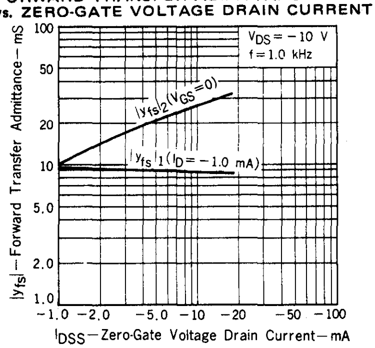
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



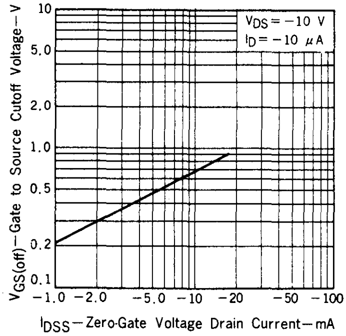
DRAIN CURRENT vs. GATE TO SOURCE VOLTAGE



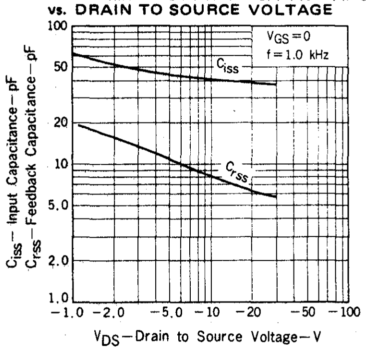
FORWARD TRANSFER ADMITTANCE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



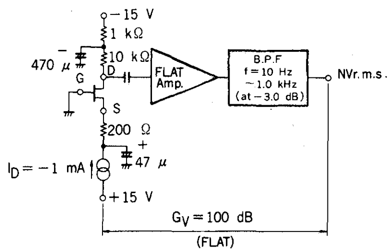
GATE TO SOURCE CUTOFF VOLTAGE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



INPUT AND FEEDBACK CAPACITANCE vs. DRAIN TO SOURCE VOLTAGE



NOISE VOLTAGE TEST CIRCUIT



$V_{DS} \doteqdot -4$ V, $I_D = -1.0$ mA, $R_G = 0$, $G_V = 100$ dB,
f = 10 Hz – 1.0 kHz (at –3 dB)

NEC
ELECTRON DEVICE

N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

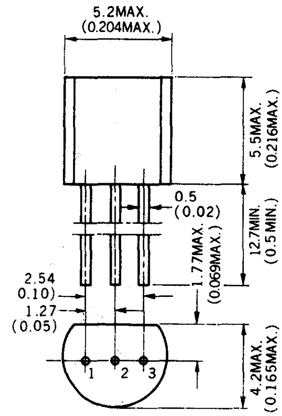
2SK49

DESCRIPTION The 2SK49 is designed for use in FM tuner of a potable RADIO RECIVER.

FEATURES

- High
  $|Y_{fs}|_2$ (V_{DS} = 5.0V, V_{GS} = 0) : 5.5m℧ TYP.
- Low C_{rss}
  C_{rss} (V_{DS} = 5.0V, V_{GS} = 0) : 0.07 pF TYP.

PACKAGE DIMENSIONS
in millimeters (inches)



1. GATE
2. SOURCE
3. DRAIN

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Temperature

Storage Temperature	-55 to +125°C
Junction Temperature	+80°C Maximum

Maximum Power Dissipation (Ta = 25°C)

Total Power Dissipation	72 mW

Maximum Voltages and Currents

V_{GDO}	Gate to Drain Voltage	-20 V
V_{GSO}	Gate to Source Voltage	-1.0 V
V_{DSX}	Drain to Source Voltage	20 V
I_D	Drain Current	10 mA
I_G	Gate Current	10 mA

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{DSS}	Zero-Gate Voltage Dratin Current	0.5	2.0	6.0	mA	V_{DS}=5.0V, V_{GS}=0
$\|Y_{fs}\|_1$	Forward Transfer Admittance	1.9	2.8		m℧	V_{DS}=5.0V, I_D=0.5mA, f=1.0kHz
$\|Y_{fs}\|_2$	Forward Transfer Admittance	1.9	5.5		m℧	V_{DS}=5.0V, V_{GS}=0, f=1.0kHz
C_{iss}	Input Capacitance		5.0	6.5	pF	V_{DS}=5.0V, V_{GS}=0, f=1.0MHz
C_{rss}	Feedback Capacitance		0.07	0.25	pF	V_{DS}=5.0V, V_{GS}=0, f=1.0MHz
C_{oss}	Output Capacitance		3.8	4.5	pF	V_{DS}=5.0V, V_{GS}=0, f=1.0MHz
G_{ps}	Power Gain	9.0	18		dB	V_{DS}=5.0V, V_{GS}=0, Z_{in}, Z_{out} = 50Ω f=100MHz, See test circuit
NF	Noise Figure		3.5	6.0	dB	V_{DS}=5.0V, V_{GS}=0, Z_{in}, Z_{out}=50Ω f=100MHz, See test circuit
I_{GSS}	Gate Cutoff Current			-50	nA	V_{GS}=-0.5V, V_{DS}=0
$V_{GS(off)}$	Gate to Source Cutoff Voltage		-0.8	-2.5	V	V_{DS}=5.0V, I_D=10μA

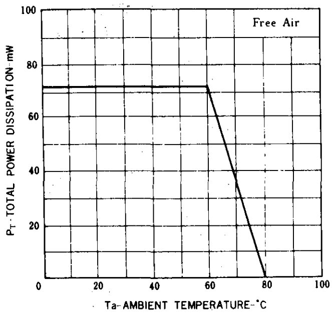
Classification of I_{DSS}

Rank	E	F	H
I_{DSS}(mA)	0.5 ~ 1.5	1.0 ~ 3.0	2.0 ~ 6.0

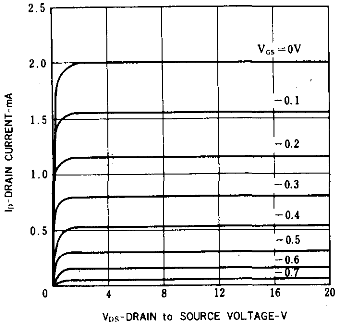
I_{DSS} Test Conditions : V_{DS} = 5.0V, V_{GS} = 0

TYPICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

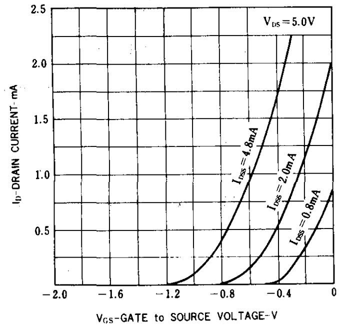
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



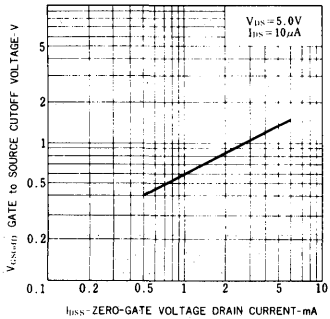
DRAIN CURRENT vs. DRAIN to SOURCE VOLTAGE



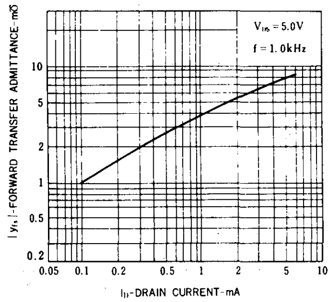
DRAIN CURRENT vs. GATE to SOURCE VOLTAGE



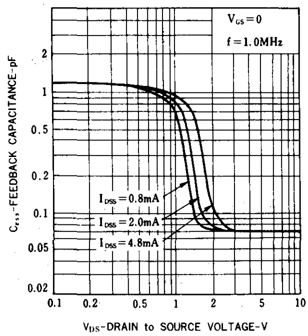
GATE to SOURCE CUTOFF VOLTAGE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



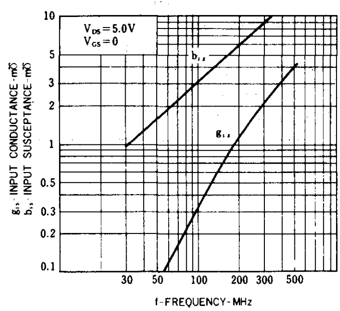
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT



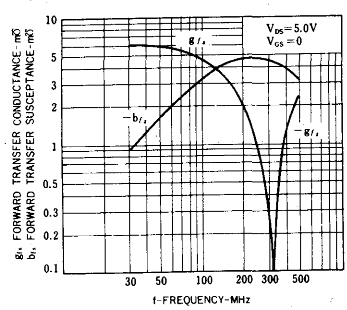
FEEDBACK CAPACITANCE vs. DRAIN to SOURCE VOLTAGE



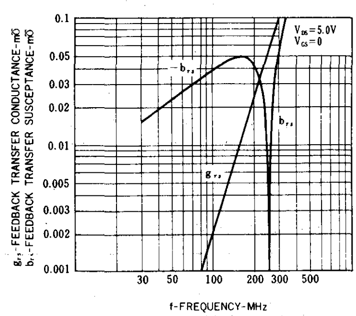
INPUT ADMITTANCE vs. FREQUENCY



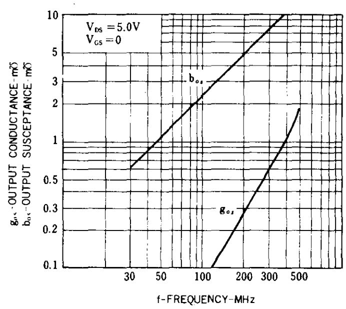
FORWARD TRANSFER ADMITTANCE vs. FREQUENCY



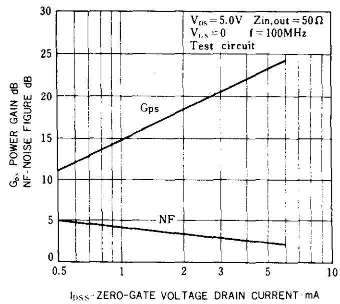
FEEDBACK TRANSFER ADMITTANCE vs. FREQUENCY



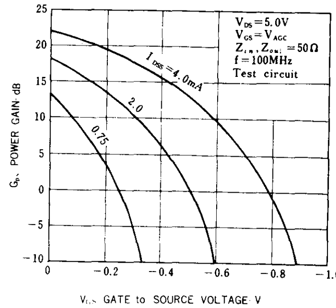
OUTPUT ADMITTANCE
vs. FREQUENCY



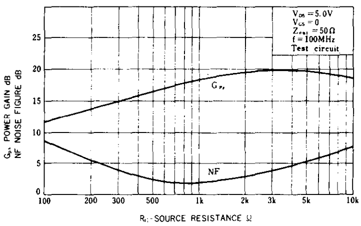
POWER GAIN and NOISE FIGURE
vs. ZERO-GATE VOLTAGE DRAIN CURRENT



POWER GAIN
vs. GATE to SOURCE VOLTAGE

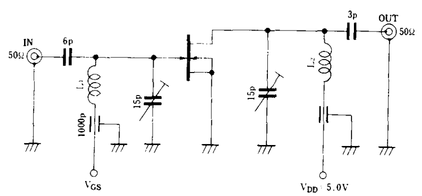


POWER GAIN and NOISE FIGURE
vs. SOURCE RESISTANCE



NOISE FIGURE and POWER GAIN
TEST CIRCUIT (f = 100 MHz)

100MHz Gps. NF測定回路



NEC
ELECTRON DEVICE

N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

2SK68

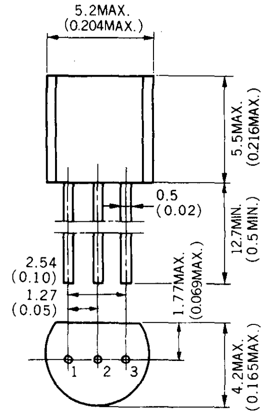
DESCRIPTION The 2SK68 is designed for use in driver stage of AF amplifier.

FEATURES

- High voltage, high |Yfs| and wide dynamic range
  $V_{GDO} > -50V$, |Yfs| ($V_{DS} = 10V$, $V_{GS} = 0$) : 12 m℧TYP.
- Low leakage current
  $I_{GSS} < -1.0nA$ ($V_{GS} = -20V$)

PACKAGE DIMENSIONS

in millimeters (inches)



1. DRAIN
2. GATE
3. SOURCE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Temperatures

Storage Temperature . . . . -55 to +125°C

Junction Temperature . . . . +125°C Maximum

Maximum Power Dissipation (Ta = 25°C)

Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents

V_{GDO}	Gate to Drain Voltage	-50 V
V_{GSO}	Gate to Source Voltage	-50 V
V_{DSX}*	Drain to Source Voltage	50 V
I_D	Drain Current	20 mA
I_G	Gate Current	10 mA

* $V_{GS} = -2.0$ V

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{DSS}	Zero-Gate Voltage Drain Current	0.5	3.0	12	mA	V_{DS}=10V, V_{GS}=0
$\|Yfs\|_1$	Forward Transfer Admittance	4.0	5.2		m℧	V_{DS}=10V, I_D=0.5mA, f=1.0kHz
$\|Yfs\|_2$	Forward Transfer Admittance	4.0	12		m℧	V_{DS}=10V, V_{GS}=0, f=1.0kHz
C_{iss}	Input Capacitance		13		pF	V_{DS}=10V, V_{GS}=0, f=1.0MHz
C_{rss}	Feedback Capacitance		2.6		pF	V_{DS}=10V, V_{GS}=0, f=1.0MHz
I_{GSS}	Gate Cutoff Current			-1.0	nA	V_{GS}=-20V, V_{DS}=0
$V_{GS(off)}$	Gate to Source Cutoff Voltage	-0.13	-0.5	-1.5	V	V_{DS}=10V, I_D=10μA

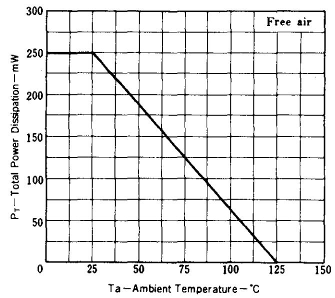
Classification of I_{DSS}

Rank	K	L	M	N
I_{DSS}(mA)	0.5 – 1.5	1.0 – 3.0	2.0 – 6.0	4.0 – 12

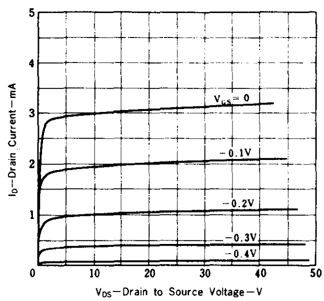
I_{DSS} Test Conditions : V_{DS} = 10V, V_{GS} = 0

TYPICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

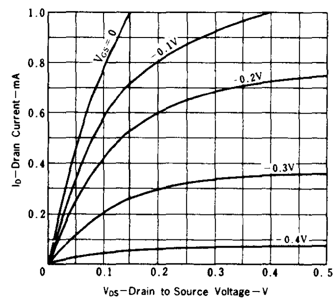
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE

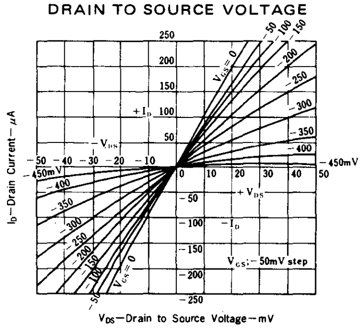


DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE

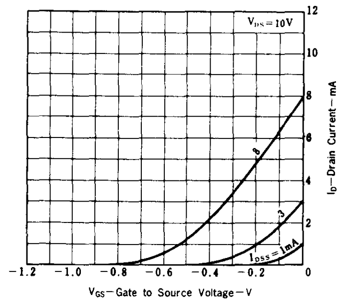


4

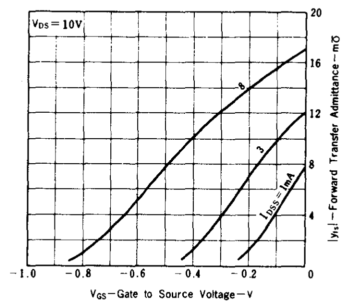
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



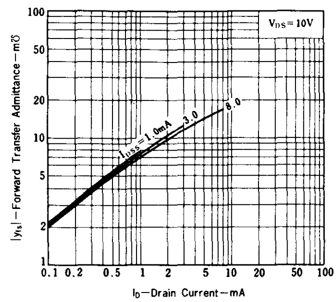
DRAIN CURRENT vs. GATE TO SOURCE VOLTAGE



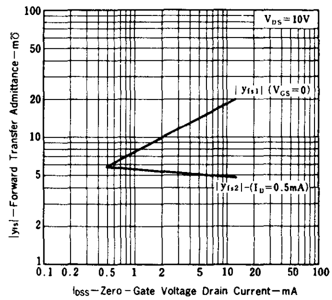
FORWARD TRANSFER ADMITTANCE vs. GATE TO SOURCE VOLTAGE



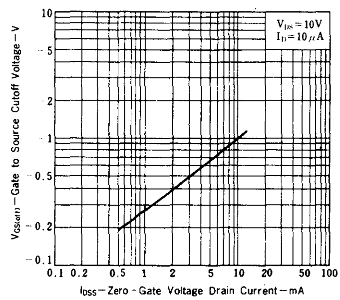
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT



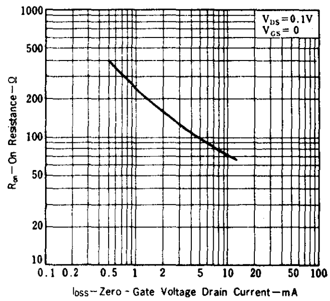
FORWARD TRANSFER ADMITTANCE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



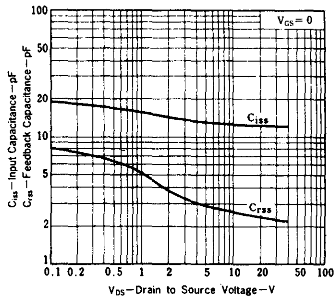
GATE TO SOURCE CUTOFF VOLTAGE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



ON RESISTANCE
vs. ZERO-GATE VOLTAGE DRAIN CURRENT



INPUT AND FEEDBACK CAPACITANCE
vs. DRAIN TO SOURCE VOLTAGE



NEC
ELECTRON DEVICE

N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

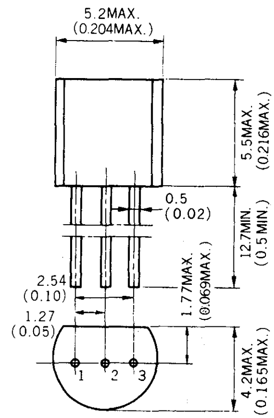
2SK68A

DESCRIPTION The 2SK68A is designed for use in driver stage of AF low noise amplifier.

FEATURES

- Low Noise Figure
  NF (V_{DS} = 10V, V_{GS} = 0, R_G = 10kΩ, f=10Hz) : 1.0 dB TYP.
- High Voltage, High |Yfs|, and Wide Dynamic Range
  $V_{GDO} > -50V$, |Yfs| (V_{DS} = 10V, V_{GS} = 0) : 12 m℧ TYP.
- Low Leakage Current
  $I_{GSS} < -1.0nA$ (V_{GS} = -20V)

PACKAGE DIMENSIONS
in millimeters (inches)



1. DRAIN	EIAJ	:	SC-43
2. GATE	JEDEC	:	TO-92
3. SOURCE	IEC	:	PA33

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Temperatures
Storage Temperature . . . . -55 to +125°C
Junction Temperature . . . . +125°C Maximum

Maximum Power Dissipation (Ta = 25°C)
Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents

V_{GDO}	Gate to Drain Voltage	-50	V
V_{GSO}	Gate to Source Voltage	-50	V
V_{DSX}*	Drain to Source Voltage	50	V
I_D	Drain Current	20	mA
I_G	Gate Current	10	mA

*V_{GS} = -2.0 V

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{DSS}	Zero-Gate Voltage Drain Current	0.5	3.0	12	mA	V_{DS}=10V, V_{GS}=0
$\|Yfs\|_1$	Forward Transfer Admittance	4.0	5.2		m℧	V_{DS}=10V, I_D=0.5mA, f=1.0kHz
$\|Yfs\|_2$	Forward Transfer Admittance	4.0	12		m℧	V_{DS}=10V, V_{GS}=0, f=1.0kHz
C_{iss}	Input Capacitance		13		pF	V_{DS}=10V, V_{GS}=0, f=1.0MHz
C_{rss}	Feedback Capacitance		2.6		pF	V_{DS}=10V, V_{GS}=0, f=1.0MHz
NF_1	Noise Figure		5.0	10	dB	V_{DS}=10V, V_{GS}=0, R_G=1.0kΩ, f=10Hz
NF_2	Noise Figure		1.0	3.0	dB	V_{DS}=10V, V_{GS}=0, R_G=1.0kΩ, f=100Hz
NF_3	Noise Figure		0.6	1.5	dB	V_{DS}=10V, V_{GS}=0, R_G=1.0kΩ, f=1.0kHz
NV	Noise Voltage		15	20	mV	See test circuit
I_{GSS}	Gate Cutoff Current			-1.0	nA	V_{GS}=-20V, V_{DS}=0
$V_{GS(off)}$	Gate to Source Cutoff Voltage	-0.13	-0.5	-1.5	V	V_{DS}=10V, I_D=10μA

Classification of I_{DSS}

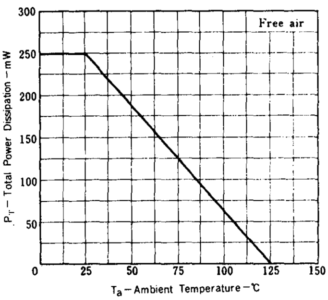
Rank	K	L	M	N
I_{DSS}(mA)	0.5 – 1.5	1.0 – 3.0	2.0 – 6.0	4.0 – 12

I_{DSS} Test Conditions : V_{DS} = 10V, V_{GS} = 0

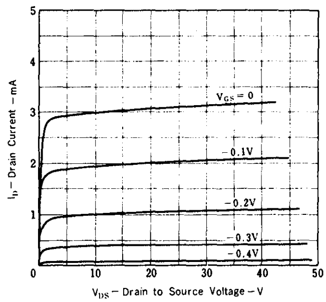
4

TYPICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

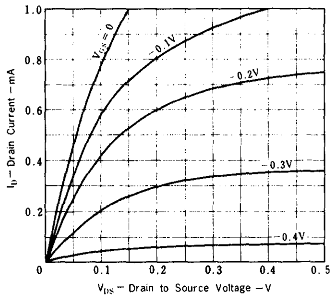
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



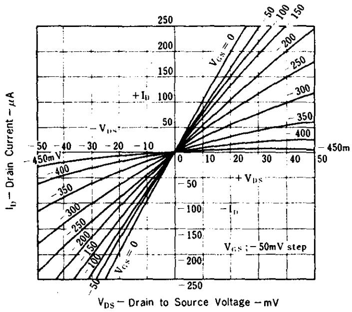
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



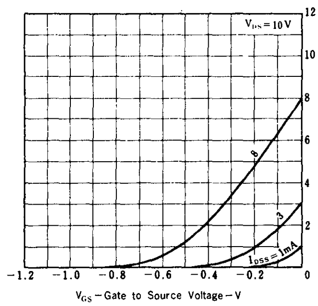
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



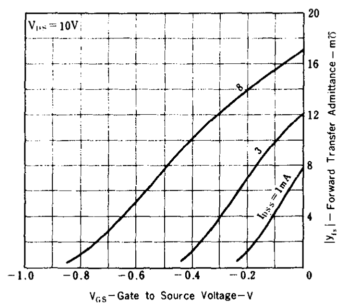
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



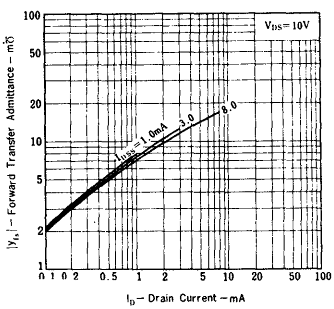
DRAIN CURRENT vs. GATE TO SOURCE VOLTAGE



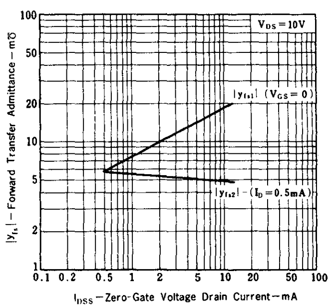
FORWARD TRANSFER ADMITTANCE vs. GATE TO SOURCE VOLTAGE



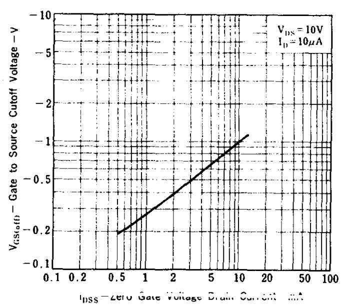
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT



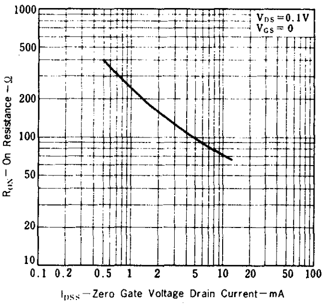
FORWARD TRANSFER ADMITTANCE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



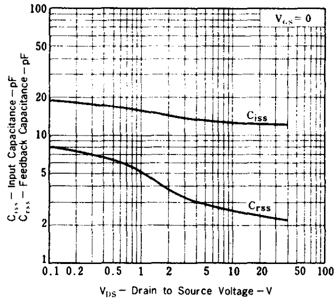
GATE TO SOURCE CUTOFF VOLTAGE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



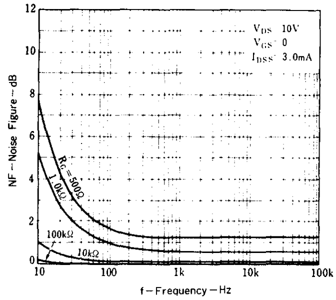
ON RESISTANCE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



INPUT AND FEEDBACK CAPACITANCE vs. DRAIN TO SOURCE VOLTAGE

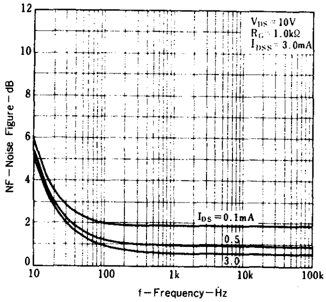


NOISE FIGURE vs. FREQUENCY

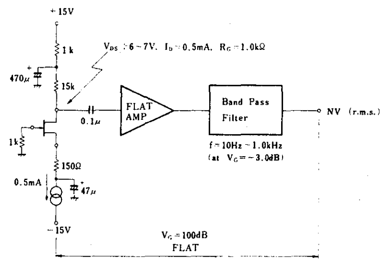


4

NOISE FIGURE vs. FREQUENCY



NOISE VOLTAGE TEST CIRCUIT



NEC
ELECTRON DEVICE

N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR
2SK104

DESCRIPTION The 2SK104 is designed for use in analog-switch, variable-resistor, RF amplifier and AF amplifier.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

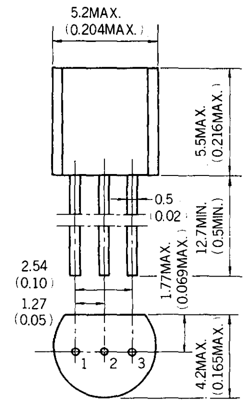
Maximum Temperature
- Storage Temperature . . . . -55 to +125°C
- Junction Temperature . . . . +125°C Maximum

Maximum Power Dissipation (Ta = 25°C)
- Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents
- Gate-Drain Voltage V_{GDO} . . . . -30 V
- Gate-Source Voltage V_{GSO} . . . . -30 V
- Drain-Source Voltage V_{DSX}* . . . . 30 V
- Drain Current I_D . . . . 20 mA
- Gate Current I_G . . . . 10 mA

*V_{GS} = - 5.0V

PACKAGE DIMENSIONS
in millimeters (inches)



1. GATE
2. SOURCE
3. DRAIN

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{GSS}	Gate Cutoff Current			-1.0	nA	V_{GS}=-30V, V_{DS}=0
I_{DSS}	Zero-Gate Voltage Drain Current	0.5	2.5	12	mA	V_{DS}=5.0V, V_{GS}=0
$V_{GS(off)}$	Gate to Source Cutoff Voltage	-0.25	-1.1	-4.5	V	V_{DS}=5.0V, I_D=10μA
$\|Y_{fs}\|_1$	Forward Transfer Admittance	1.5	2.1		m℧	V_{DS}=5.0V, I_D=0.5mA, f=1.0kHz
$\|Y_{fs}\|_2$	Forward Transfer Admittance	1.5	4.1		m℧	V_{DS}=5.0V, V_{GS}=0, f=1.0kHz
Ciss	Input Capacitance		4.1	6.0	pF	V_{DS}=10V, V_{GS}=0, f=1.0MHz
Crss	Feedback Capacitance		0.9	1.3	pF	V_{DS}=10V, V_{GS}=0, f=1.0MHz

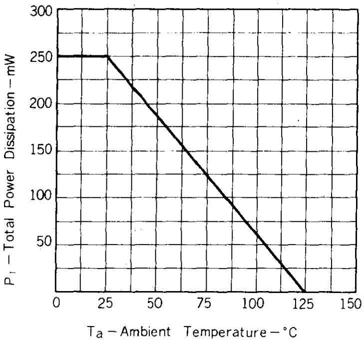
Classification of I_{DSS}

Rank	E	F	H	J
I_{DSS}(mA)	0.5 – 1.5	1.0 – 3.0	2.0 – 6.0	4.0 – 12

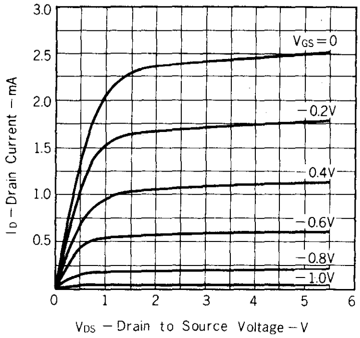
I_{DSS} Test Conditions : V_{DS} = 5.0V, V_{GS} = 0

TYPICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

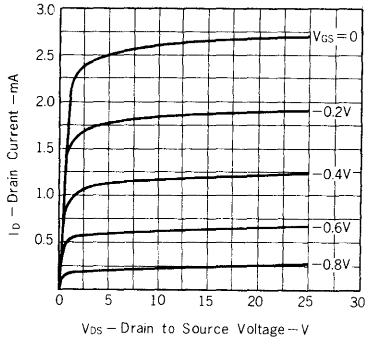
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE

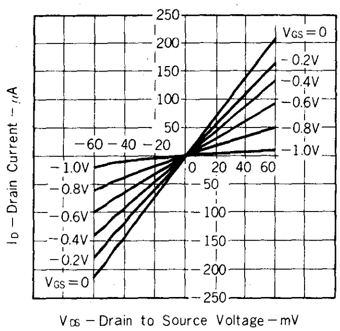


DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE

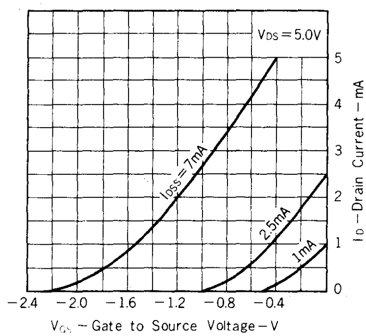


4

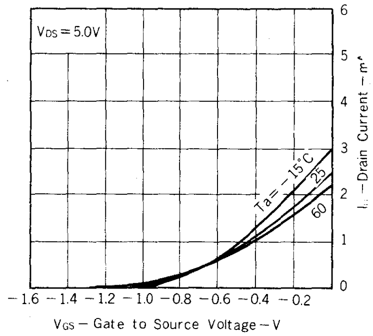
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



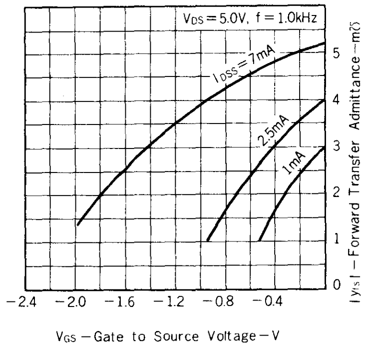
DRAIN CURRENT vs. GATE TO SOURCE VOLTAGE



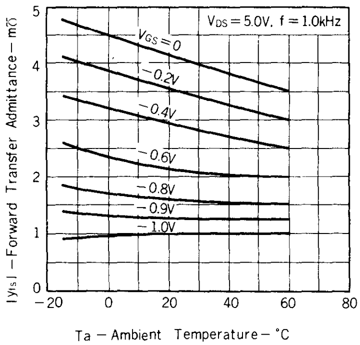
DRAIN CURRENT vs. GATE TO SOURCE VOLTAGE



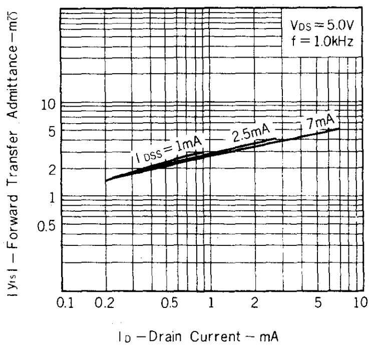
FORWARD TRANSFER ADMITTANCE vs. GATE TO SOURCE VOLTAGE



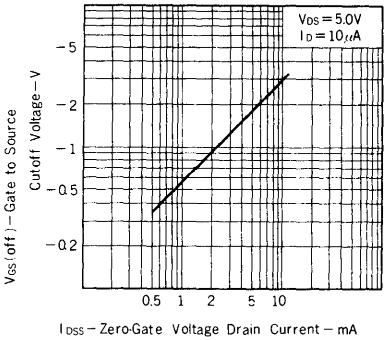
FORWARD TRANSFER ADMITTANCE vs. AMBIENT TEMPERATURE



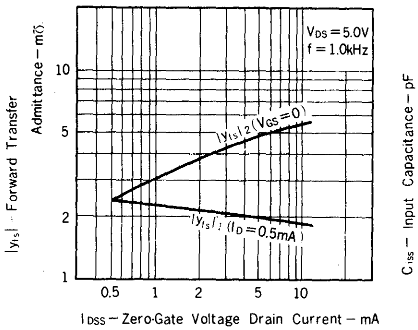
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT



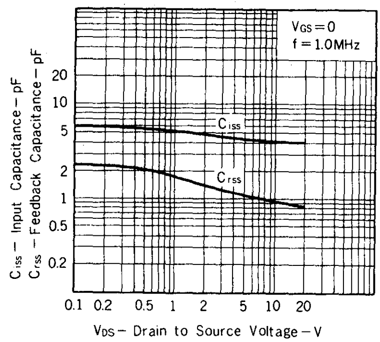
GATE TO SOURCE CUTOFF VOLTAGE
vs. ZERO-GATE VOLTAGE DRAIN CURRENT



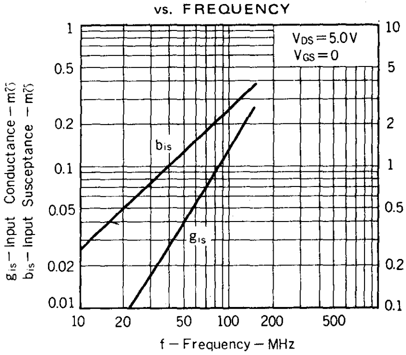
FORWARD TRANSFER ADMITTANCE
vs. ZERO-GATE VOLTAGE DRAIN CURRENT



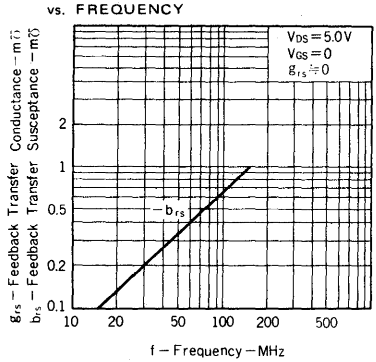
INPUT AND FEEDBACK CAPACITANCE
vs. DRAIN TO SOURCE VOLTAGE



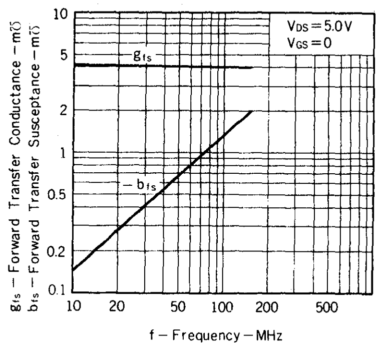
INPUT ADMITTANCE
vs. FREQUENCY



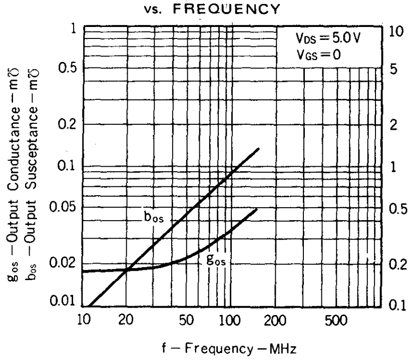
FEEDBACK TRANSFER ADMITTANCE
vs. FREQUENCY



FORWARD TRANSFER ADMITTANCE
vs. FREQUENCY



OUTPUT ADMITTANCE
vs. FREQUENCY

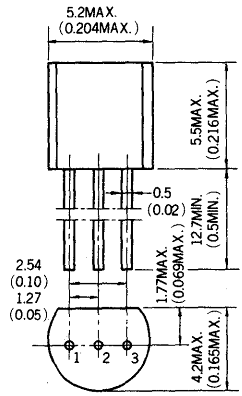


NEC
ELECTRON DEVICE

N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR
2SK105

DESCRIPTION The 2SK105 is designed for use in analog-switch, variable-resistor and AF amplifier.

PACKAGE DIMENSIONS
in millimeters (inches)



1. DRAIN
2. GATE
3. SOURCE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Temperature
- Storage Temperature . . . . -55 to +125°C
- Junction Temperature . . . . +125°C Maximum

Maximum Power Dissipation (Ta = 25°C)
- Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents
- Gate-Drain Voltage V_{GDO} . . . . -50 V
- Gate-Source Voltage V_{GSO} . . . . -50 V
- Drain-Source Voltage V_{DSX}* . . . . 50 V
- Drain Current I_D . . . . 20 mA
- Gate Current I_G . . . . 10 mA

*V_{GS} = -5.0V

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{GSS}	Gate Cutoff Current			-1.0	nA	V_{GS} = -30V, V_{DS} = 0
I_{DSS}	Zero-Gate Voltage Drain Current	0.5	2.5	12	mA	V_{DS} = 5.0V, V_{GS} = 0
$V_{GS(off)}$	Gate to Source Cutoff Voltage	-0.25	-1.1	-4.5	V	V_{DS} = 5.0V, I_D = 10μA
$\lvert Y_{fs}\rvert_1$	Forward Transfer Admittance	1.5	2.1		m℧	V_{DS} = 5.0V, I_D = 0.5mA, f = 1.0kHz
$\lvert Y_{fs}\rvert_2$	Forward Transfer Admittance	1.5	4.1		m℧	V_{DS} = 5.0V, V_{GS} = 0, f = 1.0kHz
Ciss	Input Capacitance		4.1	6.0	pF	V_{DS} = 10V, V_{GS} = 0, f = 1.0MHz
Crss	Feedback Capacitance		0.9	1.3	pF	V_{DS} = 10V, V_{GS} = 0, f = 1.0MHz

Classification of I_{DSS}

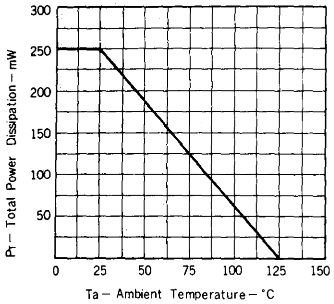
Rank	E	F	H	J
$I_{DSS(mA)}$	0.5 – 1.5	1.0 – 3.0	2.0 – 6.0	4.0 – 12

I_{DSS} Test Conditions : V_{DS} = 5.0V, V_{GS} = 0

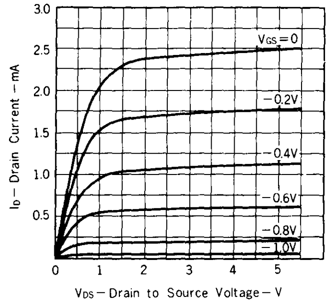
4

TYPICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

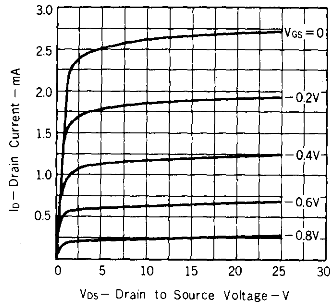
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



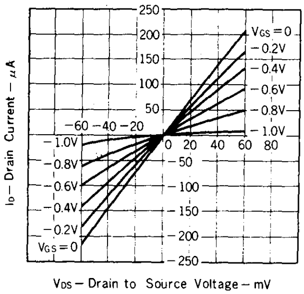
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



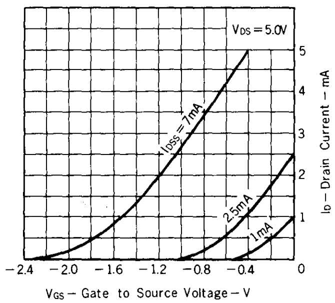
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



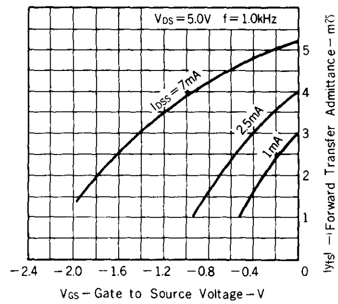
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



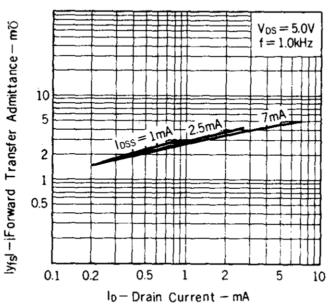
DRAIN CURRENT vs. GATE TO SOURCE VOLTAGE



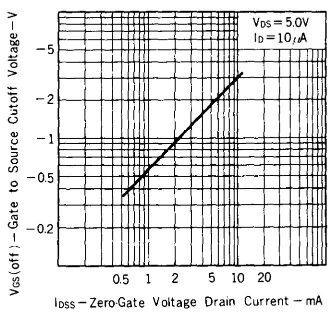
FORWARD TRANSFER ADMITTANCE vs. GATE TO SOURCE VOLTAGE



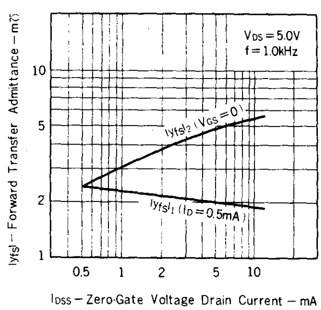
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT



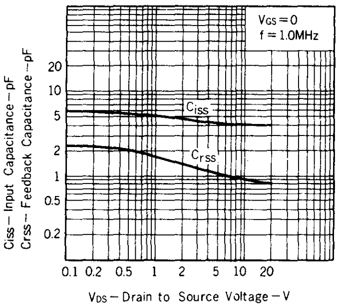
GATE TO SOURCE CUTOFF VOLTAGE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



FORWARD TRANSFER ADMITTANCE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



INPUT AND FEEDBACK CAPACITANCE
vs. DRAIN TO SOURCE VOLTAGE

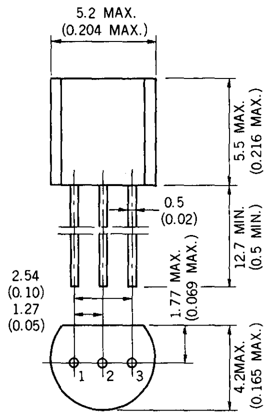


NEC
ELECTRON DEVICE

N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR
2SK162

DESCRIPTION The 2SK162 is designed for use in the first stage for Low Noise Amplifier.

PACKAGE DIMENSIONS
in millimeters (inches)



1. DRAIN	EIAJ	: SC-43
2. GATE	JEDEC	: TO-92
3. SOURCE	IEC	: PA33

FEATURES

- High $|y_{fs}|$
  $|y_{fs}|$ = 45 mS TYP. @ V_{DS} = 5.0 V, I_D = 5.0 mA, f = 1.0 kHz
- Low Noise
  e_n = 0.65 nV/$\sqrt{Hz}$ @ V_{DS} = 5.0 V, I_D = 5.0 mA, f = 1.0 kHz

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures
- Storage Temperature . . . . −55 to +125 °C
- Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation . . . . 400 mW

Maximum Voltages and Currents

V_{GDO}	Gate to Drain Voltage	−40	V
V_{GSO}	Gate to Source Voltage	−40	V
V_{DSX} *	Drain to Source Voltage	40	V
I_D	Drain Current	50	mA
I_G	Gate Current	10	mA

*V_{GS} = −2.0 V

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{DSS}	Drain Current	5.0	18	30	mA	V_{DS}=5.0 V, V_{GS}=0
NF	Noise Figure		1.1	2.5	dB	V_{DS}=5.0 V, I_D=5.0 mA, R_G=100 Ω, f=100 Hz
$\lvert y_{fs}\rvert_1$	Forward Transfer Admittance	40	45		mS	V_{DS}=5.0 V, I_D=5.0 mA, f=1.0 kHz
$\lvert y_{fs}\rvert_2$	Forward Transfer Admittance	40			mS	V_{DS}=5.0 V, V_{GS}=0, f=1.0 kHz
NV	Noise Voltage			35	mV	See Test Circuit
C_{iss}	Input Capacitance		55		pF	V_{DS}=10 V, V_{GS}=0, f=1.0 MHz
C_{rss}	Feedback Capacitance		10		pF	V_{DS}=10 V, V_{GS}=0, f=1.0 MHz
I_{GSS}	Gate Cutoff Current			−1.0	nA	V_{GS}=−20 V, V_{DS}=0
$V_{GS(off)}$	Gate to Source Cutoff Voltage			−1.2	V	V_{DS}=5.0 V, I_D=10 μA

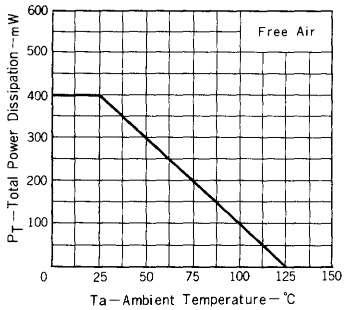
Classification of I_{DSS}

Rank	K	L	M	N
I_{DSS}(mA)	5.0 − 12	11 − 18	17 − 24	23 − 30

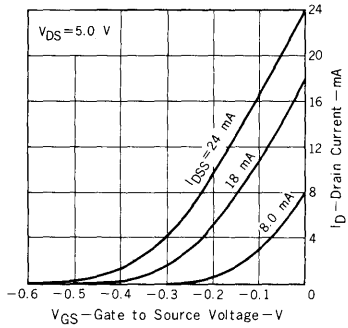
I_{DSS} Test Conditions: V_{DS} = 5.0 V, V_{GS} = 0

TYPICAL CHARACTERISTICS (Ta = 25 °C)

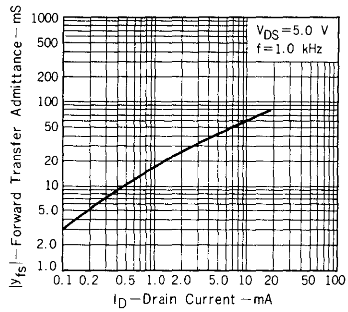
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



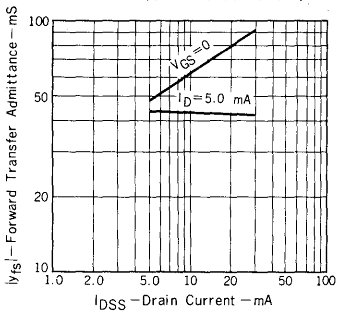
DRAIN CURRENT vs. GATE TO SOURCE VOLTAGE



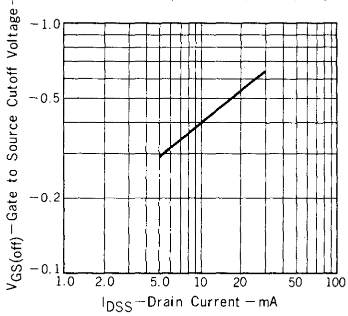
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT



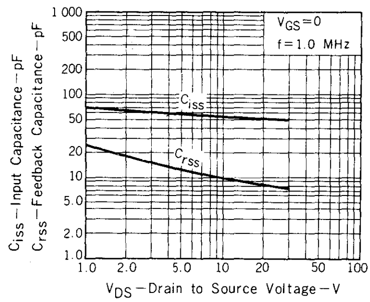
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT (CORRELATIVITY)



GATE TO SOURCE CUTOFF VOLTAGE vs. DRAIN CURRENT (CORRELATIVITY)

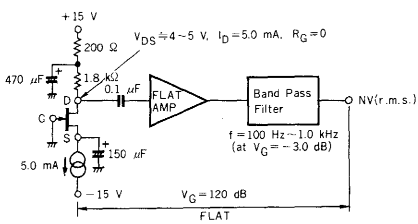


INPUT AND FEEDBACK CAPACITANCE vs. DRAIN TO SOURCE VOLTAGE



4

NOISE VOLTAGE TEST CIRCUIT



NEC
ELECTRON DEVICE

N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

2SK163

DESCRIPTION The 2SK163 is designed for use in the first stage for AF Low Noise amplifier.

FEATURES

- Low Equivalent Noise Voltage.
  $e_n = 1.3\ nV/\sqrt{Hz}$ TYP. ($V_{DS} = 10$ V, $I_D = 1.0$ mA, f = 1.0 kHz)
- High Voltage and High $|Y_{fs}|$
  $V_{DSX} > 50$ V ($V_{GS} = -2.0$ V)
  $|Y_{fs}| > 7.0$ mS ($V_{DS} = 10$ V, $I_D = 1.0$ mA, f = 1.0 kHz)

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −55 to +125 °C

Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

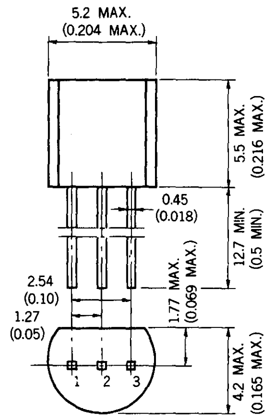
Total Power Dissipation . . . . 400 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{GDO}	Gate to Drain Voltage	−50	V
V_{GSO}	Gate to Source Voltage	−50	V
V_{DSX} *	Drain to Source Voltage	50	V
I_D	Drain Current	30	mA
I_G	Gate Current	10	mA

* $V_{GS} = -2.0$ V

PACKAGE DIMENSIONS
in millimeters (inches)



1. DRAIN
2. GATE
3. SOURCE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{DSS}	Drain Current	1.0	8.0	18	mA	$V_{DS} = 10$ V, $V_{GS} = 0$
e_n	Equivalent Noise Voltage		1.3		$nV/\sqrt{Hz}$	$V_{DS} = 10$ V, $I_D = 1.0$ mA, f = 1.0 kHz
$\|Y_{fs}\|_1$	Forward Transfer Admittance	7.0	9.0		mS	$V_{DS} = 10$ V, $I_D = 1.0$ mA, f = 1.0 kHz
$\|Y_{fs}\|_2$	Forward Transfer Admittance	7.0			mS	$V_{DS} = 10$ V, $V_{GS} = 0$, f = 1.0 kHz
NV	Noise Voltage			20	mV	See test circuit
C_{iss}	Input Capacitance		15		pF	$V_{DS} = 10$ V, $I_D = 1.0$ mA, f = 1.0 MHz
C_{rss}	Feedback Capacitance		6.0		pF	$V_{DS} = 10$ V, $I_D = 1.0$ mA, f = 1.0 MHz
I_{GSS}	Gate Cutoff Current			−1.0	nA	$V_{GS} = -20$ V, $V_{DS} = 0$
$V_{GS(off)}$	Gate to Source Cutoff Voltage	−0.2		−1.2	V	$V_{DS} = 10$ V, $I_D = 10\ \mu A$

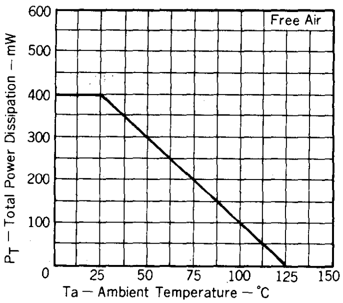
Classification of I_{DSS}

Rank	K	L	M	N
I_{DSS}(mA)	1.0 − 6.0	5.0 − 10	9.0 − 14	13 − 18

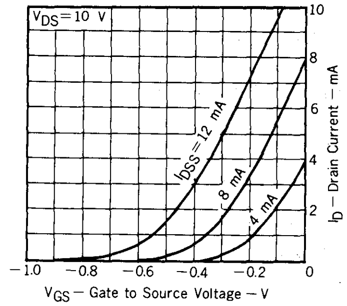
I_{DSS} Test Conditions: $V_{DS} = 10$ V, $V_{GS} = 0$

TYPICAL CHARACTERISTICS (Ta = 25 °C)

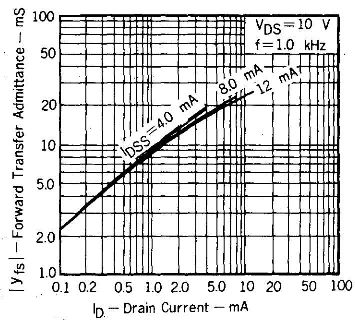
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



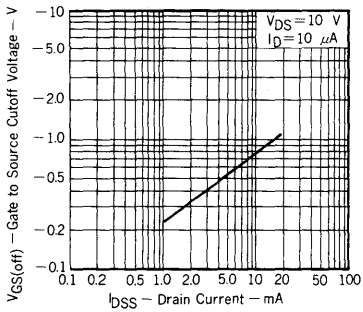
DRAIN CURRENT vs. GATE TO SOURCE VOLTAGE



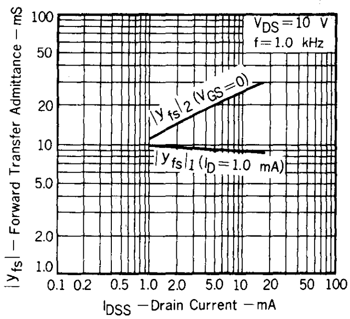
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT



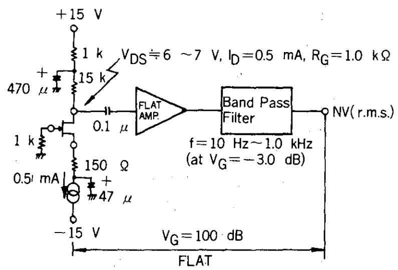
GATE TO SOURCE CUTOFF VOLTAGE vs. DRAIN CURRENT (CORRELATIVITY)



FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT (CORRELATIVITY)



NOISE VOLTAGE TEST CIRCUIT



4

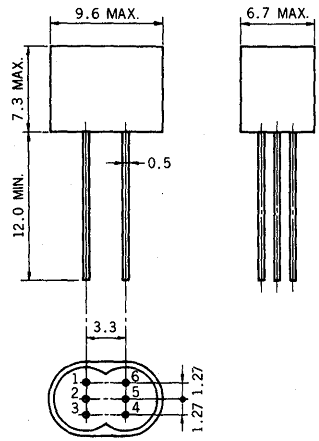
NEC
ELECTRON DEVICE

N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR
2SK194

DESCRIPTION The 2SK194 is designed for use in the first stage for differential amplifier.
Especially recommended Hi-Fi STEREO SETS.

FEATURES
- Super-Low Noise
  e_n = 0.65 nV/$\sqrt{Hz}$ TYP. @ V_{DS} = 5.0 V, I_D = 5.0 mA, f = 1.0 kHz
- High $|y_{fs}|$
  $|y_{fs}|$ = 45 mS @ V_{DS} = 5.0 V, I_D = 5.0 mA, f = 1.0 kHz
- Excellent pair balance
  ΔV_{GS} = 20 mV MAX.
  $|y_{fs}|$ Ratio = 0.95 MAX.
  @ V_{DS} = 5.0 V, I_D = 5.0 mA

PACKAGE DIMENSIONS
(Unit : mm)



1. Source 1
2. Gate 1
3. Drain 1
4. Drain 2
5. Gate 2
6. Source 2

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures
- Storage Temperature . . . . −55 to +125 °C
- Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation
- Total Power Dissipation . . . . 400 mW/Unit

Maximum Voltages and Currents

V_{GDO}	Gate to Drain Voltage	−40	V
V_{GSO}	Gate to Source Voltage	−40	V
V_{DSX}*	Drain to Source Voltage	40	V
I_D	Drain Current	50	mA
I_G	Gate Current	10	mA

*V_{GS} = −3.0 V

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{DSS}	Drain Current	5.0		24	mA	V_{DS} = 5.0 V, V_{GS} = 0
$\frac{I_{DSS(S)}}{I_{DSS(L)}}$	Drain Current Ratio	0.9		1.0		V_{DS} = 5.0 V, V_{GS} = 0 $I_{DSS(S)}/I_{DSS(L)}$*
$\|y_{fs}\|$	Forward Transfer Admittance	40	45		mS	V_{DS} = 5.0 V, I_D = 5.0 mA, f = 1.0 kHz
$\frac{\|y_{fs}\|_{(S)}}{\|y_{fs}\|_{(L)}}$	Forward Transfer Admittance Ratio	0.95		1.0		V_{DS} = 5.0 V, I_D = 5.0 mA, f = 1.0 kHz $\|y_{fs}\|_{(S)}/\|y_{fs}\|_{(L)}$*
ΔV_{GS}	Gate to Source Voltage Difference		3.0	20	mV	V_{DS} = 5.0 V, I_D = 5.0 mA $\Delta V_{GS} = V_{GS(L)} - V_{GS(S)}$*
NV	Noise Voltage		25	35	mV	See Test Circuit
C_{iss}	Input Capacitance		55		pF	V_{DS} = 10 V, V_{GS} = 0, f = 1.0 MHz
C_{rss}	Feedback Capacitance		10		pF	V_{DS} = 10 V, V_{GS} = 0, f = 1.0 MHz
$V_{GS(off)}$	Gate to Source Cutoff Voltage			−1.2	V	V_{DS} = 5.0 V, I_D = 10 μA
I_{GSS}	Gate Cutoff Current			−1.0	nA	V_{GS} = −20 V, V_{DS} = 0

*(S) : The Smaller Value, (L) : The Larger of pair

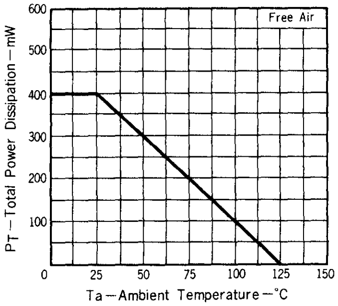
Classification of I_{DSS}

Rank	K	L	M
I_{DSS}(mA)	5.0 − 12	11 − 18	17 − 24

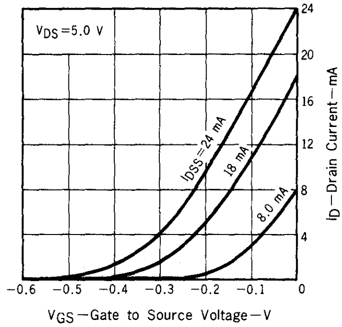
I_{DSS} Test Conditions : V_{DS} = 5.0 V, V_{GS} = 0

TYPICAL CHARACTERISTICS (Ta = 25 °C)

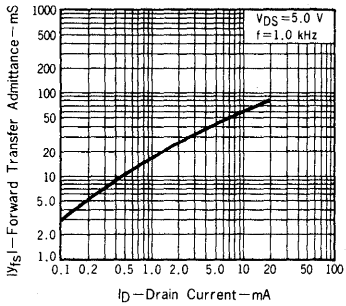
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



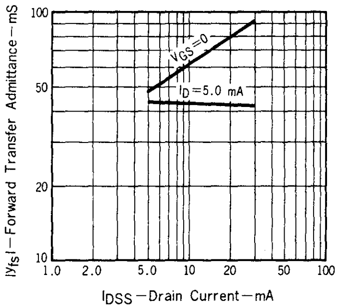
DRAIN CURRENT vs. GATE TO SOURCE VOLTAGE



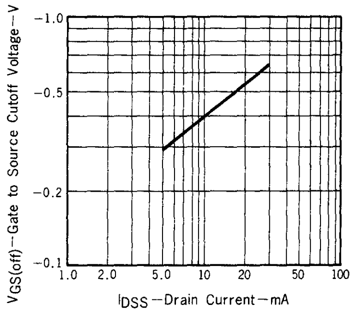
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT



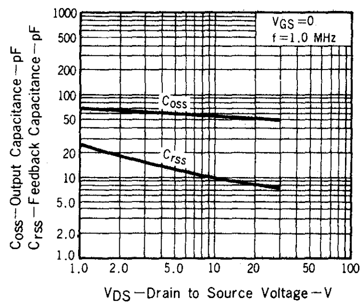
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT (CORRELATIVITY)



GATE TO SOURCE CUTOFF VOLTAGE vs. DRAIN CURRENT (CORRELATIVITY)

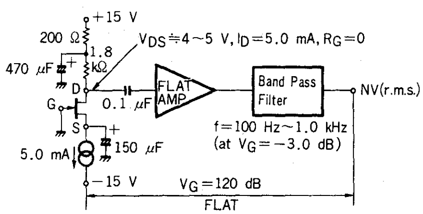


OUTPUT AND FEEDBACK CAPACITANCE vs. DRAIN TO SOURCE VOLTAGE



4

NOISE VOLTAGE TEST CIRCUIT



NEC
ELECTRON DEVICE

N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

2SK195

DESCRIPTION The 2SK195 is designed for use in FM tuner of a potable radio receiver.

FEATURES

- High $|y_{fs}|_1$: 3.5 mS TYP.
  (V_{DS} = 5.0 V, I_D = 0.5 mA, f = 1.0 kHz)
- Low C_{rss} : 0.07 pF TYP.
  (V_{DS} = 5.0 V, V_{GS} = 0)

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures

Storage Temperature . . . . −55 to +125 °C

Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

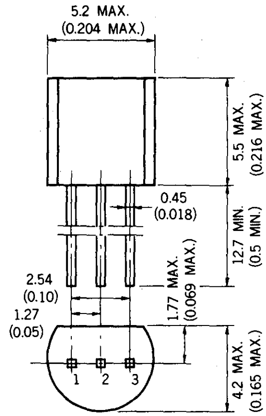
Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{GDO}	Gate to Drain Voltage	−20	V
V_{GSO}	Gate to Source Voltage	−1.0	V
V_{DSX}	Drain to Source Voltage	20	V
I_D	Drain Current	10	mA
I_G	Gate Current	10	mA

PACKAGE DIMENSIONS

in millimeters (inches)



1. GATE
2. SOURCE
3. DRAIN

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{DSS}	Zero-Gate Voltage Drain Current	0.5	2.5	8.0	mA	V_{DS}=5.0 V, V_{GS}=0
$\lvert y_{fs}\rvert_1$	Forward Transfer Admittance	2.3	3.5		mS	V_{DS}=5.0 V, I_D=0.5 mA, f=1.0 kHz
$\lvert y_{fs}\rvert_2$	Forward Transfer Admittance	2.3			mS	V_{DS}=5.0 V, I_D=0.5 mA, f=1.0 kHz
C_{iss}	Input Capacitance		5.0	6.5	pF	V_{DS}=5.0 V, V_{GS}=0, f=1.0 MHz
C_{rss}	Feedback Capacitance		0.07	0.25	pF	V_{DS}=5.0 V, V_{GS}=0, f=1.0 MHz
C_{oss}	Output Capacitance		4.5	6.0	pF	V_{DS}=5.0 V, V_{GS}=0, f=1.0 MHz
G_{ps}	Power Gain	13	21		dB	V_{DS}=5.0 V, V_{GS}=0, Z_{in}, Z_{out}=50 Ω f=100 MHz, See test circuit
NF	Noise Figure		3.0	6.0	dB	V_{DS}=5.0 V, V_{GS}=0, Z_{in}, Z_{out}=50 Ω f=100 MHz, See test circuit
I_{GSS}	Gate Cutoff Current			−100	nA	V_{GS}=−0.5 V, V_{DS}=0
$V_{GS(off)}$	Gate to Source Cutoff Voltage			−2.5	V	V_{DS}=5.0 V, I_D=10 μA

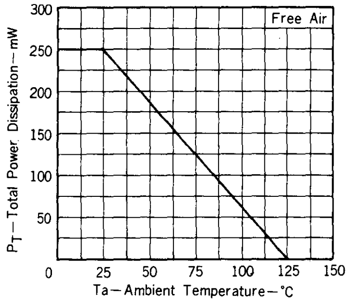
Classification of I_{DSS}

Rank	E	F	H	J
I_{DSS}(mA)	0.5 − 1.5	1.0 − 3.0	2.0 − 6.0	4.0 − 8.0

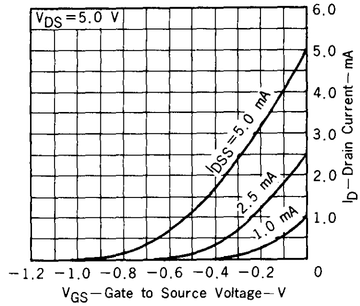
I_{DSS} Test Conditions: V_{DS} = 5.0 V, V_{GS} = 0

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

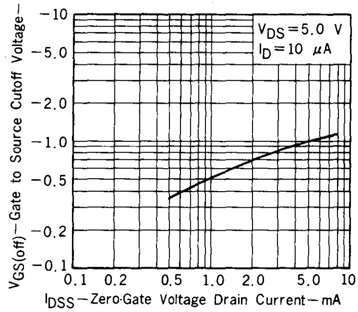
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



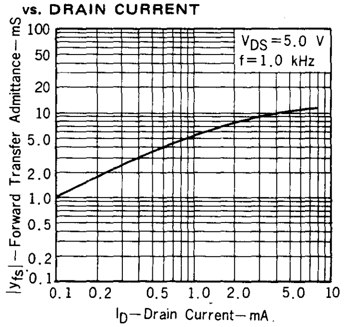
DRAIN CURRENT vs. GATE TO SOURCE VOLTAGE



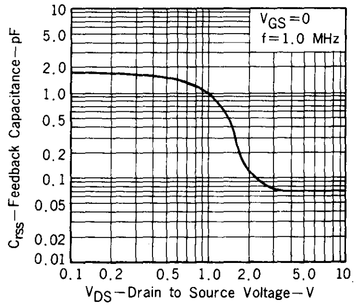
GATE TO SOURCE CUTOFF VOLTAGE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



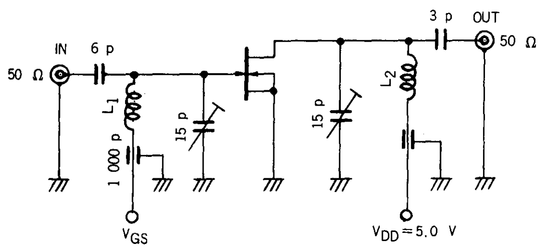
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT



FEEDBACK CAPACITANCE vs. DRAIN TO SOURCE VOLTAGE



NOISE FIGURE and POWER GAIN TEST CIRCUIT (f = 100 MHz)



TENTATIVE SPECIFICATION

NEC
ELECTRON DEVICE

SILICON POWER TRANSISTORS
2SK277,2SK278(V968)

HIGH VOLTAGE HIGH CURRENT AND HIGH SPEED SWITCHING

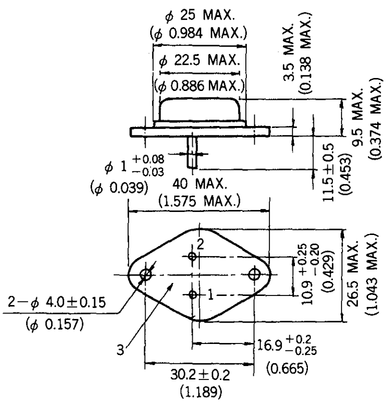
N CH POWER MOS FET

DESCRIPTION

Suitable for switching regulator, DC-DC converters.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Source
2. Gate
3. Drain (Case)

EIAJ : TC-3, TB-3
JEDEC : TO-3
IEC : C14A, B18

FEATURES

- High speed switching. $t_f \leqq 40$ ns @2 A
- Low Drain to Source resistance. $R_{DS(ON)} \leqq 1.5\ \Omega$

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25 °C)

		2SK277	2SK278	
Drain to Source Voltage	V_{DSX}	350	400	V
Gate to Source Voltage	V_{GSS}	±20		V
Continuous Drain Current	$I_{D(DC)}$	7		A
Peak Drain Current	$I_{D(pulse)}$*	10		A
Maximum Power Dissipation				
Total Power Dissipation	$P_{T(T_C=25\ °C)}$	100		W
Maximum Temperatures				
Channel Temperature	T_{ch}	150		°C
Storage Temperature	T_{stg}	−65 to 150		°C

*Pulsed PW ≦ 10 ms, duty cycle ≦ 50 %

ELECTRICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS	
Drain to Source Breakdown Voltage	BV_{DSX}	350			V	$V_{GS}=-10$ V, $I_D=10$ mA	2SK277
		400					2SK278
Gate to Source Breakdown Voltage	BV_{GSS}	±20			V	$V_{DS}=0$, $I_G=\pm100$ μA	
Drain Cutoff Current	I_{DSX}			10	mA	$V_{DS}=350$ V, $V_{GS}=-4$ V	
Gate to Source Cutoff Voltage	$V_{GS(off)}$	0	1	2	V	$V_{DS}=10$ V, $I_D=50$ mA	
Forward Transfer Admittance	$\lvert y_{fs}\rvert$	0.6	1.0		S	$V_{DS}=10$ V, $I_D=3$ A	
Drain to Source On Resistance	$R_{DS(ON)}$		1.0	1.5	Ω	$V_{GS}=15$ V, $I_D=4$ A	
Input Capacitance	C_{iss}		950	1500	pF	$V_{DS}=10$ V, $V_{GS}=-5$ V, f=1 MHz	
Output Capacitance	C_{oss}		600		pF		
Reverse Transfer Capacitance	C_{rss}		10		pF		
Turn-on Delay Time	$t_{d(on)}$		10	30	ns	$I_D=2$ A, $V_{GS(on)}=10$ V, $V_{GS(off)}=-5$ V, $R_L=75$ Ω, $V_{CC}\fallingdotseq150$ V, PW=1 μs, duty cycle≦1 %	
Rise Time	t_r		10	20	ns		
Turn-off Delay Time	$t_{d(off)}$		25	50	ns		
Fall Time	t_f		25	40	ns		

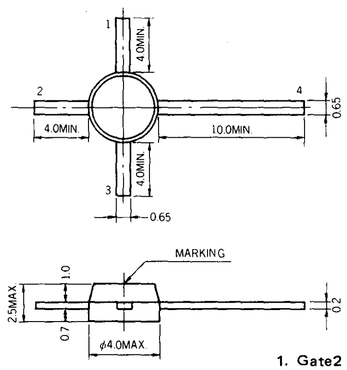
4

NEC
ELECTRON DEVICE

MOS FIELD EFFECT TRANSISTOR
3SK74

RF AMPLIFIER & MIXER FOR VHF TV
N-CHANNEL SILICON DUAL-GATE MOS FIELD-EFFECT TRANSISTOR
"DISKMOLD"

PACKAGE DIMENSIONS (Unit : mm)



1. Gate2
2. Gate1
3. Source
4. Drain

FEATURES

- Suitable for Use as RF Amplifier & Mixer in VHF TV Tuner.
- Low C_{rss} : 0.03pF TYP.
- High PG : 22dB TYP.
- Low NF : 2.0dB TYP.

ABSOLUTE MAXIMUM RATINGS ($T_a = 25°C$)

Drain to Source Voltage	V_{DSX}	20	V
Gate1 to Source Voltage	V_{G1S}	±10	V
Gate2 to Source Voltage	V_{G2S}	±10	V
Drain Current	I_D	25	mA
Total Power Dissipation	P_T	200	mW
Channel Temperature	T_{ch}	125	°C
Storage Temperature	T_{stg}	-65 to +125	°C

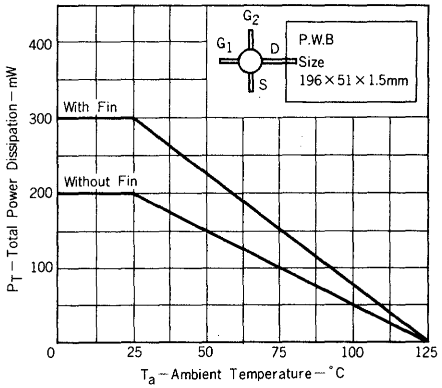
ELECTRICAL CHARACTERISTICS ($T_a = 25°C$)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Drain to Source Breakdown Voltage	BV_{DSX}	20			V	V_{G1S} = -3.0V, V_{G2S} = 3.0V, I_D = 500nA
Drain Current	I_{DSS}	7.0		25	mA	V_{DS} = 6.0V, V_{G1S} = 0, V_{G2S} = 3.0V
Gate1 to Source Cutoff Voltage	$V_{G1S(off)}$			-3.0	V	V_{DS} = 6.0V, V_{G2S} = 0, I_D = 5.0μA
Gate2 to Source Cutoff Voltage	$V_{G2S(off)}$			-3.0	V	V_{DS} = 6.0V, V_{G1S} = 0, I_D = 5.0μA
Gate1 Reverse Current	I_{G1SS}			±0.1	μA	V_{DS} = 0, V_{G1S} = ±10V, V_{G2S} = 0
Gate2 Reverse Current	I_{G2SS}			±0.1	μA	V_{DS} = 0, V_{G1S} = 0, V_{G2S} = ±10V
Forward Transfer Admittance	$\|Y_{fs}\|$	17	20		m℧	V_{DS} = 6.0V, I_D = 10mA, V_{G2S} = 3.0V f = 1kHz
Input Capacitance	C_{iss}		4.8	6.0	pF	V_{DS} = 6.0V, I_D = 10mA, V_{G2S} = 3.0V f = 1MHz
Output Capacitance	C_{oss}		2.5	3.5	pF	
Reverse Transfer Capacitance	C_{rss}		0.03	0.05	pF	
Power Gain	G_{ps}	20	22		dB	V_{DS} = 10V, I_D = 10mA, f = 200MHz * V_{G2} = 5.0V
Noise Figure	NF		2.0	3.0	dB	

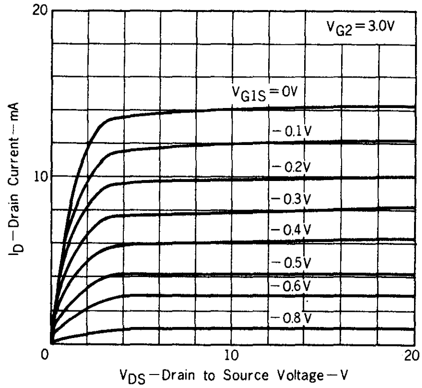
I_{DSS} Classification M : 7.0 – 13mA L : 11 – 19mA K : 17 – 25mA
*See Test Circuit

TYPICAL CHARACTERISTICS (Ta = 25°C)

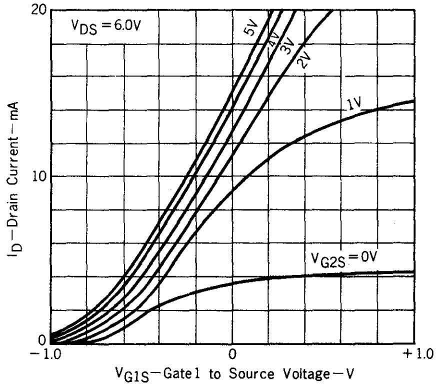
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



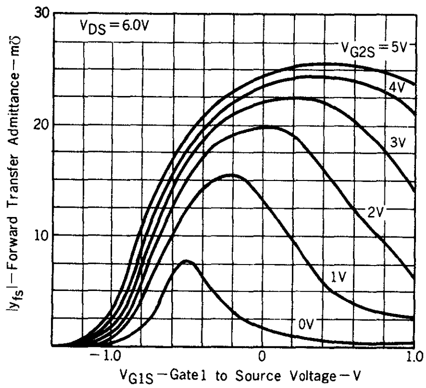
DRAIN CURRENT vs.
DRAIN TO SOURCE VOLTAGE



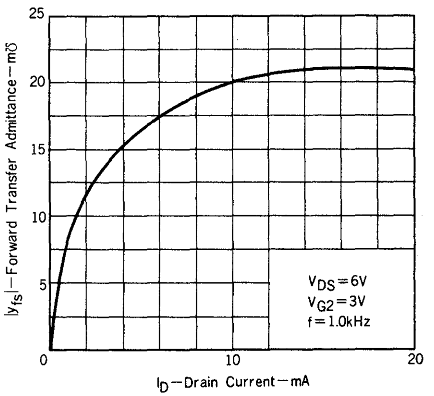
DRAIN CURRENT vs.
GATE1 TO SOURCE VOLTAGE



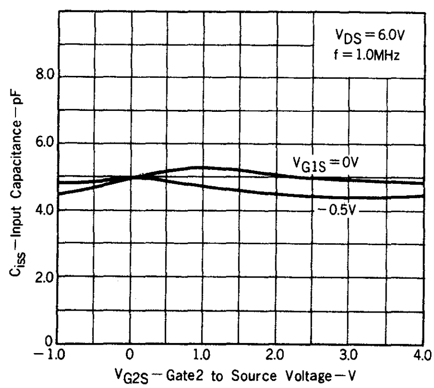
FORWARD TRANSFER ADMITTANCE vs.
GATE1 TO SOURCE VOLTAGE

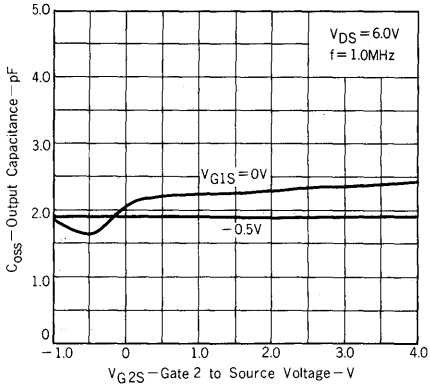


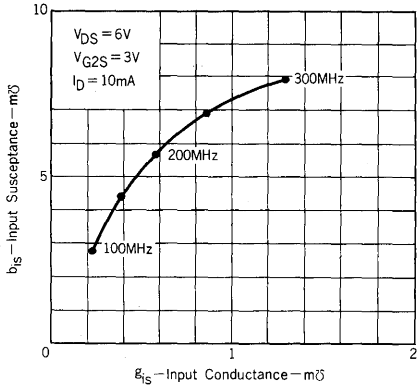
FORWARD TRANSFER ADMITTANCE vs.
DRAIN CURRENT

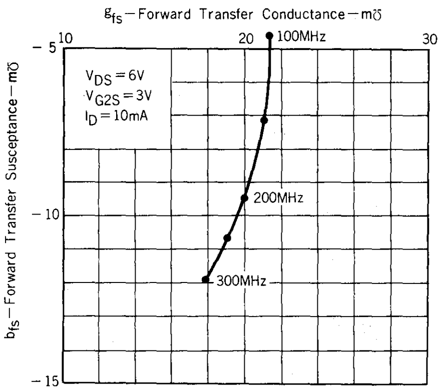


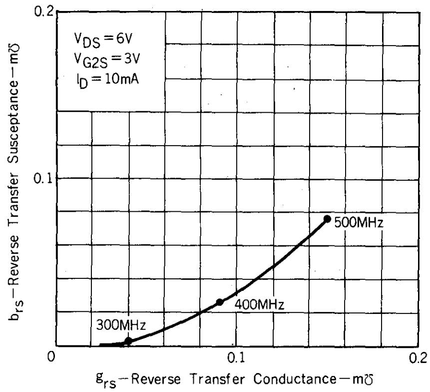
INPUT CAPACITANCE vs.
GATE2 TO SOURCE VOLTAGE

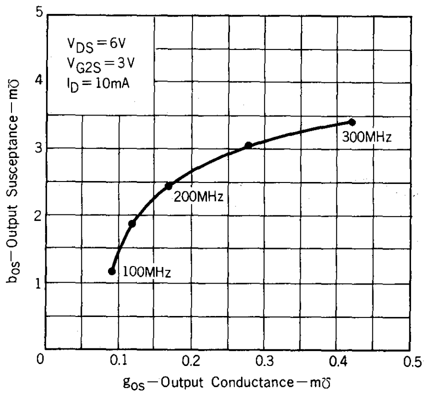


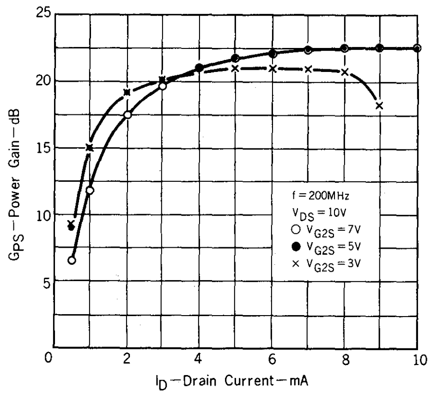

OUTPUT CAPACITANCE vs. GATE2 TO SOURCE VOLTAGE
VDS = 6.0V
f = 1.0MHz
VG1S = 0V
−0.5V
Coss − Output Capacitance − pF
VG2S − Gate 2 to Source Voltage − V


INPUT ADMITTANCE (yis) vs. FREQUENCY
VDS = 6V
VG2S = 3V
ID = 10mA
100MHz
200MHz
300MHz
bis − Input Susceptance − m℧
gis − Input Conductance − m℧

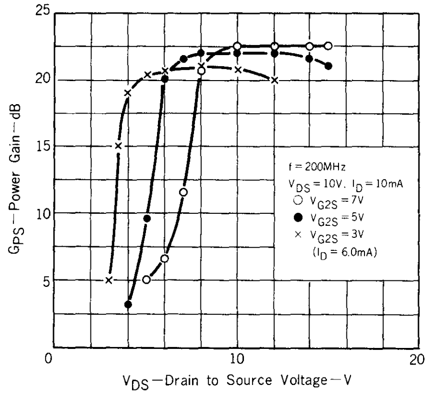

FORWARD TRANSFER ADMITTANCE (yfs) vs. FREQUENCY
gfs − Forward Transfer Conductance − m℧
VDS = 6V
VG2S = 3V
ID = 10mA
100MHz
200MHz
300MHz
bfs − Forward Transfer Susceptance − m℧


REVERSE TRANSFER ADMITTANCE (yrs) vs. FREQUENCY
VDS = 6V
VG2S = 3V
ID = 10mA
300MHz
400MHz
500MHz
brs − Reverse Transfer Susceptance − m℧
grs − Reverse Transfer Conductance − m℧

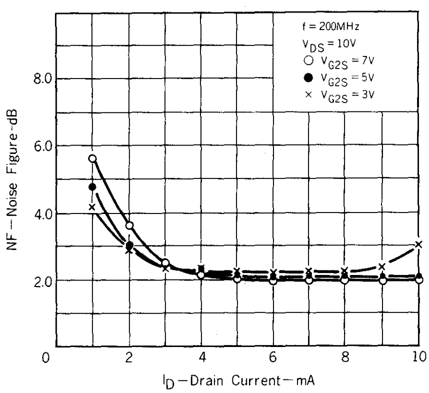

OUTPUT ADMITTANCE (yos) vs. FREQUENCY
VDS = 6V
VG2S = 3V
ID = 10mA
100MHz
200MHz
300MHz
bos − Output Susceptance − m℧
gos − Output Conductance − m℧


POWER GAIN vs. DRAIN CURRENT
f = 200MHz
VDS = 10V
○ VG2S = 7V
● VG2S = 5V
× VG2S = 3V
GPS − Power Gain − dB
ID − Drain Current − mA

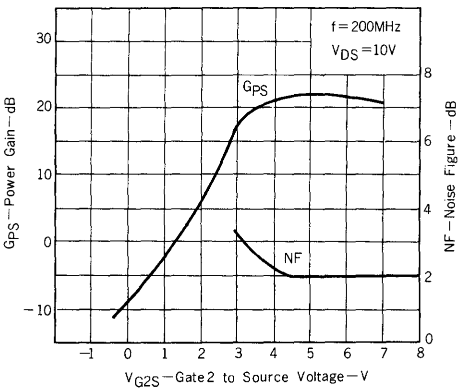
POWER GAIN vs. DRAIN TO SOURCE VOLTAGE



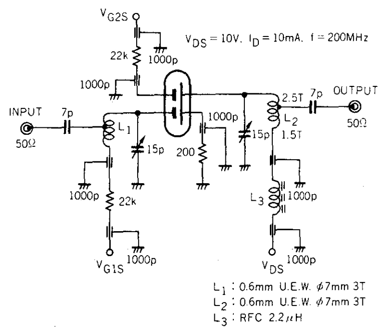
NOISE FIGURE vs. DRAIN CURRENT



NOISE FIGURE, POWER GAIN vs. GATE2 TO SOURCE VOLTAGE



200MHz Power Gain & Noise Figure Test Circuit

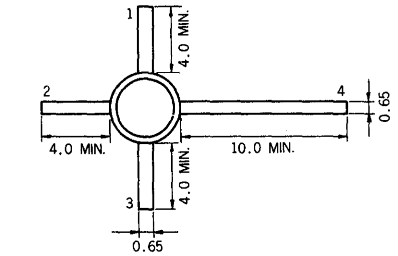


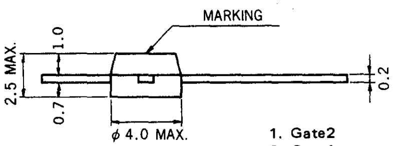
NEC
ELECTRON DEVICE

MOS FIELD EFFECT TRANSISTOR
3SK87

RF AMP. FOR UHF TV TUNER
N-CHANNEL SILICON DUAL-GATE MOS FIELD-EFFECT TRANSISTOR DISK MOLD

PACKAGE DIMENSIONS (Unit : mm)





1. Gate2
2. Gate1
3. Source
4. Drain

FEATURES

- Suitable for use as RF amplifier in UHF TV tuner. (RF Amp. for half wave length resonator : λ/2)
- Low C_{rss} : 0.02 pF TYP.
- High G_{ps} : 18 dB TYP.
- Low NF : 3.8 dB TYP.

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Drain to Source Voltage	V_{DSX}	20	V
Gate1 to Source Voltage	V_{G1S}	±10	V
Gate2 to Source Voltage	V_{G2S}	±10	V
Drain Current	I_D	25	mA
Total Power Dissipation	P_T	200	mW
Channel Temperature	T_{ch}	125	°C
Storage Temperature	T_{stg}	−55 to +125	°C

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

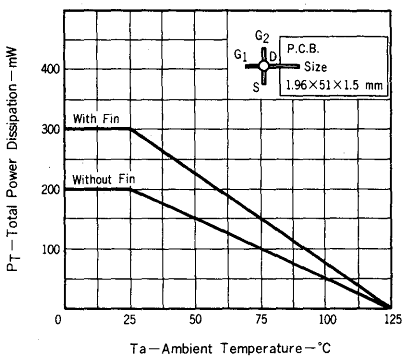
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Drain to Source Breakdown Voltage	BV_{DSX}	20	24		V	$V_{G1S}=V_{G2S}=-2$ V, $I_D=10$ μA
Drain Current	I_{DSS}	0.5		8	mA	$V_{DS}=10$ V, $V_{G2S}=4$ V, $V_{G1S}=0$
Gate1 to Source Cutoff Voltage	$V_{G1S(off)}$			−2.0	V	$V_{DS}=10$ V, $V_{G2S}=4$ V, $I_D=10$ μA
Gate2 to Source Cutoff Voltage	$V_{G2S(off)}$			−0.7	V	$V_{DS}=10$ V, $V_{G1S}=4$ V, $I_D=10$ μA
Gate1 Reverse Current	I_{G1SS}			±20	nA	$V_{DS}=0$, $V_{G1S}=\pm10$ V, $V_{G2S}=0$
Gate2 Reverse Current	I_{G2SS}			±20	nA	$V_{DS}=0$, $V_{G2S}=\pm10$ V, $V_{G1S}=0$
Forward Transfer Admittance	$\lvert Y_{fs} \rvert$	18	22		mS	$V_{DS}=10$ V, $V_{G2S}=4$ V, $I_D=10$ mA f = 1.0 kHz
Input Capacitance	C_{iss}	1.5	2.5	3.5	pF	$V_{DS}=10$ V, $V_{G2S}=4$ V, $I_D=10$ mA f = 1 MHz
Output Capacitance	C_{oss}	0.5	1.1	1.5	pF	
Reverse Transfer Capacitance	C_{rss}		0.02	0.03	pF	
Power Gain	G_{ps}*	15	18	22	dB	$V_{DS}=10$ V, $V_{G2S}=4$ V, $I_D=10$ mA f = 900 MHz
Noise Figure	NF*		3.8	5.5	dB	

I_{DSS} Classification L: 0.5 − 5 mA, K: 3 − 8 mA

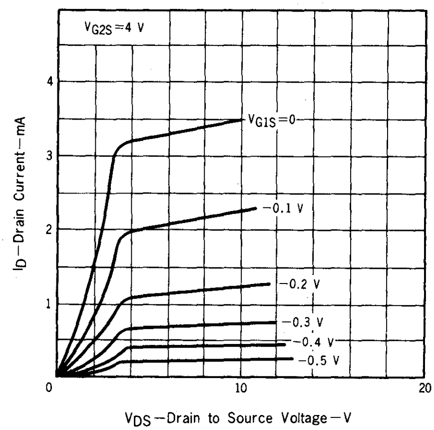
* See Test Circuit

TYPICAL CHARACTERISTICS (Ta = 25 °C)

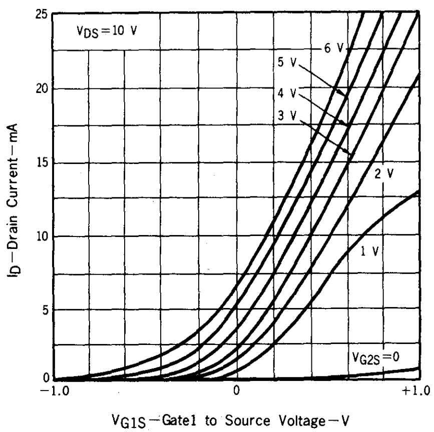
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



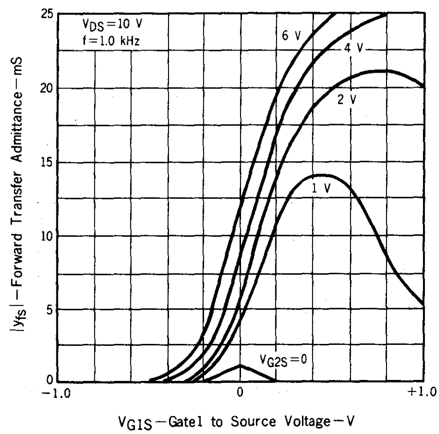
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



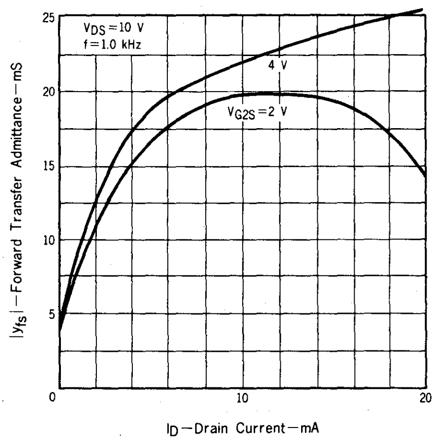
DRAIN CURRENT vs. GATE1 TO SOURCE VOLTAGE



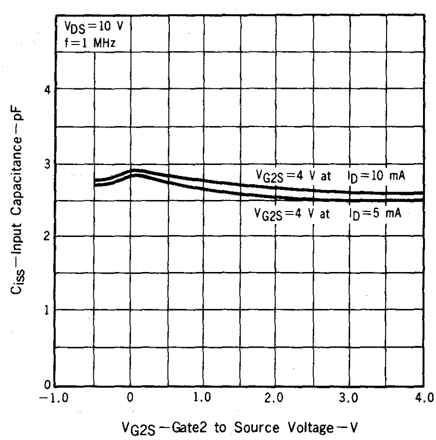
FORWARD TRANSFER ADMITTANCE vs. GATE1 TO SOURCE VOLTAGE



FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT

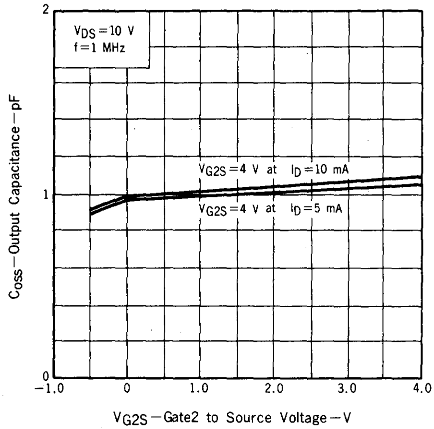


INPUT CAPACITANCE vs. GATE2 TO SOURCE VOLTAGE

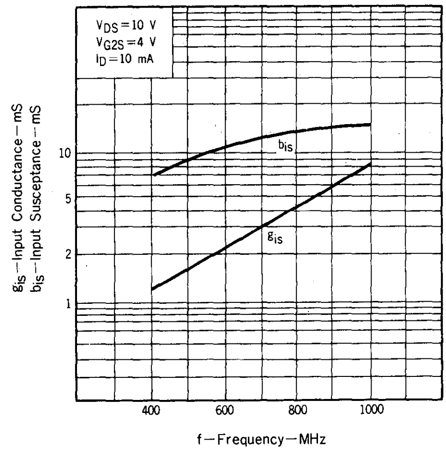


4

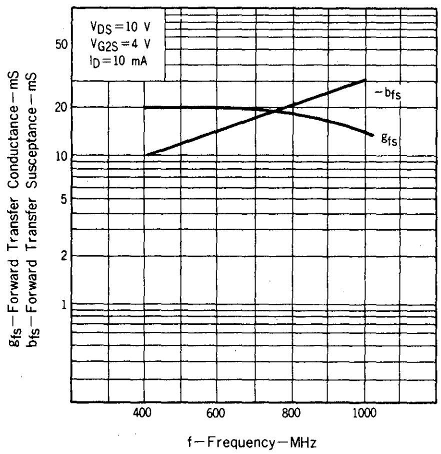
OUTPUT CAPACITANCE vs.
GATE2 TO SOURCE VOLTAGE



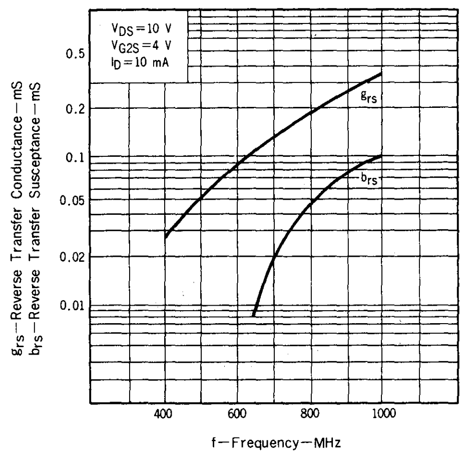
INPUT ADMITTANCE vs.
FREQUENCY



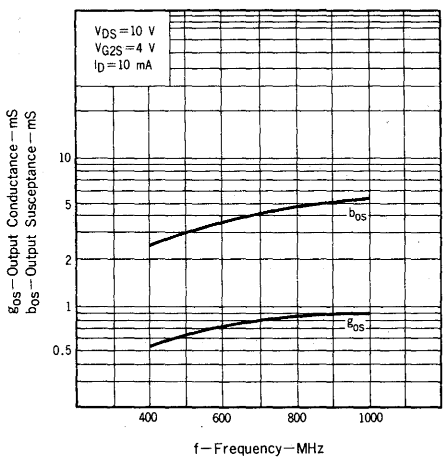
FORWARD TRANSFER ADMITTANCE vs.
FREQUENCY



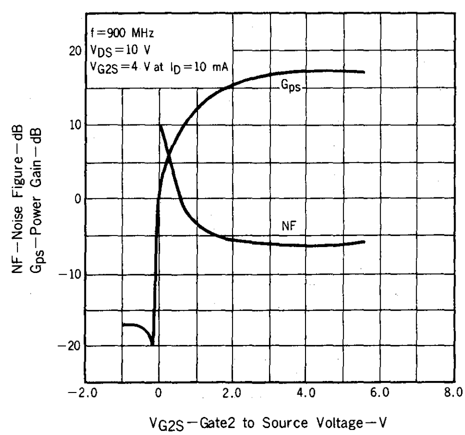
REVERSE TRANSFER ADMITTANCE vs.
FREQUENCY



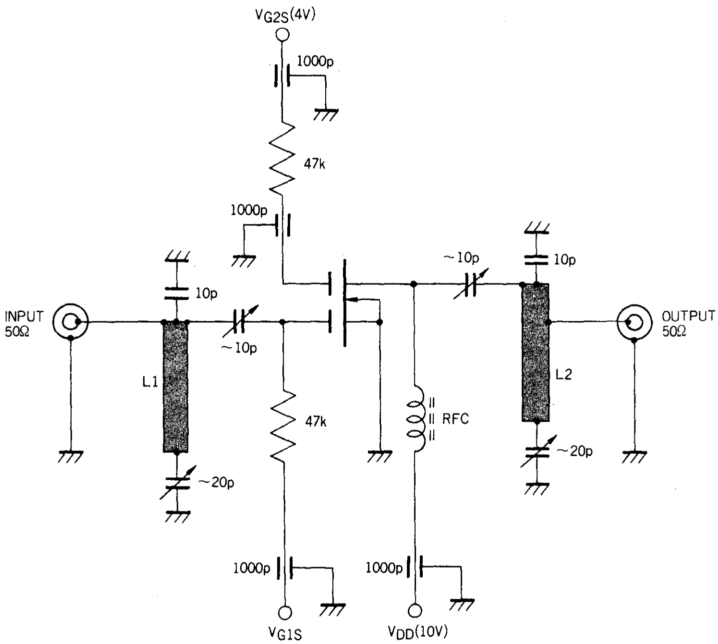
OUTPUT ADMITTANCE vs.
FREQUENCY



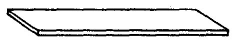
POWER GAIN AND NOISE FIGURE vs.
GATE2 TO SOURCE VOLTAGE



900 MHz G_{ps} & NF TEST CIRCUIT



L1, L2: 30×5×0.5 mm

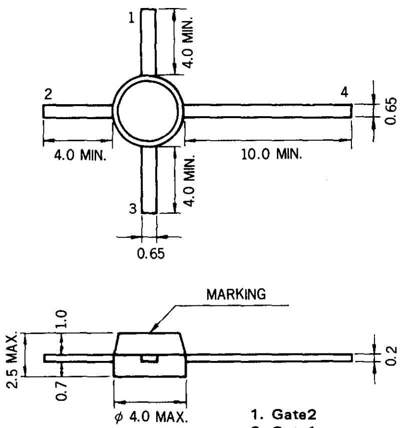


NEC
ELECTRON DEVICE

MOS FIELD EFFECT TRANSISTOR
3SK88

RF AMP. FOR UHF TV TUNER
N-CHANNEL SILICON DUAL-GATE MOS FIELD-EFFECT TRANSISTOR
DISK MOLD

PACKAGE DIMENSIONS (Unit : mm)



1. Gate2
2. Gate1
3. Source
4. Drain

FEATURES

- Suitable for use as RF amplifier in UHF TV tuner.
- Low C_{rss} : 0.02 pF TYP.
- High G_{ps} : 16 dB TYP.
- Low NF : 3.8 dB TYP.

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Drain to Source Voltage	V_{DSX}	20	V
Gate1 to Source Voltage	V_{G1S}	±10	V
Gate2 to Source Voltage	V_{G2S}	±10	V
Drain Current	I_D	25	mA
Total Power Dissipation	P_T	200	mW
Channel Temperature	T_{ch}	125	°C
Storage Temperature	T_{stg}	−65 to +125	°C

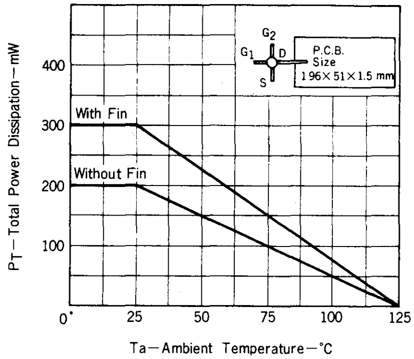
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Drain to Source Breakdown Voltage	BV_{DSX}	20			V	$V_{G1S} = V_{G2S} = -2$ V, $I_D = 10$ μA
Drain Current	I_{DSS}	0.01		6	mA	$V_{DS} = 10$ V, $V_{G2S} = 4$ V, $V_{G1S} = 0$
Gate1 to Source Cutoff Voltage	$V_{G1S(off)}$			−2.0	V	$V_{DS} = 10$ V, $V_{G2S} = 4$ V, $I_D = 10$ μA
Gate2 to Source Cutoff Voltage	$V_{G2S(off)}$			−0.7	V	$V_{DS} = 10$ V, $V_{G1S} = 4$ V, $I_D = 10$ μA
Gate1 Reverse Current	I_{G1SS}			20	nA	$V_{DS} = 0$, $V_{G1S} = \pm 10$ V, $V_{G2S} = 0$
Gate2 Reverse Current	I_{G2SS}			20	nA	$V_{DS} = 0$, $V_{G2S} = \pm 10$ V, $V_{G1S} = 0$
Forward Transfer Admittance	$\lvert Y_{fs} \rvert$	14	17		mS	$V_{DS} = 10$ V, $V_{G2S} = 4$ V, $I_D = 10$ mA, f = 1 kHz
Input Capacitance	C_{iss}	1.5	2.0	2.5	pF	$V_{DS} = 10$ V, $V_{G2S} = 4$ V, $I_D = 10$ mA f = 1 MHz
Output Capacitance	C_{oss}	0.5	1.0	1.5	pF	
Reverse Transfer Capacitance	C_{rss}		0.02	0.03	pF	
Power Gain	Gps*	14	16	18	dB	$V_{DS} = 10$ V, $V_{G2S} = 4$ V, $I_D = 10$ mA f = 900 MHz
Noise Figure	NF*		3.8	5.5	dB	

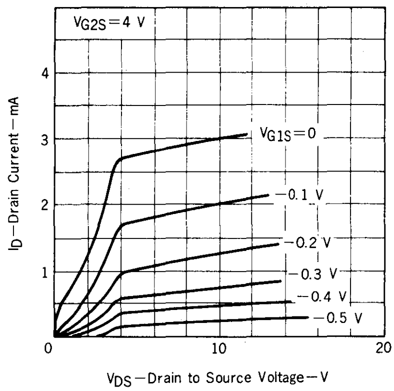
I_{DSS} Classification L: 0.01 − 2 mA K: 1 − 6 mA
*See Test Circuit

TYPICAL CHARACTERISTICS (Ta = 25 °C)

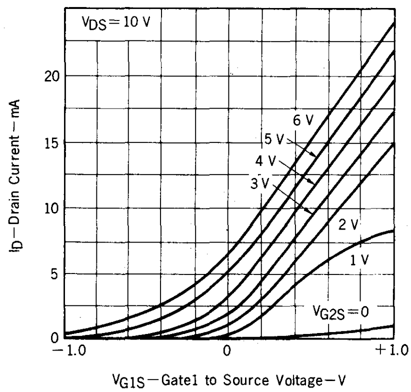
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



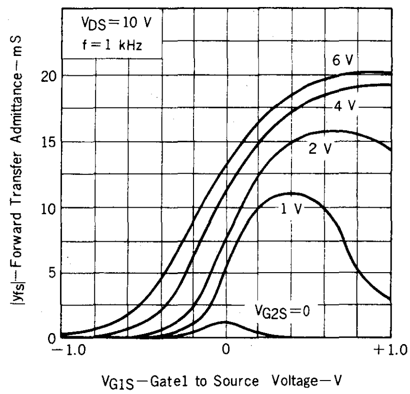
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



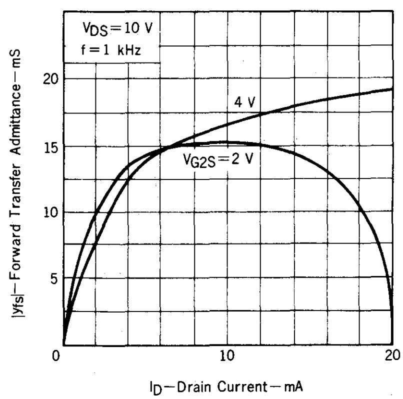
DRAIN CURRENT vs. GATE1 TO SOURCE VOLTAGE



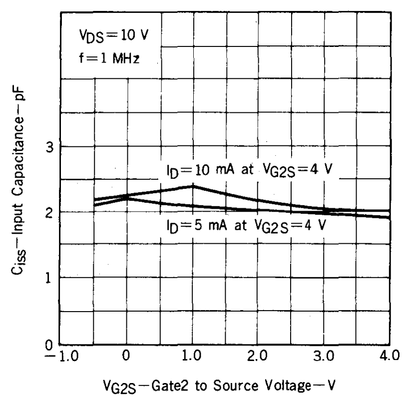
FORWARD TRANSFER ADMITTANCE vs. GATE1 TO SOURCE VOLTAGE



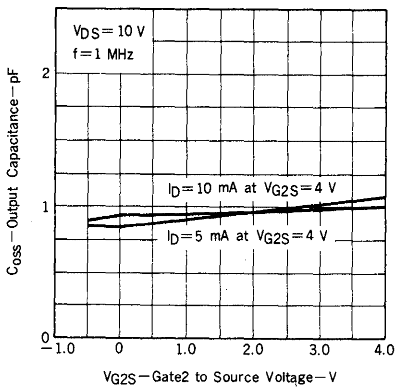
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT



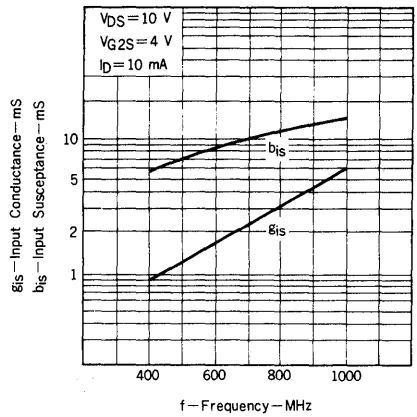
INPUT CAPACITANCE vs. GATE2 TO SOURCE VOLTAGE



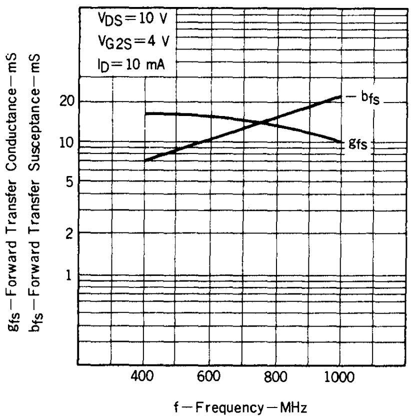
OUTPUT CAPACITANCE vs. GATE2 TO SOURCE VOLTAGE



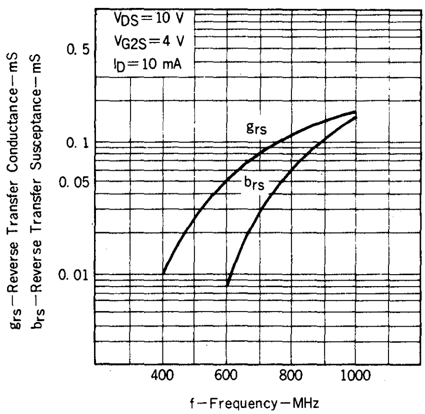
INPUT ADMITTANCE vs. FREQUENCY



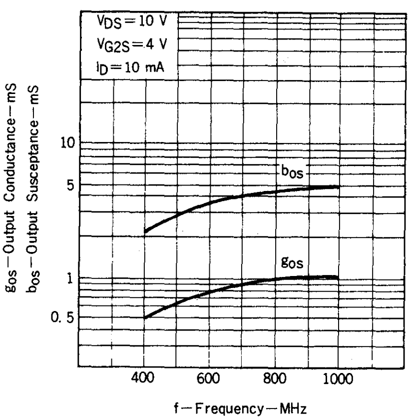
FORWARD TRANSFER ADMITTANCE vs. FREQUENCY



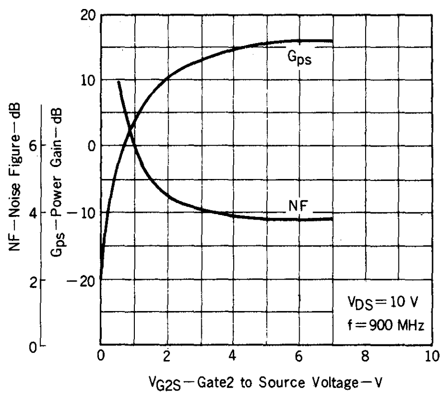
REVERSE TRANSFER ADMITTANCE vs. FREQUENCY



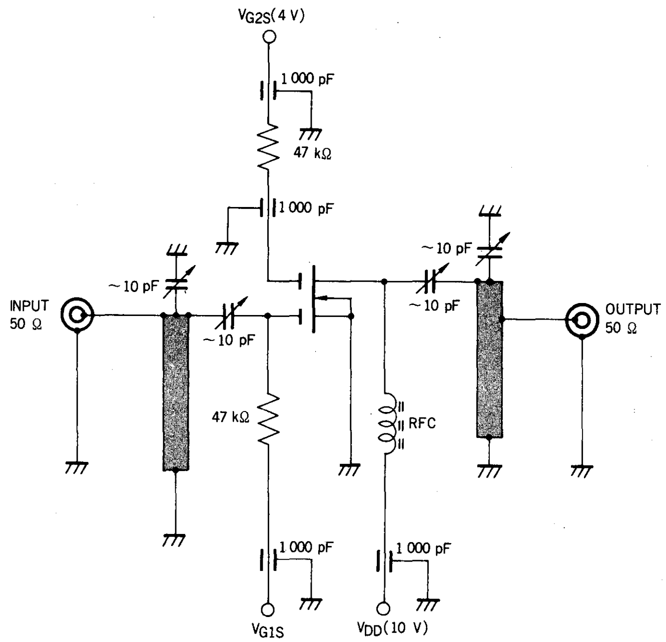
OUTPUT ADMITTANCE vs. FREQUENCY



POWER GAIN AND NOISE FIGURE vs. GATE2 TO SOURCE VOLTAGE



900 MHz G_{ps} AND NF TEST CIRCUIT



NEC
ELECTRON DEVICE

N-CHANNEL SILICON DUAL JUNCTION FIELD-EFFECT TRANSISTOR

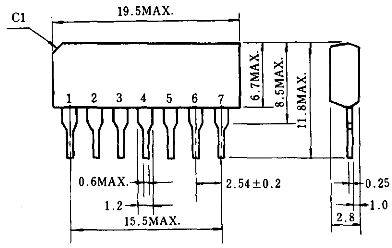
μPA68H

DESCRIPTION The μPA68H is designed for use in the top stage for differential amplifier of a stereo main amplifier.

FEATURES

- Excellent pair balance
  $\Delta V_{GS} = 20mV$ MAX.
  @$V_{DS} = 10V$, $I_D = 1.0mA$, $\Delta V_{GS} = V_{GS(L)} - V_{GS(S)}$
  $|Y_{fs}|$ Ratio; 0.95 MIN.
  @$V_{DS} = 10V$, $I_D = 1.0mA$
- High bleakdown voltage.
  $V_{GDO} > 50V$

PACKAGE DIMENSIONS (Unit : mm)



1. Drain 1
2. Gate 1
3. Source 1
4. Sub.
5. Source 2
6. Gate 2
7. Drain 2

ABSOLUTE MAXIMUM RATINGS ($T_a = 25°C$)

Maximum Temperatures

Storage Temperature .... −55 to +125°C

Junction Temperature .... +125°C Maximum

Maximum Power Dissipation

Total Power Dissipation 250mW/Unit

Maximum Voltages and Currents

V_{GDO}	Gate to Drain Voltage	−50	V
V_{GSO}	Gate to Source Voltage	−50	V
V_{DSX}*	Drain to Source Voltage	50	V
I_D	Drain Current	30	mA
I_G	Gate Current	10	mA

* $V_{GS} = -3.0V$

ELECTRICAL CHARACTERISTICS ($T_a = 25°C$)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{DSS}	Drain Current	1.0		18	mA	$V_{DS}=10V$, $V_{GS}=0$
$I_{DSS(S)}/I_{DSS(L)}$	Drain Current Ratio	0.9		1.0		$V_{DS}=10V$, $V_{GS}=0$ $I_{DSS(S)}/I_{DSS(L)}$*
$\|Y_{fs}\|$	Forward Transfer Admittance	5.0	7.0		m℧	$V_{DS}=10V$, $I_D=1.0mA$, $f=1.0kHz$
$\|Y_{fs}\|_{(S)}/\|Y_{fs}\|_{(L)}$	Forward Transfer Admittance Ratio	0.95		1.0		$V_{DS}=10V$, $I_D=1.0mA$, $f=1.0kHz$ $\|Y_{fs}\|_{(S)}/\|Y_{fs}\|_{(L)}$*
ΔV_{GS}	Gate to Source Voltage Difference		3.0	20	mV	$V_{DS}=10V$, $I_D=1.0mA$ $\Delta V_{GS}=V_{GS(L)}-V_{GS(S)}$*
NV	Noise Voltage		25	35	mV	See Test Circuit
C_{iss}	Input Capacitance		15		pF	$V_{DS}=10V$, $V_{GS}=0$, $f=1.0MHz$
C_{rss}	Feedback Capacitance		3.0		pF	$V_{DS}=10V$, $V_{GS}=0$, $f=1.0MHz$
$V_{GS(off)}$	Gate to Source Cutoff Voltage	−0.15		−2.5	V	$V_{DS}=10V$, $I_D=10\mu A$
I_{GSS}	Gate Cutoff Current			−1.0	nA	$V_{GS}=-20V$, $V_{DS}=0$

*(S) : The Smaller Value, (L) : The Larger of the pair

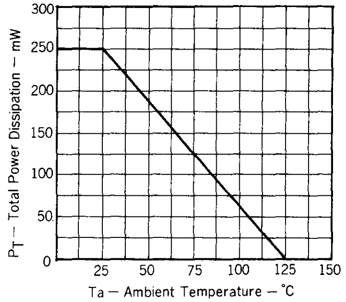
Classification of I_{DSS}

Rank	K	L	M	N
I_{DSS}(mA)	1.0 − 6.0	5.0 − 10	9.0 − 14	13 − 18

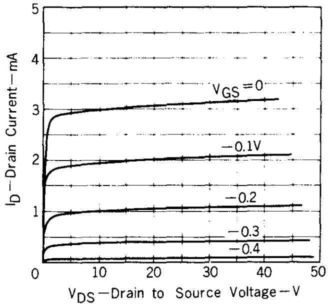
I_{DSS} Test Conditions : $V_{DS} = 10V$, $V_{GS} = 0$

TYPICAL CHARACTERISTICS (Ta = 25°C)

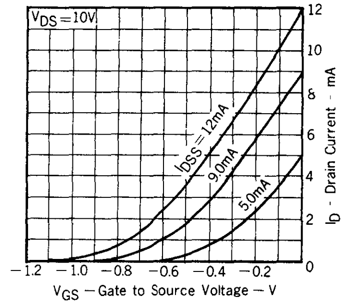
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



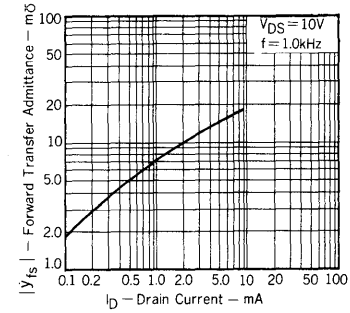
DRAIN CURRENT vs. DRAIN TO SOURCE VOLTAGE



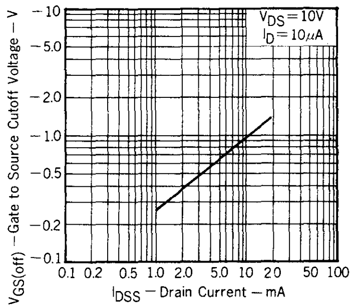
DRAIN CURRENT vs. GATE TO SOURCE VOLTAGE



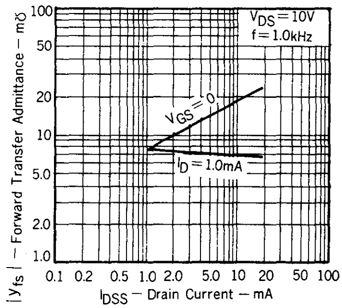
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT



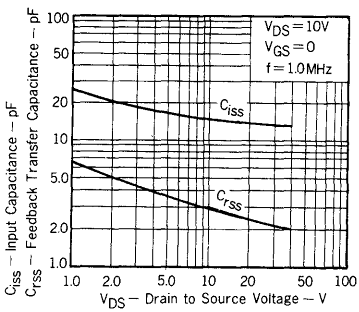
CORRELATION CURVE GATE TO SOURCE CUTOFF VOLTAGE vs. DRAIN CURRENT



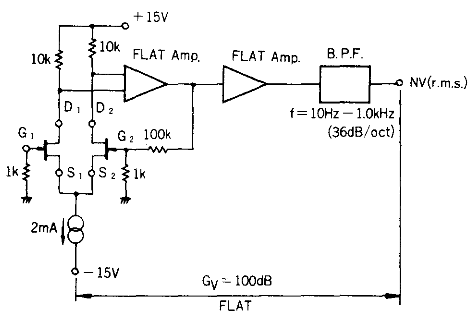
CORRELATION CURVE FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT



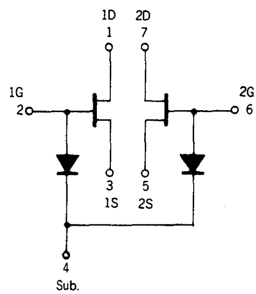
INPUT CAPACITANCE AND FEEDBACK TRANSFER CAPACITANCE vs. DRAIN TO SOURCE VOLTAGE



NOISE VOLTAGE TEST CIRCUIT



LEAD CONNECTION



Contents

Introduction

The NEC MINI MOLD is designed for hybrid IC which is an active element in micro package. There are two types of ICs used for intergration:, they are classified according to their constructions, one is monolithic IC and the other hybrid IC. At present, as the applications of electronics are spreading widly, circuit designs are diverse and high performance is required for the circuit characteristic itself. Especially, the hybrid IC is considered as more suitable for high voltage, microwave and high power circuit than the monolithic IC., therefore, use of hybrid IC is now spreading rapidly.

As the elements for the hybrid IC, the chip, beam-lead, flip-chip of a transistor and a diode, in addition to the existing transistor and diode are used. However, the conventional transistor and diode are disadvantageous to increase in integration and miniaturization. And specialized treating technique is required for use of the chip, beam-lead and flip-chip, and guarantee of the electrical characteristic of the element is limited. Thus, the yield rate is low and the field of application is not so wide.

The NEC MINI MOLD has been developed in full consideration of the above-mentioned matters concerning the manufacturing of the hybrid IC and now is mass-produced as a micro device which is easy to handle and economical to use.

1. Features of MINI MOLD

The MINI MOLD has been used for a hybrid IC conventionally and is featured as follows in comparision with the transistor chip, beam-lead, and flip-chip.

1.1. Since MINI MOLD is of micro package type, the space factor in its practical mounting is small, it is possible to make an extremly small type and high-density hybrid IC compared with conventional transistors.

1.2. MINI MOLD can easily be handled, compared with transistor chips, beam lead, flip-chips etc., and as it used well managed ribbon lead wires, its practical mounting is very easy and can be done automatically.

Photograph 1. Example of Mounting of Hybrid IC

1.3. Electrical characteristics are guaranteed in the same manner as for those of the conventional products, thus the percentage of mixing of bad products is small. This permits a realization of effective and economical assembling process.

1.4. Since the leads of ribbon type are arranged in triangle, the package is small and high frequency characteristics is excellent, despite of its plastic mold construction. MINI MOLD is applicable to various purposes of uses in the range from low frequency to ultra high frequency.

2. Outline, Structure and Manufacturing Process

2.1. Outline

Outlines shown in Fig. 1 and Fig. 2 are the package dimensions of MINI MOLD. The case is made by a box type resin of a length of 1.5mm and of a thickness of 1.1mm.

The MINI MOLD has three pins and each of them regularly forms an L-shape along the plastic resin body. (See Fig. 1) Upon your request, however, the lead wires can be finished in a flat type, in consideration of versatile mounting (See Fig.2). Furthermore, a lot of MINI MOLD transistors can be provided in a reversal pin-connection.

PACKAGE DIMENSIONS

in millimeters (inches)

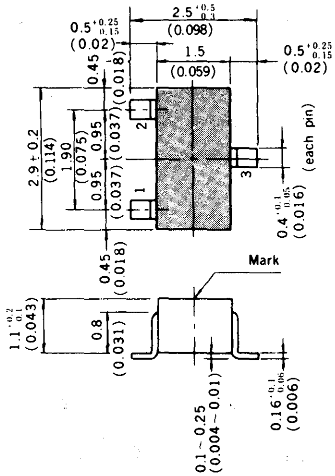


Fig. 1

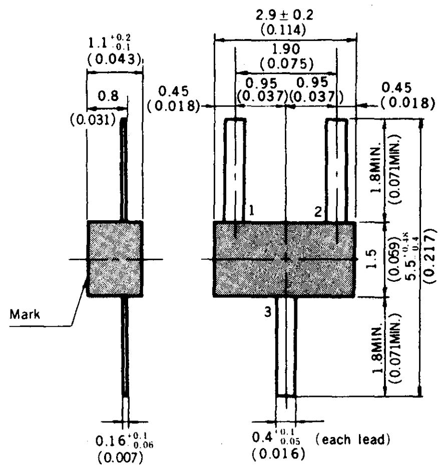


Fig. 2

Pin Connections

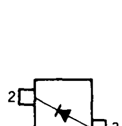
Transistor (Regular)
1. Emitter
2. Base
3. Collector

Transistor (Reversal)
1. Base
2. Emitter
3. Collector

Filed Effect Transistor
1. Drain
2. Source
3. Gate

Double Diode

Common Anode
1. Cathode
2. Cathode
3. Anode



Common Cathode
1. Anode
2. Anode
3. Cathode

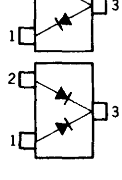


Fig. 1 . . . . Standard Type
Fig. 2 . . . . Type for Special Order (except. 2SK67)
The flat lead type, shown in Fig. 2, can be available on your request, please consult us beforehand.

2.2. Structure and Manufacturing Process

(1) Structure

Fig. 3 shows a model of the internal structure. The active element (chip) is fixed to lead ribbon No. 3 and connected to leads No.1 and No. 2, respectively from the electrodes on the chip, by using internal connecting wires (gold wires).

The package is made of epoxy resin. The lead wires are silver plated nickel alloy and are finished by dip soldering with lead-tin eutectic solder.

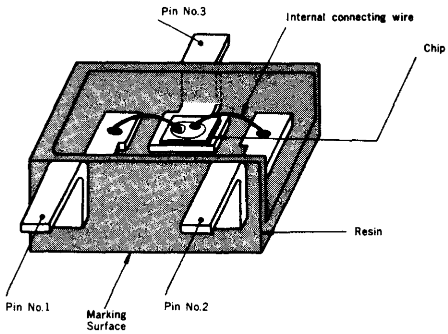


Fig. 3 Internal Structure

(2) Manufacturing Process

The manufacture of the MINI MOLD device is based upon the techniques developed for manufacturing MICRODISK Transistor and mold transistor for small signal, furthermore, accurate technique peculiar to the manufacture of the MINI MOLD was developed and is now adopted.

The manufacturing process is as shown in Fig. 4, Flow diagram. At first, the external lead is fixed to the base plate for element manufacture (manufacturing of lead frame).

Then, the chip is soldered by the special solder in the automatic element manufacturing equipment, and after the electrodes of the chip are connected to the external leads with gold wire, the resin encapsulation is done semi-automatically by batch system.

After stabilization is made through high temperature aging, etc., the leads are trimmed in proper length, and then the device is checked with respect to all DC items by the automatic selector, and classified according to the judgement of serviceable qualities and characteristic values, and then packed in case, the leads are formed as required, and the name of product is marked, thus the product is completed.

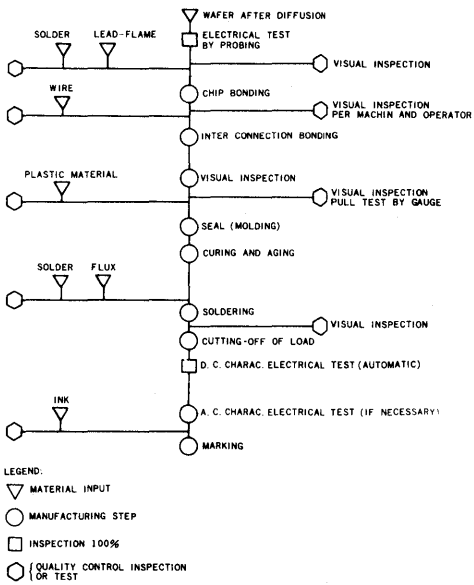


Fig. 4 Flow Diagram of MINI MOLD Manufacturing Process

3. Uses and Types

In Table 4 (page 17), main products of MINI MOLD are shown. The MINI MOLD has the same characteristic as the conventional plastic mold product regarding its construction, dielectric strength, working frequency, preservation temperature etc., it is possible to produce almost all the conventional products, for small signals.

Various types of the MINI MOLD are required in order to satisfy all purposes of hybrid ICs, so that they are being manufactured with full consideration from economical view point.

The uses of the MINI MOLD cover a wide range of from low frequency to ultra high frequency, such as low frequency amplification, amplification of HF band, VHF band, UHF band etc., frequency conversion, mixed oscillation, and high speed switching. Therefore, the MINI MOLD can be used widely in the hybrid ICs for radio, television, stereoplayer, taperecorder, camera, watch, measuring instrument, wireless instrument etc.

4. Electrical Characteristics

The determinating methods of the MINI MOLD for its absolutely maximum ratings, electrical characteristics etc. are all same as methods for conventional small signal use. Especially, the different matters from the conventional small plastic mold are as follows: the MINI MOLD has a micro structure, therefore, it has a small allowable loss as a single body. However, when we think over that the MINI MOLD is fixed to the substrate of a hybrid IC and then mold with resin, after then is used, the MINI MOLD is possible to provide a circuit design having to spare enough for small signal of alrnost uses.

In Table 1, a comparison of characteristic values of the MINI MOLD with conventional transistors is shown.

Table 1. Comparison of Characteristic Values with Conventional Transistors

Type	Working Frequency (MHz)	Allowable Loss (mW)	Allowable Current (mA)	Temperature of Junction (°C)	Storage Temperature (°C)	Size (mm)
MINI MOLD Transistor	~850	~150	~500	~125	-55~+125	2.8 x 1.5 x 11
MICRODISK Transistor	~1000	~150	~200	~150	-65~+125	3.5ϕ x 1.5
SIGNAL MOLD Transistor	~300	250~625	~1500	~125	-55~+125	5 x 5 x 4

On the Total Power Dissipation and Thermal Resistance

The total power dissipation can be calculated according to the maximum junction temperature and thermal resistance:

$$P_T = \frac{Tjmax. - Ta}{Rth}$$

Where : P_T . . . . . . Total Power dissipation

Tjmax. . . . Maximum Junction temperature

Ta . . . . . . Ambient temperature

Rth . . . . . Thermal resistance from junction to ambient

The thermal resistance of the MINI MOLD unit is 0.58°C/mW, however, when the MINI MOLD is mounted in the hybrid IC, the heat radiation from the lead is increased, and furthermore, when coated with resin or the like, the heat radiation around it is promoted, too. Thus, the thermal resistance of the MINI MOLD under mounted condition is considerably smaller than that of the unit itself.

Fig. 5, 6, 7 and 8 show the size of the substrate and P_T in the MINI MOLD.

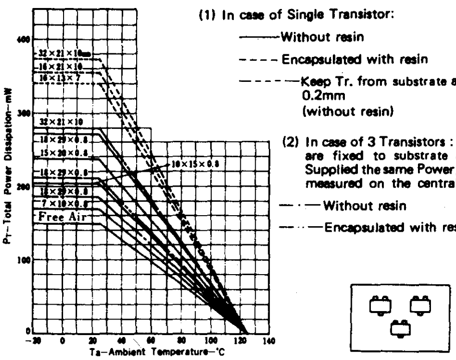


Fig. 5 P_T - Ta Characteristic (Alumina Seramic Substrate)

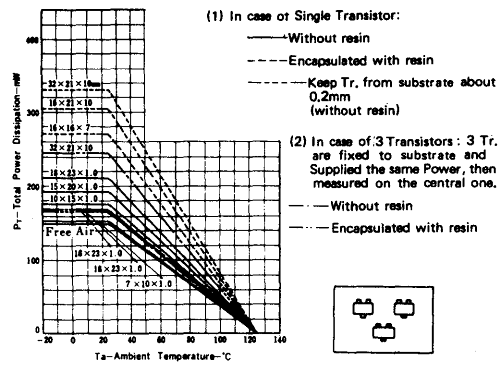


Fig. 6 P_T - Ta Characteristic (Steatite Substrate)

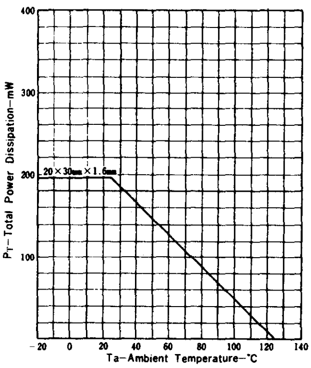


Fig. 7 P_T - Ta Characteristic (Epoxy Glass Substrate)

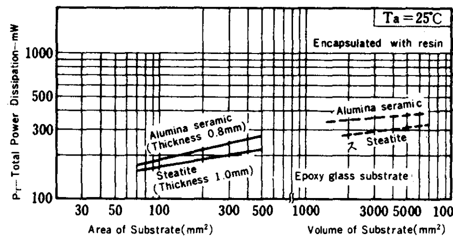


Fig. 8 P_T to Size and Volume of Substrate

5. Reliability

The reliability of the MINI MOLD is assured by the same evaluating method as for the conventional plastic mold.

As a rule, the mode of failure of plastic mold type product is different from that of hermetically sealed product. The difference is found mainly in the following 2 points:

(1) Moisture resistance

(2) Thermal stress

As for the moisture resistance, in the metal can type, the hermetically sealed inner part is isolated from the outside by the chemically reactive layer of glass-metal, on the contrary, in the present plastic mold type, the space between resine-metal (lead) is only pressed or adhered closely, and moreover there is a large difference in moisture resistance characteristic between the metal can and the resin itself.

The thermal stress is an influence which the expansion coefficient exerts on the internal connection wire.

5.1. Moisture Resistance

The moisture resistance of the plastic mold product is effected largely by the nature of the resin. A resin absorbing humidity would cause an increase in leak, and penetration of humidity in the chip would deteriorate the characteristics and melt aluminum electrode, thus causing disconnection.

The MINI MOLD is shaped by press injection of resin, for convenience's sake of manufacturing, a release compound which permits the resin separate easily from the metal cast is contained in the resin. This weakens adherence between the resin and the metal lead to some extent. But on this point, the resin provided with excellent adhesion to metals is used, selected out of many sorts of the resins.

5.2. Thermal Stress

The thermal stress causes the resin to expand or contract, thus giving stress to the internal connection wire. For testing the thermal stress, the heat shock and step stress methods are used, besides the ordinary high temperature test. The internal connection wires of plastic mold product are almost gold wires, having strength fully powerful themselves to withstand the expansion or contraction by the resin, therefore, major parts subject to the effect due to the thermal stress are the contact parts between the external lead and gold wire, and between aluminum electrode and gold wire.

The MINI MOLD is strengthened largely with newly adopted bonding method and it can be used practically without any failure.

5.3. Control Process of Reliability of MINI MOLD

The control process of reliability of the MINI MOLD is conducted according to the steps shown in the block diagram in Fig. 9. This method is systematized to maintain a stable performance by feeding the control data back to each process.

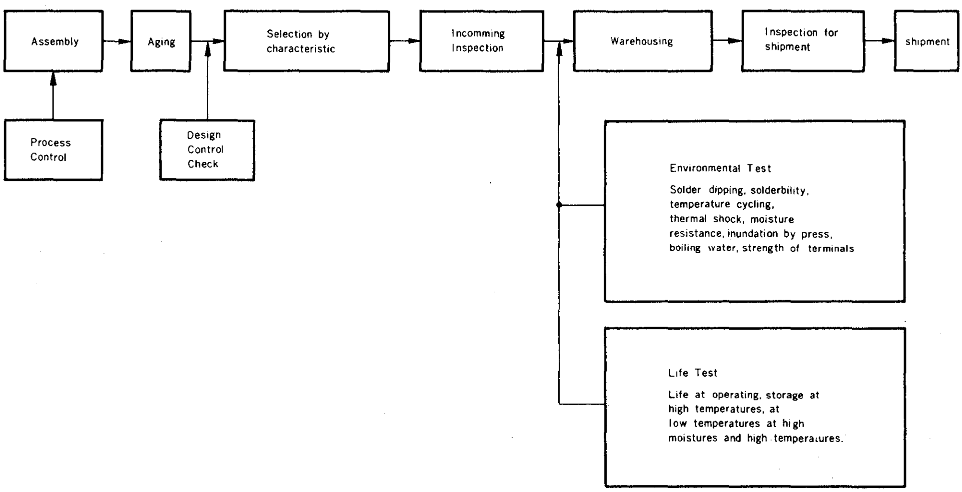


Fig. 9 Control Process of Reliability

5.4. Reliability Test Data

The tests of reliability of the MINI MOLD device are practiced monthly according to Table 2 as the form tests.

These tests are almost the acceleration tests, and for some items they are estimated up to the limit. The long life test data are typically shown in Fig. 14 and sustain an enough long life of the MINI MOLD devices against general usage. Relation with practical conditions is supported by the field data. if you request thereon, we can report the rearranged data by the prescribed method.

Data of Mechanical Strength

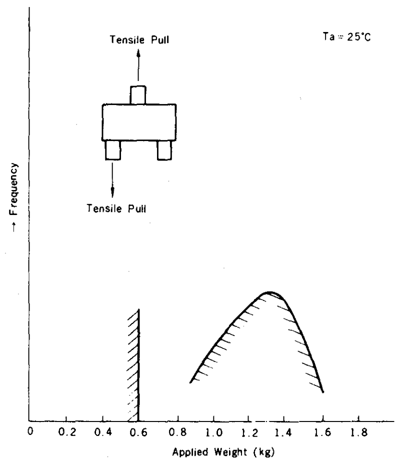


Fig. 10 Tensile Strength

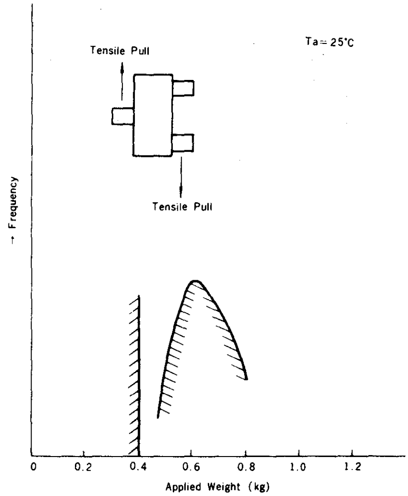


Fig. 11 Tensile Strength

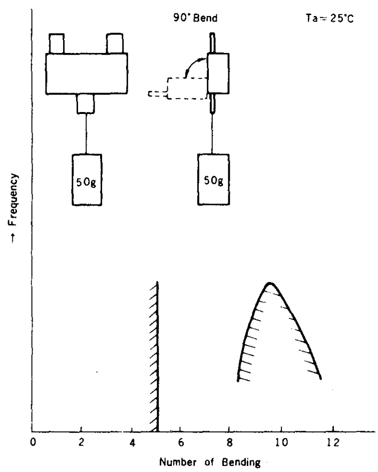


Fig. 12 Bending Strength

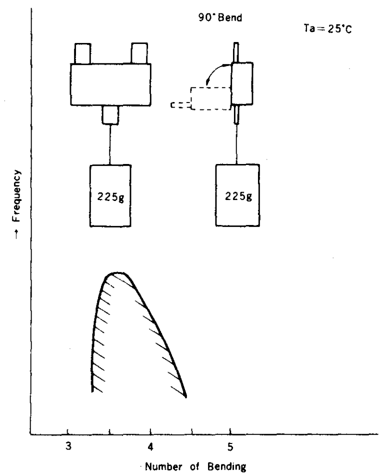


Fig. 13 Bending Strength

Table 2. Reliability Test of MINI MOLD

No.	Item of Test	Condition of Test	Duration of Test	Judgement Item
1	Physical Dimensions	Physical dimentions of product must coincide with each specification		Miss of dimensions
2	Strength of Marking	Washing with Chlorocene for 5 minutes after natural drying for 10 seconds, rub lightly.		Wear away of marking
3	Solderbility	Temperature of solder = 230°C (eutectic solder), dip the main body for 5 second one time, using flux.		Soldering quality
4	Soldering Heat	Temperature of solder = 260°C (eutectic solder), dip the main body for 5 minutes, without flux.		Deterioration of characteristic
5	Temperature Cycling	High temperature = 125°C for 30 minutes. Low temperature = - 55°C for 30 minutes.	30 cycles	Deterioration of characteristic
6	Thermal Schock	High temperature = 100°C for 10 minutes. Low temperature = 0°C for 5 minutes.	10 cycles	Deterioration of characteristic
7	Terminal Strength	Load on lead 50g, bending of 90°	3 times	Snap of lead
8	Salt Spray	Temperature = 35°C, Percent of salt = 0.6%	24 hours	Rush of Lead
9	Water Pressure	35 atomospheric pressure (Temperature 25°C), used tap water	15 hours	Deterioration of characteristic
10	Bolling	Temperature = 100°C, used tap water	15 hours	Deterioration of characteristic
11	Steady State Operating Life	Centinous application of allowable loss power	1000 hours	Deterioration of characteristic
12	High Temperature Storage Life	Temperature = 125°C	1000 hours	Deterioration of characteristic
13	Low Temperature Storage Life	Temperature = 55°C	1000 hours	Deterioration of characteristic
14	High Temperature, High Humidity Storage Life	Temperature = 60°C Humidity = 90%	500 hours	Deterioration of characteristic Rush of lead

Data of Life Test

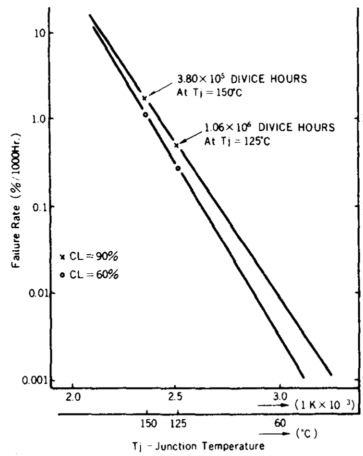


Fig. 14 Steady State Operation Life on MINI MOLD Transistor

6. Mounting Methods of MINI MOLD

The MINI MOLD has the following advantages with respect to the mounting compared with other element:

(1) The hybrid IC using the MINI MOLD has a smaller space factor compared withe the hybrid IC using the conventional transistor, since the occupation area of the MINI MOLD is reduced by 30 ~ 50%, and the space occupation area on the substrate (thickness of the hybrid IC) is reduced by 50%, therefore it can be more miniaturized.

(2) On the mounting, no through-hole for the reads is required, simply by laying wires on one side of the substrate, the circuit function which is equivalent to that of the conventional hybrid IC can be obtained. Thus the improvement of accumulation becomes possible.

(3) Since the MINI MOLD can be mounted on the substrate directly with no need to form the leads, mechanization and automatic assembling line can be realized comparatively, thus reducing the man-hour largely.

(4) Neither special technique nor large scale facilities are required for the assembling. The assembling can be performed economically. Photograph 1 shows an example of the hybrid IC using the MINI MOLD. As is seen in the photograph, the MINI MOLD is mounted on the substrate with the occupating area almost equal to that of a resistor. The mounting method of element of the MINI MOLD which is performed acutually are various corresponding to the sorts of hybrid IC, and the mounting method is adopted being suitable to the line of each maker. Some of methods are introduced as follows:

6.1. Method by using solder

The method of soldering using solder is used usualy in case of solid wiring or the parts to be fixed to the one substrate are few. The fixing of the MINI MOLD is done by flux etc., using a fine solder (under 0.5mmϕ), the tip of a soldering copper is finished finely under 1mmϕ. In this methods, the tip of soldering copper may be devised and using with a vacuum chack etc., it is possible to be automatic.

6.2. Thermal Compression Method

This method is used for hybrid IC, in which circuit is constructed only on a single side, for this method the principle of the fixing of chip, which is used commonly in manufacturing process of semiconductor element, is applied. In this method, a preparatory solder is put on the setting part of substrate and then put it on the heating element, after melting this solder, the MINI MOLD type element with flux is fixed under melting condition. Flux can be used attaching to the substrate, but take care that overappending of flux causes a bad working ability. The temperature depends on the sort of solder used, but it is desirable to work in a range of temperature of about +50 ~ 150°C.

If an automatic forwarding and a vacuum slide fastner is used, it is possible to automate and is suited for massproduction relatively.

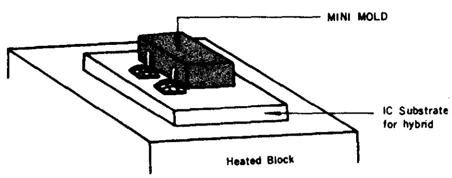
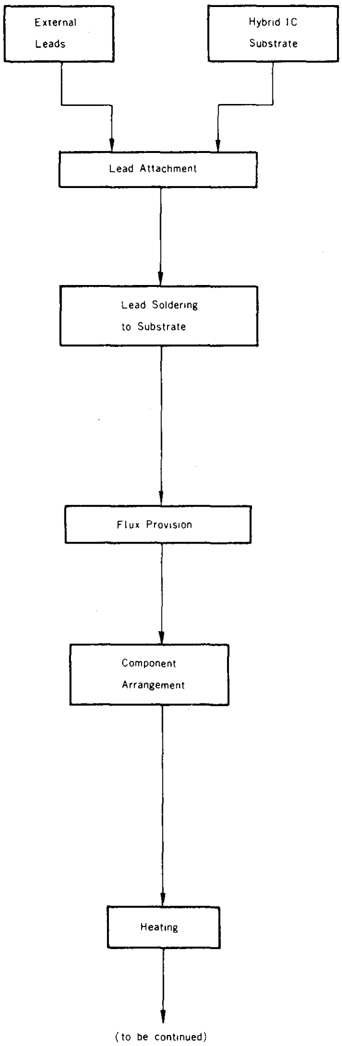


Fig. 15 Mounting Method by Thermal Compression

6.3. Method by Belt Conveyer

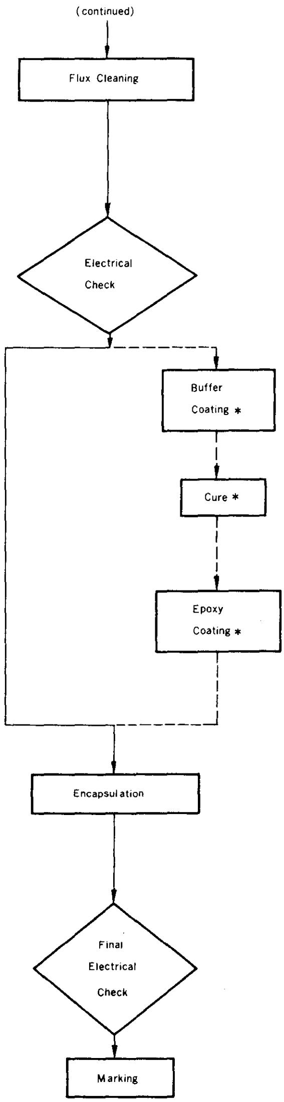
This method is suitable for massproduction, a production of about tens of thousands of hybrid per month is possible by this method.

Assembly Process



Description

- Substrate of alumina ceramic, steatite, epoxy glass, etc. The contact portions of substrate are solder dipped in advance.
- External leads are fixed to the substrate terminals. Use of lead frame may be effective, saving man-hour.
- External leads are adhered to the substrate with solder. Temperature at 220 to 250°C for about 3 seconds. Pb-Sn eutectic solder.
- The original liquid of flux is diluted to one-third in density with ethyl alcohol or the like, and the diluted flux is provided on the substrate.
- Required circuit elements such as MINI MOLD transistors, chip condensers, etc. are arranged in position on the substrate.
  For MINI MOLD transistors, it is an efficient means to employ a vacuum chuck for their holder after the magazine is matched in orientation to the substrate pattern.
  The arranged elements are lightly fixed on the substrate with flux.
- The component side is heated by tungsten heater to melt the pre-dipped solder and join the contact parts.
  Temperature at 200 to 250°C.
  Belt speed at 30 cm/minute.
  Heating time for about 1 minute.
  Solder melting time for 15 to 20 seconds.



* These processes are performed when necessary.

- Ultrasonic cleaning at 25°C, for 30 seconds.
  Care should be taken not to stroke the marking surface when the solvent still remains on the surface.
  Otherwise the marking may be erased.

- When needed, overall circuit characteristics are checked and defective elements replaced.

- Liquefied resin is used for buffer coating in either dipping or potting method.

- Temperature at 100°C, for the period of 4 hours. (in case of silicon resin)
  Curing conditions are dependant upon the resin.

- When silicon resin is used for buffer coating, epoxy resin is sprayed on the buffer coat.
  Air dry for 12 to 24 hours at room temp. follows.
  Then, curing at 70°C, for 1 hours, followed by another one at 100°C, for 3 hours.

- Pre-coated hybrid IC substrate is dipped in molding compound and then outer package material is cured. (casting mold method)
  Curing conditions at 120°C, for 12 hours.

Fig. 16 Assembly Process

5

6.4. Method by Solder Dipping

Put the MINI MOLD on the substrate and it is necessary to fix it to the substrate in order to practice solder dipping. Since in this method, the MINI MOLD is to be fixed using fluid or paste-type epoxy resin, the working processes are performed as follows:

Substrate → Epoxy resin → Arrangement of the MINI MOLD → Curing of resin (Fixing) → Application of flux → Solder dipping.

In this method, some times need to fix the MINI MOLD, but the operation is easy and the finished product is so fine.

7. Mounting Dimensions and Typical Examples of Mounting

For a design of mounting of hybrid IC, the dimensions of fixing positions of lead of the MINI MOLD are shown in Fig. 16 and 17.

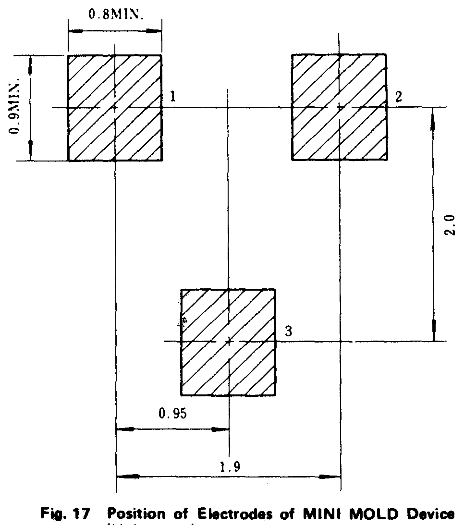


Fig. 17 Position of Electrodes of MINI MOLD Device
(Unit : mm)

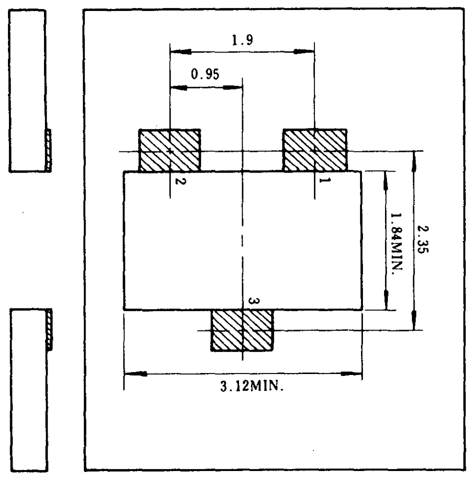
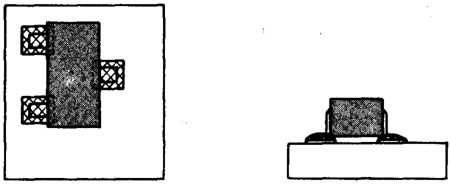


Fig. 18 Positions of Electrodes when mounted while the body is buried into the Substrate
(Unit : mm)

7.1. Mounting on the plane of the Substrate

(1) Mounting only on a single side.



Top View Cross-section

Fig. 19

(2) Mounting on the both sides.

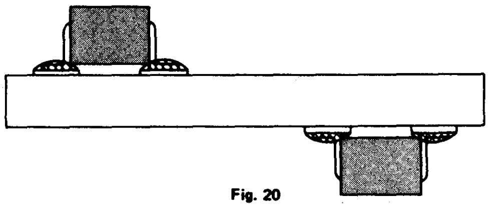
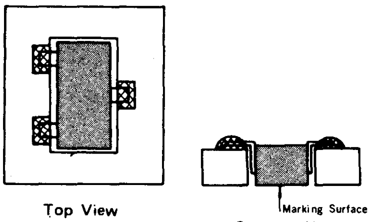


Fig. 20

7.2. Mounting by Burying of Body into the Substrate



Top View Cross-section

Fig. 21

7.3. Mounting with unreformed lead

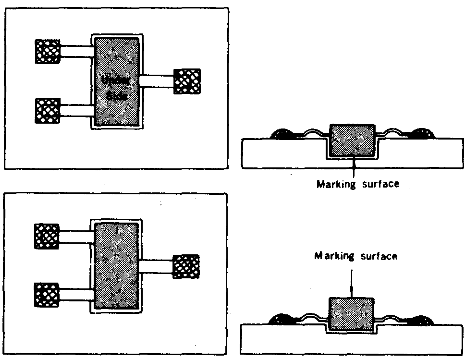


Fig. 22

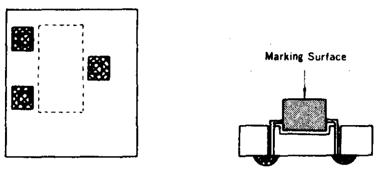


Fig. 23

Mounting using Through-holes of Substrate

8. Handling Techniques of MINI MOLD Device

It is necessary to take full cares in using the MINI MOLD device in order to maintain its high quality and reliability, in same manner as in the case of ordinary transistor. The following are environmental conditions encountered by the MINI MOLD device and cautions for handling of it.

8.1. Circuit Design

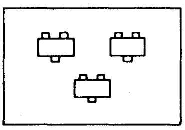
The electrical characteristics of the MINI MOLD transistor are secured in the same manner as for the conventional mold transistor. But its consuming power Pc becomes larger when it is mounted on the substrate etc., since the heat radiation is improved, so that the allowable power dissipation can be made larger. Therefore, the allowable dissipation shown in Table 3 can be derated for use. The power dissipation may differ largely according to the size of the substrate and resin coating of the package. Accordingly, it is necessary to confirm the allowable power dissipation after packaging the transistor.

Table 3. Allowable Power Dissipation when MINI MOLD is fixed to Substrate.

(1) In case of 1 MINI MOLD Transistor (Ta = 25°C)

Substrate	Without Resin		Encapsuled with Resin		Notes
	Size (mm)	Allowable Power Dissipation	Volume (mm)	Allowable Power Dissipation	
Alumina Ceramic	7 x 10 x 0.8	170 mW	16 x 13 x 7	340 mW	Adhere closely to the substrate
	10 x 15 x 0.8	204	16 x 21 x 10	366	
	15 x 20 x 0.8	238	32 x 21 x 10	374	
	18 x 29 x 0.8	272	–	–	
	18 x 29 x 0.8	212	–	–	Keep from substrate about 0.2mm
Steatite	7 x 10 x 1.0	154	16 x 21 x 7	272	Adhere closely to the substrate
	10 x 15 x 1.0	178	16 x 21 x 10	306	
	15 x 20 x 1.0	194	32 x 21 x 10	332	
	18 x 23 x 1.0	212	–	–	
	18 x 23 x 1.0	168	–	–	Keep from substrate about 0.2mm
Epoxy Glass	20 x 30 x 1.6	196	–	–	

(2) In case that 3 transistors fixed to the substrate and applied the same power, then measured at the central transistor.



Alumina Ceramic	18 x 29 x 0.8	186	32 x 21 x 10	280	Adhere closely to the base plate
Steatite	18 x 23 x 1.0	170	32 x 21 x 10	246	

8.2. Temperature at soldering, flux etc.

At time of soldering, it suffers high temperature, but it can be used at a temperature as follows, nevertheless except the case through unavoidable circumstances, it is desirable to shorten the time of soldering.

In case of solder dipping: about 250°C . . . . about 5 minutes
In case of using soldering copper: 300°C . . . . about 10 seconds
In case of high temperature circumtances: about 260°C . . . . . about 5 minutes

There are various kinds of flux used for soldering one of rosin-base flux is recommended by us.

If a anorganic flux (for example, zinc cloride) is used, its cleaning is difficult and it exerts bad influence on the reliability, so that avoid its use.

8.3. Humidity

The Moisture resistance of the MINI MOLD transistor is somewhat different than that of convenient small mold transistor, as it is very small type and quantity of resin is small and its leak pass is short.

Generally, moisture resistance cautions are taken for coating resin encapsulation (sealing) of resin which is practically outfitted on the substrate and storaged into case, but in case of hybrid IC the method is different owing to its necessary reliability.

The examples are shown as follows:

In case of storage in an airtight case after mounting
. . . . Special protection for the MINI MOLD is not necessary.

In case of encapsulation with resin after mounting
. . . . Special protection is not necessary, unless a strong mechanical stress is given.

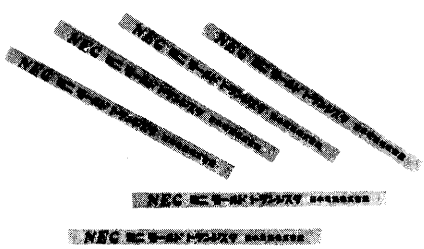
In case of using as the mounting state
. . . . It is different according to the required reliability. Avoid the use of form of the mounting only as far as possible, it is desirable to use after simple coating.

As materials for resin encapsulation and coating, there are epoxy series, silicone series etc, please consult resin makers and select a suitable resin.

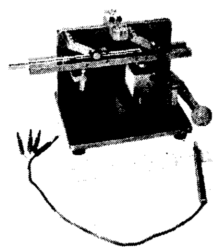
8.4. Cleaning

After soldering, please clean the flux as far as possible. As the solvents, alcohol, 1, 1, 1-trichloroethane (Chlorothene), dichlorodifluoromethane (Freon) etc. can be used, but dipping for a long time must be avoid, otherwise the marks may be erased.

Furthermore, ultrasonic cleaning is available, if it has no effect on the other parts. This method may not spoil the reliability, since the transistor is encapsulated, but the conditions may be settled loosly as long as possible.



Photograph 2



Photograph 3

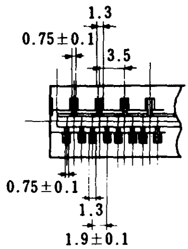


Fig. 24 Plastic tray outline drawing for MINI MOLD

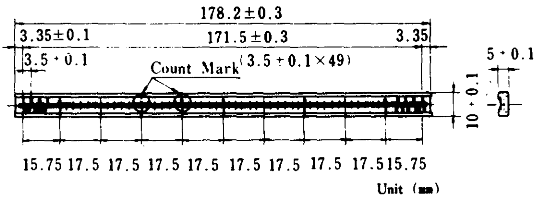


Fig. 25 Dimension of Magazine

8.5. Measuring Fixture

The MINI MOLD devices are delivered in 50-unit magazines as the minimum one. In case of inspection at acceptance, a measuring fixture of magazine is available, as shown in Photograph 3.

Put the magazine on this measuring fixture and each one can be moved by a single stroke of the lever, it is convenient to measure static parameters.

Dimensions of the magazine are shown in Fig. 24.

9. Summerized Characteristics

Bipolar Transistors

Table 4. Bipolar Transistors, Field Effect Transistors and Diodes

Type No.	Structure	Package	Application	Absolute Maximum Ratings (Ta=25°C) V_{CBO} (V)	V_{CEO} (V)	V_{EBO} (V)	I_C (mA)	P_T (mW)	T_j (°C)	Electrical Characteristics (Ta=25°C) Class Mark	h_{FE} Range	V_{CE} (V)	I_C (mA)	$V_{CE(sat)}$ (mV) TYP.	f_T (MHz) TYP.	C_{ob} (pF) TYP.
2SA811	PNP Silicon Epitaxial	NEC MINI MOLD Regular	Audio Frequency High Gain Amplifier	−50	−50	−5.0	−50	150	125	C5	135–270	−3.0	−0.5	−200	100	6.2
										C6	200–400					
										C7	300–600					
										C8	450–900					
2SA812/ 2SA812R	PNP Silicon Epitaxial	NEC MINI MOLD Regular/ NEC MINI MOLD Reversal	Audio Frequency Amplifier	−60	−50	−5.0	−100	150	125	M3/3M	60–120	−6.0	−1.0	−180	180	4.2
										M4/4M	90–180					
										M5/5M	135–270					
										M6/6M	200–400					
										M7/7M	300–600					
2SA956	PNP Silicon Epitaxial	NEC MINI MOLD Regular	Low and High Frequency Amp. Medium Speed Switch	−60	−40	−8.0	−100	150	125	H3	80–130	−1.0	−10	−60	280	7.2
										H4	110–170					
										H5	150–240					
										H6	200–320					
2SB624/ 2SB624R	PNP Silicon Epitaxial	NEC MINI MOLD Regular/ NEC MINI MOLD Reversal	Audio Frequency Amplifier	−30	−25	−5.0	−700	200	150	BV1/1BV	110–180	−1.0	−100	−250	160	17
										BV2/2BV	135–220					
										BV3/3BV	170–270					
										BV4/4BV	200–320					
										BV5/5BV	250–400					
2SB736/ 2SB736R	PNP Silicon Epitaxial	NEC MINI MOLD Regular/ NEC MINI MOLD Reversal	Audio Frequency Amplifier	−60	−60	−5.0	−300	200	150	BW1/1BW	110–180	−1.0	−50	−150	100	13
										BW2/2BW	135–220					
										BW3/3BW	170–270					
										BW4/4BW	200–320					
										BW5/5BW	250–400					
2SC1009/ 2SC1009R	NPN Silicon Epitaxial	NEC MINI MOLD Regular/ NEC MINI MOLD Reversal	Radio Frequency Amplifier, Oscillator, Mixer, Converter	50	25	5.0	50	150	125	F1/1F	30–60	3.0	0.5	100	250	1.8
										F2/2F	40–80					
										F3/3F	60–120					
										F4/4F	90–180					
										F5/5F	135–270					
2SC1321	NPN Silicon Epitaxial	NEC MINI MOLD Regular	UHF Amplifier	30	25	4.0	10	100	125	Q2	40–80	6.0	2.0	150	900	1.3
										Q3	60–120					
										Q4	90–180					
										Q5	135–270					
2SC1621/ 2SC1621R	NPN Silicon Epitaxial	NEC MINI MOLD Regular/ NEC MINI MOLD Reversal	High Speed Switch	40	20	5.0	200	150	125	B2/2B	40–80	0.5	1.0	130	500	3.0
										B3/3B	60–120					
										B4/4B	90–180					
2SC1622	NPN Silicon Epitaxial	NEC MINI MOLD Regular	Audio Frequency High Gain Amplifier	40	35	5.0	100	150	125	D6	200–400	3.0	0.5	130	100	3.2
										D7	300–600					
										D8	450–900					
2SC1623/ 2SC1623R	NPN Silicon Epitaxial	NEC MINI MOLD Regular/ NEC MINI MOLD Reversal	Audio Frequency, Intermediate Frequency Amplifier	60	50	5.0	100	150	125	L3/3L	60–120	6.0	1.0	150	250	3.2
										L4/4L	90–180					
										L5/5L	135–270					
										L6/6L	200–400					
										L7/7L	300–600					
2SC1653	NPN Silicon Epitaxial	NEC MINI MOLD Regular	High Voltage Switch	150	130	5.0	50	150	125	N2	90–180	3.0	15	100	120	2.3
										N3	135–270					
										N4	200–400					
2SC1654	NPN Silicon Epitaxial	NEC MINI MOLD Regular	High Voltage Switch	180	160	5.0	50	150	125	N5	90–180	3.0	15	100	120	2.3
										N6	135–270					
										N7	200–400					
2SC2107	NPN Silicon Epitaxial	NEC MINI MOLD Regular	High Frequency Amplifier, Medium Speed Switch	60	40	8.0	100	150	125	G3	80–130	1.0	10	50	300	2.5
										G4	110–170					
										G5	150–240					
										G6	200–320					

(to be continued)

(continued)

Type No.	Structure	Package	Application	Absolute Maximum Ratings (Ta=25°C) V_{CBO} (V)	V_{CEO} (V)	V_{EBO} (V)	I_C (mA)	P_T (mW)	T_j (°C)	Electrical Characteristics (Ta=25°C) Class Mark	h_{FE} Range	V_{CE}	I_C	$V_{CE(sat)}$ (mV) TYP.	f_T (MHz) TYP.	C_{ob} (pF) TYP.
2SC2223	NPN Silicon Epitaxial	NEC MINI MOLD Regular	High Frequency Amplifier	30	20	4.0	20	150	125	F12	40–80	6.0	1.0	100	600	1.0
										F13	60–120					
										F14	90–180					
										F6	40–180					
2SC2350	NPN Silicon Epitaxial	NEC MINI MOLD Regular	Microwave Low Noise Amplifier	30	14	3.0	50	250	150	U1	40–200	10	10		2800	0.7
2SC2351	NPN Silicon Epitaxial	NEC MINI MOLD Regular	Microwave Low Noise Amplifier	25	12	3.0	70	250	150	R2	40–120	10	20		4500	0.75
										R3	100–200					
2SD596/ 2SD596R	NPN Silicon Epitaxial	NEC MINI MOLD Regular/ NEC MINI MOLD Reversal	Audio Frequency Amplifier	30	25	5.0	700	200	150	DV1/1DV	110–180	1.0	100	200	170	13
										DV2/2DV	135–220					
										DV3/3DV	170–270					
										DV4/4DV	200–320					
										DV5/5DV	250–400					
2SD780/ 2SD780R	NPN Silicon Epitaxial	NEC MINI MOLD Regular/ NEC MINI MOLD Reversal	Audio Frequency Amplifier	60	60	5.0	300	200	150	DW1/1DW	110–180	1.0	50	150	140	6.7
										DW2/2DW	135–220					
										DW3/3DW	170–270					
										DW4/4DW	200–320					
										DW5/5DW	250–400					
NTM2222A/ NTM2222AR	NPN Silicon Epitaxial	NEC MINI MOLD Regular/ NEC MINI MOLD Reversal	General Purpose Amplifier High Speed Switch	75	40	6.0	800	200	150	B15/15B	100–300	10	150	300 (MAX.) I_C=150mA	300 (MIN.)	8.0 (MAX.)
NTM2907A/ NTM2907AR	PNP Silicon Epitaxial	NEC MINI MOLD Regular/ NEC MINI MOLD Reversal	General Purpose Amplifier, High Speed Switch	−60	−60	−5.0	−600	200	150	Y15/15Y	100–300	−10	−150	−400 (MAX.) I_C=−150mA	200 (MIN.)	8.0 (MAX.)
NTM3904/ NTM3904R	NPN Silicon Epitaxial	NEC MINI MOLD Regular/ NEC MINI MOLD Reversal	General Purpose Switch and Amplifier	60	40	6.0	200	200	150	B25/25B	100–300	1.0	10	200 (MAX.) I_C=−10mA	300 (MIN.)	4.0 (MAX.)
NTM3906/ NTM3906R	PNP Silicon Epitaxial	NEC MINI MOLD Regular/ NEC MINI MOLD Reversal	General Purpose Switch and Amplifier	−40	−40	−5.0	−200	200	150	Y25/25Y	100–300	−1.0	−10	−250 (MAX.) I_C=−10mA	250 (MIN.)	4.5 (MAX.)

Field Effect Transistors

Type No.	Structure	Package	Application	Absolute Maximum Ratings (Ta=25°C) V_{GDO} (V)	V_{GSO} (V)	I_D (mA)	P_T (mW)	T_j (°C)	Electrical Characteristics (Ta=25°C) Class Mark	I_{DSS} Range	V_{DS}	V_{GS}	$V_{GS(off)}$ (V) TYP.	$\|Y_{fs}\|$ (m℧) TYP.	C_{iss} (pF) TYP.
2SK67	Silicon N-channel Junction	NEC MINI MOLD Regular	Impedence Converter	−20		10	80	100	J2	20–40 (μA)	5.0	0	−0.8 (MAX.)	1.5	5.5
									J3	35–70 (μA)					
									J4	60–120 (μA)					
									J5	100–200 (μA)					
									J6	150–300 (μA)					
									J7	270–540 (μA)					
									J8	0.5–1.0 (mA)					
2SK160	Silicon N-channel Junction	NEC MINI MOLD Regular	Audio and Radio Frequency Amplifier	−30	−30	20	150	125	K4	0.5–1.5 (mA)	5.0	0	−1.1	4.1	4.0
									K5	1.0–3.0 (mA)					
									K6	2.0–6.0 (mA)					
									K7	4.0–12 (mA)					

Diodes

Type No.	Mark	Structure	Package	Application	Absolute Maximum Ratings (Ta=25°C)						Electrical Characteristics (Ta=25°C)						Note
					V_{RM} (V)	V_R (V)	I_{FSM} (A)	I_{FM} (mA)	I_O (mA)	T_j (°C)	V_{F_1} (V) MAX./I_F 10mA	V_{F_2} (V) MAX./I_F 50mA	V_{F_3} (V) MAX./I_F 100mA	I_R (μA) MAX./V_R (V)	C (pF) MAX.	t_{rr} (ns) MAX.	
1S2835	A3	EpSi Double	NEC MINI MOLD Common Anode	High Speed Switch	35	30	6.0* 4.0	450* 300	150* 100	125	1.0	1.0	1.2	0.1/30	4.0	4.0	Test Conditions C: V_R=0, f = 1.0MHz t_{rr}: I_F = 10mA, V_R = 6.0V, R_L = 100Ω, I_{rr} = 0.1 · I_r
1S2836	A4				75	50					1.0	1.0	1.2	0.1/50	4.0	4.0	
1S2837	A5	EpSi Double	NEC MINI MOLD Common Cathode	High Speed Switch	35	30	6.0* 4.0	450* 300	150* 100	125	1.0	1.0	1.2	0.1/30	4.0	3.0	
1S2838	A6				75	50					1.0	1.0	1.2	0.1/50	4.0	3.0	

* Total Current

10. Specifications of MINI MOLD Device

	Type Number Regular (/Reversal)	Nearest Equivalent*	TO-92 Packaged Equivalent	Page
PNP Tran-sistor	2SA811	MMBA811,MMBA812	2SA641	21
	2SA812/2SA812R	BCW29,BCW30,BCW69,BCW70,MMBTA70	2SA733,BC556,BC557,BC558,BC559,BC560	25
	2SA956	MMBA956	2SA603	29
	2SB624/2SB624R	BCX18	2SA952,JE9012	33
	2SB736/2SB736R	BCX17,MMBTA55	2SA953	35
	NTM2907A/NTM2907AR	MMBT2907,MMBT2907A	NT2907A	87
	NTM3906/NTM3906R	MMBT3906	2N3906	93
NPN Tran-sistor	2SC1009/2SC1009R	MMBC1009	2SC839	37
	2SC1321	MMBC1321,MMBT918	2SC800 (Micro Disk)	41
	2SC1621/2SC1621R	MMBC1621,MMBT2369	2SC1216 (TO-18)	45
	2SC1622	MMBC1622,MMBT6428,MMBT6429,BCW33	2SC923,BC549,BC550	49
	2SC1623/2SC1623R	MMBC1623,MMBTA20,BCW31,BCW32,BCW60,BCW71,BCW72	2SC945,BC546,BC547,BC548	53
	2SC1653	MMBC1653	2SC1278Ⓢ	57
	2SC1654	MMBC1654,MMBT5550	2SC1279Ⓢ	57
	2SC2107	MMBC2107	2SC943 (TO-18)	61
	2SC2223		2SC1674,JE9016	65
	2SC2350	MMBR2060,MMBR4957,MMBR5031	2SC2026	69
	2SC2351	MMBR901,MMBR920,MMBR930	2SC1570	73
	2SD596/2SD596R	BCX20	2SC2001,JE9013	77
	2SD780/2SD780R	BCX19,MMBTA05	2SC2002	79
	NTM2222A/NTM2222AR	MMBT2222,MMBT2222A	NT2222A	81
	NTM3904/NTM3904R	MMBT3904	2N3904	99
FET	2SK67		2SK92	105
	2SK160		2SK104	109
Diode	1S2835	BAW56,BAW66,BAW68,MMBD2835		113
	1S2836	BAW56,BAW66,BAW68,MMBD2836		113
	1S2837	BAW64,BAW65,BAW67,MMBD2837	1S953 (DO-35)	117
	1S2838	BAW64,BAW65,BAW67,MMBD2838,MMBD6100	1S954 (DO-35)	117

* Encapsulated in TO-236 (SOT-23) Package

Cross Reference Guide to Mini Mold Device

Motorola	NEC	Note	Motorola	NEC	Note	European	NEC	Note
MMBA 811	2SA 811		MMBT6429	None		BAT18	None	
MMBA 812	2SA 812		MMBTA05	None		BAV70	1S2838	
MMBA 813	2SA 812		MMBTA06	None		BAV99	1SS123	
MMBA 956	2SA 956		MMBTA13	None		BAW56	1S2836	
MMBC1009	2SC1009		MMBTA14	None		BCW29	2SA 812	
MMBC1321	2SC1321		MMBTA20	2SC1623		BCW30	2SA 812	
MMBC1621	2SC1621		MMBTA42	None		BCW31	2SC1623	
MMBC1622	2SC1622		MMBTA43	None		BCW32	2SC1623	
MMBC1623	2SC1623		MMBTA55	2SA 812		BCW33	2SC1622	
MMBC1653	2SC1653		MMBTA56	None		BCW60	NTM3904	
MMBC1654	2SC1654		MMBTA70	None		BCW61	NTM3906	
MMBC2107	2SC2107		MMBTA93	None		BCW65	NTM2222A	
MMBD2835	1S2835		MMBTH24	None		BCW66	NTM2222A	
MMBD2836	1S2836		MMBTH81	None		BCW67	NTM2907A	
MMBD2837	1S2837					BCW68	NTM2907A	
MMBD2838	1S2838					BCW69	2SA 812	
MMBD 914	None					BCW70	2SA 812	
MMBD6050	None					BCW71	2SC1623	
MMBD6100	1S2838					BCW72	2SC1623	
MMBD7000	None					BCX17	2SB 736	
MMFB4416	None					BCX18	2SB 624	
MMBF4860	None					BCX19	2SD 780	
MMBF5457	2SK94					BCX20	2SD 596	
MMBF5460	None					BCX70	NTM3904	
MMBF5484	None					BCX71	NTM3906	
MMBFU310	None					BF554	2SC1009	
MMBR 901	2SC2351	V_{CEO} Selection				BFR30	2SK 160	
						BFR31	2SK 160	
MMBR 920	2SC2351	V_{CEO} Selection				BFR35A	2SC2351	
MMBR 930	2SC2351					BFR92	2SC2351	
MMBR 931	2SC2350					BFR93	2SC2351	
MMBR2060	2SC2350					BFS17	2SC1321	
MMBR4957	2SC2350					BFS18	2SC1009	
MMBR5031	2SC2350					BSF19	2SC1009	
MMBR5179	None					BFS40	2SB 736	
MMBT 918	2SC1321					BFS41	2SB 736	
MMBT2222	NTM2222A					BFS46	2SC1321	
MMBT2222A	NTM2222A					BFS85	2SC1321	
MMBT2369	NTM2369					BFS88	2SC1321	
MMBT2907	NTM2907A					BFT75	2SC2351	
MMBT2907A	NTM2907A					BSS64	2SD 780	
MMBT3640	None					BSS79	NTM2222A	
MMBT3904	NTM3904					BSS80	NTM2222A	
MMBT3906	NTM3906					BSV35A	2SC1621	
MMBT5550	None					BSV52	NTM2369	
MMBT6428	None					BSV65	NTM2369	

NEC
ELECTRON DEVICE

SILICON TRANSISTORS
BCX51,BCX52,BCX53

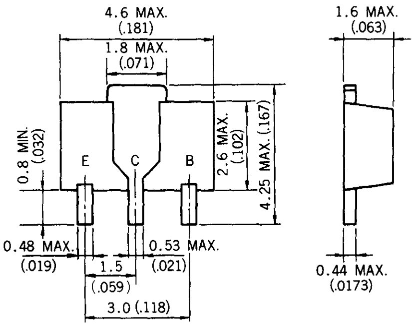
PNP SILICON EPITAXIAL TRANSISTOR
POWER MINI MOLD

DESCRIPTION

The BCX51 to 53 are designed for audio frequency power amplifier application, especially in Hybrid Integrated Circuits.

PACKAGE DIMENSIONS

in millimeters (inches)



E: Emitter
B: Base
C: Collector

FEATURES

- World Standard Miniature Package : SOT−89
- High Collector to Base Voltage : V_{CBO} >−100 V
- Excellent DC Current Gain Linearity
  : h_{FE} = 80 TYP. (V_{CE} = −2.0 V, I_C = −500 mA)
- Complements to NPN type BCX54 to 56

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

		BCX51	BCX52	BCX53	
Maximum Voltages and Currents					
Collector to Base Voltage	V_{CBO}	−45	−60	−100	V
Collector to Emitter Voltage	V_{CEO}	−45	−60	−80	V
Collector to Emitter Voltage (R_{BE} = 1 kΩ)	V_{CER}	−45	−60	−100	V
Emitter to Base Voltage	V_{EBO}		−5.0		V
Collector Current (DC)	I_C		−1.0		A
Collector Current (Pulse)*	I_C		−1.5		A
Maximum Power Dissipation					
Total Power Dissipation **	P_T		2.0		W
Maximum Temperatures					
Junction Temperature	T_j		150		°C
Storage Temperature Range	T_{stg}		−55 to +150		°C

*PW ≦ 10 ms, duty cycle ≦ 50 %
**When mounted on ceramic substrate of 2.5 cm^2 x 0.7 mm

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL		MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}				−100	nA	V_{CB} = −30 V, I_E = 0
Collector Cutoff Current	I_{CBO}				−10	μA	V_{CB} = −30 V, I_E = 0, T_j = 125 °C
Emitter Cutoff Current	I_{EBO}				−100	nA	V_{EB} = −5.0 V, I_C = 0
DC Current Gain	h_{FE1}		25				V_{CE} = −2.0 V, I_C = −5.0 mA ***
DC Current Gain	h_{FE2}	BCX51	40		250		V_{CE} = −2.0 V, I_C = −150 mA ***
		BCX52, BCX53	40		160		
DC Current Gain	h_{FE3}		25	80			V_{CE} = −2.0 V, I_C = −500 mA ***
Collector Saturation Voltage	$V_{CE(sat)}$			−0.29	−0.50	V	I_C = −500 mA, I_B = −50 mA ***
Base Saturation Voltage	$V_{BE(sat)}$			−0.9	−1.5	V	I_C = −500 mA, I_B = −50 mA ***
Base to Emitter Voltage	V_{BE}				−1.0	V	V_{CE} = −2.0 V, I_C = −500 mA ***
Gain Bandwidth Product	f_T			80		MHz	V_{CE} = −5.0 V, I_E = 10 mA
Output Capacitance	C_{ob}			26		pF	V_{CB} = −10 V, I_E = 0, f = 1.0 MHz

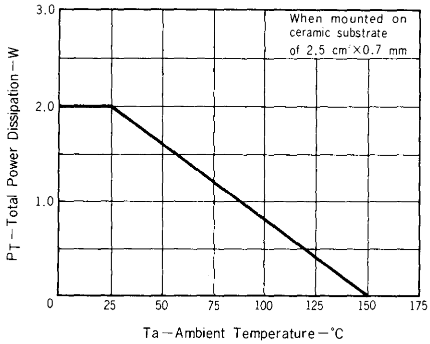
***Pulsed: PW ≦ 350 μs, duty cycle ≦ 2 %

h_{FE} Classification

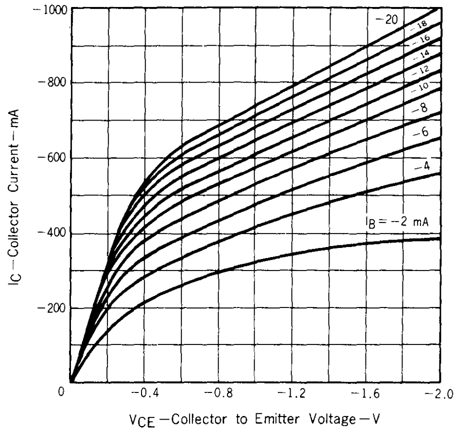
Marking	BCX51	AB	AC	AD
	BCX52	AF	AG	
	BCX53	AJ	AK	
h_{FE2}		40 – 100	60 – 160	100 – 250

TYPICAL CHARACTERISTICS (Ta = 25 °C)

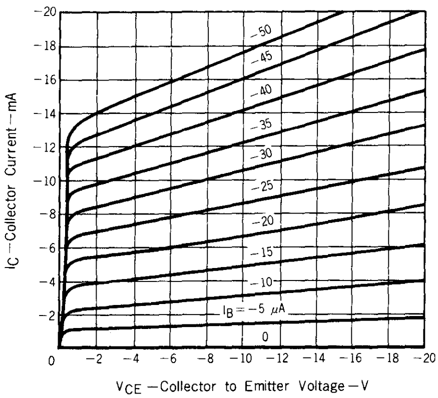
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



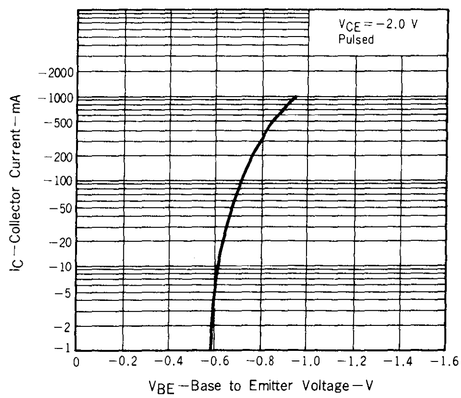
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



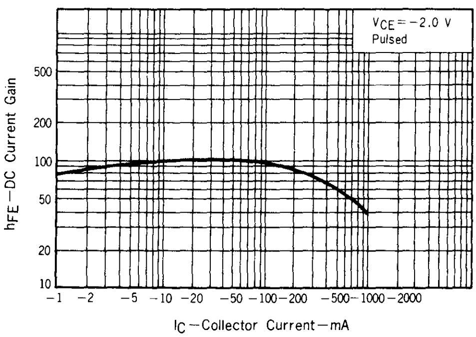
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



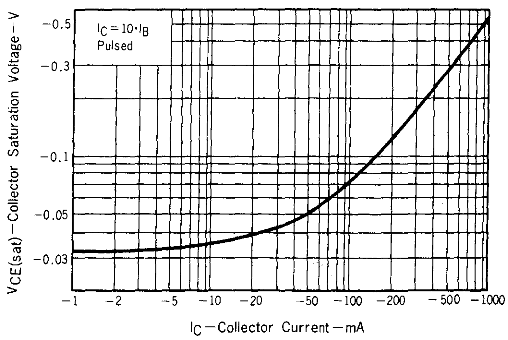
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



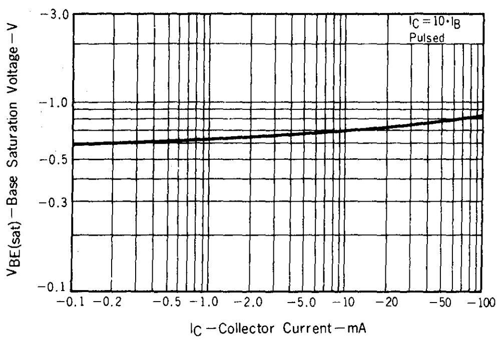
DC CURRENT GAIN vs.
COLLECTOR CURRENT



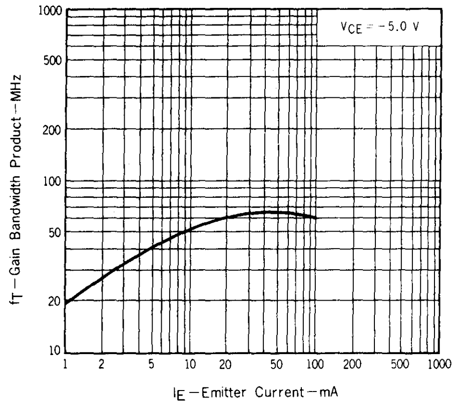
COLLECTOR SATURATION VOLTAGE vs.
COLLECTOR CURRENT



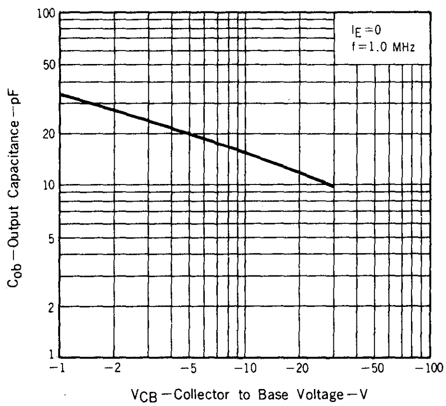
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

SILICON TRANSISTORS

BCX54,BCX55,BCX56

NPN SILICON EPITAXIAL TRANSISTOR
POWER MINI MOLD

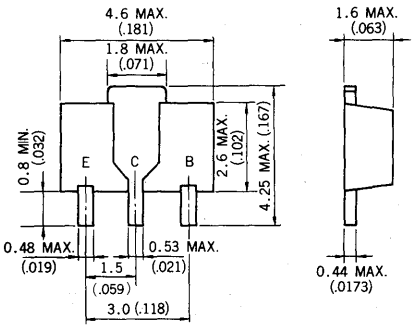
5

DESCRIPTION

The BCX54 to 56 are designed for audio frequency power amplifier application, especially in Hybrid Integrated Circuits.

PACKAGE DIMENSIONS

in millimeters (inches)



E: Emitter
B: Base
C: Collector

FEATURES

- World Standard Miniature Package : SOT−89
- High Collector to Base Voltage : $V_{CBO} > 100$ V
- Excellent DC Current Gain Linearity
  : $h_{FE} = 80$ TYP. ($V_{CE} = 2.0$ V, $I_C = 500$ mA)
- Complements to PNP type BCX51 to 53

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

		BCX54	BCX55	BCX56	
Maximum Voltages and Currents					
Collector to Base Voltage	V_{CBO}	45	60	100	V
Collector to Emitter Voltage	V_{CEO}	45	60	80	V
Collector to Emitter Voltage (R_{BE} = 1 kΩ)	V_{CER}	45	60	100	V
Emitter to Base Voltage	V_{EBO}		5.0		V
Collector Current (DC)	I_C		1.0		A
Collector Current (Pulse)*	I_C		1.5		A
Maximum Power Dissipation					
Total Power Dissipation**	P_T		2.0		W
Maximum Temperatures					
Junction Temperature	T_j		150		°C
Storage Temperature Range	T_{stg}		−55 to +150		°C

*PW ≦ 10 ms, duty cycle ≦ 50 %
**When mounted on ceramic substrate of 2.5 cm^2 x 0.7 mm

ELECTRICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

CHARACTERISTIC	SYMBOL		MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}				100	nA	V_{CB} = 30 V, I_E = 0
Collector Cutoff Current	I_{CBO}				10	μA	V_{CB} = 30 V, I_E = 0, T_j = 125 °C
Emitter Cutoff Current	I_{EBO}				100	nA	V_{EB} = 5.0 V, I_C = 0
DC Current Gain	h_{FE1}		25				V_{CE} = 2.0 V, I_C = 5.0 mA ***
DC Current Gain	h_{FE2}	BCX54	40		250		V_{CE} = 2.0 V, I_C = 150 mA ***
		BCX55, BCX56	40		160		
DC Current Gain	h_{FE3}		25	80			V_{CE} = 2.0 V, I_C = 500 mA ***
Collector Saturation Voltage	$V_{CE(sat)}$			0.15	0.50	V	I_C = 500 mA, I_B = 50 mA ***
Base Saturation Voltage	$V_{BE(sat)}$			0.9	1.50	V	I_C = 500 mA, I_B = 50 mA ***
Base to Emitter Voltage	V_{BE}				1.0	V	V_{CE} = 2.0 V, I_C = 500 mA ***
Gain Bandwidth Product	f_T			160		MHz	V_{CE} = 5.0 V, I_E = −10 mA
Output Capacitance	C_{ob}			12		pF	V_{CB} = 10 V, I_E = 0, f = 1.0 MHz

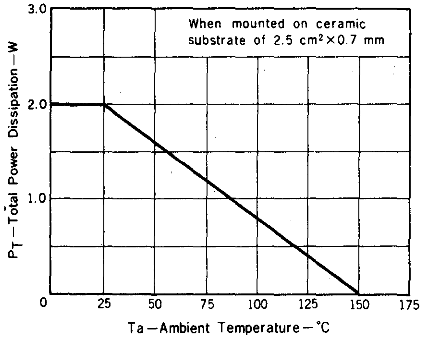
***Pulsed : PW ≦ 350 μs, duty cycle ≦ 2 %

h_{FE} Classification

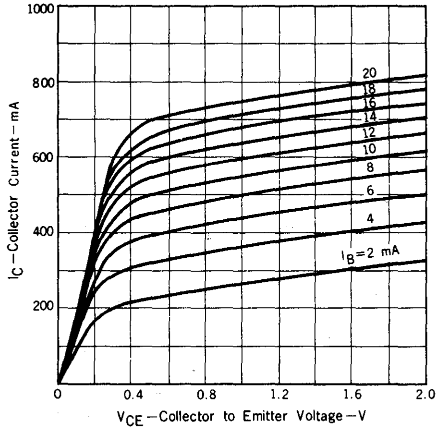
Marking	BCX54	BB	BC	BD
	BCX55	BF	BG	
	BCX56	BJ	BK	
h_{FE2}		40 – 100	60 – 160	100 – 250

TYPICAL CHARACTERISTICS (Ta = 25 °C)

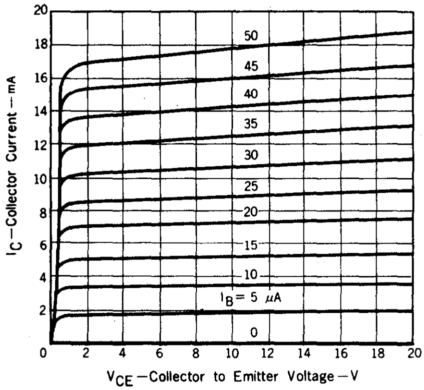
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



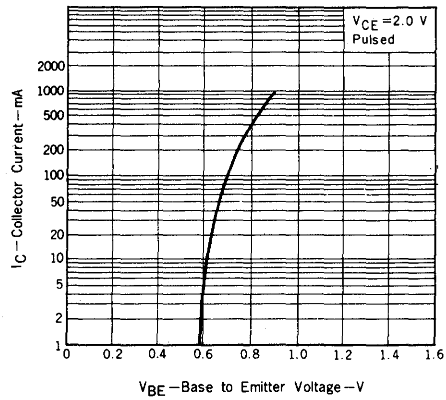
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



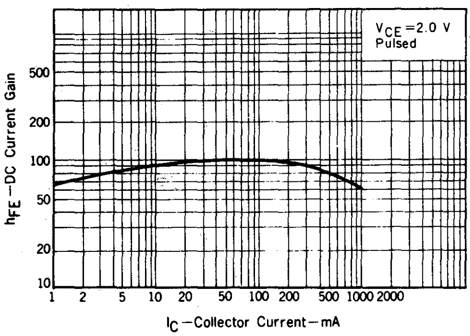
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



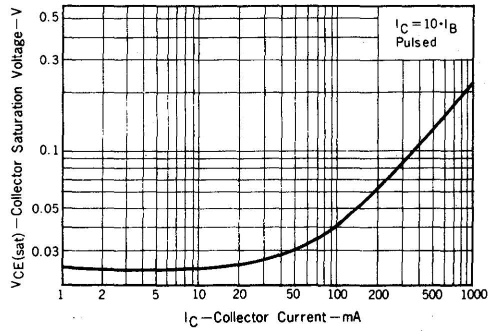
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE

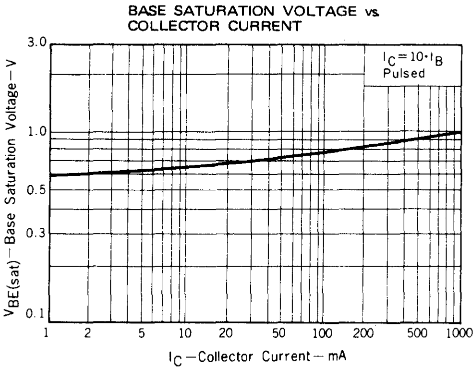


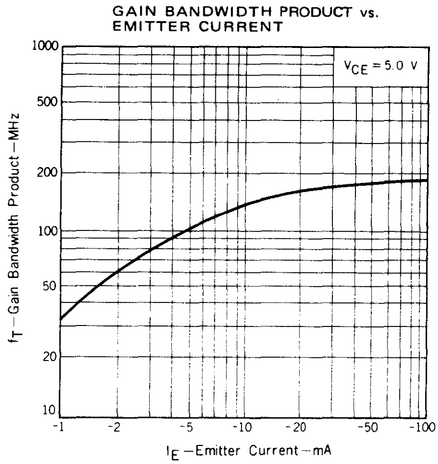
DC CURRENT GAIN vs.
COLLECTOR CURRENT

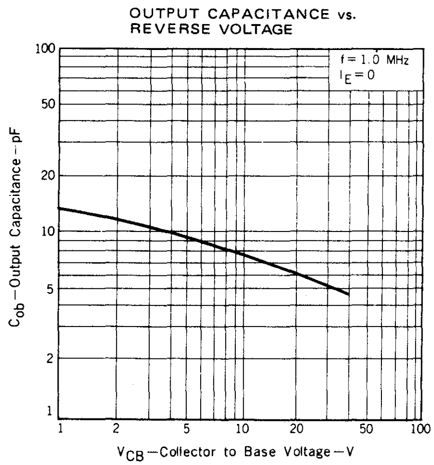


COLLECTOR SATURATION VOLTAGE
vs. COLLECTOR CURRENT




BASE SATURATION VOLTAGE vs COLLECTOR CURRENT
$I_C = 10 \cdot I_B$
Pulsed
$V_{BE(sat)}$ – Base Saturation Voltage – V
3.0
1.0
0.5
0.3
0.1
1
2
5
10
20
50
100
200
500
1000
I_C – Collector Current – mA


GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT
$V_{CE} = 5.0$ V
f_T – Gain Bandwidth Product – MHz
1000
500
200
100
50
20
10
-1
-2
-5
-10
-20
-50
-100
I_E – Emitter Current – mA


OUTPUT CAPACITANCE vs. REVERSE VOLTAGE
f = 1.0 MHz
$I_E = 0$
C_{ob} – Output Capacitance – pF
100
50
20
10
5
2
1
1
2
5
10
20
50
100
V_{CB} – Collector to Base Voltage – V

5

NEC
ELECTRON DEVICE

SILICON TRANSISTORS
NTM2222A, NTM2222AR

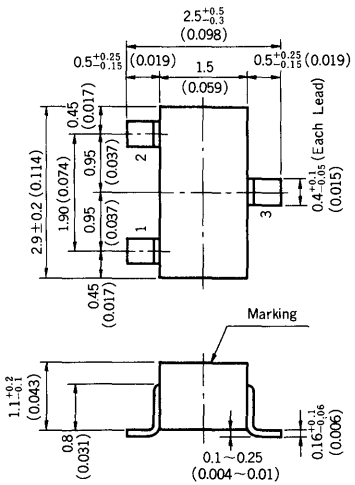
GENERAL PURPOSE AMPLIFIER, HIGH SPEED SWITCHING NPN SILICON EPITAXIAL TRANSISTOR "MINI MOLD TYPE"

DESCRIPTION

The NTM2222A, NTM2222AR are designed for general purpose amplifier and high speed switching applications, especially Hybrid Integrated Circuit.

PACKAGE DIMENSIONS

in millimeters (inches)



	NTM2222A	NTM2222AR
	1. Emitter	1. Base
	2. Base	2. Emitter
	3. Collector	3. Collector
Marking	B15	15B

FEATURES

- Complementary to NTM2907A, NTM2907AR.
- High gain bandwidth product : f_T = 300 MHz MIN.
- Low collector saturation voltage :
  $V_{CE(sat)}$ = 0.3 V MAX. (I_C = 150 mA, I_B = 15 mA)
- High speed switching.
- Electrically similar to 2N2222A.

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Voltages and Current			
Collector to Base Voltage	V_{CBO}	75	V
Collector to Emitter Voltage	V_{CEO}	40	V
Emitter to Base Voltage	V_{EBO}	6.0	V
Collector Current (DC)	I_C	800	mA
Maximum Power Dissipation			
Total Power Dissipation	P_T	200	mW
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT	TEST CONDITIONS
Collector-Base Breakdown Voltage	BV_{CBO}	75		V	$I_C = 10\ \mu A$, $I_E = 0$
Collector-Emitter Breakdown Voltage	BV_{CEO}	40		V	$I_C = 10 mA$, $I_B = 0$
Emitter-Base Breakdown Voltage	BV_{EBO}	6.0		V	$I_E = -10\ \mu A$, $I_C = 0$
Collector Cutoff Current	I_{CEX}		10	nA	$V_{CE} = 60$ V, $V_{BE} = -3.0$ V
	I_{CBO}		10	nA	$V_{CB} = 60$ V, $I_E = 0$
DC Current Gain	h_{FE1}	35			$V_{CE} = 10$ V, $I_C = 100\ \mu A$
	h_{FE2}	50			$V_{CE} = 10$ V, $I_C = 1.0$ mA
	h_{FE3}	75			$V_{CE} = 10$ V, $I_C = 10$ mA
	h_{FE4}	100	300		$V_{CE} = 10$ V, $I_C = 150$ mA *1
	h_{FE5}	40			$V_{CE} = 10$ V, $I_C = 500$ mA *1
Collector Saturation Voltage	$V_{CE(sat)1}$		0.3	V	$I_C = 150$ mA, $I_B = 15$ mA *1
	$V_{CE(sat)2}$		1.0	V	$I_C = 500$ mA, $I_B = 50$ mA *1
Base Saturation Voltage	$V_{BE(sat)1}$	0.6	1.2	V	$I_C = 150$ mA, $I_B = 15$ mA *1
	$V_{BE(sat)2}$		2.0	V	$I_C = 500$ mA, $I_B = 50$ mA *1
Gain Bandwidth Product	f_T	300		MHz	$V_{CE} = 20$ V, $I_C = 20$ mA, f = 100 MHz
Output Capacitance	C_{ob}		8.0	pF	$V_{CB} = 10$ V, $I_E = 0$, f = 1.0 MHz
Input Capacitance	C_{ib}		25	pF	$V_{EB} = 0.5$ V, $I_C = 0$ f = 1.0 MHz

*1 These parameters must be measured by pulse techniques.
PW ≦ 350 μs, duty cycle ≦ 2 %.

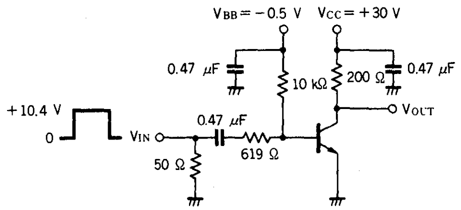
5

SWITCHING CHARACTERISTICS

CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT	TEST CONDITIONS
Delay Time	t_d		10	ns	V_{CC}=30 V, V_{BE}=−0.5 V, I_C=150 mA, I_{B1}=15 mA
Rise Time	t_r		25	ns	
Storage Time	t_{stg}		225	ns	V_{CC}=30 V, I_C=150 mA, I_{B1}=−I_{B2}=15 mA
Fall Time	t_f		60	ns	

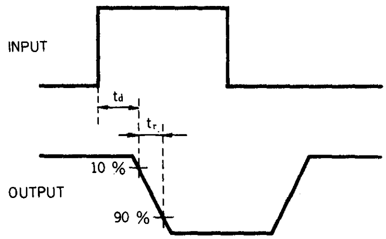
See test circuit

SWITCHING TIME TEST CIRCUIT



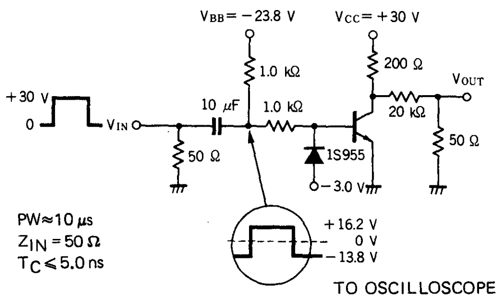
PW ≤ 200 ns
t_r ≤ 2.0 ns
Z_{IN} = 50 Ω

TO OSCILLOSCOPE
Z_{IN} > 100 kΩ
C_{IN} ≤ 12 pF
t_r < 5.0 ns

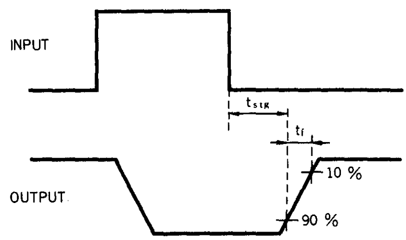


VOLTAGE WAVEFORMS

t_{on} SWITCHING



TO OSCILLOSCOPE
Z_{IN} > 100 kΩ
C_{IN} ≤ 12 pF
t_r < 5.0 ns



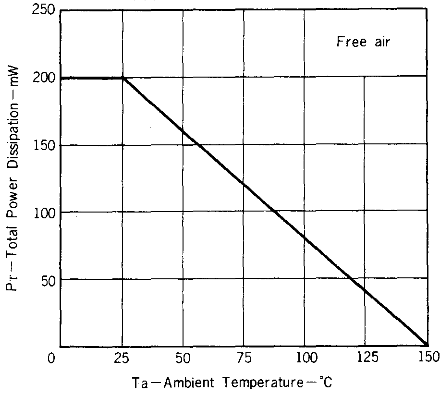
VOLTAGE WAVEFORMS

The 20 kΩ and 50 Ω resistors on the output of the test circuit are normally omitted, due to the excessive attenuation of the collector waveform. The collector voltage is monitored directly with a high impedance oscilloscope prove.

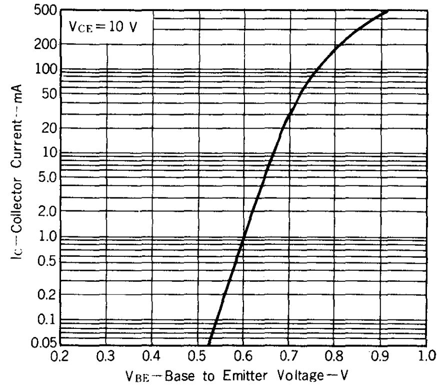
t_{off} SWITCHING

TYPICAL CHARACTERISTICS (Ta = 25 °C)

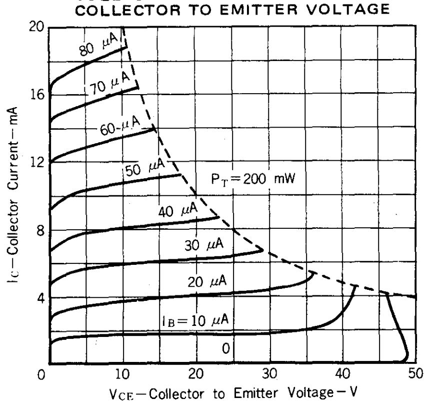
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



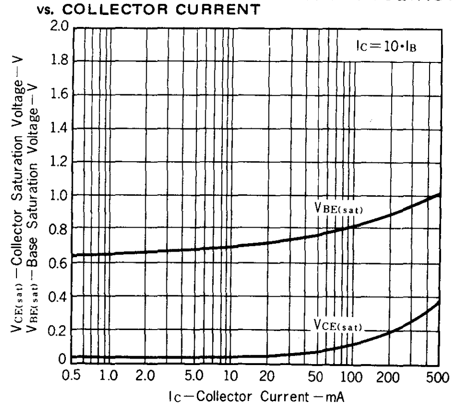
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



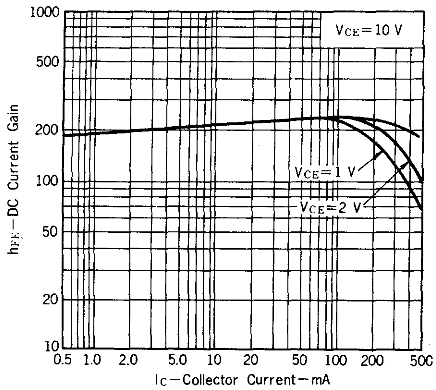
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

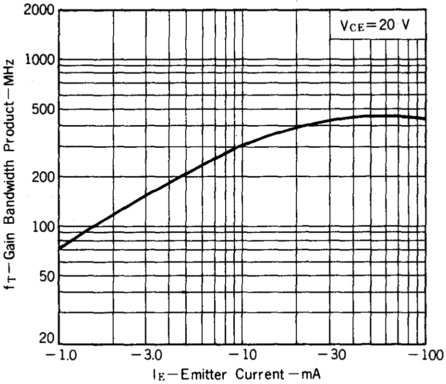


DC CURRENT GAIN vs. COLLECTOR CURRENT

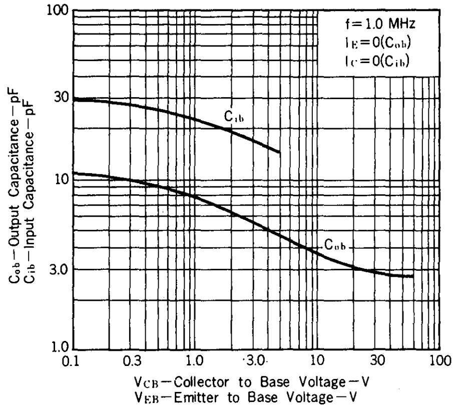


5

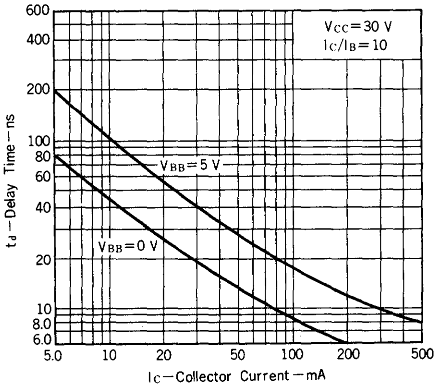
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



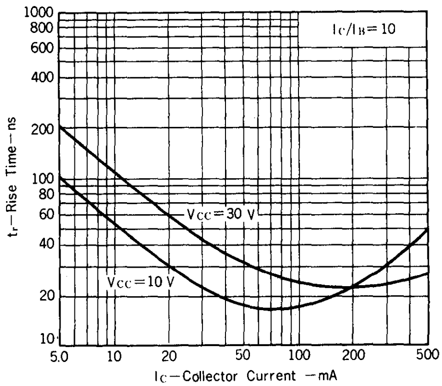
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



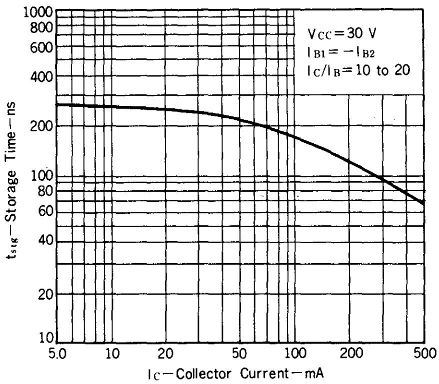
DELAY TIME vs. COLLECTOR CURRENT



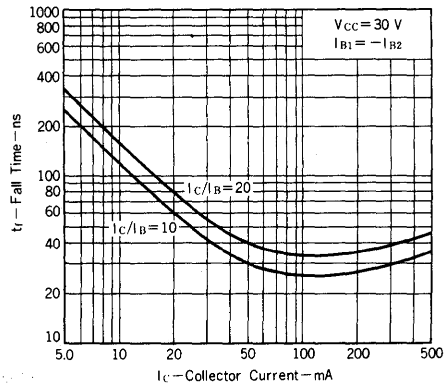
RISE TIME vs. COLLECTOR CURRENT



STORAGE TIME vs. COLLECTOR CURRENT



FALL TIME vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

SILICON TRANSISTORS

NTM2369, NTM2369R

HIGH SPEED SWITCHING, GENERAL PURPOSE AMPLIFIER NPN SILICON EPITAXIAL TRANSISTOR "MINI MOLD"

DESCRIPTION

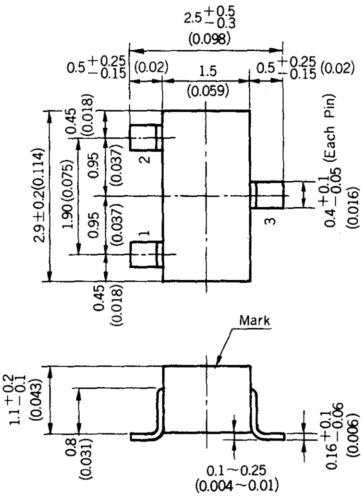
The NTM2369, NTM2369R are NPN transistors, designed for general purpose amplifier and high speed switching applications, features injection molded plastic package for hybrid IC.

FEATURES

- High frequency current gain.
- High speed switching.
- NTM2369, NTM2369R electrically similar to 2N2369.

PACKAGE DIMENSIONS

in millimeters (inches)



	NTM2369	NTM2369R
	1. Emitter	1. Base
	2. Base	2. Emitter
	3. Collector	3. Collector
Marking	B32	32B

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Voltages and Current			
Collector to Base Voltage	V_{CBO}	40	V
Collector to Emitter Voltage	V_{CEO}	15	V
Emitter to Base Voltage	V_{EBO}	4.5	V
Collector Current	I_C	200	mA
Maximum Power Dissipation			
Total Power Dissipation	P_T	200	mW
Maximum Temperatures			
Storage Temperature	T_{stg}	-55 to +150	°C
Operating Junction Temperature	T_j	150	°C

5

ELECTRICAL CHARACTERISTICS ($T_a = 25°C$)

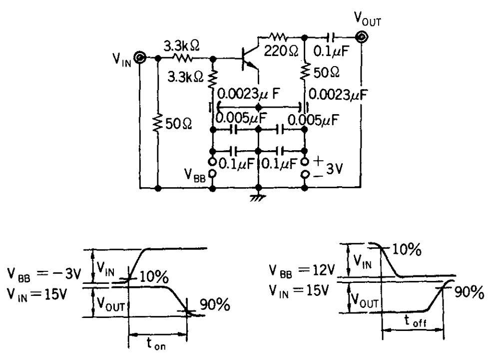
CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT	TEST CONDITIONS
Collector to Base Breakdown Voltage	BV_{CBO}	40		V	$I_C = 10\mu A$, $I_E = 0$
Collector to Emitter Breakdown Voltage	BV_{CEO}	15		V	$I_C = 10mA$, $I_B = 0$
Emitter to Base Breakdown Voltage	BV_{EBO}	4.5		V	$I_E = 10\mu A$, $I_C = 0$
Collector Cutoff Current	I_{CBO}		0.4	μA	$V_{CB} = 20V$, $I_E = 0$
DC Current Gain	h_{FE1}	40	120		$V_{CE} = 1.0V$, $I_C = 10mA$
	h_{FE2}	20			$V_{CE} = 2.0V$, $I_C = 100mA$
Collector Saturation Voltage	$V_{CE(sat)1}$		0.25	V	$I_C = 10mA$, $I_B = 1.0mA$
	$V_{CE(sat)2}$		0.45	V	$I_C = 100mA$, $I_B = 10mA$
Base Saturation Voltage	$V_{BE(sat)1}$	0.7	0.85	V	$I_C = 10mA$, $I_B = 1.0mA$
	$V_{BE(sat)2}$	0.8	1.4	V	$I_C = 100mA$, $I_B = 10mA$
Gain Bandwidth Product	f_T	500		MHz	$V_{CE} = 10V$, $I_C = 10mA$
Output Capacitance	C_{ob}		4.0	pF	$V_{CB} = 5.0V$, $I_E = 0$, $f = 1.0MHz$
Input Capacitance	C_{ib}		4.0	pF	$V_{EB} = 1.0V$, $I_C = 0$, $f = 1.0MHz$

SWITCHING CHARACTERISTICS ($T_a = 25°C$)

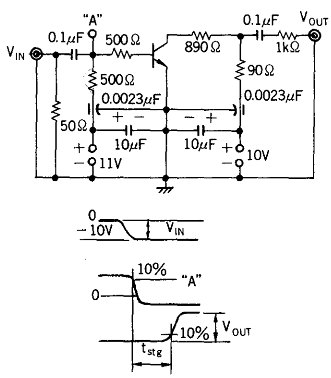
CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT	TEST CONDITIONS
Turn on Time	t_{on}		12	ns	$V_{CC} = 3.0V$, $I_C = 10mA$, $I_{B1} = 3.0mA$, $V_{BE(off)} = -1.5V$
Turn off Time	t_{off}		18	ns	$V_{CC} = 3.0V$, $I_C = 10mA$, $I_{B1} = 3.0mA$, $I_{B2} = -1.5mA$
Storage Time	t_{stg}		13	ns	$I_C = 10mA$, $I_{B1} = -I_{B2} = 10mA$

SWITCHING TIME TEST CIRCUIT

T_{on}, T_{off} TEST CIRCUIT

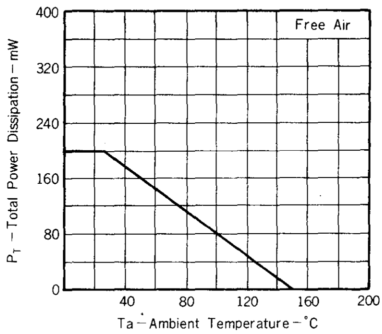


T_{stg} TEST CIRCUIT

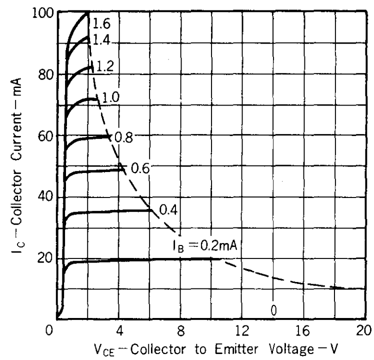


TYPICAL CHARACTERISTICS (Ta = 25°C)

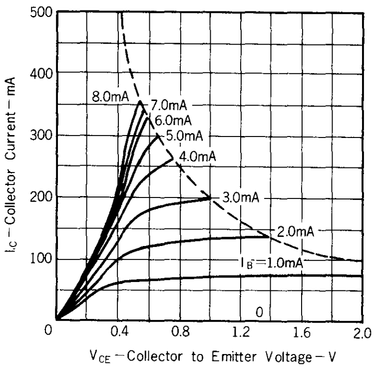
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



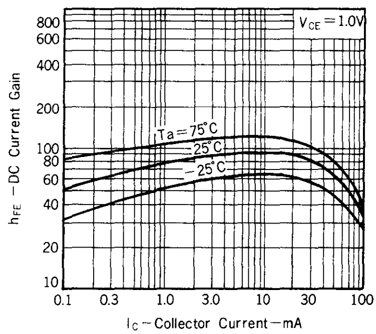
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



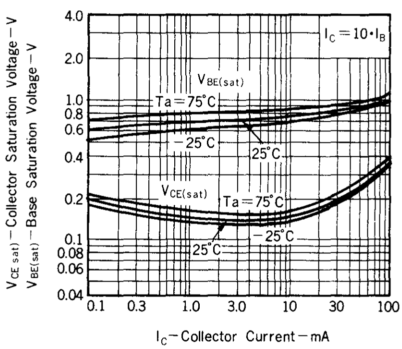
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



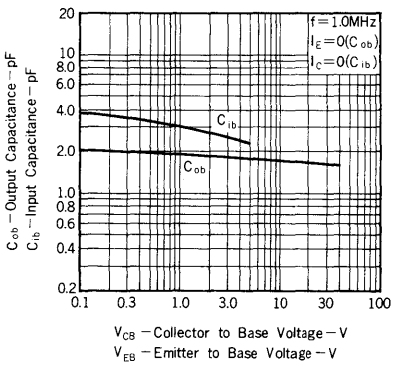
DC CURRENT GAIN vs. COLLECTOR CURRENT



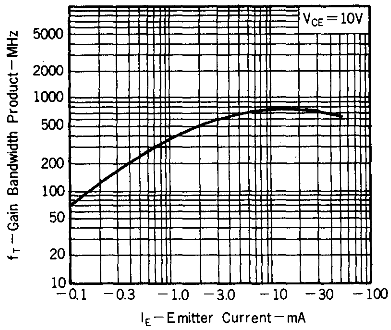
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



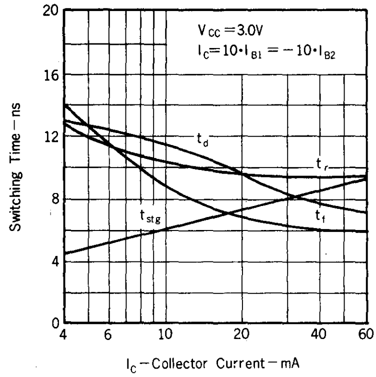
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



GAIN BANDWIDTH PRODUCT
vs. EMITTER CURRENT



SWITCHING TIME
vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

SILICON TRANSISTORS
NTM2907A, NTM2907AR

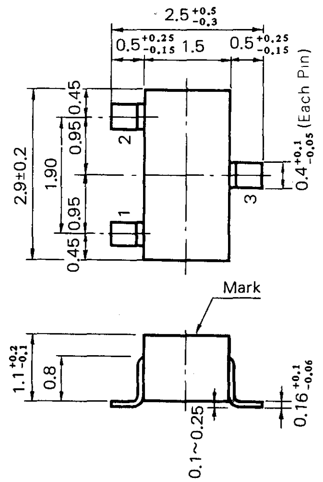
GENERAL PURPOSE AMPLIFIER, HIGH SPEED SWITCHING PNP SILICON EPITAXIAL TRANSISTOR "MINI MOLD TYPE"

DESCRIPTION

The NTM2907A, NTM2907AR are PNP Transistor, designed for general purpose amplifier and high speed switching applications, features injection molded plastic package for Hybrid IC.

PACKAGE DIMENSIONS

in millimeter



	NTM2907A	NTM2907AR
	1. Emitter	1. Base
	2. Base	2. Emitter
	3. Collector	3. Collector
Marking	Y15	15Y

FEATURES

- High frequency current gain.
- Low collector saturation voltage.
- High speed switching.
- NTM2907A, NTM2907AR electrically similar to 2N2907A.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta=25 °C)			
Collector to Base Voltage	V_{CBO}	−60	V
Collector to Emitter Voltage	V_{CEO}	−60	V
Emitter to Base Voltage	V_{EBO}	−5.0	V
Collector Current	I_C	−600	mA
Maximum Power Dissipation (Ta=25 °C)			
Total Power Dissipation	P_T	200	mW
Maximum Temperatures			
Storage Temperature Range	Tstg	−55 to +150	°C
Junction Temperature	T_j	150	°C

5

ELECTRICAL CHARACTERISTICS (Ta=25 °C)

CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT	TEST CONDITIONS
Collector to Base Breakdown Voltage	BV_{CBO}	-60		V	I_C=-10μA,I_B=0
Collector to Emitter Breakdown Voltage	BV_{CEO}	-60		V	I_C=-10mA,R_{BE}=∞
Emitter to Base Breakdown Voltage	BV_{EBO}	-5.0		V	I_E=-10μA,I_C=0
Collector Cutoff Current	I_{CEX}		-50	nA	V_{CE}=-30V,V_{BE}=-0.5V
	I_{CBO}		-50	nA	V_{CB}=-50V,I_E=0
DC Current Gain	h_{FE1}	75			V_{CE}=-10V,I_C=-100μA
	h_{FE2}	100			V_{CE}=-10V,I_C=-1.0mA
	h_{FE3}	100			V_{CE}=-10V,I_C=-10mA
	h_{FE4}	100	300		V_{CE}=-10V,I_C=-150mA *1
	h_{FE5}	50			V_{CE}=-10V,I_C=-500mA *1
Collector Saturation Voltage	$V_{CE(sat)1}$		-0.4	V	I_C=-150mA,I_B=-15mA *1
	$V_{CE(sat)2}$		-1.6	V	I_C=-500mA,I_B=-50mA *1
Base Saturation Voltage	$V_{BE(sat)1}$		-1.3	V	I_C=-150mA,I_B=-15mA *1
	$V_{BE(sat)2}$		-2.6	V	I_C=-500mA,I_B=-50mA *1
Gain Bandwidth Product	f_T	200		MHz	I_C=-50mA,V_{CE}=-20V, f=100MHz
Output Capacitance	Cob		8.0	pF	V_{CB}=-10V,I_E=0,f=1.0MHz
Input Capacitance	Cib		30	pF	V_{EB}=-2.0V, I_C=0, f=1.0MHz

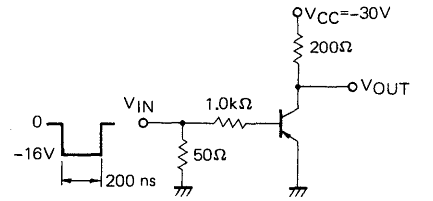
*1 These parameters must be measured using pulse techniques.
PW≦350μs, duty cycle≦2%.

SWITCHING CHARACTERISTICS (Ta=25°C)

CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT	TEST CONDITIONS
Delay Time	t_d		10	ns	V_{CC}=-30V,I_C=-150mA V_{BE}=0,I_{B1}=-15mA
Rise Time	t_r		40	ns	
Turn On Time	t_{on}		45	ns	
Storage Time	t_{stg}		80	ns	V_{CC}=-6.0V,I_C=-150mA I_{B1}=-I_{B2}=-15mA
Fall Time	t_f		30	ns	
Turn Off Time	t_{off}		100	ns	

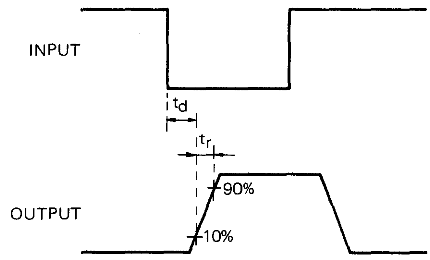
See test circuit.

SWITCHING TIME TEST CIRCUIT



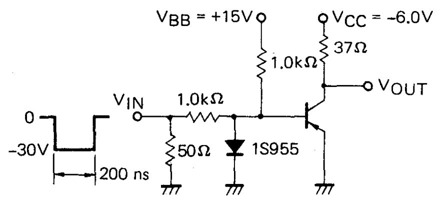
Z_O = 50Ω
PRF = 150 pps
$t_r \leq 2.0$ ns

TO OSCILLOSCOPE
$t_r \leq 5.0$ ns
Z_{IN} = 10 MΩ



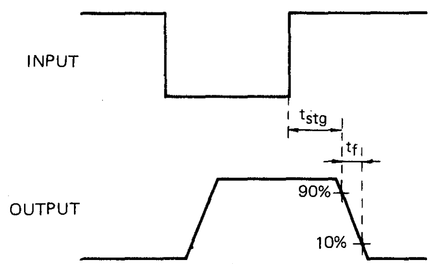
VOLTAGE WAVEFORMS

t_{on} SWITCHING



Z_O = 50Ω
PRF = 150 pps
$t_r \leq 2.0$ ns

TO OSCILLOSCOPE
$t_r \leq 5.0$ ns
Z_{IN} = 10 MΩ



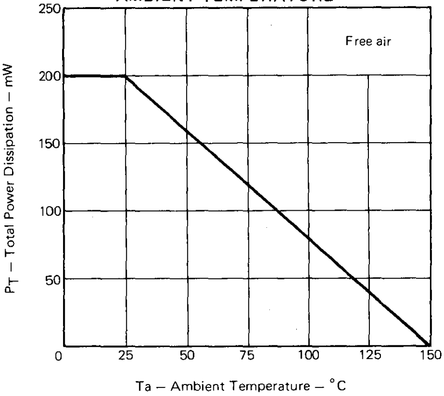
VOLTAGE WAVEFORMS

t_{off} SWITCHING

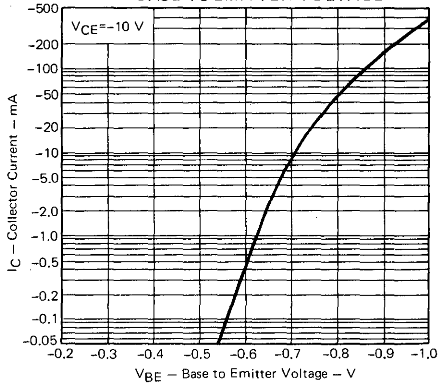
5

TYPICAL CHARACTERISTICS (Ta = 25 °C)

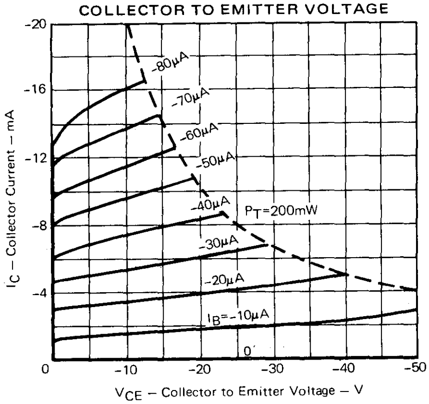
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



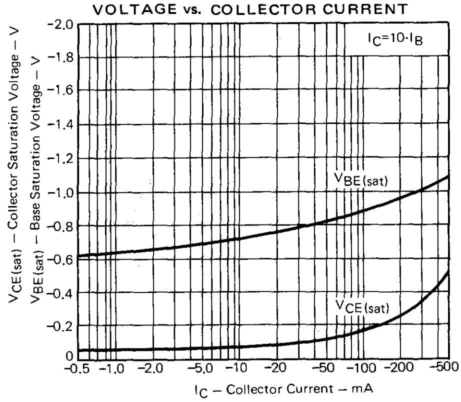
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



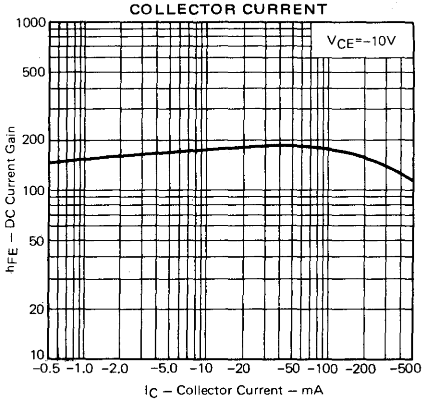
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



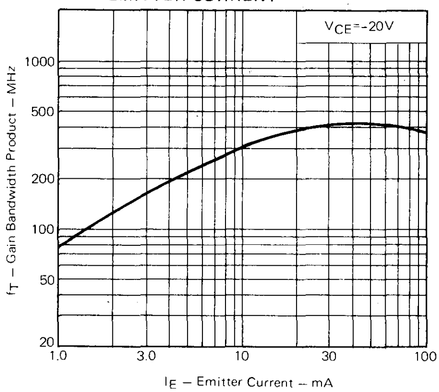
BASE AND COLLECTOR SATURATION
VOLTAGE vs. COLLECTOR CURRENT



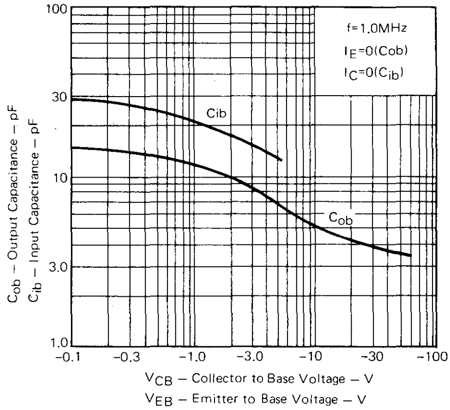
DC CURRENT GAIN vs.
COLLECTOR CURRENT



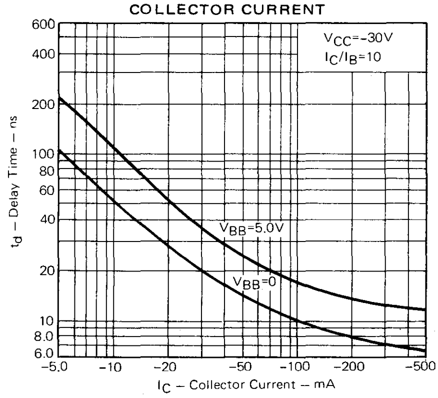
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



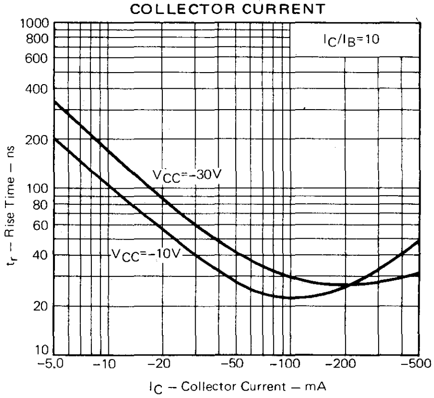
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



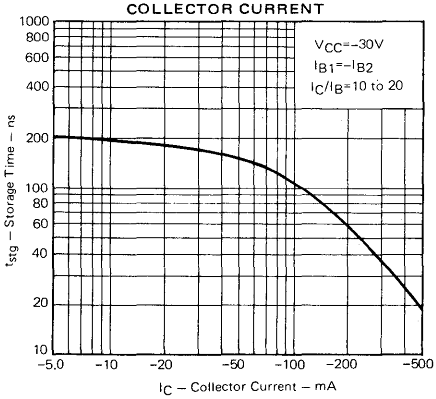
DELAY TIME vs. COLLECTOR CURRENT



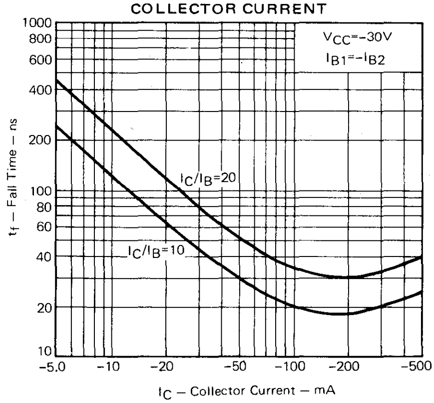
RISE TIME vs. COLLECTOR CURRENT



STORAGE TIME vs. COLLECTOR CURRENT



FALL TIME vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

SILICON TRANSISTORS
NTM3904, NTM3904R

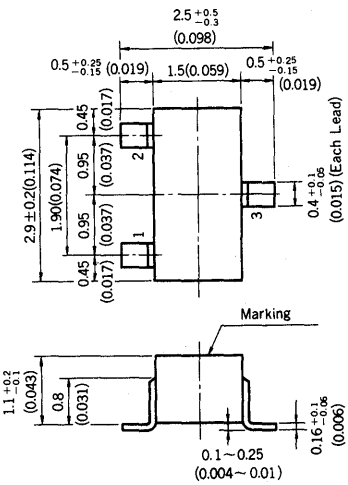
GENERAL PURPOSE SWITCHING AND AMPLIFIER NPN SILICON EPITAXIAL TRANSISTOR "MINI MOLD TYPE"

DESCRIPTION

The NTM3904, NTM3904R are designed for general purpose switching and amplifier application, especially Hybrid Integrated Circuit.

PACKAGE DIMENSIONS

in millimeters (inches)



	NTM3904	NTM3904R
	1. Emitter	1. Base
	2. Base	2. Emitter
	3. Collector	3. Collector
Marking	B25	25B

FEATURES

- Complementary to NTM3906, NTM3906R.
- High voltage : $V_{CEO} > 40$ V
- High DC current gain : h_{FE} = 100 to 300 (V_{CE} = 1.0 V, I_C = 10 mA)
- Electrically similar to 2N3904.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta = 25 °C)			
Collector to Base Voltage ($R_{BE} = \infty$)	V_{CBO}	60	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	40	V
Emitter to Base Voltage	V_{EBO}	6.0	V
Collector Current (DC)	I_C	200	mA
Maximum Power Dissipation (Ta = 25 °C)			
Total Power Dissipation	P_T	200	mW
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT	TEST CONDITIONS
Collector-Base Breakdown Voltage	BV_{CBO}	60		V	$I_C = 10\ \mu A$, $I_E = 0$
Collector-Emitter Breakdown Voltage	BV_{CEO}*	40		V	$I_C = 1.0\ mA$, $I_B = 0$
Emitter-Base Breakdown Voltage	BV_{EBO}	6.0		V	$I_E = -10\ \mu A$, $I_C = 0$
Collector Cutoff Current	I_{CEX}		50	nA	$V_{CE} = 30\ V$, $V_{BE} = -3.0\ V$
Emitter Cutoff Current	I_{EBO}		50	nA	$V_{EB} = 3.0\ V$, $I_E = 0$
DC Current Gain	h_{FE1}*	40			$V_{CE} = 1.0\ V$, $I_C = 100\ \mu A$
	h_{FE2}*	70			$V_{CE} = 1.0\ V$, $I_C = 1.0\ mA$
	h_{FE3}*	100	300		$V_{CE} = 1.0\ V$, $I_C = 10\ mA$
	h_{FE4}*	60			$V_{CE} = 1.0\ V$, $I_C = 50\ mA$
	h_{FE5}*	30			$V_{CE} = 1.0\ V$, $I_C = 100\ mA$
Collector Saturation Voltage	$V_{CE(sat)1}$*		0.2	V	$I_C = 10\ mA$, $I_B = 1.0\ mA$
	$V_{CE(sat)2}$*		0.3	V	$I_C = 50\ mA$, $I_B = 5.0\ mA$
Base Saturation Voltage	$V_{BE(sat)1}$*	0.65	0.85	V	$I_C = 10\ mA$, $I_B = 1.0\ mA$
	$V_{BE(sat)2}$*		0.95	V	$I_C = 50\ mA$, $I_B = 5.0\ mA$
Gain Bandwidth Product	f_T	300		MHz	$V_{CE} = 20\ V$, $I_C = 10\ mA$
Output Capacitance	C_{ob}		4.0	pF	$V_{CB} = 5.0\ V$, $I_E = 0$, $f = 100\ kHz$
Input Capacitance	C_{ib}		8.0	pF	$V_{EB} = 0.5\ V$, $I_C = 0$, $f = 100\ kHz$

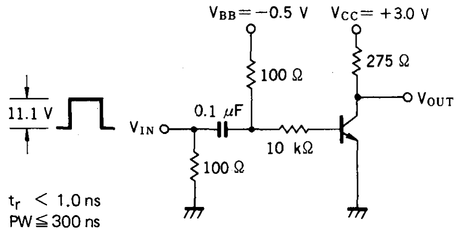
*These parameters must be measured by pulse techniques. $t_W \leqq 300\ \mu s$, duty cycle $\leqq 2\ \%$

5

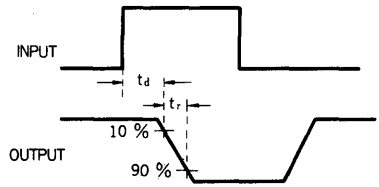
SWITCHING CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT	TEST CONDITIONS
Delay Time	t_d		35	ns	V_{CC} = 3.0 V, V_{BB} = −0.5 V I_C = 10 mA, I_{B1} = 1.0 mA
Rise Time	t_r		35	ns	
Storage Time	t_{stg}		200	ns	V_{CC} = 3.0 V, I_C = 10 mA I_{B1} = −I_{B2} = 1.0 mA
Fall Time	t_f		50	ns	

SWITCHING TIME TEST CIRCUIT

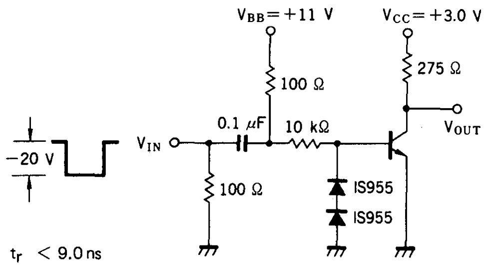


t_r < 1.0 ns
PW ≦ 300 ns
Duty cycle = 2 %

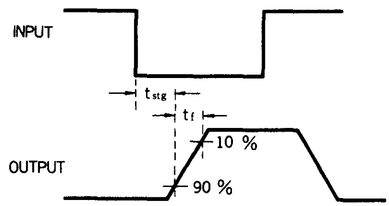


VOLTAGE WAVEFORMS

t_{on} SWITCHING



t_r < 9.0 ns
PW ≦ 300 ns
Duty cycle = 2 %

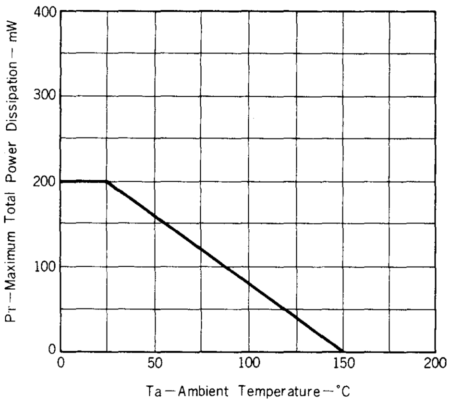


VOLTAGE WAVEFORMS

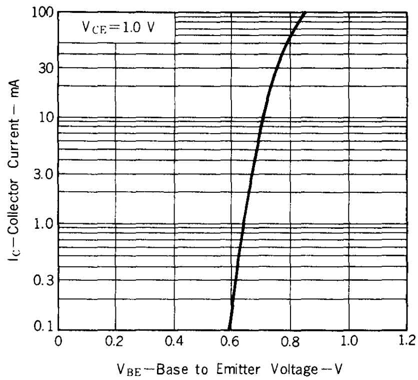
t_{off} SWITCHING

TYPICAL CHARACTERISTICS (Ta = 25 °C)

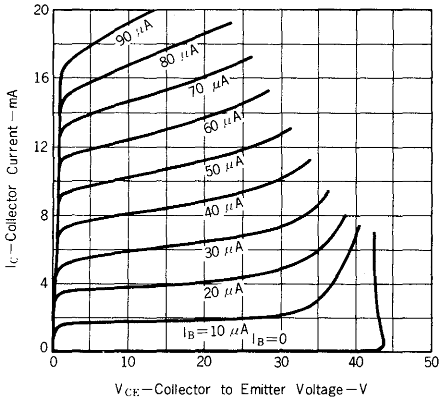
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



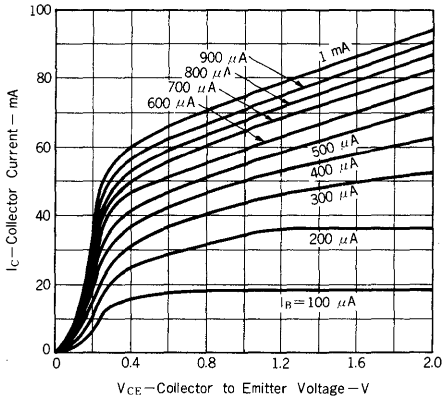
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

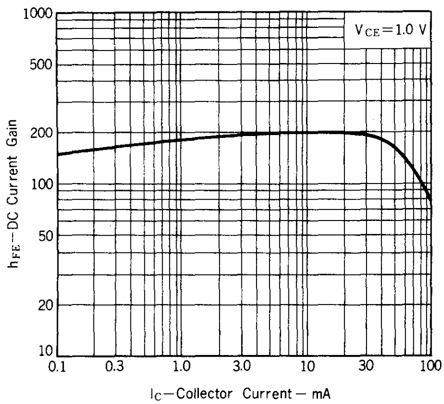


COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

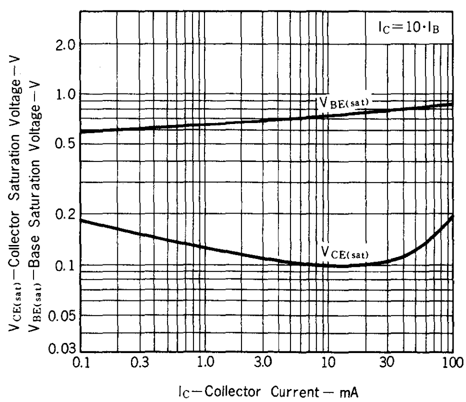


5

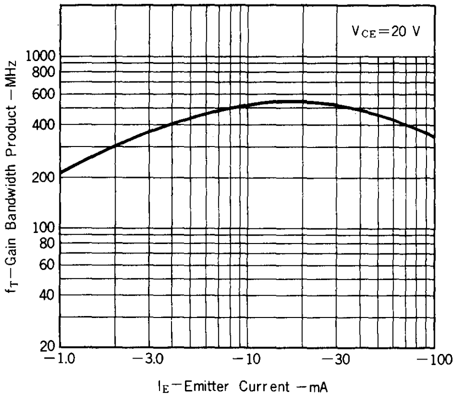
DC CURRENT GAIN vs. COLLECTOR CURRENT



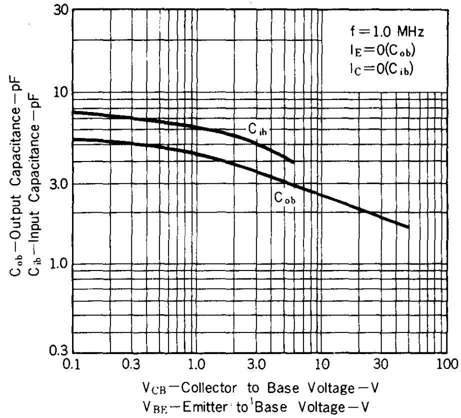
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



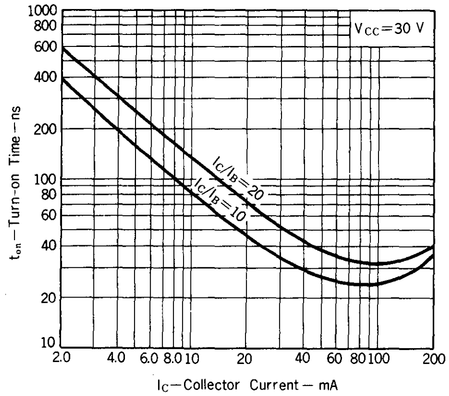
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



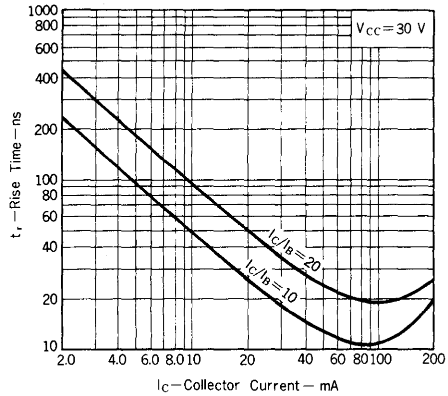
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



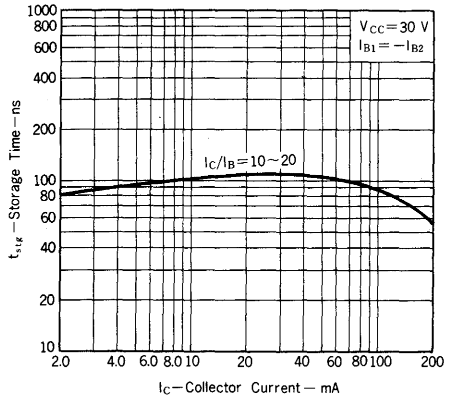
TURN-ON TIME vs. COLLECTOR CURRENT



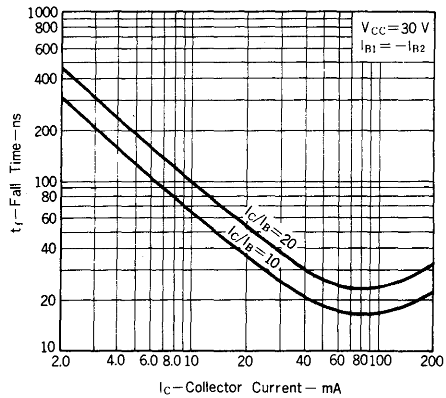
RISE TIME vs. COLLECTOR CURRENT



STORAGE TIME vs. COLLECTOR CURRENT



FALL TIME vs. COLLECTOR CURRENT



NEC
ELECTRON DEVICE

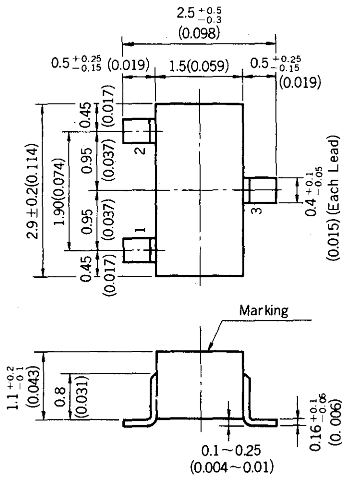
SILICON TRANSISTORS
NTM3906, NTM3906R

GENERAL PURPOSE SWITCHING AND AMPLIFIER
PNP SILICON EPITAXIAL TRANSISTOR
"MINI MOLD TYPE"

DESCRIPTION

The NTM3906, NTM3906R are designed for general purpose switching and amplifier application, especially Hybrid Integrated Circuit.

PACKAGE DIMENSIONS
in millimeters (inches)



NTM3906	NTM3906R
1. Emitter	1. Base
2. Base	2. Emitter
3. Collector	3. Collector
Marking Y25	25Y

FEATURES

- Complementary to NTM3904, NTM3904R.
- High voltage : $V_{CEO} > -40$ V
- High DC current gain : h_{FE} = 100 to 300 (V_{CE} = −1.0 V, I_C = −10 mA)
- Electrically similar to 2N3906.

5

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta = 25 °C)			
Collector to Base Voltage (R_{BE} = ∞)	V_{CBO}	-40	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	-40	V
Emitter to Base Voltage	V_{EBO}	-5.0	V
Collector Current (DC)	I_C	-200	mA
Maximum Power Dissipation (Ta = 25 °C)			
Total Power Dissipation	P_T	200	mW
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

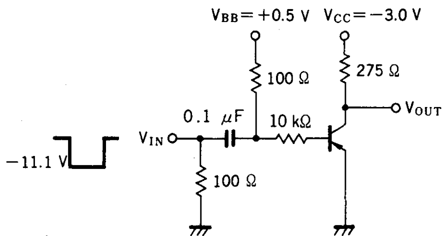
CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT	TEST CONDITIONS
Collector-Base Breakdown Voltage	BV_{CBO}	-40		V	$I_C = -10\ \mu A$, $I_E = 0$
Collector-Emitter Breakdown Voltage	BV_{CEO}*	-40		V	$I_C = -1.0$ mA, $I_B = 0$
Emitter-Base Breakdown Voltage	BV_{EBO}	-5.0		V	$I_E = -10\ \mu A$, $I_C = 0$
Collector Cutoff Current	I_{CEX}		-50	nA	$V_{CE} = -30$ V, $V_{BE} = 3.0$ V
	I_{CBO}		-50	nA	$V_{EB} = -3.0$ V, $I_E = 0$
DC Current Gain	h_{FE1}*	60			$V_{CE} = -1.0$ V, $I_C = -0.1$ mA
	h_{FE2}*	80			$V_{CE} = -1.0$ V, $I_C = -1.0$ mA
	h_{FE3}*	100	300		$V_{CE} = -1.0$ V, $I_C = -10$ mA
	h_{FE4}*	60			$V_{CE} = -1.0$ V, $I_C = -50$ mA
	h_{FE5}*	30			$V_{CE} = -1.0$ V, $I_C = -100$ mA
Collector Saturation Voltage	$V_{CE(sat)1}$*		-0.25	V	$I_C = -10$ mA, $I_B = -1.0$ mA
	$V_{CE(sat)2}$*		-0.4	V	$I_C = -50$ mA, $I_B = -5.0$ mA
Base Saturation Voltage	$V_{BE(sat)1}$*	-0.65	-0.85	V	$I_C = -10$ mA, $I_B = -1.0$ mA
	$V_{BE(sat)2}$*		-0.95	V	$I_C = -50$ mA, $I_B = -5.0$ mA
Gain Bandwidth Product	f_T	250		MHz	$I_C = -10$ mA, $V_{CE} = -20$ V
Output Capacitance	C_{ob}		4.5	pF	$V_{CB} = -5.0$ V, $I_E = 0$, f = 100 kHz
Input Capacitance	C_{ib}		10	pF	$V_{EB} = -0.5$ V, $I_C = 0$, f = 100 kHz

*These parameters must be measured by pulse techniques. $t_W \leqq 300\ \mu s$, duty cycle $\leqq 2$ %.

SWITCHING CHARACTERISTICS (Ta = 25 °C)

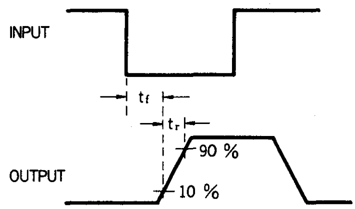
CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT	TEST CONDITIONS
Delay Time	t_d		35	ns	$V_{CC}=-3.0$ V, $V_{BE}=0.5$ V, $I_C=-10$ mA, $I_{B1}=-1.0$ mA
Rise Time	t_r		35	ns	
Storage Time	t_{stg}		225	ns	$V_{CC}=-3.0$ V, $I_C=-10$ mA, $I_{B1}=-I_{B2}=-1.0$ mA
Fall Time	t_f		75	ns	

SWITCHING TIME TEST CIRCUIT

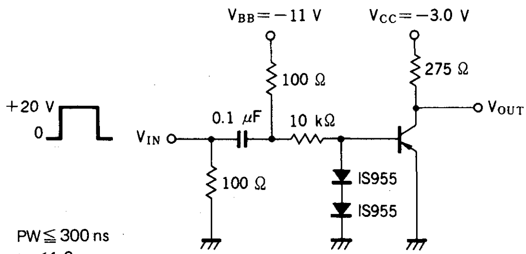


PW ≦ 300 ns
t_r < 1.0 ns
Z_{IN} = 50 Ω
Duty cycle = 2 %

t_{on} SWITCHING

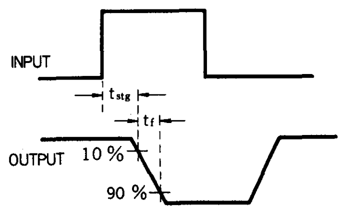


VOLTAGE WAVEFORMS



PW ≦ 300 ns
t_r < 1.0 ns
Duty cycle = 2 %

t_{off} SWITCHING

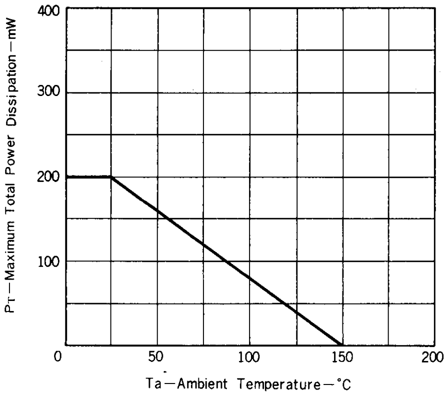


VOLTAGE WAVEFORMS

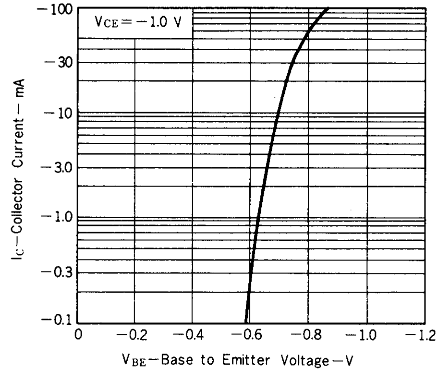
5

TYPICAL CHARACTERISTICS (Ta = 25 °C)

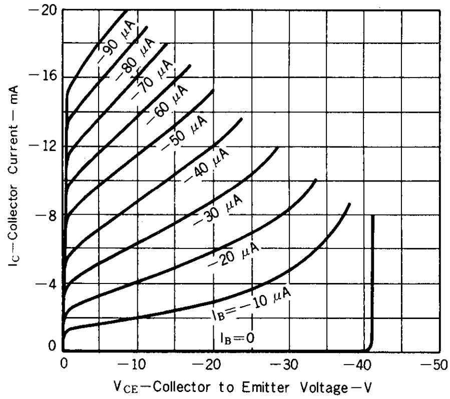
TOTAL POWER DISSIPATION
vs. AMBIENT TEMPERATURE



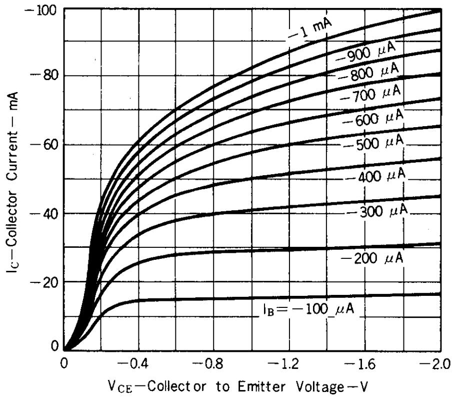
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



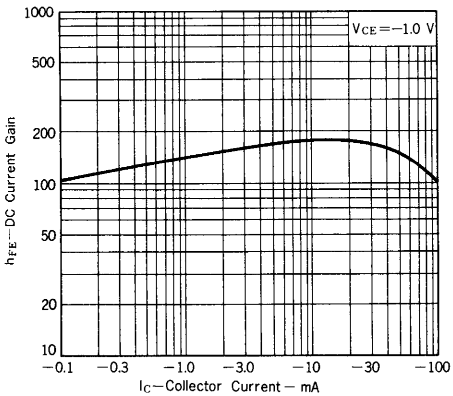
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



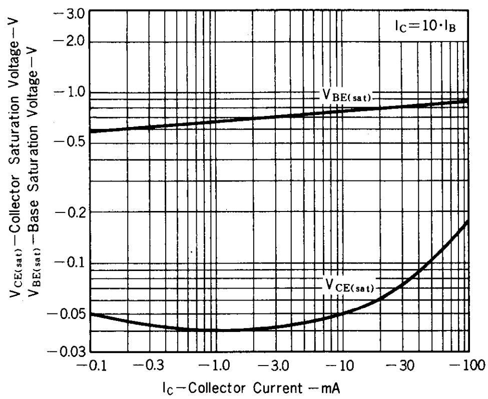
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



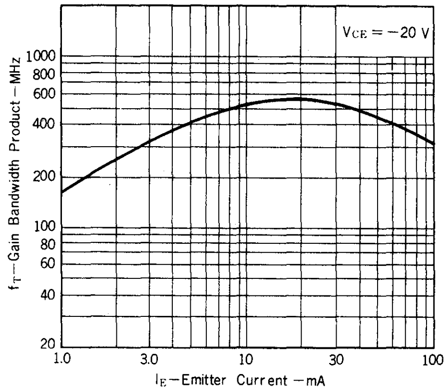
DC CURRENT GAIN vs.
COLLECTOR CURRENT



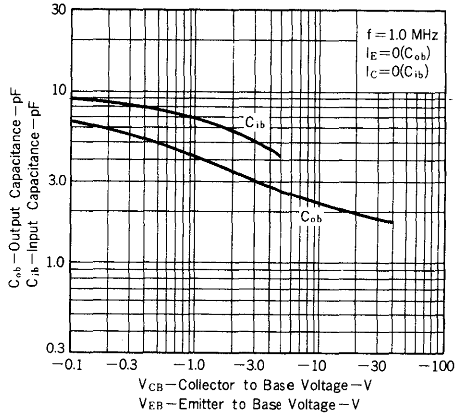
BASE AND COLLECTOR SATURATION VOLTAGE
vs. COLLECTOR CURRENT



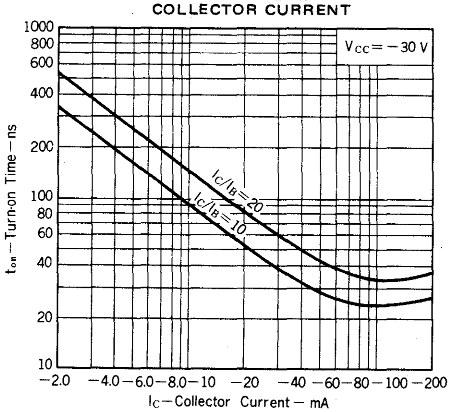
GAIN BANDWIDTH PRODUCT
vs. EMITTER CURRENT



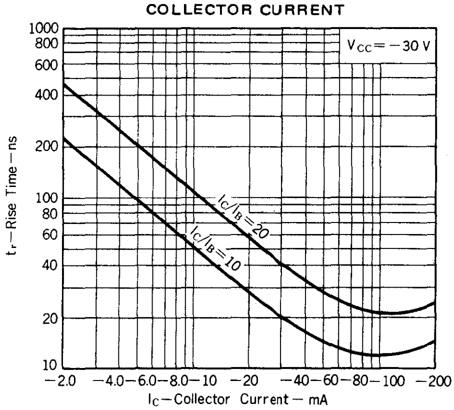
INPUT AND OUTPUT CAPACITANCE
vs. REVERSE VOLTAGE



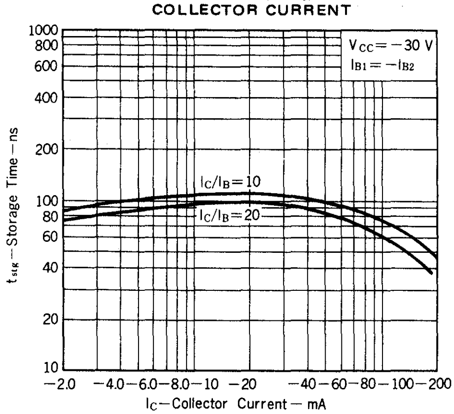
TURN-ON TIME vs.
COLLECTOR CURRENT



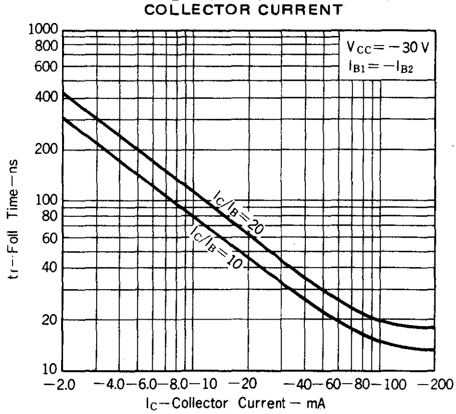
RISE TIME vs.
COLLECTOR CURRENT



STORAGE TIME vs.
COLLECTOR CURRENT



FALL TIME vs.
COLLECTOR CURRENT

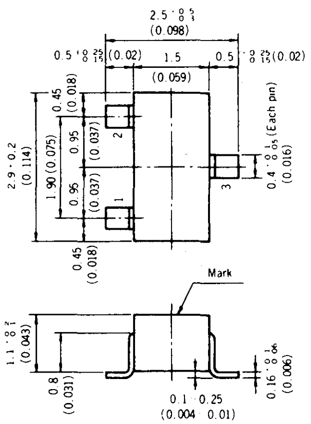


5

2SA811

Audio Frequency High Gain Amplifier
PNP Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Base
3. Collector

● High DC Current Gain: h_{FE}=450 TYP. (V_{CE}=−3.0V, I_C=−0.5mA)

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta=25°C)			
Collector to Base Voltage	V_{CBO}	−50	V
Collector to Emitter Voltage	V_{CEO}	−50	V
Emitter to Base Voltage	V_{EBO}	−5.0	V
Collector Current (DC)	I_C	−50	mA
Maximum Power Dissipation			
Total Power Dissipation at 25°C Ambient Temperature	P_T	150	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature Range	T_{stg}	−55 to +125	°C

ELECTRICAL CHARACTERISTICS (T_a = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−0.05	μA	V_{CB}=−50V, I_E=0
Emitter Cutoff Current	I_{EBO}			−0.05	μA	V_{EB}=−5.0V, I_C=0
DC Current Gain	h_{FE1}	100				V_{CE}=−3.0V, I_C=−0.1mA
DC Current Gain	h_{FE2}	135	450	900		V_{CE}=−3.0V, I_C=−0.5mA*
Collector Saturation Voltage	$V_{CE(sat)}$		−0.20	−0.30	V	I_C=−30mA, I_B=−3.0mA
Base-Emitter Voltage	V_{BE}	−0.55	−0.59	−0.65	V	V_{CE}=−3.0V, I_C=−0.5mA
Gain Bandwidth Product	f_T		100		MHz	V_{CE}=−6.0V, I_E=1.0mA
Output Capacitance	C_{ob}		6.2		pF	V_{CB}=−10V, I_E=0, f=1.0MHz

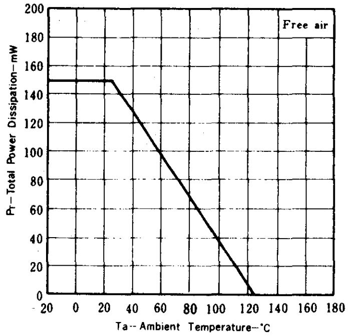
* Pulsed: PW ≦ 350μs, duty cycle ≦ 2%

h_{FE_2} Classification

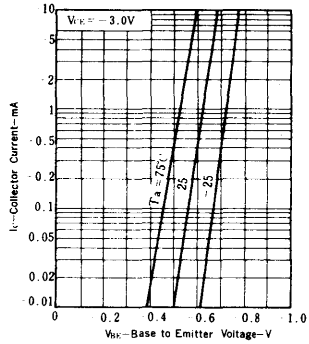
MARK	C5	C6	C7	C8
h_{FE}	135 – 270	200 – 400	300 – 600	450 – 900

TYPICAL CHARACTERISTICS (Ta = 25°C)

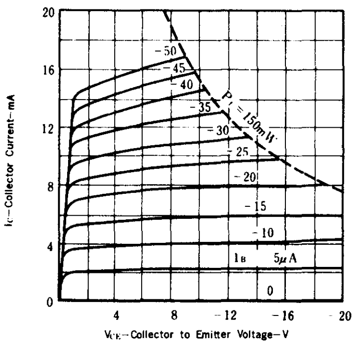
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



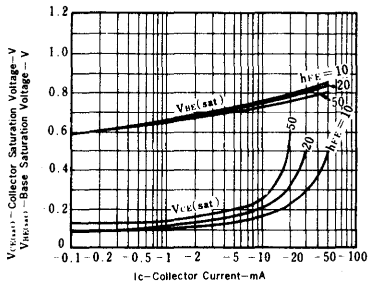
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



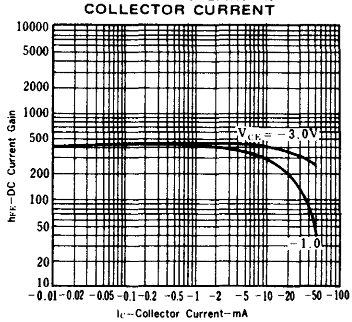
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



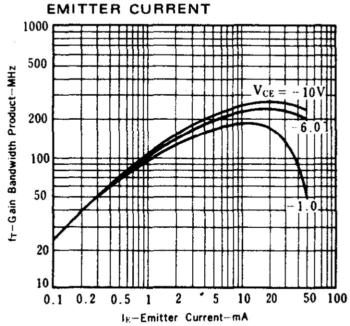
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



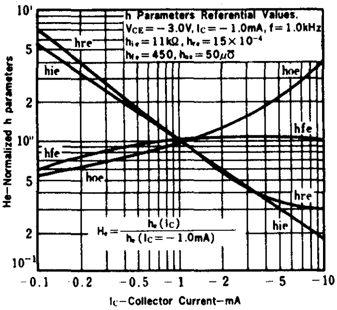
DC CURRENT GAIN vs. COLLECTOR CURRENT



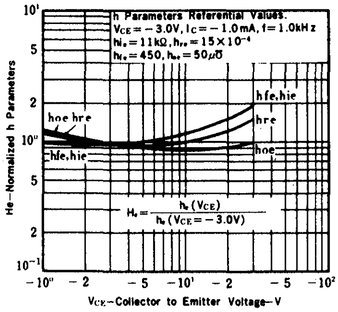
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



NORMALIZED h PARAMETER vs.
COLLECTOR CURRENT



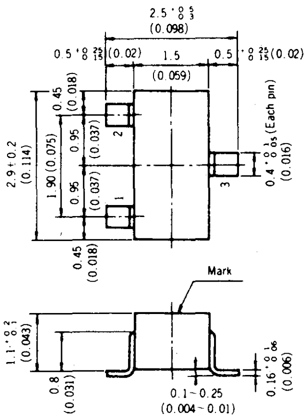
NORMALIZED h PARAMETER vs.
COLLECTOR TO EMITTER VOLTAGE



2SA812, 2SA812R

Audio Frequency, General Purpose Amplifier
PNP Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



2SA812	2SA812R
1. Emitter	1. Base
2. Base	2. Emitter
3. Collector	3. Collector

- Complementary to 2SC1623.
- High DC Current Gain: h_{FE}=200 TYP. (V_{CE}=–6.0V, I_C=–1.0mA)
- High Voltage: V_{CEO}=–50V

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta=25°C)			
Collector to Base Voltage	V_{CBO}	–60	V
Collector to Emitter Voltage	V_{CEO}	–50	V
Emitter to Base Voltage	V_{EBO}	–5.0	V
Collector Current (DC)	I_C	–100	mA
Maximum Power Dissipation			
Total Power Dissipation at 25°C Ambient Temperature	P_T	150	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature Range	T_{stg}	–55 to +125	°C

5

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			–0.1	μA	V_{CB}=–60V, I_E=0
Emitter Cutoff Current	I_{EBO}			–0.1	μA	V_{EB}=–5.0V, I_C=0
DC Current Gain	h_{FE}	60	200	600		V_{CE}=–6.0V, I_C=–1.0mA*
Collector Saturation Voltage	$V_{CE(sat)}$		–0.18	–0.3	V	I_C=–100mA, I_B=–10mA
Base-Emitter Voltage	V_{BE}	–0.55	–0.62	–0.65	V	V_{CE}=–6.0V, I_C=–1.0mA
Gain Bandwidth Product	f_T		180		MHz	V_{CE}=–6.0V, I_E=10mA
Output Capacitance	C_{ob}		4.2		pF	V_{CB}=–10V, I_E=0, f=1.0MHz

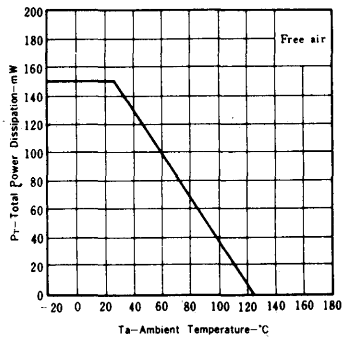
* Pulsed: PW ≦ 350μs, duty cycle ≦ 2%

h_{FE} Classification

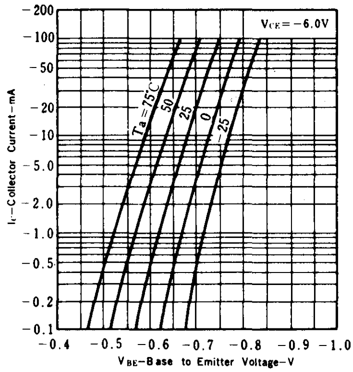
MARK						
MARK	2SA812	M3	M4	M5	M6	M7
	2SA812R	3M	4M	5M	6M	7M
h_{FE}		60 – 120	90 – 180	135 – 270	200 – 400	300 – 600

TYPICAL CHARACTERISTICS (Ta = 25°C)

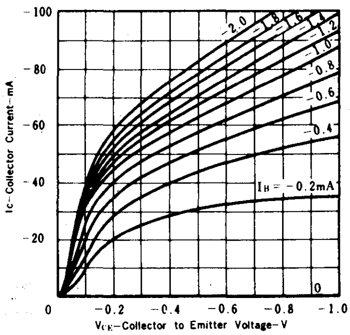
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



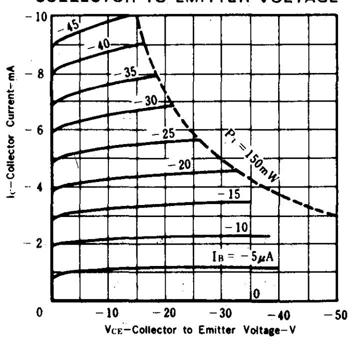
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



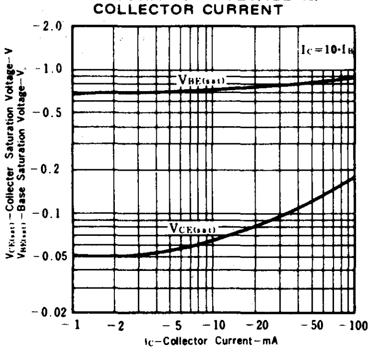
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



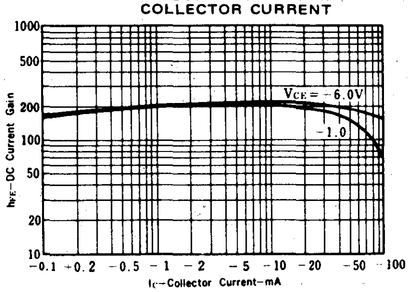
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



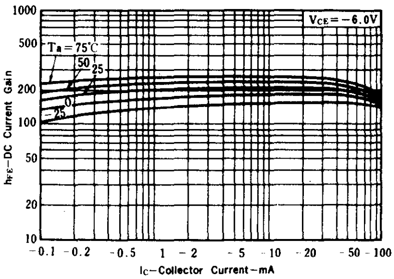
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



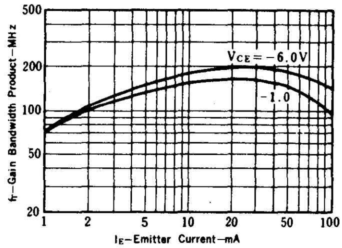
DC CURRENT GAIN vs. COLLECTOR CURRENT



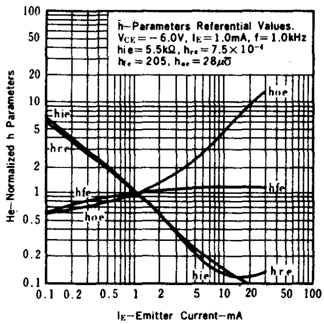
DC CURRENT GAIN vs.
COLLECTOR CURRENT



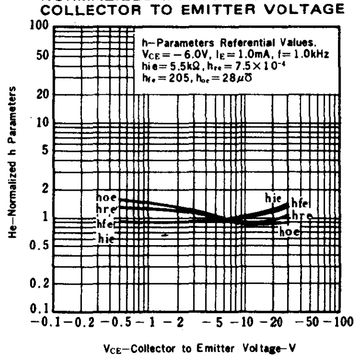
GAIN BANDWIDTH PRODUCT vs.
EMITTER CURRENT



NORMALIZED h PARAMETER vs.
EMITTER CURRENT



NORMALIZED h PARAMETER vs.
COLLECTOR TO EMITTER VOLTAGE

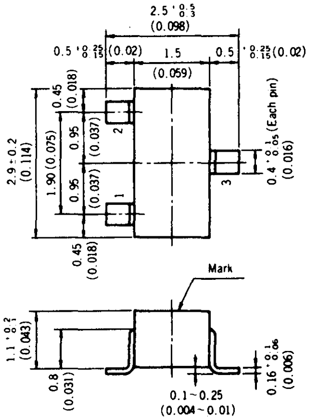


5

2SA956

General Purpose Amplifier and Switches
PNP Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Base
3. Collector

- Complementary to 2SC2107.
- Keeps stabilized operation against power voltage fluctuation:
  $V_{CEO} > -40V, V_{EBO} > -8.0V$
- High DC Current Gain and excellent linearity:
  h_{FE}=160 TYP. (V_{CE}=−1.0V, I_C=−10mA)

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta = 25°C)			
Collector to Base Voltage ($R_{BE}=\infty$)	V_{CBO}	−60	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	−40	V
Emitter to Base Voltage	V_{EBO}	−8.0	V
Collector Current (DC)	I_C	−100	mA
Maximum Power Dissipation			
Total Power Dissipation			
at 25°C Ambient Temperature	P_T	150	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature Range	T_{stg}	−55 to +125	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

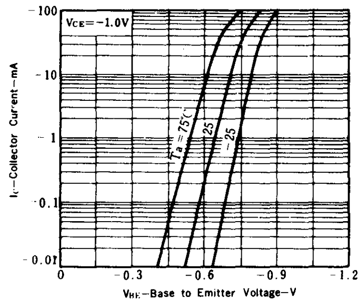
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−0.1	μA	V_{CB}=−40V, I_E=0
Emitter Cutoff Current	I_{EBO}			−0.1	μA	V_{EB}=−5.0V, I_C=0
DC Current Gain	h_{FE1}	50	155			V_{CE}=−1.0V, I_C=−1.0mA
DC Current Gain	h_{FE2}	80	160	320		V_{CE}=−1.0V, I_C=−10mA
Collector Saturation Voltage	$V_{CE(sat)}$		−0.06	−0.3	V	I_C=−10mA, I_B=−1.0mA
Base Saturation Voltage	$V_{BE(sat)}$		−0.75	−1.0	V	I_C=−10mA, I_B=−1.0mA
Gain Bandwidth Product	f_T		280		MHz	V_{CE}=−10V, I_E=10mA
Output Capasitance	C_{ob}		7.2		pF	V_{CB}=−10V, I_E=0, f=1.0MHz
Turn on Time	t_{on}		100		ns	See test circuit.
Storage Time	t_{stg}		200		ns	
Turn off Time	t_{off}		270		ns	

h_{FE2} Classification

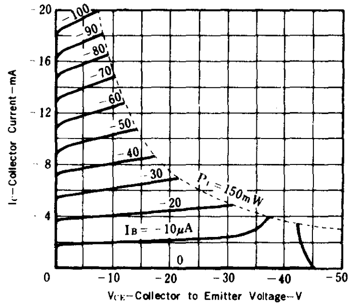
MARK	H3	H4	H5	H6
h_{FE2}	80 – 130	110 – 170	150 – 240	200 – 320

TYPICAL CHARACTERISTICS (Ta = 25°C)

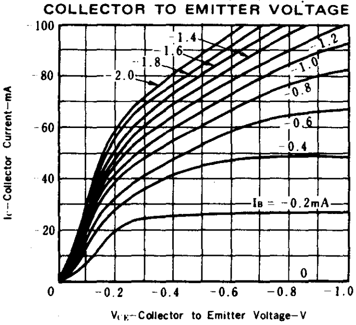
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



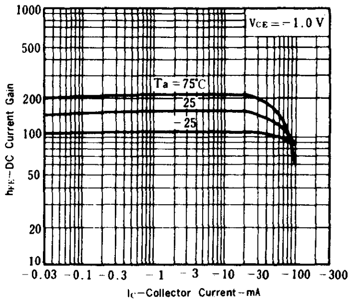
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



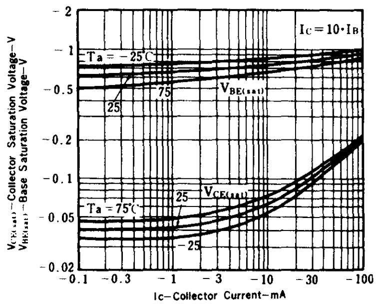
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



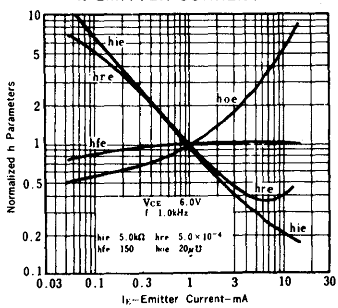
DC CURRENT GAIN vs. COLLECTOR CURRENT



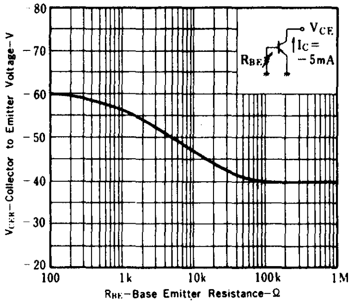
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



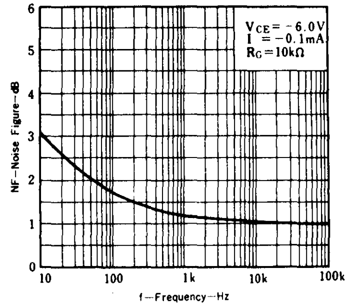
NORMALIZED h PARAMETER vs. EMITTER CURRENT



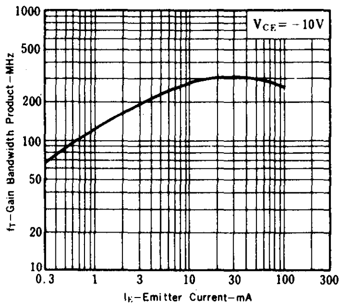
COLLECTOR TO EMITTER VOLTAGE vs. BASE EMITTER RESISTANCE



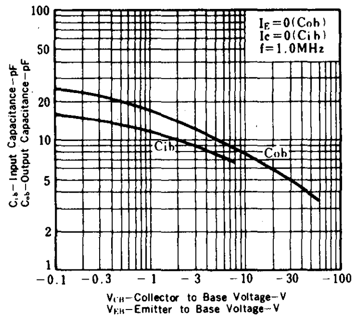
NOISE FIGURE vs. FREQUENCY



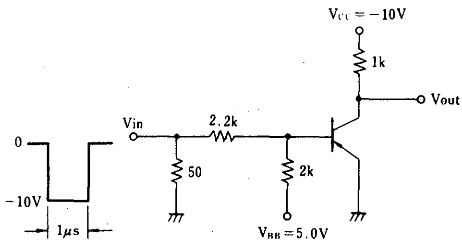
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



SWITCHING TIME TEST CIRCUIT



NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SA1173

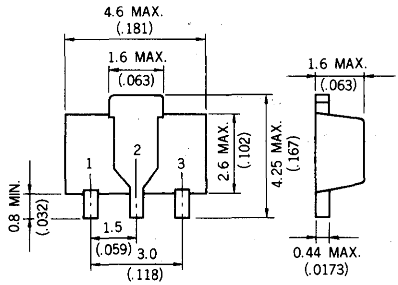
PNP SILICON EPITAXIAL TRANSISTOR
POWER MINI MOLD

DESCRIPTION

The 2SA1173 is designed for audio frequency preamplifier application, especially in Hybrid Integrated Circuits.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Emitter
2. Collector
3. Base

FEATURES

- World Standard Miniature Package : SOT−89
- High Collector to Emitter Voltage : $V_{CEO} > -140$ V
- Complements to NPN type 2SC2780

ABSOLUTE MAXIMUM RATINGS ($T_a = 25$ °C)

Maximum Voltages and Currents			
Collector to Base Voltage	V_{CBO}	−140	V
Collector to Emitter Voltage	V_{CEO}	−140	V
Emitter to Base Voltage	V_{EBO}	−5.0	V
Collector Current (DC)	I_C	−50	mA
Collector Current (Pulse)*	I_C	−100	mA
Maximum Power Dissipation			
Total Power Dissipation at 25 °C Ambient Temperature**	P_T	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

*PW ≦ 10 ms, duty cycle ≦ 50 %

**When mounted on ceramic substrate of 2.5 cm² x 0.7 mm

5

ELECTRICAL CHARACTERISTICS ($T_a = 25$ °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−100	nA	V_{CB} = −140 V, I_E = 0
Emitter Cutoff Current	I_{EBO}			−100	nA	V_{EB} = −5.0 V, I_C = 0
DC Current Gain	h_{FE1}	50	200			V_{CE} = −10 V, I_C = −1.0 mA ***
DC Current Gain	h_{FE2}	90	200	400.		V_{CE} = −10 V, I_C = −10 mA ***
Collector Saturation Voltage	$V_{CE(sat)}$		−0.18	−0.60	V	I_C = −20 mA, I_B = −2.0 mA ***
Base Saturation Voltage	$V_{BE(sat)}$		−0.79	−1.0	V	I_C = −20 mA, I_B = −2.0 mA ***
Base to Emitter Voltage	V_{BE}	−650	−695	−750	mV	V_{CE} = −10 V, I_C = −10 mA ***
Gain Bandwidth Product	f_T		80		MHz	V_{CE} = −10 V, I_E = 10 mA
Output Capacitance	C_{ob}		2.5		pF	V_{CB} = −10 V, I_E = 0, f = 1.0 MHz

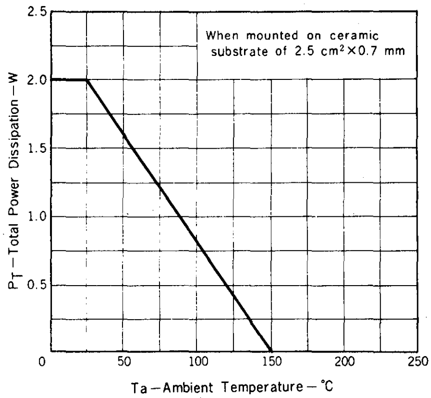
***Pulsed: PW ≦ 350 μs, duty cycle ≦ 2 %

h_{FE} Classification

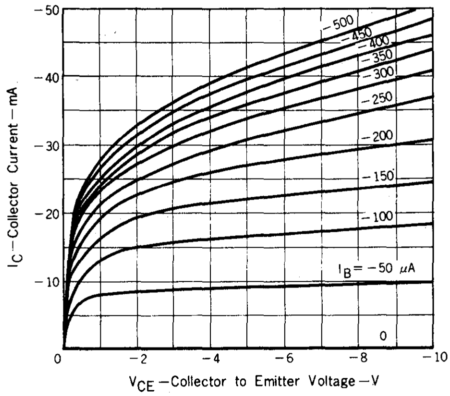
MARKING	PM	PL	PK
h_{FE2}	90 − 180	135 − 270	200 − 400

TYPICAL CHARACTERISTICS (Ta = 25 °C)

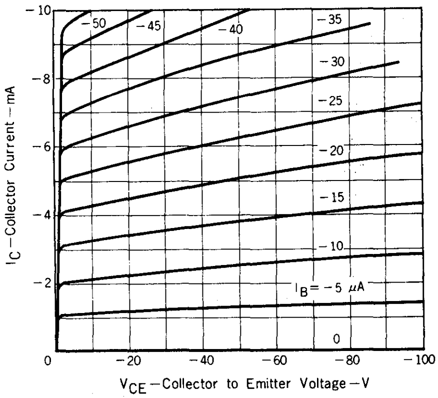
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



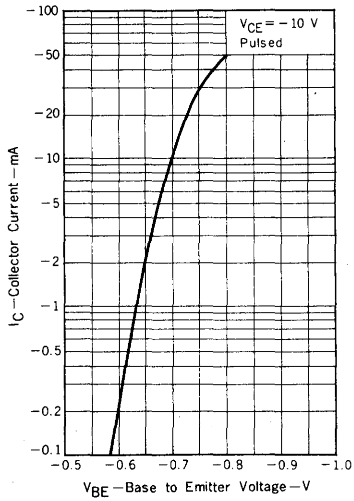
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



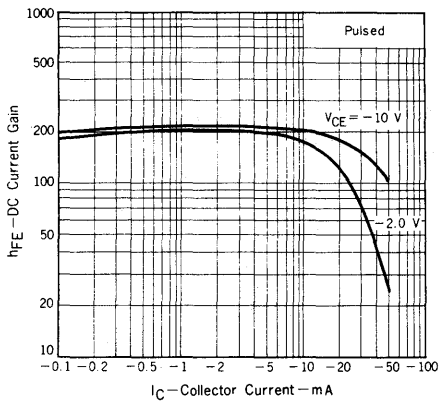
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



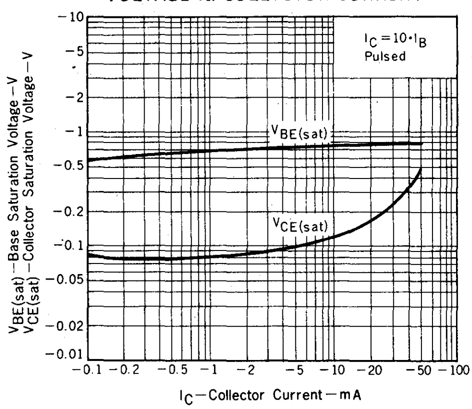
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE

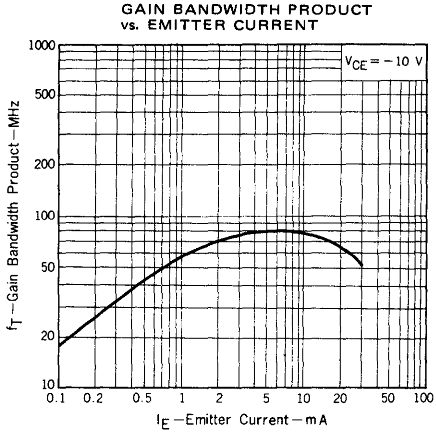


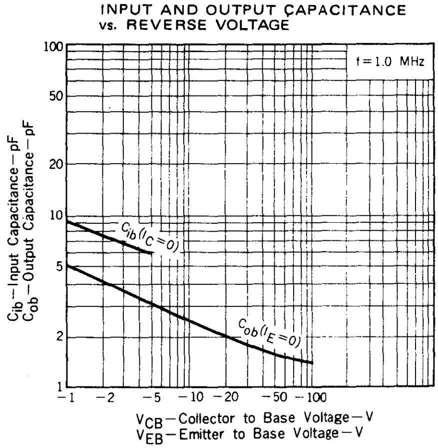
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT




GAIN BANDWIDTH PRODUCT
vs. EMITTER CURRENT
VCE = −10 V
fT − Gain Bandwidth Product − MHz
1000
500
200
100
50
20
10
0.1 0.2 0.5 1 2 5 10 20 50 100
IE − Emitter Current − mA

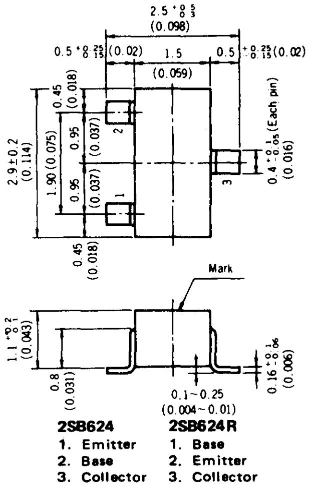

INPUT AND OUTPUT CAPACITANCE
vs. REVERSE VOLTAGE
f = 1.0 MHz
Cib − Input Capacitance − pF
Cob − Output Capacitance − pF
100
50
20
10
5
2
1
Cib (IC = 0)
Cob (IE = 0)
−1 −2 −5 −10 −20 −50 −100
VCB − Collector to Base Voltage − V
VEB − Emitter to Base Voltage − V

5

2SB624,2SB624R

Audio Frequency Power Amplifier
PNP Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



- Complimentary to 2SD596, 2SD596R
- High DC Current Gain: h_{FE} = 200 TYP. (V_{CE} =−1.0V, I_C = −100mA)

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta = 25°C)			
Collector to Base Voltage	V_{CBO}	−30	V
Collector to Emitter Voltage	V_{CEO}	−25	V
Emitter to Base Voltage	V_{EBO}	−5.0	V
Collector Current (DC)	I_C	−700	mA
Maximum Power Dissipation			
Total Power Dissipation at 25°C Ambient Temperature	P_T	200	mW
Maximum Temperatures			
Junction Temperature	Tj	150	°C
Storage Temperature Range	T_{stg}	−55 to + 150	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−0.1	μA	V_{CB}=−30V, I_E=0
Emitter Cutoff Current	I_{EBO}			−0.1	μA	V_{EB}=−5.0V, I_C=0
DC Current Gain	h_{FE1}	110	200	400		V_{CE}=−1.0V, I_C=−100mA*
DC Current Gain	h_{FE2}	50				V_{CE}=−1.0V, I_C=−700mA*
Collector Saturation Voltage	$V_{CE(sat)}$		−0.25	−0.6	V	I_C=−700mA, I_B=−70mA*
Base to Emitter Voltage	V_{BE}	−600	−640	−700	mV	V_{CE}=−6.0V, I_C=−10mA*
Gain Bandwidth Product	f_T		160		MHz	V_{CE}=−6.0V, I_E=10mA
Output Capacitance	C_{ob}		17		pF	V_{CB}=−6.0V, I_E=0, f=1.0MHz

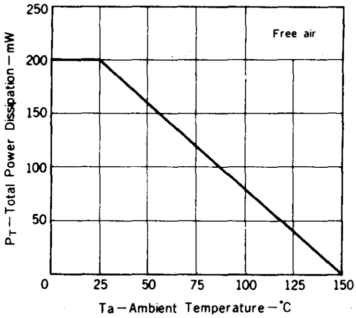
* Pulsed: PW ≦ 350 μs, duty cycle ≦ 2%

h_{FE1} Classification

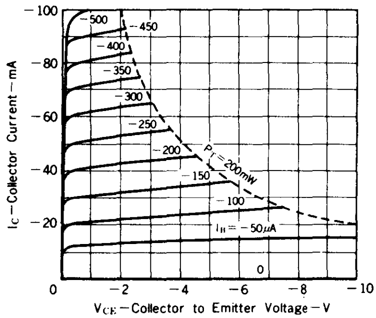
MARK						
MARK	2SB624	BV1	BV2	BV3	BV4	BV5
	2SB624R	1BV	2BV	3BV	4BV	5BV
h_{FE1}		110–180	135–220	170–270	200–320	250–400

TYPICAL CHARACTERISTICS (Ta = 25°C)

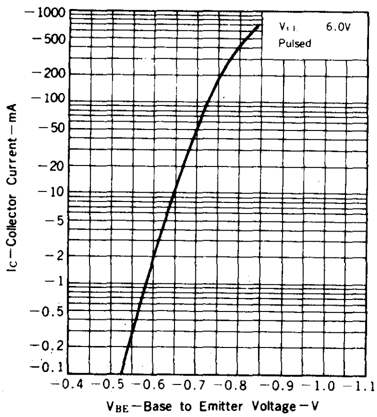
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



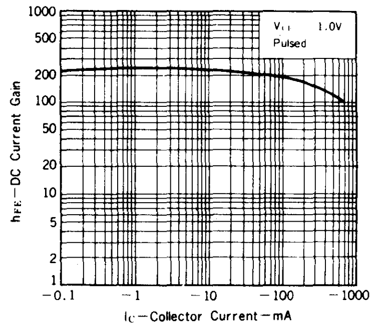
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



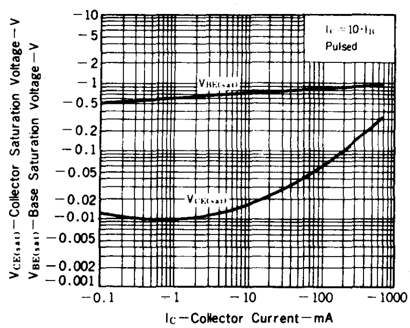
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

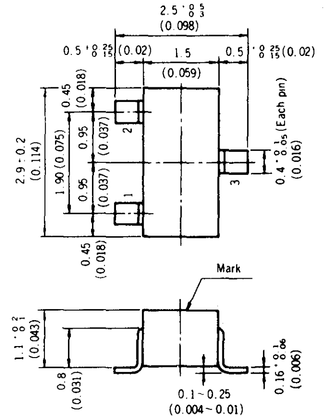


5

2SB736,2SB736R

Audio Frequency Power Amplifier
PNP Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



2SB736	**2SB736R**
1. Emitter	1. Base
2. Base	2. Emitter
3. Collector	3. Collector

- Complimentary to 2SD780, 2SD780R
- High DC current gain: h_{FE} = 200 TYP. (V_{CE} = –1.0V, I_C = –50mA)

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta = 25°C)			
Collector to Base Voltage	V_{CBO}	–60	V
Collector to Emitter Voltage	V_{CEO}	–60	V
Emitter to Base Voltage	V_{EBO}	–5.0	V
Collector Current (DC)	I_C	–300	mA
Maximum Power Dissipation			
Total Power Dissipation			
at 25°C Ambient Temperature	P_T	200	mW
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	–55 to +150	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			–0.18	μA	V_{CB}=–60V, I_E=0
Emitter Cutoff Current	I_{EBO}			–0.1	μA	V_{EB}=–5.0V, I_C=0
DC Current Gain	h_{FE1}	110	200	400		V_{CE}=–1.0V, I_C=–50mA*
DC Current Gain	h_{FE2}	30				V_{CE}=–2.0V, I_C=–300mA*
Collector Saturation Voltage	$V_{CE(sat)}$		–0.15	–0.6	V	I_C=–300mA, I_B=–30mA*
Base to Emitter Voltage	V_{BE}	–600	–660	–700	mV	V_{CE}=–6.0V, I_C=–10mA*
Gain Bandwidth Product	f_T		100		MHz	V_{CE}=–6.0V, I_E=10mA
Output Capacitance	C_{ob}		13		pF	V_{CB}=–6.0V, I_E=0, f=1.0MHz

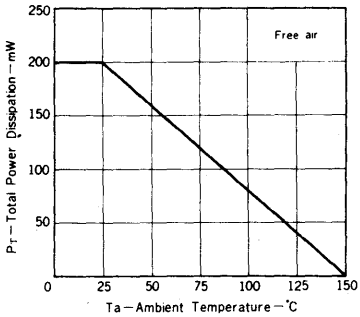
* Pulsed: PW ≦ 350 μs, duty cycle ≦ 2%

h_{FE1} Classification

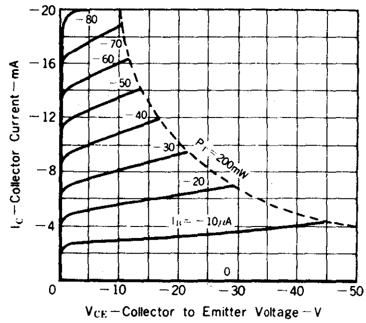
MARK						
MARK	2SB736	BW1	BW2	BW3	BW4	BW5
	2SB736R	1BW	2BW	3BW	4BW	5BW
h_{FE1}		110–180	135–220	170–270	200–320	250–400

TYPICAL CHARACTERISTICS (Ta = 25°C)

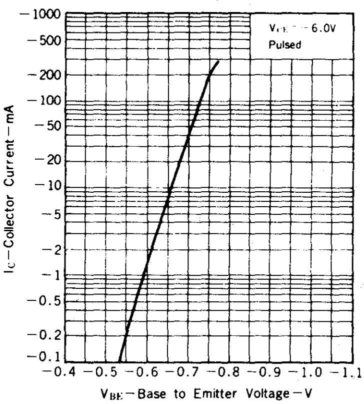
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



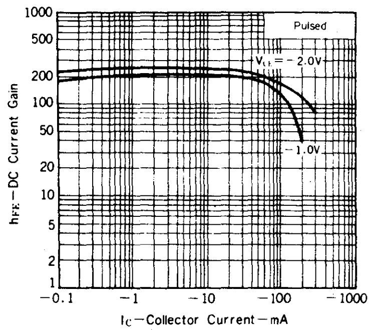
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



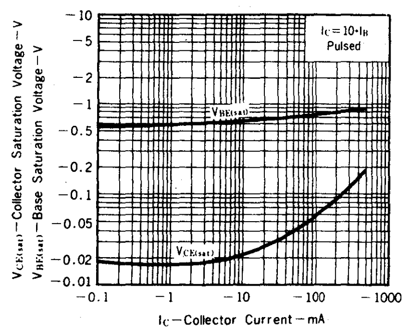
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



5

NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SB798

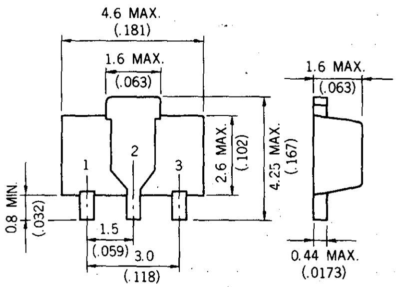
PNP SILICON EPITAXIAL TRANSISTOR
POWER MINI MOLD

DESCRIPTION

The 2SB798 is designed for audio frequency power amplifier application, especially in Hybrid Integrated Circuits.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Emitter
2. Collector
3. Base

FEATURES

- World Standard Miniature Package : SOT−89
- Low Collector Saturation Voltage : $V_{CE(sat)} < -0.4$ V ($I_C = -1.0$ A, $I_B = -100$ mA)
- Excellent DC Current Gain Linearity : $h_{FE} = 100$ TYP. ($V_{CE} = -1.0$ V, $I_C = -1.0$ A)
- Complements to NPN type 2SD999

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Voltages and Currents			
Collector to Base Voltage	V_{CBO}	−30	V
Collector to Emitter Voltage	V_{CEO}	−25	V
Emitter to Base Voltage	V_{EBO}	−5.0	V
Collector Current (DC)	I_C	−1.0	A
Collector Current (Pulse)*	I_C	−1.5	A
Maximum Power Dissipation			
Total Power Dissipation at 25 °C Ambient Temperature**	P_T	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

*PW ≦ 10 ms, duty cycle ≦ 50 %
**When mounted on ceramic substrate of 2.5 cm^2 x 0.7 mm

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−100	nA	V_{CB}=−30 V, I_E=0
Emitter Cutoff Current	I_{EBO}			−100	nA	V_{EB}=−5.0 V, I_C=0
DC Current Gain	h_{FE1}	90	200	400		V_{CE}=−1.0 V, I_C=−100 mA ***
DC Current Gain	h_{FE2}	50	100			V_{CE}=−1.0 V, I_C=−1.0 A ***
Collector Saturation Voltage	$V_{CE(sat)}$		−0.25	−0.40	V	I_C=−1.0 A, I_B=−0.10 A ***
Base Saturation Voltage	$V_{BE(sat)}$		−1.0	−1.2	V	I_C=−1.0 A, I_B=−0.10 A ***
Base to Emitter Voltage	V_{BE}	−600	−640	−700	mV	V_{CE}=−6.0 V, I_C=−10 mA ***
Gain Bandwidth Product	f_T		110		MHz	V_{CE}=−6.0 V, I_E=10 mA
Output Capacitance	C_{ob}		36		pF	V_{CB}=−6.0 V, I_E=0, f=1.0 MHz

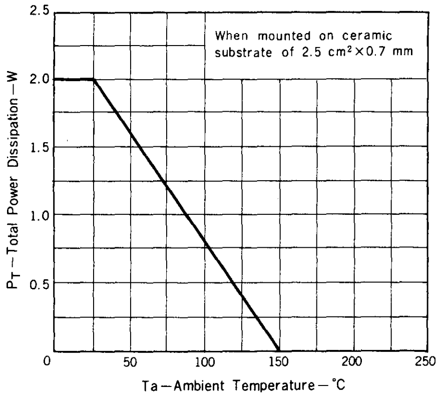
***Pulsed: PW ≦ 350 μs, duty cycle ≦ 2 %

h_{FE} Classification

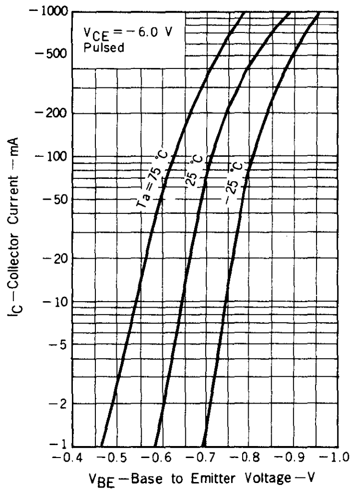
MARKING	DM	DL	DK
h_{FE1}	90 – 180	135 – 270	200 – 400

TYPICAL CHARACTERISTICS (Ta = 25 °C)

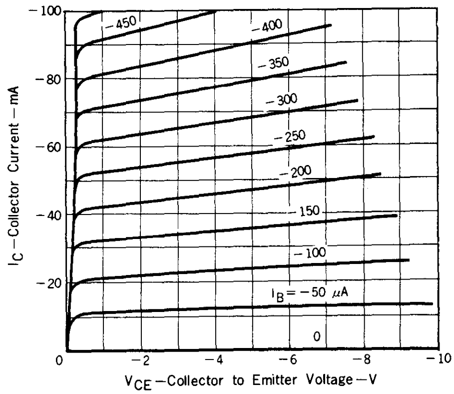
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



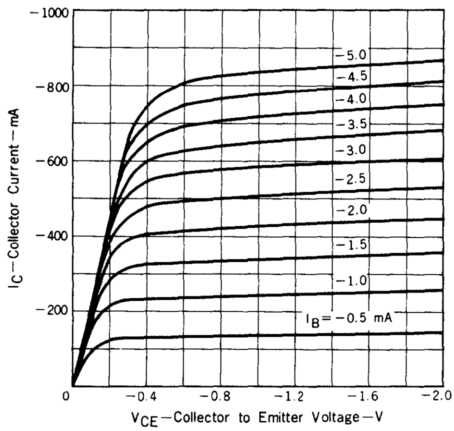
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



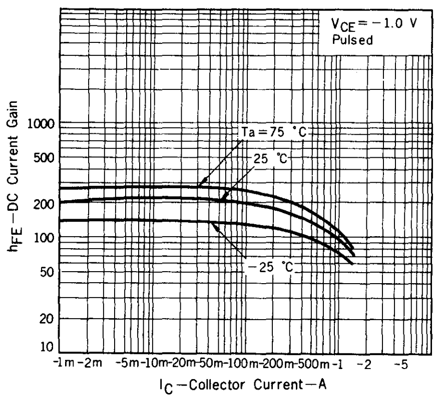
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



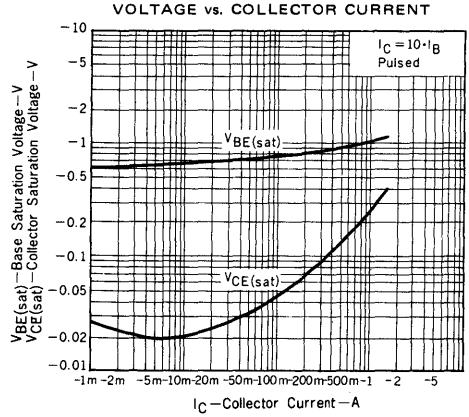
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT

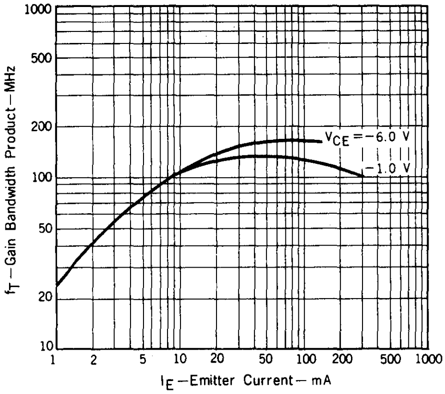


BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

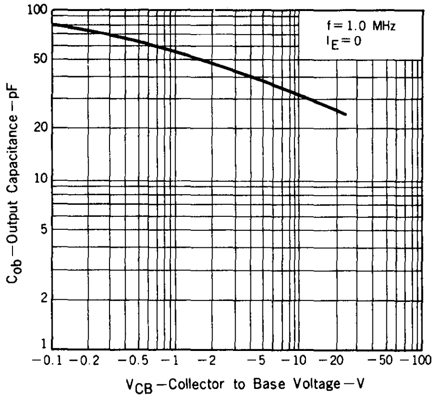


5

GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SB799

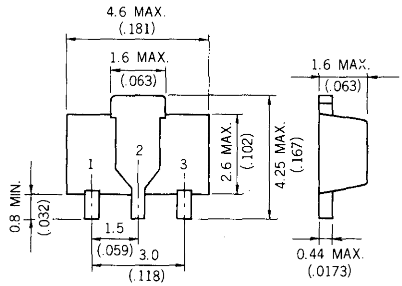
PNP SILICON EPITAXIAL TRANSISTOR
POWER MINI MOLD

DESCRIPTION

The 2SB799 is designed for audio frequency power amplifier application, especially in Hybrid Integrated Circuits.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Emitter
2. Collector
3. Base

FEATURES

- World Standard Miniature Package : SOT−89
- Low Collector Saturation Voltage : $V_{CE(sat)} < -0.4$ V ($I_C = -500$ mA, $I_B = -50$ mA)
- Complements to NPN type 2SD1000

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Voltages and Currents			
Collector to Base Voltage	V_{CBO}	−60	V
Collector to Emitter Voltage	V_{CEO}	−50	V
Emitter to Base Voltage	V_{EBO}	−5.0	V
Collector Current (DC)	I_C	−0.7	A
Collector Current (Pulse)*	I_C	−1.0	A
Maximum Power Dissipation			
Total Power Dissipation at 25 °C Ambient Temperature**	P_T	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

*PW ≦ 10 ms, duty cycle ≦ 50 %
**When mounted on ceramic substrate of 2.5 cm² x 0.7 mm

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−100	nA	V_{CB}=−60 V, I_E=0
Emitter Cutoff Current	I_{EBO}			−100	nA	V_{EB}=−5.0 V, I_C=0
DC Current Gain	h_{FE1}	90	200	400		V_{CE}=−1.0 V, I_C=−100 mA ***
DC Current Gain	h_{FE2}	50	120			V_{CE}=−1.0 V, I_C=−500 mA ***
Collector Saturation Voltage	$V_{CE(sat)}$		−0.16	−0.40	V	I_C=−500 mA, I_B=−50 mA ***
Base Saturation Voltage	$V_{BE(sat)}$		−0.9	−1.2	V	I_C=−500 mA, I_B=−50 mA ***
Base to Emitter Voltage	V_{BE}	−600	−630	−700	mV	V_{CE}=−6.0 V, I_C=−10 mA ***
Gain Bandwidth Product	f_T		120		MHz	V_{CE}=−6.0 V, I_E=10 mA
Output Capacitance	C_{ob}		25		pF	V_{CB}=−6.0 V, I_E=0, f=1.0 MHz

***Pulsed: PW ≦ 350 μs, duty cycle ≦ 2 %

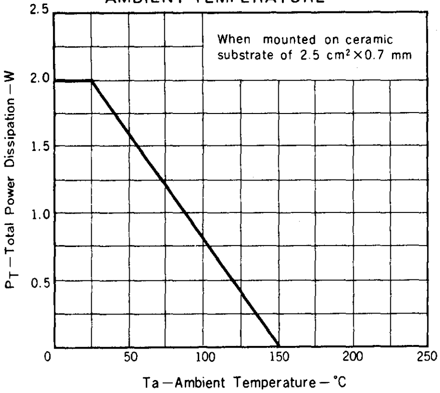
h_{FE} Classification

MARKING	MM	ML	MK
h_{FE1}	90 − 180	135 − 270	200 − 400

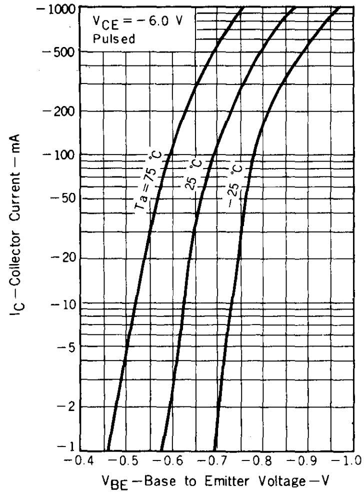
5

TYPICAL CHARACTERISTICS (Ta = 25 °C)

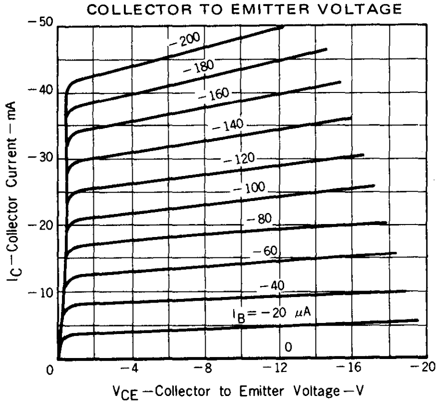
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



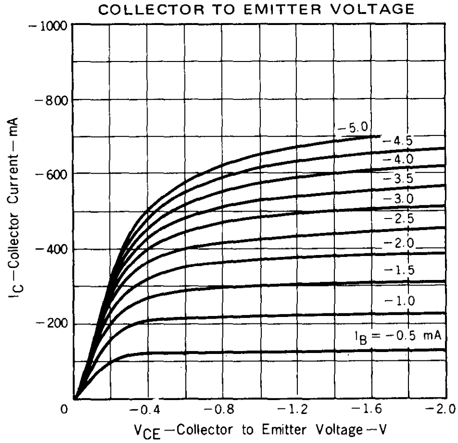
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



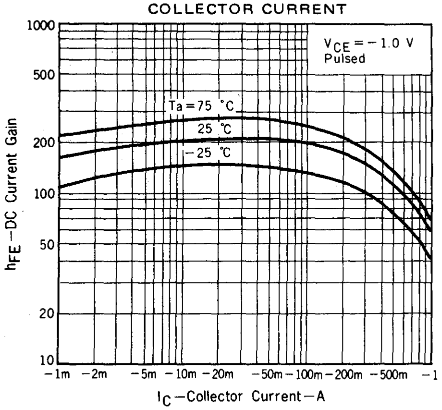
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



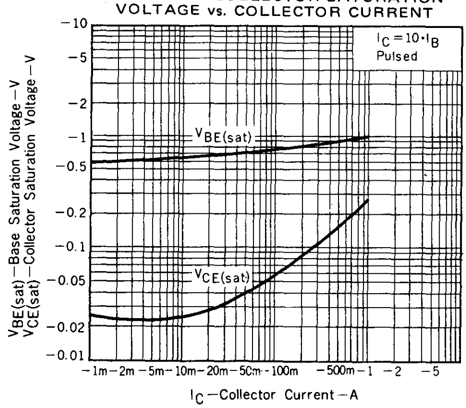
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

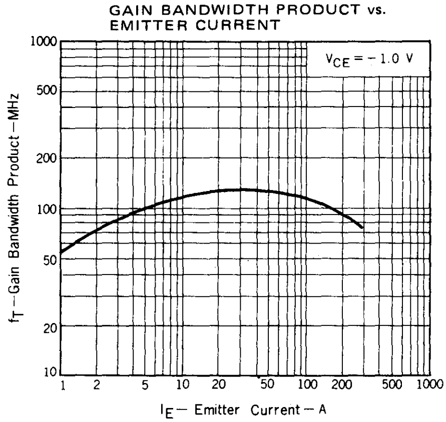


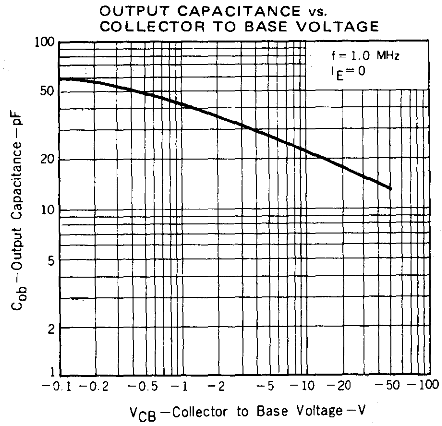
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT




GAIN BANDWIDTH PRODUCT vs.
EMITTER CURRENT
VCE = − 1.0 V
fT − Gain Bandwidth Product − MHz
1000
500
200
100
50
20
10
1 2 5 10 20 50 100 200 500 1000
IE − Emitter Current − A


OUTPUT CAPACITANCE vs.
COLLECTOR TO BASE VOLTAGE
f = 1.0 MHz
IE = 0
Cob − Output Capacitance − pF
100
50
20
10
5
2
1
−0.1 −0.2 −0.5 −1 −2 −5 −10 −20 −50 −100
VCB − Collector to Base Voltage − V

5

NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SB800

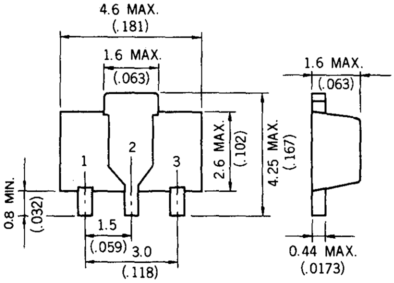
PNP SILICON EPITAXIAL TRANSISTOR
POWER MINI MOLD

DESCRIPTION

The 2SB800 is designed for audio frequency power amplifier application, especially in Hybrid Integrated Circuits.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Emitter
2. Collector
3. Base

FEATURES

- World Standard Miniature Package
  : SOT−89
- High Collector to Emitter Voltage
  : $V_{CEO} > -80$ V
- Complements to NPN type 2SD1001

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Voltages and Currents			
Collector to Base Voltage	V_{CBO}	−80	V
Collector to Emitter Voltage	V_{CEO}	−80	V
Emitter to Base Voltage	V_{EBO}	−5.0	V
Collector Current (DC)	I_C	−300	mA
Collector Current (Pulse)*	I_C	−500	mA
Maximum Power Dissipation			
Total Power Dissipation at 25 °C Ambient Temperature**	P_T	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

*PW ≦ 10 ms, duty cycle ≦ 50 %
**When mounted on ceramic substrate of 2.5 cm² × 0.7 mm

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−100	nA	V_{CB}=−80 V, I_E=0
Emitter Cutoff Current	I_{EBO}			−100	nA	V_{EB}=−5.0 V, I_C=0
DC Current Gain	h_{FE1}	90	200	400		V_{CE}=−1.0 V, I_C=−50 mA ***
DC Current Gain	h_{FE2}	30	80			V_{CE}=−2.0 V, I_C=−300 mA ***
Collector Saturation Voltage	$V_{CE(sat)}$		−0.3	−0.60	V	I_C=−300 mA, I_B=−30 mA ***
Base Saturation Voltage	$V_{BE(sat)}$		−0.9	−1.2	V	I_C=−300 mA, I_B=−30 mA ***
Base to Emitter Voltage	V_{BE}	−600	−660	−700	mV	V_{CE}=−6.0 V, I_C=−10 mA ***
Gain Bandwidth Product	f_T		100		MHz	V_{CE}=−6.0 V, I_E=10 mA
Output Capacitance	C_{ob}		13		pF	V_{CB}=−6.0 V, I_E=0, f=1.0 MHz

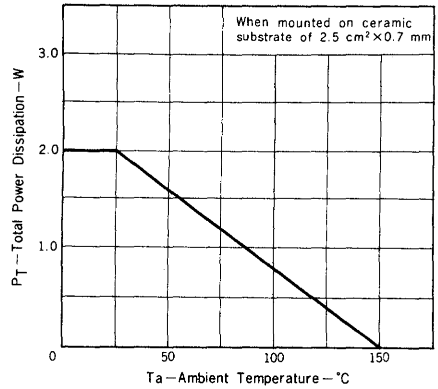
***Pulsed: PW ≦ 350 μs, duty cycle ≦ 2 %

h_{FE} Classification

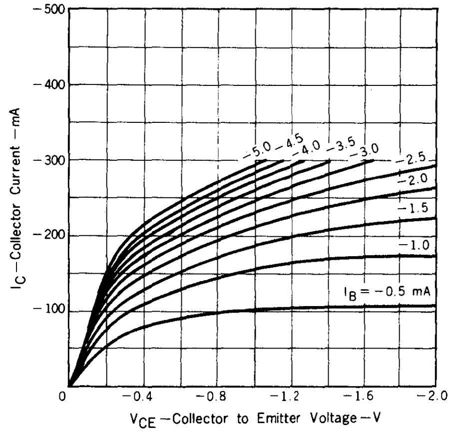
MARKING	FM	FL	FK
h_{FE1}	90 − 180	135 − 270	200 − 400

TYPICAL CHARACTERISTICS (Ta = 25 °C)

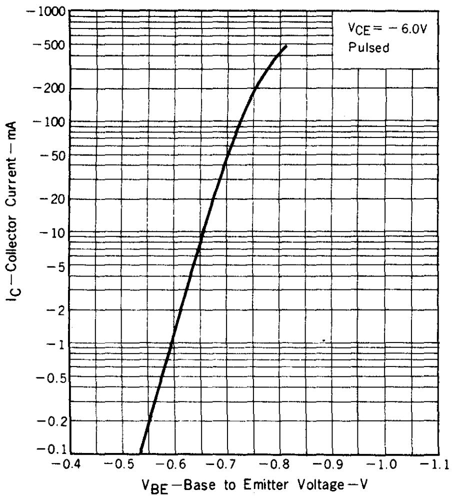
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



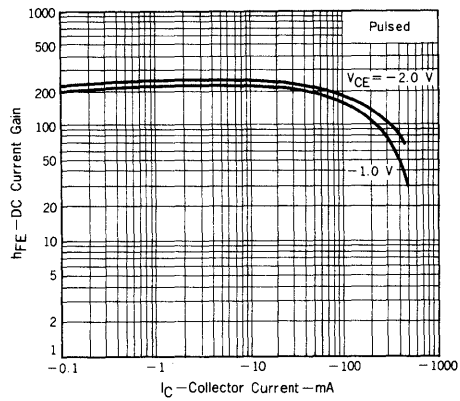
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



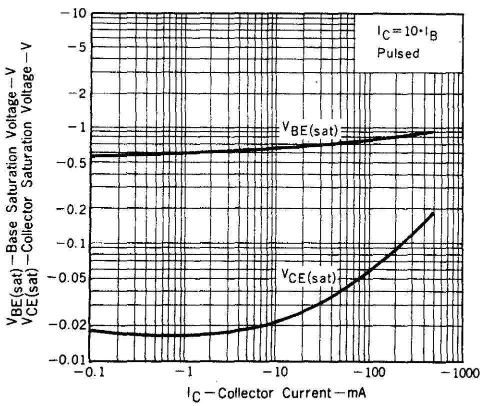
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



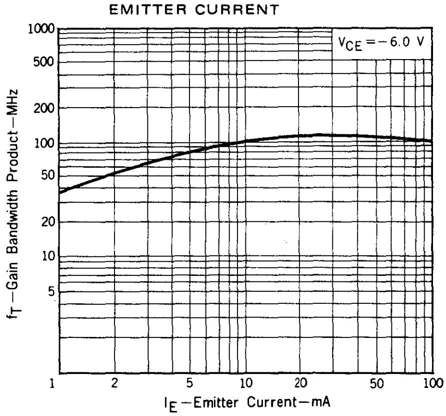
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

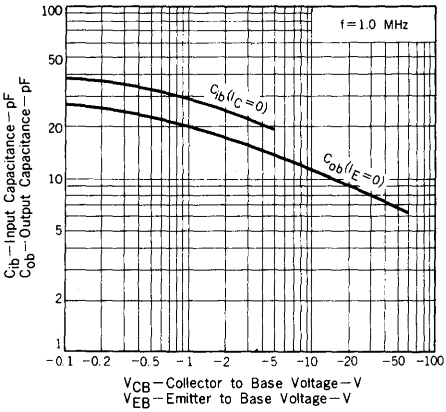


GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



5

INPUT AND OUTPUT CAPACITANCE
vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SB804

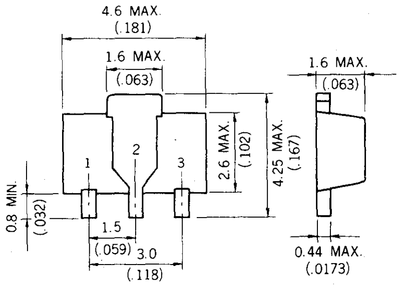
PNP SILICON EPITAXIAL TRANSISTOR
POWER MINI MOLD

DESCRIPTION

The 2SB804 is designed for audio frequency power amplifier application, especially in Hybrid Integrated Circuits.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Emitter
2. Collector
3. Base

FEATURES

- World Standard Miniature Package
  : SOT−89
- High Collector to Base Voltage
  : $V_{CBO} > -100$ V
- Excellent DC Current Gain Linearity
  : $h_{FE} = 80$ TYP. ($V_{CE} = -2.0$ V, $I_C = -500$ mA)
- Complements to NPN type 2SD1005

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Voltages and Currents			
Collector to Base Voltage	V_{CBO}	−100	V
Collector to Emitter Voltage	V_{CEO}	−80	V
Emitter to Base Voltage	V_{EBO}	−5.0	V
Collector Current (DC)	I_C	−1.0	A
Collector Current (Pulse)*	I_C	−1.5	A
Maximum Power Dissipation			
Total Power Dissipation at 25 °C Ambient Temperature**	P_T	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

*PW ≦ 10 ms, duty cycle ≦ 50 %
**When mounted on ceramic substrate of 2.5 cm² x 0.7 mm

5

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			−100	nA	$V_{CB} = -100$ V, $I_E = 0$
Emitter Cutoff Current	I_{EBO}			−100	nA	$V_{EB} = -5.0$ V, $I_C = 0$
DC Current Gain	h_{FE1}	90	200	400		$V_{CE} = -2.0$ V, $I_C = -100$ mA ***
DC Current Gain	h_{FE2}	25	80			$V_{CE} = -2.0$ V, $I_C = -500$ mA ***
Collector Saturation Voltage	$V_{CE(sat)}$		−0.29	−0.50	V	$I_C = -500$ mA, $I_B = -50$ mA ***
Base Saturation Voltage	$V_{BE(sat)}$		−0.9	−1.5	V	$I_C = -500$ mA, $I_B = -50$ mA ***
Base to Emitter Voltage	V_{BE}	−600	−640	−700	mV	$V_{CE} = -10$ V, $I_C = -10$ mA ***
Gain Bandwidth Product	f_T		80		MHz	$V_{CE} = -5.0$ V, $I_E = 10$ mA
Output Capacitance	C_{ob}		26		pF	$V_{CB} = -10$ V, $I_E = 0$, f = 1.0 MHz

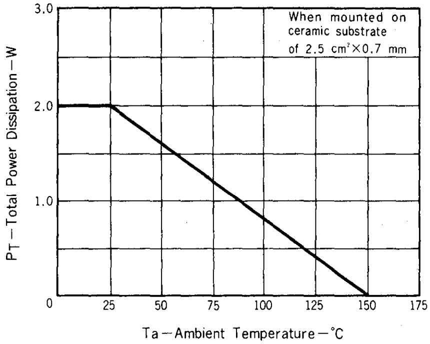
***Pulsed: PW ≦ 350 μs, duty cycle ≦ 2 %

h_{FE} Classification

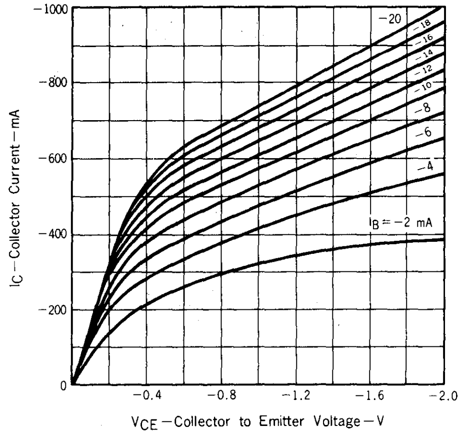
MARKING	AW	AV	AU
h_{FE1}	90 − 180	135 − 270	200 − 400

TYPICAL CHARACTERISTICS (Ta = 25 °C)

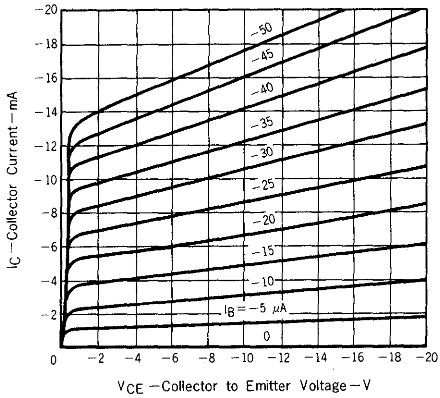
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



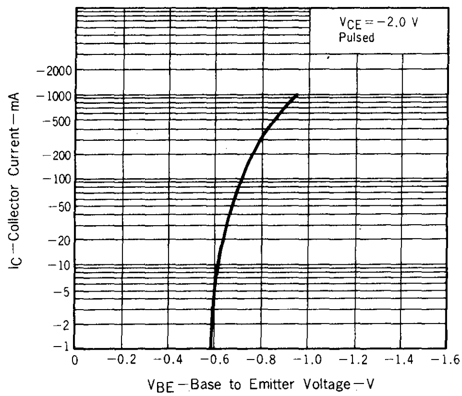
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



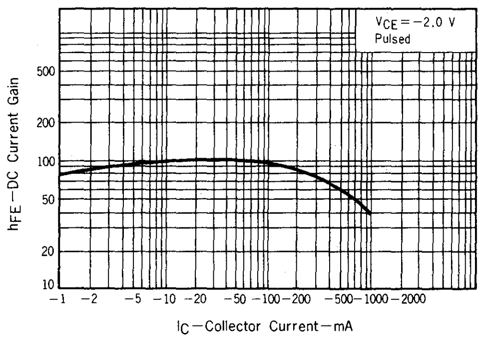
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



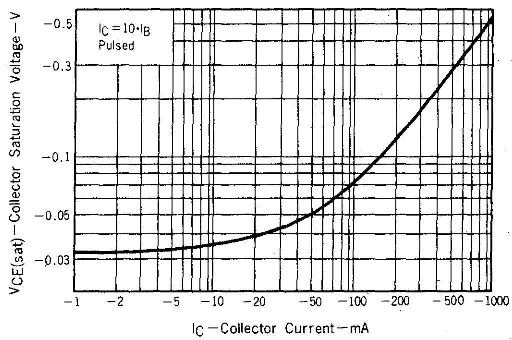
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



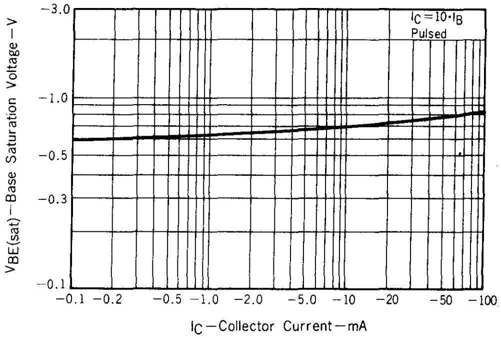
DC CURRENT GAIN vs.
COLLECTOR CURRENT



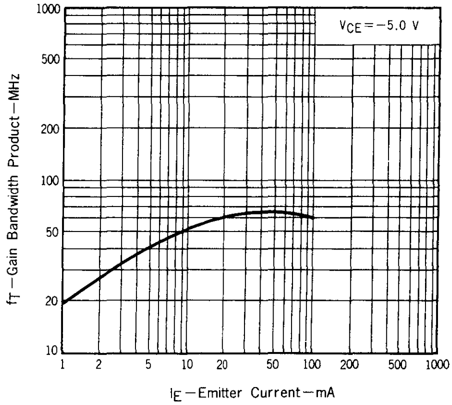
COLLECTOR SATURATION VOLTAGE vs.
COLLECTOR CURRENT



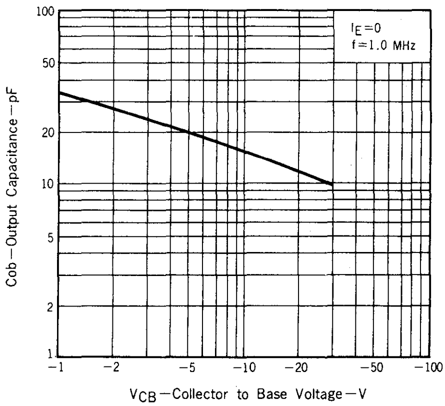
BASE SATURATION VOLTAGE vs.
COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs.
EMITTER CURRENT



OUTPUT CAPACITANCE vs.
REVERSE VOLTAGE



5

NEC
ELECTRON DEVICE

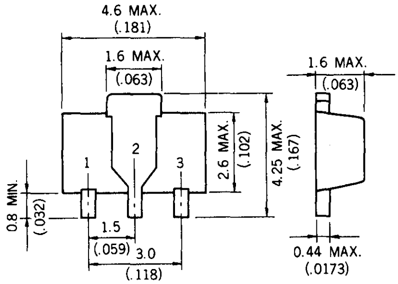
SILICON TRANSISTORS
2SB805,2SB806

PNP SILICON EPITAXIAL TRANSISTORS
POWER MINI MOLD

DESCRIPTION

The 2SB805 and 2SB806 are designed for audio frequency power amplifier application, especially in Hybrid Integrated Circuits.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Collector
3. Base

FEATURES

- World Standard Miniature Package : SOT−89
- High Collector to Emitter Voltage : V_{CEO} >−120 V (2SB806),
  : V_{CEO} >−100 V (2SB805)
- Complement to NPN type 2SD1006 and 2SD1007 respectively

ABSOLUTE MAXIMUM RATINGS (Ta=25 °C)

		2SB805	2SB806	
Maximum Voltages and Currents				
Collector to Base Voltage	V_{CBO}	−100	−120	V
Collector to Emitter Voltage	V_{CEO}	−100	−120	V
Emitter to Base Voltage	V_{EBO}	−5.0		V
Collector Current (DC)	I_C	−0.7		A
Collector Current (Pulse)*	I_C	−1.2		A
Maximum Power Dissipation				
Total Power Dissipation at 25 °C Ambient Temperature**	P_T	2.0		W
Maximum Temperatures				
Junction Temperature	T_j	150		°C
Storage Temperature Range	T_{stg}	−55 to +150		°C

*PW ≦10 ms, duty cycle ≦50 %
**When mounted on ceramic substrate of 2.5 cm^2 x 0.7 mm

ELECTRICAL CHARACTERISTICS (Ta=25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS	
Collector Cutoff Current	I_{CBO}			−100	nA	2SB805	V_{CB}=−100 V, I_E=0
				−100	nA	2SB806	V_{CB}=−120 V, I_E=0
Emitter Cutoff Current	I_{EBO}			−100	nA	V_{EB}=−5.0 V, I_C=0	
DC Current Gain	h_{FE1}	45	200			V_{CE}=−1.0 V, I_C=−5.0 mA ***	
DC Current Gain	h_{FE2}	90	200	400		V_{CE}=−1.0 V, I_C=−100 mA ***	
Collector Saturation Voltage	$V_{CE(sat)}$		−0.4	−0.6	V	I_C=−500 mA, I_B=−50 mA ***	
Base Saturation Voltage	$V_{BE(sat)}$		−0.9	−1.5	V	I_C=−500 mA, I_B=−50 mA ***	
Base to Emitter Voltage	V_{BE}	−550	−620	−650	mV	V_{CE}=−10 V, I_C=−10 mA ***	
Gain Bandwidth Product	f_T		75		MHz	V_{CE}=−10 V, I_E=10 mA	
Output Capacitance	C_{ob}		17		pF	V_{CB}=−10 V, I_E=0, f=1.0 MHz	

***Pulsed : PW ≦350 μs, duty cycle ≦2 %

h_{FE} Classification

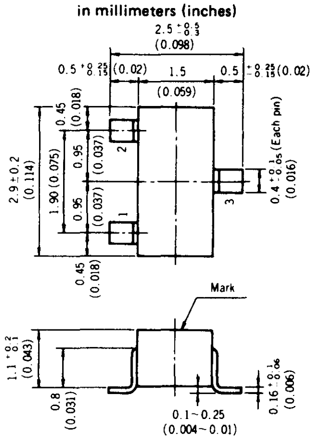
MARKING				
MARKING	2SB805	KM	KL	KK
	2SB806	KR	KQ	KP
h_{FE2}		90 − 180	135 − 270	200 − 400

2SC1009, 2SC1009R

FM/AM RF Amplifier, Mixer, Oscillator, Converter
NPN Silicon Epitaxial Transistor

PACKAGE DIMENSIONS

in millimeters (inches)



2SC1009	**2SC1009R**
1. Emitter	1. Base
2. Base	2. Emitter
3. Collector	3. Collector

- High Gain Bandwidth Product: f_T = 250MHz TYP.
- Low Output Capacitance: C_{ob}=1.8pF TYP.
- Low Noise Figure: NF = 2.5dB TYP.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta=25°C)			
Collector to Base Voltage	V_{CBO}	50	V
Collector to Emitter Voltage	V_{CEO}	25	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current (DC)	I_C	50	mA
Maximum Power Dissipation			
Total Power Dissipation			
at 25°C Ambient Temperature	P_T	150	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature Range	T_{stg}	−55 to +125	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB}=15V, I_E=0
Emitter Cutoff Current	I_{EBO}			0.1	μA	V_{EB}=3.0V, I_C=0
DC Current Gain	h_{FE}	30	100	270		V_{CE}=3.0V, I_C=0.5mA*
Collector Saturation Voltage	$V_{CE(sat)}$		0.1	0.3	V	I_C=10mA, I_B=1.0mA
Gain Bandwidth Product	f_T		250		MHz	V_{CE}=6.0V, I_E=−1.0mA
Output Capacitance	C_{ob}		1.8		pF	V_{CB}=6.0V, I_E=0, f=1.0MHz
Noise Figure	NF		2.5		dB	V_{CE}=6.0V, I_E=−0.5mA f=1.0MHz, R_G=500Ω

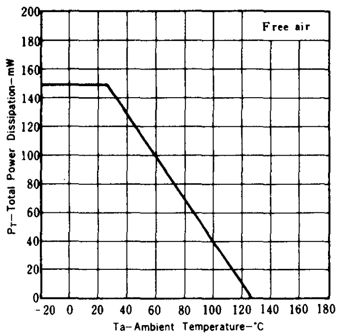
* Pulsed: PW≦ 350μs, duty cycle≦2%

h_{FE} Classification

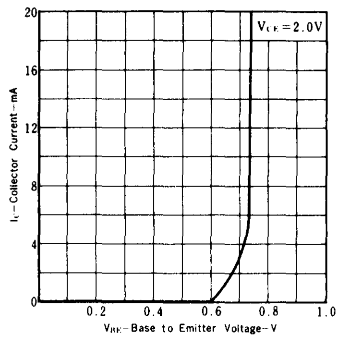
MARK						
MARK	2SC1009	F1	F2	F3	F4	F5
	2SC1009R	1F	2F	3F	4F	5F
h_{FE}		30 – 60	40 – 80	60 – 120	90 – 180	135 – 270

TYPICAL CHARACTERISTICS (Ta = 25°C)

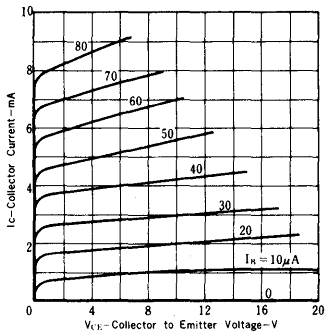
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



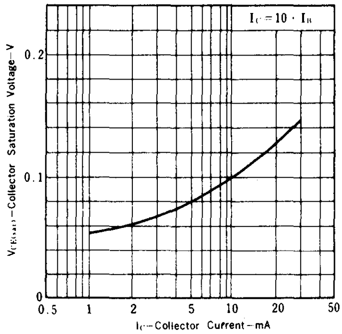
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



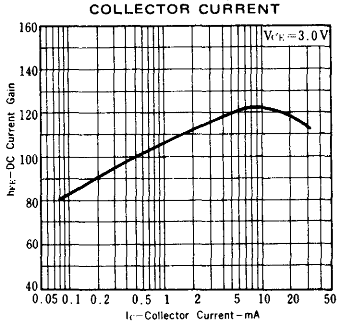
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



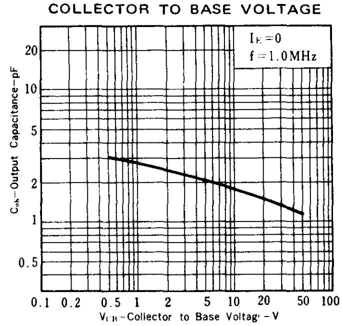
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



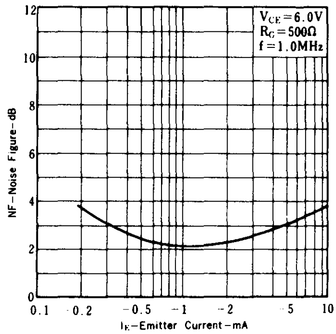
DC CURRENT GAIN vs. COLLECTOR CURRENT



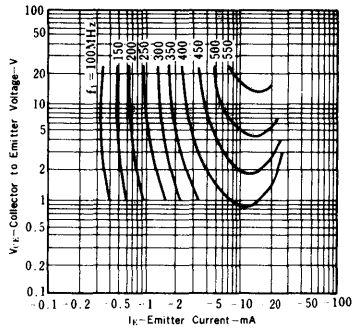
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



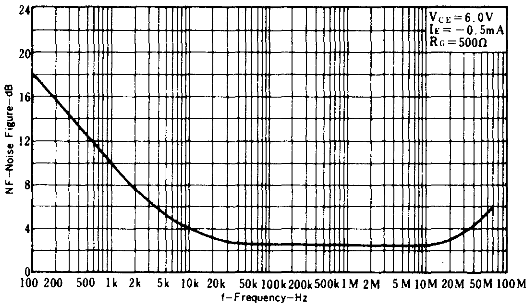
NOISE FIGURE vs. EMITTER CURRENT



GAIN BANDWIDTH PRODUCT MAP.



NOISE FIGURE vs. FREQUENCY

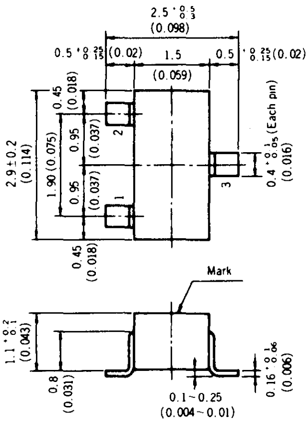


5

2SC1321

UHF Amplifier
NPN Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Base
3. Collector

- Low Noise Figure: NF = 5.0dB TYP. (f=900MHz)
- High Gain Bandwidth Product: f_T = 900MHz TYP.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta = 25°C)			
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	25	V
Emitter to Base Voltage	V_{EBO}	4.0	V
Collector Current (DC)	I_C	10	mA
Maximum Power Dissipation			
Total Power Dissipation			
at 25°C Ambient Temperature	P_T	100	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature Range	T_{stg}	−55 to +125	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB}=25V, I_E=0
Emitter Cutoff Current	I_{EBO}			0.1	μA	V_{EB}=2.0V, I_C=0
DC Current Gain	h_{FE}	40	100	270		V_{CE}=6.0V, I_C=2.0mA*
Collector Saturation Voltage	$V_{CE(sat)}$		0.15	0.6	V	I_C=10mA, I_B=1.0mA
Gain Bandwidth Product	f_T		900		MHz	V_{CE}=6.0V, I_E=−2.0mA
Output Capacitance	C_{ob}		1.3	1.8	pF	V_{CB}=6.0V, I_E=0, f=1.0MHz
Collector to Base Time Constant	$C_c \cdot r_{b'b}$			20	ps	V_{CE}=6.0V, I_E=−2.0mA f=31.9MHz
Noise Figure	NF		5.0		dB	V_{CE}=6.0V, I_E=−2.0mA R_G=50Ω, f=900MHz

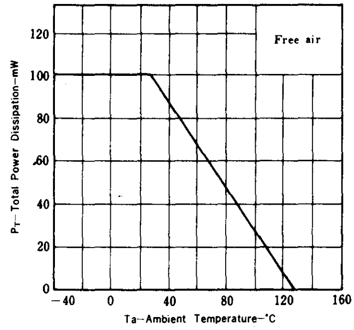
* Pulsed: PW ≦ 350μs, duty cycle ≦ 2%

h_{FE} Classification

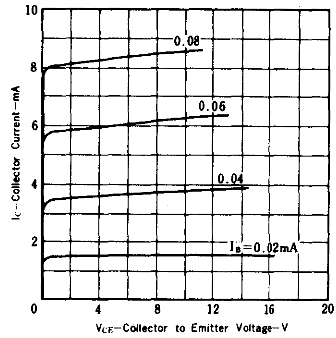
MARK	Q2	Q3	Q4	Q5
h_{FE}	40 – 80	60 – 120	90 – 180	135 – 270

TYPICAL CHARACTERISTICS (Ta = 25°C)

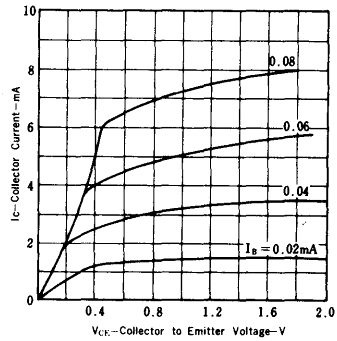
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



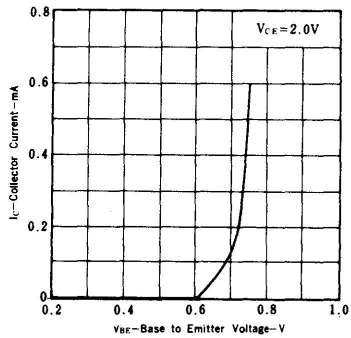
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



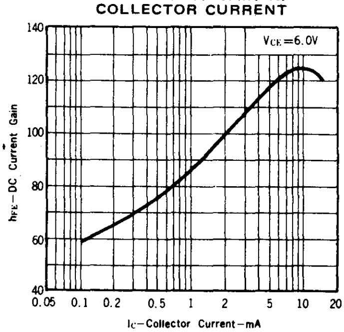
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



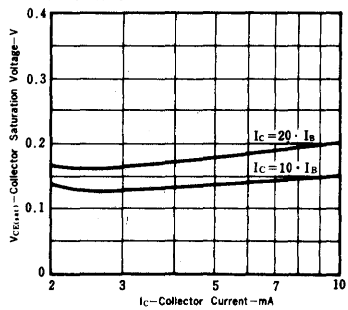
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT

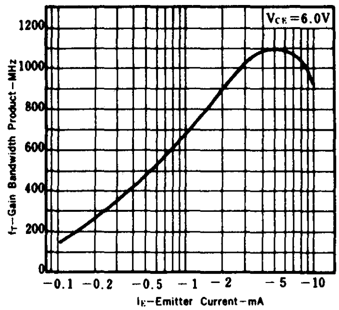


COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

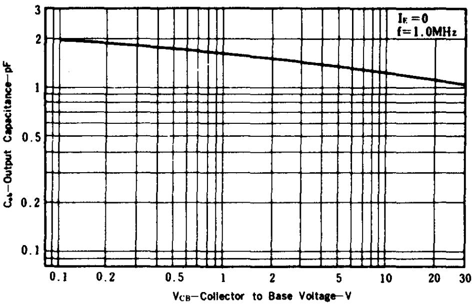


5

GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



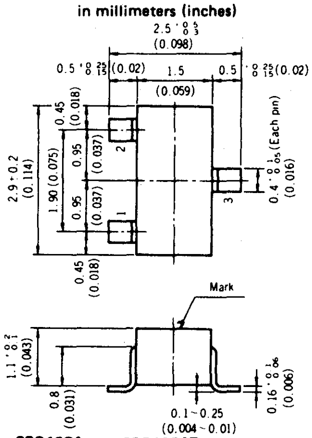
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



2SC1621, 2SC1621R

High Speed Switching
NPN Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



2SC1621
1. Emitter
2. Base
3. Collector

2SC1621R
1. Base
2. Emitter
3. Collector

- High speed switching: t_{on}=12ns TYP., t_{stg}= 7.0ns TYP., t_{off} = 18ns TYP.
- Low collector saturation voltage: $V_{CE(sat)}$ = 0.13V TYP.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta=25°C)			
Collector to Base Voltage	V_{CBO}	40	V
Collector to Emitter Voltage	V_{CEO}	20	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current (DC)	I_C	200	mA
Maximum Power Dissipation			
Total Power Dissipation			
at 25°C Ambient Temperature	P_T	150	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature Range	T_{stg}	−55 to +125	°C

5

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB}=30V, I_E=0
Emitter Cutoff Current	I_{EBO}			0.5	μA	V_{EB}=4.0V, I_C=0
DC Current Gain	h_{FE}	40	85	180		V_{CE}=0.5V, I_C= 1.0mA*
Collector Saturation Voltage	$V_{CE(sat)}$		0.13	0.20	V	I_C=10mA, I_B=1.0mA
Base Saturation Voltage	$V_{BE(sat)}$		0.74	0.90	V	I_C=10mA, I_B=1.0mA
Gain Bandwidth Product	f_T		500		MHz	V_{CE}=10V, I_E=−10mA
Output Capacitance	C_{ob}		3.0		pF	V_{CB}=10V, I_E=0, f=1.0MHz
Turn on Time	t_{on}		14		ns	See test circuits.
Storage Time	t_{stg}		10		ns	
Turn off Time	t_{off}		25		ns	

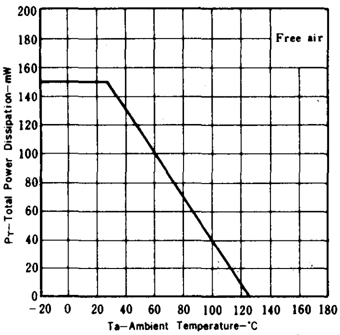
* Pulsed: PW ≦ 350μs, duty cycle ≦ 2%

h_{FE} Classification

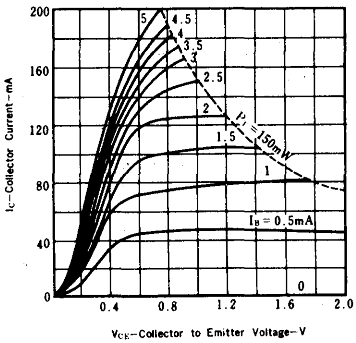
MARK				
MARK	2SC1621	B2	B3	B4
	2SC1621R	2B	3B	4B
h_{FE}		40 – 80	60 – 120	90 – 180

TYPICAL CHARACTERISTICS (Ta = 25°C)

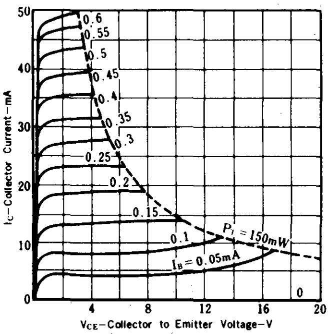
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



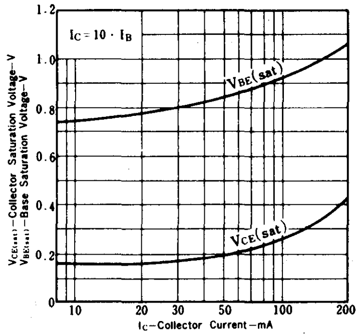
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



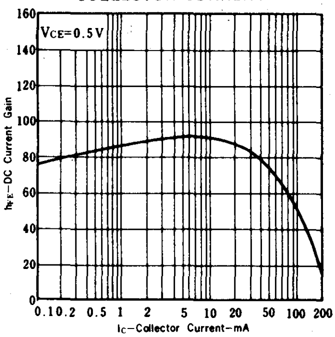
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



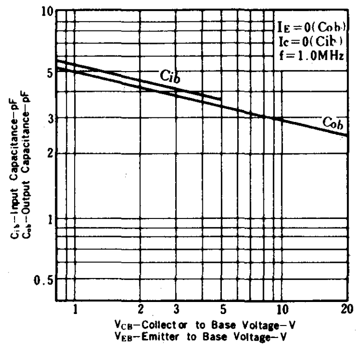
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



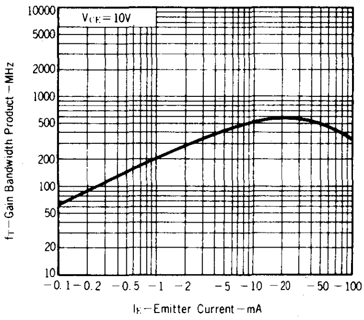
DC CURRENT GAIN vs. COLLECTOR CURRENT



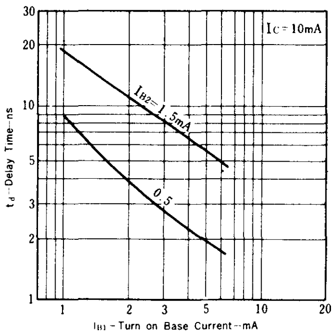
INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



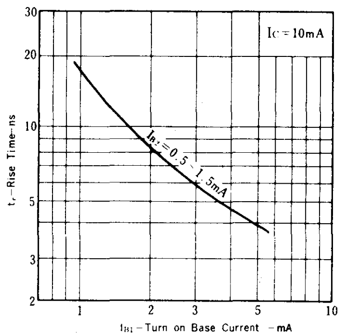
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



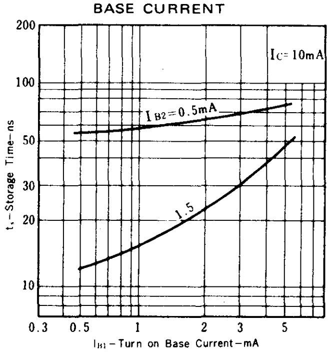
DELAY TIME vs. BASE CURRENT



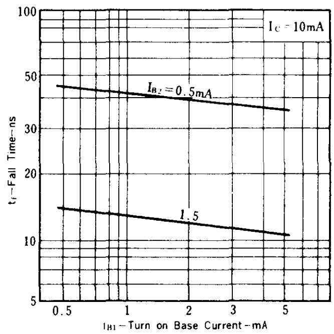
RISE TIME vs. BASE CURRENT



STORAGE TIME vs. BASE CURRENT



FALL TIME vs. BASE CURRENT



SWITCHING TIME TEST CIRCUITS

Fig. 1 t_{on}, t_{off} TEST CIRCUIT

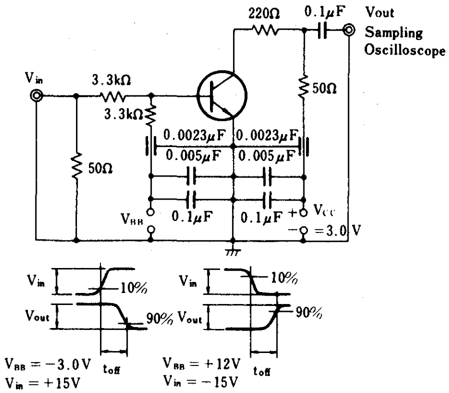
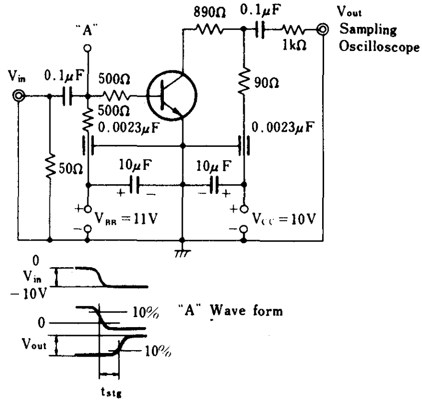


Fig. 2 t_{stg} TEST CIRCUIT

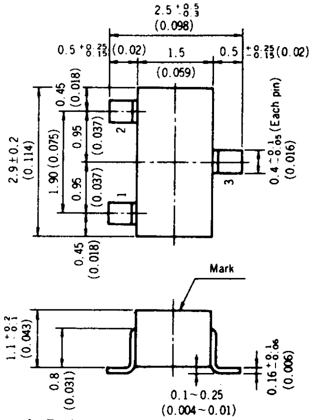


Note: <t_d, t_r, t_{stg} and t_f is measured variable V_{in}, V_{BB} in Fig.1, Fig.2

2SC1622

Audio Frequency High Gain Amplifier
NPN Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Base
3. Collector

- High DC Current Gain: h_{FE}=500 TYP. (V_{CE}=3.0V, I_C=0.5mA)

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta=25°C)			
Collector to Base Voltage	V_{CBO}	40	V
Collector to Emitter Voltage	V_{CEO}	35	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current (DC)	I_C	100	mA
Maximum Power Dissipation			
Total Power Dissipation at 25°C Ambient Temperature	P_T	150	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature Range	T_{stg}	–55 to +125	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.05	μA	V_{CB}=40V, I_E=0
Emitter Cutoff Current	I_{EBO}			0.05	μA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE1}	150				V_{CE}=3.0V, I_C=0.1mA
DC Current Gain	h_{FE2}	200	500	900		V_{CE}=3.0V, I_C=0.5mA*
Collector Saturation Voltage	$V_{CE(sat)}$		0.13	0.30	V	I_C=100mA, I_B=10mA
Base-Emitter Voltage	V_{BE}	0.55	0.58	0.65	V	V_{CE}=3.0V, I_C=0.5mA
Gain Bandwidth Product	f_T		100		MHz	V_{CE}=6.0V, I_E=–1.0mA
Output Capacitance	C_{ob}		3.2		pF	V_{CB}=6.0V, I_E=0, f=1.0MHz

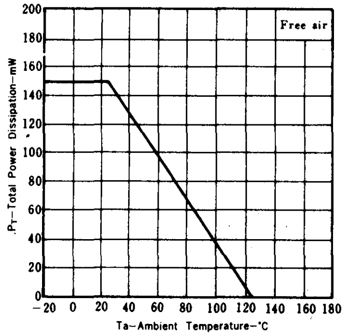
*Pulsed: PW≦ 350μs, duty cycle≦ 2%

h_{FE2} Classification

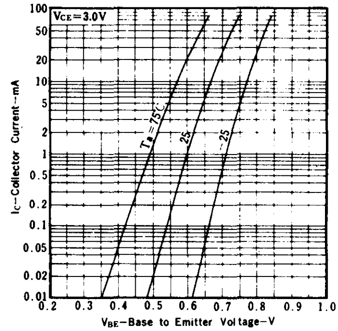
MARK	D6	D7	D8
h_{FE2}	200 – 400	300 – 600	450 – 900

TYPICAL CHARACTERISTICS (Ta = 25°C)

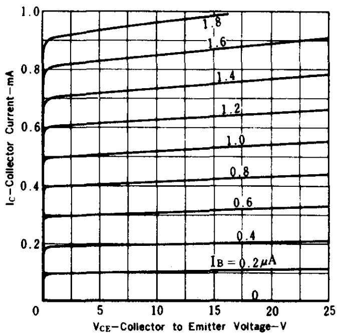
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



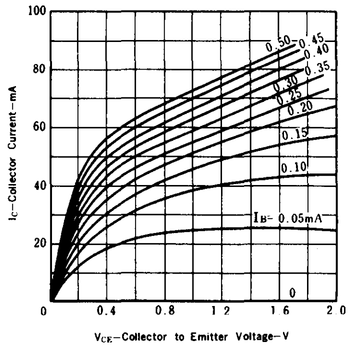
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



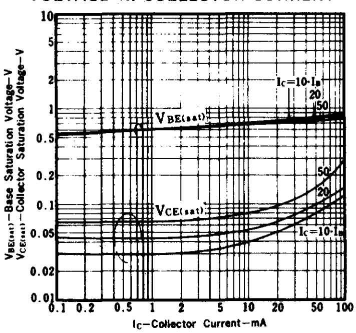
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



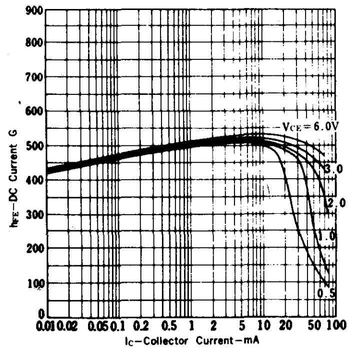
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



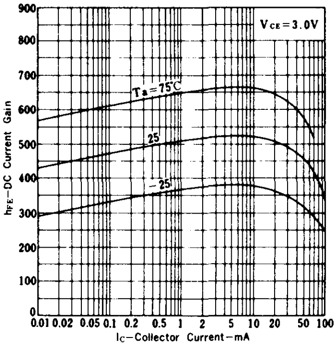
BASE AND COLLECTOR SATURATION
VOLTAGE vs. COLLECTOR CURRENT



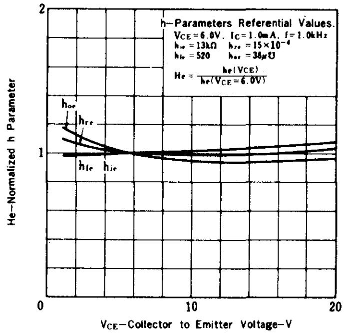
DC CURRENT GAIN vs.
COLLECTOR CURRENT



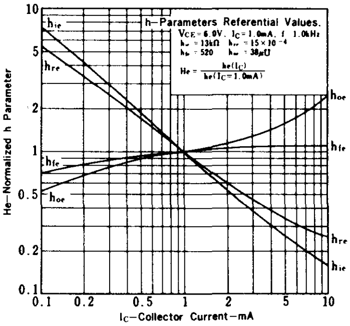
DC CURRENT GAIN vs. COLLECTOR CURRENT



NORMALIZED h PARAMETER vs. COLLECTOR TO EMITTER VOLTAGE



NORMALIZED h PARAMETER vs. COLLECTOR CURRENT

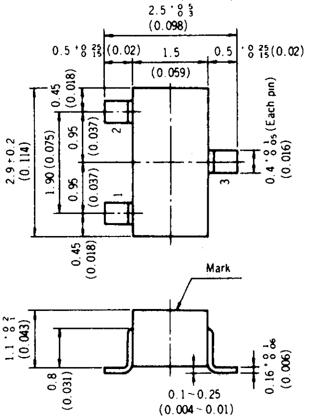


5

2SC1623, 2SC1623R

Audio Frequency and 455 kHz IF Amplifier
NPN Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



2SC1623
1. Emitter
2. Base
3. Collector

2SC1623R
1. Base
2. Emitter
3. Collector

- High DC Current Gain: h_{FE}=200 TYP. (V_{CE}=6.0V, I_C=1.0mA)
- High Voltage: V_{CEO}=50V

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta=25°C)			
Collector to Base Voltage	V_{CBO}	60	V
Collector to Emitter Voltage	V_{CEO}	50	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current (DC)	I_C	100	mA
Maximum Power Dissipation			
Total Power Dissipation at 25°C Ambient Temperature	P_T	150	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature Range	T_{stg}	−55 to +125	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB}=60V, I_E=0
Emitter Cutoff Current	I_{EBO}			0.1	μA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE}	60	200	600		V_{CE}=6.0V, I_C=1.0mA*
Collector Saturation Voltage	$V_{CE(sat)}$		0.15	0.3	V	I_C=100mA, I_B=10mA
Base Saturation Voltage	$V_{BE(sat)}$		0.86	1.0	V	I_C=100mA, I_B=10mA
Base Emitter Voltage	V_{BE}	0.55	0.62	0.65	V	V_{CE}=6.0V, I_C=1.0mA
Gain Bandwidth Product	f_T		250		MHz	V_{CE}=6.0V, I_E=−10mA
Output Capacitance	C_{ob}		3.0		pF	V_{CB}=6.0V, I_E=0, f=1.0MHz

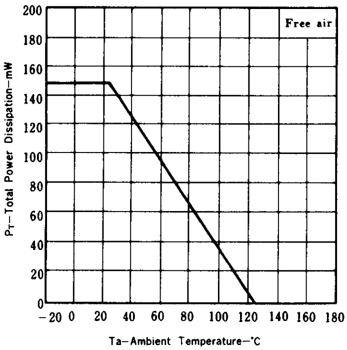
* Pulsed: PW ≦ 350μs, duty cycle ≦ 2%

h_{FE} Classification

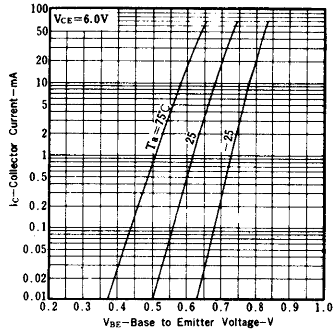
MARK						
MARK	2SC1623	L3	L4	L5	L6	L7
	2SC1623R	3L	4L	5L	6L	7L
h_{FE}		60 – 120	90 – 180	135 – 270	200 – 400	300 – 600

TYPICAL CHARACTERISTICS (Ta = 25°C)

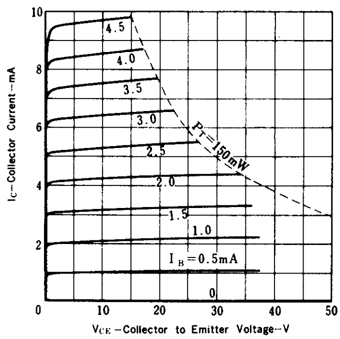
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



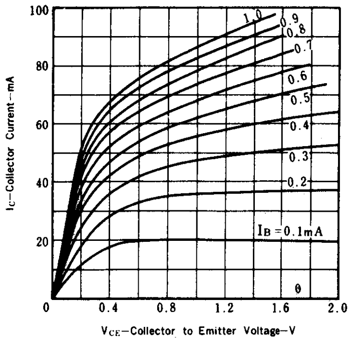
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



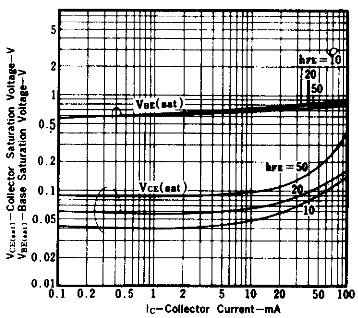
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



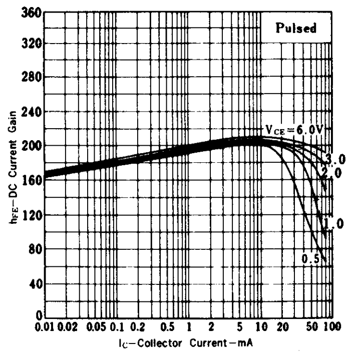
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



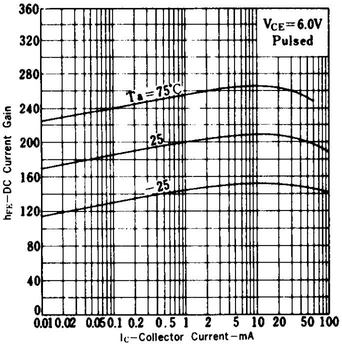
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



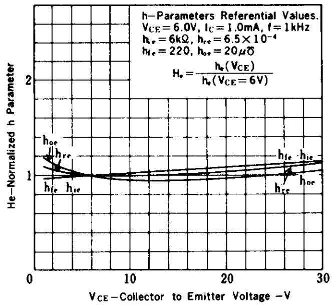
DC CURRENT GAIN vs. COLLECTOR CURRENT



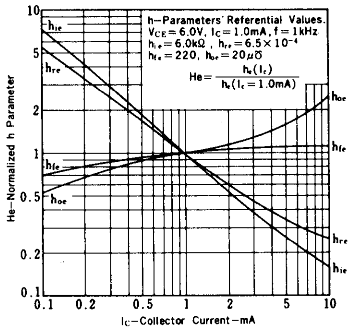
DC CURRENT GAIN vs. COLLECTOR CURRENT



NORMALIZED h PARAMETER vs. COLLECTOR TO EMITTER VOLTAGE



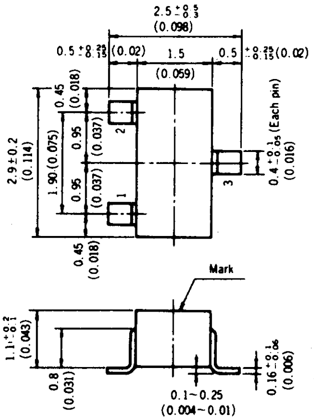
NORMALIZED h PARAMETER vs. COLLECTOR CURRENT



2SC1653, 2SC1654

Display Tube Drive, High Voltage Switching
NPN Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Base
3. Collector

- High Voltage V_{CEO}: 2SC1653 130V, 2SC1654 160V
- High DC Current Gain: h_{FE}=130 TYP. (V_{CE}=3.0V, I_C=15mA)

ABSOLUTE MAXIMUM RATINGS

		2SC1653	2SC1654	
Maximum Voltages and Current (Ta=25°C)				
Collector to Base Voltage	V_{CBO}	150	180	V
Collector to Emitter Voltage	V_{CEO}	130	160	V
Emitter to Base Voltage	V_{EBO}	5.0		V
Collector Current (DC)	I_C	50		mA
Maximum Power Dissipation				
Total Power Dissipation at 25°C Ambient Temperature	P_T	150		mW
Maximum Temperatures				
Junction Temperature	T_j	125		°C
Storage Temperature Range	T_{stg}	−55 to +125		°C

5

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB}=130V, I_E=0
Emitter Cutoff Current	I_{EBO}			0.1	μA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE1}	50	180			V_{CE}=3.0V, I_C=1.0mA
	h_{FE2}	90	200	400		V_{CE}=3.0V, I_C=15mA*
Collector Saturation Voltage	$V_{CE(sat)}$		0.1	0.5	V	I_C=10mA, I_B=1.0mA
Base Saturation Voltage	$V_{BE(sat)}$		0.73	1.0	V	I_C=10mA, I_B=1.0mA
Gain Bandwidth Product	f_T		120		MHz	V_{CE}=10V, I_E=−10mA
Output Capacitance	C_{ob}		2.3		pF	V_{CB}=10V, I_E=0, f=1.0MHz

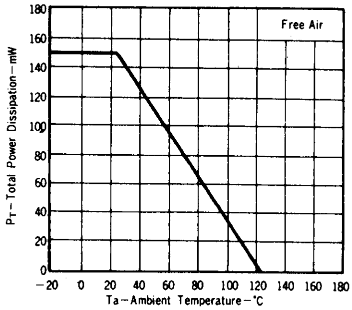
* Pulsed: PW ≦ 350μs, duty cycle ≦ 2%

h_{FE2} Classification

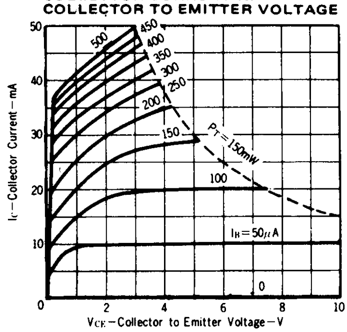
MARK				
MARK	2SC1653	N2	N3	N4
	2SC1654	N5	N6	N7
h_{FE2}		90–180	135–270	200–400

TYPICAL CHARACTERISTICS (Ta = 25°C)

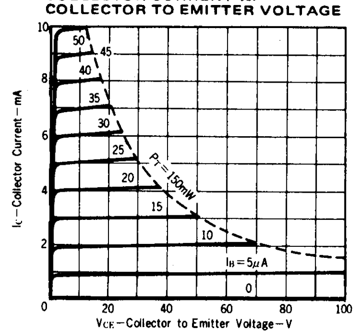
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



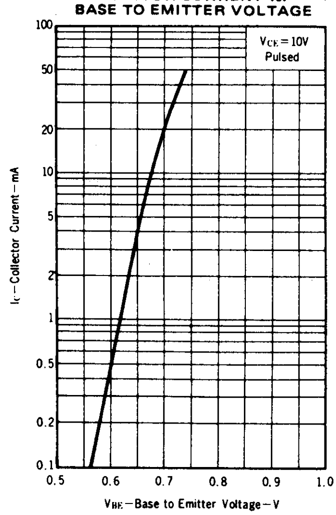
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



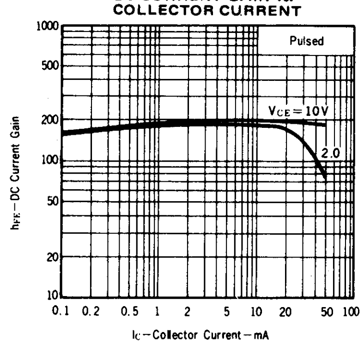
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



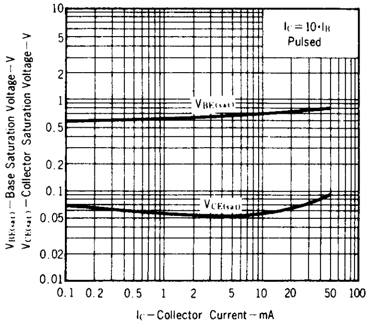
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



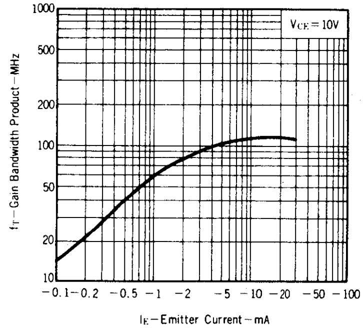
DC CURRENT GAIN vs. COLLECTOR CURRENT



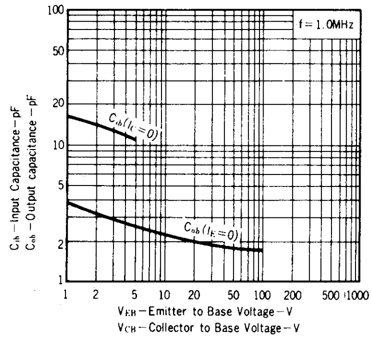
BASE AND COLLECTOR
SATURATION VOLTAGE vs.
COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs.
EMITTER CURRENT



INPUT AND OUTPUT
CAPACITANCE vs.
REVERSE VOLTAGE

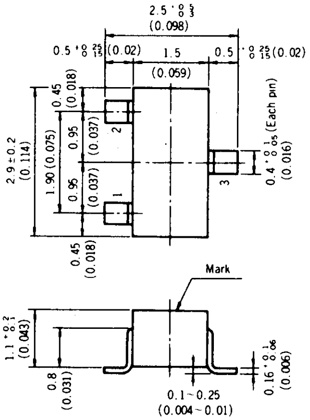


5

2SC2107

General Purpose Amplifier and Switches
NPN Silicon Epitaxial Transistor
Industrial Use

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Base
3. Collector

- Complementary to 2SA956
- Keeps stabilized operation against power voltage fluctuation:
  $V_{CEO} > 40V$, $V_{EBO} > 8.0V$
- High DC Current Gain and excellent linearity:
  h_{FE}=150 TYP. (V_{CE}=1.0V, I_C=10mA)

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta=25°C)			
Collector to Base Voltage ($R_{BE}=\infty$)	V_{CBO}	60	V
Collector to Emitter Voltage (Open Base)	V_{CEO}	40	V
Emitter to Base Voltage	V_{EBO}	8.0	V
Collector Current (DC)	I_C	100	mA
Maximum Power Dissipation			
Total Power Dissipation			
at 25°C Ambient Temperature	P_T	150	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature Range	T_{stg}	–55 to +125	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°)

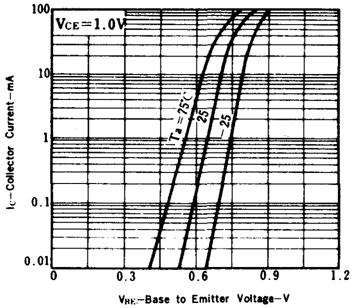
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			100	nA	V_{CB}=40V, I_E=0
Emitter Cutoff Current	I_{EBO}			100	nA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE1}	50	150			V_{CE}=1.0V, I_C=1.0mA
DC Current Gain	h_{FE2}	80	160	320		V_{CE}=1.0V, I_C=10mA
Collector Saturation Voltage	$V_{CE(sat)}$		0.05	0.3	V	I_C=10mA, I_B=1.0mA
Base Saturation Voltage	$V_{BE(sat)}$		0.75	1.0	V	I_C=10mA, I_B=1.0mA
Gain Bandwidth Product	f_T		300		MHz	V_{CE}=10V, I_E=–10mA
Output Capacitance	C_{ob}		2.5		pF	V_{CB}=10V, I_E=0, f=1.0MHz
Turn on Time	t_{on}		45		ns	See test circuit.
Storage Time	t_{stg}		190		ns	
Turn off Time	t_{off}		250		ns	

h_{FE2} Classification

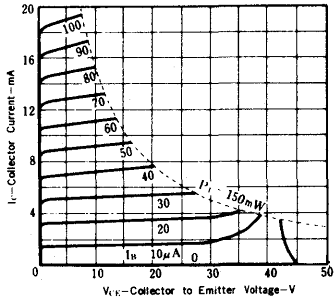
MARK	G3	G4	G5	G6
h_{FE2}	80 – 130	110 – 170	150 – 240	200 – 320

TYPICAL CHARACTERISTICS (Ta = 25°C)

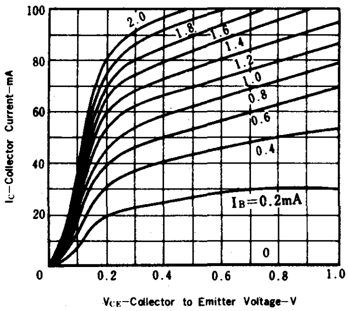
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



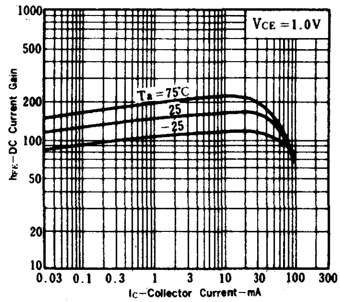
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



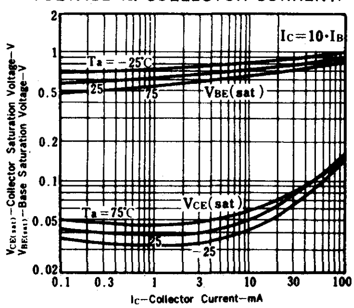
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



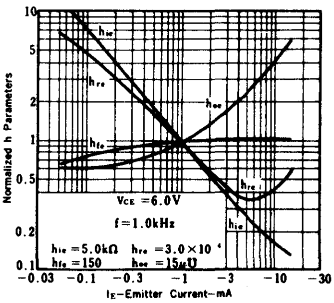
DC CURRENT GAIN vs. COLLECTOR CURRENT



BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT.

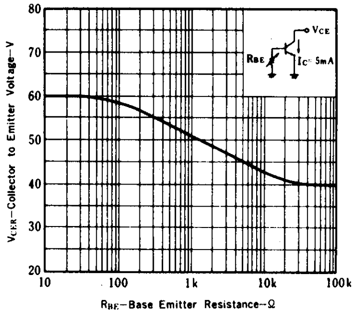


NORMALIZED h PARAMETER vs. EMITTER CURRENT

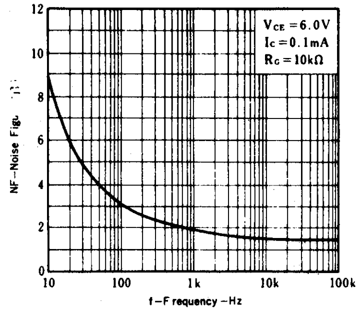


5

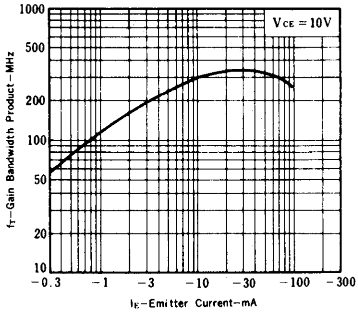
COLLECTOR TO EMITTER VOLTAGE vs. BASE EMITTER RESISTANCE



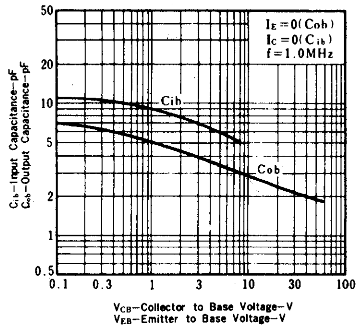
NOISE FIGURE vs. FREQUENCY



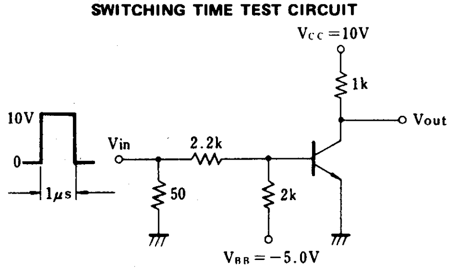
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



INPUT AND OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



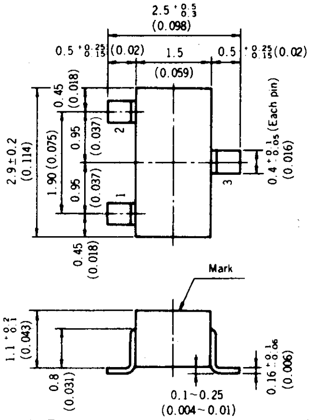
SWITCHING TIME TEST CIRCUIT



2SC2223

High Frequency Amplifier
NPN Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Base
3. Collector

- High gain bandwidth product: f_T = 600MHz TYP.
- Low output capacitance: C_{ob} = 1.0pF TYP.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Maximum Voltages and Current			
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	20	V
Emitter to Base Voltage	V_{EBO}	4.0	V
Collector Current (DC)	I_C	20	mA
Maximum Power Dissipation			
Total Power Dissipation	P_T	150	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature Range	T_{stg}	−55 to +125	°C

5

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

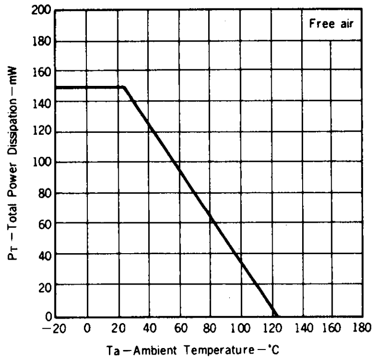
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB}=30V, I_E=0
Emitter Cutoff Current	I_{EBO}			0.1	μA	V_{EB}=4.0V, I_C=0
DC Current Gain	h_{FE}	40	90	180		V_{CE}=6.0V, I_C=1.0mA
Collector Saturation Voltage	$V_{CE(sat)}$		0.1	0.3	V	I_C=10mA, I_B=1.0mA
Base to Emitter Voltage	V_{BE}		0.72		V	V_{CE}=6.0V, I_C=1.0mA
Gain Bandwidth Product	f_T		600		MHz	V_{CE}=6.0V, I_E=−1.0mA
Output Capacitance	C_{ob}		1.0		pF	V_{CB}=6.0V, I_E=0, f=1.0MHz
Collector to Base Time Constant	$C_c \cdot r_{b'b}$		12		ps	V_{CE}=6.0V, I_E=−1.0mA, f=31.9MHz
Noise Figure	NF		3.0		dB	V_{CE}=6.0V, I_E=−1.0mA, R_G=50Ω f=100MHz See test circuit

h_{FE} Classification

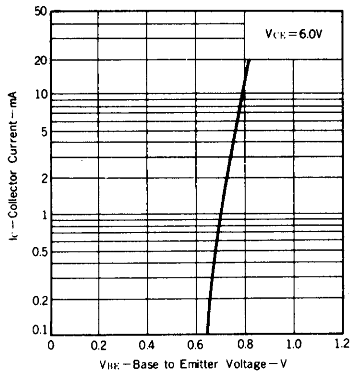
MARK	F12	F13	F14	F6
h_{FE}	40 – 80	60 – 120	90 – 180	40 – 180

TYPICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

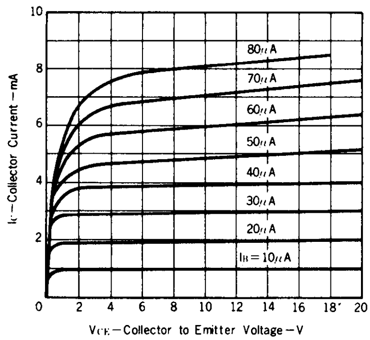
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



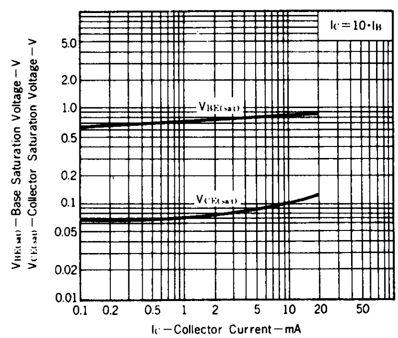
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



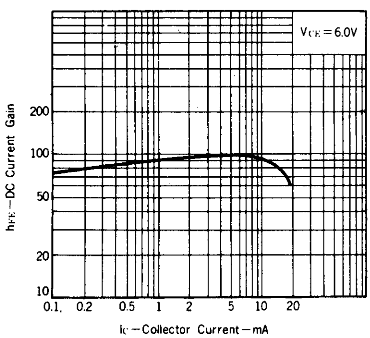
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



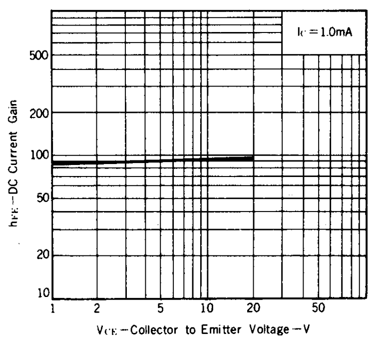
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



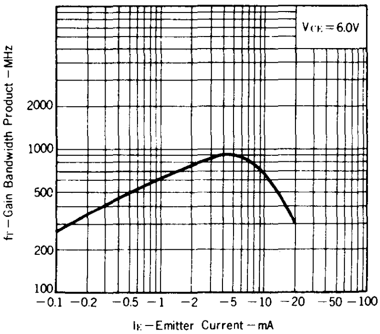
DC CURRENT GAIN vs. COLLECTOR CURRENT



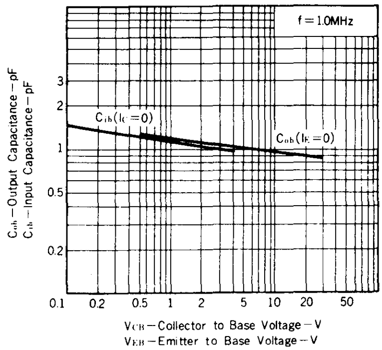
DC CURRENT GAIN vs. COLLECTOR TO EMITTER VOLTAGE



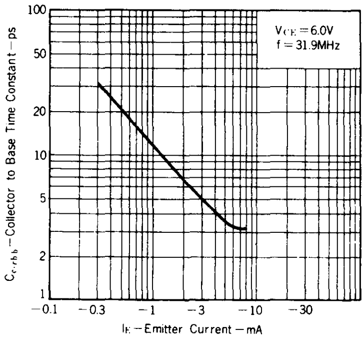
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



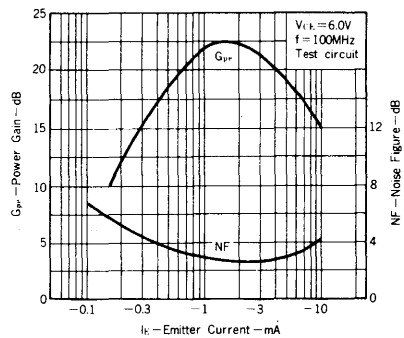
INPUT CAPACITANCE vs. EMITTER TO BASE VOLTAGE, OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



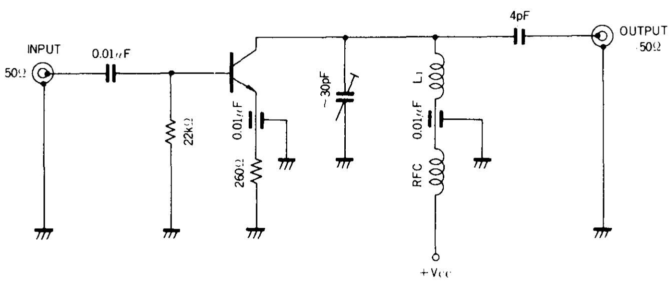
COLLECTOR TO BASE TIME CONSTANT vs. EMITTER CURRENT



POWER GAIN, NOISE FIGURE vs. EMITTER CURRENT



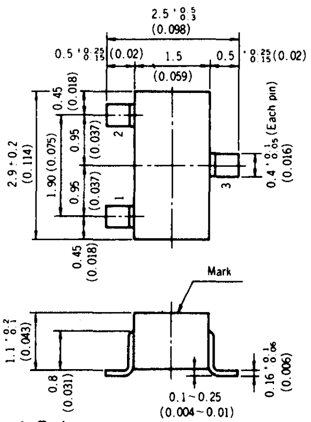
100MHz G_{pe}, NF TEST CIRCUIT



2SC2350

High Frequency Low Noise Amplifier
NPN Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Base
3. Collector

Mark U1

- Low Noise Figure: NF=2.3 dB TYP. (f=500MHz)
- High Maximum Available Gain: MAG = 17dB TYP. (f=500MHz)

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta = 25°C)

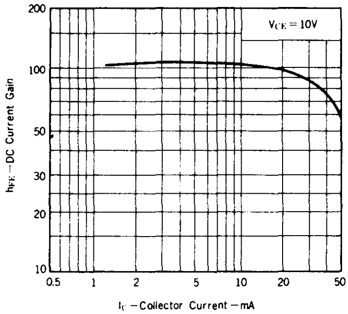
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	14	V
Emitter to Base Voltage	V_{EBO}	3.0	V
Collector Current (DC)	I_C	50	mA
Maximum Power Dissipation			
Total Power Dissipation			
at 25°C Ambient Temperature	P_T	250	mW
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	–55 to +150	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

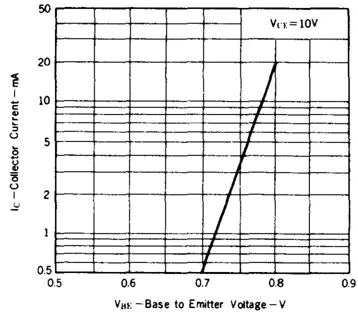
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB} = 15V, I_E = 0
Emitter Cutoff Current	I_{EBO}			0.1	μA	V_{EB} = 2.0V, I_C = 0
DC Current Gain	h_{FE}	40		200		V_{CE} = 10V, I_C = 10mA
Gain Bandwidth Product	f_T		2.8		GHz	V_{CE} = 10V, I_C = 10mA
Output Capacitance	C_{ob}		0.7	1.0	pF	V_{CB} = 10V, I_E = 0, f = 1.0MHz
Insertion Power Gain	$\|S_{21e}\|^2$	13	14.5		dB	V_{CE} = 10V, I_C = 10mA, f = 500MHz
Noise Figure	NF		2.3	3.5	dB	V_{CE} = 10V, I_C = 3mA, f = 500MHz
Maximum Available Gain	MAG		17		dB	V_{CE} = 10V, I_C = 10mA, f = 500MHz

TYPICAL CHARACTERISTICS (Ta = 25°C)

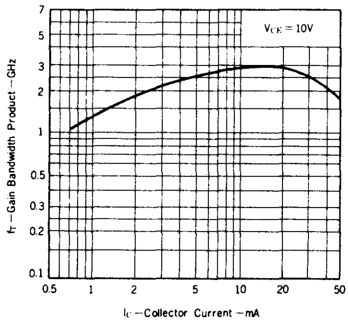
DC CURRENT GAIN vs. COLLECTOR CURRENT



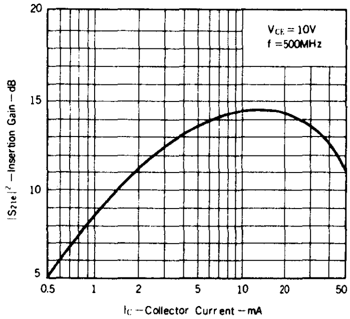
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



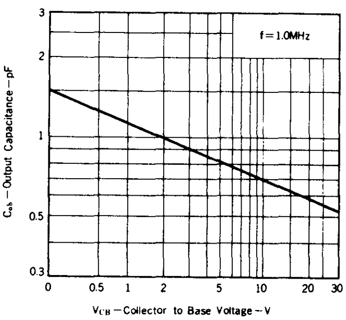
GAIN BANDWIDTH PRODUCT vs. COLLECTOR CURRENT



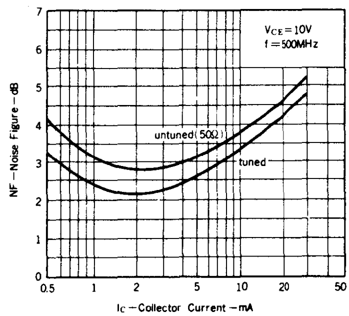
INSERTION GAIN vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE

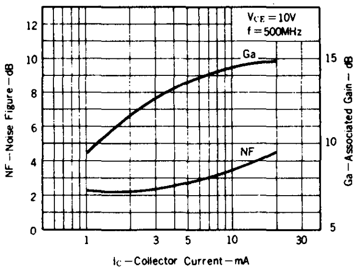


NOISE FIGURE vs. COLLECTOR CURRENT



5

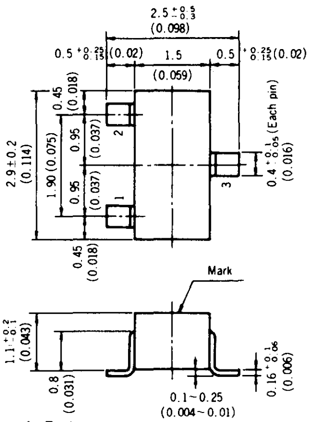
NF, Ga vs. COLLECTOR CURRENT



2SC2351

High Frequency Low Noise Amplifier NPN Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Base
3. Collector

- Low Noise Figure: NF=1.5 dB TYP. (f=1.0 GHz)
- High Maximum Available Gain: MAG=14dB TYP. (f=1.0 GHz)

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta = 25°C)			
Collector to Base Voltage	V_{CBO}	25	V
Collector to Emitter Voltage	V_{CEO}	12	V
Emitter to Base Voltage	V_{EBO}	3.0	V
Collector Current (DC)	I_C	70	mA
Maximum Power Dissipation			
Total Power Dissipation			
at 25°C Ambient Temperature	P_T	250	mW
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

5

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

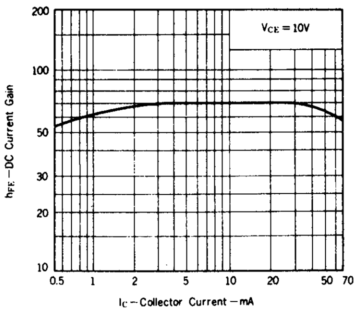
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB} = 15V, I_E = 0
Emitter Cutoff Current	I_{EBO}			0.1	μA	V_{EB} = 2.0V, I_C = 0
DC Current Gain	h_{FE}	40		200		V_{CE} = 10V, I_C = 20mA
Gain Bandwidth Product	f_T		4.5		GHz	V_{CE} = 10V, I_C = 20mA
Output Capacitance	C_{ob}		0.75	1.0	pF	V_{CB} = 10V, I_E = 0, f = 1.0MHz
Insertion Power Gain	$\|S_{21}e\|^2$	9	11		dB	V_{CE} = 10V, I_C = 20mA, f = 1.0GHz
Noise Figure	NF		1.5	3.0	dB	V_{CE} = 10V, I_C = 5mA, f = 1.0GHz
Maximum Available Gain	MAG		14		dB	V_{CE} = 10V, I_C = 20mA, f = 1.0GHz

h_{FE} Classification

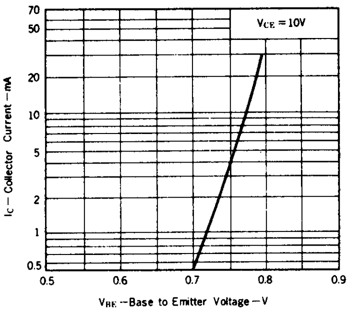
MARK	R2	R3
h_{FE}	40–120	100–200

TYPICAL CHARACTERISTICS (Ta = 25°C)

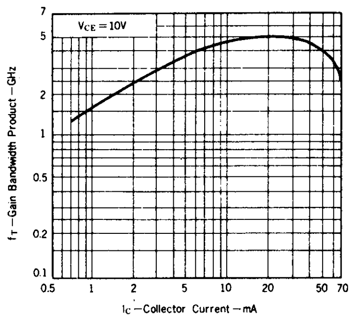
DC CURRENT GAIN vs.
COLLECTOR CURRENT



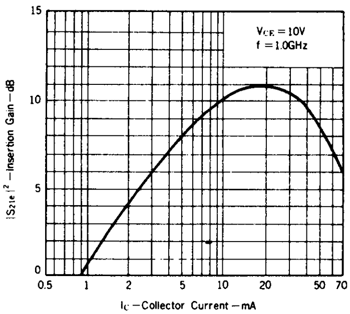
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



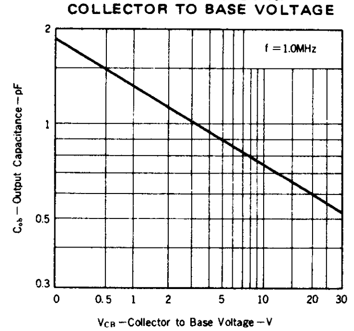
GAIN BANDWIDTH PRODUCT vs.
COLLECTOR CURRENT



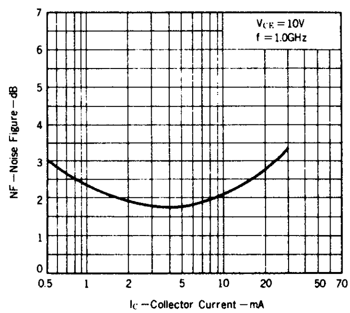
INSERTION GAIN vs.
COLLECTOR CURRENT



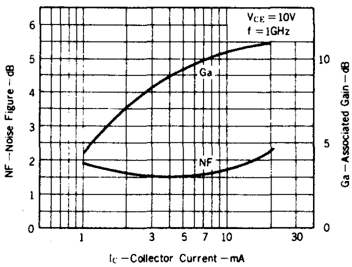
OUTPUT CAPACITANCE vs.
COLLECTOR TO BASE VOLTAGE



NOISE FIGURE
COLLECTOR CURRENT



NF, Ga vs. COLLECTOR CURRENT



5

NEC
ELECTRON DEVICE

SILICON TRANSISTORS
2SC2756, 2SC2756R

VHF MIXER
NPN SILICON EPITAXIAL TRANSISTOR

DESCRIPTION

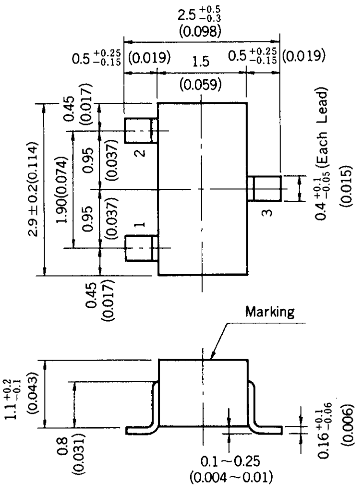
The 2SC2756, 2SC2756R are NPN silicon epitaxial transistor intended for use as a VHF mixer in a tuner of a TV receiver.
The device features are high conversion gain and low distortion.

FEATURES

- Low C_{re} : 0.4pF TYP.
- High conversion gain : 15dB TYP.
- Excellent h_{FE} linearity.

PACKAGE DIMENSIONS

in millimeters (inches)



2SC2756	2SC2756R
1. Emitter	1. Base
2. Base	2. Emitter
3. Collector	3. Collector

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

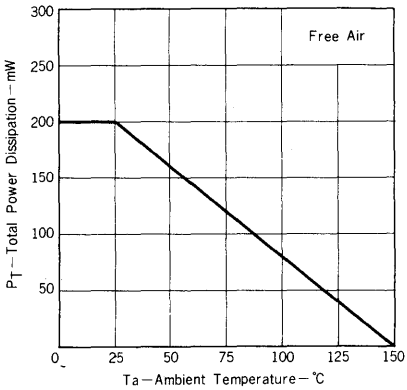
Maximum Voltages and Current			
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	20	V
Emitter to Base Voltage	V_{EBO}	4.0	V
Collector Current	I_C	30	mA
Maximum Power Dissipation			
Total Power Dissipation	P_T	200	mW
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	-55 to +150	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

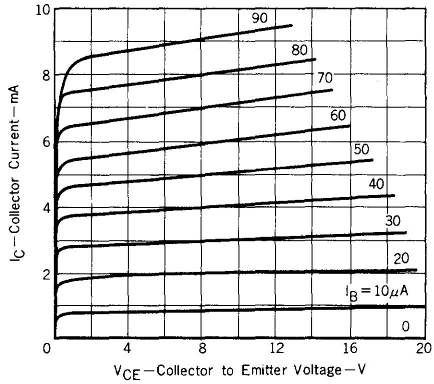
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB} = 20V, I_E = 0
DC Current Gain	h_{FE}	60	100	240		V_{CE} = 10V, I_C = 5.0mA
Collector Saturation Voltage	$V_{CE(sat)}$			0.5	V	I_C = 10mA, I_B = 1.0mA
Gain Bandwidth Product	f_T	500	850		MHz	V_{CE} = 10V, I_E = -5.0mA
Feed Back Capacitance	C_{re}		0.4	0.7	pF	V_{CB} = 10V, I_E = 0, f = 1.0MHz
Conversion Gain	G_C	12			dB	V_{CE} = 10V, I_E = -5.0mA f = 200MHz, f_{LO} = 258MHz

TYPICAL CHARACTERISTICS (Ta = 25°C)

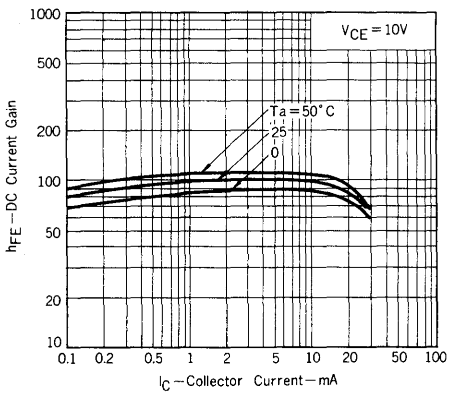
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



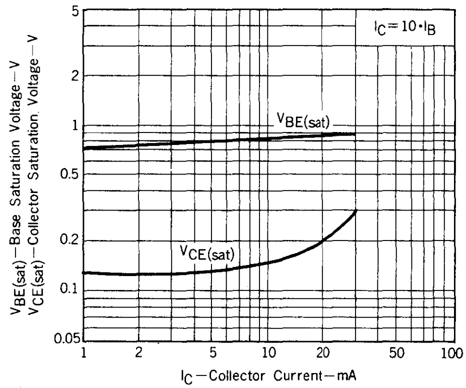
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



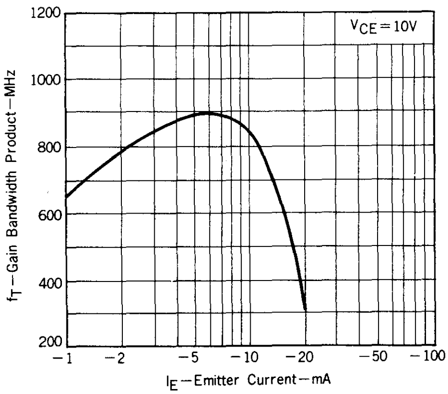
DC CURRENT GAIN vs. COLLECTOR CURRENT



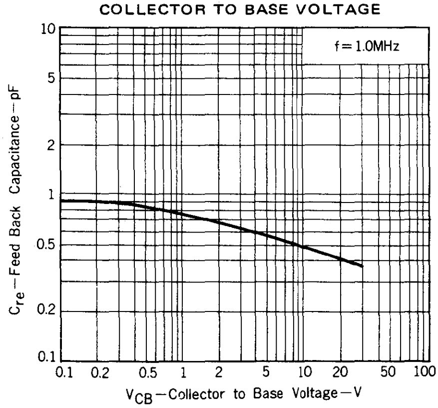
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

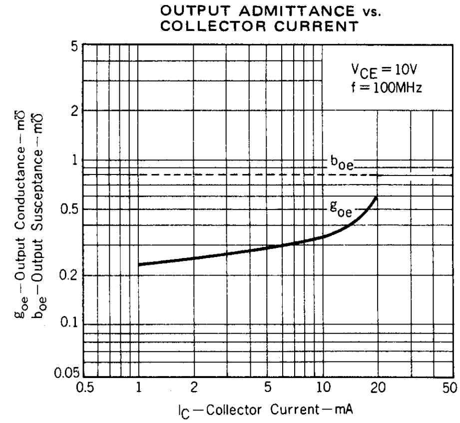


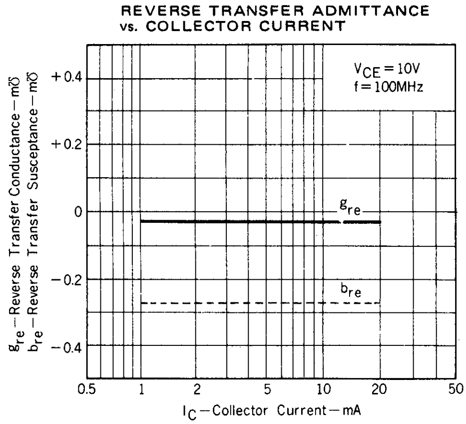
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT

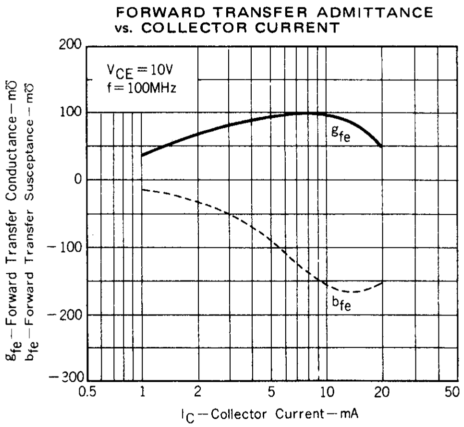


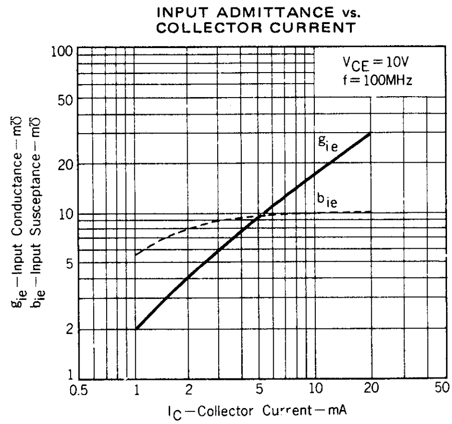
FEED BACK CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



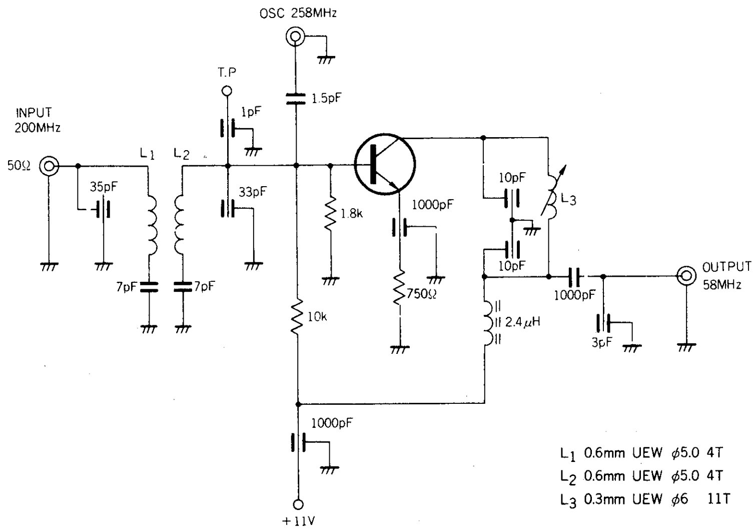








CONVERSION GAIN TEST CIRCUIT



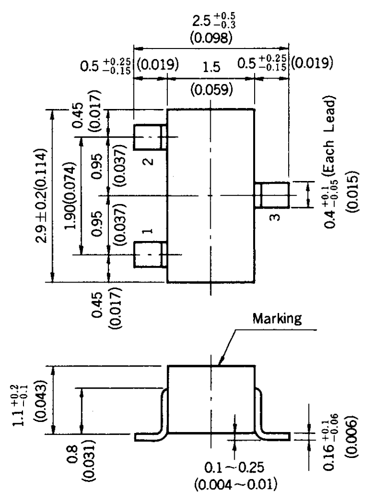
L1 0.6mm UEW ϕ5.0 4T
L2 0.6mm UEW ϕ5.0 4T
L3 0.3mm UEW ϕ6 11T

NEC
ELECTRON DEVICE

SILICON TRANSISTORS
2SC2757, 2SC2757R

UHF/VHF OSCILLATOR AND VHF MIXER
NPN SILICON EPITAXIAL TRANSISTOR

PACKAGE DIMENSIONS
in millimeters (inches)



2SC2757	2SC2757R
1. Emitter	1. Base
2. Base	2. Emitter
3. Collector	3. Collector

DESCRIPTION

The 2SC2757, 2SC2757R are NPN silicon epitaxial transistor intended for use as VHF and UHF oscillators and a VHF mixer in a tuner of a TV receiver.

The device features stable oscillation and small frequency drift against any change of the supply voltage and the ambient temperature.

FEATURES

- High gain bandwidth product; $f_T = 1100MHz$ TYP.
- Low collector to base time constant; $C_c \cdot r_{b'b} = 10ps$ TYP.
- Low output capacitance; $C_{ob} = 1.5pF$ MAX.

5

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

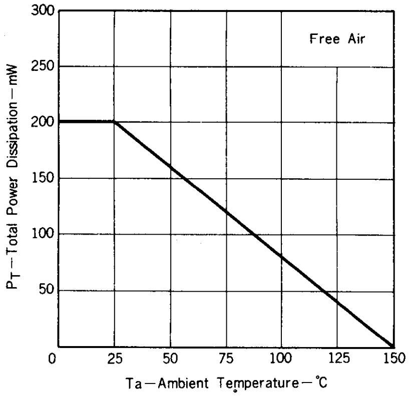
Maximum Voltages and Current			
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	15	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current	I_C	50	mA
Maximum Power Dissipation			
Total Power Dissipation	P_T	200	mW
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	-55 to +150	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

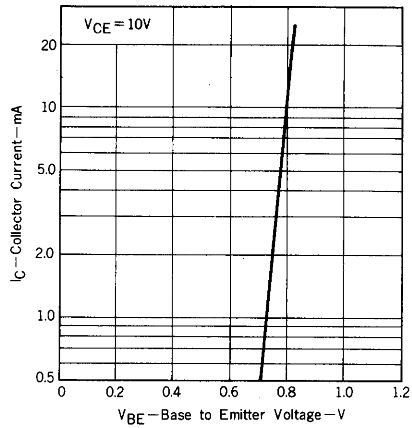
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	$V_{CB} = 12V$, $I_E = 0$
DC Current Gain	h_{FE}	60	100	240		$V_{CE} = 10V$, $I_C = 5.0mA$
Collector Saturation Voltage	$V_{CE(sat)}$			0.5	V	$I_C = 10mA$, $I_B = 1.0mA$
Gain Bandwidth Product	f_T	800	1100		MHz	$V_{CE} = 10V$, $I_E = -5.0mA$
Output Capacitance	C_{ob}			1.5	pF	$V_{CB} = 10V$, $I_E = 0$, $f = 1.0MHz$
Collector to Base Time Constant	$C_c \cdot r_{b'b}$		10	15	ps	$V_{CE} = 10V$, $I_E = -5.0mA$, $f = 31.9MHz$

TYPICAL CHARACTERISTICS (Ta = 25°C)

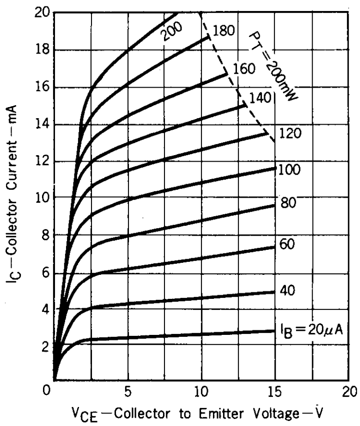
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



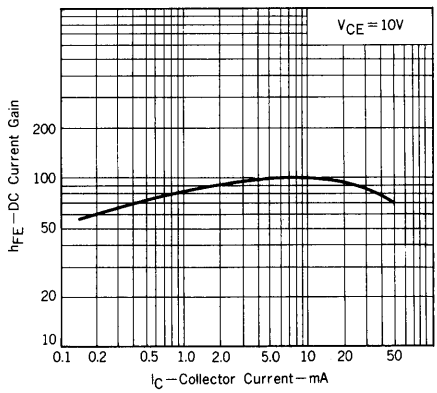
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



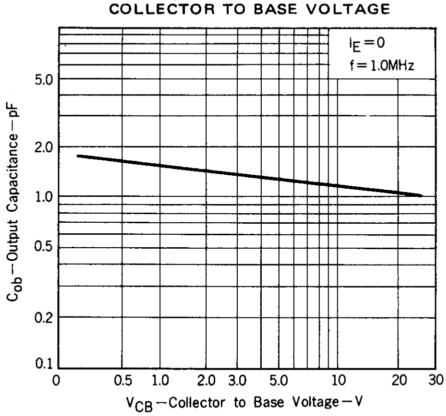
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



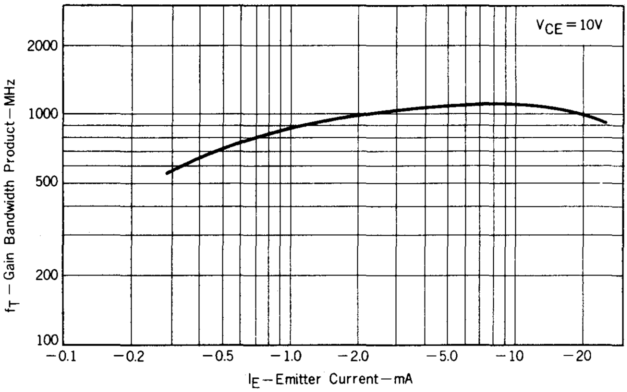
DC CURRENT GAIN vs. COLLECTOR CURRENT



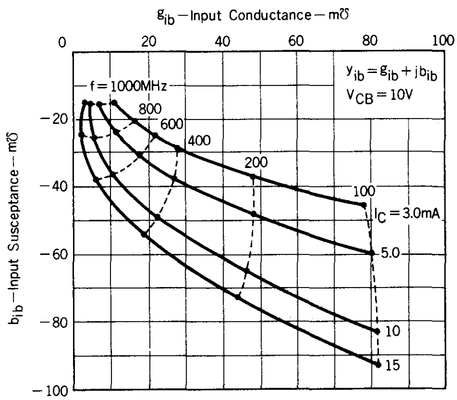
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



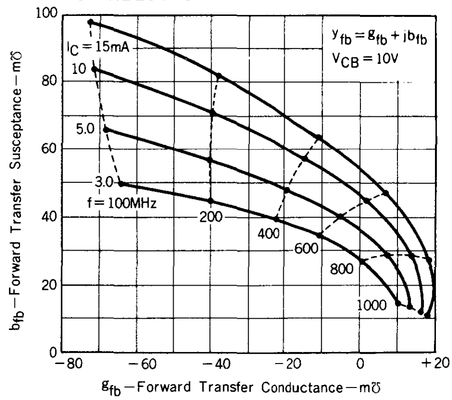
GAIN BANDWIDTH PRODUCT
vs. EMITTER CURRENT



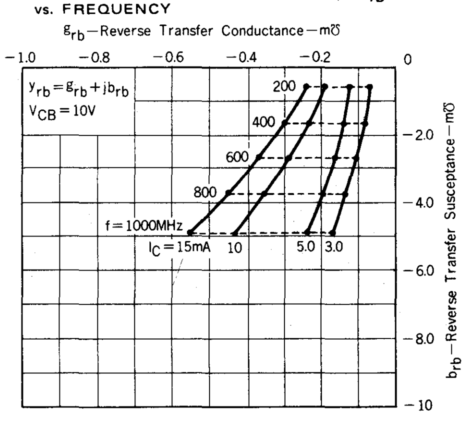
INPUT ADMITTANCE (y_{ib})
vs. FREQUENCY



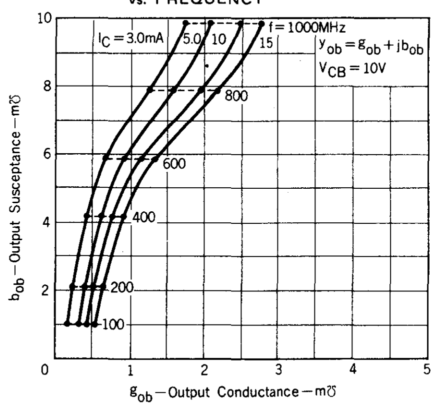
FORWARD TRANSFER ADMITTANCE (y_{fb})
vs. FREQUENCY



REVERSE TRANSFER ADMITTANCE (y_{rb})
vs. FREQUENCY



OUTPUT ADMITTANCE (y_{ob})
vs. FREQUENCY

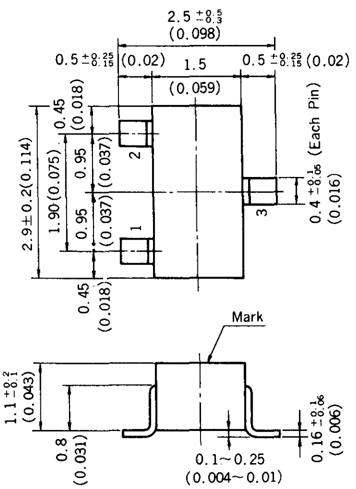


NEC
ELECTRON DEVICE

SILICON TRANSISTORS
2SC2758,2SC2758R

RF AMP. FOR UHF TV TUNER
NPN SILICON TRANSISTOR

PACKAGE DIMENSIONS
in millimeters (inches)



2SC2758	2SC2758R
1. Emitter	1. Base
2. Base	2. Emitter
3. Collector	3. Collector

The 2SC2758, 2SC2758R are specifically designed for UHF RF amplifier applications. The 2SC2758 and 2SC2758R feature high power gain, low noise, and excellent forward AGC characteristics in a tiny plastic package designed to realize easy and economical mounting for Hybrid IC.

- High power gain. ; 14dB MIN.
- Low noise figure. ; 4.5dB TYP.
- Forward AGC characteristic.
- Easy & economical mounting realizable with plastic mold package for Hybrid IC.

ABSOLUTE MAXIMUM RATINGS ($T_a = 25°C$)

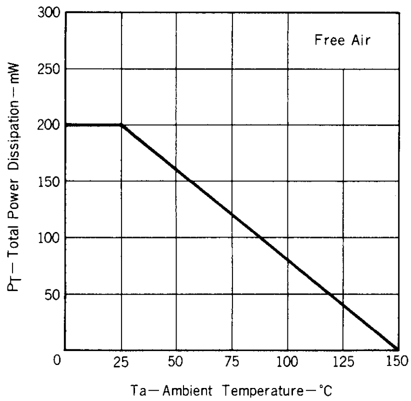
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	25	V
Emitter to Base Voltage	V_{EBO}	4.0	V
Collector Current	I_C	20	mA
Total Power Dissipation	P_T	200	mW
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	-55 to +150	°C

ELECTRICAL CHARACTERISTICS ($T_a = 25°C$)

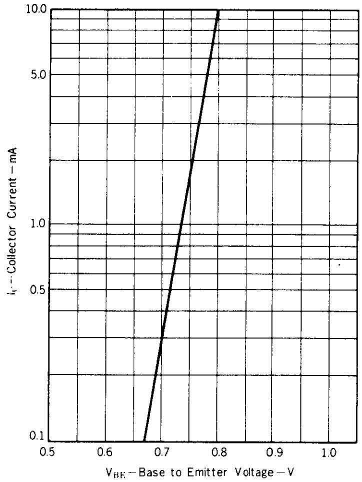
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	$V_{CB} = 25V$, $I_E = 0$
DC Current Gain	h_{FE}	60	100	240		$V_{CE} = 10V$, $I_C = 3.0mA$
Gain Bandwidth Product	f_T	750	900		MHz	$V_{CE} = 10V$, $I_E = -3.0mA$
Output Capacitance	C_{ob}		0.6	0.8	pF	$V_{CB} = 10V$, $I_E = 0$, $f = 1MHz$
Noise Figure	NF		4.5	6.0	dB	$V_{CB} = 10V$, $I_E = -3.0mA$, $f = 900MHz$
Power Gain	G_{pb}	14			dB	$V_{CB} = 10V$, $I_E = -3.0mA$, $f = 900MHz$
AGC Current	I_{AGC}	-7	-10	-11	mA	I_E for which $G_{pbAGC} = G_{pb} - 30dB$

TYPICAL CHARACTERISTICS (Ta = 25°C)

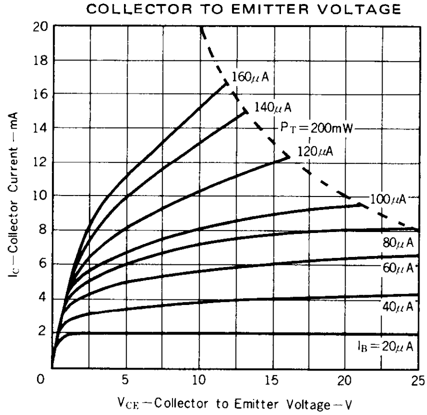
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



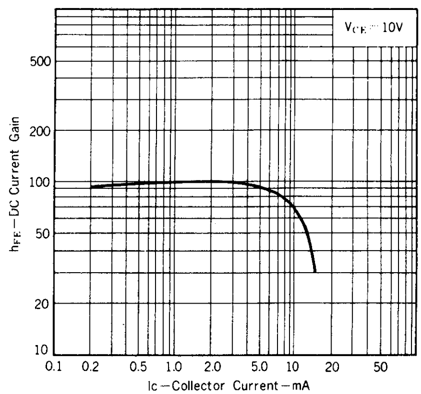
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



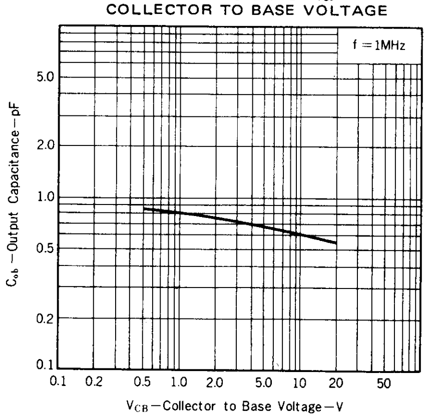
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



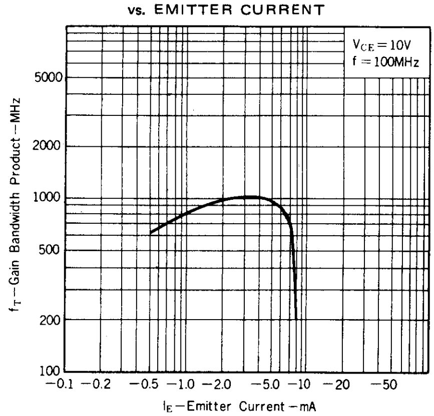
DC CURRENT GAIN vs. COLLECTOR CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



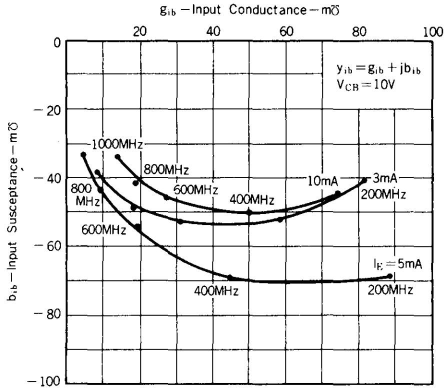
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



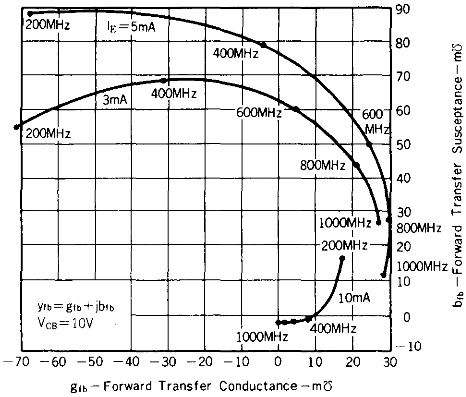
5

TYPICAL CHARACTERISTICS of "Y" PARAMETERS

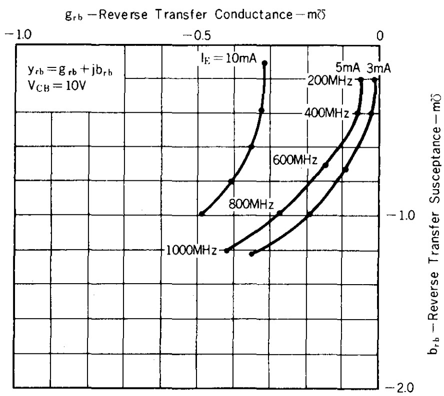
INPUT ADMITTANCE (y_{ib}) vs. FREQUENCY



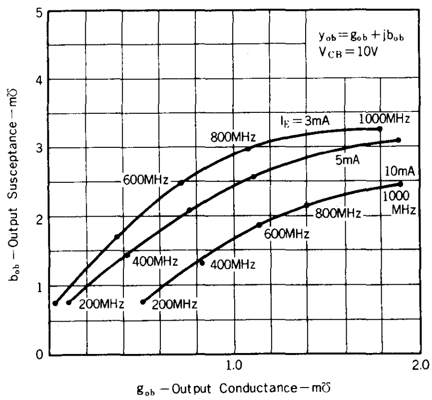
FORWARD TRANSFER ADMITTANCE (y_{fb}) vs. FREQUENCY



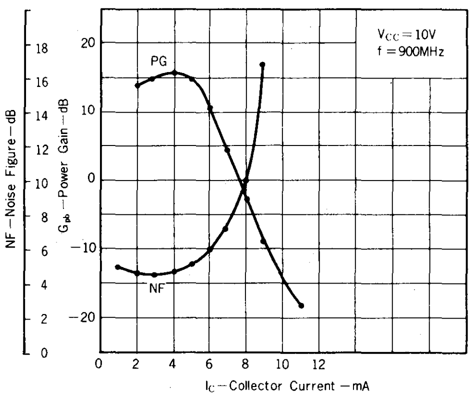
REVERSE TRANSFER ADMITTANCE (y_{rb}) vs. FREQUENCY



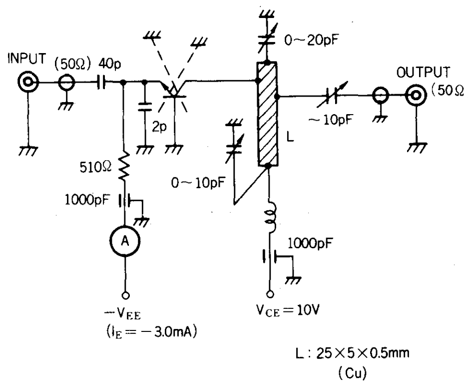
OUTPUT ADMITTANCE (y_{ob}) vs. FREQUENCY



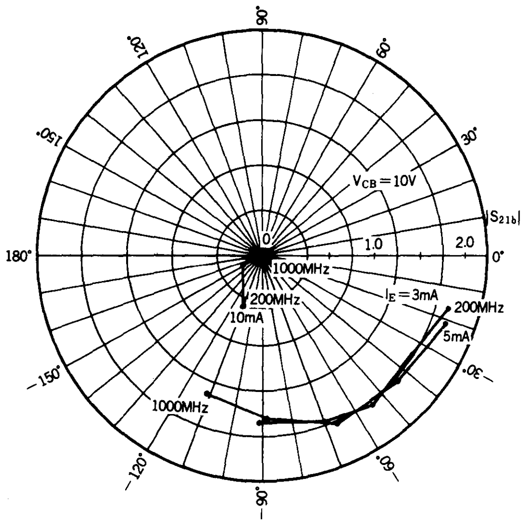
NOISE FIGURE, POWER GAIN vs. COLLECTOR CURRENT



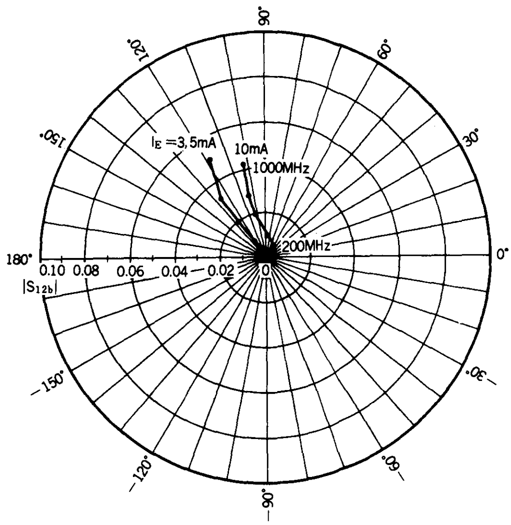
900 MHz G_{pb} & NF Test Circuit



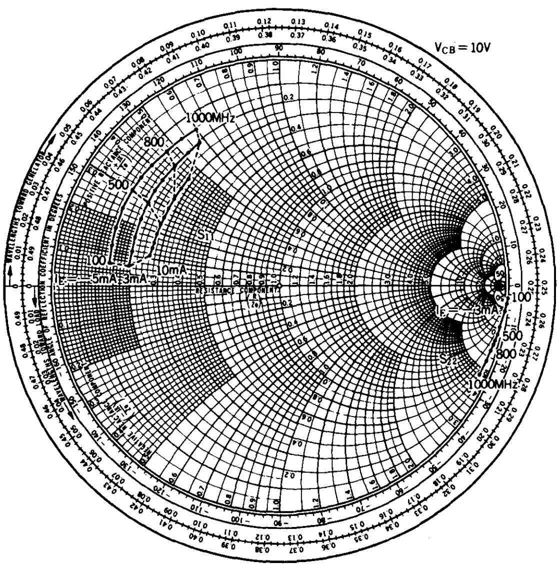
S_{21b} vs. f



S_{12b} vs. f



S_{11} vs. f, S_{22} vs. f



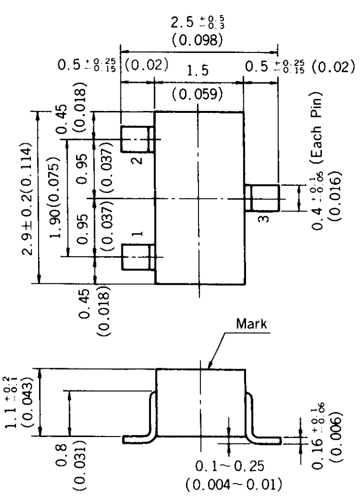
5

NEC
ELECTRON DEVICE

SILICON TRANSISTORS
2SC2759,2SC2759R

UHF/VHF MIXER, UHF OSCILLATOR
NPN SILICON EPITAXIAL TRANSISTOR

PACKAGE DIMENSIONS
in millimeters (inches)



2SC2759	2SC2759R
1. Emitter	1. Base
2. Base	2. Emitter
3. Collector	3. Collector

The 2SC2759, 2SC2759R are specially designed for use as VHF and UHF mixer and UHF oscillators in a tuner of TV receiver. The 2SC2759 and 2SC2759R feature high conversion gain and low distortion for mixer application, stable oscillation and small frequency drift against any change of the supply voltage and ambient temperature for oscillator application.

- Low noise. NF : 4.0dB (TYP.)
- High conversion gain. G_{cb} : 12.5dB (TYP.)
- Easy & economical mounting realizable with plastic mold package for Hybrid IC.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

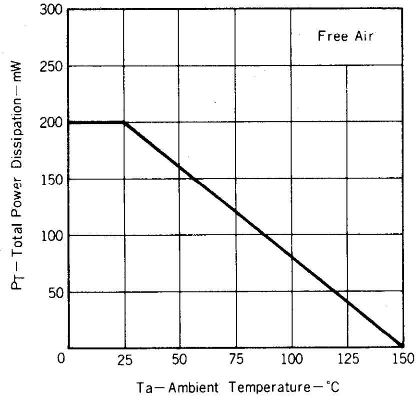
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	14	V
Emitter to Base Voltage	V_{EBO}	3.0	V
Collector Current	I_C	50	mA
Total Power Dissipation	P_T	200	mW
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	-55 to +150	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

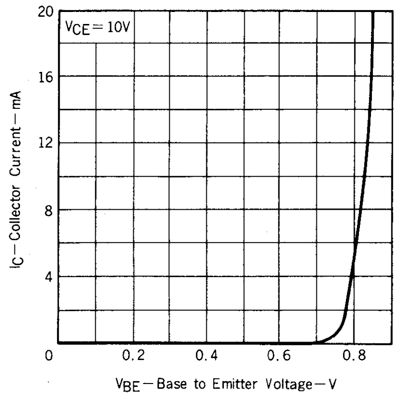
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB} = 15V, I_E = 0
DC Current Gain	h_{FE}	40	100	180		V_{CE} = 10V, I_C = 5.0mA
Gain Bandwidth Product	f_T	1.5	2.3		GHz	V_{CE} = 10V, I_E = -5.0mA
Output Capacitance	C_{ob}		1.0	1.3	pF	V_{CB} = 10V, I_E = 0, f = 1MHz
Noise Figure	NF		4.0	5.0	dB	V_{CB} = 10V, I_E = -5.0mA, f = 900MHz
Power Gain	G_{pb}	14	16		dB	V_{CB} = 10V, I_E = -5.0mA, f = 900MHz
Conversion Gain	G_{cb}	10	12.5		dB	f_{RF} = 900MHz, f_{LOC} = 930MHz V_{CB} = 10V, I_E = -5.0mA Local level = 110mV

TYPICAL CHARACTERISTICS (Ta = 25°C)

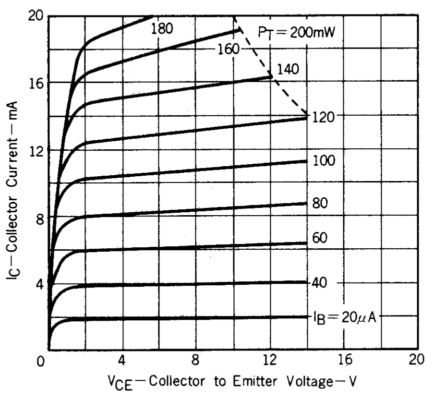
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



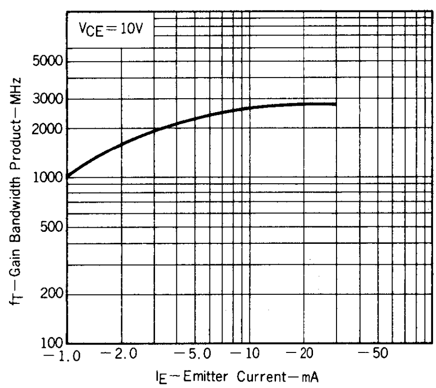
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



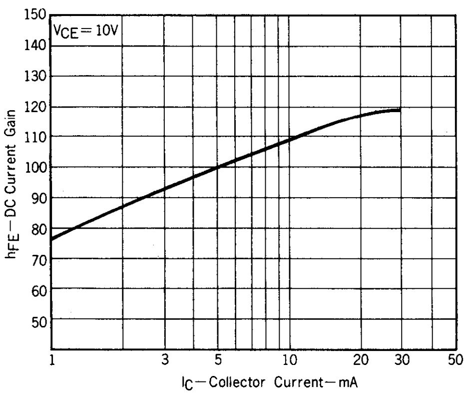
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



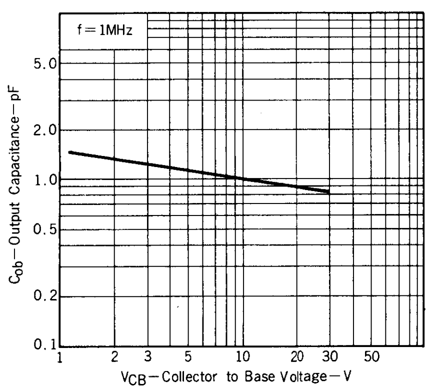
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



DC CURRENT GAIN vs. COLLECTOR CURRENT



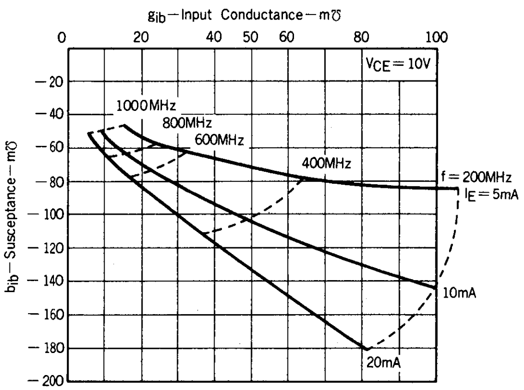
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



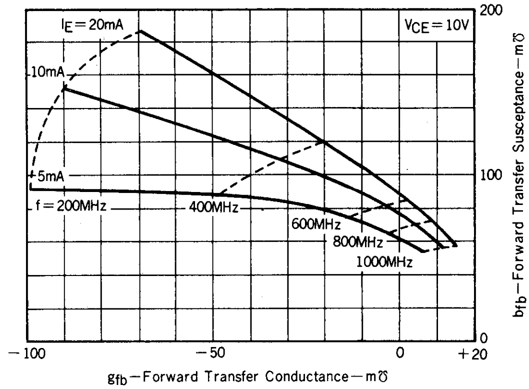
5

TYPICAL SMALL SIGNAL "Y" PARAMETERS (Common Base)

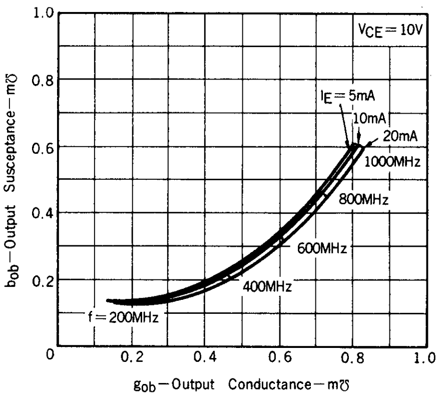
INPUT ADMITTANCE (Y_{ib}) vs. FREQUENCY



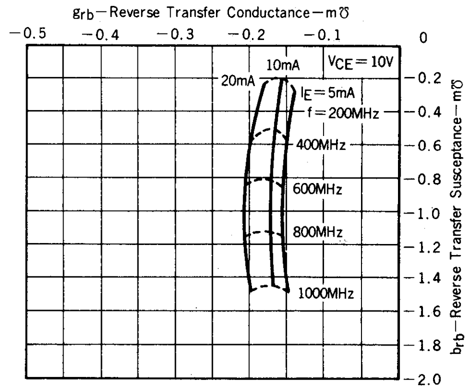
FORWARD TRANSFER ADMITTANCE (Y_{fb}) vs. FREQUENCY



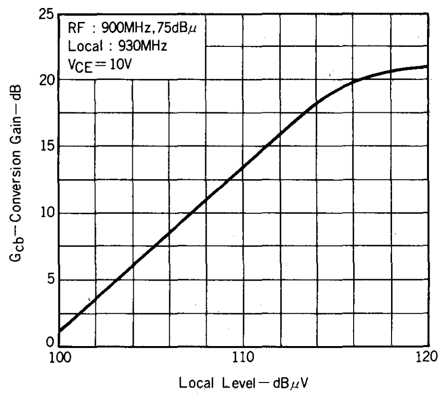
OUTPUT ADMITTANCE (Y_{ob}) vs. FREQUENCY



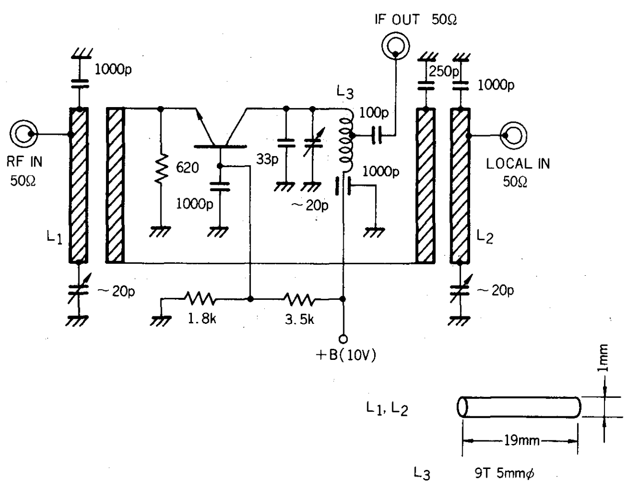
REVERSE TRANSFER ADMITTANCE (Y_{rb}) vs. FREQUENCY



CONVERSION GAIN vs. LOCAL OSCILLATOR LEVEL



900MHz G_{cb} Test Circuit



5

NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SC2780

NPN SILICON EPITAXIAL TRANSISTOR
POWER MINI MOLD

DESCRIPTION

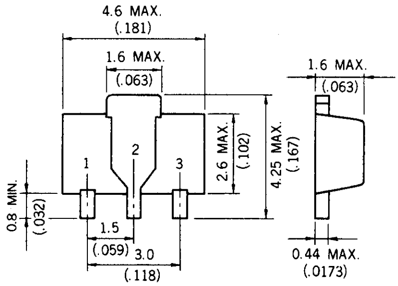
The 2SC2780 is designed for audio frequency preamplifier application, especially in Hybrid Integrated Circuits.

FEATURES

- World Standard Miniature Package
  : SOT–89
- High Collector to Emitter Voltage
  : $V_{CEO} > 140$ V
- Complements to PNP type 2SA1173

PACKAGE DIMENSIONS

in millimeters (inches)



1. Emitter
2. Collector
3. Base

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Voltages and Currents			
Collector to Base Voltage	V_{CBO}	140	V
Collector to Emitter Voltage	V_{CEO}	140	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current (DC)	I_C	50	mA
Collector Current (Pulse)*	I_C	100	mA
Maximum Power Dissipation			
Total Power Dissipation at 25 °C Ambient Temperature**	P_T	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

*PW ≦ 10 ms, duty cycle ≦ 50 %
**When mounted on ceramic substrate of 2.5 cm^2 x 0.7 mm

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			100	nA	V_{CB}=140 V, I_E=0
Emitter Cutoff Current	I_{EBO}			100	nA	V_{EB}=5.0 V, I_C=0
DC Current Gain	h_{FE1}	50	180			V_{CE}=10 V, I_C=1.0 mA ***
DC Current Gain	h_{FE2}	90	200	400		V_{CE}=10 V, I_C=10 mA ***
Collector Saturation Voltage	$V_{CE(sat)}$		0.07	0.60	V	I_C=20 mA, I_B=2.0 mA ***
Base Saturation Voltage	$V_{BE(sat)}$		0.75	1.0	V	I_C=20 mA, I_B=2.0 mA ***
Base to Emitter Voltage	V_{BE}	650	685	750	mV	V_{CE}=10 V, I_C=10 mA ***
Gain Bandwidth Product	f_T		120		MHz	V_{CE}=10 V, I_E=−10 mA
Output Capacitance	C_{ob}		2.3		pF	V_{CB}=10 V, I_E=0, f=1.0 MHz

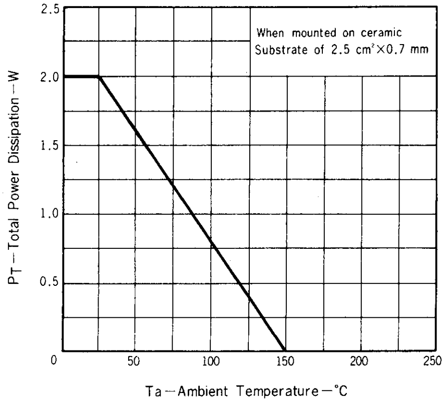
***Pulsed: PW ≦ 350 μs, duty cycle ≦ 2 %

h_{FE} Classification

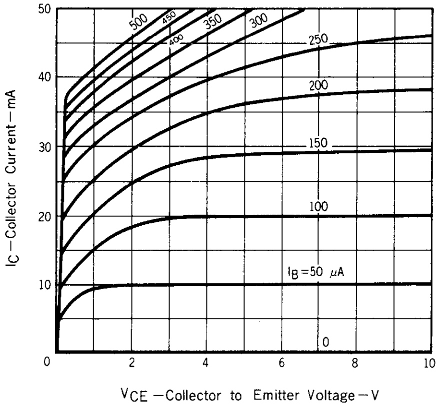
MARKING	NM	NL	NK
h_{FE2}	90 – 180	135 – 270	200 – 400

TYPICAL CHARACTERISTICS (Ta = 25 °C)

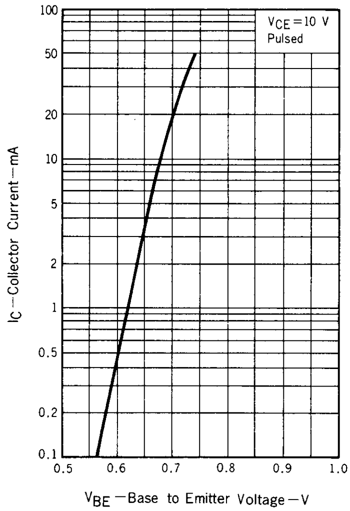
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



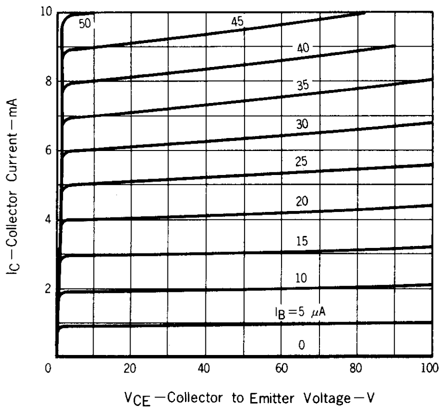
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



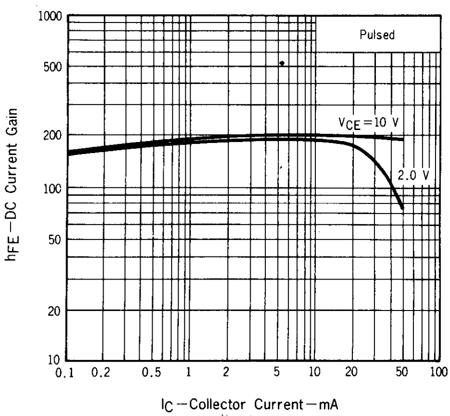
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



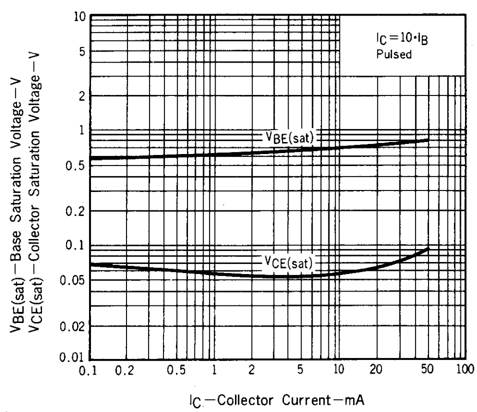
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT

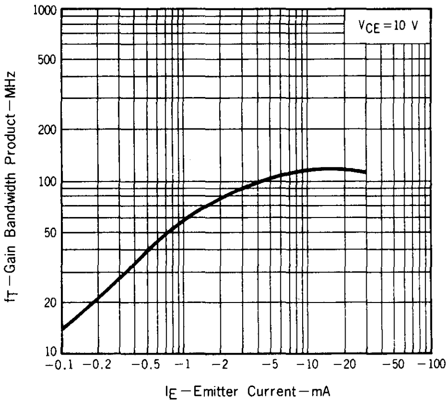


BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

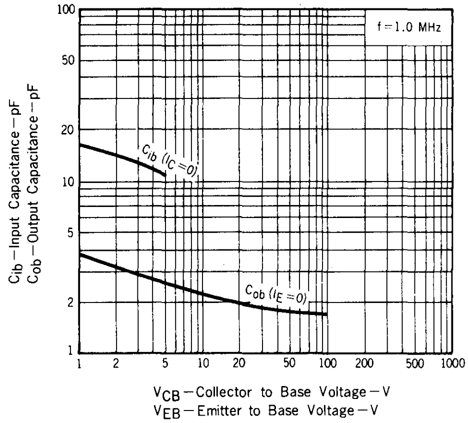


5

GAIN BANDWIDTH PRODUCT vs.
EMITTER CURRENT



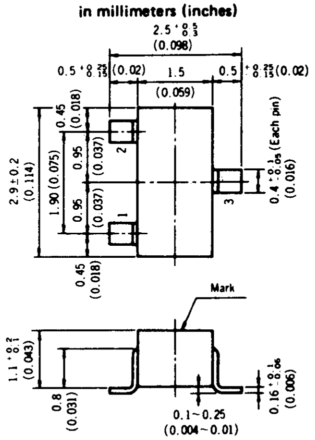
INPUT AND OUTPUT CAPACITANCE vs.
REVERSE VOLTAGE



2SD596,2SD596R

Audio Frequency Power Amplifier
NPN Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



2SD596
1. Emitter
2. Base
3. Collector

2SD596R
1. Base
2. Emitter
3. Collector

- Complimentary to 2SB624, 2SB624R
- High DC Current Gain: h_{FE} = 200 TYP. (V_{CE}=1.0V, I_C= 100mA)

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta = 25°C)			
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	25	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current (DC)	I_C	700	mA
Maximum Power Dissipation			
Total Power Dissipation			
at 25°C Ambient Temperature	P_T	200	mW
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

5

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB}=30V, I_E=0
Emitter Cutoff Current	I_{EBO}			0.1	μA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE1}	110	200	400		V_{CE}=1.0V, I_C=100mA *
DC Current Gain	h_{FE2}	50				V_{CE}=1.0V, I_C=700mA *
Collector Saturation Voltage	$V_{CE(sat)}$		0.20	0.6	V	I_C=700mA, I_B=70mA *
Base to Emitter Voltage	V_{BE}	600	640	700	mV	V_{CE}=6.0V, I_C=10mA *
Gain Bandwidth Product	f_T		170		MHz	V_{CE}=6.0V, I_E=−10mA
Output Capacitance	C_{ob}		13		pF	V_{CB}=6.0V, I_E=0, f=10MHz

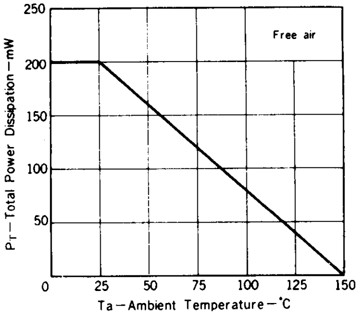
* Pulsed: PW ≦ 350 μs, duty cycle ≦ 2%

h_{FE1} Classification

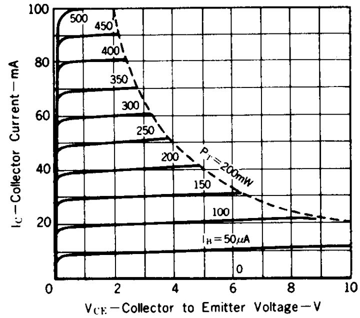
MARK						
MARK	2SD596	DV1	DV2	DV3	DV4	DV5
	2SD596R	1DV	2DV	3DV	4DV	5DV
h_{FE1}		110–180	135–220	170–270	200–320	250–400

TYPICAL CHARACTERISTICS (Ta=25°C)

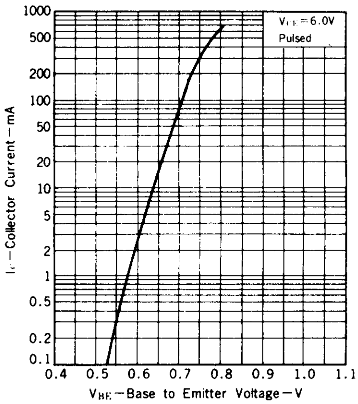
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



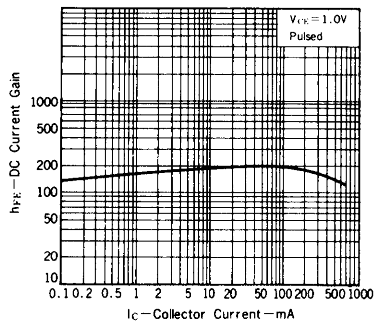
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



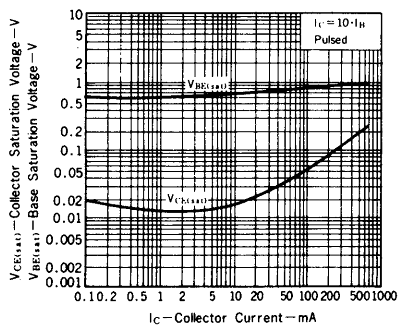
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT



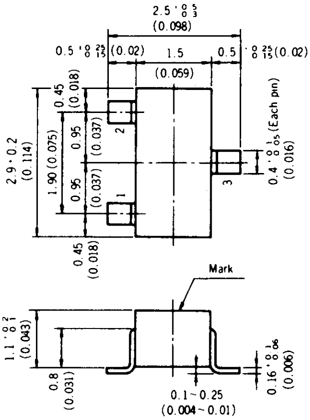
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



2SD780,2SD780R

Audio Frequency Power Amplifier
NPN Silicon Epitaxial Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



2SD780
1. Emitter
2. Base
3. Collector

2SD780R
1. Base
2. Emitter
3. Collector

- Complimentary to 2SB736, 2SB736R
- High DC Current Gain: h_{FE} = 200 TYP. (V_{CE} = 1.0V, I_C=50mA)

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Current (Ta = 25°C)			
Collector to Base Voltage	V_{CBO}	60	V
Collector to Emitter Voltage	V_{CEO}	60	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current (DC)	I_C	300	mA
Maximum Power Dissipation			
Total Power Dissipation at 25°C Ambient Temperature	P_T	200	mW
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			0.1	μA	V_{CB}=60V, I_E=0
Emitter Cutoff Current	I_{EBO}			0.1	μA	V_{EB}=5.0V, I_C=0
DC Current Gain	h_{FE1}	110	200	400		V_{CE}=1.0V, I_C=50mA *
DC Current Gain	h_{FE2}	30				V_{CE}=2.0V, I_C=300mA *
Collector Saturation Voltage	$V_{CE(sat)}$		0.15	0.6	V	I_C=300mA, I_B=30mA *
Base to Emitter Voltage	V_{BE}	600	645	700	mV	V_{CE}=6.0V, I_C=10mA *
Gain Bandwidth Product	f_T		140		MHz	V_{CE}=6.0V, I_E=−10mA
Output Capacitance	C_{ob}		6.7		pF	V_{CB}=6.0V, I_E=0, f=1.0MHz

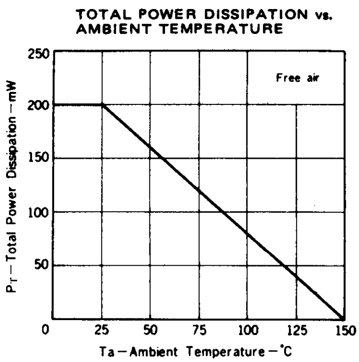
* Pulsed: PW ≦ 350 μs, duty cycle ≦ 2%

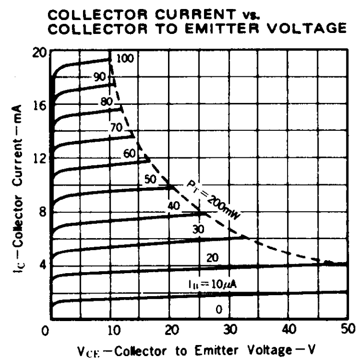
h_{FE1} Classification

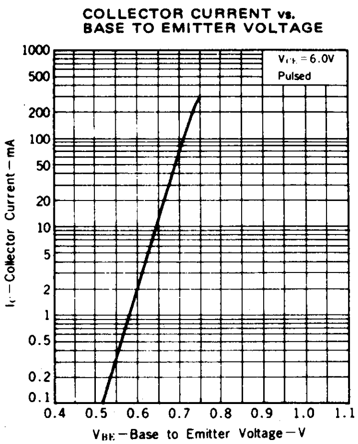
MARK						
MARK	2SD780	DW1	DW2	DW3	DW4	DW5
	2SD780R	1DW	2DW	3DW	4DW	5DW
h_{FE1}		110–180	135–220	170–270	200–320	250–400

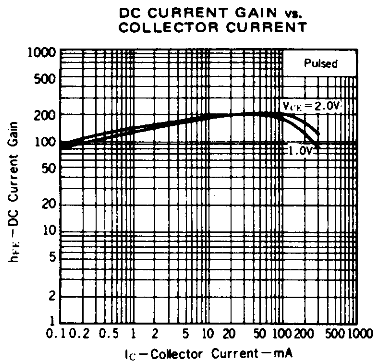
5

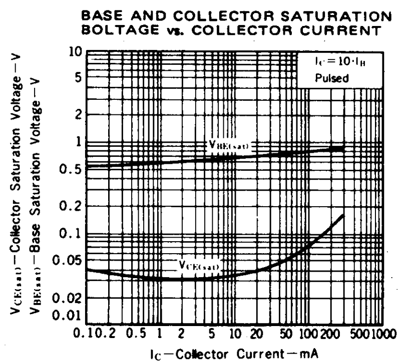
TYPICAL CHARACTERISTICS (Ta = 25°C)











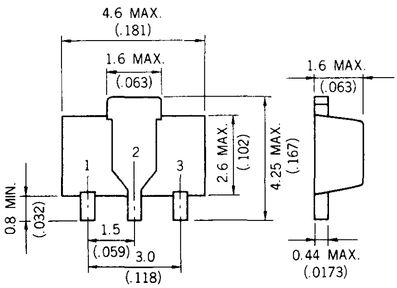
NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SD999

NPN SILICON EPITAXIAL TRANSISTOR
POWER MINI MOLD

DESCRIPTION
The 2SD999 is designed for audio frequency power amplifier application, especially in Hybrid Integrated Circuits.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Emitter
2. Collector
3. Base

FEATURES
- World Standard Miniature Package
  : SOT−89
- Low Collector Saturation Voltage
  : $V_{CE(sat)} < 0.4$ V ($I_C = 1.0$ A, $I_B = 100$ mA)
- Excellent DC Current Gain Linearity
  : $h_{FE} = 140$ TYP. ($V_{CE} = 1.0$ V, $I_C = 1.0$ A)
- Complements to PNP type 2SB798

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Voltages and Currents			
Collector to Base Voltage	V_{CBO}	30	V
Collector to Emitter Voltage	V_{CEO}	25	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current (DC)	I_C	1.0	A
Collector Current (Pulse)*	I_C	1.5	A
Maximum Power Dissipation			
Total Power Dissipation at 25 °C Ambient Temperature**	P_T	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

*PW ≦ 10 ms, duty cycle ≦ 50 %
**When mounted on ceramic substrate of 2.5 cm² x 0.7 mm

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			100	nA	V_{CB}=30 V, I_E=0
Emitter Cutoff Current	I_{EBO}			100	nA	V_{EB}=5.0 V, I_C=0
DC Current Gain	h_{FE1}	90	200	400		V_{CE}=1.0 V, I_C=100 mA ***
DC Current Gain	h_{FE2}	50	140			V_{CE}=1.0 V, I_C=1.0 A ***
Collector Saturation Voltage	$V_{CE(sat)}$		0.21	0.40	V	I_C=1.0 A, I_B=0.10 A ***
Base Saturation Voltage	$V_{BE(sat)}$		1.0	1.2	V	I_C=1.0 A, I_B=0.10 A ***
Base to Emitter Voltage	V_{BE}	600	630	700	mV	V_{CE}=6.0 V, I_C=10 mA ***
Gain Bandwidth Product	f_T		130		MHz	V_{CE}=6.0 V, I_E=−10 mA
Output Capacitance	C_{ob}		22		pF	V_{CB}=6.0 V, I_E=0, f=1.0 MHz

***Pulsed: PW ≦ 350 μs, duty cycle ≦ 2 %

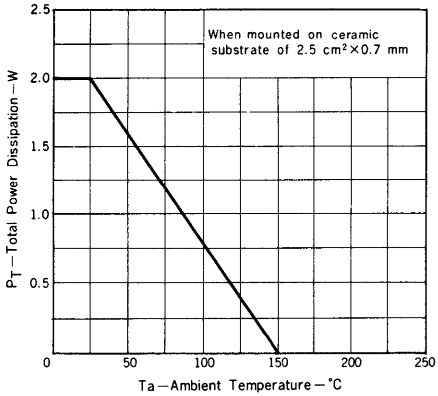
h_{FE} Classification

MARKING	CM	CL	CK
h_{FE1}	90 − 180	135 − 270	200 − 400

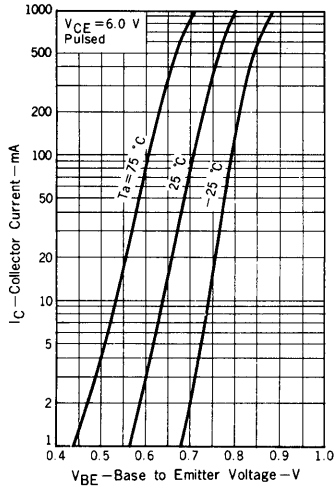
5

TYPICAL CHARACTERISTICS (Ta = 25 °C)

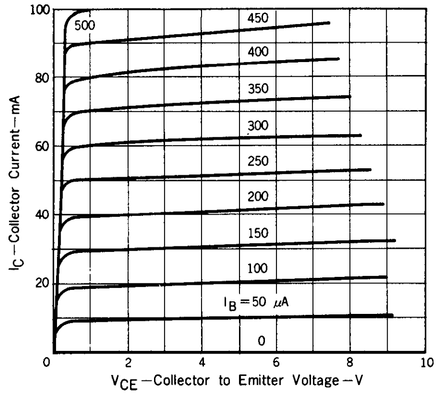
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



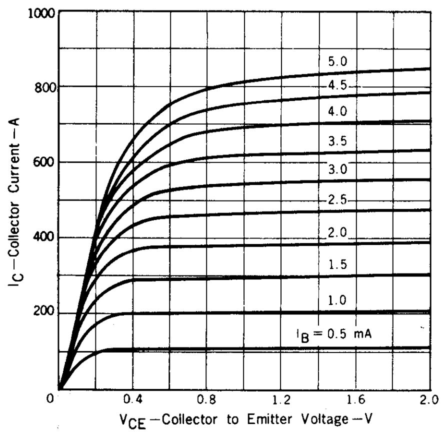
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



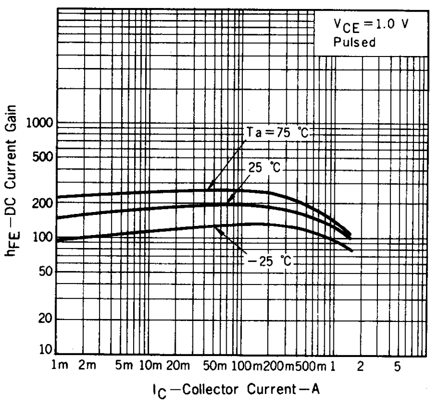
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



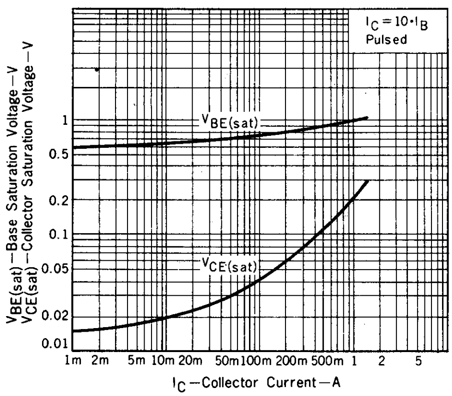
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



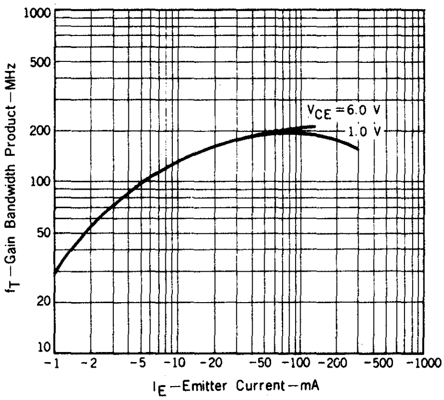
DC CURRENT GAIN vs. COLLECTOR CURRENT



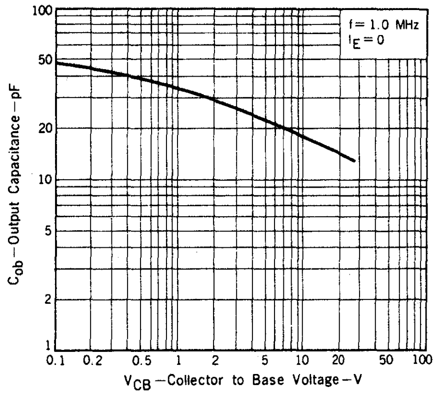
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



5

NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SD1000

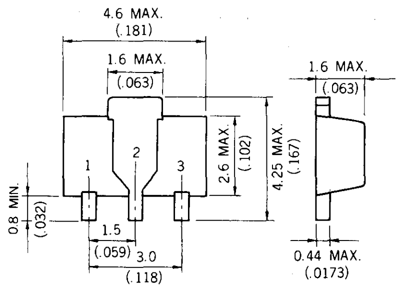
NPN SILICON EPITAXIAL TRANSISTOR
POWER MINI MOLD

DESCRIPTION

The 2SD1000 is designed for audio frequency power amplifier application, especially in Hybrid Integrated Circuits.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Emitter
2. Collector
3. Base

FEATURES

- World Standard Miniature Package
  : SOT−89
- Low Collector Saturation Voltage
  : $V_{CE(sat)} < 0.4$ V ($I_C = 500$ mA, $I_B = 50$ mA)
- Complements to PNP type 2SB799

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Voltages and Currents			
Collector to Base Voltage	V_{CBO}	60	V
Collector to Emitter Voltage	V_{CEO}	50	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current (DC)	I_C	0.7	A
Collector Current (Pulse)*	I_C	1.0	A
Maximum Power Dissipation			
Total Power Dissipation at 25 °C Ambient Temperature**	P_T	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

*PW ≦ 10 ms, duty cycle ≦ 50 %
**When mounted on ceramic substrate of 2.5 cm² x 0.7 mm

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			100	nA	V_{CB}=60 V, I_E=0
Emitter Cutoff Current	I_{EBO}			100	nA	V_{EB}=5.0 V, I_C=0
DC Current Gain	h_{FE1}	90	200	400		V_{CE}=1.0 V, I_C=100 mA ***
DC Current Gain	h_{FE2}	50	150			V_{CE}=1.0 V, I_C=500 mA ***
Collector Saturation Voltage	$V_{CE(sat)}$		0.12	0.40	V	I_C=500 mA, I_B=50 mA ***
Base Saturation Voltage	$V_{BE(sat)}$		0.9	1.2	V	I_C=500 mA, I_B=50 mA ***
Base to Emitter Voltage	V_{BE}	600	635	700	mV	V_{CE}=6.0 V, I_C=10 mA ***
Gain Bandwidth Product	f_T		110		MHz	V_{CE}=6.0 V, I_E=−10 mA
Output Capacitance	C_{ob}		13		pF	V_{CB}=6.0 V, I_E=0, f=1.0 MHz

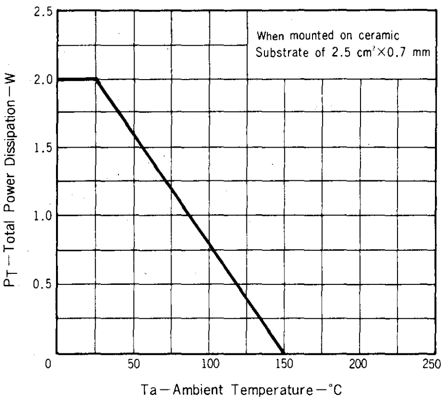
***Pulsed: PW ≦ 350 μs, duty cycle ≦ 2 %

h_{FE} Classification

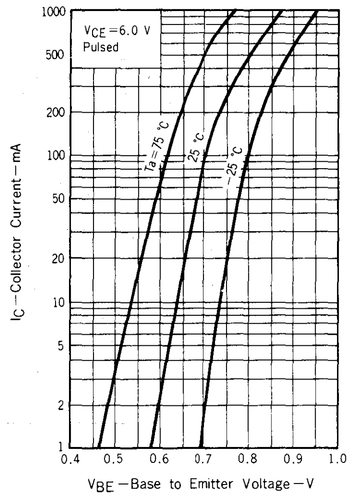
MARKING	LM	LL	LK
h_{FE1}	90 – 180	135 – 270	200 – 400

TYPICAL CHARACTERISTICS (Ta = 25 °C)

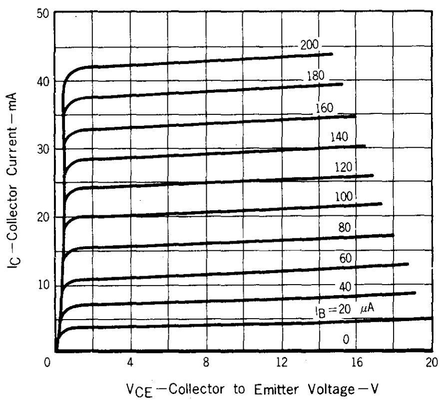
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



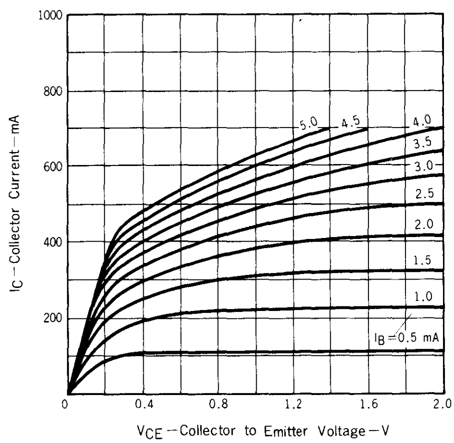
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE

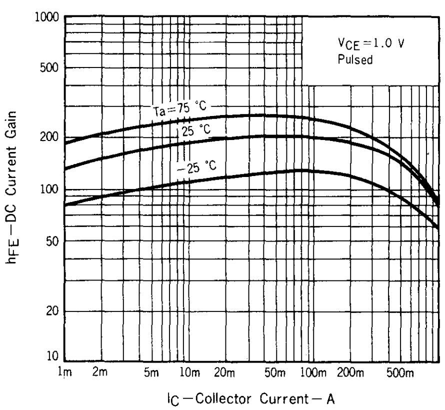


COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE

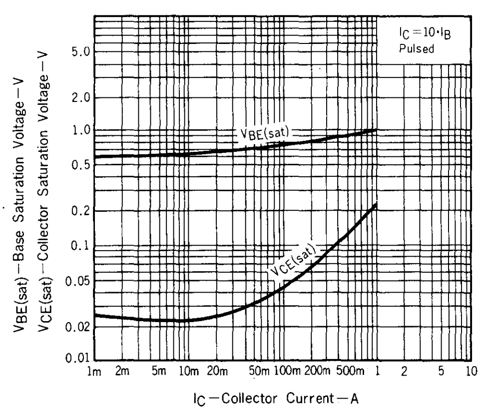


5

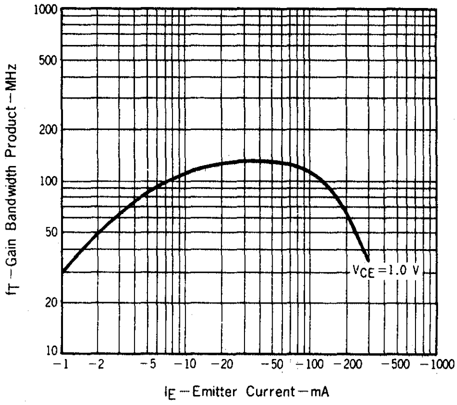
DC CURRENT GAIN vs.
COLLECTOR CURRENT



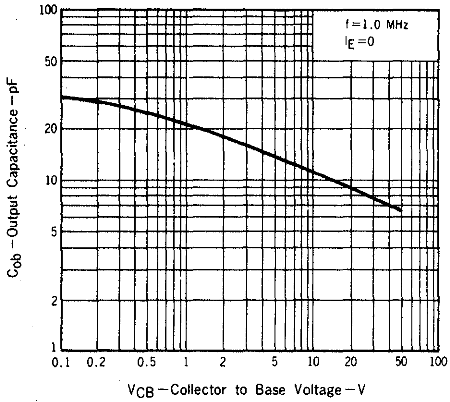
BASE AND COLLECTOR SATURATION
VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SD1001

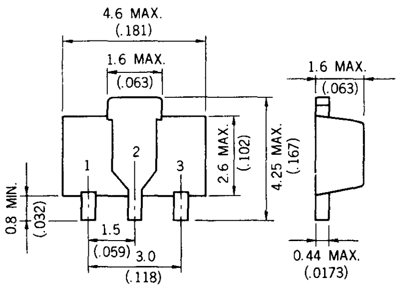
NPN SILICON EPITAXIAL TRANSISTOR
POWER MINI MOLD

DESCRIPTION

The 2SD1001 is designed for audio frequency power amplifier application, especially in Hybrid Integrated Circuits.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Emitter
2. Collector
3. Base

FEATURES

- World Standard Miniature Package : SOT−89
- High Collector to Emitter Voltage : $V_{CEO} > 80$ V
- Complements to PNP type 2SB800

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Voltages and Currents			
Collector to Base Voltage	V_{CBO}	80	V
Collector to Emitter Voltage	V_{CEO}	80	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current (DC)	I_C	300	mA
Collector Current (Pulse)*	I_C	500	mA
Maximum Power Dissipation			
Total Power Dissipation at 25 °C Ambient Temperature**	P_T	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

*PW ≦ 10 ms, duty cycle ≦ 50 %
**When mounted on ceramic substrate of 2.5 cm² x 0.7 mm

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			100	nA	V_{CB}=80 V, I_E=0
Emitter Cutoff Current	I_{EBO}			100	nA	V_{EB}=5.0 V, I_C=0
DC Current Gain	h_{FE1}	90	200	400		V_{CE}=1.0 V, I_C=50 mA ***
DC Current Gain	h_{FE2}	30	80			V_{CE}=2.0 V, I_C=300 mA ***
Collector Saturation Voltage	$V_{CE(sat)}$		0.15	0.60	V	I_C=300 mA, I_B=30 mA ***
Base Saturation Voltage	$V_{BE(sat)}$		0.86	1.2	V	I_C=300 mA, I_B=30 mA ***
Base to Emitter Voltage	V_{BE}	600	645	700	mV	V_{CE}=6.0 V, I_C=10 mA ***
Gain Bandwidth Product	f_T		140		MHz	V_{CE}=6.0 V, I_E=−10 mA
Output Capacitance	C_{ob}		7.0		pF	V_{CB}=6.0 V, I_E=0, f=1.0 MHz

***Pulsed: PW ≦ 350 μs, duty cycle ≦ 2 %

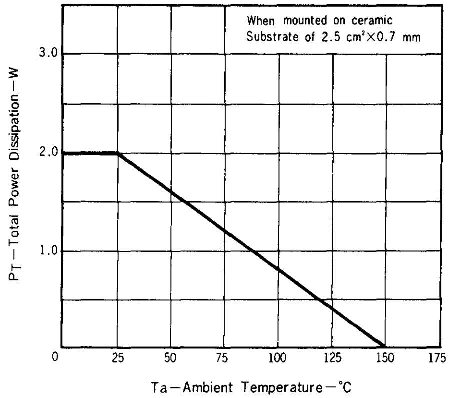
h_{FE} Classification

MARKING	EM	EL	EK
h_{FE1}	90 – 180	135 – 270	200 – 400

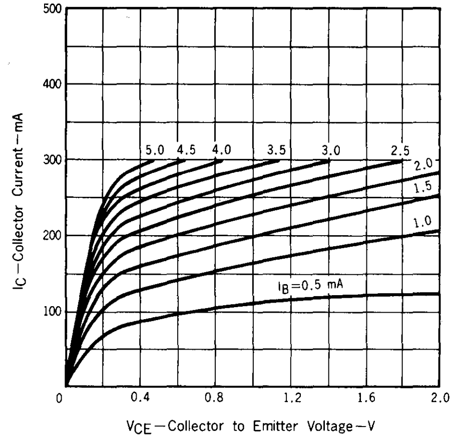
5

TYPICAL CHARACTERISTICS (Ta = 25 °C)

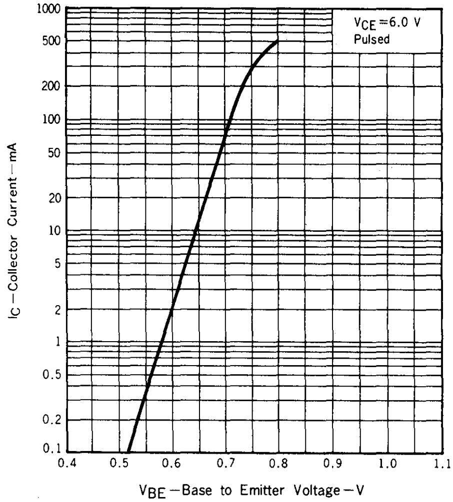
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



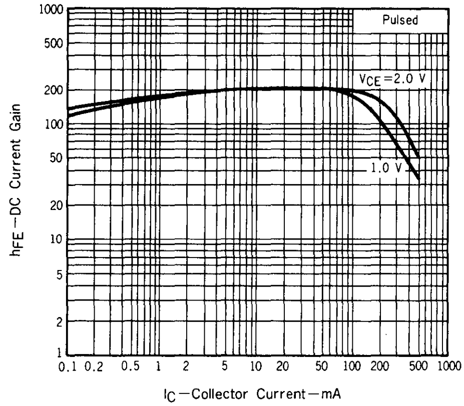
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



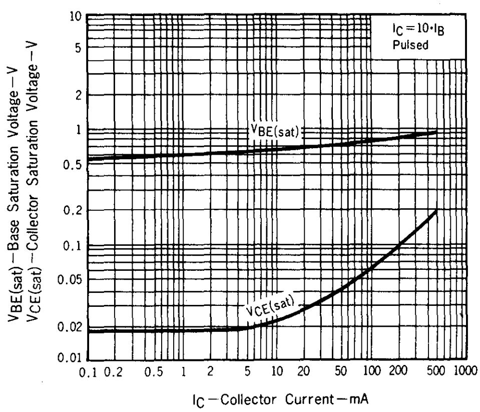
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



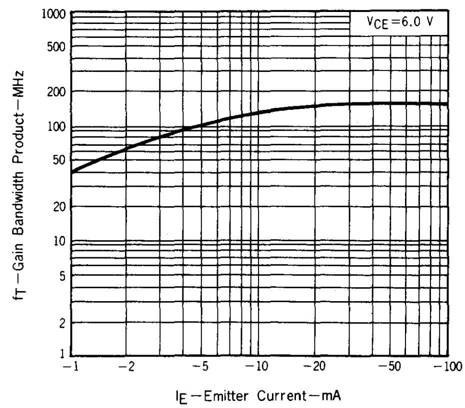
DC CURRENT GAIN vs. COLLECTOR CURRENT



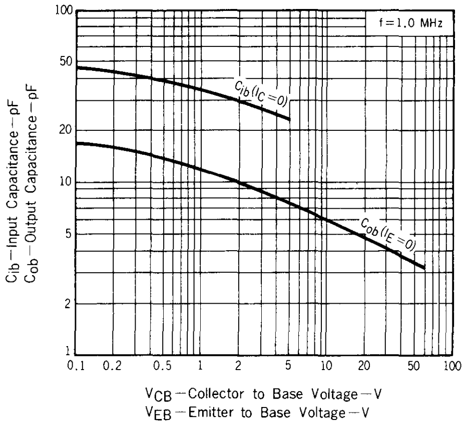
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



INPUT AND OUTPUT CAPACITANCE
vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

SILICON TRANSISTOR
2SD1005

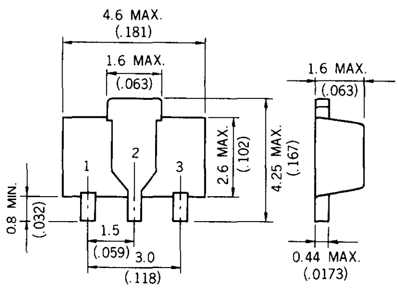
NPN SILICON EPITAXIAL TRANSISTOR
POWER MINI MOLD

DESCRIPTION

The 2SD1005 is designed for audio frequency power amplifier application, especially in Hybrid Integrated Circuits.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Emitter
2. Collector
3. Base

FEATURES

- World Standard Miniature Package
  : SOT−89
- High Collector to Base Voltage
  : $V_{CBO} > 100$ V
- Excellent DC Current Gain Linearity
  : $h_{FE} = 80$ TYP. ($V_{CE} = 2.0$ V, $I_C = 500$ mA)
- Complements to PNP type 2SB804

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Voltages and Currents			
Collector to Base Voltage	V_{CBO}	100	V
Collector to Emitter Voltage	V_{CEO}	80	V
Emitter to Base Voltage	V_{EBO}	5.0	V
Collector Current (DC)	I_C	1.0	A
Collector Current (Pulse)*	I_C	1.5	A
Maximum Power Dissipation			
Total Power Dissipation at 25 °C Ambient Temperature**	P_T	2.0	W
Maximum Temperatures			
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_{stg}	−55 to +150	°C

*PW ≦ 10 ms, duty cycle ≦ 50 %
**When mounted on ceramic substrate of 2.5 cm² x 0.7 mm

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			100	nA	V_{CB}=100 V, I_E=0
Emitter Cutoff Current	I_{EBO}			100	nA	V_{EB}=5.0 V, I_C=0
DC Current Gain	h_{FE1}	90	200	400		V_{CE}=2.0 V, I_C=100 mA ***
DC Current Gain	h_{FE2}	25	80			V_{CE}=2.0 V, I_C=500 mA ***
Collector Saturation Voltage	$V_{CE(sat)}$		0.15	0.50	V	I_C=500 mA, I_B=50 mA ***
Base Saturation Voltage	$V_{BE(sat)}$		0.9	1.50	V	I_C=500 mA, I_B=50 mA ***
Base to Emitter Voltage	V_{BE}	600	630	700	mV	V_{CE}=10 V, I_C=10 mA ***
Gain Bandwidth Product	f_T		160		MHz	V_{CE}=5.0 V, I_E=−10 mA
Output Capacitance	C_{ob}		12		pF	V_{CB}=10 V, I_E=0, f=1.0 MHz

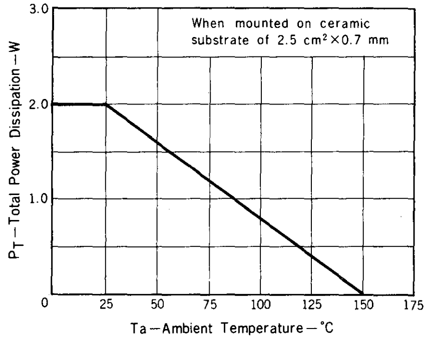
***Pulsed: PW≦350 μs, duty cycle≦2 %

h_{FE} Classification

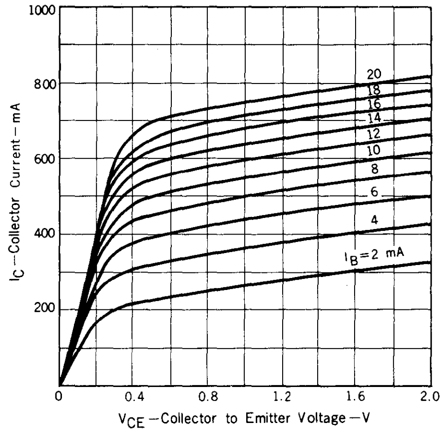
MARKING	BW	BV	BU
h_{FE1}	90 − 180	135 − 270	200 − 400

TYPICAL CHARACTERISTICS (Ta = 25 °C)

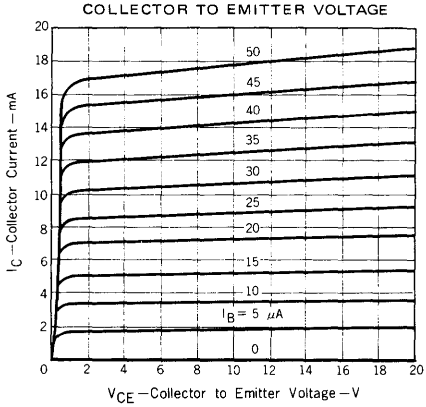
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



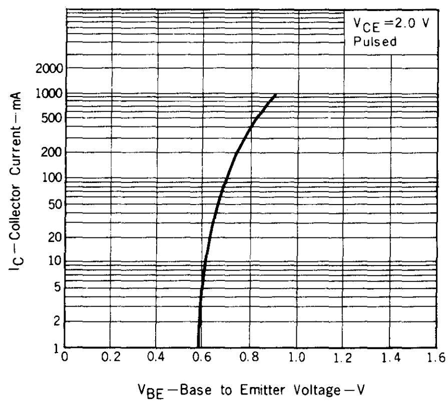
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



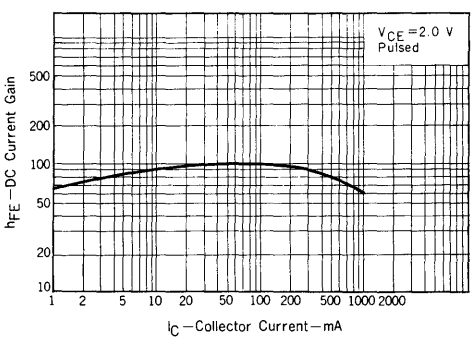
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



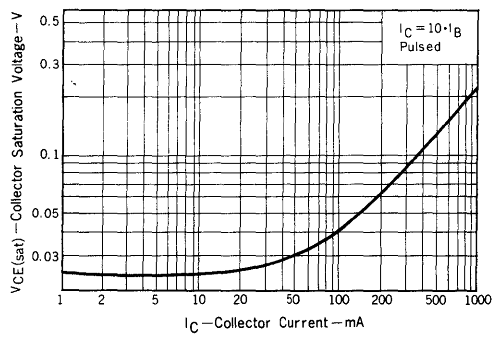
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



DC CURRENT GAIN vs. COLLECTOR CURRENT

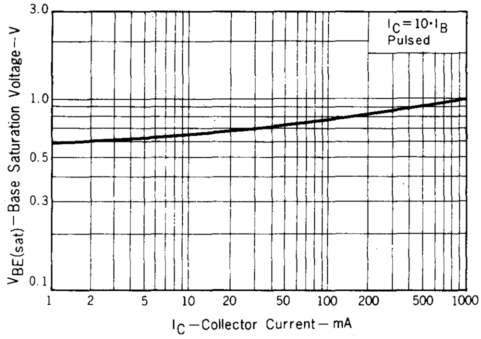


COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT

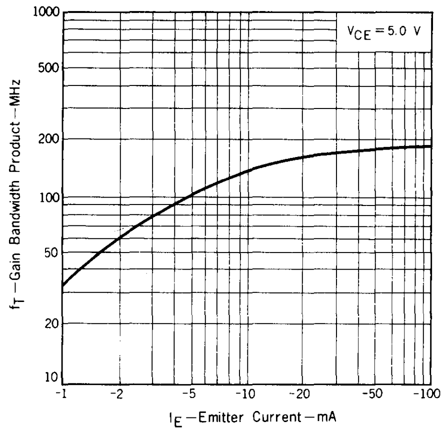


5

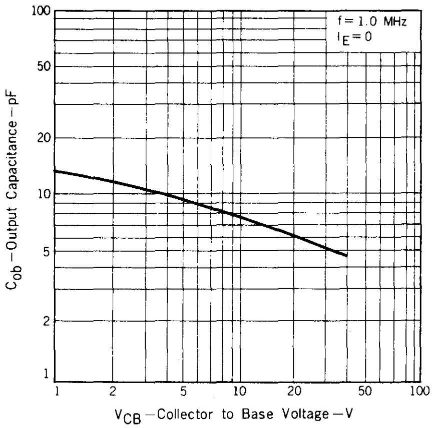
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

SILICON TRANSISTORS
2SD1006,2SD1007

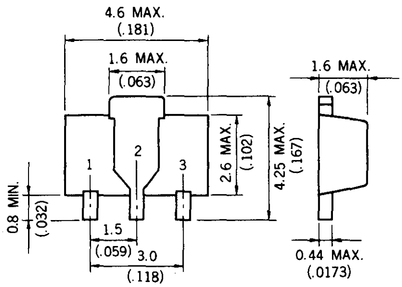
NPN SILICON EPITAXIAL TRANSISTORS POWER MINI MOLD

DESCRIPTION

The 2SD1006 and 2SD1007 are designed for audio frequency power amplifier application, especially in Hybrid Integrated Circuits.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Emitter
2. Collector
3. Base

FEATURES

- World Standard Miniature Package : SOT−89
- High Collector to Emitter Voltage : $V_{CEO} > 120$ V (2SD1007)
  : $V_{CEO} > 100$ V (2SD1006)
- Complement to PNP type 2SB805 and 2SB806 respectively.

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

		2SD1006	2SD1007	
Maximum Voltages and Currents				
Collector to Base Voltage	V_{CBO}	100	120	V
Collector to Emitter Voltage	V_{CEO}	100	120	V
Emitter to Base Voltage	V_{EBO}	5.0		V
Collector Current (DC)	I_C	0.7		A
Collector Current (Pulse)*	I_C	1.2		A
Maximum Power Dissipation				
Total Power Dissipation at 25 °C Ambient Temperature**	P_T	2.0		W
Maximum Temperatures				
Junction Temperature	T_j	150		°C
Storage Temperature Range	T_{stg}	−55 to +150		°C

*PW ≦10 ms, duty cycle ≦50 %
**When mounted on ceramic substrate of 2.5 cm² x 0.7 mm

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS	
Collector Cutoff Current	I_{CBO}			100	nA	2SD1006	V_{CB}=100 V, I_E=0
				100	nA	2SD1007	V_{CB}=120 V, I_E=0
Emitter Cutoff Current	I_{EBO}			100	nA	V_{EB}=5.0 V, I_C=0	
DC Current Gain	h_{FE1}	45	200			V_{CE}=1.0 V, I_C=5.0 mA	***
DC Current Gain	h_{FE2}	90	200	400		V_{CE}=1.0 V, I_C=100 mA	***
Collector Saturation Voltage	$V_{CE(sat)}$		0.3	0.6	V	I_C=500 mA, I_B=50 mA	***
Base Saturation Voltage	$V_{BE(sat)}$		0.9	1.5	V	I_C=500 mA, I_B=50 mA	***
Base to Emitter Voltage	V_{BE}	550	620	650	mV	V_{CE}=10 V, I_C=10 mA	***
Gain Bandwidth Product	f_T		90		MHz	V_{CE}=10 V, I_E=−10 mA	
Output Capacitance	C_{ob}		12		pF	V_{CB}=10 V, I_E=0, f=1.0 MHz	

***Pulsed: PW ≦350 μs, duty cycle ≦2 %

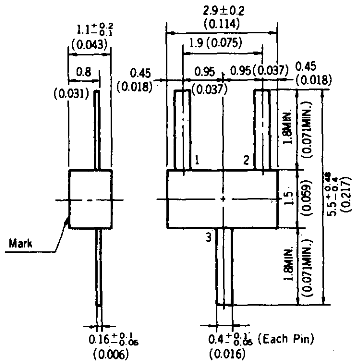
h_{FE} Classification

MARKING				
MARKING	2SD1006	HM	HL	HK
	2SD1007	HR	HQ	HP
h_{FE2}		90 − 180	135 − 270	200 − 400

2SK67

Impedance Converter
N-channel Silicon Junction FET

PACKAGE DIMENSIONS
in millimeters (inches)



1. Source
2. Drain
3. Gate

- Low zero gate voltage drain current: I_{DSS} = 200μA TYP.
- High forward transfer admittance:
  $|y_{fs2}|$ = 1500μ℧ TYP. (V_{DS} = 5.0V, V_{GS} = 0)

ABSOLUTE MAXIMUM RATINGS

Maximum Voltage and Currents (Ta=25°C)			
Gate to Drain Voltage	V_{GDO}	−20	V
Gate Current	I_G	10	mA
Drain Current (DC)	I_D	10	mA
Maximum Power Dissipation			
Total Power Dissipation at 25°C Ambient Temperature	P_T	80	mW
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature Range	T_{stg}	−55 to +100	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

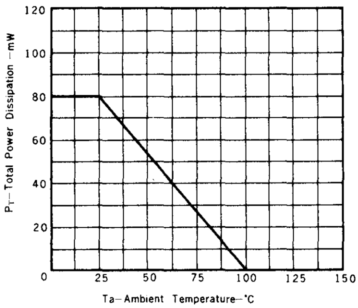
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Zero-Gate-Voltage Drain Current	I_{DSS}	20		1000	μA	V_{DS}=5.0V, V_{GS}=0
Gate-Source Cutoff Voltage	$V_{GS(off)}$			-0.8	V	V_{DS}=5.0V, I_D=1.0μA
Forward Transfer Admittance	$\|Y_{fs1}\|$	350			μ℧	V_{DS}=5.0V, I_D=30μA, f=1.0kHz
	$\|Y_{fs2}\|$		1500		μ℧	V_{DS}=5.0V, V_{GS}=0, f=1.0kHz
Input Capacitance	C_{iss}		5.5		pF	V_{DS}=5.0V, V_{GS}=0, f=1.0MHz
Output Capacitance	C_{oss}		2.7		pF	

I_{DSS} Classification

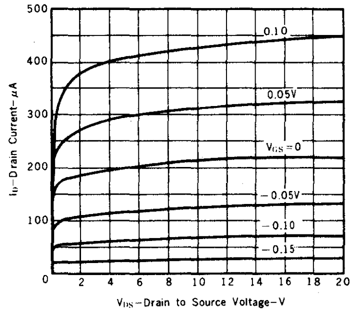
MARK	J2	J3	J4	J5	J6	J7	J8
I_{DSS}(μA)	20 – 40	35 – 70	60 – 120	100 – 200	150 – 300	270 – 540	500 – 1000

TYPICAL CHARACTERISTICS (Ta = 25°C)

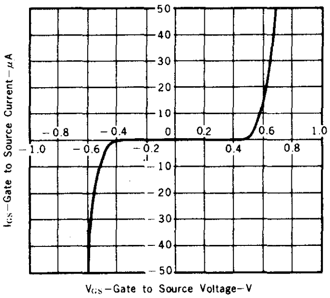
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



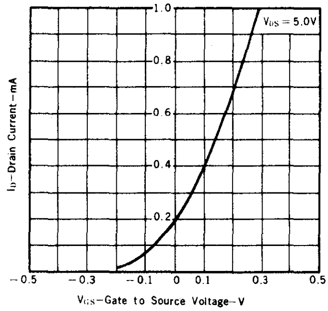
DRAIN CURRENT vs.
DRAIN TO SOURCE VOLTAGE



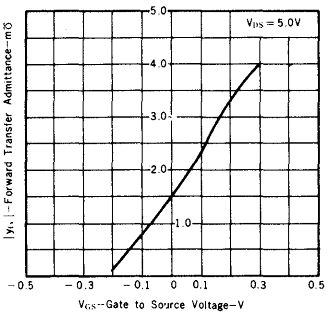
GATE TO SOURCE CURRENT vs.
GATE TO SOURCE VOLTAGE



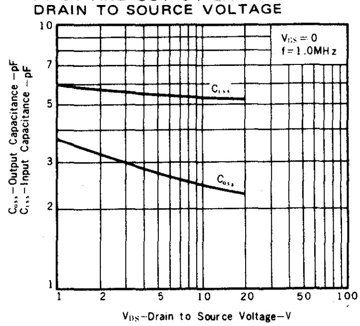
DRAIN CURRENT vs.
GATE TO SOURCE VOLTAGE



FORWARD TRANSFER ADMITTANCE vs.
GATE TO SOURCE VOLTAGE

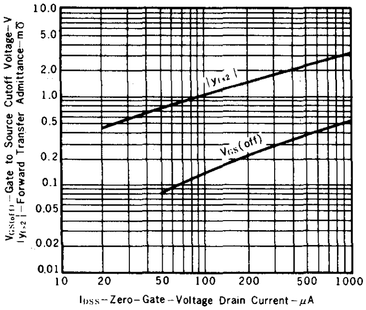


INPUT AND OUTPUT CAPACITANCE vs.
DRAIN TO SOURCE VOLTAGE



5

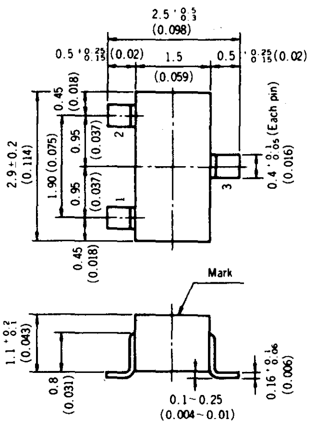
GATE TO SOURCE CUTOFF VOLTAGE
AND FORWARD TRANSFER ADMITTANCE vs.
ZERO-GATE-VOLTAGE DRAIN CURRENT



2SK160

AF & RF Amplifier
N-Channel Silicon Junction Field Effect Transistor

PACKAGE DIMENSIONS
in millimeters (inches)



1. Drain
2. Source
3. Gate

- General Purpose

ABSOLUTE MAXIMUM RATINGS (T_a=25°C)

Maximum Voltages and Currents			
Gate to Drain Voltage	V_{GDO}	–30	V
Gate to Source Voltage	V_{GSO}	–30	V
Drain Current (DC)	I_D	20	mA
Gate Current (DC)	I_G	10	mA
Maximum Power Dissipation			
Total Power Dissipation at 25°C Ambient Temperature	P_T	150	mW
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature Range	T_{stg}	–55 to +125	°C

5

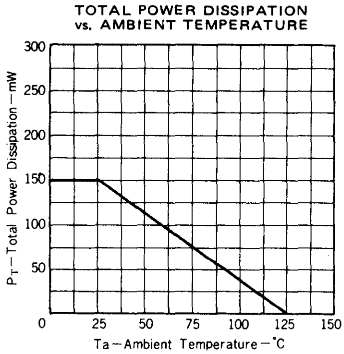
ELECTRICAL CHARACTERISTICS (T_a = 25°C)

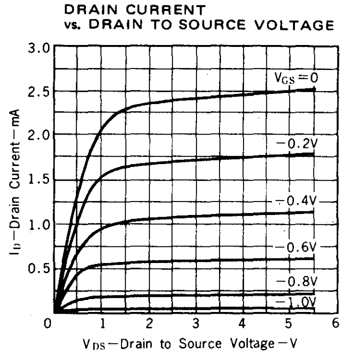
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Gate Cutoff Current	I_{GSS}			–10	nA	V_{GS}=–30V, V_{DS}=0
Zero-Gate Voltage Drain Current	I_{DSS}	0.5	2.5	12	mA	V_{DS}=5.0V, V_{GS}=0
Gate to Source Cutoff Voltage	$V_{GS(off)}$	–0.25	–1.1	–4.5	V	V_{DS}=5.0V, I_D=10μA
Forward Transfer Admittance	$\|Y_{fs}\|_1$	1.5	2.1		m℧	V_{DS}=5.0V, I_D=0.5mA, f=1.0kHz
Forward Transfer Admittance	$\|Y_{fs}\|_2$	1.5	4.1		m℧	V_{DS}=5.0V, V_{GS}=0, f=1.0kHz
Input Capacitance	C_{iss}		4.0		pF	V_{DS}=10V, V_{GS}=0, f=1.0MHz
Feedback Capacitance	C_{rss}		0.9		pF	V_{DS}=10V, V_{GS}=0, f=1.0MHz

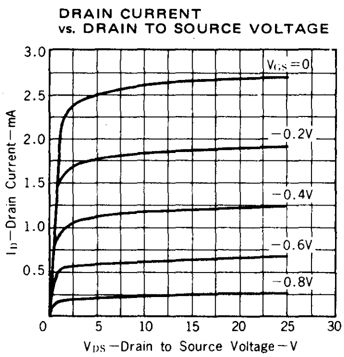
I_{DSS} Classification

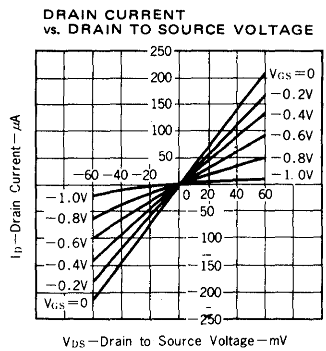
MARK	K4	K5	K6	K7
I_{DSS}(mA)	0.5 – 1.5	1.0 – 3.0	2.0 – 6.0	4.0 – 12

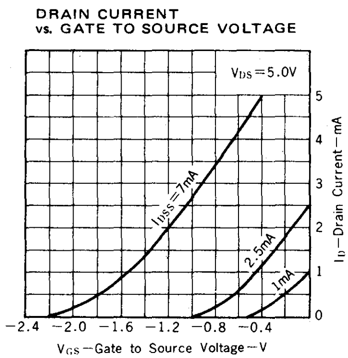
TYPICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

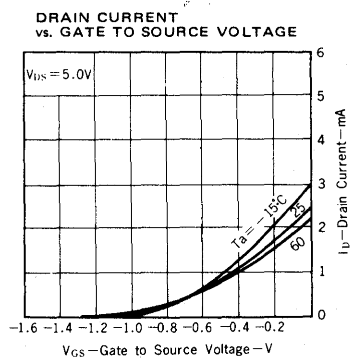




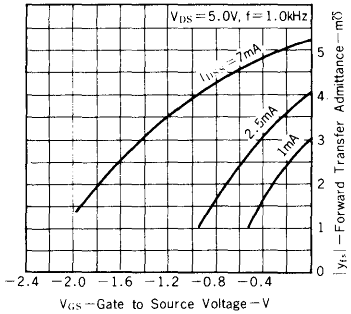




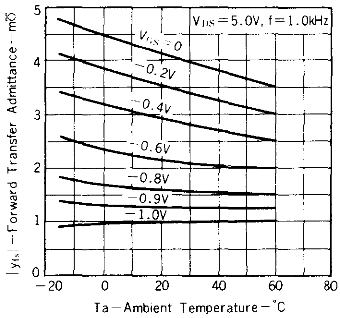




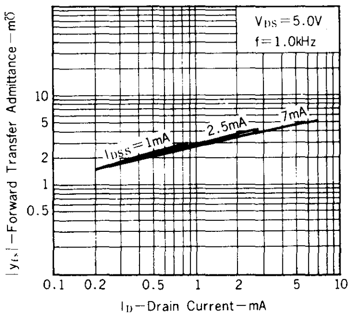
FORWARD TRANSFER ADMITTANCE vs. GATE TO SOURCE VOLTAGE



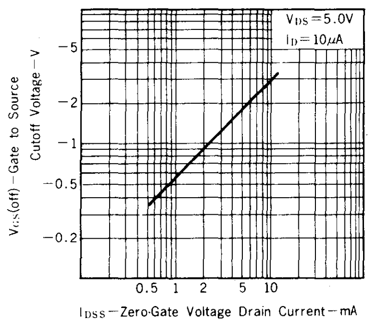
FORWARD TRANSFER ADMITTANCE vs. AMBIENT TEMPERATURE



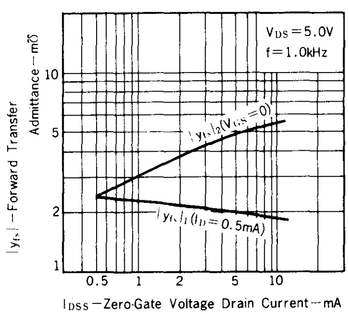
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT



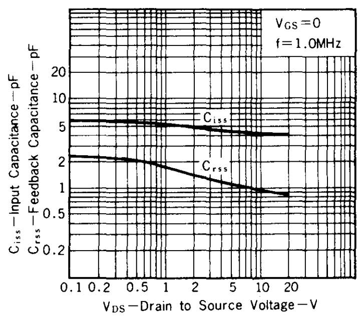
GATE TO SOURCE CUTOFF VOLTAGE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



FORWARD TRANSFER ADMITTANCE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



INPUT AND FEEDBACK CAPACITANCE vs. DRAIN TO SOURCE VOLTAGE

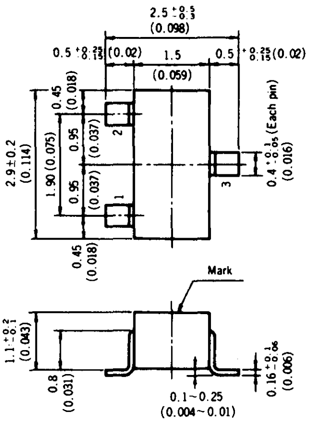


5

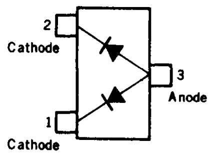
1S2835, 1S2836

High Speed Switching
Silicon Epitaxial Double Diodes : Common Anode

PACKAGE DIMENSIONS
in millimeters (inches)



Connection Diagram
(Top View)



Mark	
1S2835	A3
1S2836	A4

- Low capacitance: C_t = 2.5pF TYP.
- High speed switching: t_{rr} = 4.0ns MAX.
- Wide applications including switching, limitter, clipper.
- Double diode configuration assures economical use.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta = 25°C)		IS2835	IS2836	
Peak Reverse Voltage	V_{RM}	35	75	V
DC Reverse Voltage	V_R	30	50	V
Surge Current (1 μs)*	I_{FSM}	6.0	6.0	A
Surge Current (1 μs)	I_{FSM}	4.0	4.0	A
Peak Forward Current*	I_{FM}	450	450	mA
Peak Forward Current	I_{FM}	300	300	mA
Average Rectified Current*	I_o	150	150	mA
Average Rectified Current	I_o	100	100	mA
Maximum Temperatures				
Junction Temperature	T_j	125	125	°C
Storage Temperature Range	T_{stg}	−55 to +125	−55 to +125	°C
Thermal Resistance				
Junction to Ambient*	$R_{th(j-a)}$	1.0	1.0	°C/mW
Junction to Ambient	$R_{th(j-a)}$	0.67	0.67	°C/mW

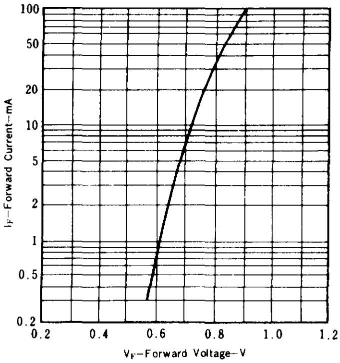
* Both diodes loaded simultaneously.

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

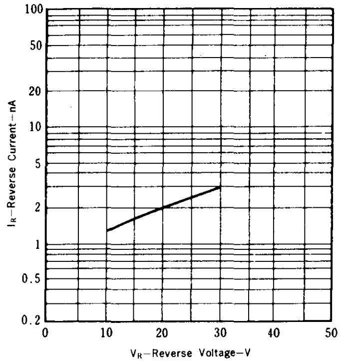
CHARACTERISTIC	SYMBOL	1S2835 (A3)			1S2836 (A4)			UNIT	TEST CONDITIONS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
Forward Voltage	V_{F1}		0.72	1.0		0.72	1.0	V	* I_F=10mA
	V_{F2}		0.83	1.0		0.83	1.0	V	I_F=50mA
	V_{F3}		0.9	1.2		0.9	1.2	V	I_F=100mA
Reverse Current	I_R			0.1				μA	V_R=30V
	I_R						0.1	μA	V_R=50V
Capacitance	C_t		2.5	4.0		2.5	4.0	pF	V_R=0, f=1.0MHz
Reverse Recovery Time	t_{rr}			4.0			4.0	ns	See test circuit.

TYPICAL CHARACTERISTICS (Ta = 25°C)

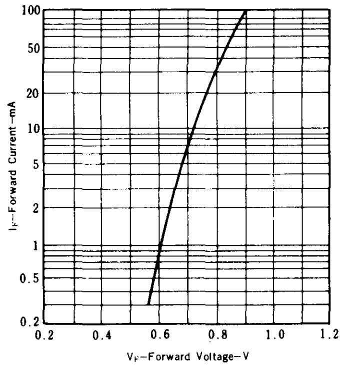
1S2835 FORWARD CURRENT vs. FORWARD VOLTAGE



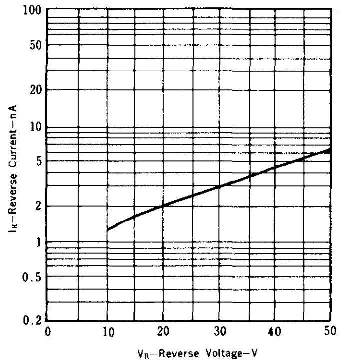
1S2835 REVERSE CURRENT vs. REVERSE VOLTAGE



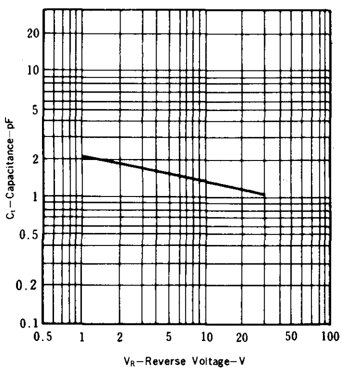
1S2836 FORWARD CURRENT vs. FORWARD VOLTAGE



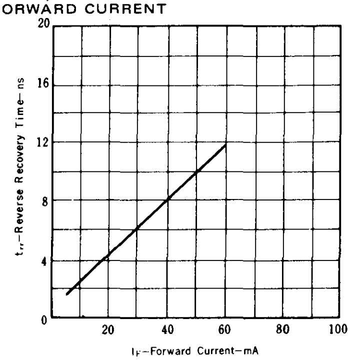
1S2836 REVERSE CURRENT vs. REVERSE VOLTAGE



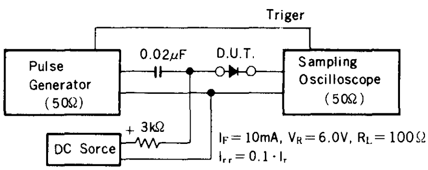
1S2835, 2836 TERMINAL CAPACITANCE vs. REVERSE VOLTAGE

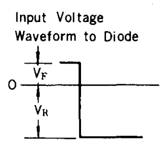


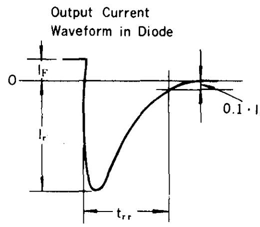
1S2835, 2836 REVERSE RECOVERY TIME vs. FORWARD CURRENT



t_{rr} REVERSE RECOVERY TIME TEST CIRCUIT



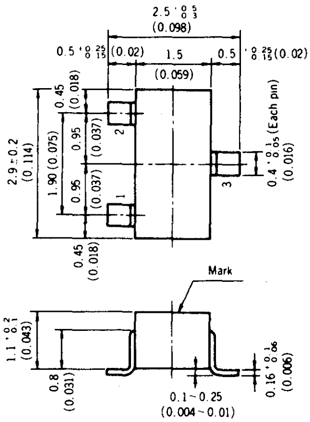




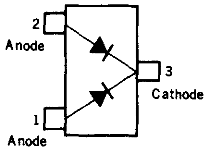
1S2837, 1S2838

High Speed Switching
Silicon Epitaxial Double Diodes: Common Cathode

PACKAGE DIMENSIONS
in millimeters (inches)



Connection Diagram (Top View)



Mark
1S2837 A5
1S2838 A6

- Low capacitance: C_t = 1.1pF TYP.
- High speed switching: t_{rr} =3.0ns MAX.
- Wide applications including switching, limitter, clipper.
- Double diode configuration assures economical use.

ABSOLUTE MAXIMUM RATINGS

Maximum Voltages and Currents (Ta=25°C)		IS2837	IS2838	
Peak Reverse Voltage	V_{RM}	35	75	V
DC Reverse Voltage	V_R	30	50	V
Surge Current (1 μs)*	I_{FSM}	6.0	6.0	A
Surge Current (1 μs)	I_{FSM}	4.0	4.0	A
Peak Forward Current*	I_{FM}	450	450	mA
Peak Forward Current	I_{FM}	300	300	mA
Average Rectified Current*	I_o	150	150	mA
Average Rectified Current	I_o	100	100	mA
Maximum Temperatures				
Junction Temperature	T_j	125	125	°C
Storage Temperature Range	T_{stg}	−55 to +125	−55 to +125	°C
Thermal Resistance				
Junction to Ambient*	$R_{th(j\text{-}a)}$	1.0	1.0	°C/mW
Junction to Ambient	$R_{th(j\text{-}a)}$	0.67	0.67	°C/mW

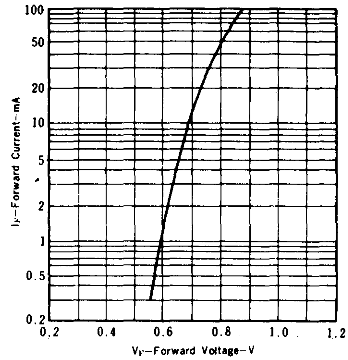
* Both diodes loaded simultaneously.

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

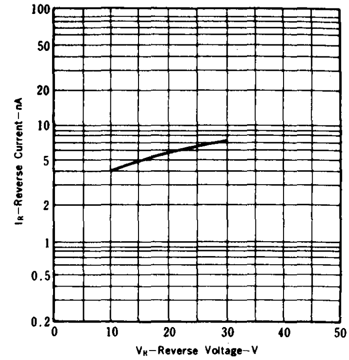
CHARACTERISTIC	SYMBOL	1S2837 (A5)			1S2838 (A6)			UNIT	TEST CONDITIONS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
Forward Voltage	V_{F1}		0.7	1.0		0.7	1.0	V	I_F=10mA
	V_{F2}		0.79	1.0		0.79	1.0	V	I_F=50mA
	V_{F3}		0.85	1.2		0.85	1.2	V	I_F=100mA
Reverse Current	I_R			0.1				μA	V_R=30V
	I_R						0.1	μA	V_R=50V
Capacitance	C_t		1.1	4.0		1.1	4.0	pF	V_R=0, f=1.0MHz
Reverse Recovery Time	t_{rr}			3.0			3.0	ns	See test circuit

TYPICAL CHARACTERISTICS (Ta = 25°C)

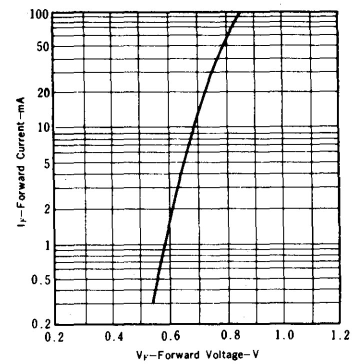
1S2837 FORWARD CURRENT vs. FORWARD VOLTAGE



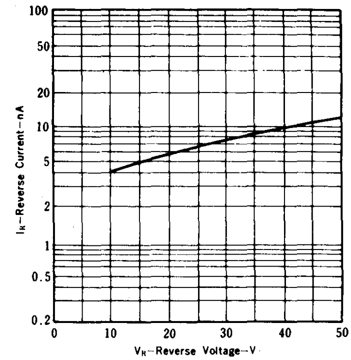
1S2837 REVERSE CURRENT vs. REVERSE VOLTAGE



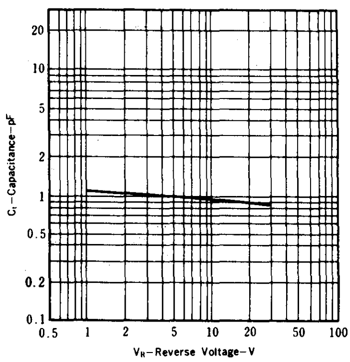
1S2838 FORWARD CURRENT vs. FORWARD VOLTAGE



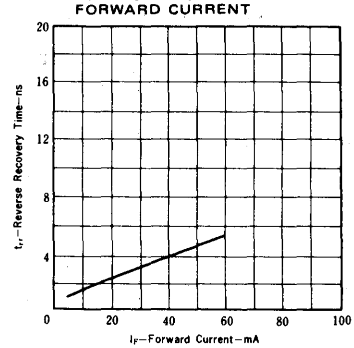
1S2838 REVERSE CURRENT vs. REVERSE VOLTAGE



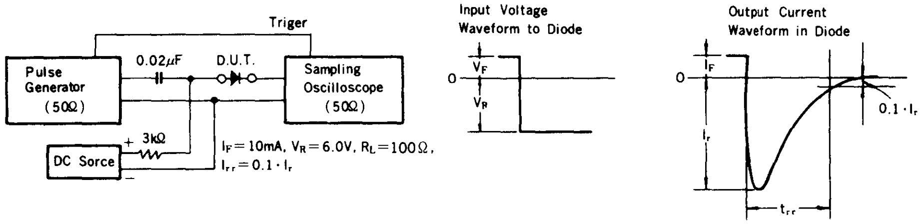
1S2837, 1S2838 TERMINAL CAPACITANCE vs. REVERSE VOLTAGE



1S2837, 1S2838 REVERSE RECOVERY TIME vs. FORWARD CURRENT



t_{rr} REVERSE RECOVERY TIME TEST CIRCUIT



Contents

SST Transistors

NEC
ELECTRON DEVICE

SST MOLD TRANSISTOR SERIES

6

DESCRIPTION

The SST (Small Size Transfer) MOLD TRANSISTOR SERIES are designed for high density assembly of equipment, and these are very suitable for minimizing and lightening of sets.

Especially recommended for thin type portable radio, micro cassette tape recorder, camera and the other small type equipment.

FEATURES

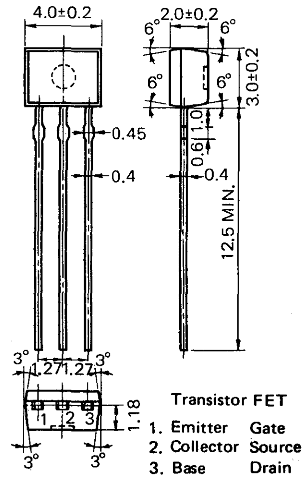
- Small Package
- Abundant Kinds (11 Types)
  FM/RF to Audio Output Stage
- High Total Power Dissipation
  P_T = 250 mW ~ 350 mW (Depends on Type No.)
- Same lead-to-lead Space as TO-92 Type

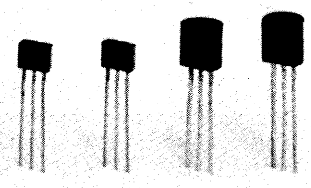
LINE UP

TYPE NO.	APPLICATION
2SK193	FM/RF Amplifier
2SC2786	FM/RF, MIX., CONV.
2SC2787	FM/AM IF, AM/CONV.
2SC2784	AF Low Noise Amplifier
2SA1174	AF Low Noise Amplifier
2SC2785	General Purpose Amplifier
2SA1175	General Purpose Amplifier
2SD1020	AF Driver
2SB810	AF Driver
2SD1021	AF/Driv., Output
2SB811	AF/Driv., Output

PACKAGE DIMENSIONS

in millimeters





SST MOLD   TO-92 MOLD

QUICK REFERENCE TABLE (1)

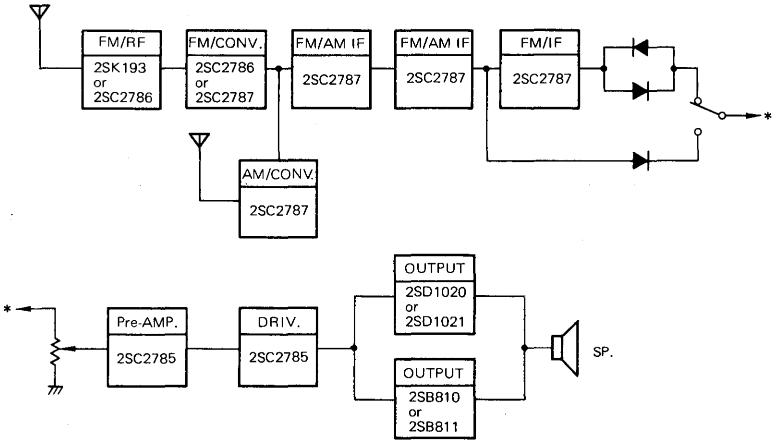
Type No.	Polarity	Absolute Maximum Ratings			h_{FE} and I_{DSS} Classification											Test Condition
		V_{CEO}/V_{GDO}^* (V)	I_C/I_D^* (mA)	P_T (mW)	40 – 80	60 – 120	90 – 180	110 – 180	135 – 220	170 – 270	200 – 320	250 – 400	300 – 600	400 – 800	600 – 1200	V_{CE}/V_{DS}^* I_C
2SK193	N-ch	–20*	10*	250	Rank I_{DSS}(mA)	U 0.5 – 1.0	E 0.75 – 1.5	F 1.0 – 2.0	P 1.5 – 3.0	K 2.0 – 4.0	L 3.0 – 6.0	M 4.0 – 8.0				5.0 V* V_{GS}=0
2SC2786	NPN	20	20	300	M	L	K									6.0 V 1.0 mA
2SC2787	NPN	30	30	300	M	L	K									6.0 V 1.0 mA
2SC2784	NPN	60	50	300							P		F	E	U	6.0 V 1.0 mA
2SA1174	PNP	–60	–50	300							P		F	E	U	–6.0 V –1.0 mA
2SC2785	NPN	50	100	300				R	J	H	F	E	K			6.0 V 1.0 mA
2SA1175	PNP	–50	–100	300				R	J	H	F	E	K			–6.0 V –1.0 mA
2SD1020	NPN	25	700	350				M	J	H	F	E				1.0 V 100 mA
2SB810	PNP	–25	–700	350				M	J	H	F	E				–1.0 V –100 mA
2SD1021	NPN	25	1000	350				M	J	H	F	E				1.0 V 100 mA
2SB811	PNP	–25	–1000	350				M	J	H	F	E				–1.0 V –100 mA

QUICK REFERENCE TABLE (2)

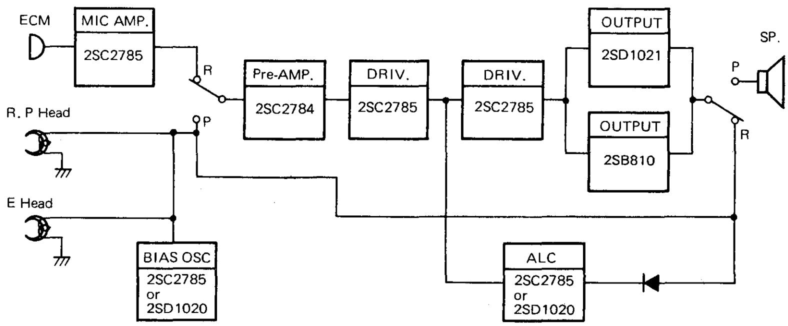
Type No.	$V_{CE(sat)}$ (mV)	TYP. Test Condition	f_T(MHz) $\|y_{fs}\|$*(mS)	TYP. Test Condition	Cob(pF) C_{rss}*(pF)	TYP. Test Condition	NV(mV) NF*(dB)	TYP. Test Condition	Equivalent Type No. To TO-92 Package	Others
2SK193			8.5*	V_{DS}=5.0 V V_{GS}=0 f=1.0 kHz	0.07*	V_{DS}=5.0 V V_{GS}=0 f=1.0 MHz	3.0*	V_{DS}=5.0 V V_{GS}=0 R_S=50 Ω f=100 MHz	2SK195	
2SC2786	100	I_C=10 mA I_B=1.0 mA	600	V_{CE}=6.0 V I_C=1.0 mA	1.0	V_{CB}=6.0 V I_E=0 f=1.0 MHz	3.0*	V_{CE}=6.0 V I_C=1.0 mA R_S=50 Ω f=100 MHz	2SC1674	
2SC2787	80	I_C=10 mA I_B=1.0 mA	250	V_{CE}=6.0 V I_C=1.0 mA	1.9	V_{CB}=6.0 V I_E=0 f=1.0 MHz	2.0*	V_{CE}=6.0 V I_C=1.0 mA R_S=500 Ω f=1.0 MHz	2SC1675	
2SC2784	70	I_C=10 mA I_B=1.0 mA	110	V_{CE}=6.0 V I_C=1.0 mA	1.6	V_{CB}=30 V I_E=0 f=1.0 MHz	25	V_{CE}=5.0 V I_C=1.0 mA R_S=100 kΩ f=10 Hz~1.0 kHz Av=80 dB	2SC1845	Complementary Pair
2SA1174	−90	I_C=−10 mA I_B=−1.0 mA	100	V_{CE}=−6.0 V I_C=−1.0 mA	2.0	V_{CB}=−30 V I_E=0 f=1.0 MHz	25	V_{CE}=−5.0 V I_C=−1.0 mA R_S=100 kΩ f=10 Hz~1.0 kHz Av=80 dB	2SA992	
2SC2785	150	I_C=100 mA I_B=10 mA	250	V_{CE}=6.0 V I_C=10 mA	3.0	V_{CB}=6.0 V I_E=0 f=1.0 MHz	0.8*	V_{CE}=6.0 V I_C=0.1 mA R_S=2.0 kΩ f=1.0 kHz	2SC945	Complementary Pair
2SA1175	−180	I_C=−100 mA I_B=−10 mA	180	V_{CE}=−6.0 V I_C=−1.0 mA	4.5	V_{CB}=−6.0 V I_E=0 f=1.0 MHz	6.0*	V_{CE}=−6.0 V I_C=−0.3 mA R_S=10 kΩ f=100 Hz	2SA733	
2SD1020	200	I_C=700 mA I_B=70 mA	170	V_{CE}=6.0 V I_C=10 mA	13	V_{CB}=6.0 V I_E=0 f=1.0 MHz			2SC2001	Complementary Pair
2SB810	−250	I_C=−700 mA I_B=−70 mA	160	V_{CE}=−6.0 V I_C=−10 mA	17	V_{CB}=−6.0 V I_E=0 f=1.0 MHz			2SA952	
2SD1021	210	I_C=1000 mA I_B=100 mA	100	V_{CE}=6.0 V I_C=10 mA	22	V_{CB}=6.0 V I_E=0 f=1.0 MHz			2SD471	Complementary Pair
2SB811	−250	I_C=−1000 mA I_B=−100 mA	110	V_{CE}=−6.0 V I_C=−10 mA	36	V_{CB}=−6.0 V I_E=0 f=1.0 MHz			2SB564	

BLOCK DIAGRAM FOR EXAMPLE

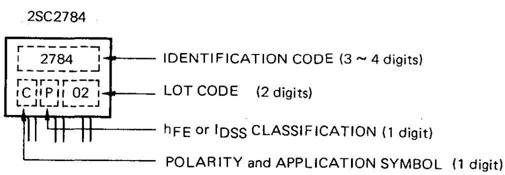
1. THIN TYPE PORTABLE RADIO (Po ≦ 400 mW)



2. MICRO CASSETTE TAPE RECORDER



MARKING EXAMPLE



A: PNP TRANSISTOR for HIGH FREQUENCY
B: PNP TRANSISTOR for LOW FREQUENCY
C: NPN TRANSISTOR for HIGH FREQUENCY
D: NPN TRANSISTOR for LOW FREQUENCY
K: N-ch. FIELD-EFFECT TRANSISTOR

NEC
ELECTRON DEVICE

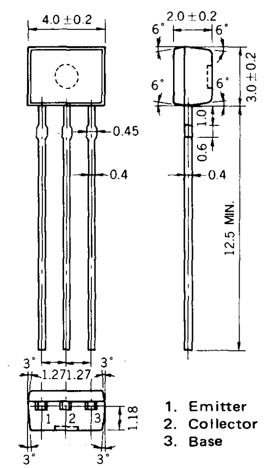
PNP SILICON TRANSISTOR
2SA1174

DESCRIPTION The 2SA1174 is best for use as the middle range amplifier in Hi-Fi stereo control amplifiers, power amplifiers, and etc.

FEATURES

- High Voltage. V_{CEO} : −60 V
- Low Output Capacitance. C_{ob} : 2.0 pF TYP. (V_{CB}=−30 V)
- High h_{FE}. h_{FE} : 500 TYP. (V_{CE}=−6.0 V, I_C=−1.0 mA)
- Super Low Noise. NV : 25 mV TYP. (See test circuit.)
- Complementary to the NEC 2SC2785 NPN transistor.

PACKAGE DIMENSIONS
in millimeters



1. Emitter
2. Collector
3. Base

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures
- Storage Temperature . . . . −55 to +125 °C
- Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation . . . . 300 mW

Maximum Voltages and Currents
- V_{CBO} Collector to Base Voltage . . . . −60 V
- V_{CEO} Collector to Emitter Voltage . . . . −60 V
- V_{EBO} Emitter to Base Voltage . . . . −5.0 V
- I_C Collector Current . . . . −50 mA
- I_B Base Current. . . . . −10 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	150	500		–	V_{CE}=−6.0 V, I_C=−0.1 mA
h_{FE2}	DC Current Gain	200	500	800	–	V_{CE}=−6.0 V, I_C=−1.0 mA
f_T	Gain Bandwidth Product	50	100		MHz	V_{CE}=−6.0 V, I_C=−1.0 mA
Cob	Output Capacitance		2.0	3.0	pF	V_{CB}=−30 V, I_E=0, f=1.0 MHz
NV	Noise Voltage		25	40	mV	V_{CE}=−5.0 V, I_C=−1.0 mA, R_G=100 kΩ Gv=80 dB, f=10 Hz to 1.0 kHz
I_{CBO}	Collector Cutoff Current			−50	nA	V_{CB}=−60 V, I_E=0
I_{CEO}	Collector Cutoff Current			−1.0	μA	V_{CE}=−60 V, R_{BE}=∞
I_{EBO}	Emitter Cutoff Current			−50	nA	V_{EB}=−5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	−0.55	−0.61	−0.65	V	V_{CE}=−6.0 V, I_C=−1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.09	−0.30	V	I_C=−10 mA, I_B=−1.0 mA

Classification of h_{FE2}

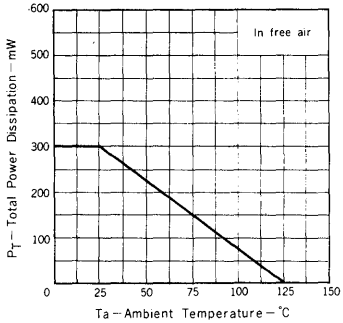
Rank	P	F	E
Range	200 – 400	300 – 600	400 – 800

h_{FE2} Test Conditions : V_{CE} = −6.0 V, I_C = −1.0 mA

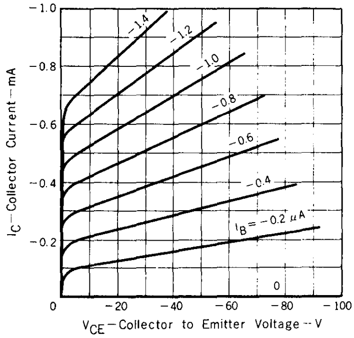
6

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

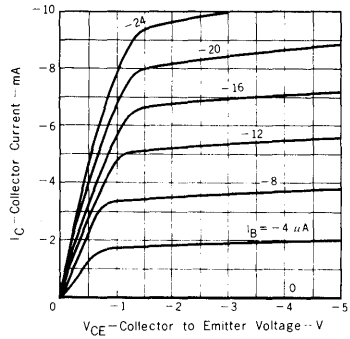
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



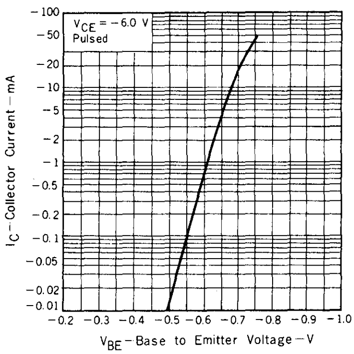
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



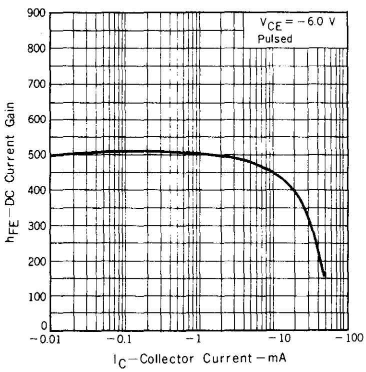
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



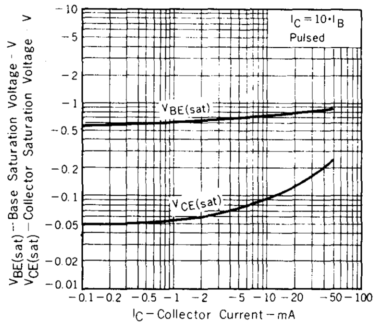
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



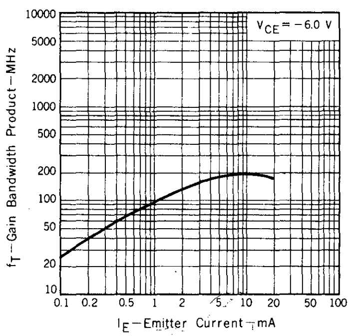
DC CURRENT GAIN vs. COLLECTOR CURRENT



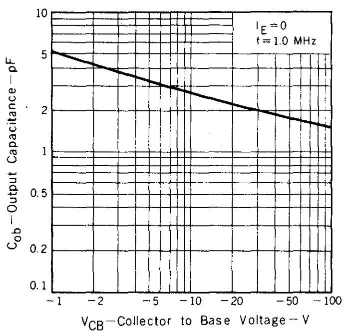
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



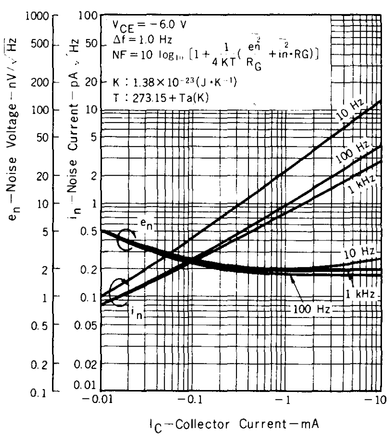
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



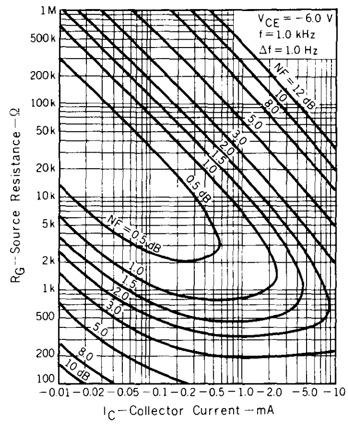
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



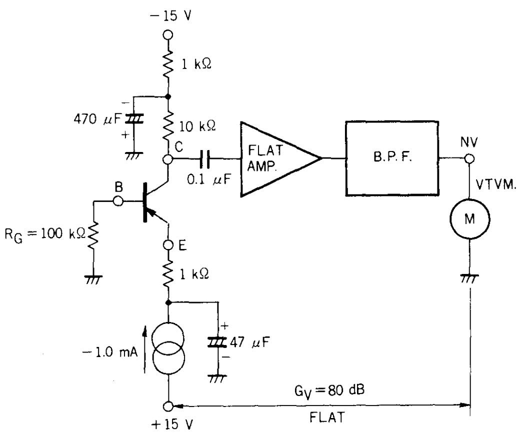
e_n AND i_n vs. COLLECTOR CURRENT



NOISE FIGURE MAP



NOISE VOLTAGE TEST CIRCUIT



$V_{CE} \doteqdot -5$ V, $I_C = -1.0$ mA, $R_G = 100$ kΩ, $G_V = 80$ dB, FLAT(f = 10 Hz to 1.0 kHz)

6

NEC
ELECTRON DEVICE

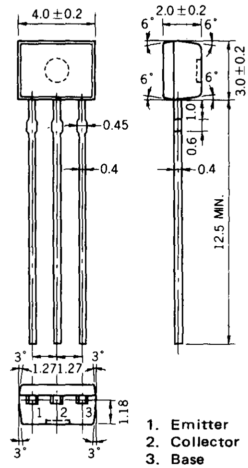
PNP SILICON TRANSISTOR
2SA1175

DESCRIPTION The 2SA1175 is designed for use in driver stage of AF amplifier.

FEATURES

- High h_{FE} and excellent linearity : 200 TYP.
  h_{FE} (I_C = −1.0 mA)
- Complementary to the NEC 2SC2785 NPN transistor.

PACKAGE DIMENSIONS
in millimeters



ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures

Storage Temperature		−55 to +125 °C
Junction Temperature		+125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation		300 mW

Maximum Voltages and Currents

V_{CBO}	Collector to Base Voltage	−60 V
V_{CEO}	Collector to Emitter Voltage	−50 V
V_{EBO}	Emitter to Base Voltage	−5.0 V
I_C	Collector Current	−100 mA
I_B	Base Current	−20 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	110	200	600		V_{CE}=−6.0 V, I_C=−1.0 mA
NF	Noise Figure		6.0	20	dB	V_{CE}=−6.0 V, I_C=−0.3 mA, R_G=10 kΩ, f=100 Hz
f_T	Gain Bandwidth Product	50	180		MHz	V_{CE}=−6.0 V, I_C=−1.0 mA
C_{ob}	Output Capacitance		4.5	6.0	pF	V_{CB}=−10 V, I_E=0, f=1.0 MHz
I_{CBO}	Collector Cutoff Current			−0.1	μA	V_{CB}=−60 V, I_E=0
I_{EBO}	Emitter Cutoff Current			−0.1	μA	V_{EB}=−5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	−0.55	−0.62	−0.65	V	V_{CE}=−6.0 V, I_C=−1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		−0.18	−0.3	V	I_C=−100 mA, I_B=−10 mA

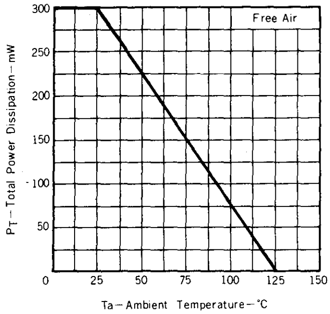
Classification of h_{FE}

Rank	R	J	H	F	E	K
Range	110 – 180	135 – 220	170 – 270	200 – 320	250 – 400	300 – 600

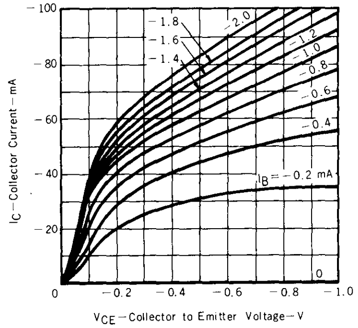
h_{FE} Test Conditions : V_{CE}=−6.0 V, I_C=−1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

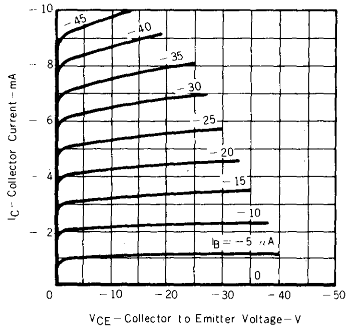
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



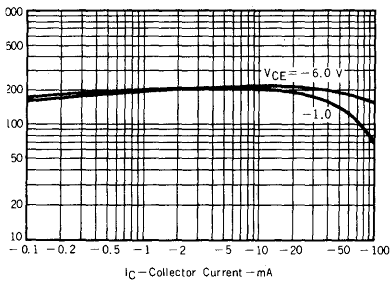
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



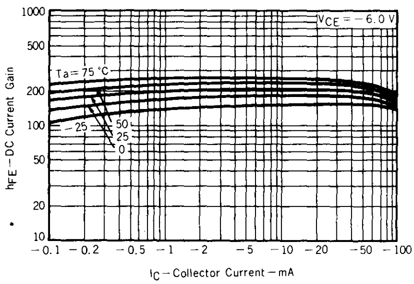
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



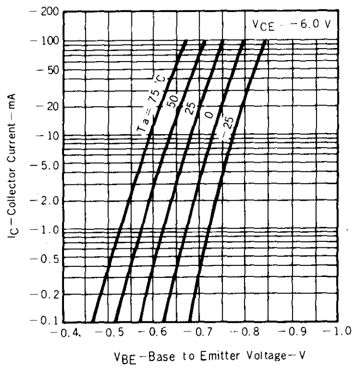
DC CURRENT GAIN vs. COLLECTOR CURRENT



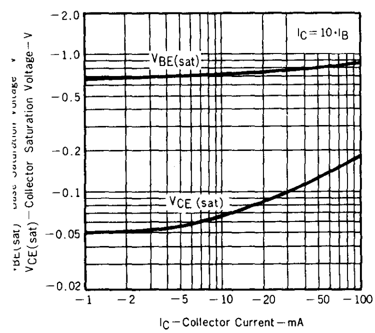
DC CURRENT GAIN vs. COLLECTOR CURRENT



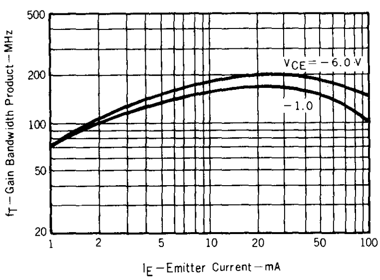
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



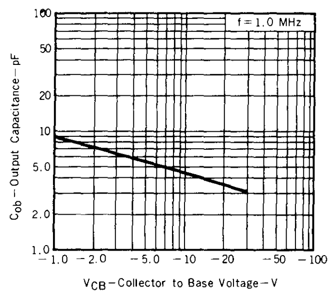
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



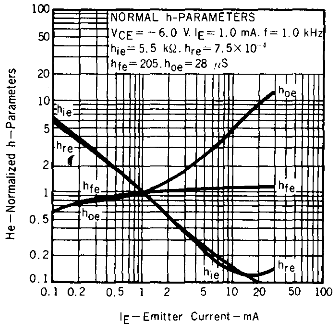
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



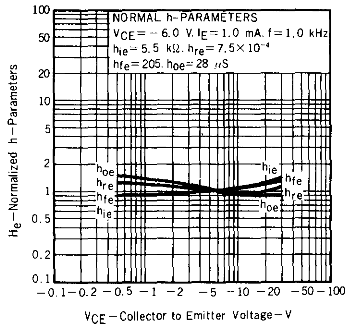
OUTPUT CAPACITANCE vs. REVERSE VOLTAGE



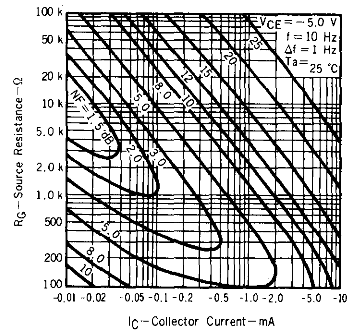
NORMALIZED h-PARAMETERS vs. EMITTER CURRENT



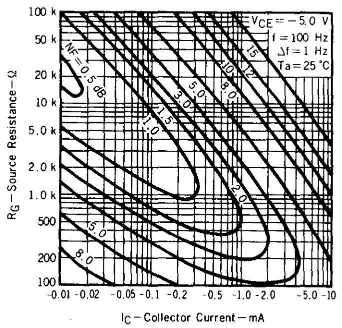
NORMALIZED h-PARAMETERS vs. COLLECTOR TO EMITTER VOLTAGE



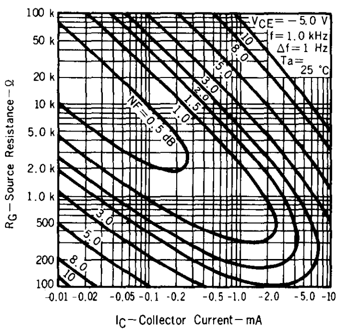
NOISE FIGURE MAP 1



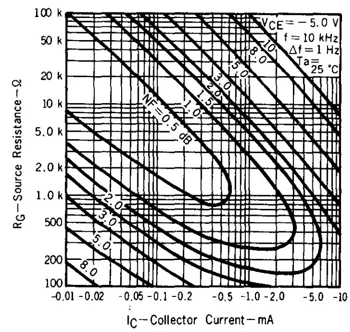
NOISE FIGURE MAP 2



NOISE FIGURE MAP 3



NOISE FIGURE MAP 4



NEC
ELECTRON DEVICE

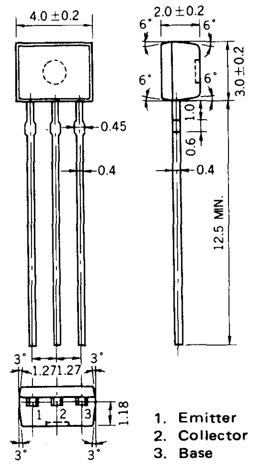
PNP SILICON TRANSISTOR
2SB810

DESCRIPTION The 2SB810 is designed for use in output stage of portable radio and cassette type tape recorder, general purpose applications.

FEATURES

- High total power dissipation.
  $P_T = 350$ mW
- High h_{FE} and low $V_{CE(sat)}$.
  $h_{FE}(I_C = -100$ mA) : 200 TYP.
  $V_{CE(sat)}(-700$ mA) : −0.25 V TYP.
- Complementary to the NEC 2SD1020 NPN transistor.

PACKAGE DIMENSIONS
in millimeters



1. Emitter
2. Collector
3. Base

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures
Storage Temperature . . . . −55 to +150 °C
Junction Temperature . . . . +150 °C Maximum
Maximum Power Dissipation (Ta = 25 °C)
Total Power Dissipation . . . . 350 mW
Maximum Voltages and Currents
V_{CBO} Collector to Base Voltage . . . . −30 V
V_{CEO} Collector to Emitter Voltage . . . . −25 V
V_{EBO} Emitter to Base Voltage . . . . −5.0 V
I_C Collector Current . . . . −700 mA
I_B Base Current. . . . . −150 mA

6

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}*	DC Current Gain	110	200	400	–	V_{CE}=−1.0 V, I_C=−100 mA
h_{FE2}*	DC Current Gain	50	100		–	V_{CE}=−1.0 V, I_C=−700 mA
C_{ob}	Collector to Base Capacitance		17	40	pF	V_{CB}=−6.0 V, I_E=0, f=1.0 MHz
f_T	Gain Bandwidth Product	50	160		MHz	V_{CE}=−6.0 V, I_C=−10 mA
V_{BE}*	Base to Emitter Voltage	−600	−640	−700	mV	V_{CE}=−6.0 V, I_C=−10 mA
$V_{CE(sat)}$*	Collector Saturation Voltage		−0.25	−0.4	V	I_C=−700 mA, I_B=−70 mA
$V_{BE(sat)}$*	Base Saturation Voltage		−0.95	−1.2	V	I_C=−700 mA, I_B=−70 mA
I_{CBO}	Collector Cutoff Current			−100	nA	V_{CB}=−30 V, I_E=0
I_{EBO}	Emitter Cutoff Current			−100	nA	V_{EB}=−5.0 V, I_C=0

* Pulsed PW ≦ 350 μs, duty cycle ≦ 2.0 %

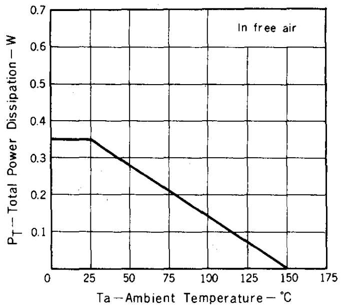
Classification of h_{FE1}

Rank	M	J	H	F	E
Range	110 – 180	135 – 220	170 – 270	200 – 320	250 – 400

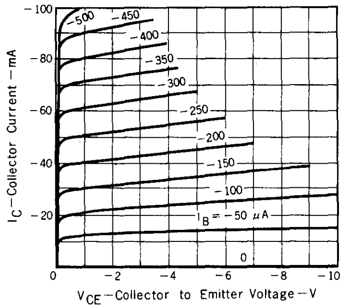
h_{FE1} Test Conditions : V_{CE} = −1.0 V, I_C = −100 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

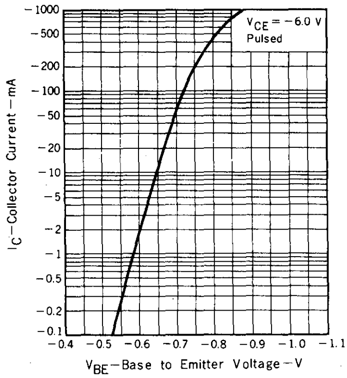
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



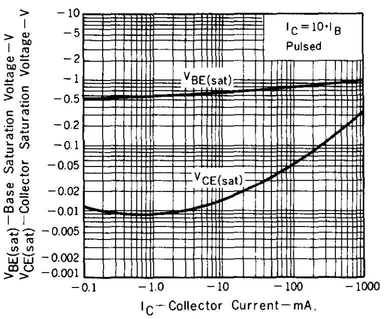
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



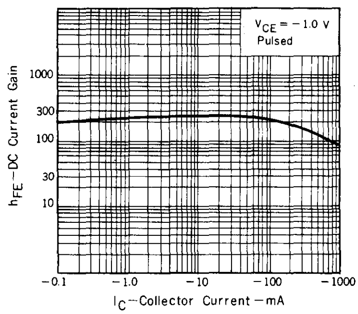
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



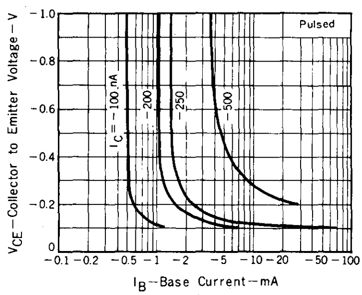
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



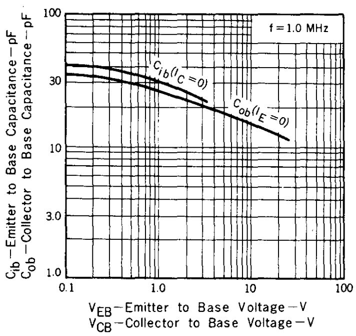
DC CURRENT GAIN vs. COLLECTOR CURRENT



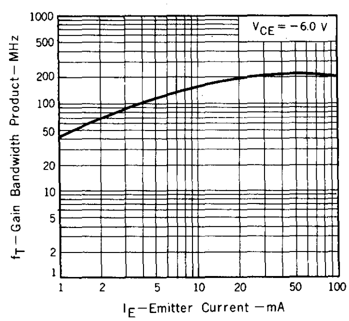
COLLECTOR TO EMITTER VOLTAGE vs. BASE CURRENT



EMITTER TO BASE AND COLLECTOR TO BASE CAPACITANCE vs. REVERSE VOLTAGE



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



NEC
ELECTRON DEVICE

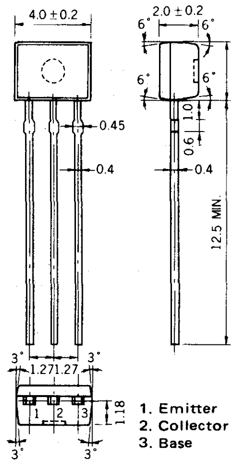
PNP SILICON TRANSISTOR
2SB811

DESCRIPTION The 2SB811 is designed for use in driver and output stages of audio frequency amplifiers.

FEATURES

- High Total Power Dissipation: 1.0 W at 25 °C Ambient Temperature.
- Complementary to the NEC 2SD1021 Transistor.

PACKAGE DIMENSIONS
in millimeters



ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
Storage Temperature .... –55 to +150 °C
Junction Temperature .... +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
Total Power Dissipation .... 350 mW
Thermal Resistance (Junction to Ambient) ...... 429 °C/W

Maximum Voltages and Currents (Ta = 25 °C)
V_{CBO} Collector to Base Voltage .... –30 V
V_{CEO} Collector to Emitter Voltage .... –25 V
V_{EBO} Emitter to Base Voltage .... –5.0 V
I_C Collector Current .... –1.0 A
I_B Base Current .... –0.1 A

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	90	200	400	–	V_{CE}=–1.0 V, I_C=–0.1 A
h_{FE2}	DC Current Gain	50	100		–	V_{CE}=–1.0 V, I_C=–1.0 A
f_T	Gain Bandwidth Product		110		MHz	V_{CE}=–6.0 V, I_C=–10 mA
C_{ob}	Collector to Base Capacitance		36		pF	V_{CB}=–6.0 V, I_E=0, f=1.0 MHz
I_{CBO}	Collector Cutoff Current			–100	nA	V_{CB}=–30 V, I_E=0
I_{EBO}	Emitter Cutoff Current			–100	nA	V_{EB}=–5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	–600	–640	–700	mV	V_{CE}=–6.0 V, I_C=–10 mA
$V_{CE(sat)}$	Collector Saturation Voltage		–0.25	–0.35	V	I_C=–1.0 A, I_B=–0.1 A
$V_{BE(sat)}$	Base Saturation Voltage		–1.0	–1.2	V	I_C=–1.0 A, I_B=–0.1 A

Classification of h_{FE1}

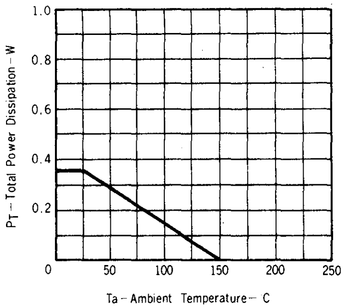
Rank	M	J	H	F	E
Range	110 – 180	135 – 220	170 – 270	200 – 320	250 – 400

h_{FE1} Test Conditions: V_{CE}=–1.0 V, I_C=–0.1 A

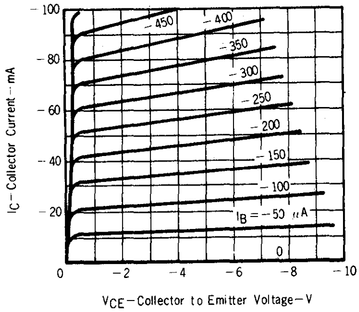
6

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

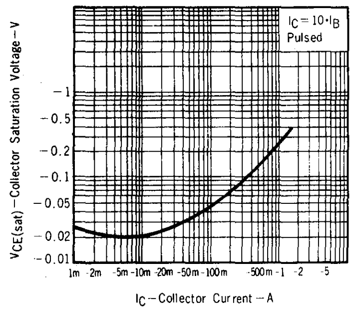
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



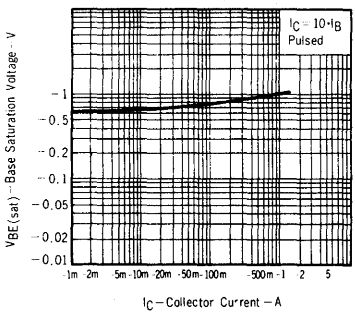
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



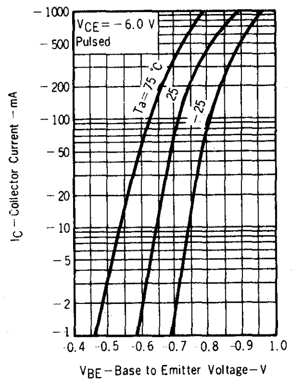
COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



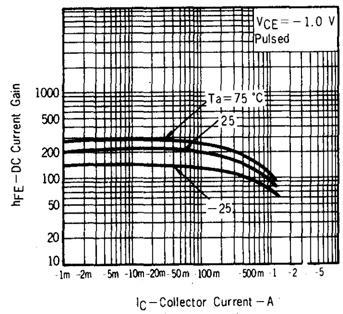
BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



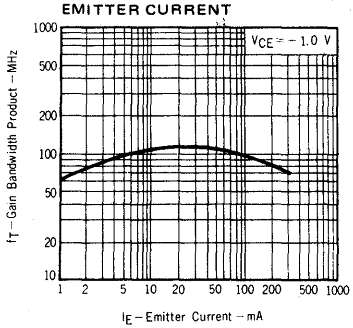
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



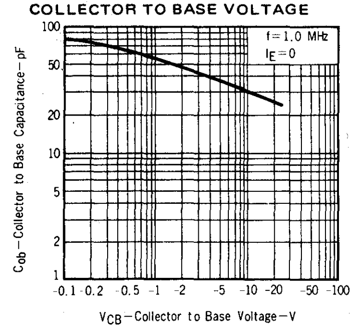
DC CURRENT GAIN vs. COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



COLLECTOR TO BASE CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE

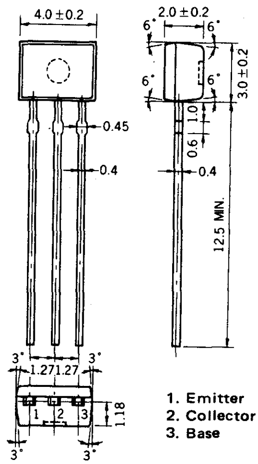


NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC2784

DESCRIPTION The 2SC2784 is the best for use as the middle range amplifier in Hi-Fi stereo control amplifiers, power amplifiers, and etc.

PACKAGE DIMENSIONS
in millimeters



FEATURES

- High voltage. V_{CEO} : 60 V
- Low output capacitance. C_{ob} : 1.6 pF TYP. (V_{CB} = 30 V)
- High h_{FE} h_{FE} : 600 TYP. (V_{CE} = 6.0 V, I_C = 1.0 mA)
- Super low noise. NV : 25 mV TYP. (See test circuit.)
- Complementary to the NEC 2SA1174 PNP transistor.

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures
- Storage Temperature .... –55 to +125 °C
- Junction Temperature .... +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation .... 300 mW

Maximum Voltages and Currents
- V_{CBO} Collector to Base Voltage .... 60 V
- V_{CEO} Collector to Emitter Voltage .... 60 V
- V_{EBO} Emitter to Base Voltage .... 5.0 V
- I_C Collector Current .... 50 mA
- I_B Base Current .... 10 mA

6

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	150	580		–	V_{CE}=6.0 V, I_C=0.1 mA
h_{FE2}	DC Current Gain	200	600	1200	–	V_{CE}=6.0 V, I_C=1.0 mA
f_T	Gain Bandwidth Product	50	110		MHz	V_{CE}=6.0 V, I_C=1.0 mA
C_{ob}	Output Capacitance		1.6	2.5	pF	V_{CB}=30 V, I_E=0, f=1.0 MHz
NV	Noise Voltage		25	40	mV	V_{CE}=5.0 V, I_C=1.0 mA, R_G=100 kΩ G_V=80 dB, f=10 Hz to 1.0 kHz
I_{CBO}	Collector Cutoff Current			50	nA	V_{CB}=60 V, I_E=0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE}=60 V, R_{BE}=∞
I_{EBO}	Emitter Cutoff Current			50	nA	V_{EB}=5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	0.55	0.59	0.65	V	V_{CE}=6.0 V, I_C=1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.07	0.30	V	I_C=10 mA, I_B=1.0 mA

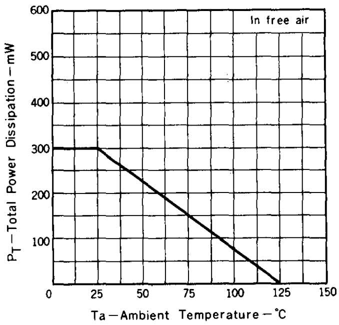
Classification of h_{FE2}

Rank	P	F	E	U
Range	200 – 400	300 – 600	400 – 800	600 – 1200

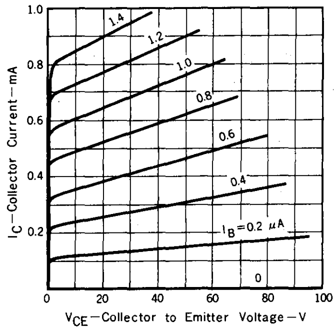
h_{FE2} Test Conditions : V_{CE} = 6.0 V, I_C = 1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

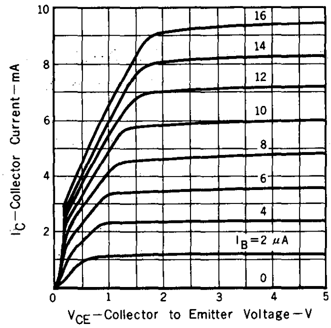
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



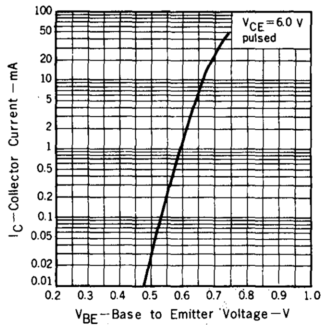
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



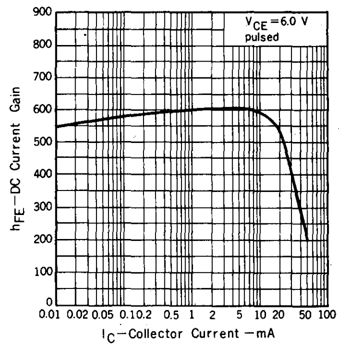
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



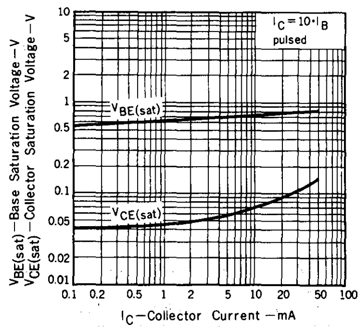
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



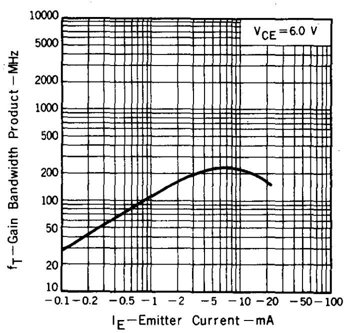
DC CURRENT GAIN vs. COLLECTOR CURRENT



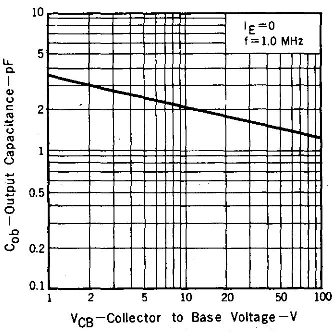
COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT



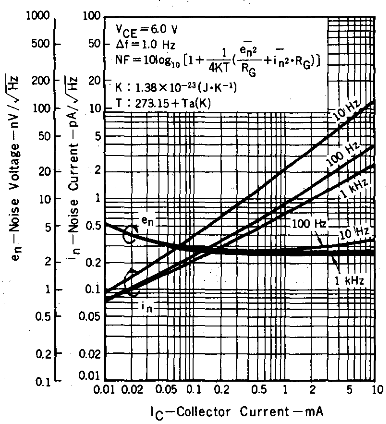
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



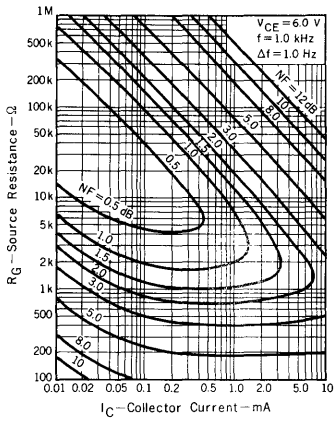
OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



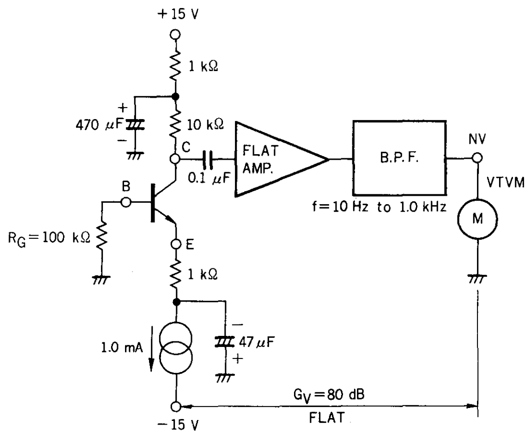
e_n AND i_n vs. COLLECTOR CURRENT



NOISE FIGURE MAP



NOISE VOLTAGE TEST CIRCUIT



V_{CE}≑5 V, I_C=1.0 mA, R_G=100 kΩ, G_V=80 dB, FLAT(f=10 Hz to 1.0 kHz)

6

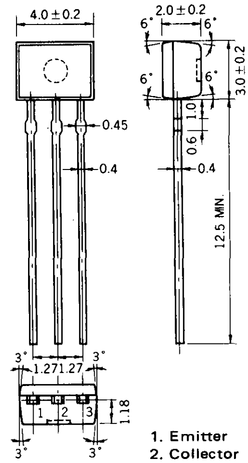
NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC2785

DESCRIPTION The 2SC2785 is designed for use in driver stage of AF amplifier and low speed switching.

FEATURES
- High Voltage ($V_{CEO} > 50$ V)
- Excellent h_{FE} Linearity
  h_{FE1} (0.1 mA)/h_{FE2} (1.0 mA) : 0.92 TYP.
- Complementary to the NEC 2SA1175 PNP Transistor.

PACKAGE DIMENSIONS
in millimeters



1. Emitter
2. Collector
3. Base

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures
- Storage Temperature .... –55 to +125 °C
- Junction Temperature .... +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation .... 300 mW

Maximum Voltages and Currents
- V_{CBO} Collector to Base Voltage .... 60 V
- V_{CEO} Collector to Emitter Voltage .... 50 V
- V_{EBO} Emitter to Base Voltage .... 5.0 V
- I_C Collector Current .... 100 mA
- I_B Base Current .... 20 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	50	185			V_{CE}=6.0 V, I_C=0.1 mA
h_{FE2}	DC Current Gain	90	200	600		V_{CE}=6.0 V, I_C=1.0 mA
NF	Noise Figure		0.8	15	dB	V_{CE}=6.0 V, I_C=0.1 mA, R_G=2.0 kΩ, f=1.0 kHz
f_T	Gain Bandwidth Product	150	250	450	MHz	V_{CE}=6.0 V, I_E=–10 mA
C_{ob}	Collector to Base Capacitance		3.0	4.0	pF	V_{CB}=6.0 V, I_E=0, f=1.0 MHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB}=60 V, I_E=0
I_{CEO}	Collector Cutoff Current			1.0	μA	V_{CE}=40 V, I_B=0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB}=5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	0.55	0.62	0.65	V	V_{CE}=6.0 V, I_C=1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.15	0.3	V	I_C=100 mA, I_B=10 mA
$V_{BE(sat)}$	Base Saturation Voltage		0.86	1.0	V	I_C=100 mA, I_B=10 mA

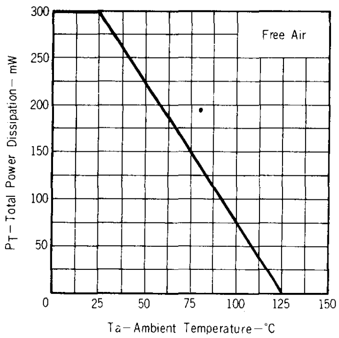
Classification of h_{FE2}

Rank	R	J	H	F	E	K
Range	110 – 180	135 – 220	170 – 270	200 – 320	250 – 400	300 – 600

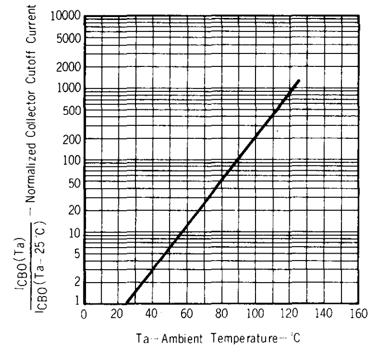
h_{FE2} Test Conditions : V_{CE}=6.0 V, I_C=1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25°C unless otherwise noted)

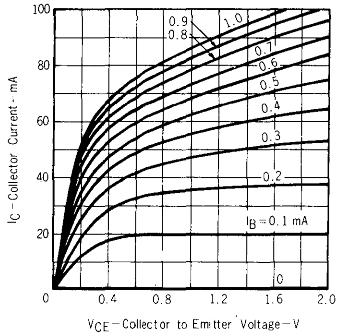
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



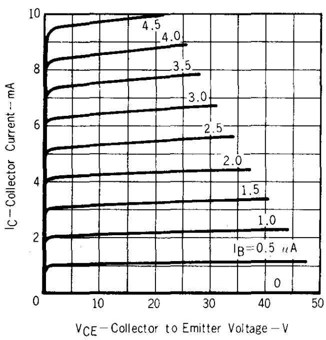
NORMALIZED COLLECTOR CUTOFF CURRENT vs. AMBIENT TEMPERATURE



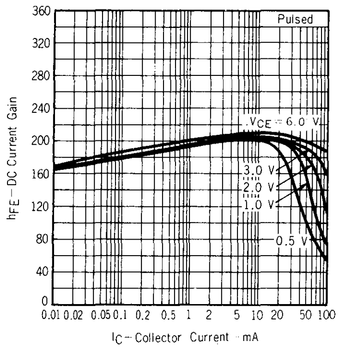
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



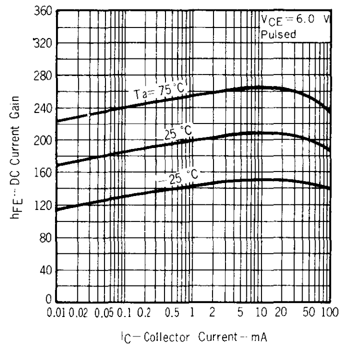
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



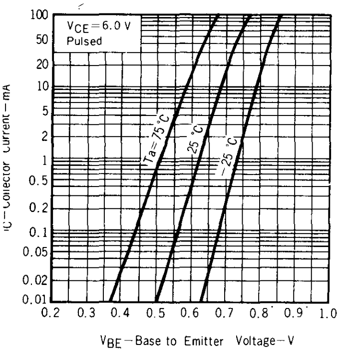
DC CURRENT GAIN vs. COLLECTOR CURRENT



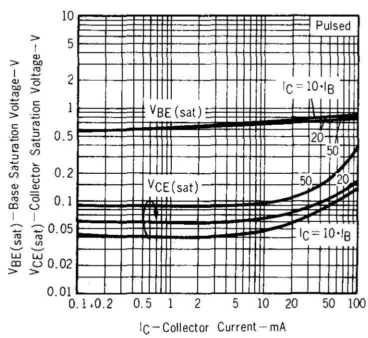
DC CURRENT GAIN vs. COLLECTOR CURRENT



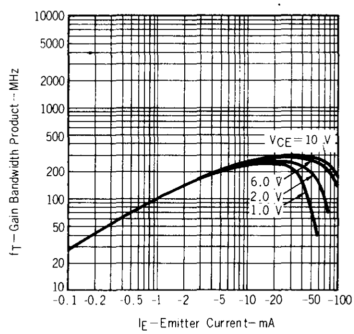
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



COLLECTOR AND BASE SATURATION VOLTAGE vs. COLLECTOR CURRENT

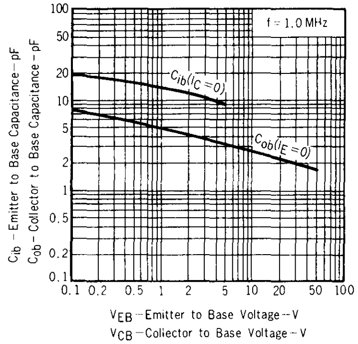


GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT

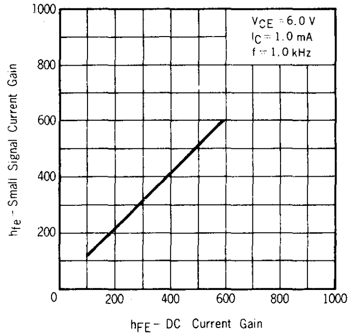


6

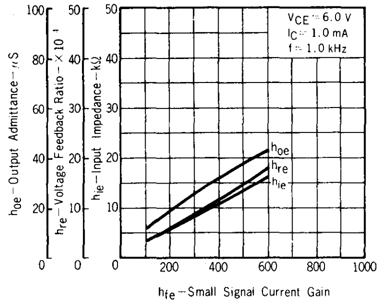
EMITTER TO BASE AND COLLECTOR TO BASE CAPACITANCE vs. REVERSE VOLTAGE



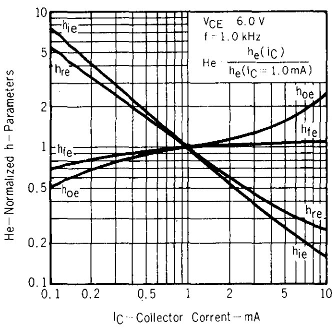
SMALL SIGNAL CURRENT GAIN vs. DC CURRENT GAIN



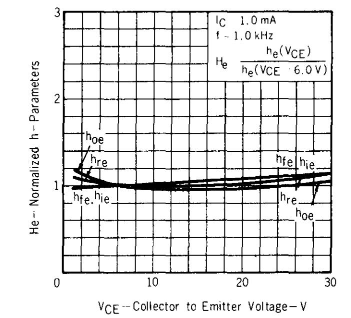
INPUT IMPEDANCE, VOLTAGE FEEDBACK RATIO AND OUTPUT ADMITTANCE vs. SMALL SIGNAL CURRENT GAIN



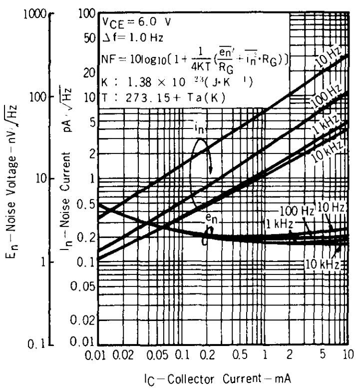
NORMALIZED h-PARAMETERS vs. COLLECTOR CURRENT



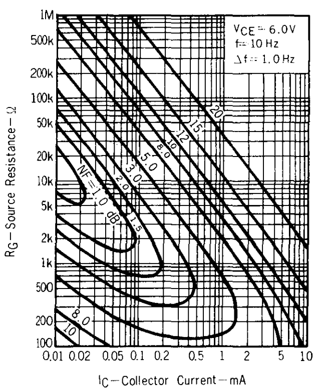
NORMALIZED h-PARAMETERS vs. COLLECTOR TO EMITTER VOLTAGE



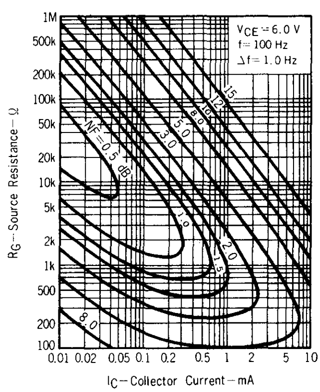
E_n AND I_n vs. COLLECTOR CURRENT



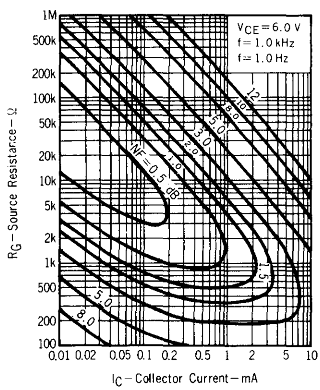
NOISE FIGURE MAP 1



NOISE FIGURE MAP 2



NOISE FIGURE MAP 3



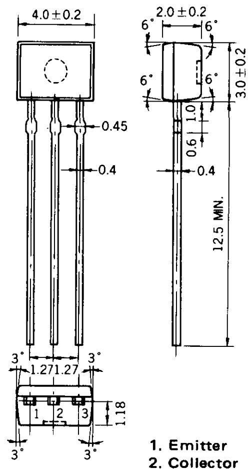
NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SC2786

DESCRIPTION The 2SC2786 is designed for use in FM RF amplifier and local oscillator of FM tuner.

FEATURES
- High gain bandwidth product (f_T = 600 MHz TYP.)
- Small output capacitance (C_{ob} = 1.0 pF TYP.)
- Low noise figure (NF = 3.0 dB TYP. @100 MHz)

PACKAGE DIMENSIONS
in millimeters



1. Emitter
2. Collector
3. Base

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures
- Storage Temperature .... –55 to +125 °C
- Junction Temperature .... +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation .... 300 mW

Maximum Voltages and Currents
- V_{CBO} Collector to Base Voltage .... 30 V
- V_{CEO} Collector to Emitter Voltage .... 20 V
- V_{EBO} Emitter to Base Voltage ....4.0 V
- I_C Collector Current .... 20 mA
- I_B Base Current .... 20 mA

6

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	40	90	180	–	V_{CE}=6.0 V, I_C=1.0 mA
C_{ob}	Output Capacitance		1.0	1.3	pF	V_{CB}=6.0 V, I_E=0, f=1.0 MHz
NF	Noise Figure		3.0	5.0	dB	V_{CE}=6.0 V, I_E=–1.0 mA, R_G=50 Ω f=100 MHz, See test circuit
f_T	Gain Bandwidth Product	400	600		MHz	V_{CE}=6.0 V, I_E=–1.0 mA
G_{pe}	Power Gain	18	22		dB	V_{CE}=6.0 V, I_E=–1.0 mA, R_G=50 Ω f=100 MHz, See test circuit
$C_c \cdot r_{b'b}$	Collector to Base Time Constant		12	15	ps	V_{CE}=6.0 V, I_E=–1.0 mA, f=31.9 MHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB}=30 V, I_E=0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB}=4.0 V, I_C=0
V_{BE}	Base to Emitter Voltage		0.72		V	V_{CE}=6.0 V, I_C=1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.1	0.3	V	I_C=10 mA, I_B=1.0 mA

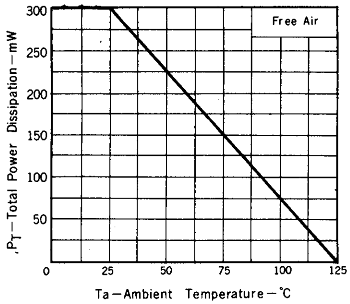
Classification of h_{FE}

Rank	M	L	K
Range	40 – 80	60 – 120	90 – 180

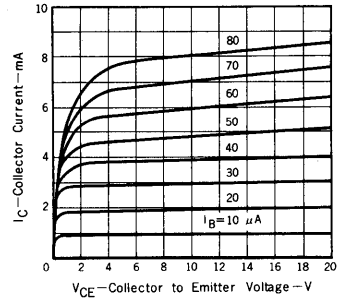
h_{FE} Test Conditions : V_{CE}=6.0 V, I_C=1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

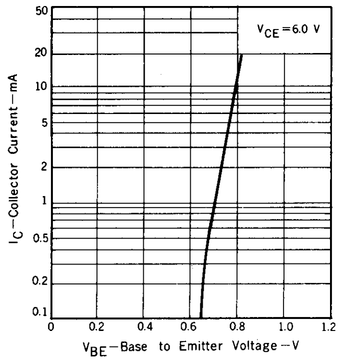
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



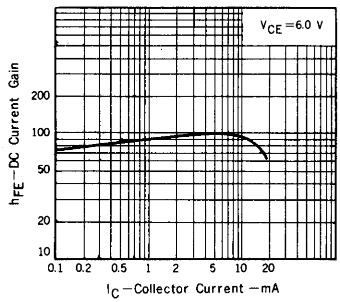
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



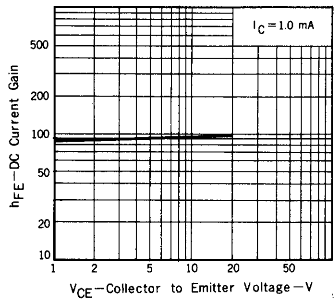
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



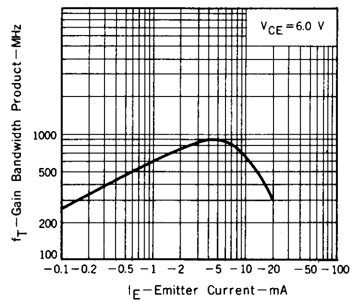
DC CURRENT GAIN vs. COLLECTOR CURRENT



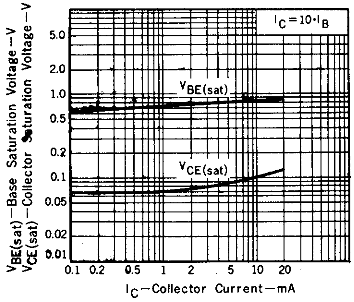
DC CURRENT GAIN vs. COLLECTOR TO EMITTER VOLTAGE



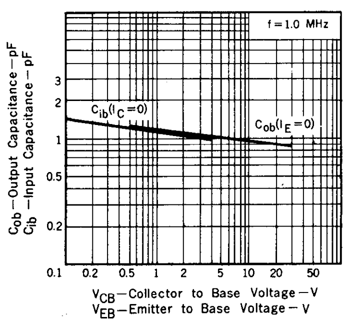
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



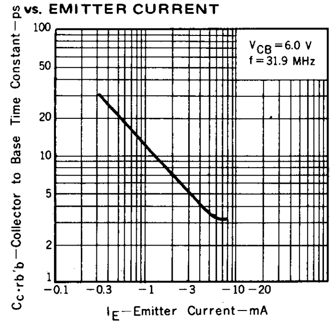
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



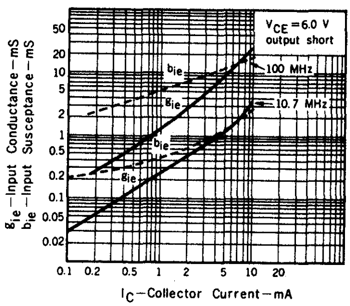
INPUT CAPACITANCE vs. EMITTER TO BASE VOLTAGE, OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



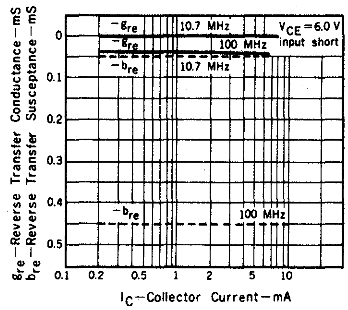
COLLECTOR TO BASE TIME CONSTANT vs. EMITTER CURRENT



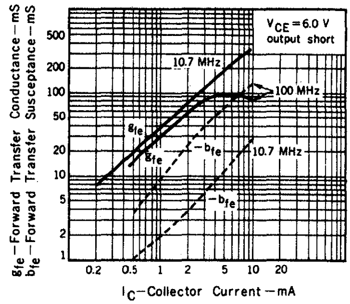
INPUT ADMITTANCE vs. COLLECTOR CURRENT



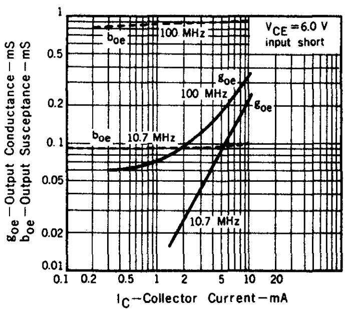
REVERSE TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



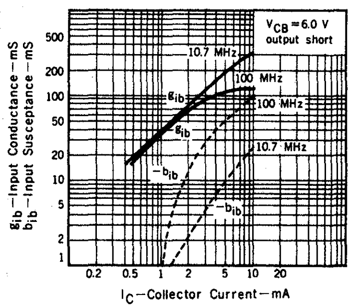
FORWARD TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



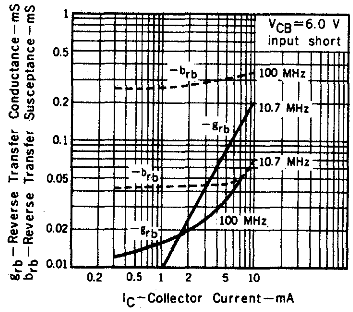
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



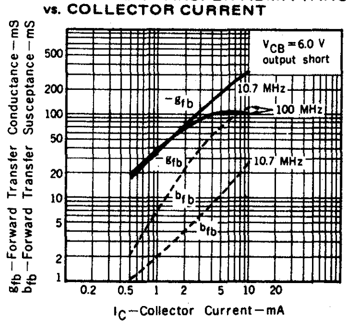
INPUT ADMITTANCE vs. COLLECTOR CURRENT



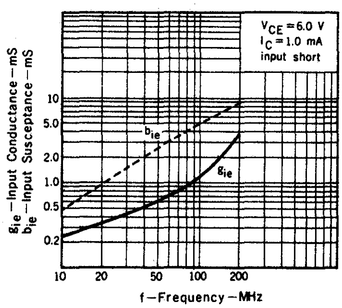
REVERSE TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



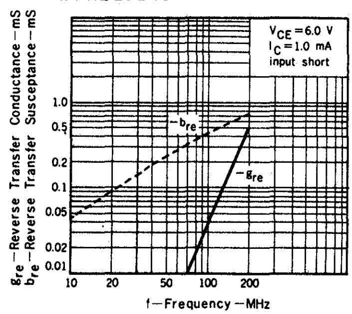
FORWARD TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



INPUT ADMITTANCE vs. FREQUENCY

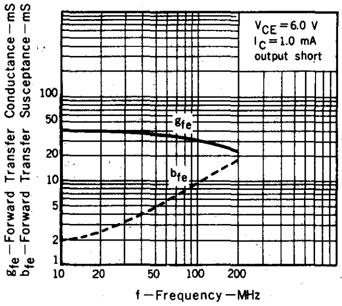


REVERSE TRANSFER ADMITTANCE vs. FREQUENCY

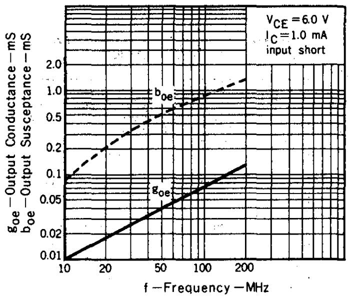


6

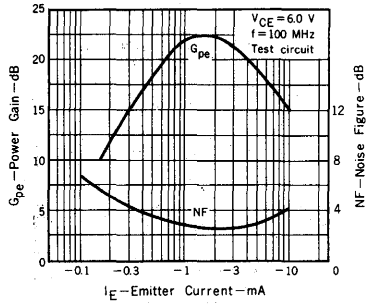
FORWARD TRANSFER ADMITTANCE vs. FREQUENCY



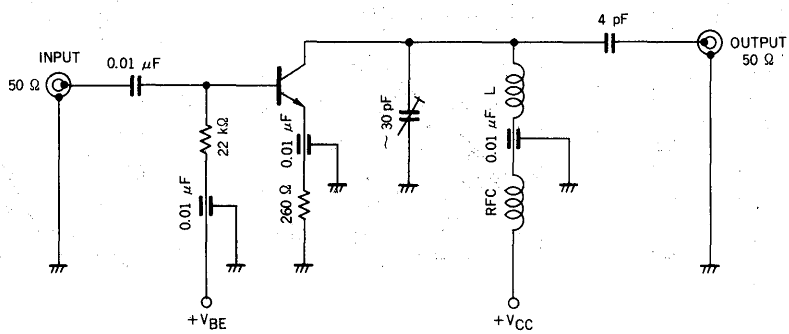
OUTPUT ADMITTANCE vs. FREQUENCY



POWER GAIN, NOISE FIGURE vs. EMITTER CURRENT



100MHz G_{pe}, NF TEST CIRCUIT



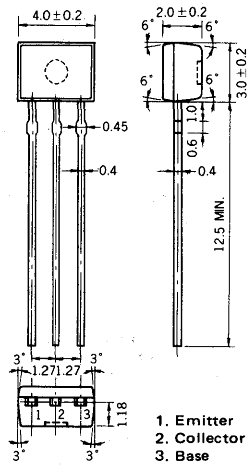
NPN SILICON TRANSISTOR
2SC2787

DESCRIPTION The 2SC2787 is designed for use in AM converter, AM/FM IF amplifier and local oscillator of AM/FM tuner.

FEATURES

- Small output capacitance (C_{ob} = 1.9 pF TYP.)
- Low noise figure (NF = 2.0 dB TYP. @1.0 MHz)

PACKAGE DIMENSIONS
in millimeters



ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures

Storage Temperature .... –55 to +125 °C

Junction Temperature .... +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)

Total Power Dissipation .... 300 mW

Maximum Voltages and Currents

V_{CBO} Collector to Base Voltage .... 50 V

V_{CEO} Collector to Emitter Voltage .... 30 V

V_{EBO} Emitter to Base Voltage .... 5.0 V

I_C Collector Current .... 30 mA

I_B Base Current .... 30 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE}	DC Current Gain	40	90	180	–	V_{CE}=6.0 V, I_C=1.0 mA
C_{ob}	Output Capacitance		1.9	2.2	pF	V_{CB}=6.0 V, I_E=0, f=1.0 MHz
NF	Noise Figure		2.0	4.0	dB	V_{CE}=6.0 V, I_E=–1.0 mA, R_G=500 Ω, f=1.0 MHz
f_T	Gain Bandwidth Product	150	250		MHz	V_{CE}=6.0 V, I_E=–1.0 mA
$C_c \cdot r_{b'b}$	Collector to Base Time Constant		10	15	ps	V_{CE}=6.0 V, I_E=–10 mA, f=31.9 MHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB}=50 V, I_E=0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB}=5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	0.65	0.70	0.75	V	V_{CE}=6.0 V, I_C=1.0 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.08	0.30	V	I_C=10 mA, I_B=1.0 mA

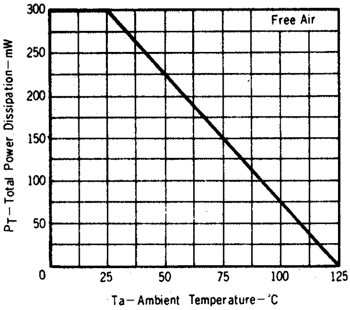
Classification of h_{FE}

Rank	M	L	K
Range	40 – 80	60 – 120	90 – 180

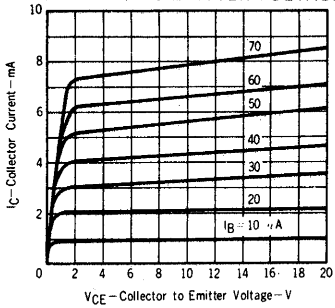
h_{FE} Test Conditions : V_{CE}=6.0 V, I_C=1.0 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

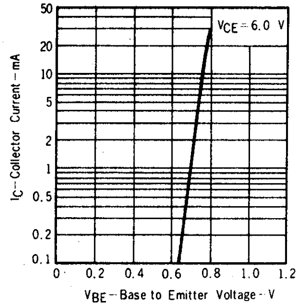
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



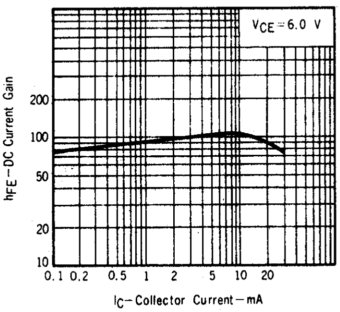
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



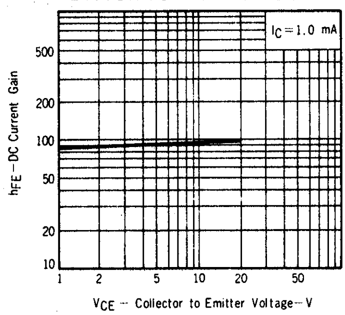
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



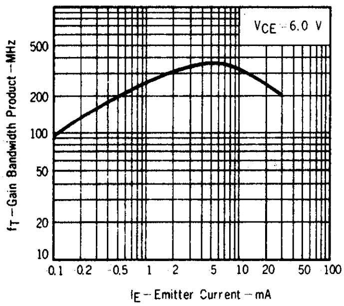
DC CURRENT GAIN vs. COLLECTOR CURRENT



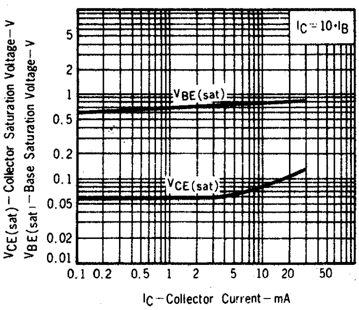
DC CURRENT GAIN vs. COLLECTOR TO EMITTER VOLTAGE



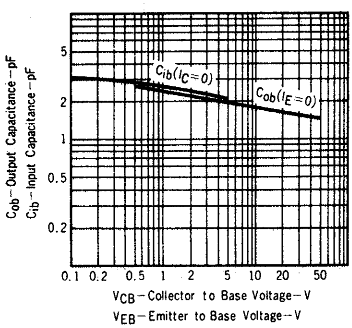
GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



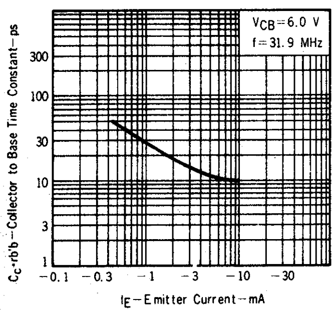
BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



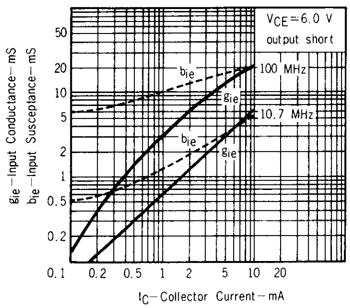
INPUT CAPACITANCE vs. EMITTER TO BASE VOLTAGE, OUTPUT CAPACITANCE vs. COLLECTOR TO BASE VOLTAGE



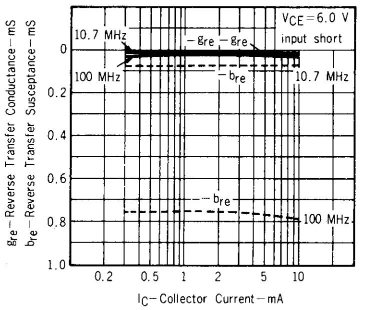
COLLECTOR TO BASE TIME CONSTANT vs. EMITTER CURRENT



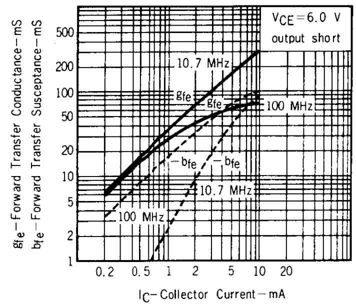
INPUT ADMITTANCE vs. COLLECTOR CURRENT



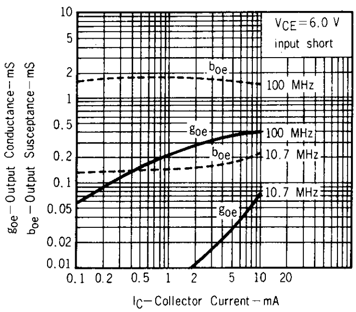
REVERSE TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



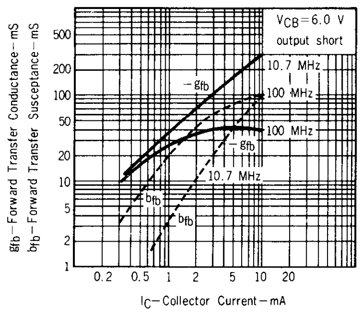
FORWARD TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



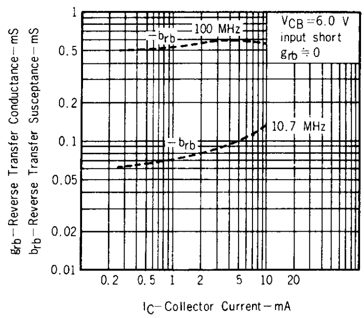
OUTPUT ADMITTANCE vs. COLLECTOR CURRENT



FORWARD TRANSFER ADMITTANCE vs. COLLECTOR CURRENT

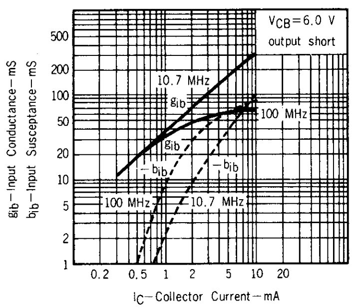


REVERSE TRANSFER ADMITTANCE vs. COLLECTOR CURRENT



6

INPUT ADMITTANCE vs. COLLECTOR CURRENT



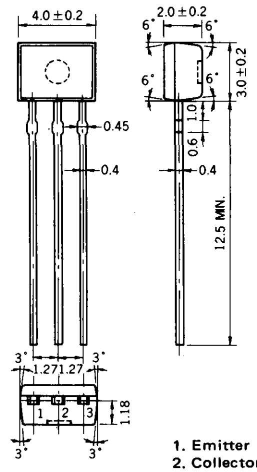
NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SD1020

DESCRIPTION The 2SD1020 is designed for use in output stage of portable RADIO and cassette type tape recorder, general purpose applications.

FEATURES
- High total power dissipation.
  P_T = 350 mW
- High h_{FE} and low $V_{CE(sat)}$
  h_{FE} (I_C = 100 mA) : 200 TYP.
  $V_{CE(sat)}$ (700 mA) : 0.20 V TYP.
- Complementary to the NEC 2SB810 PNP transistor.

PACKAGE DIMENSIONS
in millimeters



1. Emitter
2. Collector
3. Base

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures
- Storage Temperature .... −55 to + 150 °C
- Junction Temperature .... +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation .... 350 mW

Maximum Voltages and Currents
- V_{CBO} Collector to Base Voltage ....30 V
- V_{CEO} Collector to Emitter Voltage ....25 V
- V_{EBO} Emitter to Base Voltage .... 5.0 V
- I_C Collector Current .... 700 mA
- I_B Base Current .... 150 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}*	DC Current Gain	110	200	400	–	V_{CE}=1.0 V, I_C=100 mA
h_{FE2}*	DC Current Gain	50	140		–	V_{CE}=1.0 V, I_C=700 mA
C_{ob}	Collector to Base Capacitance		13	25	pF	V_{CB}=6.0 V, I_E=0, f=1.0 MHz
f_T	Gain Bandwidth Product	50	170		MHz	V_{CE}=6.0 V, I_C=10 mA
V_{BE}*	Base to Emitter Voltage	600	640	700	mV	V_{CE}=6.0 V, I_C=10 mA
$V_{CE(sat)}$*	Collector Saturation Voltage		0.2	0.4	V	I_C=700 mA, I_B=70 mA
$V_{BE(sat)}$*	Base Saturation Voltage		0.95	1.2	V	I_C=700 mA, I_B=70 mA
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB}=30 V, I_E=0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB}=5.0 V, I_C=0

*Pulsed PW ≦ 350 μs, duty cycle ≦ 2.0 %

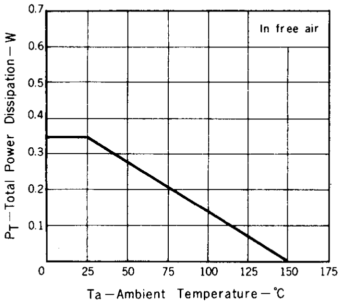
Classification of h_{FE1}

Rank	M	J	H	F	E
Range	110 – 180	135 – 220	170 – 270	200 – 320	250 – 400

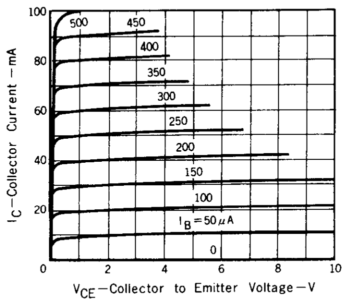
h_{FE1} Test Conditions : V_{CE} = 1.0 V, I_C = 100 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

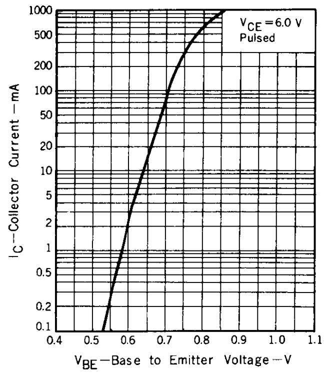
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



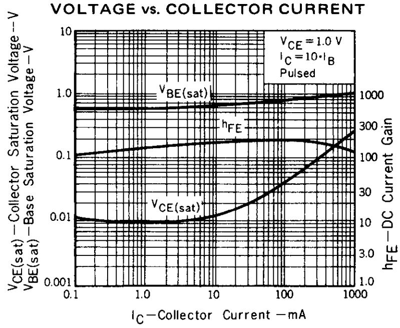
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



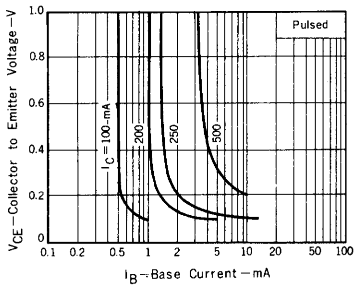
COLLECTOR CURRENT vs. BASE TO EMITTER VOLTAGE



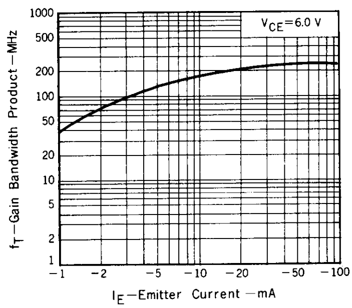
DC CURRENT GAIN, BASE AND COLLECTOR SATURATION VOLTAGE vs. COLLECTOR CURRENT



COLLECTOR TO EMITTER VOLTAGE vs. BASE CURRENT

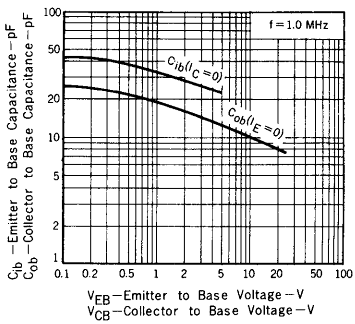


GAIN BANDWIDTH PRODUCT vs. EMITTER CURRENT



6

EMITTER TO BASE AND COLLECTOR TO BASE CAPACITANCE vs. REVERSE VOLTAGE



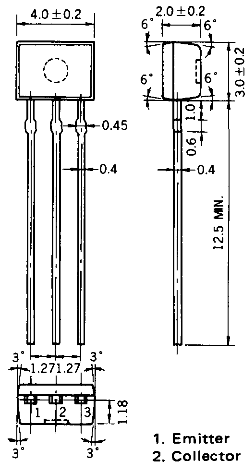
NEC
ELECTRON DEVICE

NPN SILICON TRANSISTOR
2SD1021

DESCRIPTION The 2SD1021 is designed for use in driver and output stages of audio frequency amplifiers.

FEATURES
- High total power dissipation: 350 mW at 25 °C Ambient Temperature.
- Complementary to the NEC 2SB811 PNP transistor.

PACKAGE DIMENSIONS
in millimeters



1. Emitter
2. Collector
3. Base

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures
- Storage Temperature .... –55 to + 150 °C
- Junction Temperature .... +150 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation .... 350 mW
- Thermal Resistance (Junction to Ambient) ...... 429 °C/W

Maximum Voltages and Currents (Ta = 25 °C)
- V_{CBO} Collector to Base Voltage .... 30 V
- V_{CEO} Collector to Emitter Voltage .... 25 V
- V_{EBO} Emitter to Base Voltage .... 5.0 V
- I_C Collector Current .... 1.0 A
- I_B Base Current .... 0.1 A

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
h_{FE1}	DC Current Gain	90	200	400	–	V_{CE}=1.0 V, I_C=0.1 A
h_{FE2}	DC Current Gain	50	140		–	V_{CE}=1.0 V, I_C=1.0 A
f_T	Gain Bandwidth Product		100		MHz	V_{CE}=6.0 V, I_C=10 mA
C_{ob}	Collector to Base Capacitance		22		pF	V_{CB}=6.0 V, I_E=0, f=1.0 MHz
I_{CBO}	Collector Cutoff Current			100	nA	V_{CB}=30 V, I_E=0
I_{EBO}	Emitter Cutoff Current			100	nA	V_{EB}=5.0 V, I_C=0
V_{BE}	Base to Emitter Voltage	600	630	700	mV	V_{CE}=6.0 V, I_C=10 mA
$V_{CE(sat)}$	Collector Saturation Voltage		0.21	0.35	V	I_C=1.0 A, I_B=0.1 A
$V_{BE(sat)}$	Base Saturation Voltage		1.0	1.2	V	I_C=1.0 A, I_B=0.1 A

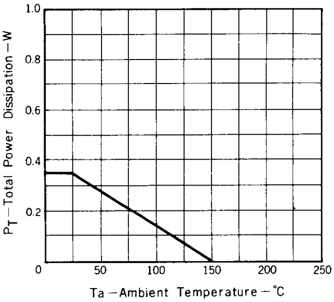
Classification of h_{FE1}

Rank	M	J	H	F	E
Range	110 – 180	135 – 220	170 – 270	200 – 320	250 – 400

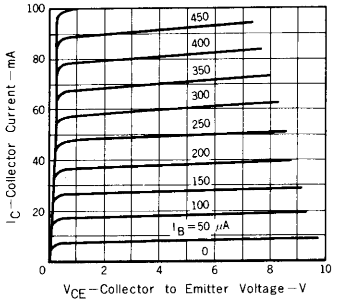
h_{FE1} Test Conditions : V_{CE}=1.0 V, I_C=0.1 A

TYPICAL CHARACTERISTICS (Ta=25 °C unless otherwise noted)

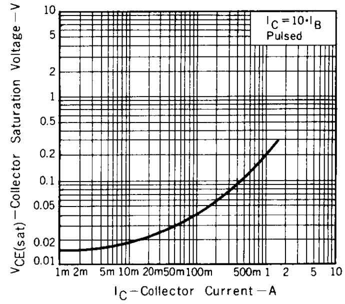
TOTAL POWER DISSIPATION vs.
AMBIENT TEMPERATURE



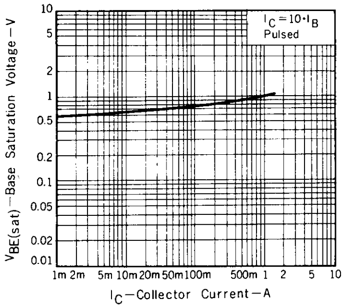
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



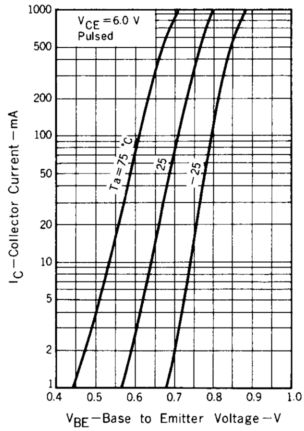
COLLECTOR SATURATION VOLTAGE
vs. COLLECTOR CURRENT



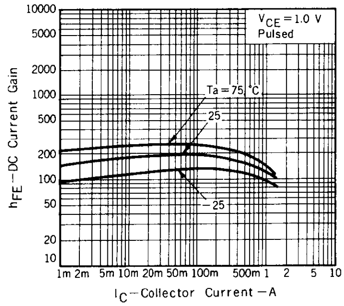
BASE SATURATION VOLTAGE
vs. COLLECTOR CURRENT



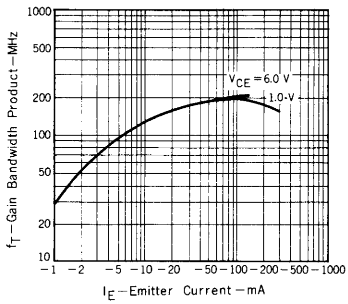
COLLECTOR CURRENT vs.
BASE TO EMITTER VOLTAGE



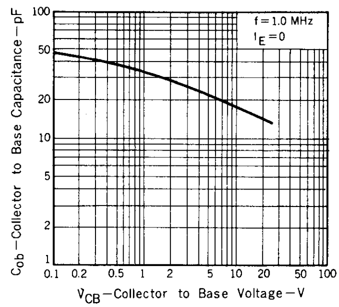
DC CURRENT GAIN vs.
COLLECTOR CURRENT



GAIN BANDWIDTH PRODUCT vs.
EMITTER CURRENT



COLLECTOR TO BASE CAPACITANCE vs.
COLLECTOR TO BASE VOLTAGE



NEC
ELECTRON DEVICE

N-CHANNEL JUNCTION FIELD-EFFECT TRANSISTOR

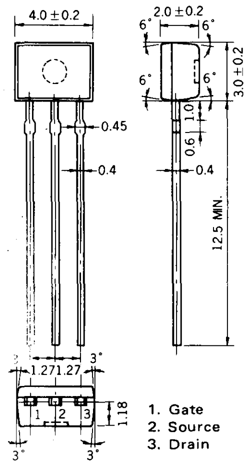
2SK193

DESCRIPTION The 2SK193 is designed for use in FM tuner of a potable radio receiver.

FEATURES

- High $|y_{fs}|_1$: 3.5 mS TYP.
  $|y_{fs}|_1$ (V_{DS} = 5.0 V, I_D = 0.5 mA, f = 1.0 kHz)
- Low C_{rss} : 0.07 pF TYP.
  C_{rss} (V_{DS} = 5.0 V, V_{GS} = 0)

PACKAGE DIMENSIONS
in millimeters



ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Maximum Temperatures
- Storage Temperature . . . . −55 to +125 °C
- Junction Temperature . . . . +125 °C Maximum

Maximum Power Dissipation (Ta = 25 °C)
- Total Power Dissipation . . . . 250 mW

Maximum Voltages and Currents (Ta = 25 °C)

V_{GDO}	Gate to Drain Voltage	−20	V
V_{GSO}	Gate to Source Voltage	−1.0	V
V_{DSX}*	Drain to Source Voltage	20	V
I_D	Drain Current	10	mA
I_G	Gate Current	10	mA

* V_{GS} = −2.5 V

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
I_{DSS}	Zero-Gate Voltage Drain Current	0.5	2.5	8.0	mA	V_{DS} = 5.0 V, V_{GS} = 0
$\|y_{fs}\|_1$	Forward Transfer Admittance	2.3	3.5		mS	V_{DS} = 5.0 V, I_D = 0.5 mA, f = 1.0 kHz
$\|y_{fs}\|_2$	Forward Transfer Admittance	2.3	8.5		mS	V_{DS} = 5.0 V, V_{GS} = 0, f = 1.0 kHz
C_{iss}	Input Capacitance		5.0	6.5	pF	V_{DS} = 5.0 V, V_{GS} = 0, f = 1.0 MHz
C_{rss}	Feedback Capacitance		0.07	0.25	pF	V_{DS} = 5.0 V, V_{GS} = 0, f = 1.0 MHz
C_{oss}	Output Capacitance		4.5	6.0	pF	V_{DS} = 5.0 V, V_{GS} = 0, f = 1.0 MHz
G_{ps}	Power Gain	13	21		dB	V_{DS} = 5.0 V, V_{GS} = 0, Z_{in}, Z_{out} = 50 Ω f = 100 MHz, See test circuit
NF	Noise Figure		3.0	6.0	dB	V_{DS} = 5.0 V, V_{GS} = 0, Z_{in}, Z_{out} = 50 Ω f = 100 MHz, See test circuit
I_{GSS}	Gate Cutoff Current			−100	nA	V_{GS} = −0.5 V, V_{DS} = 0
$V_{GS(off)}$	Gate to Source Cutoff Voltage			−2.5	V	V_{DS} = 5.0 V, I_D = 10 μA

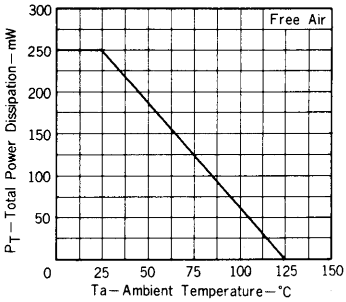
Classification of I_{DSS}

Rank	U	E	F	P	K	L	M
I_{DSS}(mA)	0.5 − 1.0	0.75 − 1.5	1.0 − 2.0	1.5 − 3.0	2.0 − 4.0	3.0 − 6.0	4.0 − 8.0

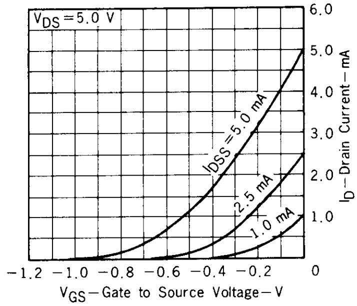
I_{DSS} Test Conditions: V_{DS} = 5.0 V, V_{GS} = 0

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

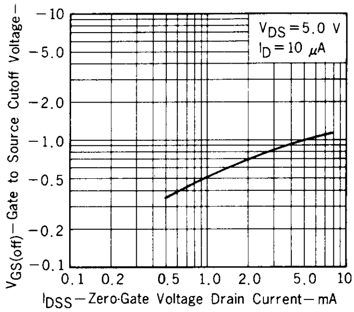
TOTAL POWER DISSIPATION vs. AMBIENT TEMPERATURE



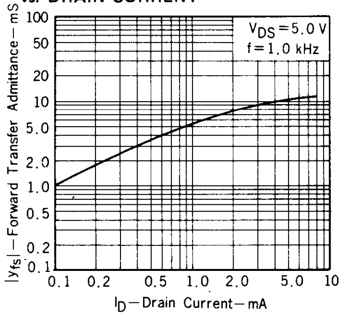
DRAIN CURRENT vs. GATE TO SOURCE VOLTAGE



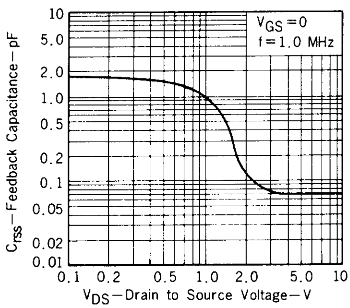
GATE TO SOURCE CUTOFF VOLTAGE vs. ZERO-GATE VOLTAGE DRAIN CURRENT



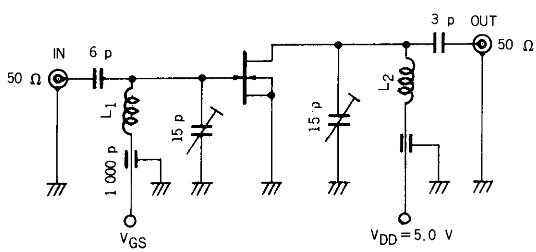
FORWARD TRANSFER ADMITTANCE vs. DRAIN CURRENT



FEEDBACK CAPACITANCE vs. DRAIN TO SOURCE VOLTAGE



NOISE FIGURE and POWER GAIN TEST CIRCUIT (f = 100 MHz)



Contents

Varactors, Mixer, Schottky and Switching

NEC
ELECTRON DEVICE

SILICON SWITCHING DIODES
1S953, 1S954, 1S955

HIGH SPEED SWITCHING
SILICON EPITAXIAL DIODES

DESCRIPTION

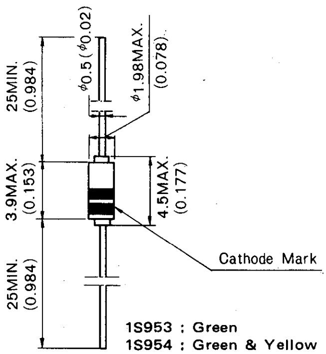
The 1S953, 1S954 and 1S955 are silicon epitaxial diodes designed for high speed switching applications.

FEATURES

- Miniature Package
- High Power Dissipation
- Low Capacitance
- Fast Recovery Time
- Low Leakage
- High Conductance

PACKAGE DIMENSIONS

in millimeters (inches)



1S953 : Green
1S954 : Green & Yellow
1S955 : Green & Green

EIAJ : SC-40
JEDEC : DO-35

ABSOLUTE MAXIMUM RATINGS

		1S953	1S954	1S955	
Maximum Voltages and Currents (T_a = 25°C)					
Peak Reverse Voltage	V_{RM}	35	75	100	V
Reverse Voltage	V_R	30	50	75	V
Peak Forward Surge Current (1 μs)	$I_{F\ (surge)}$	2000	4000	4000	mA
Peak Forward Current	I_{FM}	300	600	600	mA
Average Rectified Current	I_O	100	200	200	mA
Maximum Power Dissipation (T_a = 25°C)					
Power Dissipation	P		500		mW
Maximum Temperatures					
Junction Temperature	T_j		200		°C
Storage Temperature	T_{stg}		−65 to +200		°C

ELECTRICAL CHARACTERISTICS (T_a = 25°C)

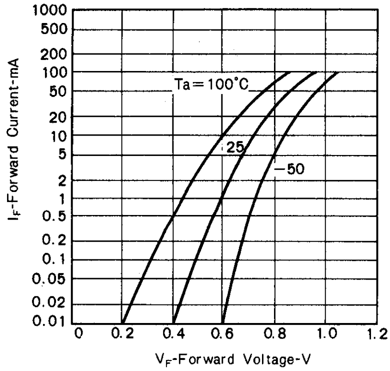
CHARACTERISTIC	SYMBOL	1S953			1S954			1S955			UNIT	TEST CONDITIONS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
Forward Voltage	V_F		0.8	1.0							V	I_F = 30 mA
	V_F					0.9	1.0				V	I_F = 100 mA
	V_F								0.9	1.0	V	I_F = 150 mA
Reverse Current	I_R		0.01	0.1							μA	V_R = 30 V
	I_R					0.015	0.1				μA	V_R = 50 V
	I_R								0.03	0.1	μA	V_R = 75 V
Terminal Capacitance	C_t		2.0	4.0		2.0	3.5		2.0	3.0	pF	V_R = 0, f = 1.0 MHz
Reverse Recovery Time	t_{rr}		2.0	3.0		2.0	3.0		2.0	3.0	ns	I_F = 10 mA, V_R = 6.0 V, R_L = 100Ω

7

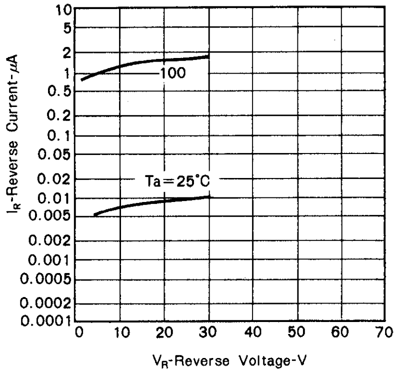
TYPICAL CHARACTERISTICS (T_a = 25°C)

1S953

FORWARD CURRENT
vs. FORWARD VOLTAGE

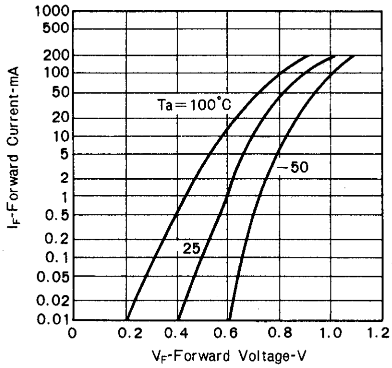


REVERSE CURRENT
vs. REVERSE VOLTAGE

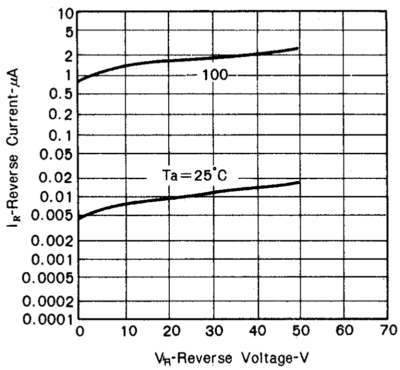


1S954

FORWARD CURRENT
vs. FORWARD VOLTAGE

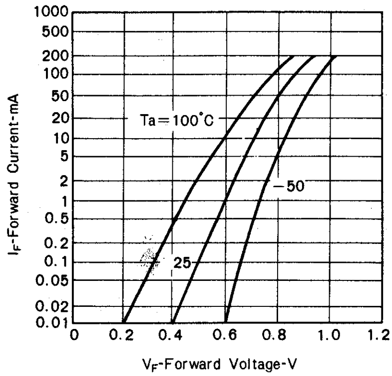


REVERSE CURRENT
vs. REVERSE VOLTAGE

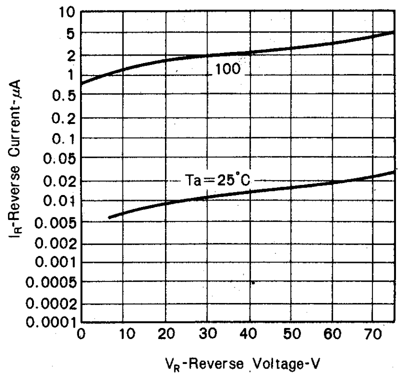


1S955

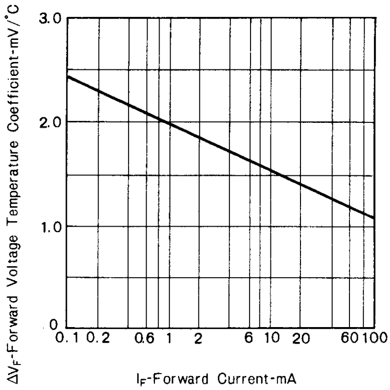
FORWARD CURRENT
vs. FORWARD VOLTAGE



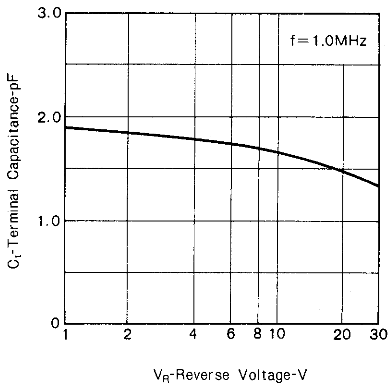
REVERSE CURRENT
vs. REVERSE VOLTAGE



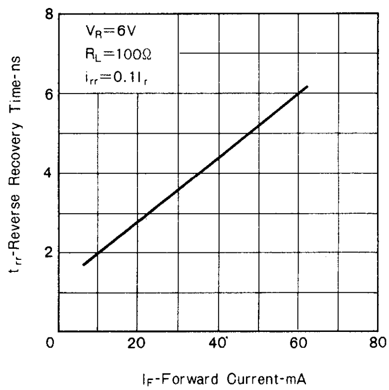
FORWARD VOLTAGE TEMPERATURE COEFFICIENT vs. FORWARD CURRENT



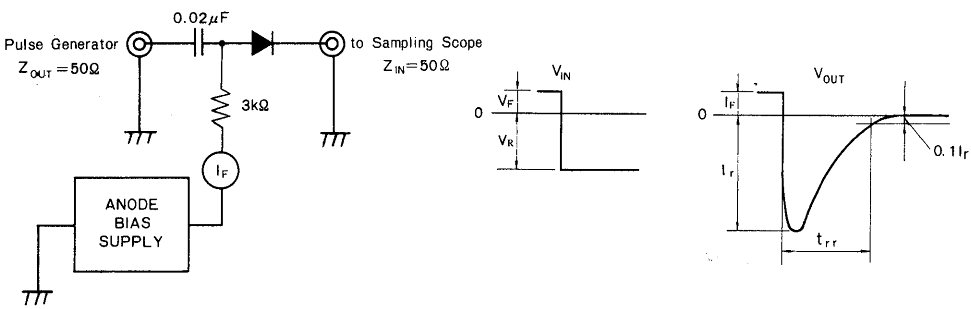
TERMINAL CAPACITANCE vs. REVERSE VOLTAGE



REVERSE RECOVERY TIME vs. FORWARD CURRENT



t_{rr} REVERSE RECOVERY TIME TEST CIRCUIT



Test Conditions : I_F = 10 mA, V_R = 6.0 V, R_L = 100Ω

NEC
ELECTRON DEVICE

VARACTOR DIODE
1S2207(B)

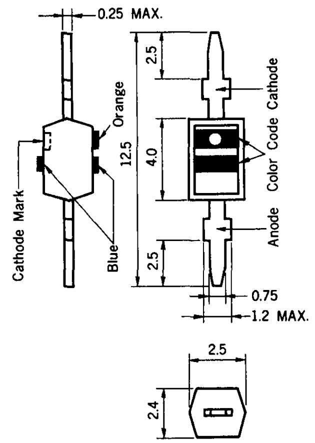
DESCRIPTION

The 1S2207(B) is a hyper-abrupt junction type voltage-variable capacitance diode.
It is designed for electronic tuning circuit applications in VHF and UHF bands and features high Q, high capacitance ratio and high reliability.

FEATURES

- High Q.
- High capacitance ratio.
- Low leakage current.

PACKAGE DIMENSIONS
in millimeters (inches)



ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Peak Reverse Voltage	V_{RM}	27	V
DC Reverse Voltage	V_R	25	V
Storage Temperature	T_{stg}	−55 to +125	°C

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

SYMBOL	CHARACTERISTIC	NC MIN.	NC TYP.	NC MAX.	KC, LC, MC MIN.	KC, LC, MC TYP.	KC, LC, MC MAX.	UNIT	TEST CONDITIONS
V_R	Reverse Voltage	25			25			V	I_R = 1.0 μA
C_{t2}	Terminal Capacitance	11.0		17.0				pF	V_R = 2.0 V, f = 1.0 MHz
C_{t3}					9.50		14.0		V_R = 3.0 V, f = 1.0 MHz
C_{t6}					5.75		9.75		V_R = 6.0 V, f = 1.0 MHz
C_{t10}		3.8		6.4	3.80		6.40		V_R = 10 V, f = 1.0 MHz
N1	Capacitance Ratio	2.5		3.10					C_{t2}/C_{t10}
N2					2.20		2.60		C_{t3}/C_{t10}
r_s	Seriese Resistance			0.6			0.6	Ω	C_t = 9.0 pF, f = 50 MHz

C_{t6} Classification

Rank	KC	LC	MC
C_{t6}(pF)	7.75 – 9.75	6.50 – 8.75	5.75 – 7.50

C_{t6} Test Condition: V_R = 6.0 V, f = 1.0 MHz

TYPICAL CHARACTERISTICS (Ta = 25 °C)

TERMINAL CAPACITANCE vs. REVERSE VOLTAGE

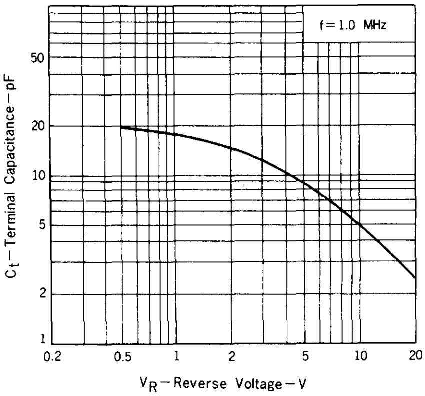
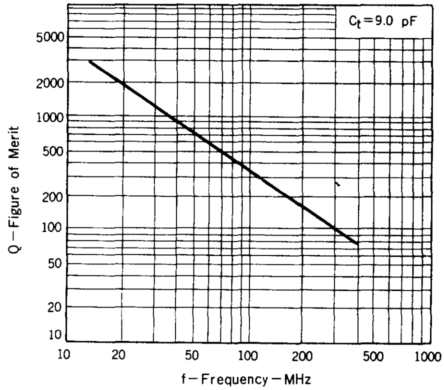
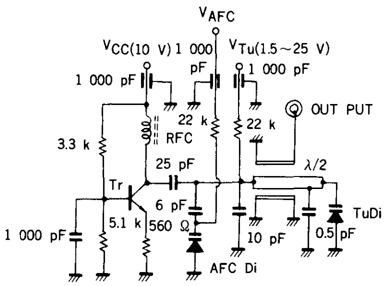


FIGURE OF MERIT vs. FREQUENCY

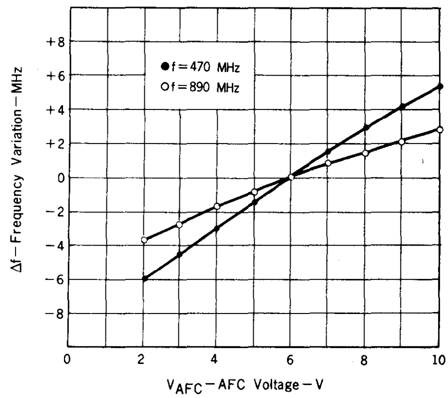


AFC Test Circuit



Tr : 2SC288A(5·B) (or 2SC1730)
Tuning Diode : 1S2208(B)

FREQUENCY VARIATION vs. AFC VOLTAGE



7

NEC
ELECTRON DEVICE

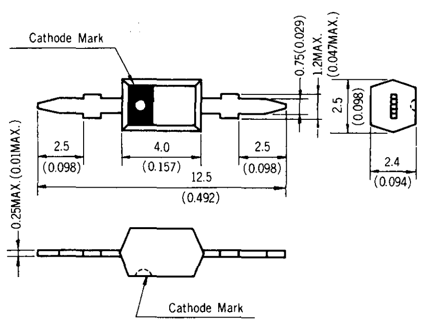
VARACTOR DIODES
1S2208(B),1S2209(B)

UHF/VHF TUNER
SILICON EPITAXIAL DIODES
ESVAC®

The 1S2208(B) and 1S2209(B) are a hyper-abrupt junction type voltage-variable capacitance diodes.

The 1S2208(B) and 1S2209(B) are designed for electronic tuning circuit application in UHF and VHF.

PACKAGE DIMENSIONS
in millimeters (inches)



FEATURES

- Low series resistance. 0.35Ω TYP.
- High capacitance ratio.
- Low leakage current.
- High reliability.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Peak Reverse Voltage	V_{RM}	30	V
DC Reverse Voltage	V_R	30	V
Storage Temperature	T_{stg}	-55 to +125	°C

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	1S2208(B)			1S2209(B)			UNIT	TEST CONDITIONS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
Reverse Voltage	V_R	30			30			V	$I_R = 1.0\mu A$
Capacitance	C_{t3}	11.0		12.65	10.3		12.90	pF	$V_R = 3.0V$, f = 1.0MHz
	C_{t25}	2.0		2.3	2.0		2.5	pF	$V_R = 25V$, f = 1.0MHz
Capacitance Ratio	N	4.5			4.0				C_{t3}/C_{t25}
Series Resistance	r_s		0.35	0.6		0.35	0.6	Ω	C = 9.0pF, f = 50MHz

NOTE : Diodes are available in matched sets of 20, 60, 120, 120xn units.
For two diodes of one set the following conditions are relevant :
The variations ΔC in capacitance values at V_R = 3, 10, 18 and 25V are less than 2% for 1S2208(B), 3% for 1S2209(B).

$$\Delta C = \frac{Cmax. - Cmin.}{Cmin.} \times 100\ (\%)$$

TYPICAL CHARACTERISTICS (Ta = 25°C)

TERMINAL CAPACITANCE vs. REVERSE VOLTAGE

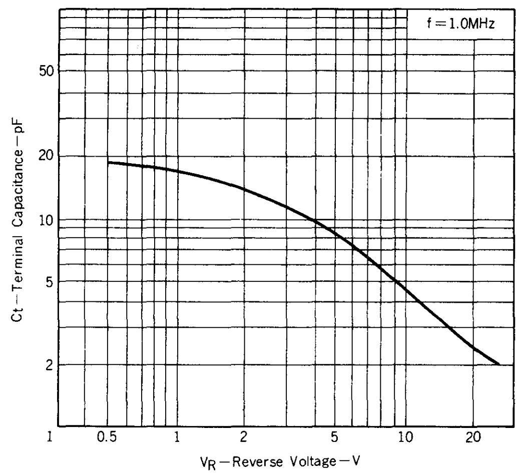
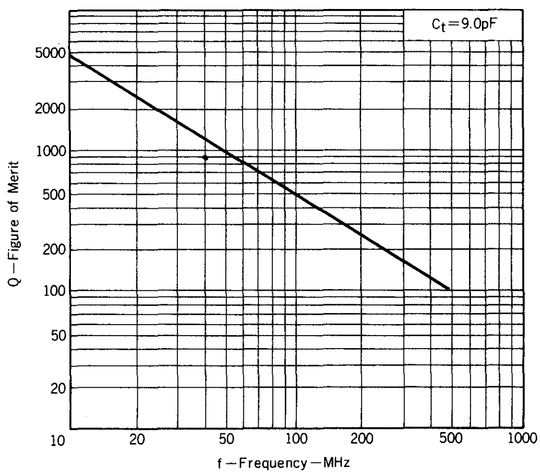


FIGURE OF MERIT vs. FREQUENCY



7

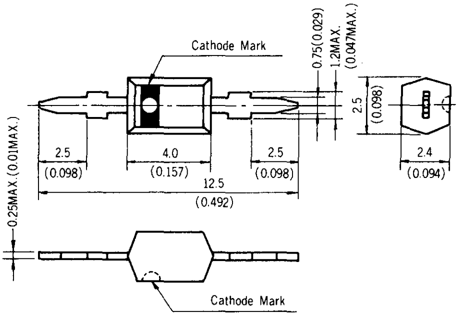
NEC
ELECTRON DEVICE

SILICON SWITCHING DIODE
1S2222

UHF/VHF ELECTRONIC TUNER & VHF LOW, HIGH CH. SWITCH
SILICON EPITAXIAL DIODE

The 1S2222 is designed for electronic tuning circuit applications in UHF/VHF bands switch and VHF (Low CH., High CH.) bands switch.

PACKAGE DIMENSIONS
in millimeters (inches)



FEATURES

- Low series resistance.
- Low terminal capacitance.
- High reliability.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Reverse Voltage	V_R	35	V
Average Rectified Current	I_O	100	mA
Power Dissipation	P_D	250	mW
Storage Temperature	T_{stg}	-65 to +150	°C

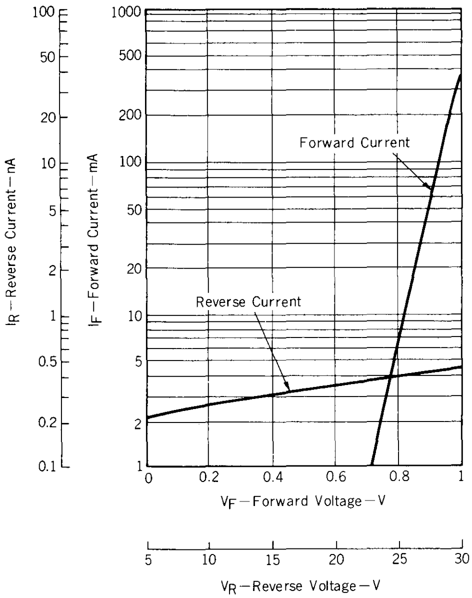
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F			1.1	V	I_F = 100mA
Reverse Voltage	V_R	35			V	I_R = 1.0μA
Reverse Current	I_R		0.5	50	nA	V_R = 30V
Series Resistance	r_s		0.6	1.0	Ω	I_F = 10mA, f = 100MHz
Terminal Capacitance	C_t		0.8	1.0	pF	V_R = 15V, f = 1.0MHz

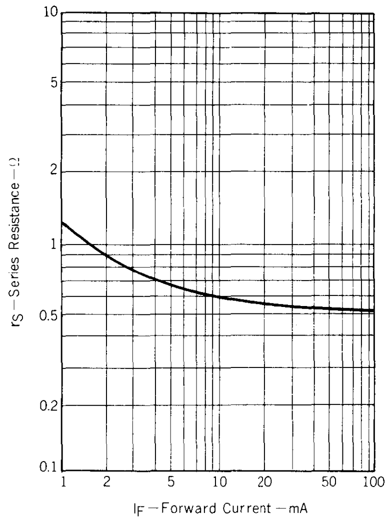
TYPICAL CHARACTERISTICS (Ta = 25°C)

FORWARD CURRENT vs. FORWARD VOLTAGE

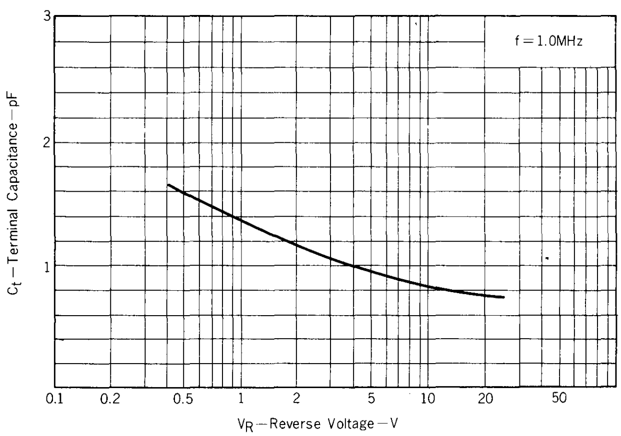
REVERSE CURRENT vs. REVERSE VOLTAGE



SERIES RESISTANCE vs. FORWARD CURRENT



TERMINAL CAPACITANCE vs. REVERSE VOLTAGE



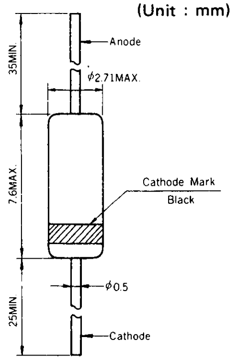
7

NEC
ELECTRON DEVICE

UHF DETECTOR & MIXER DIODE
1SS16

SILICON EPITAXIAL SCHOTTKY BARRIER DIODE
UHF MIXER
"SILICON ESBAR"

PACKAGE DIMENSIONS
(Unit : mm)



- Low Capacitance.
- High Conductance.
- Low Noise.
- High Immunity of Surge Current.

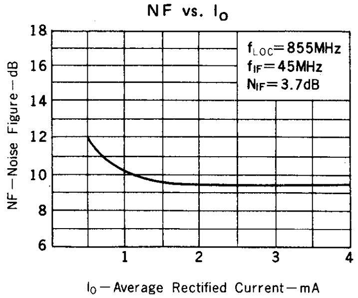
ABSOLUTE MAXIMUM RATINGS ($T_a = 25°C$)

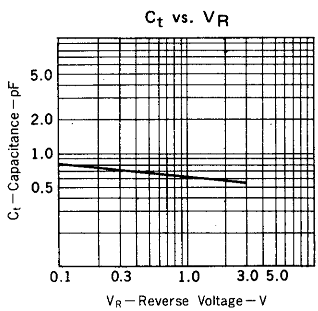
Peak Reverse Voltage	V_{RM}	5.0	V
Average Rectified Current	I_O	30	mA
Storage Temperature	T_{stg}	-65 to +100	°C

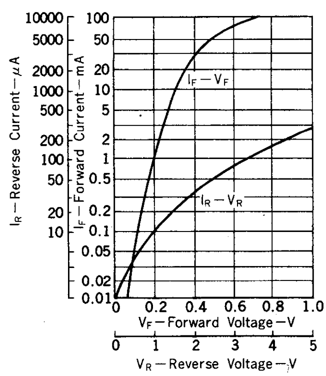
ELECTRICAL CHARACTERISTICS ($T_a = 25°C$)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Current	I_F	30			mA	$V_F = 0.5V$
Reverse Current	I_R			25	μA	$V_R = 0.5V$
Capacitance	C_t			0.9	pF	$V_R = 0.2V$, f = 1.0MHz
Noise Figure	NF		9.5	10.5	dB	$f_{LOC} = 855MHz$, $f_{IF} = 45MHz$ $N_{IF} = 3.7dB$, $I_o = 2.0mA$
Reverse Burn Out	B_o	2.0			erg	

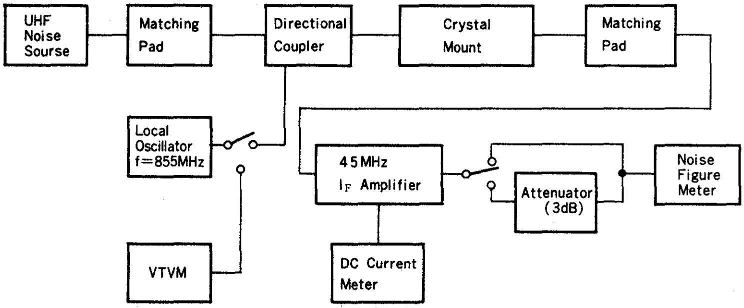
TYPICAL CHARACTERISTICS ($T_a = 25°C$)



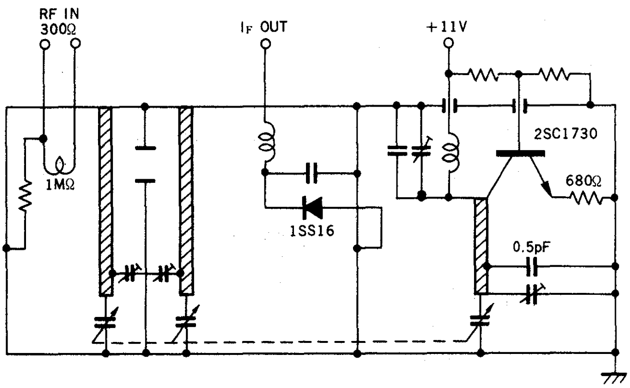


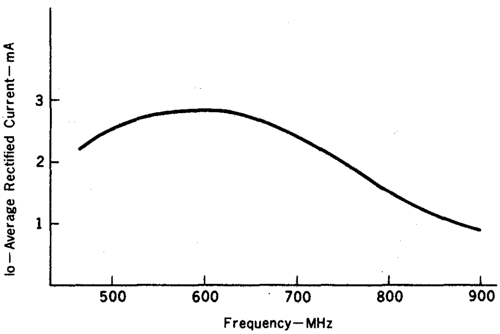


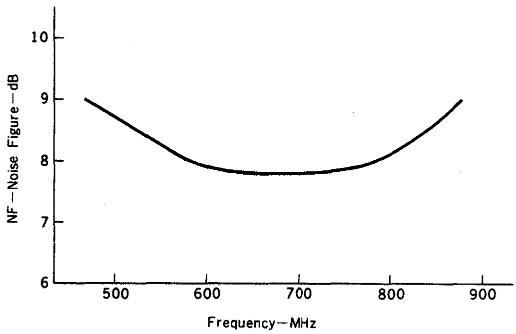
NF TEST CIRCUIT



TYPICAL APPLICATION for UHF TV TUNER







7

NEC
ELECTRON DEVICE

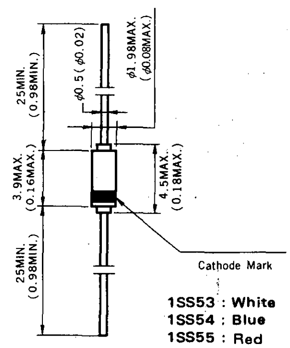
SILICON DIODES
1SS53,1SS54,1SS55

GENERAL PURPOSE
SILICON EPITAXIAL PLANAR DIODES

DESCRIPTION

The 1SS53, 1SS54, and 1SS55 are silicon epitaxial planar diodes designed for general purpose applications.

PACKAGE DIMENSIONS
in millimeters (inches)



1SS53 : White
1SS54 : Blue
1SS55 : Red

EIAJ : SC-40
JEDEC : DO-35

FEATURES

- Miniature package
- High power dissipation
- Low leakage
- Low price

ABSOLUTE MAXIMUM RATINGS

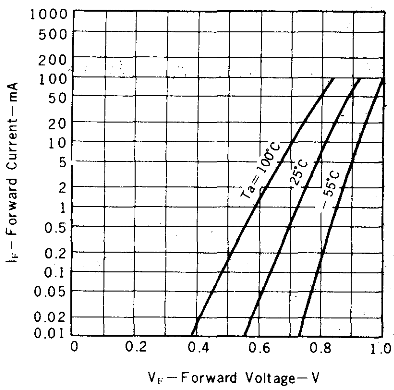
		1SS53	1SS54	1SS55	
Maximum Voltages and Currents (T_a = 25°C)					
Peak Reverse Voltage	V_{RM}	35	75	100	V
Reverse Voltage	V_R	30	50	75	V
Peak Forward Surge Current (1 μs)	$I_{F\,(surge)}$		2000		mA
Peak Forward Current	I_{FM}		300		mA
Average Rectified Current	I_O		100		mA
Maximum Power Dissipation (T_a = 25°C)					
Power Dissipation	P		500		mW
Maximum Temperatures					
Junction Temperature	T_j		200		°C
Storage Temperature	T_{stg}		-65 to +200		°C

ELECTRICAL CHARACTERISTICS (T_a = 25°C)

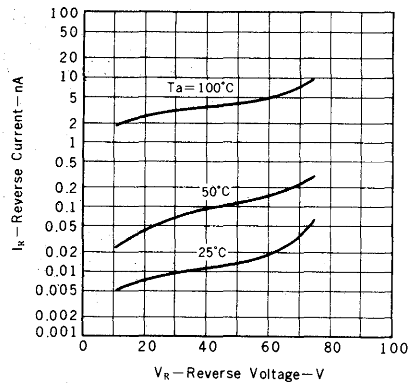
CHARACTERISTIC	SYMBOL	1SS53			1SS54			1SS55			UNIT	TEST CONDITIONS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
Forward Voltage	V_F		0.7	0.8		0.7	0.8		0.7	0.8	V	I_F = 1.0 mA
	V_F		0.85	1.0		0.85	1.0		0.85	1.0	V	I_F = 30 mA
Reverse Current	I_R			0.1							μA	V_R = 30 V
	I_R						0.1				μA	V_R = 50 V
	I_R									0.1	μA	V_R = 75 V
Terminal Capacitance	C_t			6.0			5.0			4.0	pF	V_R = 0, f = 1.0 MHz
Reverse Recovery Time	t_{rr}		20	100		20	100		20	100	ns	I_F = 10 mA, V_R = 6.0 V, R_L = 100Ω

TYPICAL CHARACTERISTICS ($T_a = 25°C$)

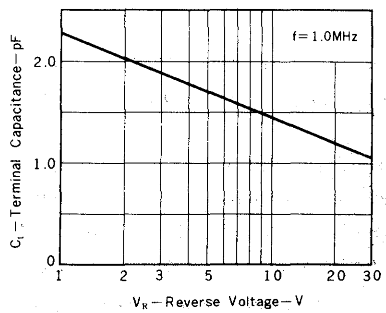
FORWARD CURRENT vs. FORWARD VOLTAGE



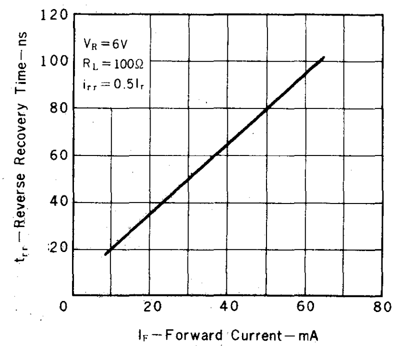
REVERSE CURRENT vs. REVERSE VOLTAGE (1SS55)



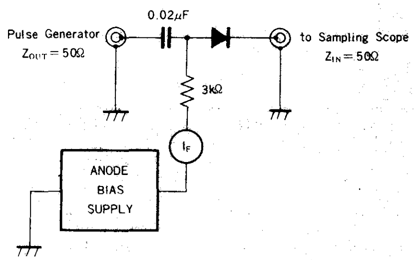
TERMINAL CAPACITANCE vs. REVERSE VOLTAGE

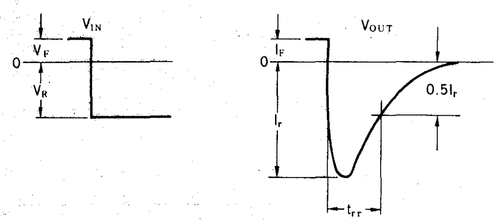


REVERSE RECOVERY TIME vs. FORWARD CURRENT



t_{rr} REVERSE RECOVERY TIME TEST CIRCUIT





Test Conditions : I_F = 10 mA, V_R = 6.0 V, R_L = 100Ω

7

NEC
ELECTRON DEVICE

MIXER DIODE
1SS97

UHF MIXER
SILICON EPITAXIAL SCHOTTKY BARRIER DIODE

DESCRIPTION AND APPLICATIONS

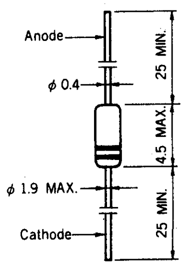
The 1SS97 is silicon epitaxial schottky barrier diode, especially designed for mixing, switching, log or A-D converting, frequency discriminating sampling and wave shaping.

FEATURES

- Small size glass package. (DO-35 TYPE)
- High breakdown voltage: V_R = 10 V MIN. at I_R = 10 μA
- Bach matched.
- Low cost.

PACKAGE DIMENSIONS
in millimeters

JEDEC : DO-35



Color Code (from cathode)
Green, Blue

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Reverse Voltage	V_R	10	V
Forward Current	I_F	35	mA
DC Power Dissipation	P_d	150	mW
Junction Temperature	T_j	+175	°C
Storage Temperature	T_{stg}	-65 to +175	°C
Reverse Burnout *	B_o	2.0	erg

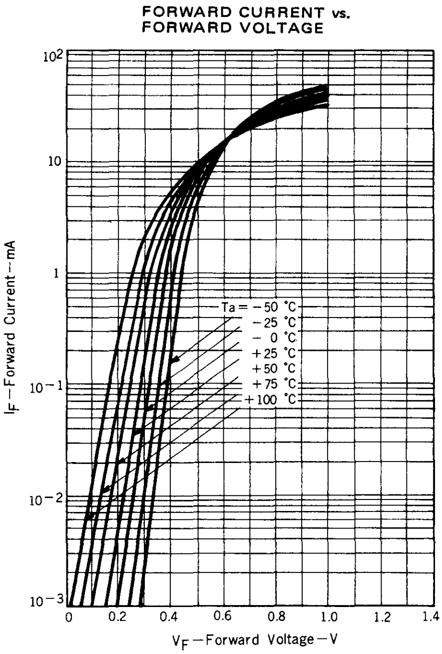
Note * : Capacitor charge method C(charge) = 25 pF

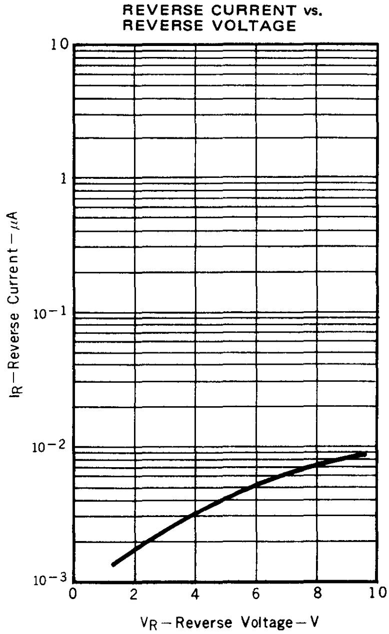
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

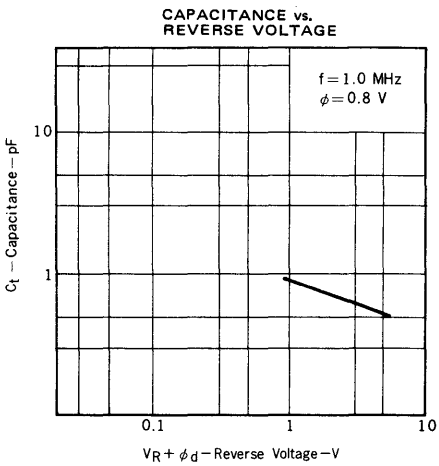
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Reverse Voltage	V_R	10			V	I_R = 10 μA
Foward Voltage	V_F	0.46		0.55	V	I_F = 10 mA
Delta Forward Voltage *	ΔV_F			10	mV	I_F = 10 mA
Capacitance	C_t			1.0	pF	V_R = 0, f = 1.0 MHz
Delta Capacitance *	ΔC_t			0.2	pF	V_R = 0, f = 1.0 MHz

Note * : Difference of V_F, C_t.

TYPICAL CHARACTERISTICS (Ta = 25 °C)







7

NEC
ELECTRON DEVICE

MIXER DIODE
1SS98

UHF DETECTOR, MIXER
SILICON EPITAXIAL SCHOTTKY BARRIER DIODE

DESCRIPTION AND APPLICATIONS

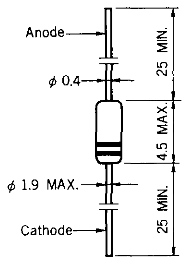
The 1SS98 is silicon epitaxial schottky barrier diode, especially designed for mixing, log or A-D converting, video detecting, frequency discriminating, sampling and wave shaping.

FEATURES

- Small size glass package. (DO-35 TYPE)
- Midle turn-on voltage. V_F = 0.34 V MAX. at I_F = 1 mA
- Low cost.

PACKAGE DIMENSIONS
in millimeters

JEDEC : DO-35



Color Code (from cathode)
Orange, Blue

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Reverse Voltage	V_R	5.0	V
Forward Current	I_F	50	mA
DC Power Dissipation	P_d	150	mW
Junction Temperature	T_j	+175	°C
Storage Temperature	T_{stg}	-65 to +175	°C
Reverse Burnout *	B_o	2.0	erg

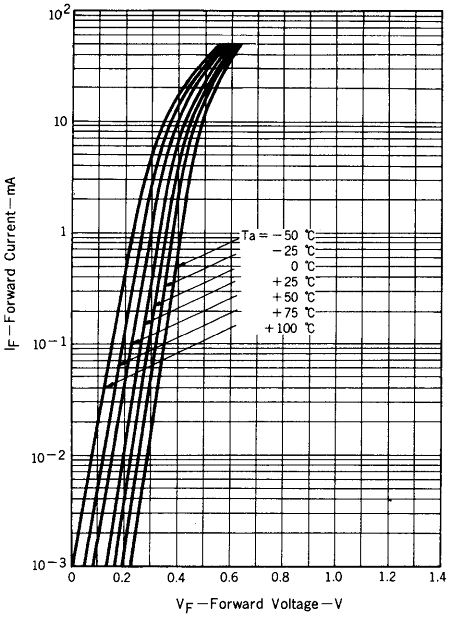
Note * : Capacitor charge method C(charge) = 25 pF

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

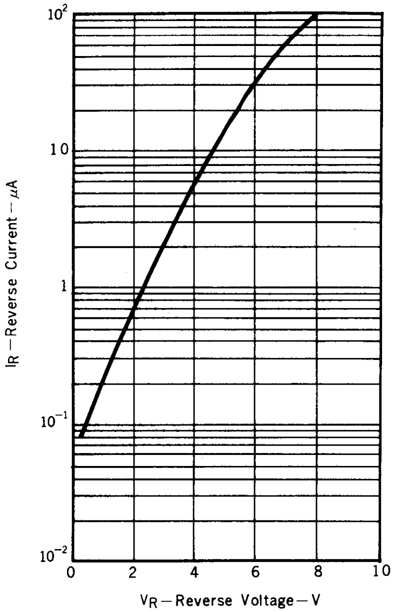
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Reverse Voltage	V_R	5.0			V	I_R = 100 μA
Reverse Current	I_R			500	nA	V_R = 1.0 V
Forward Voltage	V_{F1}			0.34	V	I_F = 1.0 mA
Forward Voltage	V_{F2}			0.45	V	I_F = 10 mA
Capacitance	C_t			1.0	pF	V_R = 0, f = 1.0 MHz

TYPICAL CHARACTERISTICS (Ta = 25 °C)

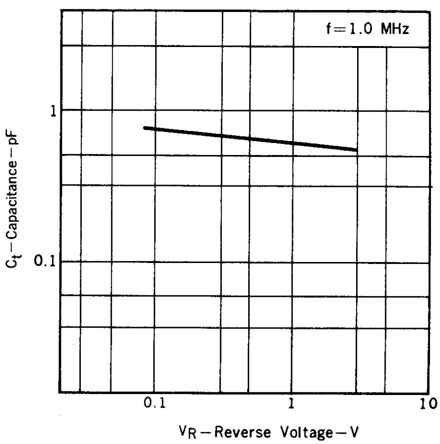
FORWARD CURRENT vs. FORWARD VOLTAGE



REVERSE CURRENT vs. REVERSE VOLTAGE



CAPACITANCE vs. REVERSE VOLTAGE



7

DETECTOR & MIXER DIODE
1SS99

UHF DETECTOR & MIXER
SILICON EPITAXIAL SCHOTTKY BARRIER DIODE

DESCRIPTION AND APPLICATIONS

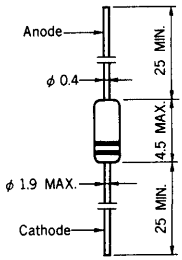
The 1SS99 is silicon epitaxial schottky barrier diode, especially designed for mixing, log or A-D converting, video detecting, frequency discriminating, sampling and wave shaping.

FEATURES

- Small size glass package. (DO-35 TYPE)
- Low noise figure.
- Low turn-on voltage. $V_F = 0.23$ V MAX. at $I_F = 1$ mA
- Low capacitance. $C_t = 0.9$ pF MAX. at 1 MHz, $V_R = 0.2$ V
- Low cost.

PACKAGE DIMENSIONS
in millimeters

JEDEC : DO-35



Color Code (from cathode)
Black, Blue

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

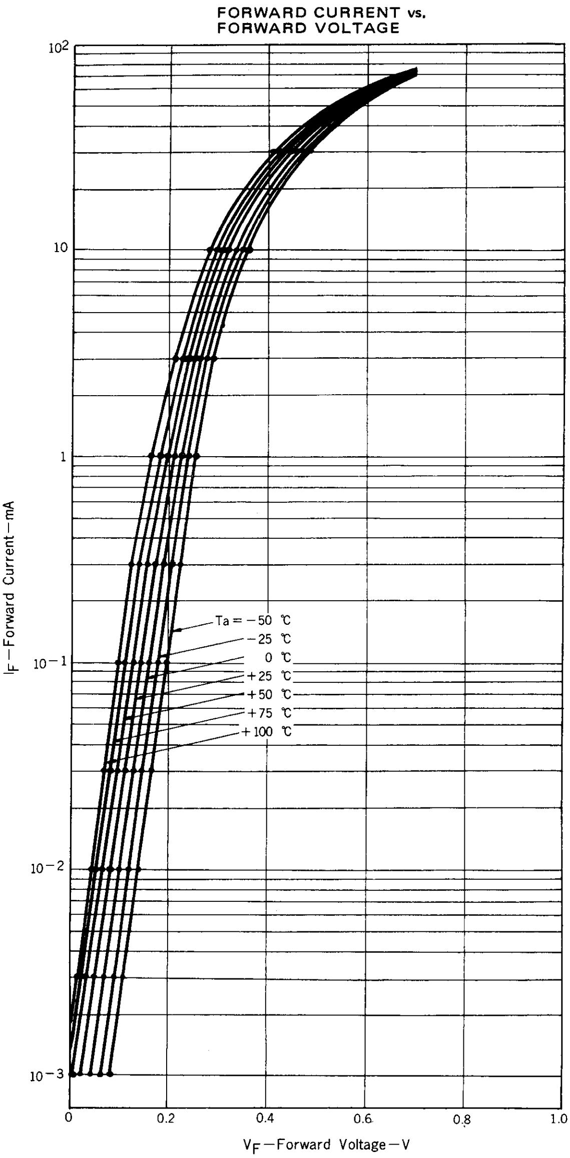
Peak Reverse Voltage	V_{RM}	5.0	V
Forward Current	I_F	30	mA
DC Power Dissipation	P_d	150	mW
Junction Temperature	T_j	+175	°C
Storage Temperature	T_{stg}	-65 to +175	°C
Reverse Burnout *	B_O	2.0	erg

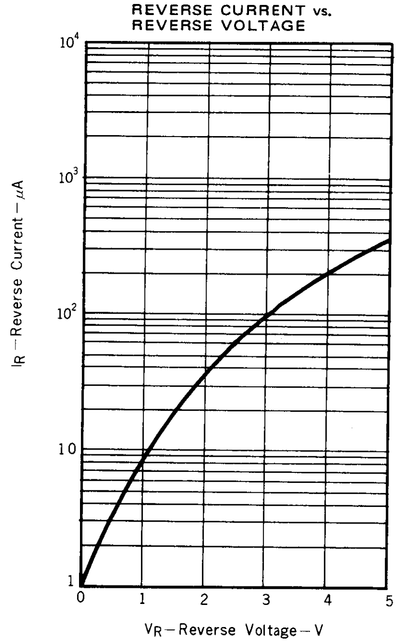
Note * : Capacitor charge method C(charge) = 25 pF

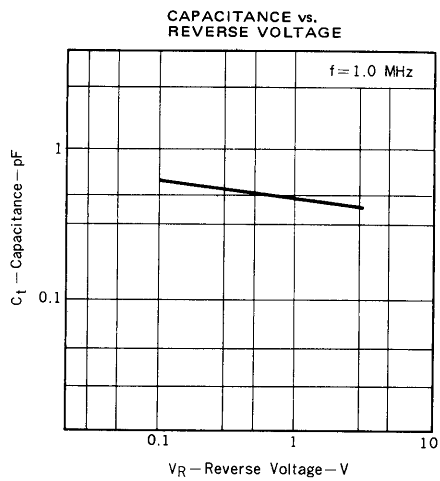
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Reverse Current	I_R			25	μA	V_R = 0.5 V
Forward Voltage	V_F			0.23	V	I_F = 1.0 mA
Forward Current	I_F	30			mA	V_F = 0.5 V
Capacitance	C_t			0.9	pF	V_R = 0.2 V, f = 1 MHz

TYPICAL CHARACTERISTICS (Ta = 25 °C)







7

NEC
ELECTRON DEVICE

MIXER DIODE
1SS101

UHF MIXER, SWITCHING
SILICON EPITAXIAL SCHOTTKY BARRIER DIODE

DESCRIPTION AND APPLICATIONS

The 1SS101 is silicon epitaxial schottky barrier diode, especially designed for mixing, switching, log or A-D converting, frequency discriminating, sampling and wave shaping.

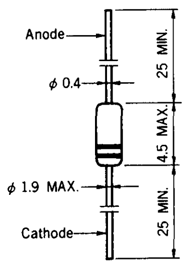
FEATURES

- Small size glass package. (DO-35 TYPE)
- High breakdown voltage. V_R = 70 V MIN. at I_R = 10 μA
- High turn-on voltage. V_F = 0.41 V MAX. at I_F = 1 mA
- Low cost.

PACKAGE DIMENSIONS

in millimeters

JEDEC : DO-35



Color Code (from cathode)
Red, Blue

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Reverse Voltage	V_R	70	V
Forward Current	I_F	15	mA
DC Power Dissipation	P_d	150	mW
Junction Temperature	T_j	+175	°C
Storage Temperature	T_{stg}	−65 to +175	°C
Reverse Burnout *	B_O	2.0	erg

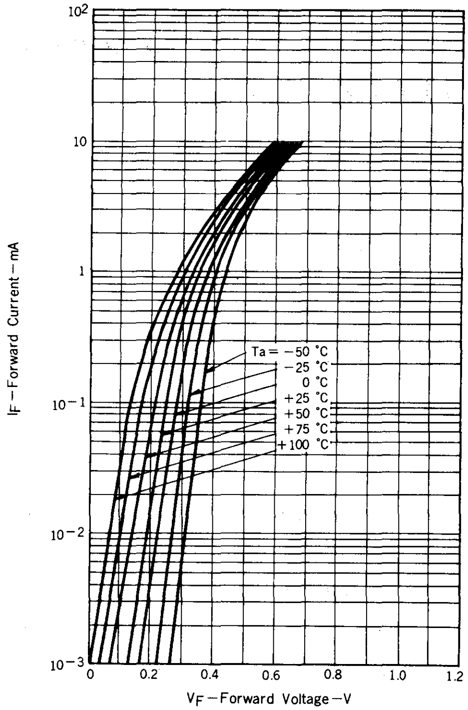
Note * : Capacitor charge method C(charge) = 25 pF

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

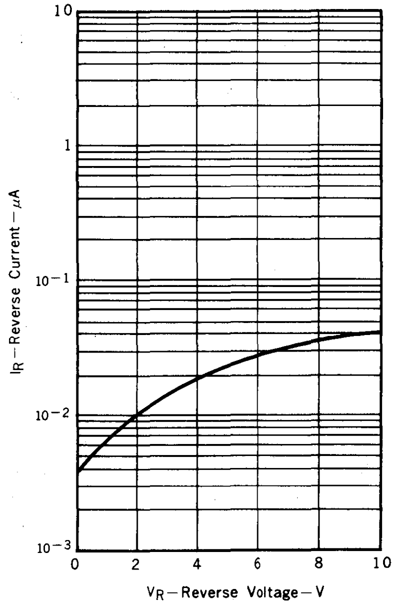
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Reverse Voltage	V_R	70			V	I_R = 10 μA
Reverse Current	I_R			200	nA	V_R = 50 V
Forward Voltage	V_F			0.41	V	I_F = 1.0 mA
Forward Current	I_F	15			mA	V_F = 1.0 V
Capacitance	C_t			2.0	pF	V_R = 0, f = 1.0 MHz

TYPICAL CHARACTERISTICS (Ta = 25 °C)

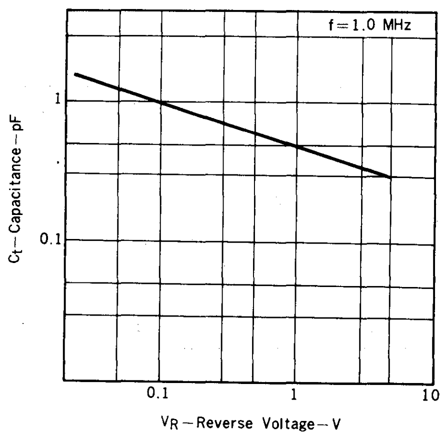
FORWARD CURRENT vs. FORWARD VOLTAGE



REVERSE CURRENT vs. REVERSE VOLTAGE



CAPACITANCE vs. REVERSE VOLTAGE



7

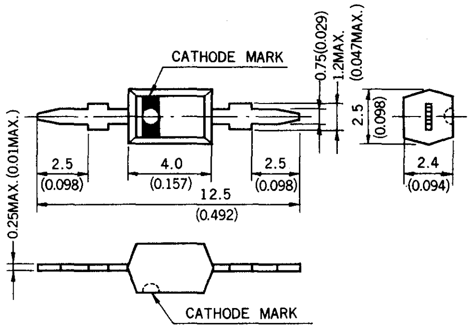
NEC ELECTRON DEVICE

SILICON SWITCHING DIODE
1SS103

UHF/VHF Electronic Tuner & VHF Low, High Ch. Switch
SILICON EPITAXIAL PLANAR DIODE

PACKAGE DIMENSIONS

in millimeters (inches)



FEATURES

- Low series resistance r_s.
- Low leakage current.
  $I_R \leqq 50$ nA at $V_R = 30$ V
- High reliability.

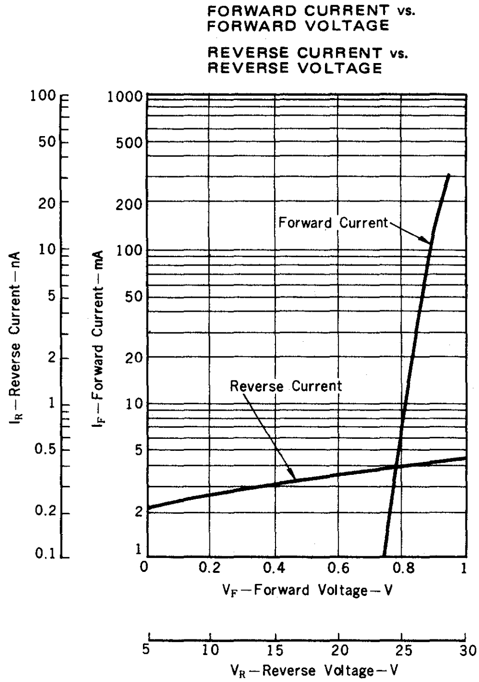
ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

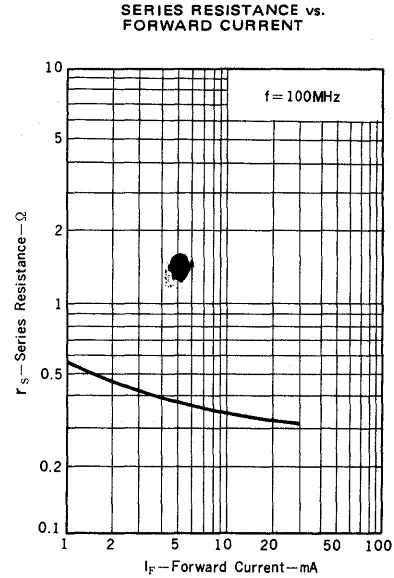
Reverse Voltage	V_R	35	V
Average Rectified Current	I_o	100	mA
Power Dissipation	P_D	150	mW
Storage Temperature	T_{stg}	-65 to +150	°C

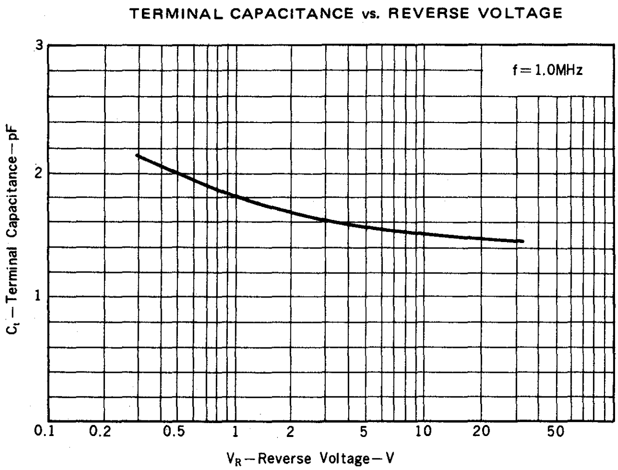
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F			1.1	V	I_F = 100 mA
Reverse Voltage	V_R	35			V	I_R = 1.0 μA
Reverse Current	I_R		0.5	50	nA	V_R = 30 V
Series Resistance	r_s		0.5	0.6	Ω	I_F = 2.0 mA, f = 100 MHz
Terminal Capacitance	C_t		1.5	2.0	pF	V_R = 15 V, f = 1.0 MHz

TYPICAL CHARACTERISTICS (Ta = 25°C)







7

PIN DIODE
1SV34

VHF/UHF RF ATTENUATIG AND SWITCHING SILICON PIN DIODE

FEATURES

- Low cost.
- Large dynamic range.
  Typical resistance swing 5Ω to 10kΩ.
- Low series resistance.
  Rs=8 Ω TYP. @ I_F=10mA, f=100MHz
- Low capacitance.
  Ct=0.5pF MAX. @ V_R=50V, f=1MHz

DESCRIPTION AND APPLICATIONS

The 1SV34 silicon PIN diode, especially designed for VHF/UHF band switching, attenuating.
The RF resistance of a PIN diode is a function of the current flowing in the diode. The current controlled resistars are specified for use in control applications such as ATT, AGC, and RF modulators.

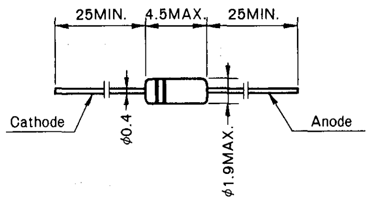
ABSOLUTE MAXIMUM RATINGS (Ta=25 °C)

Reverse Voltage	V_R	100	V
Forward Current	I_F	50	mA
Peak Reverse Voltage	V_{RM}	110	V
Peak Forward Current	I_{FM}	150	mA
DC Power Dissipation	P_d	250	mW
Junction Temperature	Tj	+175	°C
Storage Temperature	Tstg	−65 to +175	°C
Solder Temperature (Note 1)		260	°C

Note ; Less than 5 seconds, more than 1.5 mm off the lead connection.

PACKAGE DIMENSIONS (Unit : mm)

JEDEC : DO-35

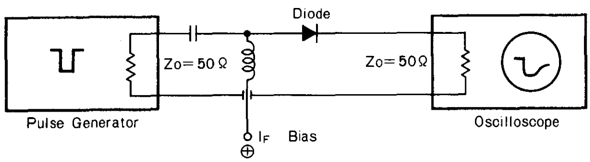


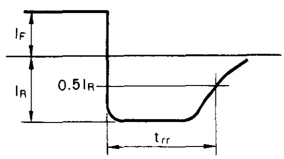
Color Code (from cathode)
Orange, Yellow

ELECTRICAL CHARACTERISTICS (Ta=25°C)

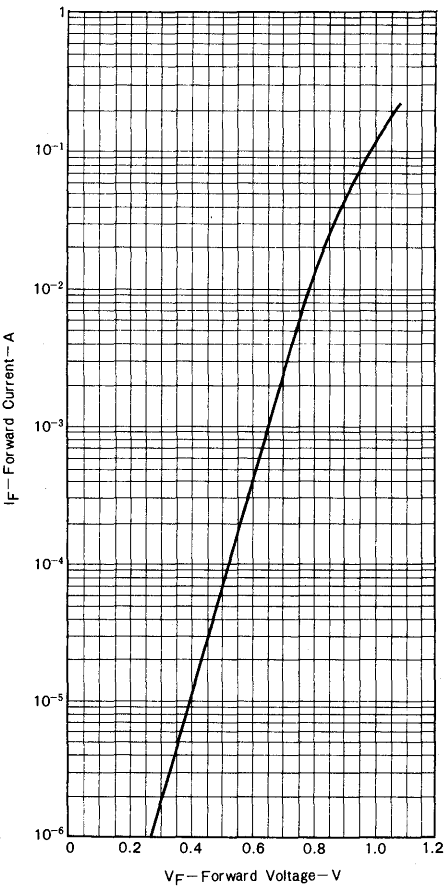
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		0.95	1.1	V	I_F=50mA
Reverse Current	I_R			10	μA	V_R=100V
Capacitance	Ct		0.3	0.5	pF	V_R= 50V, f=1.0MHz
Series Resistance	R_{ds}	6.0	8.0	10	Ω	I_F=10mA, f=100MHz
Parallel Resistance	R_{dp}	2.0	2.5		kΩ	I_F=10μA, f=100MHz
Life Time	τ		2.0		μs	I_F=10mA
Recovery Time	t_{rr}		1.0		μs	I_F=10mA, I_R=16mA*

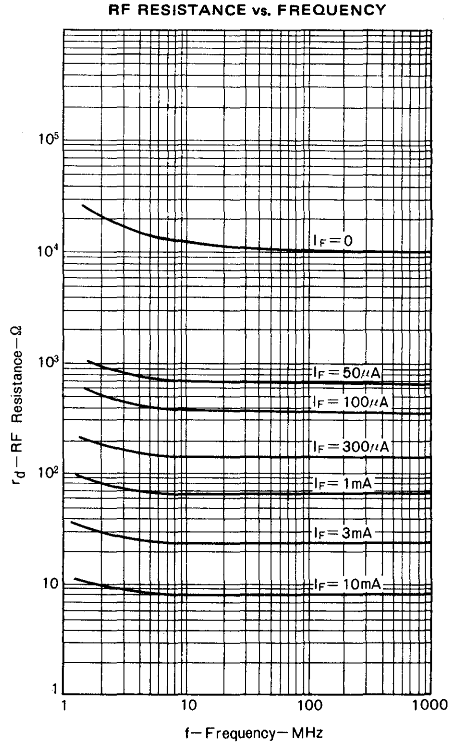
* MEASUREMENT BLOCK DIAGRAM



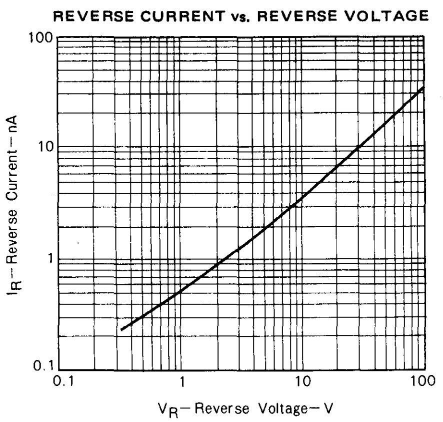


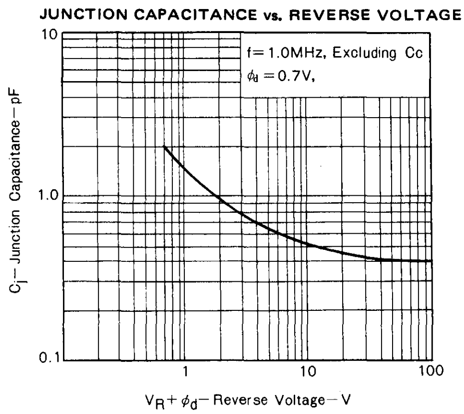
TYPICAL CHARACTERISTICS (Ta=25°C)

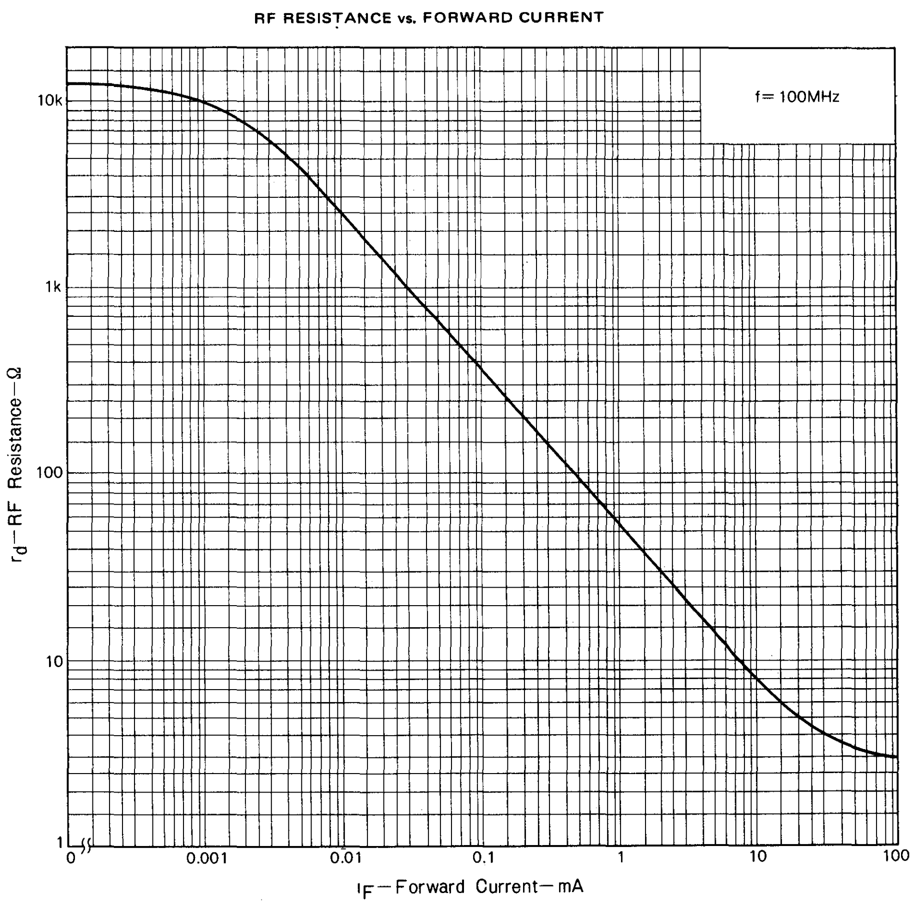




7


REVERSE CURRENT vs. REVERSE VOLTAGE
100
10
1
0.1
IR− Reverse Current − nA
0.1
1
10
100
VR− Reverse Voltage− V


JUNCTION CAPACITANCE vs. REVERSE VOLTAGE
f= 1.0MHz, Excluding Cc
φd =0.7V,
10
1.0
0.1
Cj− Junction Capacitance − pF
1
10
100
VR+ φd− Reverse Voltage− V


RF RESISTANCE vs. FORWARD CURRENT
f= 100MHz
10k
1k
100
10
1
rd−RF Resistance−Ω
0
0.001
0.01
0.1
1
10
100
IF − Forward Current− mA

NEC
ELECTRON DEVICE

VARACTOR DIODES
1SV50, 1SV50(1), 1SV50S

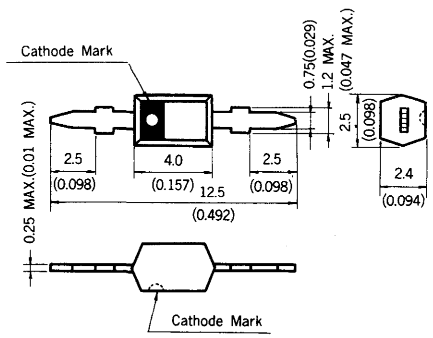
FM/VHF TUNER, AFC
SILICON EPITAXIAL DIODE
ESVAC®

DESCRIPTION

The 1SV50 and 1SV50(1) are a hyper-abrupt junction type voltage-variable capacitance diodes.
These are designed for electronic tuning circuit applications in FM and VHF bands and features high Q, high capacitance ratio, and high reliability.
1SV50S is designed for AFC circuit applications in FM and VHF bands.

PACKAGE DIMENSIONS

in millimeters (inches)



FEATURES

- High Q : Excellent Q values at FM and VHF frequencies.
- High capacitance ratio.
- 3 % capacitance tolerance.
- Low leakage current.
  $I_R \leqq 10$ nA at $V_R = 28$ V.

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Peak Reverse Voltage	V_{RM}	30	V
DC Reverse Voltage	V_R	30	V
Storage Temperature	T_{stg}	−55 to +125	°C
Power Dissipation	P_D	250	mW

7

1SV50, 1SV50(1)
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	1SV50			1SV50(1)			UNIT	TEST CONDITIONS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
Reverse Voltage	V_R	30			30			V	I_R=1.0 μA
Reverse Current	I_{R1}			10			10	nA	V_R=28 V, Ta=25 °C
Reverse Current	I_{R2}			50			50	nA	V_R=28 V, Ta=70 °C
Capacitance	C_{t3}	28.0		32.5	29.0		34.0	pF	V_R=3.0 V, f=1.0 MHz
	C_{t25}	4.90		5.80	4.90		5.80	pF	V_R=25 V, f=1.0 MHz
Capacitance Ratio	N	5.0		6.5	5.5		7.5		C_{t3}/C_{t25}
Series Resistance	r_s			0.5			0.5	Ω	C_t=29 pF, f=50 MHz
Capacitance Tolerance	ΔC			3.0			3.0	%	NOTE

NOTE : Diodes are available in matched sets of 20, 60, 120, 120×n units.
For two diodes of one set the following conditions are relevant :
The variations ΔC in capacitance values at V_R = 3, 10, 18 and 25 V are less than 3 % for 1SV50 and 1SV50(1).

$$\Delta C = \frac{C max. - C min.}{C min.} \times 100 \ (\%)$$

1SV50S
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Reverse Voltage	V_R	30			V	I_R = 1.0 μA
Reverse Current	I_{R1}			10	nA	V_R = 28 V, Ta = 25 °C
Reverse Current	I_{R2}			50	nA	V_R = 28 V, Ta = 70 °C
Capacitance	C_{t3}	23.0		36.0	pF	f = 1.0 MHz, V_R = 3.0 V
	C_{t6}	14.0		22.0	pF	f = 1.0 MHz, V_R = 6.0 V
Capacitance Ratio	N	1.3		2.1		C_{t3}/C_{t6}
Seriese Resistance	r_s			0.5	Ω	C = 30 pF, f = 50 MHz

TYPICAL CHARACTERISTICS (Ta = 25 °C)

TERMINAL CAPACITANCE vs. REVERSE VOLTAGE

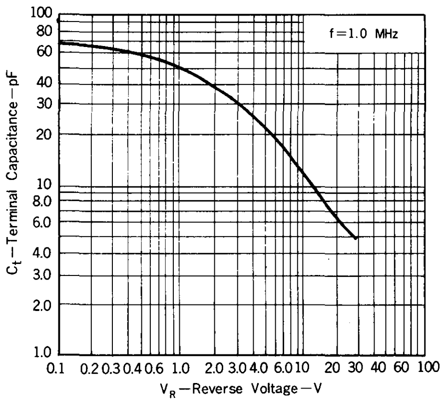
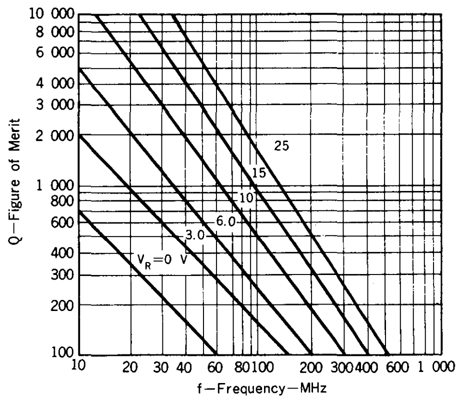
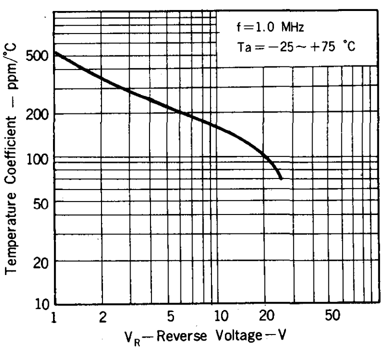


FIGURE OF MERIT vs. FREQUENCY



TEMPERATURE COEFFICIENT vs. REVERSE VOLTAGE



NEC
ELECTRON DEVICE

SILICON PIN DIODE
1SV77

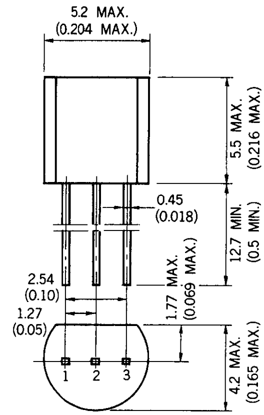
DESCRIPTION

The 1SV77 is designed for RF variable attenuator and switching circuit applications in FM, car radio and CB.

FEATURES

- Low Cost.
- Wide Frequency Range.
- Low Insertion Loss.
- Low 3rd Harmonic Distortion.
- Wide Dynamic Range.

PACKAGE DIMENSIONS
in millimeters (inches)



1. ANODE
2. SUBSTRATE
3. CATHODE

EIAJ : SC-43
JEDEC : TO-92
IEC : PA33

ABSOLUTE MAXIMUM RATINGS

Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature	T_{stg}	−55 to +125	°C
Maximum Power Dissipation (Ta = 25 °C)			
Power Dissipation	P_T	250	mW
Maximum Voltages and Currents (Ta = 25 °C)			
Peak Reverse Voltage	V_{RM}	70	V
Reverse Voltage	V_R	50	V
Peak Forward Current (1 μs)	I_{FM}	70	mA
Forward Current	I_F	50	mA

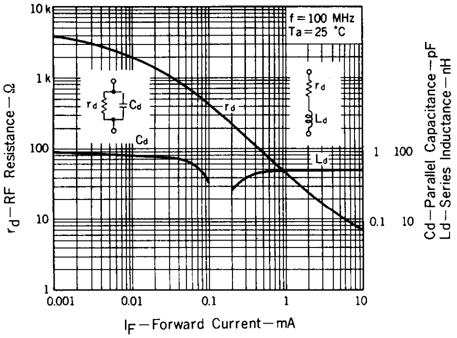
7

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

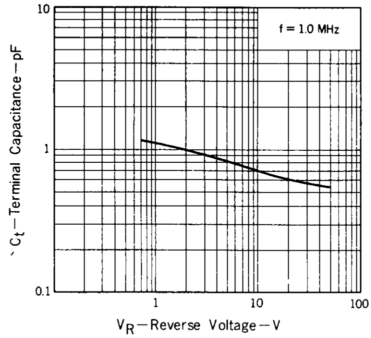
SYMBOL	CHARACTERISTIC	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
V_F	Forward Voltage		0.9	1.1	V	I_F = 50 mA
I_R	Reverse Current			0.1	μA	V_R = 30 V
C_t	Terminal Capacitance		0.7	1.0	pF	V_R = 10 V, f = 1.0 MHz
r_{ds}	RF Series Resistance		7.0	10	Ω	I_F = 10 mA, f = 100 MHz
r_{dp}	RF Parallel Resistance	1.0	2.0		kΩ	I_F = 10 μA, f = 100 MHz
τ	Minority Carrier Lifetime		2.0		μs	I_F = 10 mA
t_{rr}	Reverse Recovery Time		0.8		μs	I_F = 10 mA, I_R = 16 mA, R_L = 50 Ω

TYPICAL CHARACTERISTICS (Ta = 25 °C unless otherwise noted)

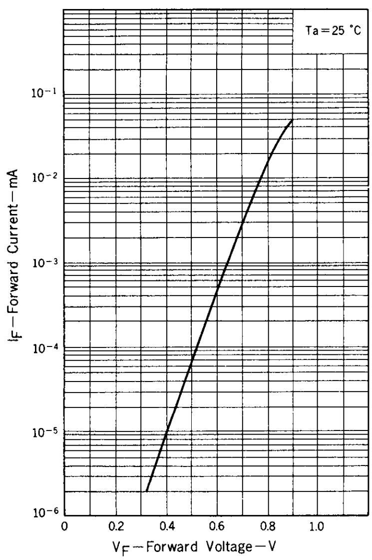
RF RESISTANCE vs. FORWARD CURRENT



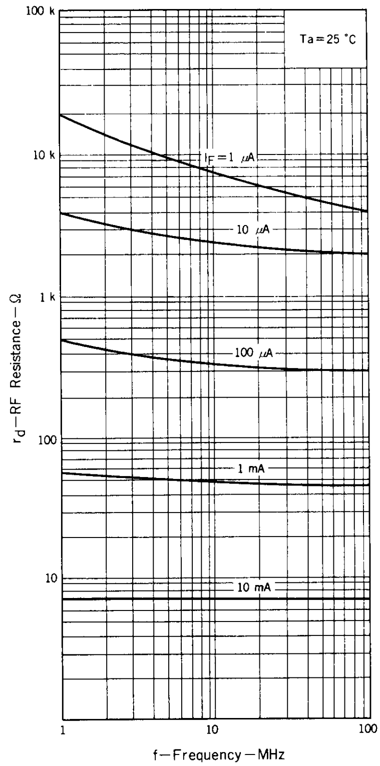
TERMINAL CAPACITANCE vs. REVERSE VOLTAGE



FORWARD CURRENT vs. FORWARD VOLTAGE



RF RESISTANCE vs. FREQUENCY



PIN DIODE

1SV80

VHF/UHF RF ATTENUATIG AND SWITCHING SILICON PIN DIODE

DESCRIPTION AND APPLICATIONS

The 1SV80 silicon PIN diode, especially designed for VHF/UHF band switching, attenuating.

The RF resistance of a PIN diode is a function of the current flowing in the diode. The current controlled resistors are specified for use in control applications such as ATT, AGC, RF modulators.

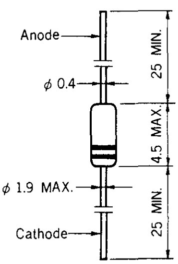
FEATURES

- Low cost.
- Large dynamic range.
- Low series resistance.
  $R_s = 10\ \Omega$ TYP. @ $I_F = 10$ mA, f = 100 MHz
- Low capacitance
  $C_t = 0.5$ pF MAX. @ $V_R = 15$ V, f = 1 MHz

PACKAGE DIMENSIONS

in millimeters

JEDEC : DO-35



Color Code (from cathode)
Red, Green

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Reverse Voltage	V_R	30	V
Forward Current	I_F	50	mA
Peak Forward Current	I_{FM}	150	mA
DC Power Dissipation	P_d	250	mW
Junction Temperature	T_j	+175	°C
Storage Temperature	T_{stg}	-65 to +175	°C
Solder Temperature (Note)		260	°C

Note : Less than 5 seconds, more than 1.5 mm off the lead connection.

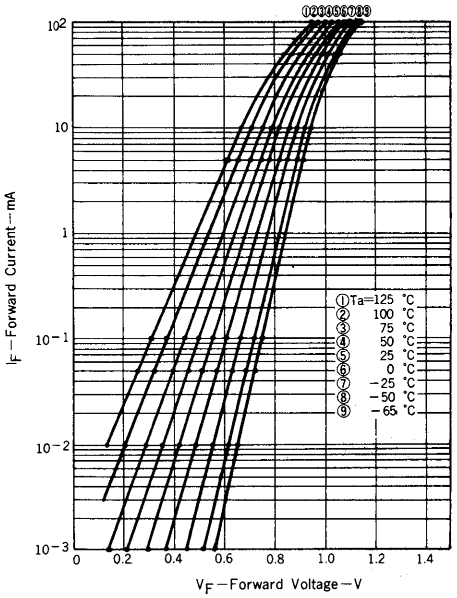
7

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

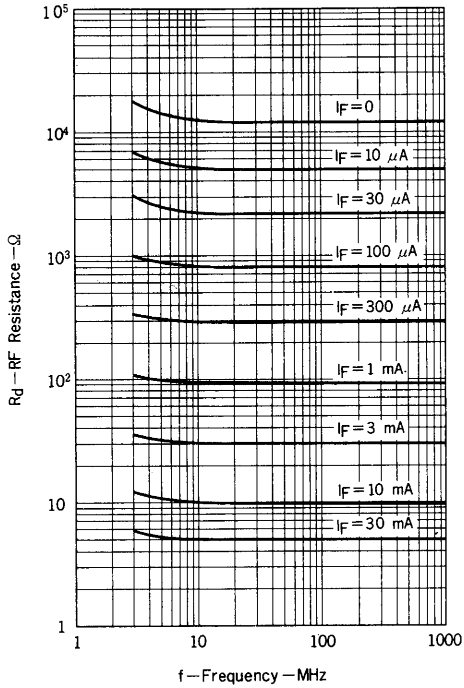
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		0.95	1.1	V	$I_F = 50$ mA
Reverse Voltage	V_R	30			V	$I_R = 10\ \mu A$
Capacitance	C_t		0.3	0.5	pF	$V_R = 15$ V, f = 1.0 MHz
Series Resistance	R_{ds}		10	15	Ω	$I_F = 10$ mA, f = 100 MHz
Parallel Resistance	R_{dp}	1.0	3.0		kΩ	$I_F = 10\ \mu A$, f = 100 MHz
Life Time	τ		2.0		μs	$I_F = 10$ mA
Recovery Time	t_{rr}		1.0		μs	$I_F = 10$ mA, $I_R = 16$ mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

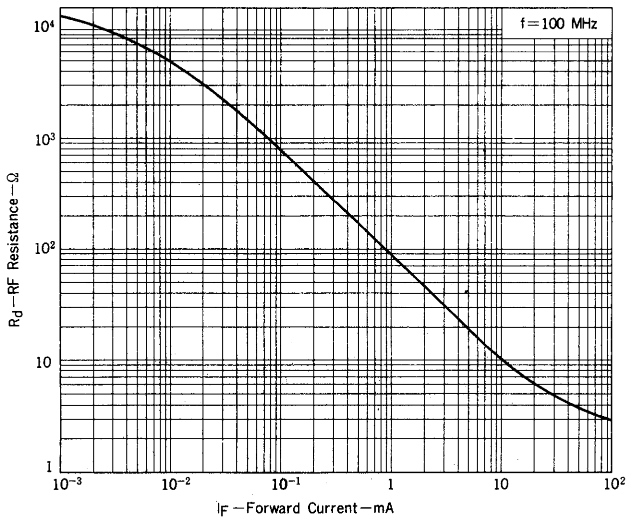
FORWARD CURRENT vs. FORWARD VOLTAGE



RF RESISTANCE vs. FREQUENCY



RF RESISTANCE vs. FORWARD CURRENT

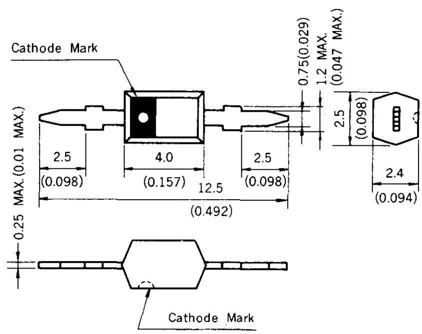


NEC
ELECTRON DEVICE

VARACTOR DIODE
1SV88

VHF CATV TUNER
SILICON EPITAXIAL DIODE
ESVAC®

PACKAGE DIMENSIONS
in millimeters (inches)



The 1SV88 is a hyper-abrupt junction type voltage capacitance diode.
1SV88 is designed for electronic tuning circuit application in CATV tuner, and features high capacitance ratio and high reliability.

FEATURES

- High capacitance ratio. N : 11 at C_3/C_{25} (TYP.)
- 3 % capacitance tolerance.
- Low leakage current. I_R = 10 nA at V_R = 28 V

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Peak Reverse Voltage	V_{RM}	30	V
DC Reverse Voltage	V_R	30	V
Storage Temperature	T_{stg}	−55 to +125	°C
Power Dissipation	P_D	250	mW

7

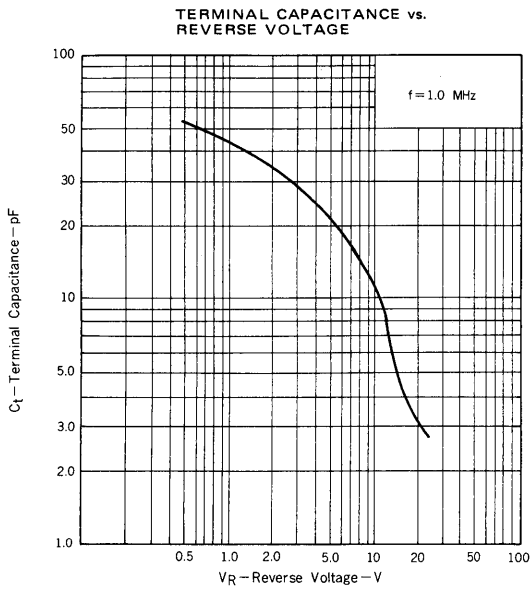
TYPICAL CHARACTERISTICS (Ta = 25 °C)

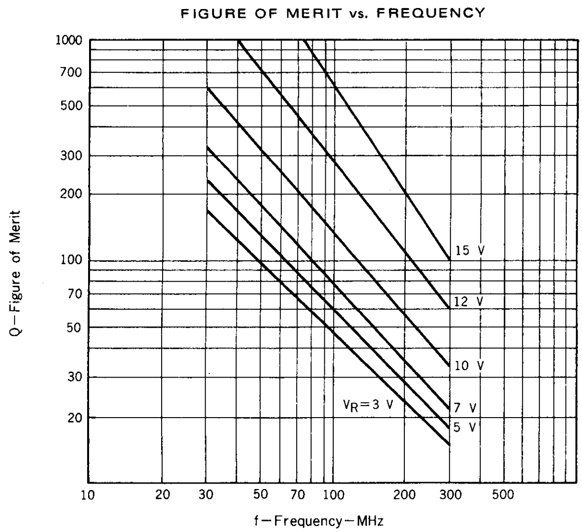
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Reverse Current	I_{R1}			10	nA	V_R = 28 V
Reverse Current	I_{R2}			50	nA	V_R = 28 V, Ta = 80 °C
Reverse Voltage	V_R	30			V	I_R = 1.0 μA
Capacitance	C_{t3}	26	29	32.0	pF	V_R = 3.0 V, f = 1.0 MHz
Capacitance	C_{t25}	2.6	2.8	3.0	pF	V_R = 25 V, f = 1.0 MHz
Capacitance Ratio	N	8.5	11.0	12.5		C_{t3}/C_{t25}
Series Resistance	r_s			0.9	Ω	f = 1.0 MHz, C_t = 9 pF
Capacitance Tolerance	ΔC			3.0	%	NOTE

NOTE : Diodes are available in matched sets of 24, 60, 120, 120 x n units.
For two diodes of one set the following conditions are relevant :
The variations ΔC in capacitance values at V_R = 3, 10, 18 and 25 V are less than 3 % for 1SV88.

$$\Delta C = \frac{Cmax. - Cmin.}{Cmin.} \times 100\ (\%)$$

TYPICAL CHARACTERISTICS (Ta = 25 °C)





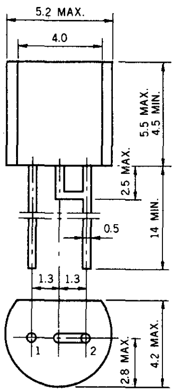
NEC
ELECTRON DEVICE

VARACTOR DIODE
1SV118

AM TUNER
SILICON EPITAXIAL DIODES
ESVAC®

The 1SV118 is a hyper-abrupt junction type voltage-variable capacitance diode. It is designed for electronic tuning circuit application in AM band.

PACKAGE DIMENSIONS
(Unit : mm)



Pin Connection
1. Anode
2. Cathode

FEATURES

- High capacitance ratio ; C_2/C_{25} : 27 (TYP.)
- High figure of merit ; Q (min.) ≧200
- Low dynamic capacitance variation
- 3 % capacitance tolerance

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

DC Reverse Voltage	V_R	30	V
Power Dissipation	P_d	250	mW
Storage Temperature	T_{stg}	−55 to +125	°C
Operating Temperature	T_{opt}	−30 to 80	°C

7

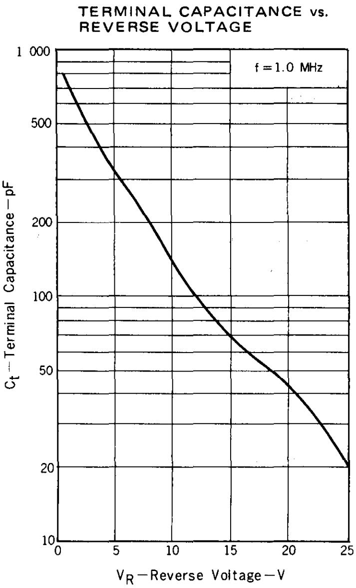
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

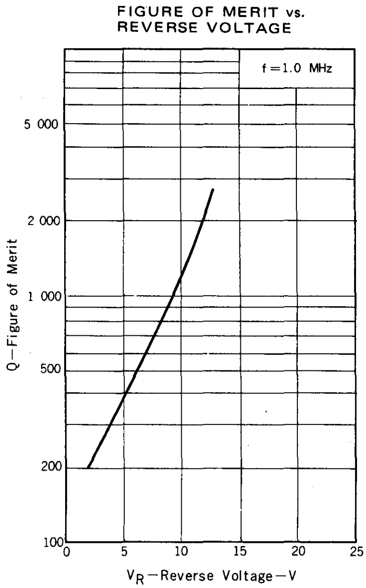
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Reverse Current	I_{R1}			100	nA	V_R = 30 V
Reverse Current	I_{R2}			500	nA	V_R = 30 V, Ta = 80 °C
Reverse Voltage	V_R	30			V	I_R = 1.0 μA
Capacitance	C_{t2}	555	600	665	pF	V_R = 2.0 V, f = 1.0 MHz
Capacitance	C_{t25}	18	22	30	pF	V_R = 25 V, f = 1.0 MHz
Capacitance Ratio	N	22	27			C_{t2}/C_{t25}
Figure of Merit	Q	200	250			V_R = 3.0 V, f = 1.0 MHz
Capacitance Tolerance	ΔC			3.0	%	NOTE
				1.0	pF	NOTE

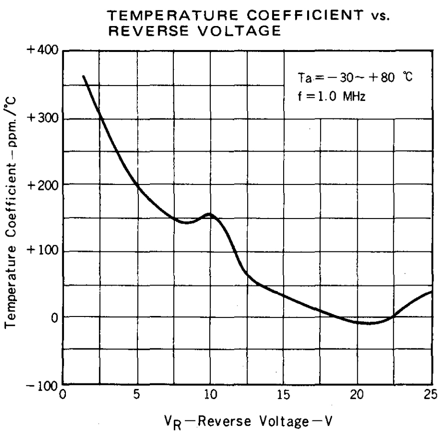
NOTE : Diodes are available in matched sets of 2, 3 units.
For two diodes of one set the following conditions are relevant :
The variations ΔC in capacitance values at V_R = 2, 10, 18 V are less than 3 % for 1SV118.

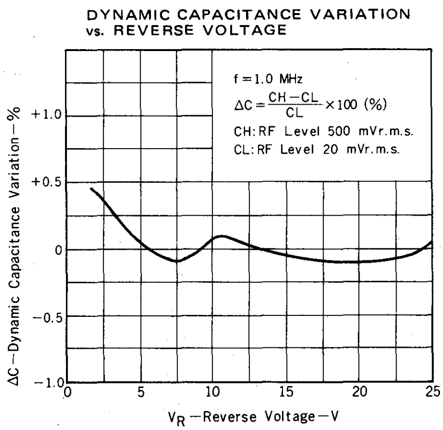
$$\Delta C = \frac{Cmax. - Cmin.}{Cmin.} \times 100\ (\%) \cdots (V_R = 2, 10, 18\ V),\ \Delta C \leqq Cmax. - Cmin. \cdots (V_R = 25\ V)$$

TYPICAL CHARACTERISTICS (Ta = 25 °C)







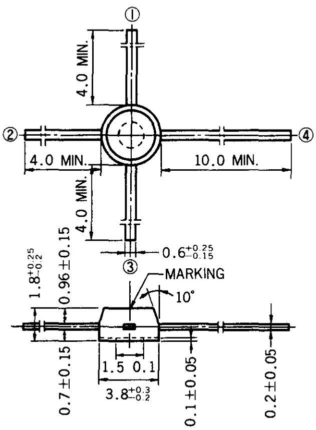


NEC
ELECTRON DEVICE

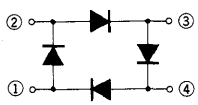
UHF MODULATOR DIODE QUAD
ND487R1-3R

UHF DOUBLE BALANCED MODULATOR
SILICON EPITAXIAL SCHOTTKY BARRIER DIODE QUAD

PACKAGE DIMENSIONS
(Unit : mm)



CONFIGURATION



The ND487R1-3R is schottky barrier diode quad interconnected in ring configuration, especially designed for use in double balanced mixers, phase detectors, AM modulators, and pulse modulators.

FEATURES

- Monolithic array
- Diode ring configuration
- Wideband operation
- Small size package
- Low cost

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

DC Power Dissipation	P_d	75	mW/Junction
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−65 to +150	°C
Soldering Temperature		230	°C for 10 s

7

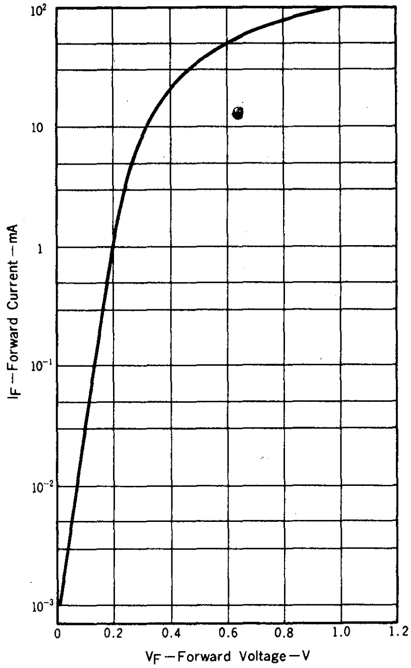
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_{F1}			0.7	V	I_F = 50 mA
Forward Voltage	V_{F2}		0.2	0.3	V	I_F = 1.0 mA
Delta Forward Voltage	ΔV_{F2} (NOTE1)			0.02	V	I_F = 1.0 mA
Terminal Capacitance	C_t (NOTE2)		0.9	1.2	pF	V_R = 0, f = 1.0 MHz
Delta Terminal Capacitance	ΔC_t (NOTE1)			0.2	pF	V_R = 0, f = 1.0 MHz

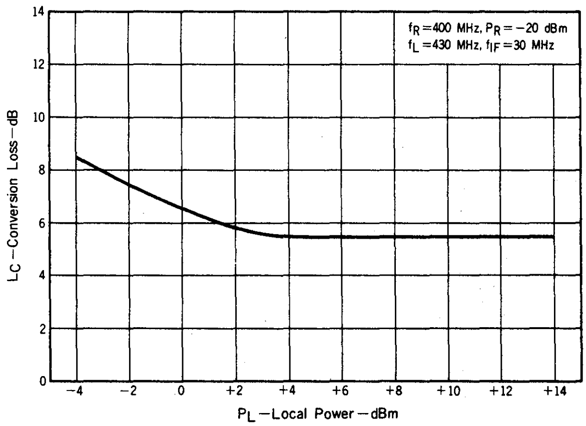
NOTE 1 : Difference of V_F, C_t
2 : Measurement terminal ①−④, ②−③

TYPICAL CHARACTERISTICS (Ta = 25 °C)

FORWARD CURRENT vs. FORWARD VOLTAGE



CONVERSION LOSS vs. LOCAL POWER



NEC
ELECTRON DEVICE

UHF MODULATOR DIODE QUAD
ND487R2-3R

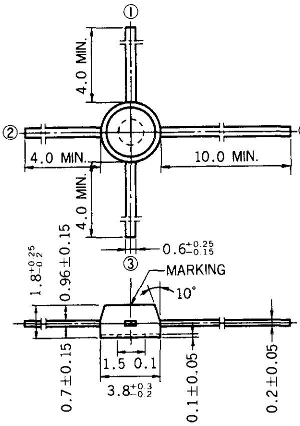
UHF DOUBLE BALANCED MODULATOR
SILICON EPITAXIAL SCHOTTKY BARRIER DIODE QUAD

The ND487R2-3R is schottky barrier diode quad interconnected in ring configuration, especially designed for use in double balanced mixers, phase detectors, AM modulators, and pulse modulators.

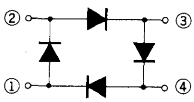
FEATURES

- Monolithic array
- Diode ring configuration
- Wideband operation
- Small size package
- Low cost

PACKAGE DIMENSIONS
(Unit : mm)



CONFIGURATION



ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

DC Power Dissipation	P_d	75	mW/Junction
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−65 to +150	°C
Soldering Temperature		230	°C for 10 s

7

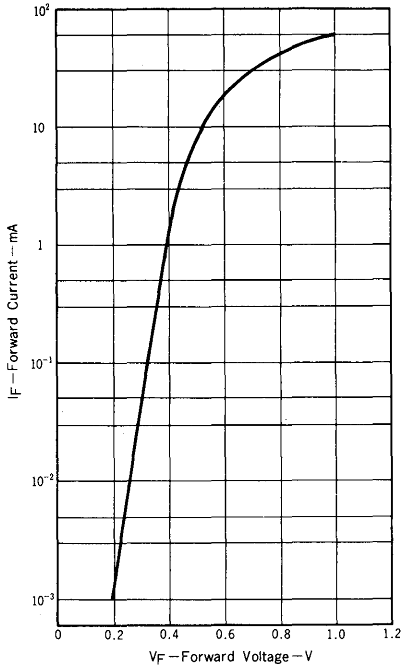
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_{F1}			1.0	V	I_F = 50 mA
Forward Voltage	V_{F2}		0.4	0.5	V	I_F = 1.0 mA
Delta Forward Voltage	ΔV_{F2}(NOTE1)			0.02	V	I_F = 1.0 mA
Terminal Capacitance	C_t(NOTE2)		0.9	1.2	pF	V_R = 0, f = 1.0 MHz
Delta Terminal Capacitance	ΔC_t(NOTE1)			0.2	pF	V_R = 0, f = 1.0 MHz

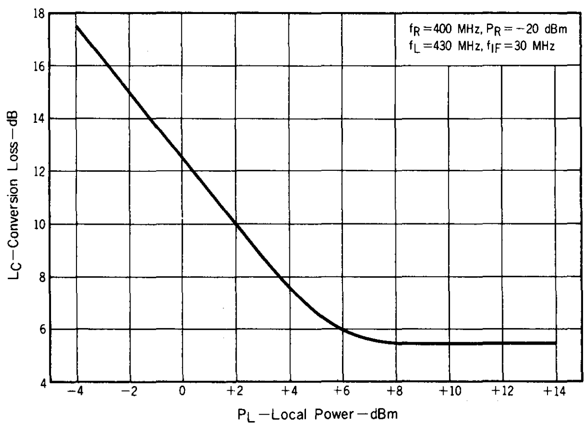
NOTE 1 : Difference of V_F, C_t
2 : Measurement terminal ①–④, ②–③

TYPICAL CHARACTERISTICS (Ta = 25 °C)

FORWARD CURRENT vs. FORWARD VOLTAGE



CONVERSION LOSS vs. LOCAL POWER



NEC
ELECTRON DEVICE

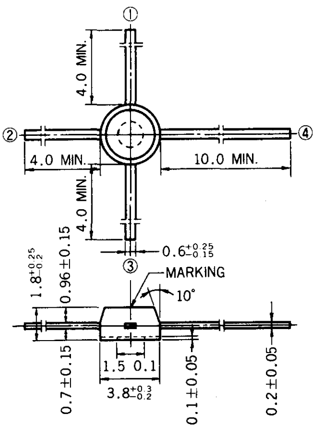
UHF MODULATOR DIODE QUAD
ND487C1-3R

UHF DOUBLE BALANCED MODULATOR
SILICON EPITAXIAL SCHOTTKY BARRIER DIODE QUAD

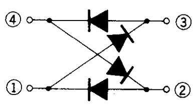
The ND487C1-3R is schottky barrier diode quad interconnected in cross configuration, especially designed for use in double balanced mixers, phase detectors, AM modulators, and pulse modulators.

PACKAGE DIMENSIONS

(Unit : mm)



CONFIGURATION



FEATURES

- Monolithic array
- Diode cross configuration
- Wideband operation
- Small size package
- Low cost

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

DC Power Dissipation	P_d	75	mW/Junction
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−65 to +150	°C
Soldering Temperature		230	°C for 10 s

7

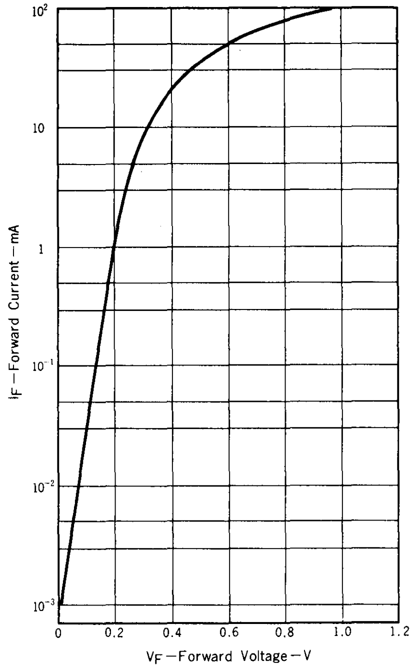
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_{F1}			0.7	V	I_F = 50 mA
Forward Voltage	V_{F2}		0.2	0.3	V	I_F = 1.0 mA
Delta Forward Voltage	ΔV_{F2} (NOTE1)			0.02	V	I_F = 1.0 mA
Terminal Capacitance	C_t (NOTE2)		0.9	1.2	pF	V_R = 0, f = 1.0 MHz
Delta Terminal Capacitance	ΔC_t (NOTE1)			0.2	pF	V_R = 0, f = 1.0 MHz

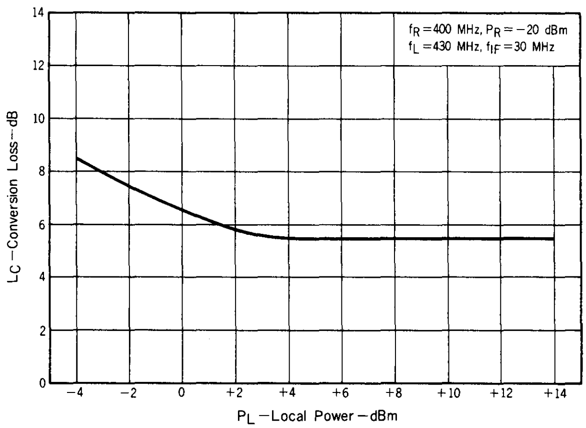
NOTE 1 : Difference of V_F, C_t
2 : Measurement terminal ①–④ ②–③

TYPICAL CHARACTERISTICS (Ta = 25 °C)

FORWARD CURRENT vs. FORWARD VOLTAGE



CONVERSION LOSS vs. LOCAL POWER

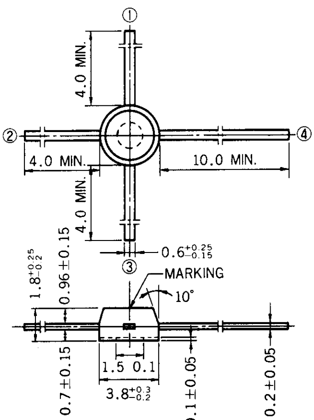


NEC
ELECTRON DEVICE

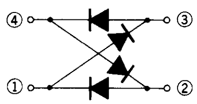
UHF MODULATOR DIODE QUAD
ND487C2-3R

UHF DOUBLE BALANCED MODULATOR
SILICON EPITAXIAL SCHOTTKY BARRIER DIODE QUAD

PACKAGE DIMENSIONS
(Unit : mm)



CONFIGURATION



The ND487C2-3R is schottky barrier diode quad interconnected in cross configuration, especially designed for use in double balanced mixers, phase detectors, AM modulators, and pulse modulators.

FEATURES

- Monolithic array
- Diode cross configuration
- Wideband operation
- Small size package
- Low cost

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

DC Power Dissipation	P_d	75	mW/Junction
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−65 to +150	°C
Soldering Temperature		230	°C for 10 s

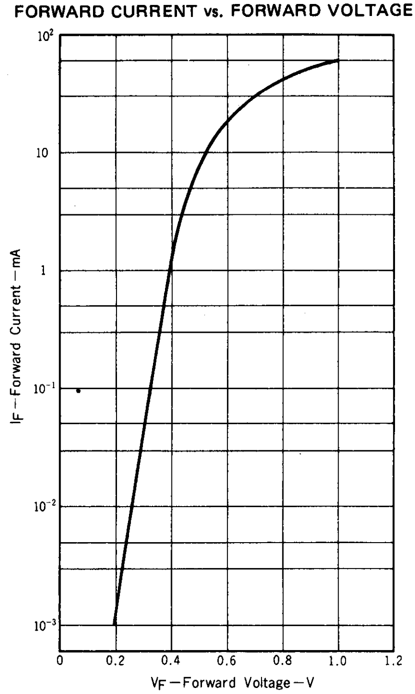
7

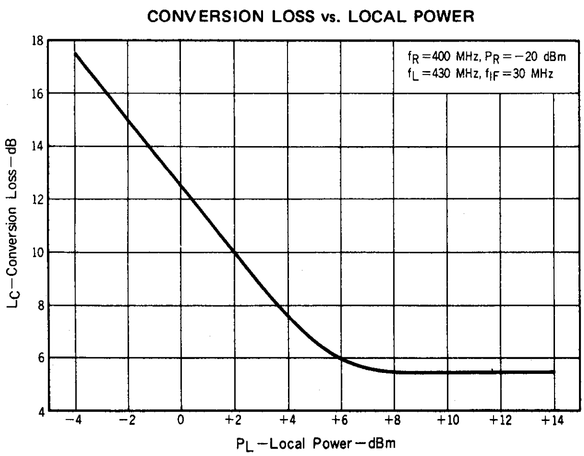
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_{F1}			1.0	V	I_F = 50 mA
Forward Voltage	V_{F2}		0.4	0.5	V	I_F = 1 mA
Delta Forward Voltage	ΔV_{F2}(NOTE1)			0.02	V	I_F = 1 mA
Terminal Capacitance	C_t(NOTE2)		0.9	1.2	pF	V_R = 0, f = 1.0 MHz
Delta Terminal Capacitance	ΔC_t(NOTE1)			0.2	pF	V_R = 0 , f = 1.0 MHz

NOTE 1 : Difference of V_F, C_t
2 : Measurement terminal ①−④, ②−③

TYPICAL CHARACTERISTICS (Ta = 25 °C)





Contents

Opto Devices

NEC
ELECTRON DEVICE

PHOTO TRANSISTOR
PH101

NPN EPITAXIAL DARLINGTON PHOTOTRANSISTOR
PHOTO DETECTOR

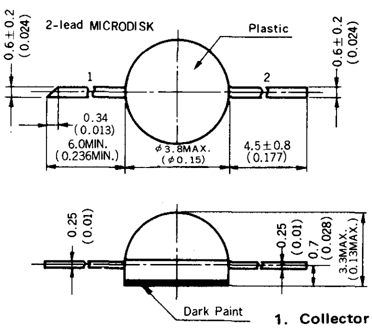
– NEPOC SERIES –

DESCRIPTION

The PH101 is a miniature NPN sillicon phototransistor having exceptionally stable characteristics and high illuminance sensitivity mounted in a two-terminal MICRODISK package. The spectral response, extending from 4,000 to 10,000Å, is compatible with daylight, tungsten, and gallium arsenide sources. The packaging of this unit permits close-spacing in linear arrays. Its low cost and volume producibility opens new areas of use anywhere a photo detector is desirable.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Collector
2. Emitter

* Soldering conditions are at 260°C or less within 5sec. at 3 mm or farther from the case.

FEATURES

- Low cost.
- Low Leakage Current.
- Wide Spectral Response.
- Convenient MICRODISK Package.
- Wide Temperature Range.
- Compact, Rugged, Light Weight.
- High Sensitivity.

APPLICATIONS

- Optical Switching and Encoding.
- Intrusion Alarm.
- Tape and Card Reader Sensor.
- Level Control
- Motor governor.

ABSOLUTE MAXIMUM RATINGS

Maximum Collector to Emitter Voltage (Ta=25°C)	V_{CEO}	20	V
Maximum Collector Current (Ta=25°C)	I_C	50	mA
Maximum Power Dissipation (Ta=25°C)	P_C	100	mW
Maximum Temperatures (Ta=25°C)			
Junction Temperature	T_j	80	°C
Storage Temperature	T_{stg}	–30 to +80	°C

8

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Dark Current	I_{CE01}			0.5	μA	V_{CE} = 15V, L = 0
Collector to Emitter Dark Current	I_{CE02}			500	μA	V_{CE} = 15V, L = 0, Ta = 80°C
Collector Saturation Voltage	$V_{CE\ (sat)}$		0.7	1.5	V	I_C = 10 mA, L* = 1,000 lx
Photo Current	I_L	4	12		mA	V_{CE} = 2.0V, L* = 100 lx

* Measured with a tungsten filament lamp operated at a color temperature of 2854°K.

TYPICAL CHARACTERISTICS (Ta = 25°C)

PHOTO CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE

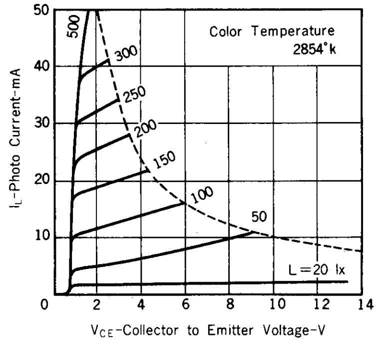
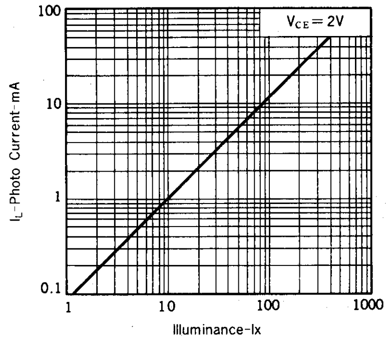
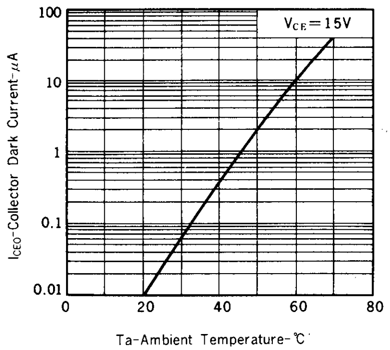


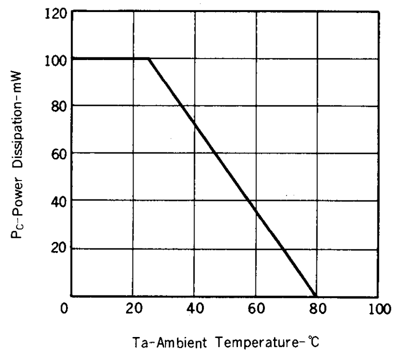
PHOTO CURRENT vs. ILLUMINANCE



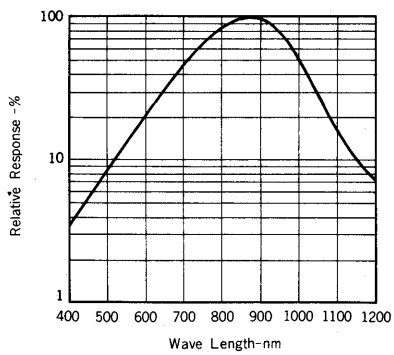
COLLECTOR DARK CURRENT vs.
AMBIENT TEMPERATURE



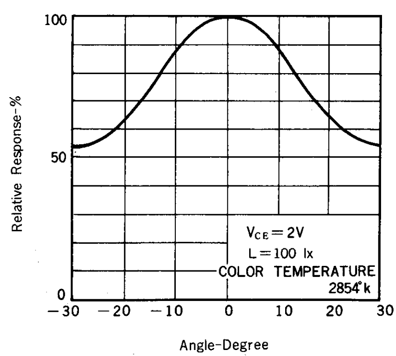
POWER DISSIPATION vs.
AMBIENT TEMPERATURE



SPECTRAL RESPONSE



ANGULAR RESPONSE



NEC
ELECTRON DEVICE

PHOTO TRANSISTOR
PH102

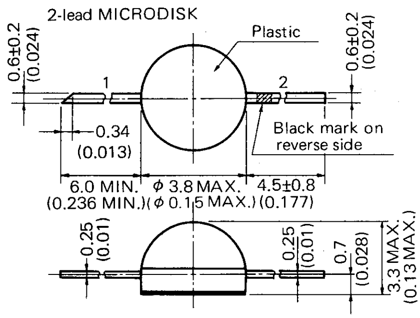
NPN EPITAXIAL PHOTOTRANSISTOR
PHOTO DETECTOR

—NEPOC SERIES—

DESCRIPTION

The PH102 is a miniature NPN sillicon phototransistor having exceptionally stable characteristics mounted in a two-terminal MICRODISK package. The spectral response, extending from 400 to 1000 nm, is compatible with daylight, tungsten, and gallium arsenide sources. The packaging of this unit permits close-spacing in linear arrays. Its low cost and volume producibility opens new areas of use anywhere a photo detector is desirable.

PACKAGE DIMENSIONS
in millimeters (inches)



1. Collector
2. Emitter

* **Soldering conditions are at 260 °C or less within 5 s at 3 mm or farther from the case.**

FEATURES

- High speed.
- Low cost.
- Low leakage current.
- Wide spectral response.
- Wide temperature range.
- Compact, rugged, light weight.
- High sensitivity.

APPLICATIONS

- Optical switching and encoding.
- Intrusion alarm.
- Tape and card reader sensor.
- Level control.
- Motor governor.

ABSOLUTE MAXIMUM RATINGS

Maximum Collector to Emitter Voltage (Ta=25 °C)	V_{CEO}	30	V
Maximum Collector Current (Ta=25 °C)	I_C	40	mA
Maximum Power Dissipation (Ta=25 °C)	P_C	100	mW
Maximum Temperatures (Ta = 25 °C)			
Junction Temperature	T_j	80	°C
Storage Temperature	Tstg	−30 to +80	°C

8

ELECTRO-OPTICAL CHARACTERISTICS (Ta=25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Dark Current	I_{CEO}			200	nA	V_{CE}=10 V, L=0 lx
Collector Saturation Voltage	$V_{CE\ (sat)}$			0.3	V	I_C=0.5 mA, L*=1,000 lx
Photo Current	I_L	50	180		μA	V_{CE}=2.0 V, L*=100 lx
Fall Time	t_f		5		μs	V_{CE}=10 V, I_L=2 mA, R_L=100 Ω
Rise Time	t_r		5		μs	V_{CE}=10 V, I_L=2 mA, R_L=100 Ω

*Measured with a tungsten filament lamp operated at a color temperature of 2854 K.

TYPICAL CHARACTERISTICS (Ta = 25 °C)

POWER DISSIPATION vs. AMBIENT TEMPERATURE

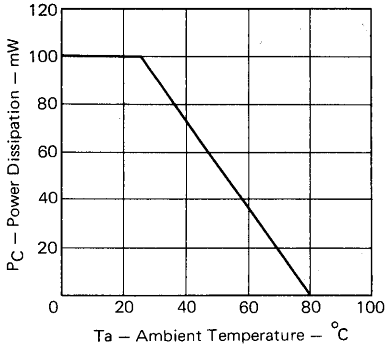


PHOTO CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

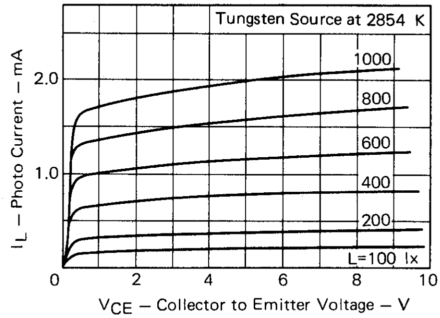
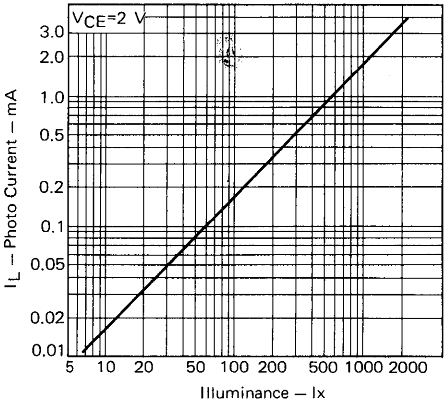
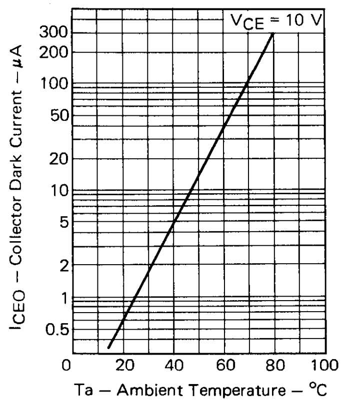


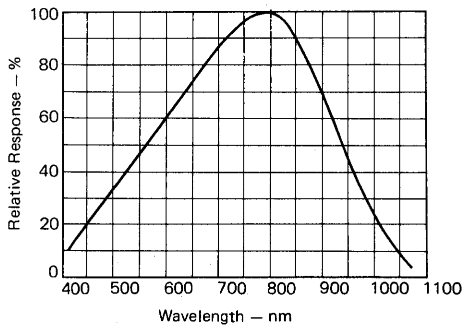
PHOTO CURRENT vs. ILLUMINANCE



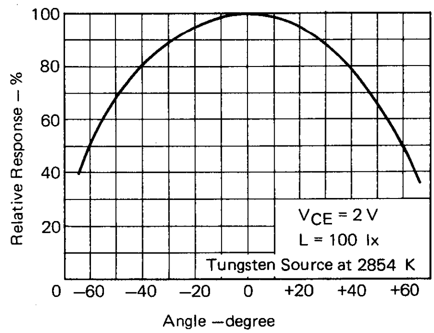
COLLECTOR DARK CURRENT vs. AMBIENT TEMPERATURE



SPECTRAL RESPONSE



ANGULAR RESPONSE



NEC
ELECTRON DEVICE

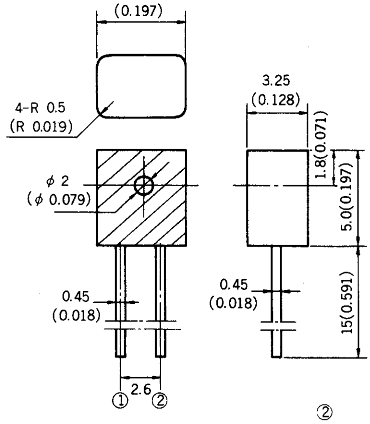
PHOTO TRANSISTOR
PH103

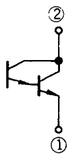
DARLINGTON PHOTO TRANSISTOR

—NEPOC SERIES—

The PH103 is a darlington photo transistor in a plastic molded package, and very suitable for a detector of a photo interrupter.

PACKAGE DIMENSIONS
in millimeters (inches)





① Emitter
② Collector

ABSOLUTE MAXIMUM RATINGS ($T_a = 25\ ^\circ C$)

Collector to Emitter Voltage	V_{CEO}	30	V
Collector Current	I_C	50	mA
Power Dissipation	P_D	100	mW
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	−40 to +100	°C

ELECTRICAL CHARACTERISTICS ($T_a = 25\ ^\circ C$)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Dark Current	I_{CEO}		10	400	nA	$V_{CE} = 10$ V, L = 0 lx
Collector Saturation Voltage	$V_{CE(sat)}$		0.7	1.5	V	$I_C = 10$ mA, L = 1 000 lx*
Photo Current	I_L	2.0			mA	$V_{CE} = 2$ V, L = 100 lx*

*Measured with a tungsten filament lamp operated at a color temperature of 2 854 K.

TYPICAL CHARACTERISTICS (Ta = 25 °C)

PHOTO CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

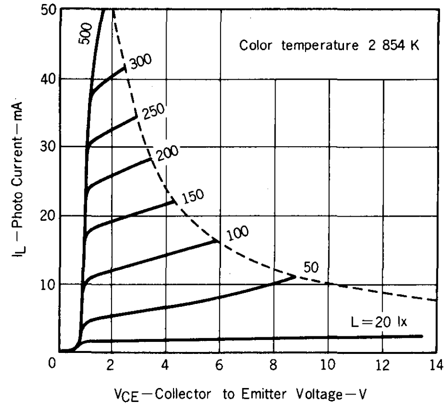
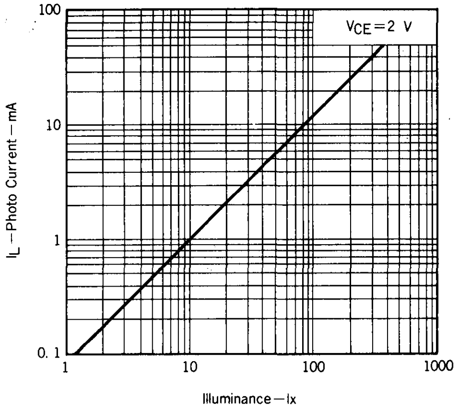
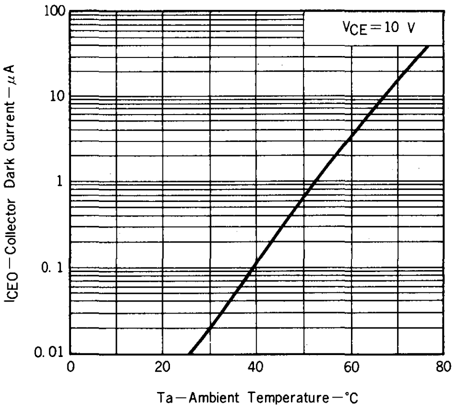


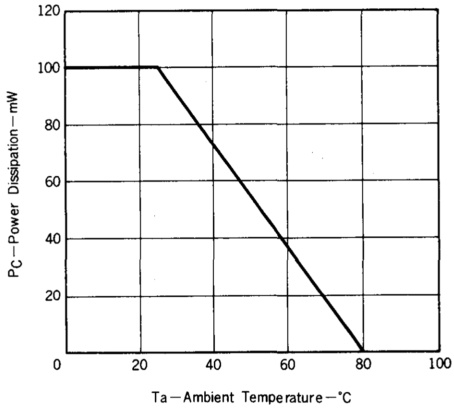
PHOTO CURRENT vs. ILLUMINANCE



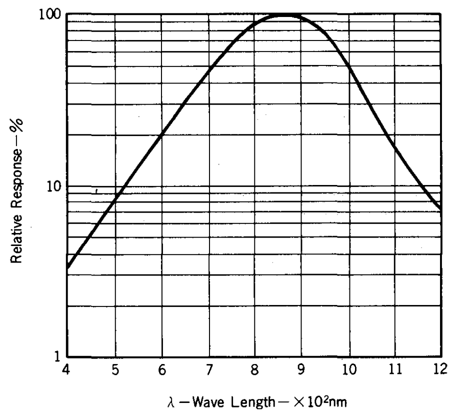
COLLECTOR DARK CURRENT vs. AMBIENT TEMPERATURE



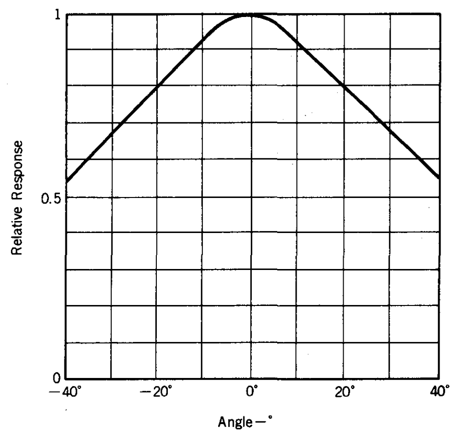
POWER DISSIPATION vs. AMBIENT TEMPERATURE



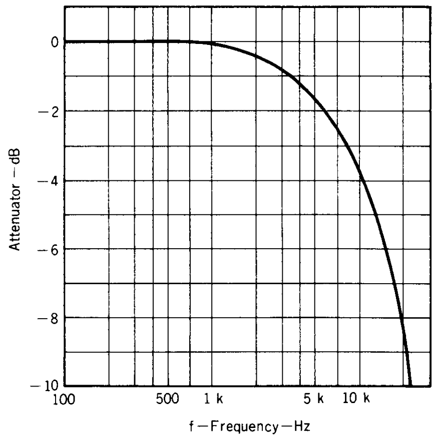
SPECTRAL RESPONSE



SPATIAL DISTRIBUTION



FREQUENCY RESPONSE



FREQUENCY RESPONSE TEST CIRCUIT

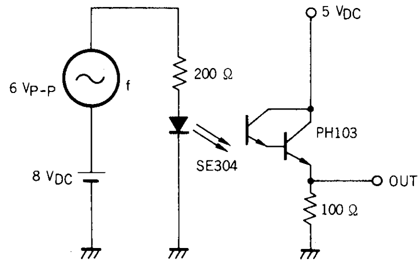


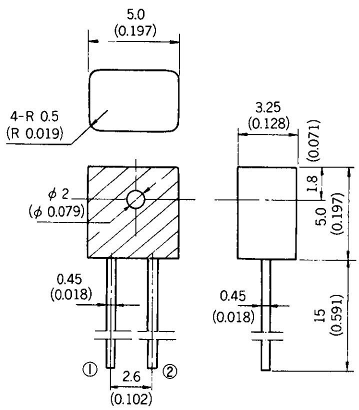
PHOTO TRANSISTOR
PH104

PHOTO TRANSISTOR

—NEPOC SERIES—

The PH104 is a photo transistor in a plastic molded package, and very suitable for a detector of a photo interrupter.

PACKAGE DIMENSIONS
in millimeters (inches)



①Emitter
②Collector

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Collector to Emitter Voltage	V_{CEO}	30	V
Collector Current	I_C	40	mA
Power Dissipation	P_C	100	mW
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	−40 to +100	°C

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector to Emitter Dark Current	I_{CEO}			100	nA	V_{CE} = 10 V, L = 0 lx
Collector saturation Voltage	$V_{CE(sat)}$			0.3	V	I_C = 0.5 mA, L = 1 000 lx*
Photo Current	I_L	20			μA	V_{CE} = 2.0 V, L = 100 lx*
Fall Time	t_f		5		μs	V_{CC} = 10 V, I_L = 2 mA, R_L = 100 Ω

*Measured with a tungsten filament lamp operated at a color temperature of 2 854 K.

TYPICAL CHARACTERISTICS (Ta = 25 °C)

POWER DISSIPATION vs. AMBIENT TEMPERATURE

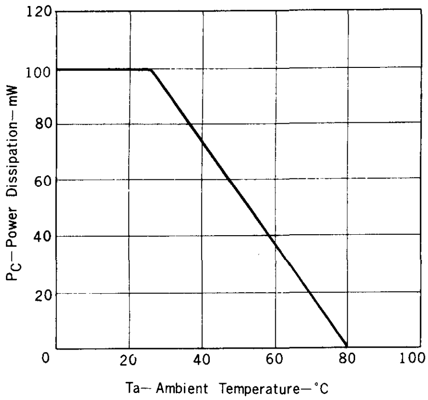


PHOTO CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

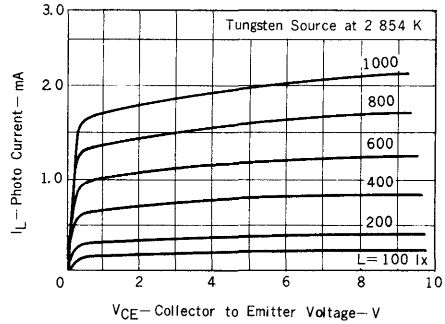
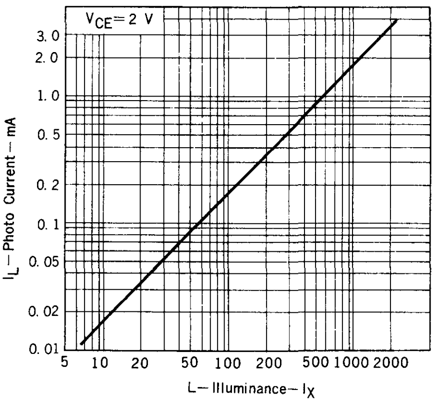
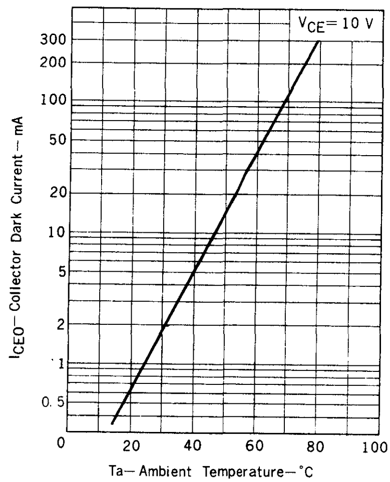


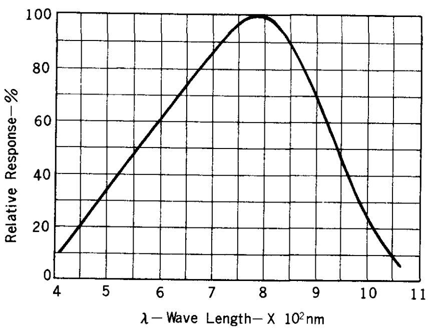
PHOTO CURRENT vs. ILLUMINANCE



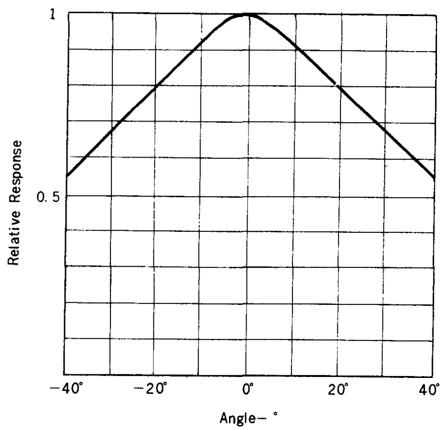
COLLECTOR DARK CURRENT vs. AMBIENT TEMPERATURE



SPECTRAL RESPONSE

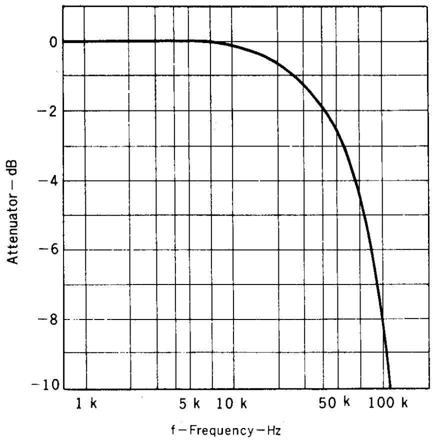


SPATIAL DISTRIBUTION

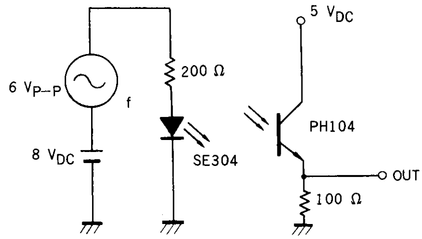


8

FREQUENCY RESPONSE



FREQUENCY RESPONSE TEST CIRCUIT



NEC
ELECTRON DEVICE

PHOTO DIODE
PH201A

PHOTO DETECTOR
GaAsP PHOTE DIODE

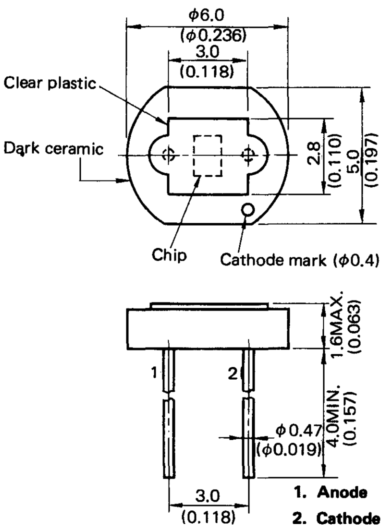
—NEPOC SERIES—

DESCRIPTION

The PH201A is a GaAsP (gallium arsenide phosphide) photo diode designed for use as a photo detector of electronic camera.

It features wide active area, close spectral response to that of human eye and wide light current range.

PACKAGE DIMENSIONS
in millimeters (inches)



* **Soldering conditions are at 260°C or less Within 10sec. at 0.5mm or farther from the case.**

FEATURES

- Suitable for photo detector applications in cameras.
- No filter is required.
  The spectral response matches with the response of human eye.
- Low dark current.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Reverse Voltage	V_R	5.0	V
Forward Current	I_F	1.0	mA
Operating Temperature	Topt	−30 to +60	°C
Storage Temperature	Tstg	−40 to +80	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Photo Current	I_{sh}	60	90	120	nA	100 lx(3)
Dark Current	I_D		0.3	3.0	pA	V_R = 2.0V
Photo Current Ratio	R(1)		10^6			0.001~1,000 lx(3)
Relative Spectral Response			See Fig.1			
Rise Time	t_r		150		μs	See rise time test circuit
Variation of Photo Current	Δ (2)		13		%	100 lx(3)(4)

8

Notes:

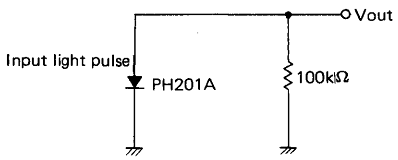
(1) $R = \dfrac{I_{sh} \text{ at } 1{,}000 \text{ lx}}{I_{sh} \text{ at } 0.001 \text{ lx}}$

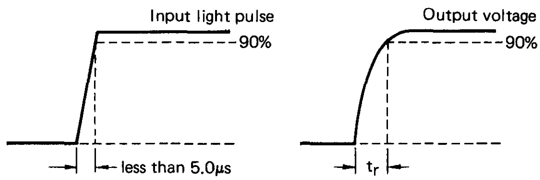
(2) Δ = (I_{sh} at a color temperature of 2854 K − I_{sh} at a color temperature of 4870 K)/(I_{sh} at a color temperature of 2854 K) x 100(%)

(3) Measured with a tungsten filament lamp operated at a color temperature of 2854 K.

(4) Measured at a color temperature of 4870 K.

RISE TIME TEST CIRCUIT

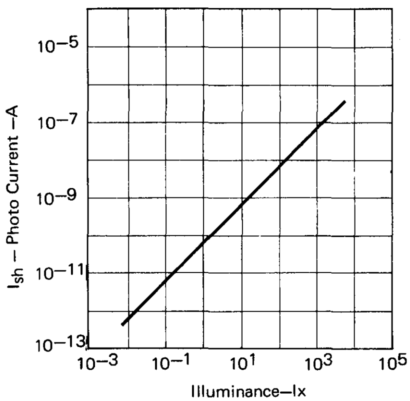




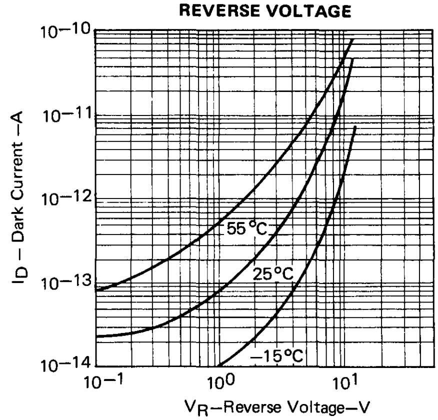
Note: Light source is a LED that the PH201A gets 100 lx illumination.

TYPICAL CHARACTERISTICS (Ta = 25 °C)

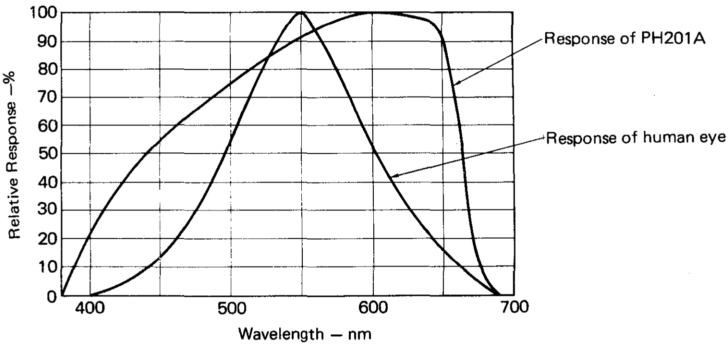
PHOTO CURRENT vs. ILLUMINANCE



DARK CURRENT vs. REVERSE VOLTAGE



RELATIVE SPECTRAL RESPONSE



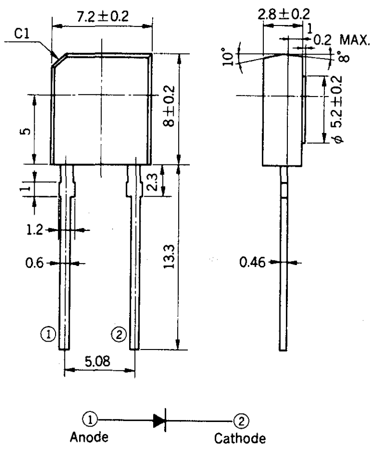
NEC
ELECTRON DEVICE

PHOTO DIODE
PH302

PLASTIC MOLDED PIN PHOTO DIODE

—NEPOC SERIES—

PACKAGE DIMENSIONS
(Unit: mm)



DESCRIPTION

PH302 is a photo diode with PIN structure. It has a wide photo-receiving area and high speed response enabling applications for various remote controlling equipments. The resin material itself used for the package has filter effect to pass only infrared.

FEATURES

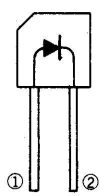
- Ultra high speed response. (t_r. t_f = 50 ns)
- Coincidence of the wavelength of maximum sensitivity with that of an infrared LED. ($\lambda_{s\ MAX.}$ = 940 nm)
- High sensitivity. (50 nA/lx)
- Wide dynamic range.

ABSOLUTE MAXIMUM RATINGS

Maximum Reverse Voltage (Ta=25 °C)	V_R	32	V
Maximum Power Dissipation (Ta=25 °C)	P_D	150	mW
Maximum Temperatures			
Junction Temperature	T_j	80	°C
Storage Temperature	T_{stg}	–40 to +80	°C

8

CONNECTION DIAGRAM

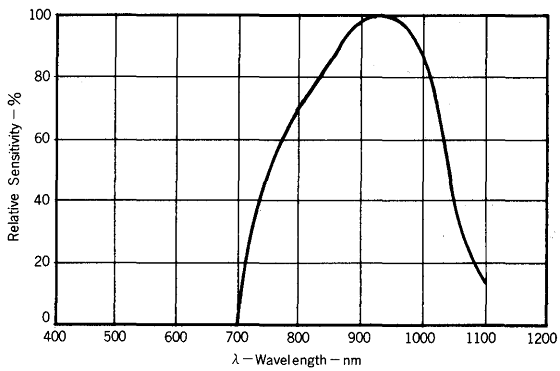


ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

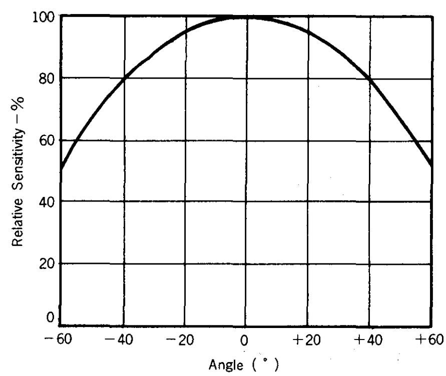
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Dark Current	I_R			30	nA	V_R=10 V
Wave length of the max. sensitivity	$\lambda_{MAX.}$		940		nm	
Quantum yield (Electron per photon)	η		0.88			λ=940 nm
Spectral sensitivity	S	35	50		nA/lx	V_R=5 V
Spectral sensitivity	S		0.6		A/W	λ=940 nm
Open circuit voltage	V_L		285		mV	E_V=100 lx
Open circuit voltage	V_L		365		mV	E_V=1 000 lx
Rise and fall time of the photocurrent from 10 % to 90 % and 90 % to 10 % of the final value	t_r, t_f		125		ns	R_L=1 kΩ, V_R=0 V, λ=940 nm
	t_r, t_f		50		ns	R_L=1 kΩ, V_R=5 V, λ=940 nm
Capacitance	C_t		14		pF	V_R=5 V, f=1 MHz
Radiant sensitive area	A		9		mm^2	
Noise equivalent power	NEP		4.2×10^{-14}		$W/\sqrt{Hz}$	V_R=10 V
Detection limit	D		6.6×10^{12}		$cm\sqrt{Hz}/W$	

TYPICAL CHARACTERISTICS (Ta = 25 °C)

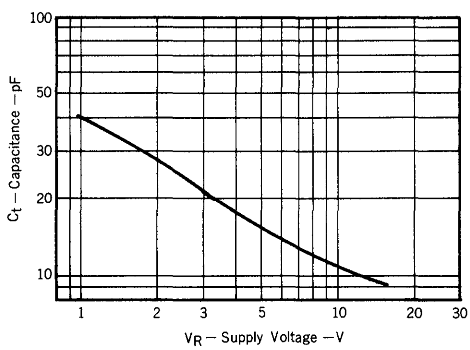
WAVELENGTH SENSITIVITY



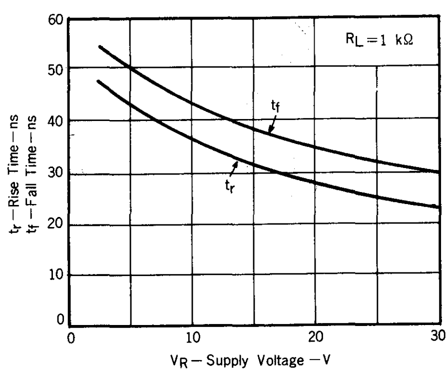
DIRECTIONAL CHARACTERISTIC



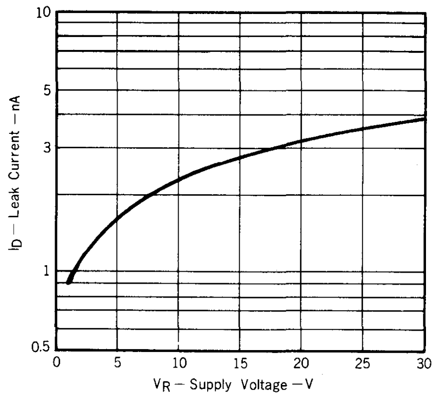
CAPACITANCE vs. SUPPLY VOLTAGE



RISE TIME / FALL TIME vs. SUPPLY VOLTAGE



LEAK CURRENT vs. SUPPLY VOLTAGE



LEAK CURRENT vs. AMBIENT TEMPERATURE

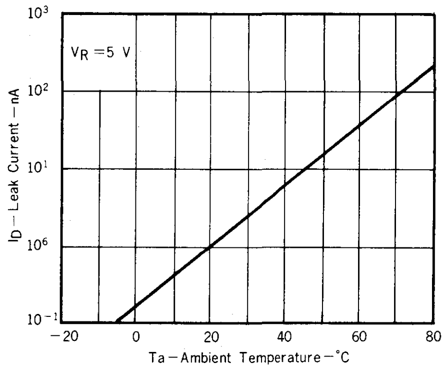
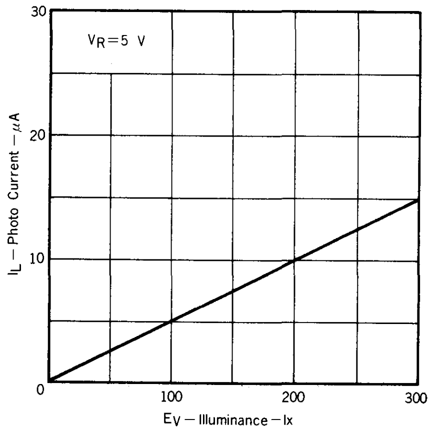


PHOTO CURRENT vs. ILLUMINANCE



RELATIVE vs. AMBIENT TEMPERATURE

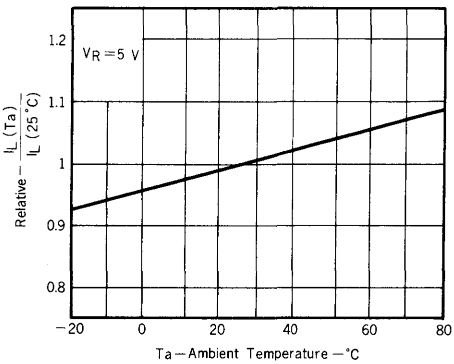


PHOTO CURRENT vs. SUPPLY VOLTAGE

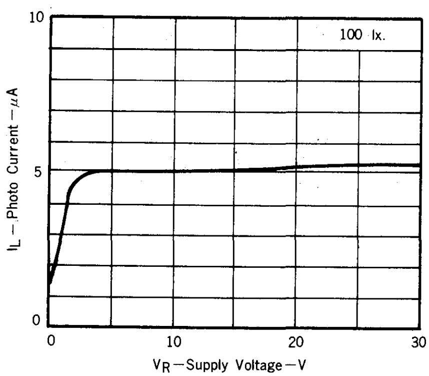
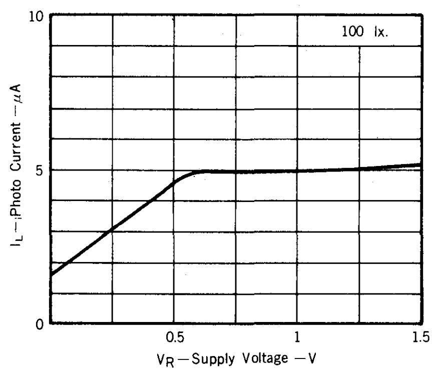
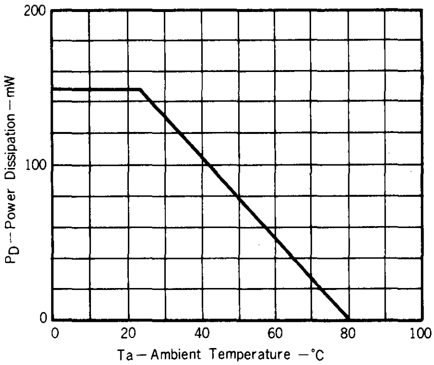


PHOTO CURRENT vs. SUPPLY VOLTAGE



8

POWER DISSIPATION vs.
AMBIENT TEMPERATURE



HANDLING PRECAUTIONS:

1. The full resin-molded PH302 has generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin if the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

NEC
ELECTRON DEVICE

PHOTO COUPLER
PS2001B

PHOTO COUPLER
INDUSTRIAL USE

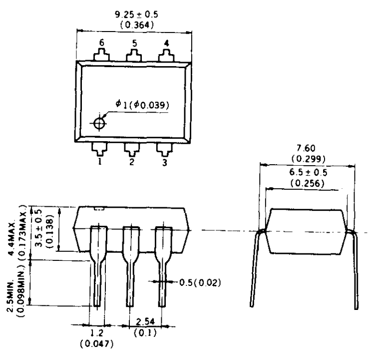
– NEPOC SERIES –

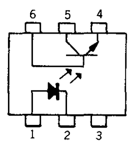
DESCRIPTION

The PS2001B is an optically coupled isolator containing a GaAs light emitting diode and an NPN silicon photo transistor.

PACKAGE DIMENSIONS

in millimeters (inches)





(Top view)
1. Anode
2. Cathode
3. NC
4. Emitter
5. Collector
6. Base

FEATURES

- High isolation voltage — 2500V_{DC} Rating
- High transfer ratio — 30% MIN.
- High speed switching — t_r, t_f = 5.0 μs TYP.
- Economical, compact, Dual In-Line Plastic Package

APPLICATIONS

- Interface circuit for various instrumentations, control equipments.
- Chopper circuits.
- Computer and peripheral manufactures.
- Pulse transformer.
- Data Communication equipment.

8

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Diode			
Reverse Voltage	V_R	5.0	V
Forward Current	I_F	60	mA
Power Dissipation	P_D	100	mW
Transistor			
Collector to Emitter Voltage	V_{CEO}	30	V
Collector Current	I_C	50	mA
Power Dissipation	P_C	150	mW
Isolation Voltage * 1	BV	2500	V_{DC}
Storage Temperature	T_{stg}	-55 to +125	°C
Operating Temperature	T_{opt}	-55 to +100	°C

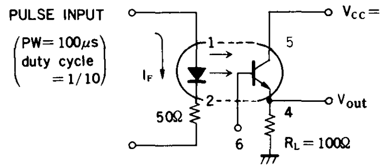
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

	CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Diode	Forward Voltage	V_F		1.1	1.4	V	I_F = 20 mA
	Reverse Current	I_R			20	μA	V_R = 4.0V
	Junction Capacitance	C		100		pF	V = 0, f = 1.0 MHz
Transistor	Collector to Emitter Dark Current	I_{CEO}			200	nA	V_{CE} = 10V, I_F = 0
	DC Current Gain	h_{FE}		400			I_C = 4.0mA, V_{CE} = 5.0V
Coupled	Current Transfer Ratio	CTR(I_C/I_F)	30			%	I_F = 20 mA, V_{CE} = 5.0V
	Collector Saturation Voltage	$V_{CE\ (sat)}$			0.3	V	I_F = 20 mA, I_C = 2.0 mA
	Isolation Resistance	$R_{1\text{-}2}$	10^{11}			Ω	$V_{in\text{-}out}$ = 1.0 kV
	Isolation Capacitance	$C_{1\text{-}2}$		0.8		pF	V = 0, f = 1.0 MHz
	Rise Time	t_r		5.0		μs	V_{CC} = 5.0V, I_F = 20 mA, R_L = 100Ω *2
	Fall Time	t_f		5.0		μs	V_{CC} = 5.0V, I_F = 20 mA, R_L = 100Ω *2

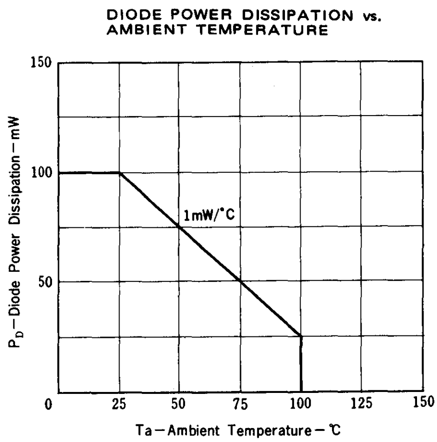
* 1 Measuring Condition

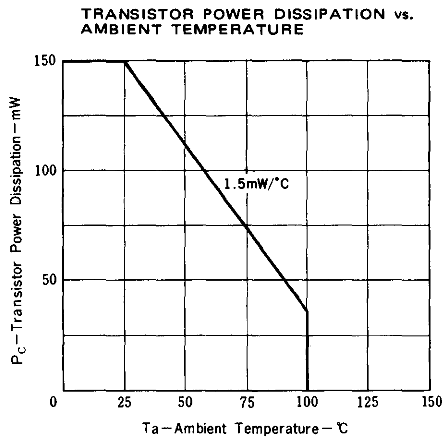
DC or AC voltage for 1 minute at Ta = 25°C, RH = 60%
Between input (pin No. 1, 2 and No. 3 Common) and output (pin No. 4, 5 and No. 6 Common)

* 2 Test Circuit for Switching Time

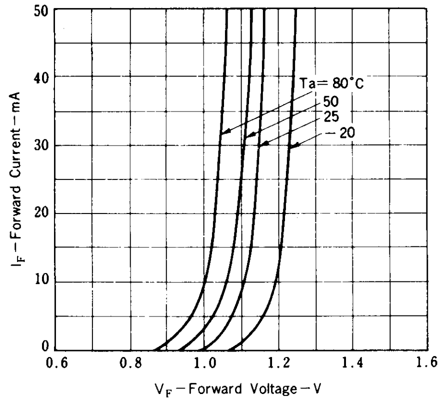


TYPICAL CHARACTERISTICS (Ta = 25°C)

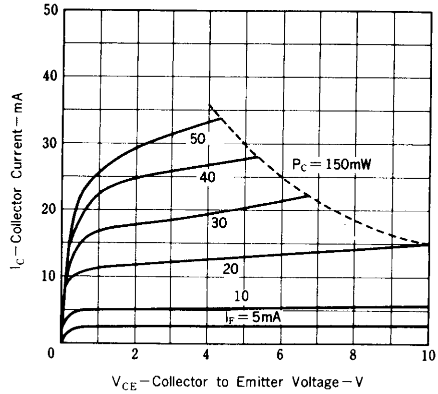




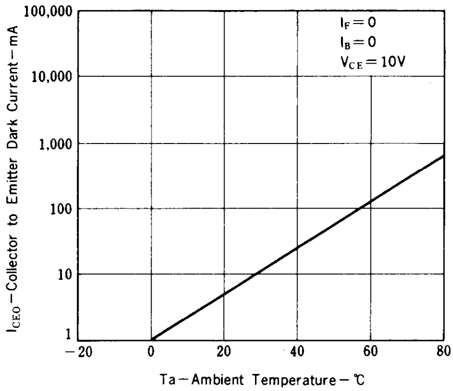
FORWARD CURRENT vs. FORWARD VOLTAGE



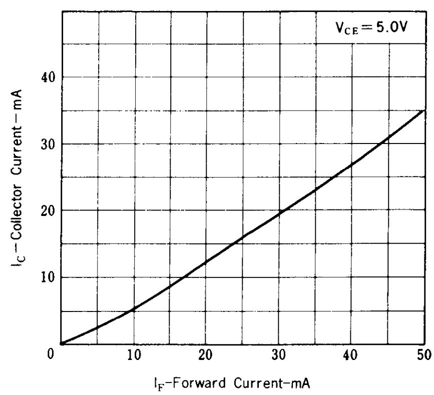
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



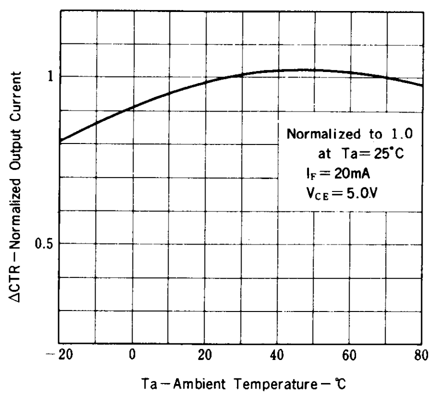
COLLECTOR TO EMITTER DARK CURRENT vs. AMBIENT TEMPERATURE



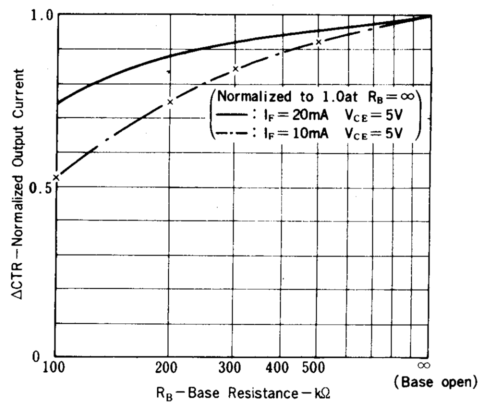
COLLECTOR CURRENT vs. FORWARD CURRENT



NORMALIZED OUTPUT CURRENT vs. AMBIENT TEMPERATURE

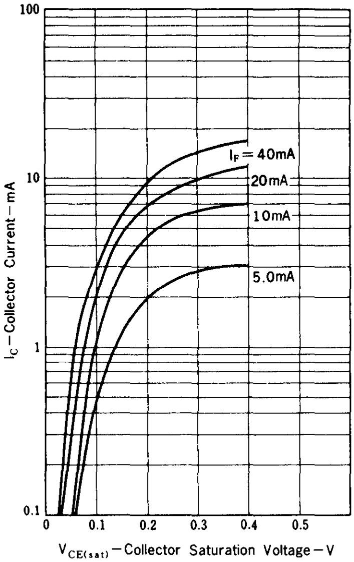


NORMALIZED OUTPUT CURRENT vs. BASE RESISTANCE

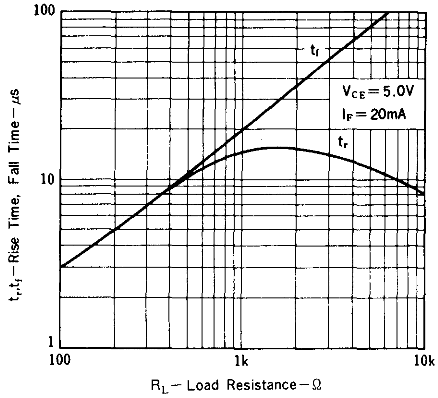


8

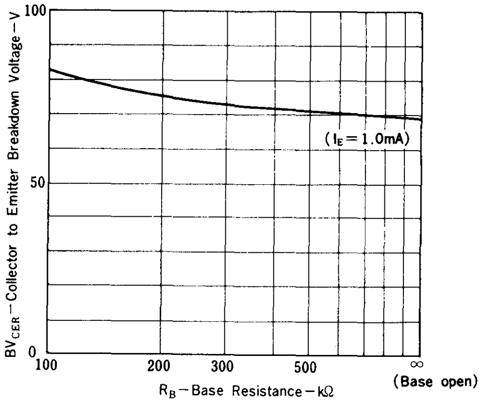
COLLECTOR CURRENT vs.
COLLECTOR SATURATION VOLTAGE



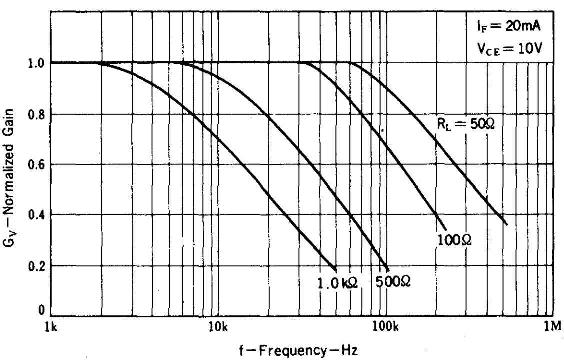
SWITCHING TIME vs.
LOAD RESISTANCE



COLLECTOR TO EMITTER BREAKDOWN
VOLTAGE vs. BASE RESISTANCE



FREQUENCY RESPONSE



NEC
ELECTRON DEVICE

PHOTO COUPLER
PS2002B

PHOTO COUPLER
INDUSTRIAL USE

— NEPOC SERIES —

DESCRIPTION

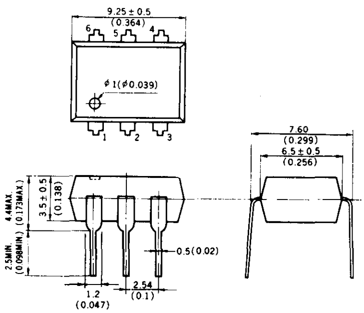
The PS2002B is an optically coupled isolator containing a GaAsP light emitting diode and an NPN silicon darlington- connected phototransistor.

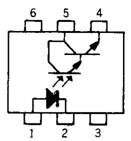
FEATURES

- High Voltage Isolation 2500V_{DC} MIN.
- High Transfer Ratio 100% MIN.
- Economical, Compact, Plastic Dual In-Line Package

PACKAGE DIMENSIONS

in millimeters (inches)





(Top view)
1. Anode
2. Cathode
3. NC
4. Emitter
5. Collector
6. NC

APPLICATIONS

- ECR
- Automat
- Replacement of pulse transformer.
- Other replacement of mechanical relay and reed relays.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Diode			
Reverse Voltage	V_R	7.0	V
Forward Current	I_F	50	mA
Power Dissipation	P_D	100	mW
Transistor			
Collector to Emitter Voltage	V_{CEO}	40	V
Collector Current	I_C	50	mA
Power Dissipation	P_C	100	mW
Isolation Voltage*1	BV	2500	V_{DC}
Storage Temperature	T_{stg}	-55 to +125	°C
Operating Temperature	T_{opt}	-55 to +100	°C

8

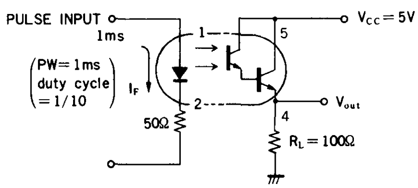
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

	CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Diode	Forward Voltage	V_F			1.9	V	I_F = 5.0 mA
	Reverse Current	I_R			2.0	μA	V_R = 4.0V
	Junction Capacitance	C		100		pF	V = 0, f = 1.0 MHz
Transistor	Collector to Emitter Dark Current	I_{CEO}			400	nA	V_{CE} = 10V, I_F = 0
	DC Current Gain	h_{FE}		5000			I_C = 4.0mA, V_{CE} = 2.0V
Coupled	Current Transfer Ratio	CTR(I_C/I_F)	100			%	I_F = 5.0mA, V_{CE} = 2.0V
	Collector Saturation Voltage	$V_{CE\ (sat)}$			1.2	V	I_F = 5.0 mA, I_C = 2.0 mA
	Isolation Resistance	R_{1-2}	10^{11}			Ω	V_{in-out} = 1.0 kV
	Isolation Capacitance	C_{1-2}		0.8		pF	V = 0, f = 1.0 MHz
	Rise Time	t_r		100		μs	V_{CC} = 5.0V, I_F = 10 mA, R_L = 100 Ω *2
	Fall Time	t_f		120		μs	V_{CC} = 5.0V, I_F = 10 mA, R_L = 100Ω *2

* 1 Measuring Condition

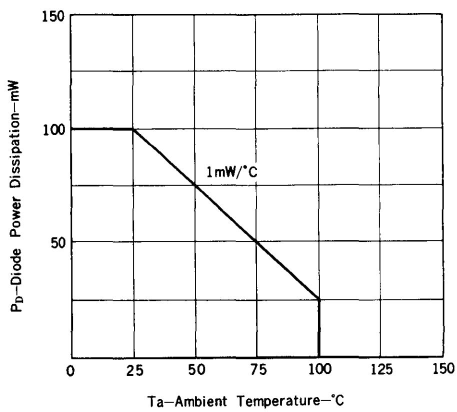
DC or AC voltage for 1 minute at Ta = 25°C,
RH = 60%
Between input (pin No. 1, 2 and No. 3 Common)
and output (pin No. 4, 5 and No. 6 Common)

* 2 Test Circuit for Switching Time

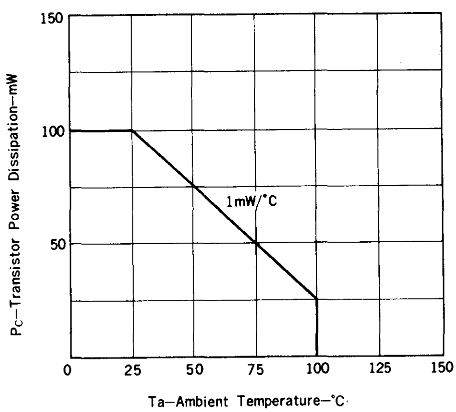


TYPICAL CHARACTERISTICS (Ta = 25°C)

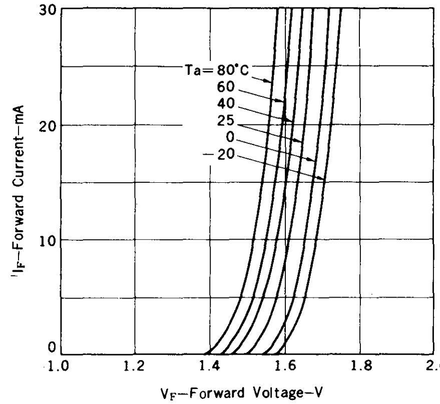
DIODE POWER DISSIPATION vs. AMBIENT TEMPERATURE



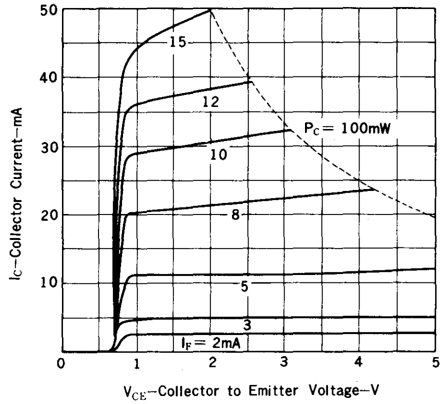
TRANSISTOR POWER DISSIPATION vs. AMBIENT TEMPERATURE



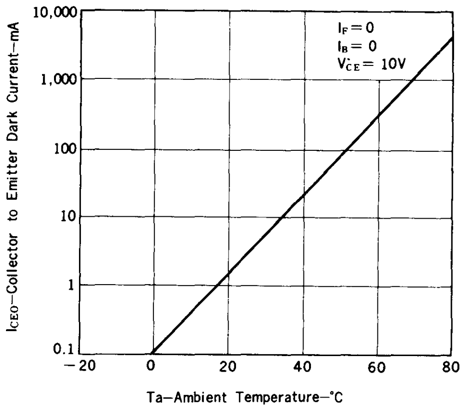
FORWARD CURRENT vs.
FORWARD VOLTAGE



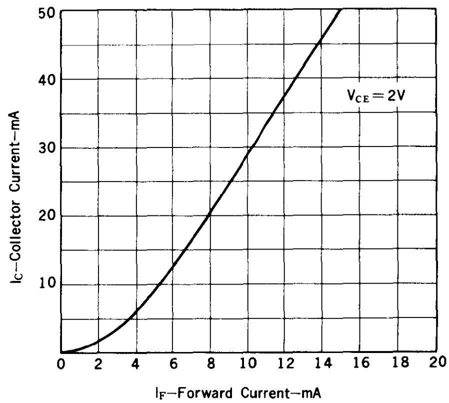
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



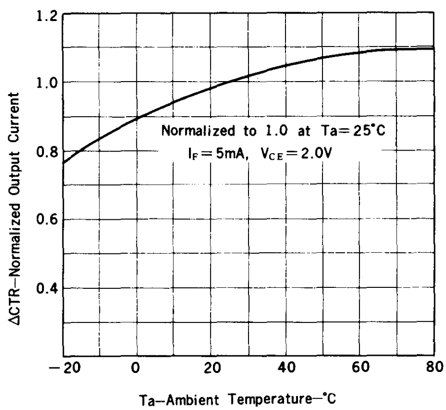
COLLECTOR TO EMITTER DARK CURRENT vs.
AMBIENT TEMPERATURE



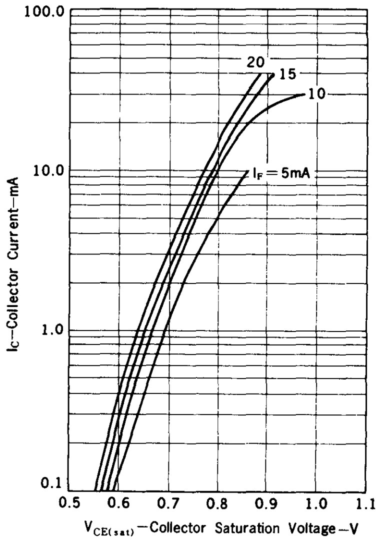
COLLECTOR CURRENT vs.
FORWARD CURRENT



NORMALIZED OUTPUT CURRENT vs.
AMBIENT TEMPERATURE

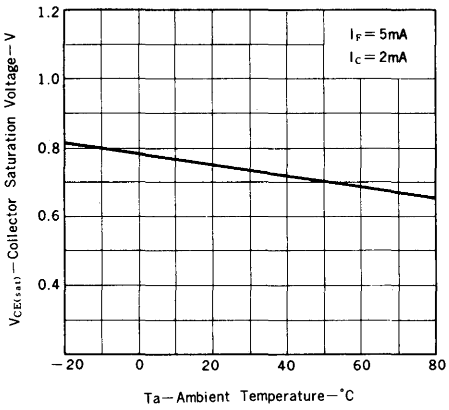


COLLECTOR CURRENT vs.
COLLECTOR SATURATION VOLTAGE



8

COLLECTOR SATURATION VOLTAGE vs. AMBIENT TEMPERATURE



NEC
ELECTRON DEVICE

PHOTO COUPLER
PS2003B

PHOTO COUPLER

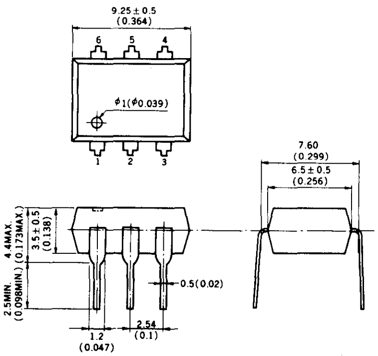
– NEPOC SERIES –

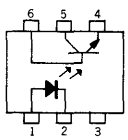
DESCRIPTION

The PS2003B is an optically coupled isolator containing a GaAs light emitting diode and an NPN silicon photo transistor.

PACKAGE DIMENSIONS

in millimeters (inches)





(Top view)
1. Anode
2. Cathode
3. NC
4. Emitter
5. Collector
6. Base

FEATURES

- High isolation voltage — $2500V_{DC}$ Rating
- High transfer ratio — 20% MIN.
- High speed switching — t_r, t_f = 5.0 μs TYP.
- Economical, compact, Dual In-Line Plastic Package

APPLICATIONS

- Interface circuit for various instrumentations, control equipments.
- Chopper circuits.
- Computer and peripheral manufactures.
- Pulse transformer.
- Data communication equipment.

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

Diode			
Reverse Voltage	V_R	5.0	V
Forward Current	I_F	40	mA
Power Dissipation	P_D	100	mW
Transistor			
Collector to Emitter Voltage	V_{CEO}	30	V
Collector Current	I_C	50	mA
Power Dissipation	P_C	150	mW
Isolation Voltage*1	BV	2500	V_{DC}
Storage Temperature	T_{stg}	-55 to +125	°C
Operating Temperature	T_{opt}	-55 to +100	°C

8

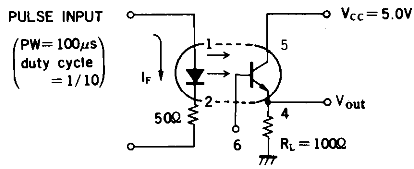
ELECTRICAL CHARACTERISTICS (Ta = 25°C)

	CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Diode	Forward Voltage	V_F		1.1	1.4	V	I_F = 20 mA
	Reverse Current	I_R			20	μA	V_R = 4.0V
	Junction Capacitance	C		40		pF	V = 0, f = 1.0 MHz
Tran-sistor	Collector to Emitter Dark Current	I_{CEO}			200	nA	V_{CE} = 10V, I_F = 0
	DC Current Gain	h_{FE}		700			I_C = 4.0mA, V_{CE} = 5.0V
Coupled	Current Transfer Ratio	CTR(I_C/I_F)	20			%	I_F = 20 mA, V_{CE} = 5.0V
	Collector Saturation Voltage	$V_{CE\ (sat)}$			0.3	V	I_F = 20 mA, I_C = 2.0 mA
	Isolation Resistance	R_{1-2}	10^{11}			Ω	V_{in-out} = 1.0 kV
	Isolation Capacitance	C_{1-2}		0.8		pF	V = 0, f = 1.0 MHz
	Rise Time	t_r		5.0		μs	V_{CC} = 5.0V, I_F = 20 mA, R_L = 100Ω *2
	Fall Time	t_f		5.0		μs	V_{CC} = 5.0V, I_F = 20 mA, R_L = 100Ω *2

* 1 Measuring Condition

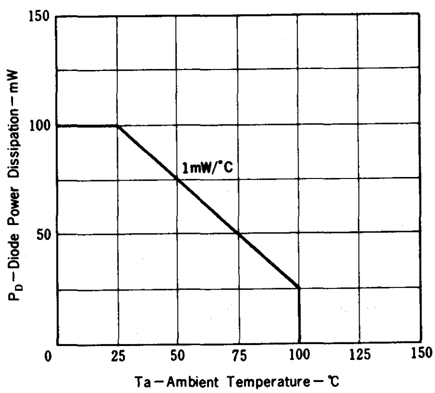
DC or AC voltage for 1 minute at Ta = 25°C, RH = 60%
Between input (pin No. 1, 2 and No. 3 Common) and output (pin No. 4, 5 and No. 6 Common)

* 2 Test Circuit for Switching Time

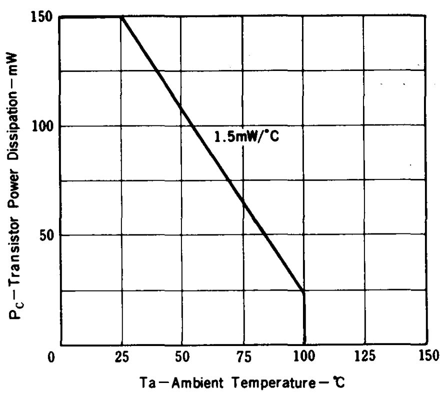


TYPICAL CHARACTERISTICS (Ta = 25°C)

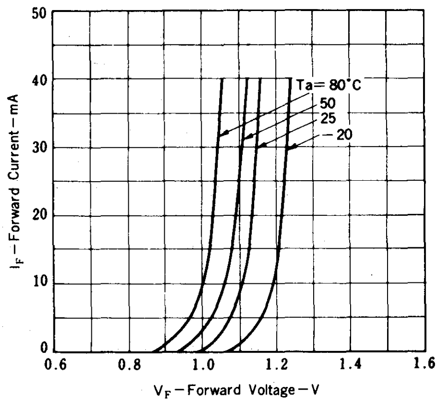
DIODE POWER DISSIPATION vs. AMBIENT TEMPERATURE



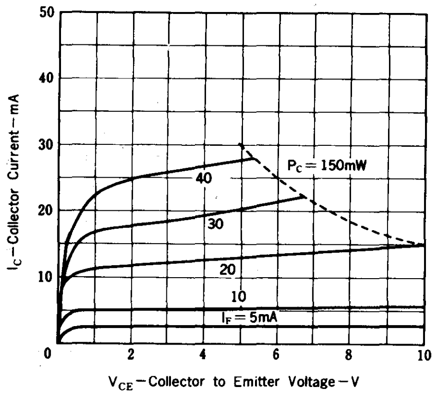
TRANSISTOR POWER DISSIPATION vs. AMBIENT TEMPERATURE



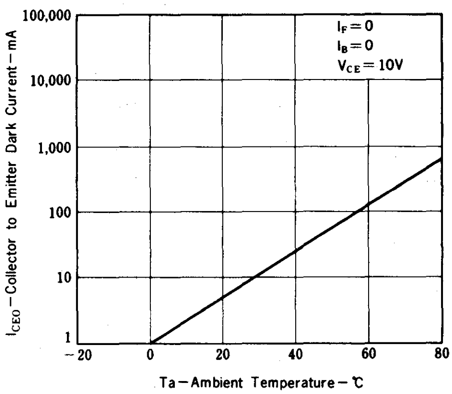
FORWARD CURRENT vs. FORWARD VOLTAGE



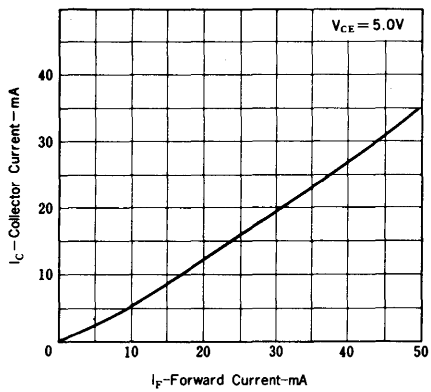
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



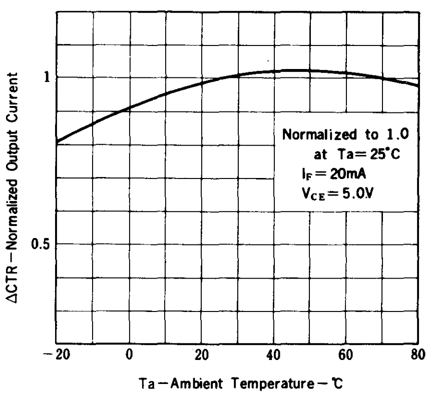
COLLECTOR TO EMITTER DARK CURRENT vs. AMBIENT TEMPERATURE



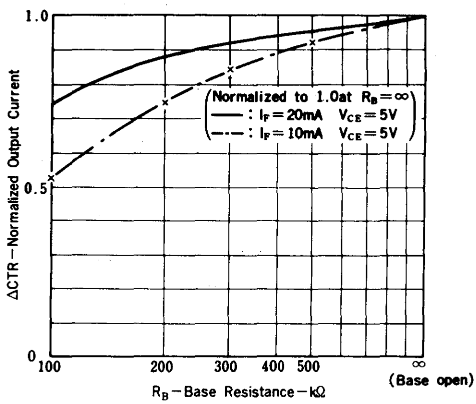
COLLECTOR CURRENT vs. FORWARD CURRENT



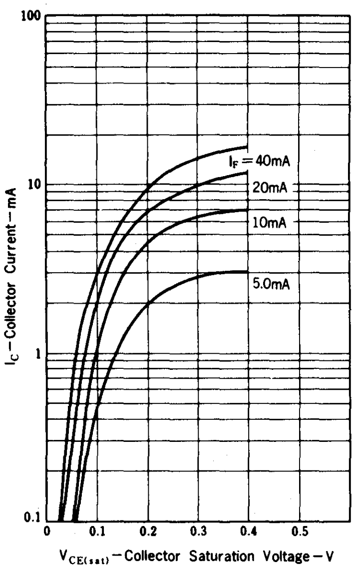
NORMALIZED OUTPUT CURRENT vs. AMBIENT TEMPERATURE



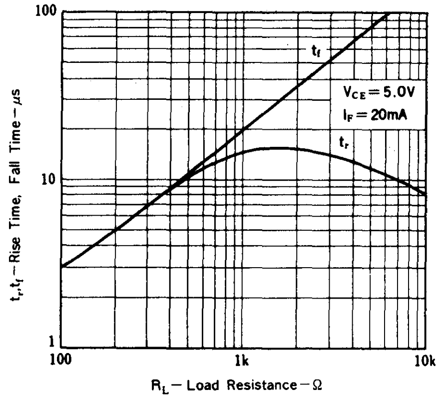
NORMALIZED OUTPUT CURRENT vs. BASE RESISTANCE



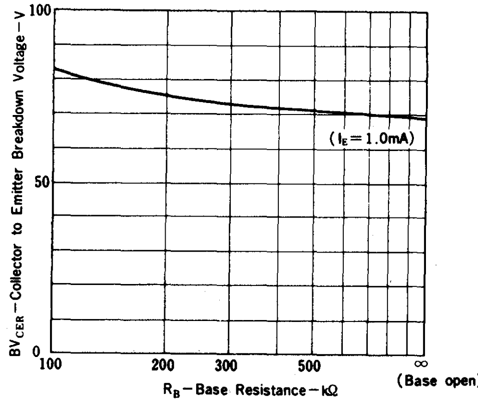
COLLECTOR CURRENT vs.
COLLECTOR SATURATION VOLTAGE



SWITCHING TIME vs.
LOAD RESISTANCE



COLLECTOR TO EMITTER BREAKDOWN
VOLTAGE vs. BASE RESISTANCE



FREQUENCY RESPONSE

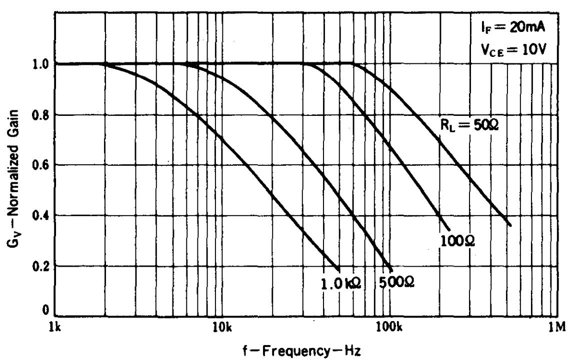


PHOTO COUPLER
INDUSTRIAL USE

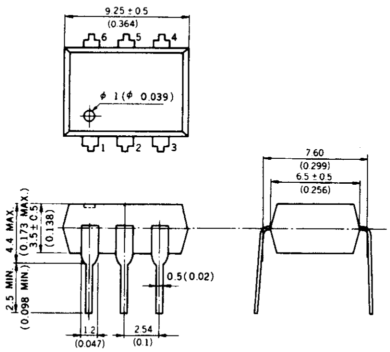
– NEPOC SERIES –

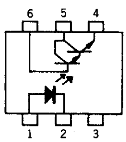
DESCRIPTION

The PS2004B is an optically coupled isolator containing a GaAs light emitting diode and an NPN silicon darlington phototransistor in a plastic DIP (Dual In-Line Package)

PACKAGE DIMENSIONS

in millimeters (inches)





1. Anode
2. Cathode
3. NC
4. Emitter
5. Collector
6. Base

FEATURES

- High voltage isolation 2 500 V MIN.
- Ultra high transfer ratio 1 300 % MIN.
- Economical, compact, plastic dual in-line package
- Large output current 200 mA MAX.

APPLICATIONS

- Copy machine.
- Replaceable from mechanical relays and reed relays.
- Replaceable from pulse transformer.

ABSOLUTE MAXIMUM RATINGS ($T_a = 25$ °C)

Diode			
Reverse Voltage	V_R	5.0	V
Forward Current	I_F	50	mA
Power Dissipation	P_D	100	mW
Transistor			
Collector to Emitter Voltage	V_{CEO}	30	V
Collector Current	I_C	200	mA
Power Dissipation	P_C	200	mW
Total Power Dissipation	P_{total}	250	mW
Isolation Voltage*1	BV	2 500	V_{DC}
Isolation Voltage*1	BV	2 000	$V_{AC(r.m.s.)}$
Storage Temperature	T_{stg}	−55 to +125	°C
Operating Temperature	T_{opt}	−55 to +100	°C

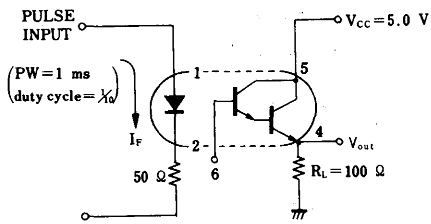
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

	CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Diode	Forward Voltage	V_F			1.4	V	I_F = 20 mA
	Reverse Current	I_R			5.0	μA	V_R = 4.0 V
	Junction Capacitance	C		100		pF	V = 0, f = 1.0 MHz
Transistor	Collector to Emitter Dark Current	I_{CEO}			400	nA	V_{CE} = 10 V, I_F = 0
Coupled	Current Transfer Ratio	CTR(I_C/I_F)	1300			%	I_F = 5.0 mA, V_{CE} = 2.0 V
	Collector Saturation Voltage	$V_{CE\ (sat)}$			1.2	V	I_F = 5.0 mA, I_C = 2.0 mA
	Isolation Resistance	R_{1-2}	10^{11}			Ω	V_{in-out} = 1.0 kV
	Isolation Capacitance	C_{1-2}		0.8		pF	V = 0, f = 1.0 MHz
	Rise Time	t_r		100		μs	V_{CC}=5.0 V, I_F=5.0 mA, R_L=100 Ω *2
	Fall Time	t_f		250		μs	V_{CC}=5.0 V, I_F=5.0 mA, R_L=100 Ω *2

*** 1. Measuring Condition**

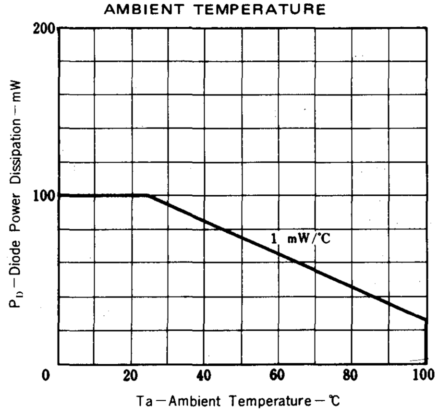
DC or AC voltage for 1 minute at Ta=25 °C, RH=60 %
Between input (pin No. 1, 2 and No. 3 Common) and output (pin No. 4, 5 and No. 6 Common)

*** 2. Test Circuit for Switching Time**

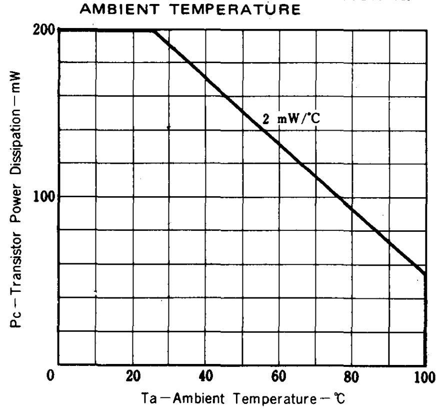


TYPICAL CHARACTERISTICS (Ta=25 °C)

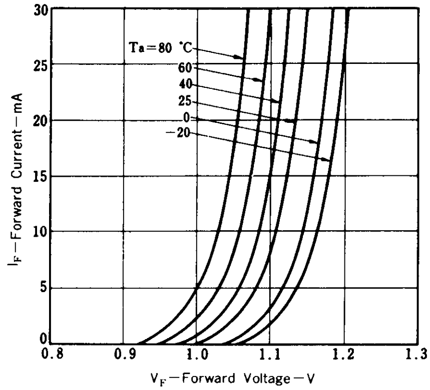
DIODE POWER DISSIPATION vs. AMBIENT TEMPERATURE



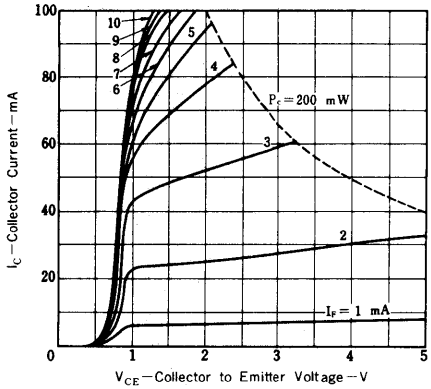
TRANSISTOR POWER DISSIPATION vs. AMBIENT TEMPERATURE



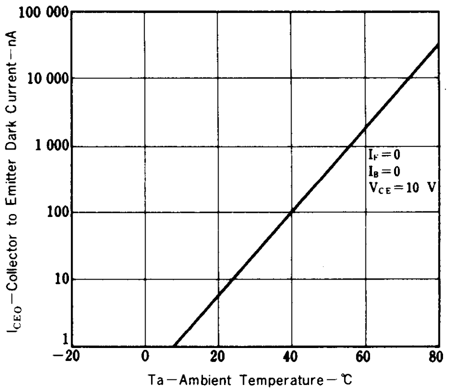
FORWARD CURRENT vs.
FORWARD VOLTAGE



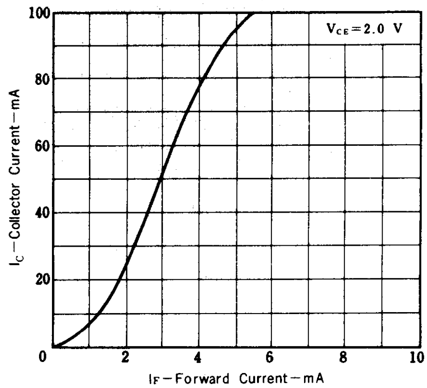
COLLECTOR CURRENT vs.
COLLECTOR TO EMITTER VOLTAGE



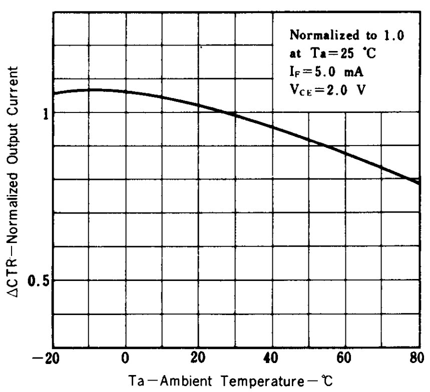
COLLECTOR TO EMITTER DARK CURRENT vs.
AMBIENT TEMPERATURE



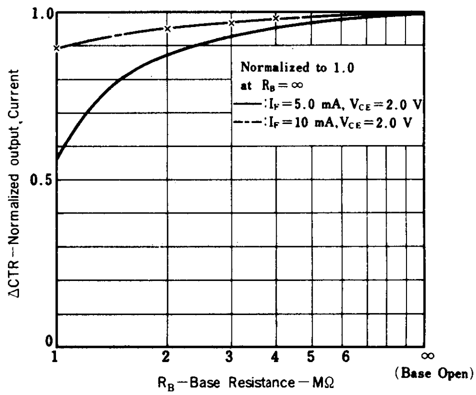
COLLECTOR CURRENT vs.
FORWARD CURRENT



NORMALIZED OUTPUT CURRENT vs.
AMBIENT TEMPERATURE



NORMALIZED OUTPUT CURRENT vs.
BASE RESISTANCE



8

PHOTO COUPLER
PS2005B

PHOTO COUPLER
INDUSTRIAL USE

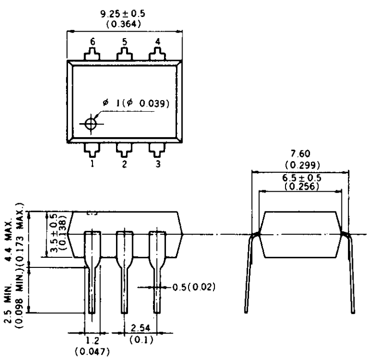
– NEPOC SERIES –

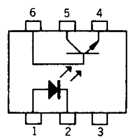
DESCRIPTION

The PS2005B is an optically coupled isolator containing a GaAsP light emitting diode and an NPN silicon phototransistor.

PACKAGE DIMENSIONS

in millimeters (inches)





1. Anode
2. Cathode
3. NC
4. Emitter
5. Collector
6. Base

FEATURES

- High voltage isolation 2 500 V
- Large forward input (current) 150 mA MAX.
- High transfer ratio 10 % MIN.
- High speed switching t_r, t_f = 5 μs TYP.
- Economical, compact, plastic dual in-line package

APPLICATIONS

- Telephone-Telegraph lines receivers.
- Replaceable from a read relay.

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Diode			
Reverse Voltage	V_R	7.0	V
Forward Current	I_F	150	mA
Power Dissipation	P_D	200	mW
Transistor			
Collector to Emitter Voltage	V_{CEO}	30	V
Collector Current	I_C	50	mA
Power Dissipation	P_C	150	mW
Total Power Dissipation	P_{total}	250	mW
Isolation Voltage*1	BV	2 500	V_{DC}
Isolation Voltage*1	BV	2 000	V_{AC} (r.m.s.)
Storage Temperature	T_{stg}	–55 to +125	°C
Operating Temperature	T_{opt}	–55 to +100	°C

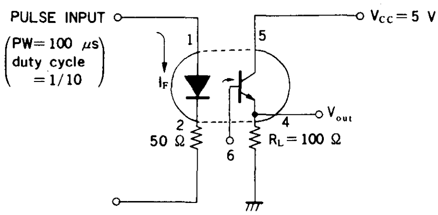
ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

	CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Diode	Forward Voltage	V_F			2.0	V	I_F = 100 mA
	Reverse Current	I_R			5.0	μA	V_R = 4.0 V
	Junction Capacitance	C		250		pF	V = 0, f = 1.0 MHz
Tran-sistor	Collector to Emitter Dark Current	I_{CEO}			200	nA	V_{CE} = 10 V, I_F = 0
	DC Current Gain	h_{FE}		400			I_C = 4.0 mA, V_{CE} = 5.0 V
Coupled	Current Transfer Ratio	CTR(I_C/I_F)	10			%	I_F = 100 mA, V_{CE} = 5.0 V
	Collector Saturation Voltage	$V_{CE(sat)}$			0.3	V	I_F = 100 mA, I_C = 4.0 mA
	Isolation Resistance	$R_{1\text{-}2}$	10^{11}			Ω	$V_{in\text{-}out}$ = 1.0 kV
	Isolation Capacitance	$C_{1\text{-}2}$		0.8		pF	V = 0, f = 1.0 MHz
	Rise Time	t_r		5.0		μs	V_{CC}=5.0 V, I_F=100 mA, R_L=100 Ω *2
	Fall Time	t_f		5.0		μs	V_{CC}=5.0 V, I_F=100 mA, R_L=100 Ω *2

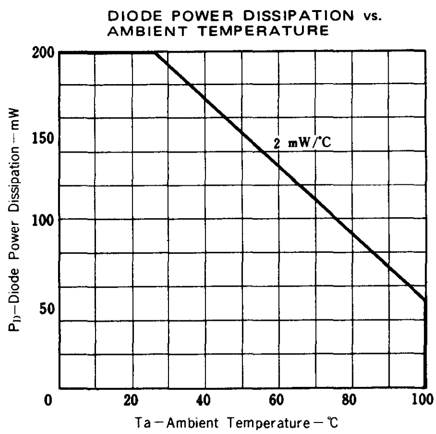
*** 1. Measuring Condition**

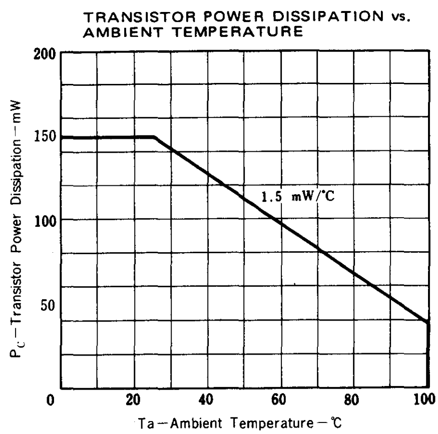
DC or AC voltage for 1 minute at Ta = 25 °C
RH = 60 %
Between input (pin No. 1, 2 and No. 3 Common) and output (pin No. 4, 5 and No. 6 Common)

*** 2. Test Circuit for Switching Time**



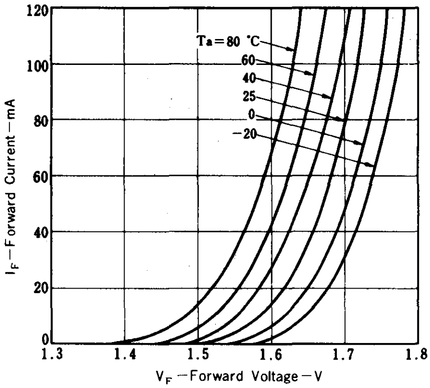
TYPICAL CHARACTERISTICS (Ta = 25 °C)



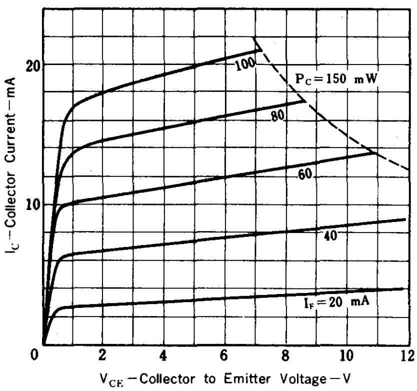


8

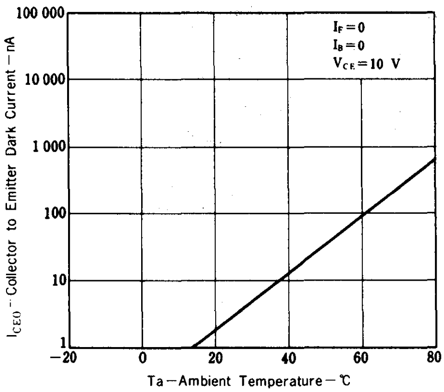
FORWARD CURRENT vs. FORWARD VOLTAGE



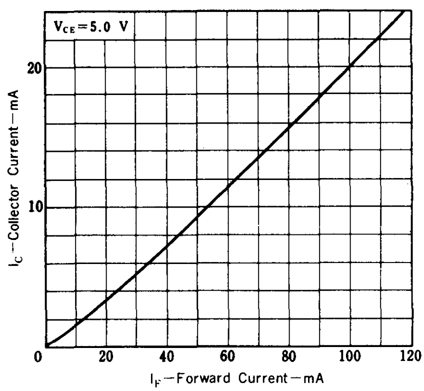
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



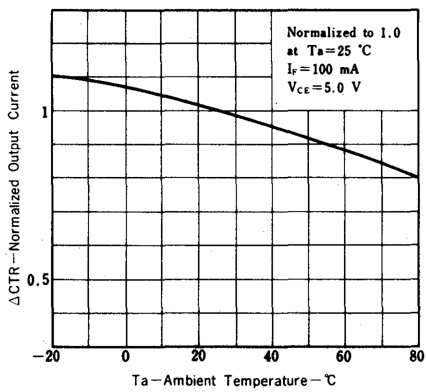
COLLECTOR TO EMITTER DARK CURRENT vs. AMBIENT TEMPERATURE



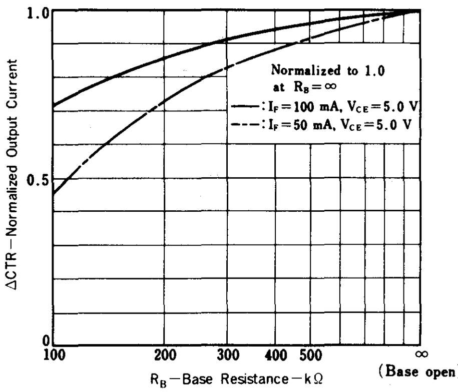
COLLECTOR CURRENT vs. FORWARD CURRENT



NORMALIZED OUTPUT CURRENT vs. AMBIENT TEMPERATURE



NORMALIZED OUTPUT CURRENT vs. BASE RESISTANCE



NEC
ELECTRON DEVICE

PHOTO COUPLER
PS2006, PS2006(1)

HIGH SPEED PHOTO COUPLER

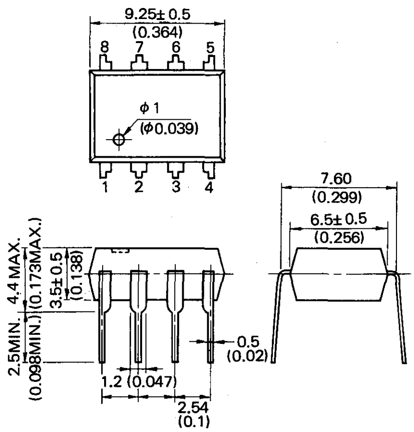
—NEPOC SERIES—

DESCRIPTION

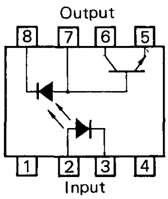
The PS2006, PS2006(1) are high speed photo couplers containing a GaAsP light emitting diode and a p-n photodiode connected to a high speed transistor.

The CTR are 15% MIN. for PS2006 and 7% MIN. for PS2006(1).

PACKAGE DIMENSIONS in millimeters (inches)



PIN CONNECTION



PIN		Function
Input	1.	NC
	2.	Anode
	3.	Cathode
	4.	NC
Output	5.	Emitter
	6.	Vo
	7.	Base
	8.	Vcc

FEATURES

- High isolation voltage 3000 V_{DC} MIN.
- High speed response t_{PHL}, t_{PLH}=300ns TYP.
- Compact, dual in-line plastic package
- Equivalent to HP's 5082-4350 Series

APPLICATIONS

- Interface circuit for various instrumentations, control equipments.
- Floating power supply feedback networks.
- Computer and peripheral manufactures.
- Pulse transformer.
- High speed digital and analog line receivers.

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Diode			
Reverse Voltage	V_R	5	V
Forward Current	I_F	25	mA
Power Dissipation	P_D	45	mW
Detector			
Supply Voltage	Vcc	–0.5 to +15	V
Output Voltage	Vo	–0.5 to +15	V
Output Current	Io	8	mA
Emitter to Base Voltage	V_{EBO}	5	V
Power Dissipation	Pc	100	mW
Isolation Voltage *1	BV	3000	V_{DC}
Storage Temperature	Tstg	–55 to +125	°C
Operating Temperature	Topt	–55 to +100	°C

8

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

	CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Diode	Forward Voltage	V_F		1.43	1.7	V	I_F=16mA
	Reverse Current	I_R		0.01	10	μA	V_R=5V
	Forward Voltage Temperature Coefficient	$\frac{\Delta V_F}{\Delta T}$		−1.51		mV/°C	I_F=16mA
	Capacitance	C_t		60		pF	V=0,f=1MHz
Detector	High Level Output Current	$I_{OH(1)}$		3	500	nA	I_F=0mA,Vcc=Vo=5.5V
	High Level Output Current	$I_{OH(2)}$			100	μA	I_F=0mA,Vcc=Vo=15V
	DC Current Gain	h_{FE}		120			Vo= 5V,Io=3mA
Coupled	Current Transfer Ratio	CTR	15/7	22		%	I_F=16mA,Vcc=4.5V Vo=0.4V
	Low Level Output Voltage	V_{OL}		0.1	0.4	V	I_F=16mA,Vcc=4.5V Io=2.4mA/1.1mA
	Low Level Supply Current	I_{CCL}		50		μA	I_F=16mA,Vo=Open, Vcc=15V
	High Level Supply Current	I_{CCH}		0.01	1	μA	I_F=0mA,Vo=Open, Vcc=15V
	Isolation Resistance	$R_{1\text{-}2}$		10^{12}		Ω	Vin-out=1kV
	Isolation Capacitance	$C_{1\text{-}2}$		0.7		pF	V=0,f=1MHz
	Propagation Delay Time to Low Output Level	*2 t_{PHL}		0.3/0.5	0.8/1.5	μs	I_F=16mA,Vcc=5V R_L=1.9kΩ/4.1kΩ
	Propagation Delay Time to High Output Level	*2 t_{PLH}		0.3/0.8	0.8/1.5	μs	I_F=16mA,Vcc=5V R_L=1.9kΩ/4.1kΩ

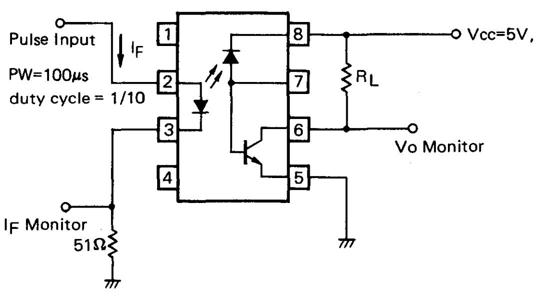
In Characteristics " / " indicates PS2006/PS2006(1).

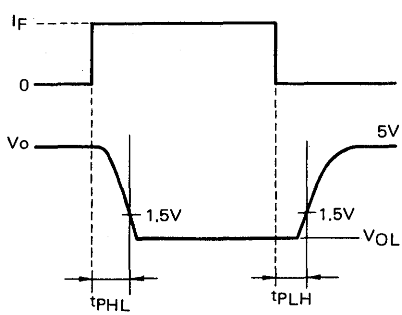
*1 Measuring Condition

DC voltage for 1 minute at Ta=25 °C, RH=60%

Between input (pin No. 1, 2, 3, 4 Common) and output (pin No. 5, 6, 7, 8 Common)

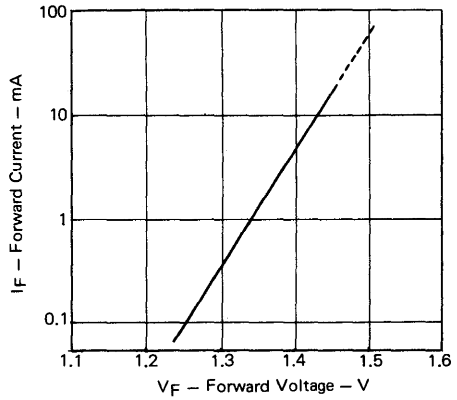
*2 Measuring Circuit



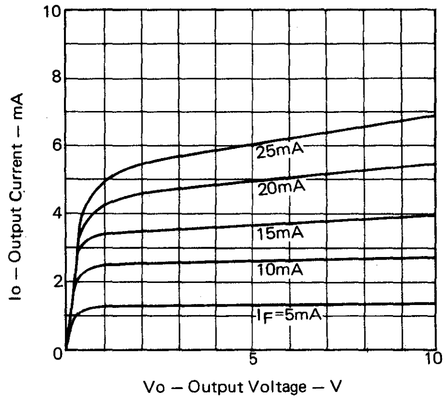


TYPICAL CHARACTERISTICS (Ta = 25 °C)

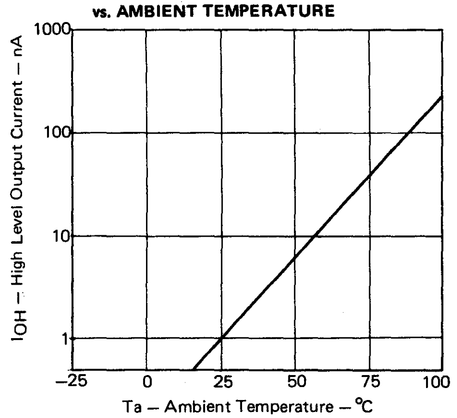
FORWARD CURRENT vs. FORWARD VOLTAGE



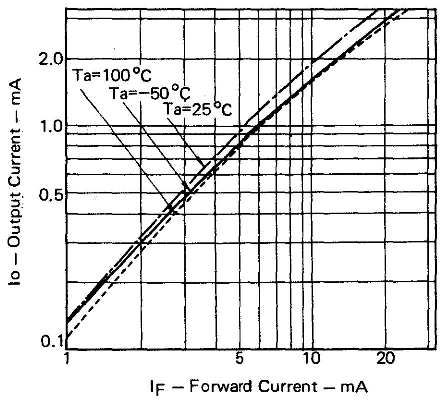
OUTPUT CURRENT vs. OUTPUT VOLTAGE



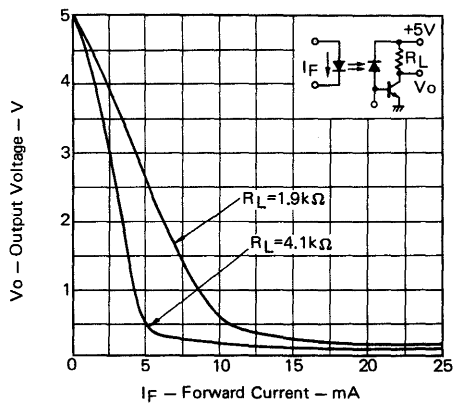
HIGH LEVEL OUTPUT CURRENT vs. AMBIENT TEMPERATURE



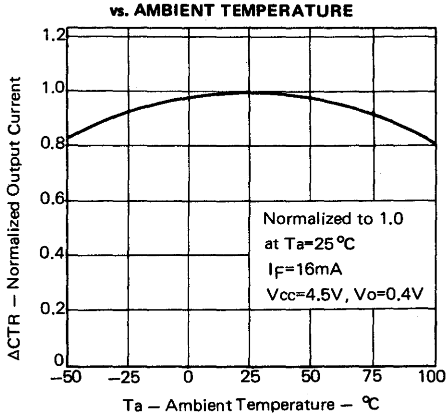
OUTPUT CURRENT vs. FORWARD CURRENT



OUTPUT VOLTAGE vs. FORWARD CURRENT

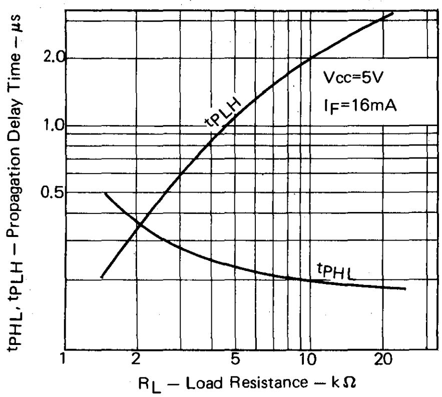


NORMALIZED OUTPUT CURRENT vs. AMBIENT TEMPERATURE

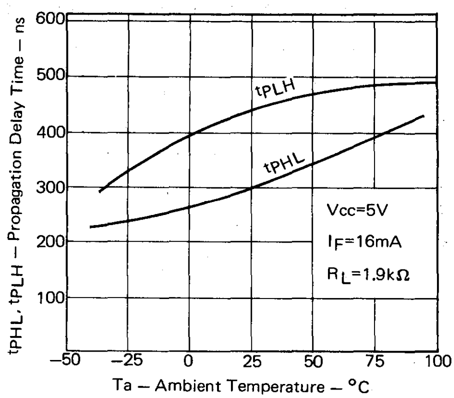


8

PROPAGATION DELAY TIME vs. LOAD RESISTANCE



PROPAGATION DELAY TIME vs. AMBIENT TEMPERATURE



NEC
ELECTRON DEVICE

PHOTO COUPLER
PS2007B

HIGH SPEED PHOTO COUPLER

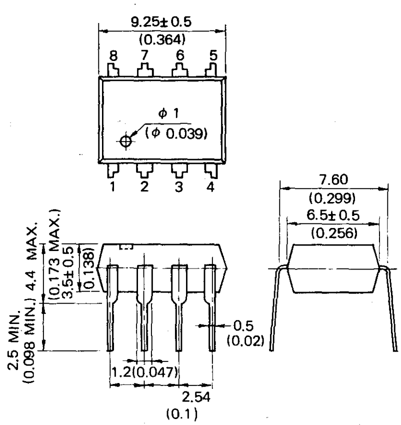
—NEPOC SERIES—

DESCRIPTION

The PS2007B is a high speed photo coupler containing a GaAsP light emitting diode and an integrated detector consisting of a photodiode and a high gain linear amplifier that drives a schottky clamped open collector output transistor in a plastic DIP (Dual In-Line Package).

PACKAGE DIMENSIONS

in millimeters (inches)



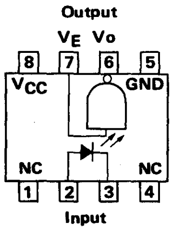
FEATURES

- Ultra high speed — 50 ns TYP.
- High isolation voltage — 3 000 V_{DC} MIN.
- Low input current req. — 5 mA
- Economical, compact, plastic dual in-line package
- TTL compatible — 5 V Supply
- Equivalent to HP's 5082-4360, 6N137

APPLICATIONS

- Line receiver
- Floating power supply
- Computer and peripheral memory
- Replaceable from mechanical relays and reed relays
- Replaceable from pulse transformer

PIN CONNECTION



PIN		Function
Input	1.	NC
	2.	Anode
	3.	Cathode
	4.	NC
Output	5.	GND
	6.	Vo
	7.	V_E
	8.	V_{CC}

ABSOLUTE MAXIMUM RATINGS (Ta=25 °C)

Diode			
Reverse Voltage	V_R	5	V
Forward Current	I_F	10	mA
Detector			
Supply Voltage	Vcc	7	V
Output Voltage	Vo	7	V
Output Current	Io	50	mA
Enable Voltage	V_E	5.5	V
Power Dissipation	Pc	85	mW
Isolation Voltage	BV *1	3000	V_{DC}
Storage Temperature	Tstg	–55 to +125	°C
Operating Temperature	Topt	0 to +70	°C

8

ELECTRICAL CHARACTERISTICS (Ta = 0 to 70 °C)

	CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Diode	Forward Voltage	V_F		1.42	1.7	V	I_F=10 mA, Ta=25 °C
Diode	Reverse Current	I_R		0.01	10	μA	V_R=5 V, Ta=25 °C
Diode	Capacitance	C_t		60		pF	V=0, f=1.0 MHz
Detector	High Level Enable Current	I_{EH}		−0.8		mA	Vcc=5.5 V, V_{EH}=2.0 V
Detector	Low Level Enable Current	I_{EL}		−1.2	−2.0	mA	Vcc=5.5 V, V_{EL}=0.5 V
Coupled	High Level Output Current	I_{OH}		30	250	μA	Vcc=Vo=5.5 V, I_F=250 μA V_E=2.0 V
Coupled	Low Level Output Voltage	V_{OL}		0.4	0.6	V	Vcc=5.5 V, V_E=2.0 V I_F=5 mA, Io=13 mA
Coupled	Low Level Supply Current	I_{CCL}		10	18	mA	Vcc=5.5 V, V_E=2 V I_F=10 mA
Coupled	High Level Supply Current	I_{CCH}		7	15	mA	Vcc=5.5 V, V_E=0.5 V I_F=0 mA

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

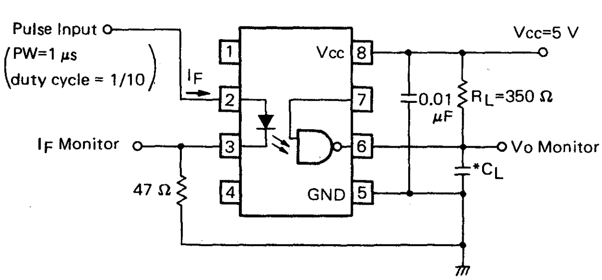
	CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Coupled	Current Transfer Ratio	CTR		600		%	I_F=5 mA,Vcc=5 V,R_L=100 Ω
Coupled	Isolation Resistance	R_{1-2}		10^{12}		Ω	$V_{in\text{-}out}$=1 kV
Coupled	Isolation Capacitance	C_{1-2}		0.7		pF	V=0, f=1 MHz
Coupled	Propagation Delay Time to Low Output Level	t_{PHL} *2		50	75	ns	I_F=7.5 mA, Vcc=5 V R_L=350 Ω, C_L=15 pF
Coupled	Propagation Delay Time to High Output Level	t_{PLH} *2		50	75	ns	
Coupled	Propagation Delay Time of Enable to Low Output Level	t_{EHL}		15		ns	I_F=7.5 mA, Vcc=5 V R_L=350 Ω, V_{EH}=3 V C_L=15 pF
Coupled	Propagation Delay Time of Enable to High Output Level	t_{ELH}		30		ns	

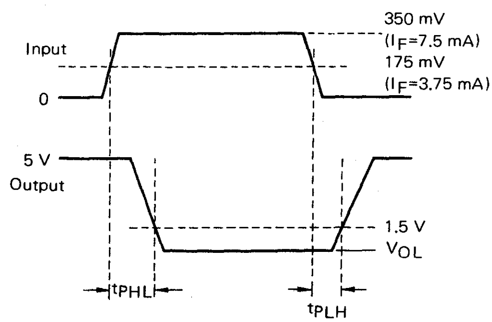
*1 Measuring Condition

DC voltage for 1 minute at Ta = 25 °C, RH = 60 %

Between input (pin No. 1, 2, 3, 4 Common) and Output (Pin No. 5, 6, 7, 8 Common)

*2 Measuring Circuit

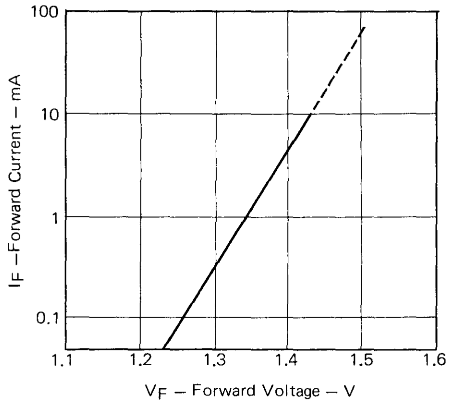




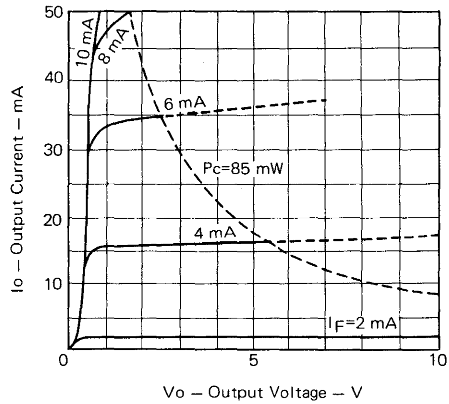
*C_L is approximately 15 pF, which includes probe and stray wiring capacitance.

TYPICAL CHARACTERISTICS (Ta = 25 °C)

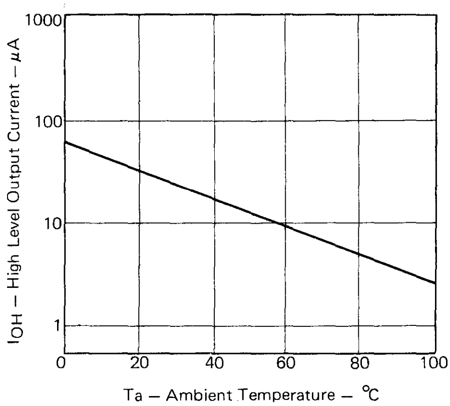
FORWARD CURRENT vs. FORWARD VOLTAGE



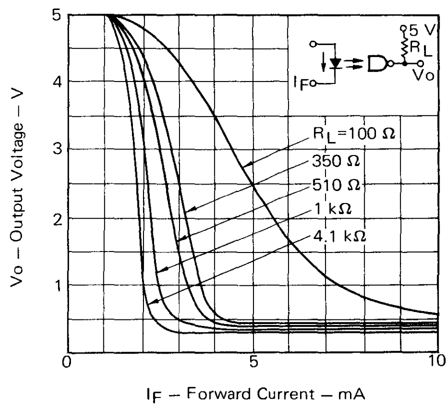
OUTPUT CURRENT vs. OUTPUT VOLTAGE



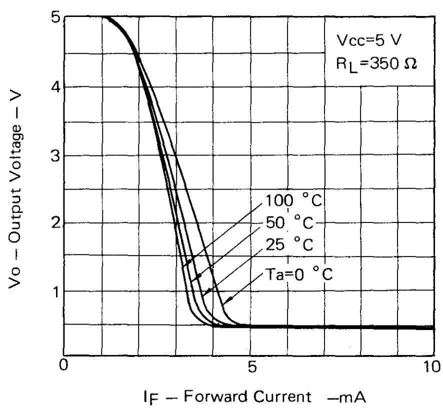
HIGH LEVEL OUTPUT CURRENT vs. AMBIENT TEMPERATURE



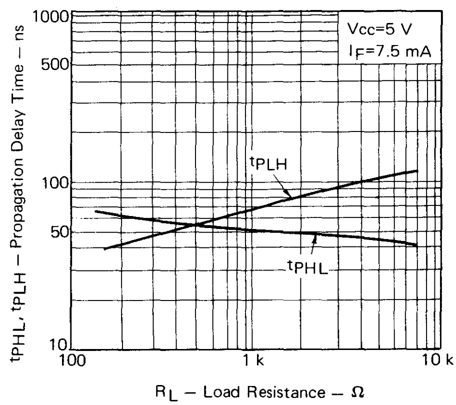
OUTPUT VOLTAGE vs. FORWARD CURRENT



OUTPUT VOLTAGE vs. FORWARD CURRENT

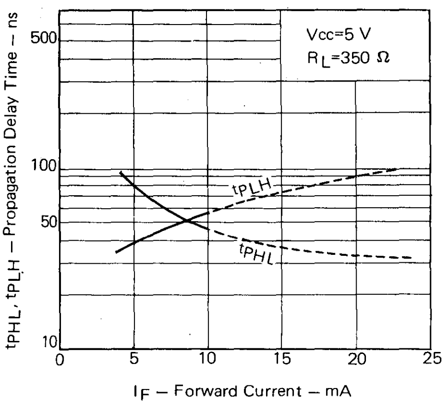


PROPAGATION DELAY TIME vs. LOAD RESISTANCE



8

PROPAGATION DELAY TIME vs. FORWARD CURRENT



PROPAGATION DELAY TIME vs. AMBIENT TEMPERATURE

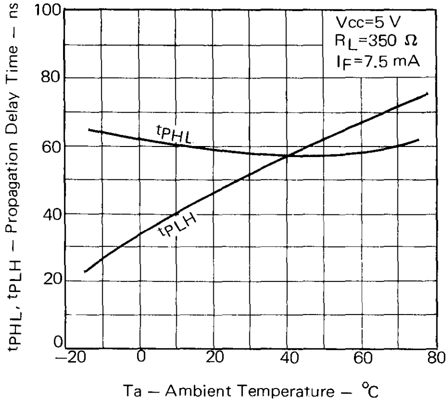


PHOTO COUPLER
PS2010

PHOTO COUPLER

— NEPOC SERIES —

DESCRIPTION

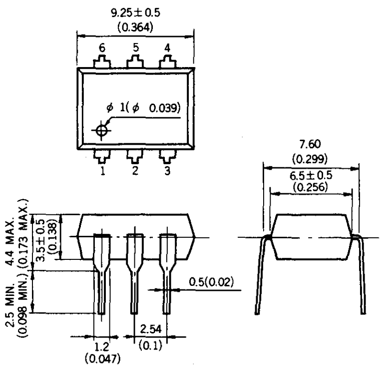
The PS2010 is an optically coupled isorator containing a GaAs light emitting diode and an NPN silicon photo transistor.

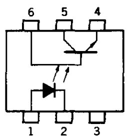
PS2010 all rank : MCT2, H11A2 ~H11A5, 4N25~4N28

PS2010 K rank : H11A1

Compatible with MCT2, H11A1~H11A5 and 4N25~4N28

PACKAGE DIMENSIONS
in millimeters (inches)





(Top view)
1. Anode
2. Cathode
3. NC
4. Emitter
5. Collector
6. Base

FEATURES

- High isolation voltage — 2 000 V_{AC}, 2 500 V_{DC}
- High transfer ratio — 20 % MIN.
- High speed switching — t_r, t_f = 4 μs TYP.
- Economical, compact, Dual In-Line Plastic Package

APPLICATIONS

- Interface circuit for various instrumentations, control equipments.
- Chopper circuits.
- Computer and peripheral manufactures.
- Pulse transformer.
- Data communication equipment.

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

Diode			
Reverse Voltage	V_R	5.0	V
Forward Current (DC)	I_F	80	mA
Power Dissipation	P_D	150	mW
Peak Forward Current (300 μs, 2 % duty cycle)	$I_{F(peak)}$	3	A
Transistor			
Collector to Emitter Voltage	V_{CEO}	30	V
Collector to Base Voltage	V_{CBO}	70	V
Emitter to Collector Voltage	V_{ECO}	7	V
Collector Current	I_C	100	mA
Power Dissipation	P_C	150	mW
Isolation Voltage*[1]	BV	2 500	V_{DC}
Isolation Voltage*[1]	BV	2 000	V_{AC}
Storage Temperature	T_{stg}	−55 to +150	°C
Operating Temperature	T_{opt}	−55 to +100	°C
Lead Temperature (Soldering 10 s)		260	°C
Total Power Dissipation	P_T	250	mW

8

ELECTRICAL CHARACTERISTICS ($T_a = 25\ ^\circ C$)

	CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Diode	Forward Voltage	V_F		1.1	1.4	V	$I_F = 10$ mA
	Forward Voltage	V_F		1.2	1.5	V	$I_F = 50$ mA
	Reverse Current	I_R			10	μA	$V_R = 5$ V
	Junction Capacitance	C		50		pF	V = 0, f = 1.0 MHz
Transistor	Collector to Emitter Dark Current	I_{CEO}			50	nA	$V_{CE} = 10$ V, $I_F = 0$
	DC Current Gain	h_{FE}		700			$I_C = 2$ mA, $V_{CE} = 5.0$ V
	Collector to Emitter Breakdown Voltage	BV_{CEO}	30	60		V	$I_C = 1$ mA, $I_B = 0$
	Collector to Base Breakdown Voltage	BV_{CBO}	70	120		V	$I_C = 100$ μA, $I_E = 0$
	Emitter to Collector Breakdown Voltage	BV_{ECO}	7	9		V	$I_E = 100$ μA, $I_B = 0$
Coupled	Current Transfer Ratio *3	CTR(I_C/I_F)	20			%	$I_F = 10$ mA, $V_{CE} = 5.0$ V
	Collector Saturation Voltage	$V_{CE(sat)}$			0.3	V	$I_F = 10$ mA, $I_C = 2.0$ mA
	Isolation Resistance	$R_{1\text{-}2}$	10^{11}			Ω	$V_{in\text{-}out} = 1.0$ kV
	Isolation Capacitance	$C_{1\text{-}2}$		0.8		pF	V = 0, f = 1.0 MHz
	Rise Time	t_r		4		μs	$V_{CC} = 5.0$ V, $I_C = 2$ mA, $R_L = 100$ Ω *2
	Fall Time	t_f		4		μs	$V_{CC} = 5.0$ V, $I_C = 2$ mA, $R_L = 100$ Ω *2

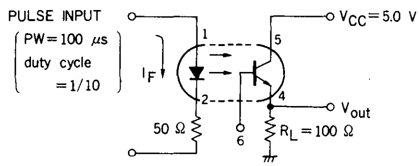
***1 Measuring Condition**

DC or AC voltage for 1 minute at Ta = 25 °c, RH = 60 %
Between input (pin No. 1, 2 and No. 3 Common) and output (pin No. 4,5 and No. 6 Common)

***3 CTR rank**

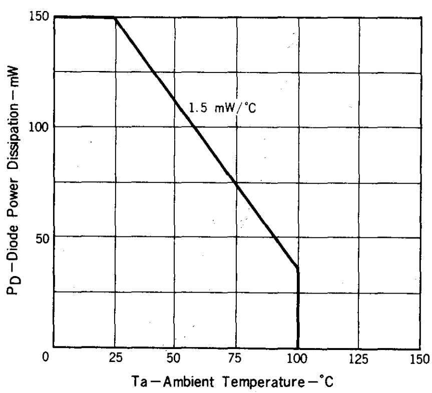
K : 80 % ~
L : 40 % ~
M : 20 % ~

***2 Test Circuit for Switching Time**

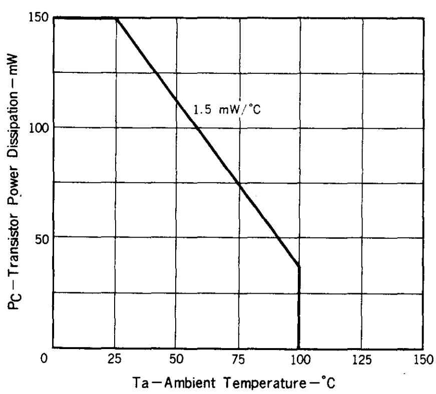


TYPICAL CHARACTERISTICS ($T_a = 25\ ^\circ C$)

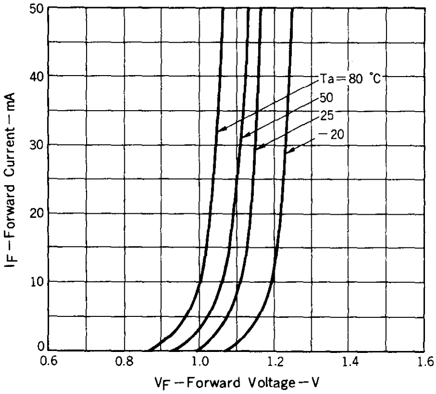
DIODE POWER DISSIPATION vs. AMBIENT TEMPERATURE



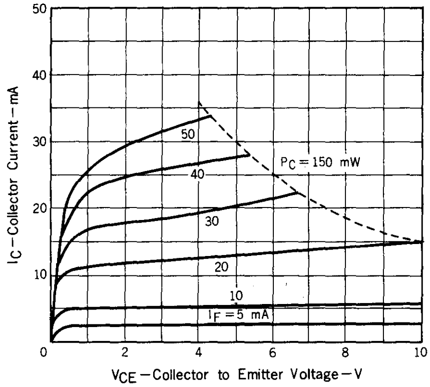
TRANSISTOR POWER DISSIPATION vs. AMBIENT TEMPERATURE



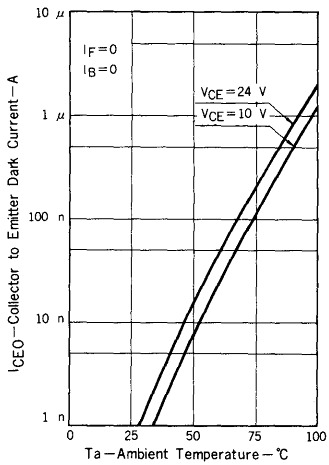
FORWARD CURRENT vs. FORWARD VOLTAGE



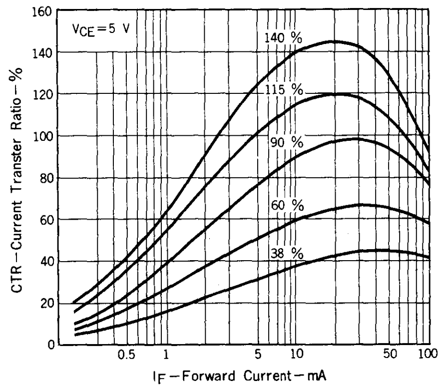
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE



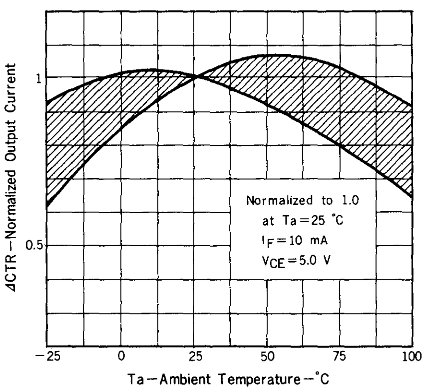
COLLECTOR TO EMITTER DARK CURRENT vs. AMBIENT TEMPERATURE



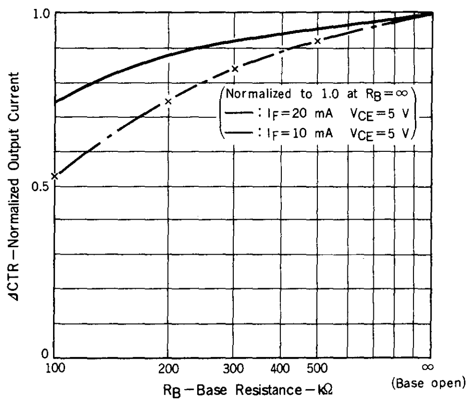
CURRENT TRANSFER RATIO vs. FORWARD CURRENT



NORMALIZED OUTPUT CURRENT vs. AMBIENT TEMPERATURE

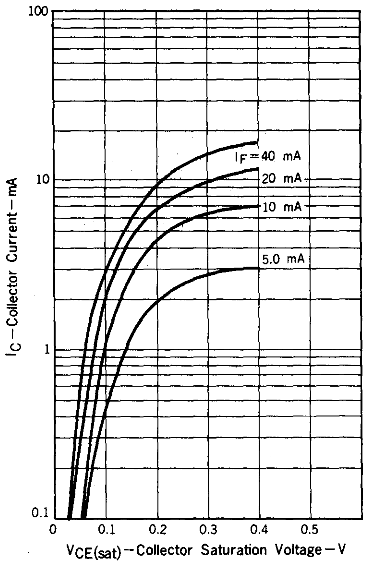


NORMALIZED OUTPUT CURRENT vs. BASE RESISTANCE

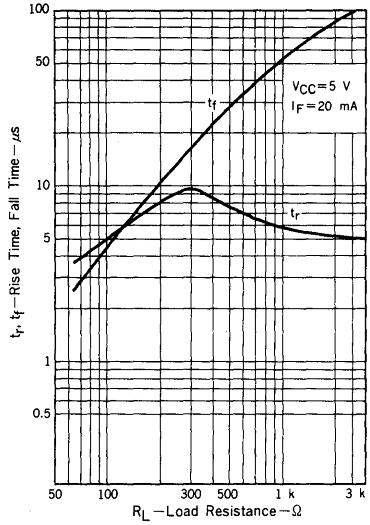


8

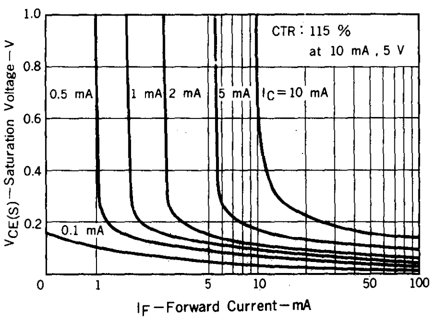
COLLECTOR CURRENT vs. COLLECTOR SATURATION VOLTAGE



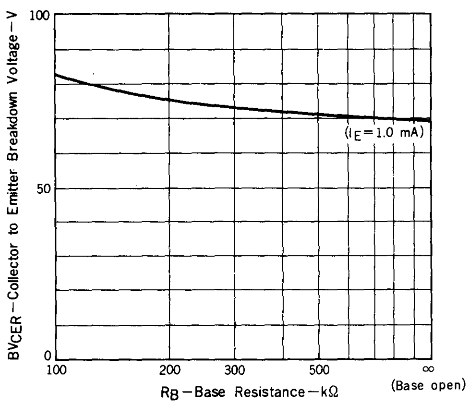
SWITCHING TIME vs. LOAD RESISTANCE



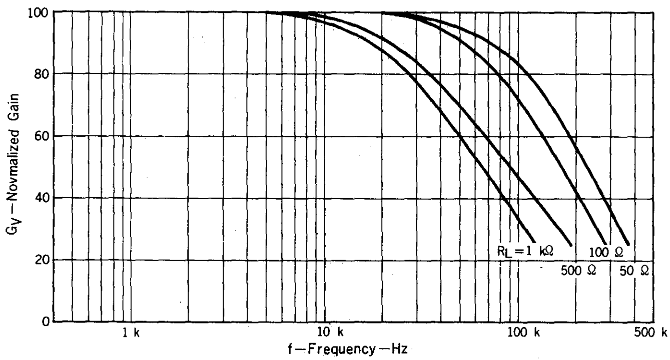
SATURATION VOLTAGE vs. FORWARD CURRENT



COLLECTOR TO EMITTER BREAKDOWN VOLTAGE vs. BASE RESISTANCE



FREQUENCY RESPONSE



NEC
ELECTRON DEVICE

PHOTO SCR COUPLERS
PS3001, PS3002

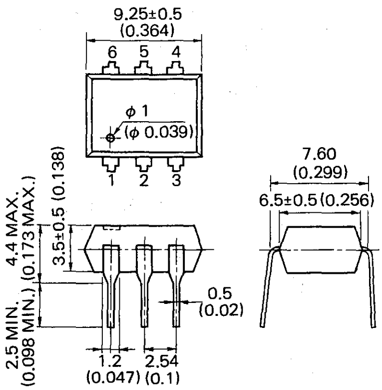
PHOTO SCR COUPLER

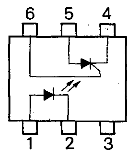
—NEPOC SERIES—

DESCRIPTION

The PS3001 and PS3002 are optically coupled isolators containing GaAs infrared emitting diode and a PNPN silicon photo SCR.

PACKAGE DIMENSIONS in millimeters (inches)





1. Anode
2. Cathode
3. NC
4. Cathode
5. Anode
6. Gate

(Top View)

FEATURES

- High Voltage Isolation 2 500 V_{DC} MIN.
- Low Turn on Current 12 mA MAX.
- Plastic dual-in-line package
- High Speed Switching
- Economical, Compact.

APPLICATIONS

- Interface circuit for various instrumentations, control equipments
- Replaceable from a reed relay

ABSOLUTE MAXIMUM RATINGS (Ta=25 °C)

Diode			
Reverse Voltage	V_R	6	V
Forward Current (DC)	I_F	80	mA
Peak Forward Current	I_{FP}	3	A
Power Dissipation	P_D	100	mW
SCR			
Peak Off and Reverse Voltage	V_{DRM}, V_{RRM}	PS3001 200	V
		PS3002 400	V
Direct On-State Current	I_T	300	mA
Peak pulse current *1	I_{TP}	3	A
Peak surge on Current	I_{TSM}	3	A
Power Dissipation	P_{SCR}	350	mW
Isolation Voltage *2	BV	2 500	V_{DC}
Storage Temperature	Tstg	–55 to +125	°C
Operation Temperature	Topt	–55 to +100	°C
Lead Soldering Time (at 260 °C)		10	s

8

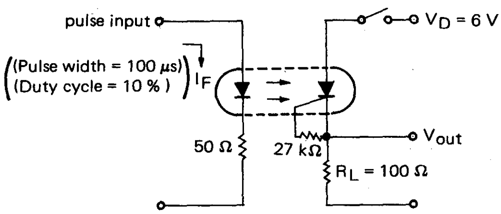
ELECTRICAL CHARACTERISTICS (Ta=25 °C)

	CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Diode	Forward Voltage	V_F		1.1	1.4	V	I_F=20 mA
	Reverse Current	I_R			10	μA	V_R=6 V
	Junction Capacitance	C_t		50		pF	V=0, f=1.0 MHz
Photo SCR	Peak Off-State Current	I_{DRM}			100	μA	V_{DRM}=Rated R_{GK}=27 kΩ Ta=100 °C
	Reverse Current	I_{RRM}			100	μA	
	On State Voltage	V_{TM}			1.3	V	I_T=300 mA
	Holding Current	I_H		0.2	1	mA	R_{GK}=27 kΩ, V_D=24 V
	Rate of rise of forward blocking Voltage	dV/dt	0.5	1.0		V/μs	V_{DRM}=Rated R_{GK}=27 kΩ, Ta=100 °C
Coupled	Turn on Current	I_{FT}		5	12	mA	V_D=6 V, R_{GK}=27 kΩ
	Isolation breakdown Voltage	$V_{1\text{-}2}$	2 500			V_{DC}	DC/1 minute
	Isolation Resistance	$R_{1\text{-}2}$	10^{11}			Ω	Vin-out=1.0 kV
	Isolation Capacitance	$C_{1\text{-}2}$		0.8		pF	V=0, f=1.0 MHz
	Turn on Time *3	t_{on}		10		μs	I_{FT}=50 mA, V_D=6 V R_{GK}=27 kΩ, R_L=100 Ω

*1 pulse width = 100 μs
Repetitive Frequency = 100 Hz

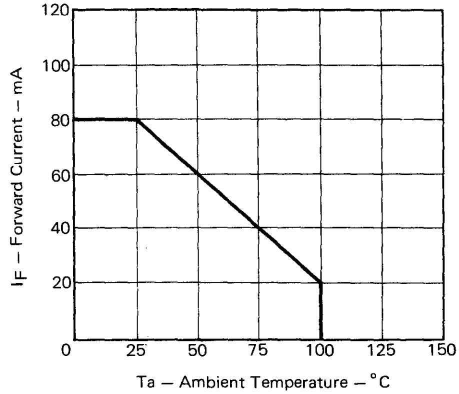
*2 Measuring Condition
DC voltage for 1 minute at Ta = 25 °C;
RH = 60 %
Between input (pin No. 1, 2 and No. 3 Common) and output (pin No. 4, 5 and No. 6 Common)

*3 Turn on Time Test Circuit

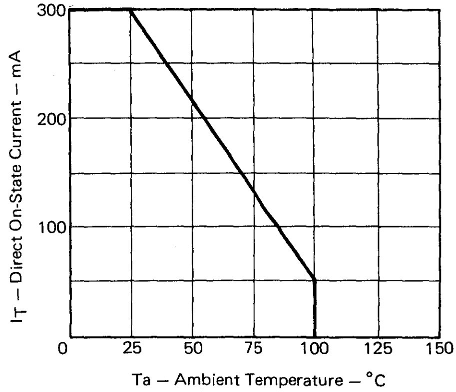


TYPICAL CHARACTERISTICS (Ta=25 °C)

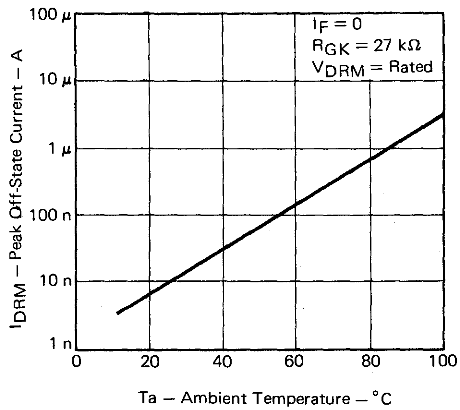
FORWARD CURRENT vs. AMBIENT TEMPERATURE



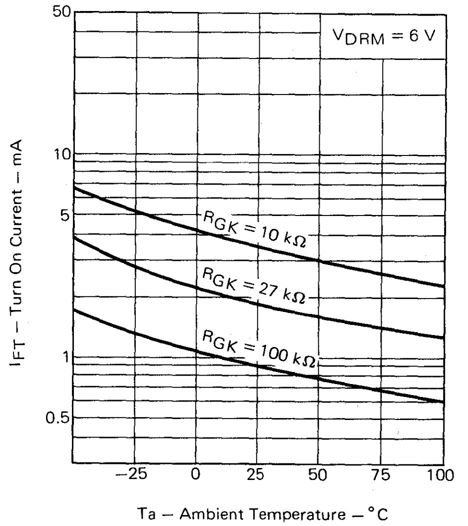
DIRECT ON-STATE CURRENT vs. AMBIENT TEMPERATURE



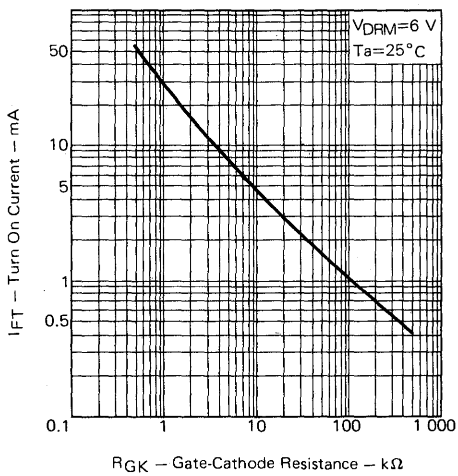
PEAK OFF-STATE CURRENT vs. AMBIENT TEMPERATURE



TURN ON CURRENT vs. AMBIENT TEMPERATURE



TURN ON CURRENT vs. GATE-CATHODE RESISTANCE



8

NEC
ELECTRON DEVICE

PHOTO INTERRUPTERS

PS4001,PS4003,PS4005,PS4007,PS4009

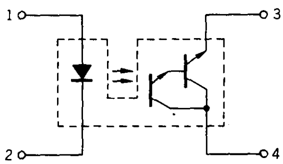
PHOTO INTERRUPTER

NEPOC SERIES

DESCRIPTION

The PS4001, PS4003, PS4005, PS4007, PS4009 are photo coupled interrupter modules containing a GaAs light emitting diode and an NPN silicon darlington connected photo-transistor.

CONNECTION DIAGRAM (Top View)



1. Anode
2. Cathode
3. Emitter
4. Collector

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

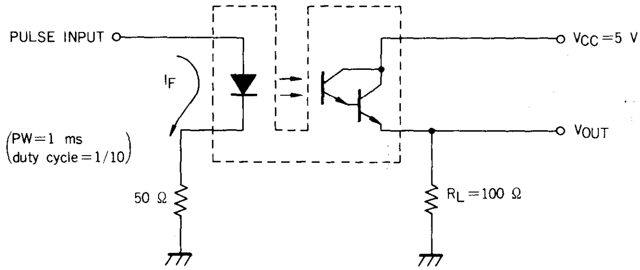
Diode			
Reverse Voltage	V_R	5.0	V
Forward Current	I_F	50	mA
Power Dissipation	P_D	100	mW
Transistor			
Collector to Emitter Voltage	V_{CEO}	30	V
Collector Current	I_C	50	mA
Power Dissipation	P_C	100	mW
Storage Temperature	T_{stg}	−40 to +100	°C
Operating Temperature	T_{opt}	−20 to +80	°C

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC		SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Diode	Forward Voltage	V_F		1.1	1.4	V	I_F = 20 mA
	Reverse Current	I_R			20	μA	V_R = 4.0 V
	Junction Capacitance	C		100		pF	V = 0, f = 1.0 MHz
Transistor	Collector to Emitter Dark Current	I_{CEO}			400	nA	V_{CE} = 10 V, I_F = 0
Coupled	Current Transfer Ratio	CTR (I_C/I_F)	20 ※			%	I_F = 10 mA, V_{CE} = 2.0 V
	Collector Saturation Voltage	$V_{CE(sat)}$			1.2	V	I_F = 10 mA, I_C = 0.5 mA
	Rise Time	t_r		200		μs	V_{CC} = 5.0 V, I_C = 2.0 mA, R_L = 100 Ω *
	Fall Time	t_f		200		μs	V_{CC} = 5.0 V, I_C = 2.0 mA, R_L = 100 Ω *

※ PS4003 : 15 % MIN., Others : 20 % MIN.

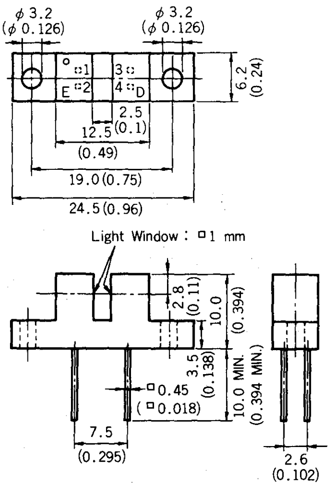
* Test Circuit for Switching Time



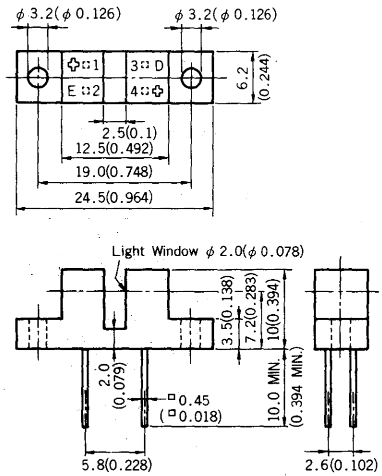
PACKAGE DIMENSIONS

in millimeters (inches)

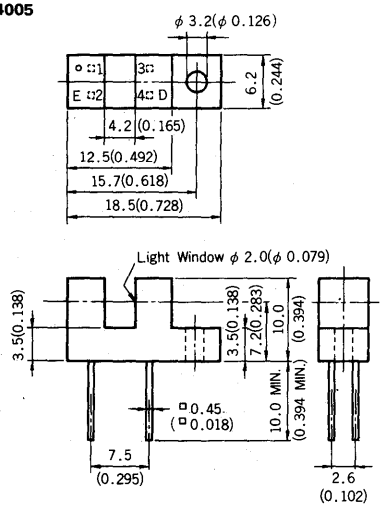
PS4001



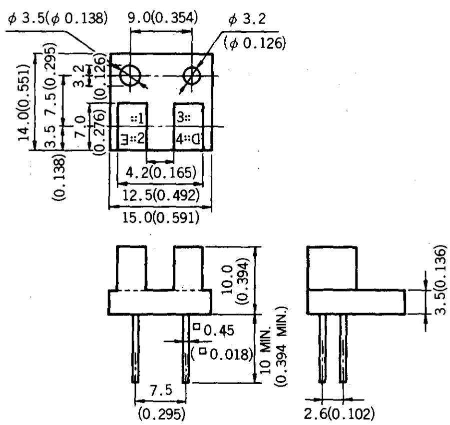
PS4003



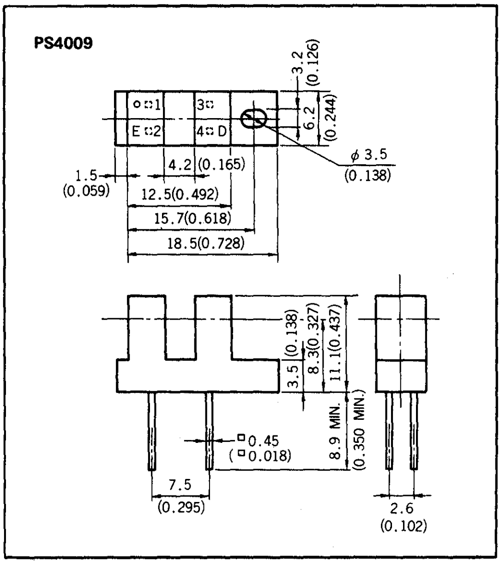
PS4005



PS4007

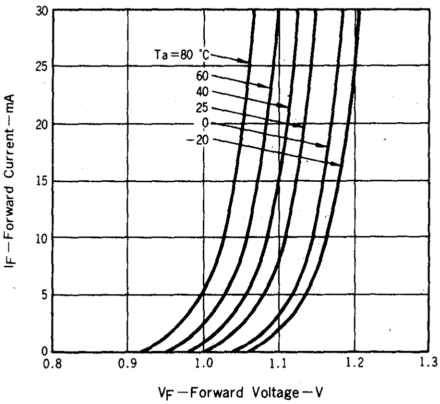


8

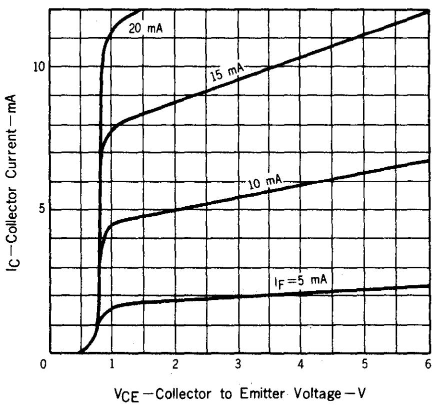


TYPICAL CHARACTERISTICS (Ta = 25 °C)

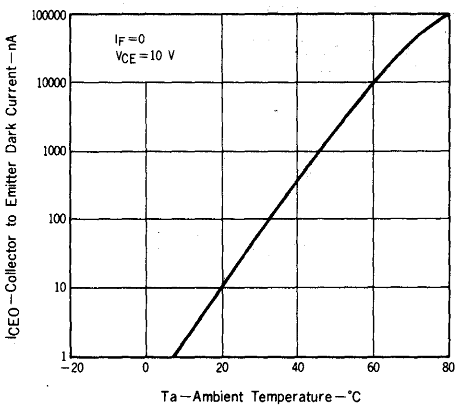
FORWARD CURRENT vs. FORWARD VOLTAGE



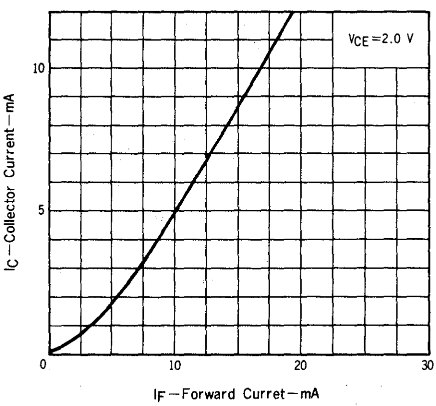
COLLECTOR CURRENT vs. COLLECTOR TO EMITTER VOLTAGE

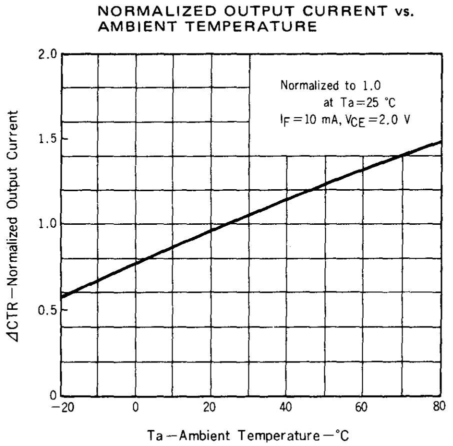


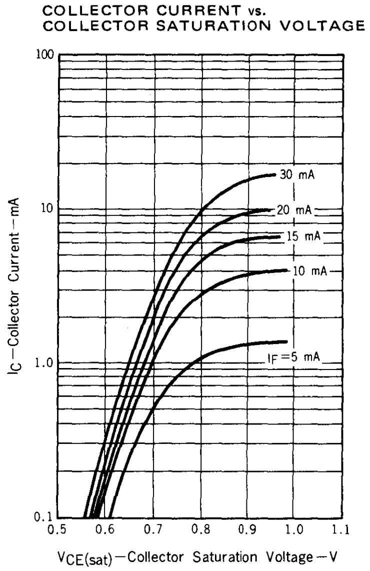
COLLECTOR TO EMITTER DARK CURRENT vs. AMBIENT TEMPERATURE

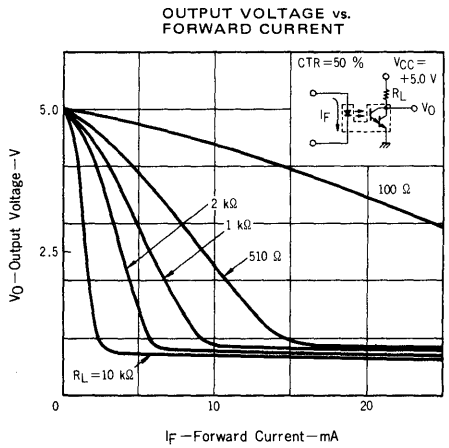


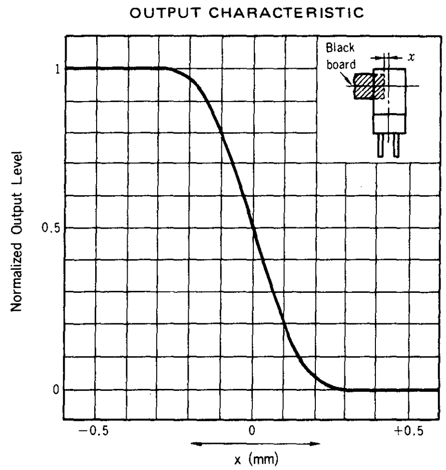
COLLECTOR CURRENT vs. FORWARD CURRENT



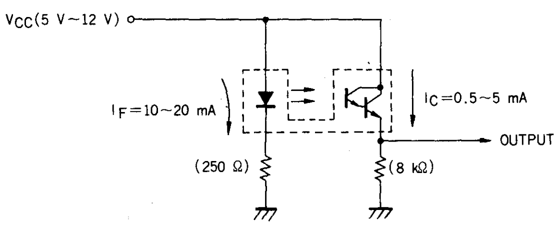








TYPICAL APPLICATION



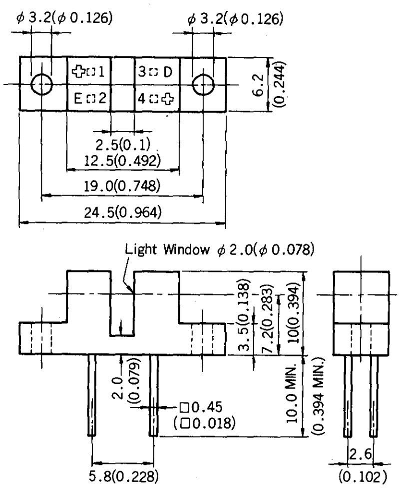
NEC
ELECTRON DEVICE

PHOTO INTERRUPTER
PS4008

PHOTO INTERRUPTER

—NEPOC SERIES—

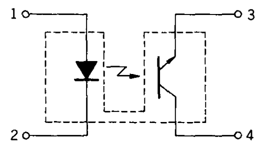
PACKAGE DIMENSIONS
in millimeters (inches)



DESCRIPTION

The PS4008 photo coupled interrupter module containing a GaAs light emitting diode and an NPN silicon photo-transistor.

CONNECTION DIAGRAM (Top View)

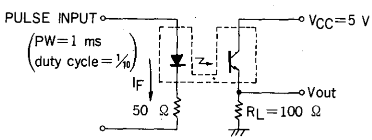


1. Anode
2. Cathode
3. Emitter
4. Collector

ABSOLUTE MAXIMUM RATINGS (T_a = 25 °C)

Diode			
Reverse Voltage	V_R	5.0	V
Forward Current	I_F	50	mA
Power Dissipation	P_D	100	mW
Transistor			
Collector to Emitter Voltage	V_{CEO}	30	V
Collector Current	I_C	40	mA
Power Dissipation	P_C	100	mW
Storage Temperature	T_{stg}	−40 to +100	°C
Operating Temperature	T_{opt}	−20 to + 80	°C

*Test Circuit for Switching Time

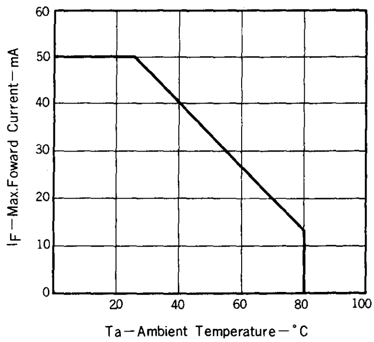


ELECTRICAL CHARACTERISTICS (T_a = 25 °C)

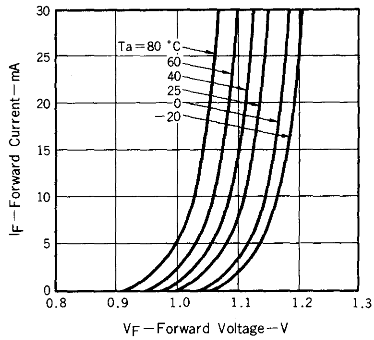
	CHARACTERISTICS	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Diode	Forward Voltage	V_F		1.1	1.4	V	I_F=20 mA
	Reverse Current	I_R			20	μA	V_R=4.0 V
	Junction Capacitance	C		100		pF	V=0, f=1.0 MHz
Transistor	Collector to Emitter Dark Current	I_{CEO}			100	nA	V_{CE}=10 V, I_F=0
Coupled	Output Current	I_C	50	200		μA	I_F=10 mA, V_{CE}=2.0 V
	Collector Saturation Voltage	$V_{CE(sat)}$			0.3	V	I_F=10 mA, I_C=50 μA
	Rise Time	t_r		5		μs	V_{CC}=5.0 V, I_C=50 μA, R_L=100 Ω*
	Fall Time	t_f		5		μs	V_{CC}=5.0 V, I_C=50 μA, R_L=100 Ω*

TYPICAL CHARACTERISTICS (Ta = 25 °C)

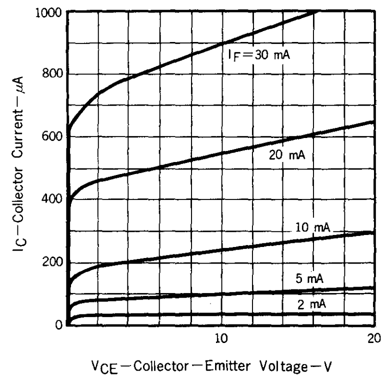
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



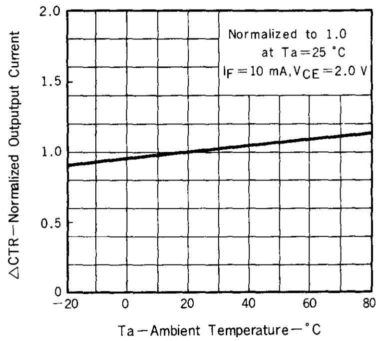
FORWARD CURRENT vs. FORWARD VOLTAGE



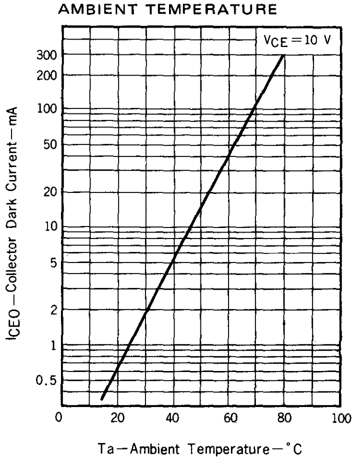
COLLECTOR CURRENT vs. COLLECTOR EMITTER VOLTAGE



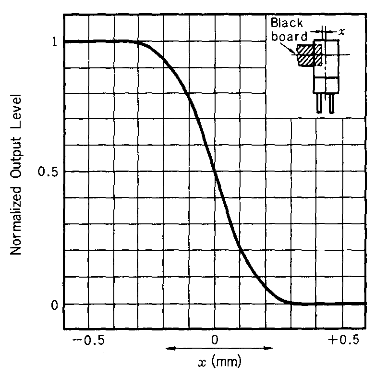
NORMALIZED OUTPUT CURRENT vs. AMBIENT TEMPERATURE



COLLECTOR DARK CURRENT vs. AMBIENT TEMPERATURE



OUTPUT CHARACTERISTIC



8

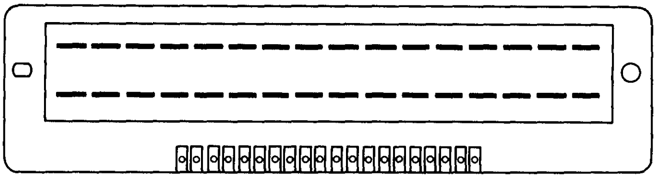
NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SB101, SB101A

LED BAR GRAPHIC DISPLAY

—NEPOC SERIES—

SKETCH



FEATURES

- Bright green, Bright red.
- Low cost.
- Very suitable for bar graphic display of cassette deck.
- 16 LED bar, 2 lines.

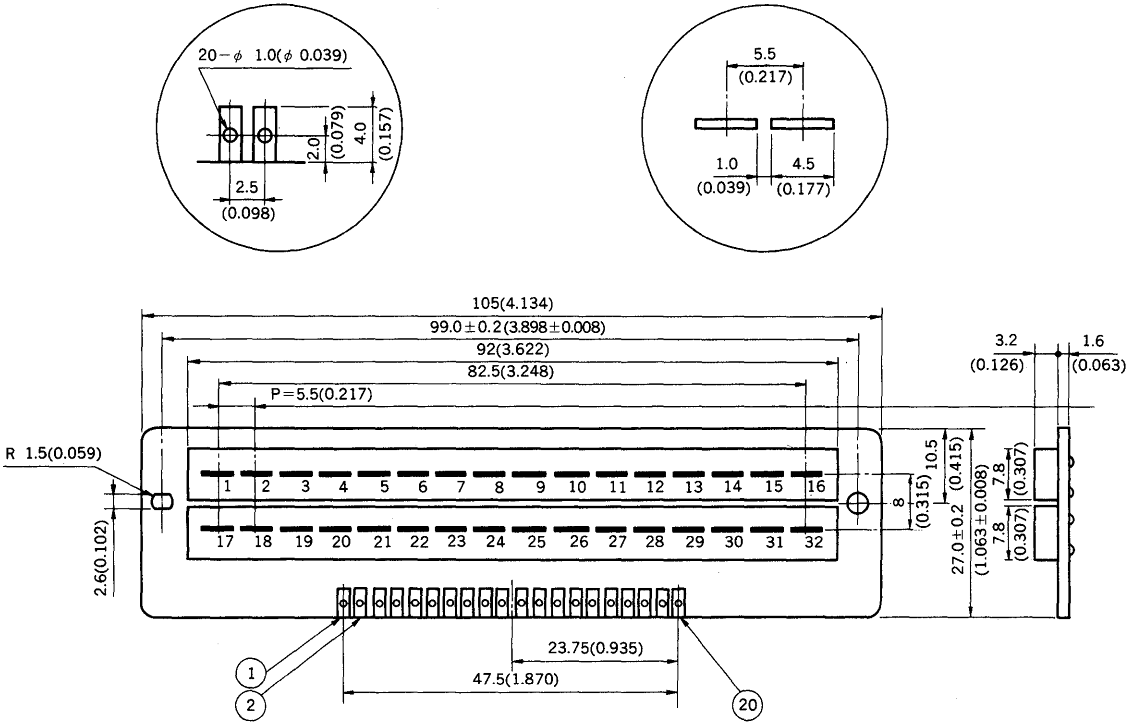
ABSOLUTE MAXIMUM RATINGS

Forward Current (DC)	I_F	20	mA/seg.
Forward Current (pulse duty 1/4, PW≦ 3 ms)	$I_{F(pulse)}$	60	mA/seg.
Reverse Voltage	V_R	3	V
Operating Temperature	T_{opt}	−20 to +60	°C
Storage Temperature	T_{stg}	−20 to +75	°C

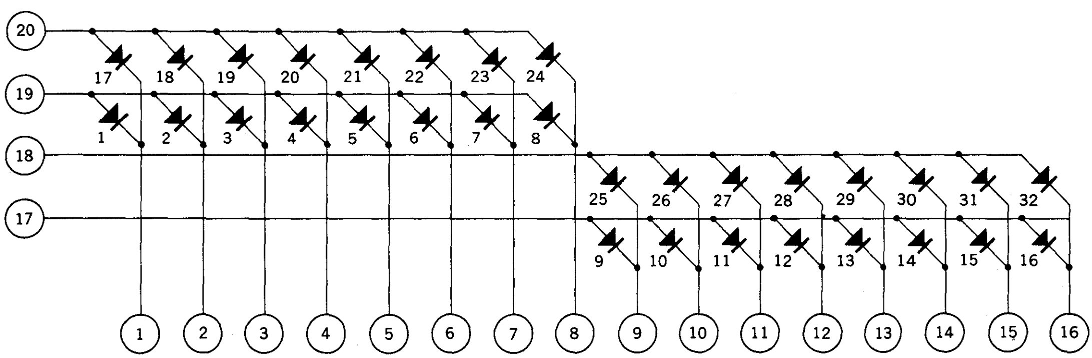
ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage (red)	V_F		1.9	2.5	V	I_F = 10 mA
Forward Voltage (green)	V_F		2.0	2.5	V	I_F = 10 mA
Reverse Current (red, green)	I_R			10	μA	V_R = 3 V
Luminous Intensity (red)	I_v	100			μcd	I_F = 7 mA
Luminous Intensity (green)	I_v	100			μcd	I_F = 15 mA
Peak Emission Wavelength (red)	λ_{peak}		630		nm	I_F = 10 mA
Peak Emission Wavelength (green)	λ_{peak}		565		nm	I_F = 10 mA
Spectral Line Half Width (red)	$\Delta\lambda$		40		nm	I_F = 10 mA
Spectral Line Half Width (green)	$\Delta\lambda$		40		nm	I_F = 10 mA

PACKAGE DIMENSIONS
in millimeters (inches)



TERMINAL CONNECTION

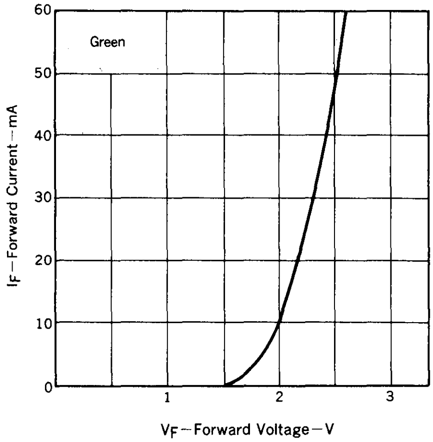


SEGMENT CHARACTERISTICS

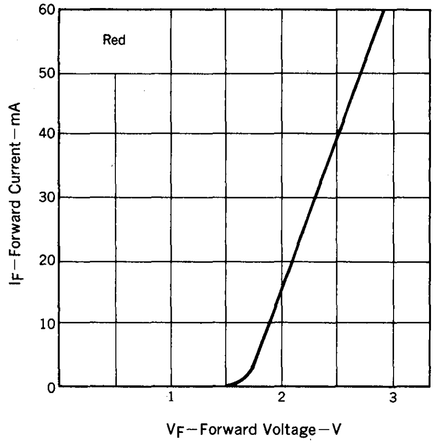
LED Number / Type Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
SB101	Red						Green										Red						Green									
SB101A	Green										Red						Green										Red					

TYPICAL CHARACTERISTICS (Ta = 25 °C)

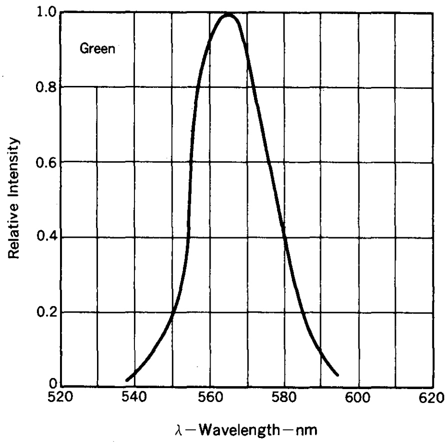
FORWARD CURRENT vs. FORWARD VOLTAGE



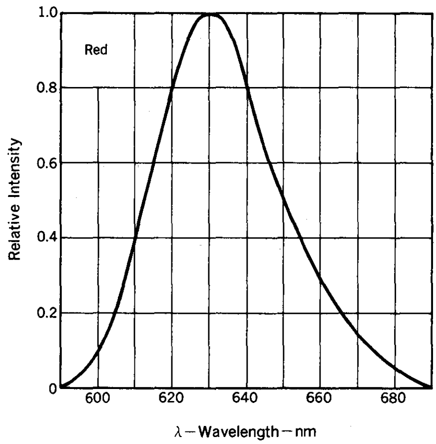
FORWARD CURRENT vs. FORWARD VOLTAGE



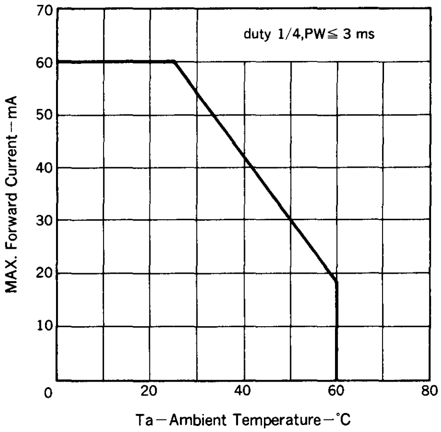
SPECTRAL DISTRIBUTION



SPECTRAL DISTRIBUTION



MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SE301A

GaAs INFRARED EMITTING DIODE
INDUSTRIAL USE

– NEPOC SERIES –

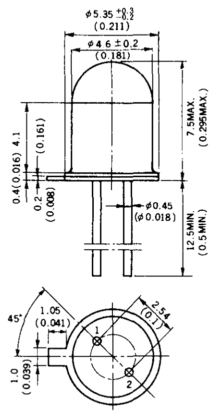
DESCRIPTION

The SE301A is a GaAs (Gallium Arsenide) Infrared Emitting Diode which is mounted on a TO-18 hermetically sealed header with a glass lens. On forward bias, it emits a spectrally narrow band of radiation peaking at 940nm. The close wavelength match of this device to silicon sensors makes it ideally suited for all source-sense applications. Its low cost and volume producibility open new areas of use anywhere an infrared source is desirable.

PACKAGE DIMENSIONS

in millimeters (inches)

TO-18
Header
With
Glass Lens.



(Bottom View)

1. Cathode
2. Anode(Case)

* Soldering conditions are at 260°C or less within 5sec. at 1.5 mm or farther from the case.

FEATURES

- Low cost.
- High output power - 3mW MIN.
- Fast switching time.
- Long life-solid state reliability.
- Compact, rugged, lightweight.
- Spectrally matched to silicon sensors.

APPLICATIONS

- Paper tape and punch card readers.
- Optical encoders.
- Photochoppers.
- High speed optoelectronic data links.

ABSOLUTE MAXIMUM RATINGS

Maximum Power Dissipation (Ta = 25°C)	P	150	mW
Maximum Forward Current (Ta = 25°C)	I_F	100	mA
Maximum Pulse Forward Current (Ta=25°C)	I_{FP}*	1.0	A
Maximum Reverse Voltage (Ta = 25°C)	V_R	5.0	V
Maximum Temperatures			
Junction Temperature	T_j	125	°C
Storage Temperature	T_{stg}	−65 to +125	°C

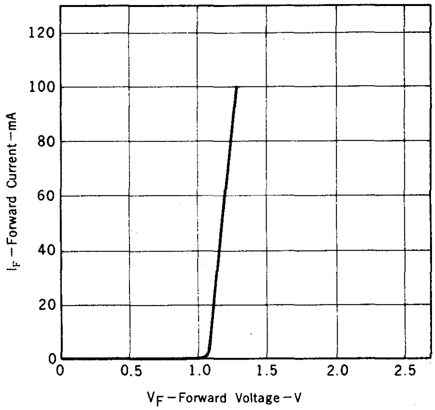
ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		1.2	1.45	V	I_F = 50 mA
Pulse Forward Voltage	V_{FP}*		2.0	5.0	V	I_{FP} = 1.0A
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		940		nm	I_F = 50 mA
Spectral Line Half Width	$\Delta\lambda$		60		nm	I_F = 50 mA
Output Power	P_O	3.0			mW	I_F = 50 mA
Peak Output Power	P_{peak}*	15			mW	I_{FP} = 1.0A
Light Turn-On and Turn-Off	t_{on}, t_{off}		1		μs	

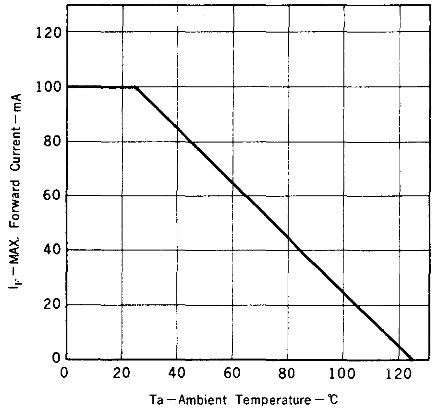
* f = 1.0 kHz, duty cycle 1%

TYPICAL CHARACTERISTICS (Ta = 25°C)

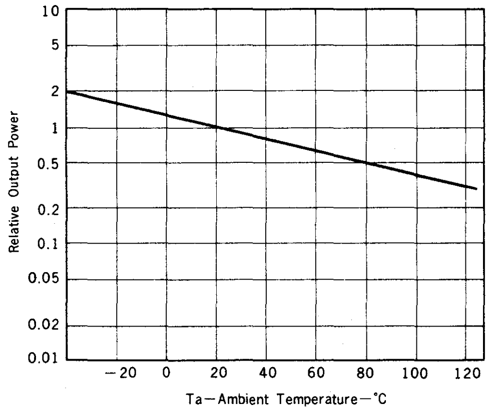
FORWARD CURRENT vs. FORWARD VOLTAGE



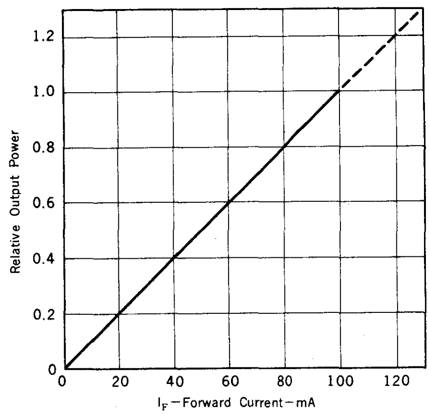
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



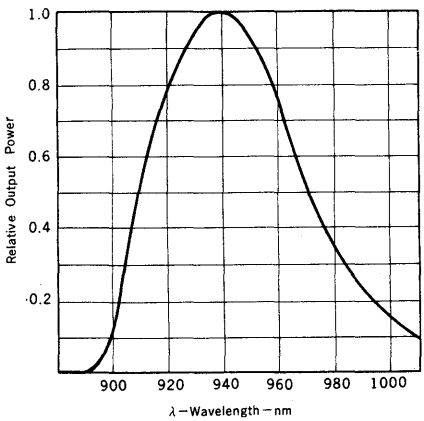
RELATIVE OUTPUT POWER vs. AMBIENT TEMPERATURE



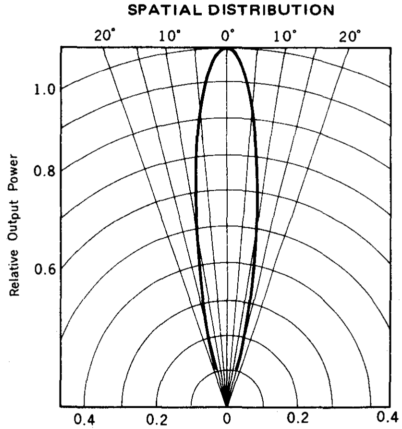
RELATIVE OUTPUT POWER vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



SPATIAL DISTRIBUTION



8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SE302A

GaAs INFRARED EMITTING DIODE INDUSTRIAL USE

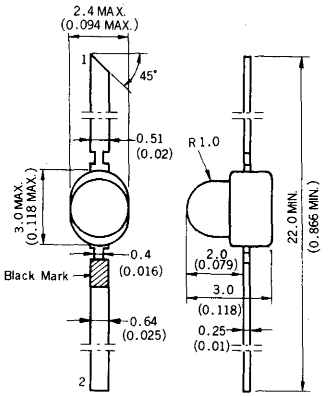
– NEPOC SERIES –

DESCRIPTION

The SE302A is a GaAs (Gallium Arsenide) Infrared Light Emitting Diode which is mounted on the lead frame and molded in clear plastic lens. On forward bias, it emits a spectrally narrow band of radiation peaking at 940 nm. The close wavelength match of this device to silicon sensors makes it ideally suited for all source-sense applications. Its low cost and volume producibility open new areas of use anywhere an infrared source is desirable.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Anode
2. Cathode

* Soldering conditions are at 260 °C or less within 5 s at 3 mm or farther from the case.

FEATURES

- Low cost.
- High Output Power
- Fast Switching Time.
- Long Life-Solid State Reliability.
- Compact, Rugged, Lightweight.
- Spectrally Matched to Silicon Sensors. (Good Compatibility with darlington Photo transistor (PH101).)
- Easily assembled in linear arrays.
- Compatible with integrated circuits.

APPLICATIONS

- Electro optical switches.
- Card and tape reader sources.
- Optical Encoders.
- Photochoppers, Isolator.
- High Speed Optoelectronic Data Links.
- Photo coupler.

ABSOLUTE MAXIMUM RATINGS

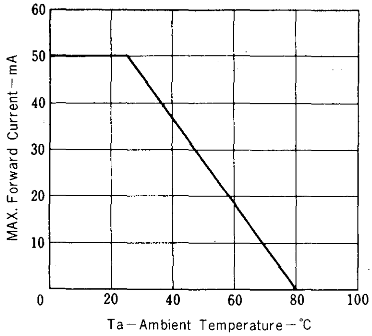
Maximum Power Dissipation (Ta = 25 °C)	P	75	mW
Maximum Forward Current (Ta = 25 °C)	I_F	50	mA
Maximum Reverse Voltage (Ta = 25 °C)	V_R	3.0	V
Maximum Temperatures			
Junction Temperature	T_j	80	°C
Storage Temperature	T_{stg}	-30 to +80	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

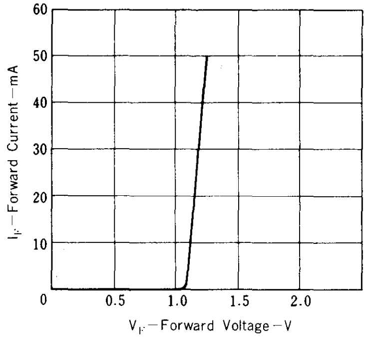
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		1.2	1.4	V	I_F = 30 mA
Reverse Current	I_R			50	μA	V_R = 3.0 V
Capacitance	C		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		940		nm	I_F = 30 mA
Spectral Line Half Width	$\Delta\lambda$		60		nm	I_F = 30 mA
Output Power	P_O	1.0	1.5		mW	I_F = 30 mA
Light Turn-On and Turn-Off	t_{on}, t_{off}		1.0		μs	I_F = 30 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

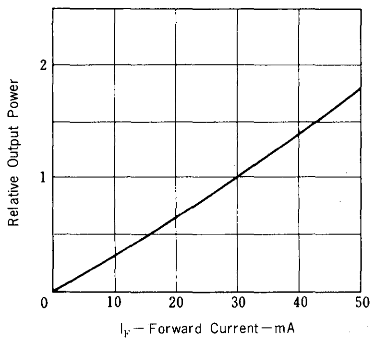
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



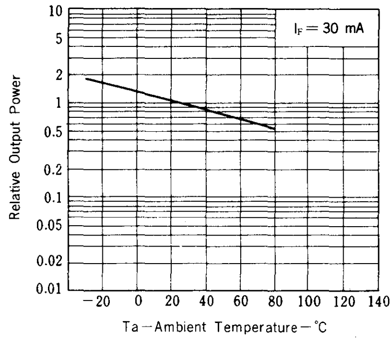
FORWARD CURRENT vs. FORWARD VOLTAGE



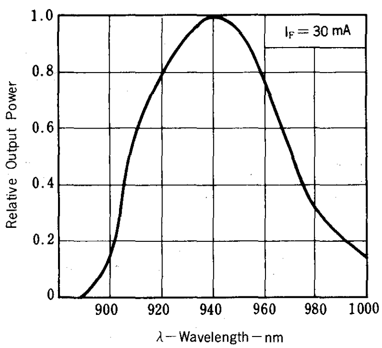
RELATIVE OUTPUT POWER vs. FORWARD CURRENT



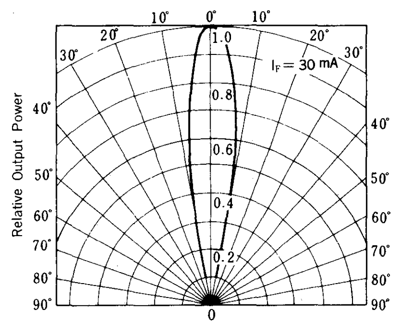
RELATIVE OUTPUT POWER vs. AMBIENT TEMPERATURE



SPECTRAL DISTRIBUTION



SPATIAL DISTRIBUTION



8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SE303A

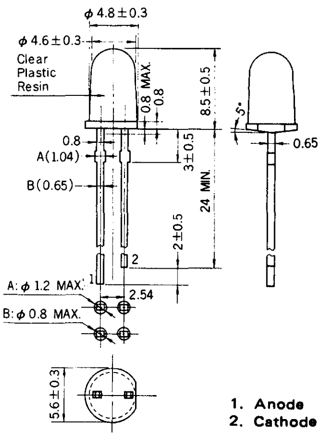
GaAs INFRARED EMITTING DIODE

—NEPOC SERIES—

DESCRIPTION

The SE303A is a GaAs (Gallium Arsenide) Infrared Emitting Diode which is mounted on the lead frames and molded in plastic. On forward bias, it emits a spectrally narrow band of radiation peaking at 940 nm.

PACKAGE DIMENSIONS
in millimeters



1. Anode
2. Cathode

FEATURES

- Economical.
- High output power.
- Wide half angle.
- Good linearity.
- Spectrally matched to silicon sensors.
- Long lead.

APPLICATIONS

- Light source for TV remote control.
- Light source for smoke detector.
- Optical encoders.
- Photochoppers, Isolator.

ABSOLUTE MAXIMUM RATINGS

Maximum Power Dissipation (Ta=25 °C)	P	150	mW
Maximum Forward Current (Ta=25 °C)	I_F	100	mA
Maximum Pulse Forward Current (Ta=25 °C)	I_{FP}*	1.0	A
Maximum Reverse Voltage (Ta=25 °C)	V_R	5.0	V
Maximum Temperatures			
Junction Temperature	T_j	+80	°C
Storage Temperature	T_{stg}	−30 to +80	°C

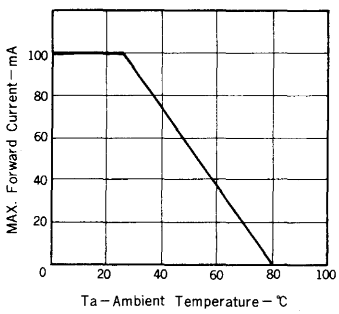
ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

CHARACTERISTICS	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		1.25	1.45	V	I_F = 50 mA
Pulse Forward Voltage	V_{FP}*		2.5	3.0	V	I_{FP} = 1.0 A
Capacitance	C_t		40		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		940		nm	I_F = 50 mA
Spectral Line Half Width	$\Delta\lambda$		60		nm	I_F = 50 mA
Output Power	P_O	3.0	6.5		mW	I_F = 50 mA
Peak Output Power	P_{FP}*	15			mW	I_{FP} = 1.0A
Light Turn-On and Turn-Off	t_{on}, t_{off}		1		μs	

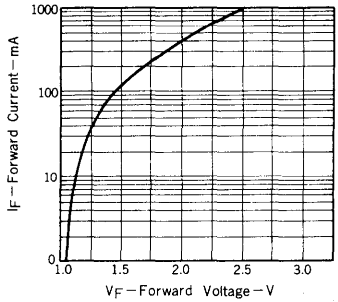
*f = 1.0 kHz, duty cycle 1 %

TYPICAL CHARACTERISTICS (Ta = 25 °C)

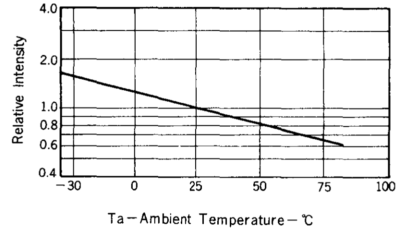
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



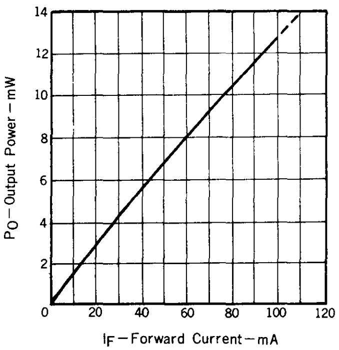
FORWARD CURRENT vs. FORWARD VOLTAGE



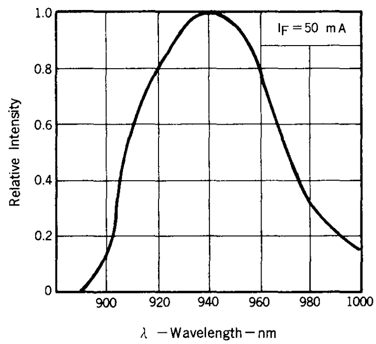
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



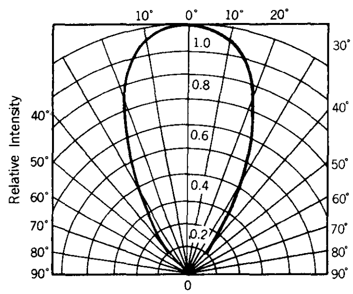
OUTPUT POWER vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



SPATIAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it sbould be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

NEC
ELECTRON DEVICE

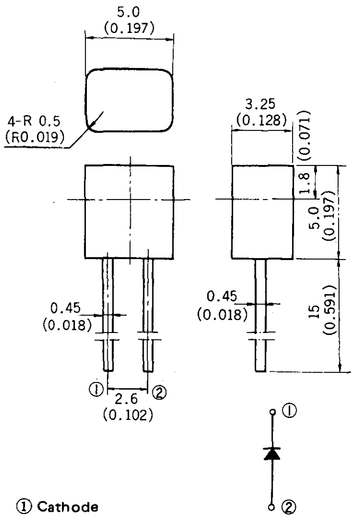
LIGHT EMITTING DIODE
SE304

GaAs INFRARED EMITTING DIODE

—NEPOC SERIES—

The SE304 is a GaAs(Gallium Arsenide) Infrared LED in a plastic molded package, and very suitable for a detecter of a photo interrupter. On forward bias, it emits a spectrally narrow band of radiation peaking at 940 nm.

PACKAGE DIMENSIONS
in millimeters (inches)



① Cathode
② Anode

ABSOLUTE MAXIMUM RATINGS (Ta = 25 °C)

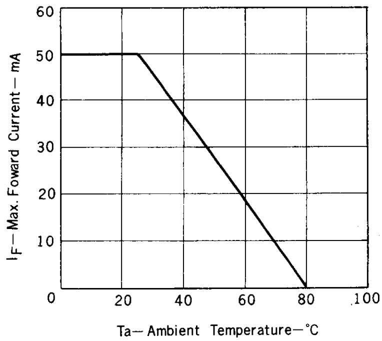
Power Dissipation	P_D	100	mW
Forward Current	I_F	50	mA
Reverse Voltage	V_R	5	V
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	-40 to +100	°C

ELECTRICAL CHARACTERISTICS (Ta = 25 °C)

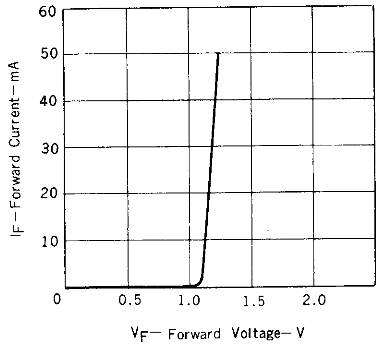
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		1.2	1.4	V	I_F = 30 mA
Reverse Current	I_R			10	μA	V_R = 3 V
Capasitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emittion Wavelength	λpeak		940		nm	I_F = 30 mA
Spectral Line Half Width	Δλ		60		nm	I_F = 30 mA
Output Power	Po	1.0	1.5		mW	I_F = 30 mA
Light Turn-On and Turn-Off	t_{on}, t_{off}		1		μs	I_F = 30 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

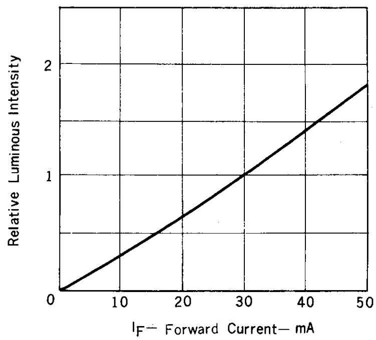
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



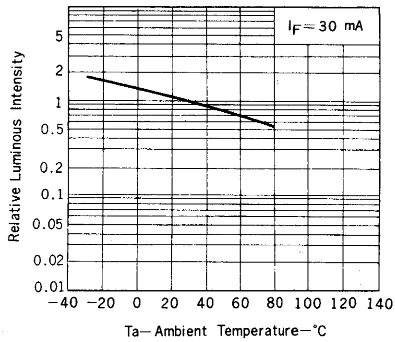
FORWARD CURRENT vs. FORWARD VOLTAGE



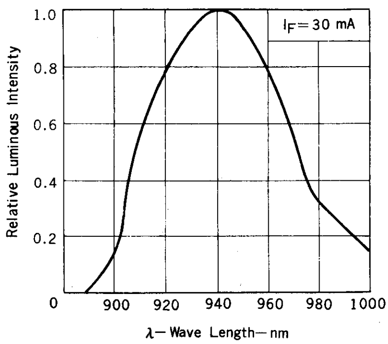
RELATIVE LUMINOUS INTENSITY vs. FORWARD CURRENT



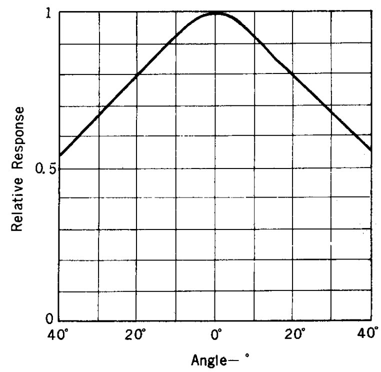
RELATIVE LUMINOUS INTENSITY vs. AMBIENT TEMPERATURE



SPECTRAL DISTRIBUTION



SPATIAL DISTRIBUTION



8

LIGHT EMITTING DIODES
SG203DA, SG203TA

NEC
ELECTRON DEVICE

GaP HIGH INTENSITY LED
Green

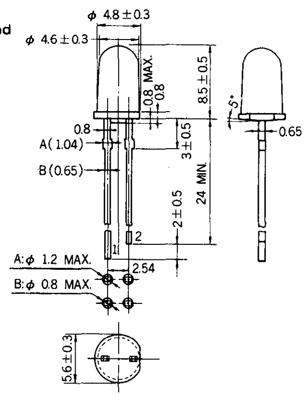
—NEPOC SERIES—

DESCRIPTION

The SG203DA and SG203TA are full resin-molded LED lamps and emit bright and vivid green light. They are especially suitable for such electronic equipments as for audio uses which require high brightness displays.

PACKAGE DIMENSIONS
in millimeters

SG203DA
Green Diffused
Plastic lens.
SG203TA
Green Clear
Plastic lens.



1. Anode
2. Cathode

FEATURES

- High intensity.
- Wide angle.
- Long lead.
- Low cost.
- Compatible with integrated circuits.

APPLICATIONS

- Visual displays.
- Guard system.
- Mobile equipment readout.
- Stereo equipment readout.
- Transceiver readout.

ABSOLUTE MAXIMUM RATINGS

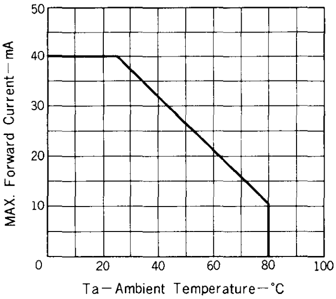
Maximum Power Dissipation (Ta=25 °C)	P	100	mW
Maximum Forward Current (Ta=25 °C)	I_F	40	mA
Maximum Reverse Voltage (Ta=25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	–40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

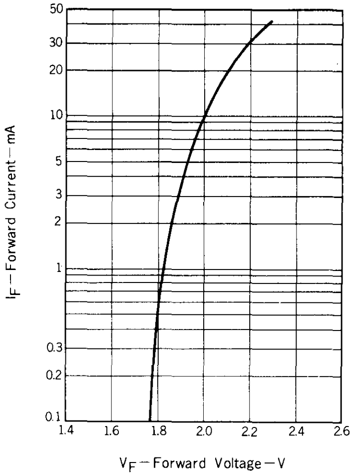
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.2	2.6	V	I_F = 20 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		60		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		565		nm	I_F = 20 mA
Spectral Line Half Width	$\Delta\lambda$		40		nm	I_F = 20 mA
Luminous Intensity (SG203DA)	I_V	2	8		mcd	I_F = 20 mA
Luminous Intensity (SG203TA)	I_V	6	13		mcd	I_F = 20 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

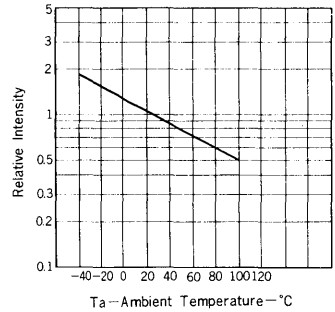
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



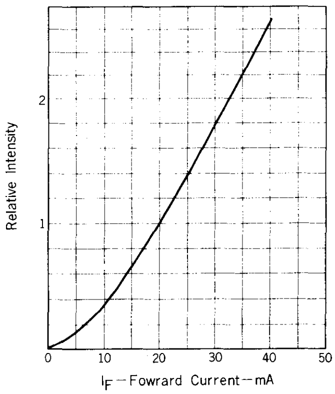
FORWARD CURRENT vs. FORWARD VOLTAGE



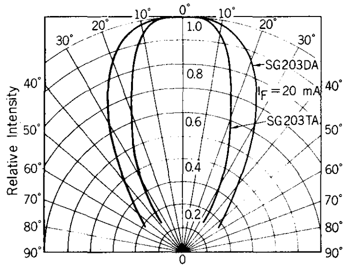
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



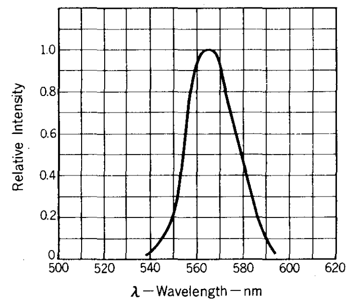
RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



SPATIAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODES
SG205D, SG205T

GaP LIGHT EMITTING DIODE
GREEN

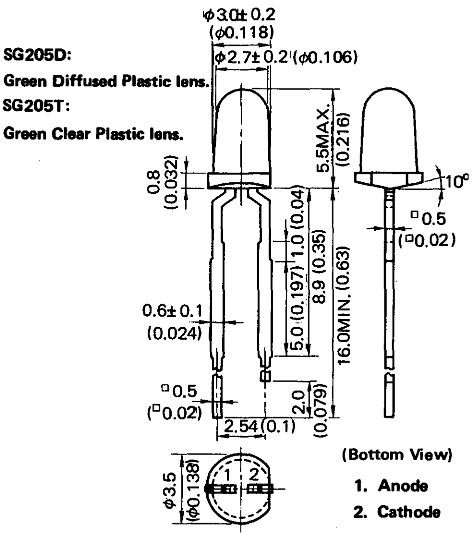
—NEPOC SERIES—

DESCRIPTION

The SG205D, SG205T are Gap (Gallium Phosphide) Light Emitting Diodes which are mounted on the lead frames and molded in green diffused, green clear plastic respectively. They are ideally suited for front panel indicator applications.

PACKAGE DIMENSIONS

in millimeters (inches)



*** Soldering conditions are at 260°C or less Within 5sec. at 5 mm or farther from the case.**

FEATURES

- Long life – solid state reliability.
- Low cost.
- High intensity with low current.
- Versatile mounting on PC board or panel.
- Compatible with Integrated Circuits.
- Fast switching time.

APPLICATIONS

- Visual displays.
- Guard system.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

Maximum Power Dissipation (Ta = 25°C)	P	100	mW
Maximum Forward Current (Ta = 25°C)	I_F	40	mA
Maximum Reverse Voltage (Ta = 25°C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	80	°C
Storage Temperature	Tstg	–30 to +80	°C

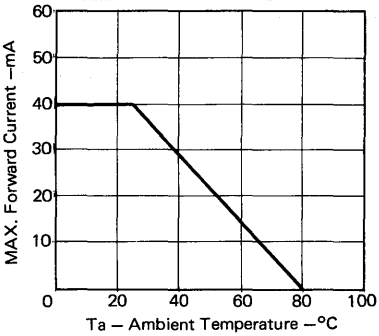
ELECTRO-OPTICAL CHARACTERISTICS (Ta=25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F			2.5	V	I_F = 20mA
Reverse Current	I_R		0.01	50	μA	V_R = 4.5V
Capacitance	C_t		60		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ peak		565		nm	I_F = 20 mA
Spectral Line Half Width	Δλ		30		nm	I_F = 20 mA
Luminous Intensity	I_{V1}/I_{V2} *	1/2	3/5		mcd	I_F = 20 mA

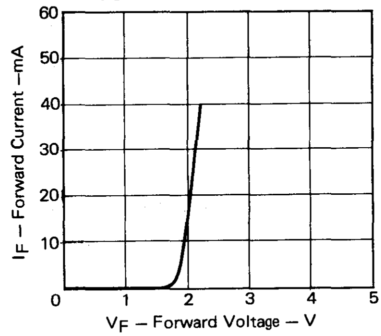
*I_{V1}/I_{V2}: Luminous Intensity of SG205D/Luminous Intensity of SG205T

TYPICAL CHARACTERISTICS (Ta = 25°C)

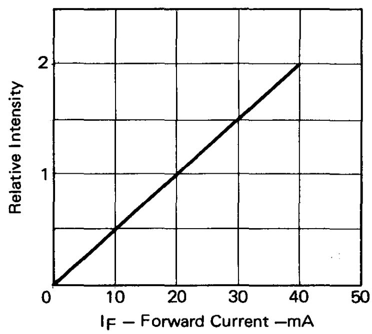
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



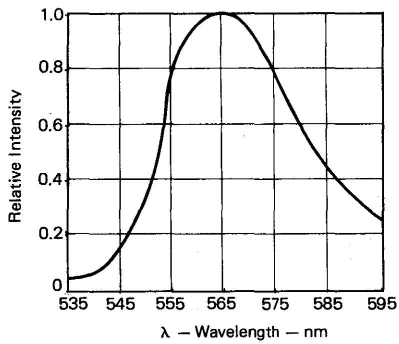
FORWARD CURRENT vs. FORWARD VOLTAGE



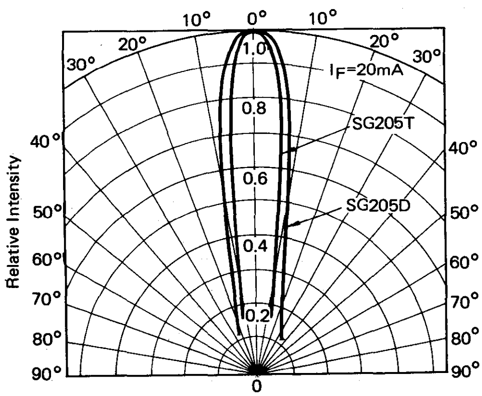
RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



SPATIAL DISTRIBUTION



8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SG206D,206T

GaP LIGHT EMITTING DIODE

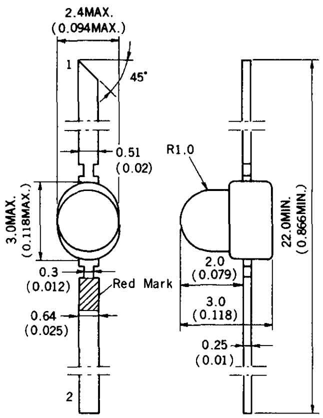
– NEPOC SERIES –

DESCRIPTION

The SG206D, SG206T are GaP (Gallium Phosphide) Light Emitting Diodes which are mounted on the lead frames and molded in green diffused, green clear plastic respectively. They are ideally suited for front panel indicator applications.

PACKAGE DIMENSIONS

in millimeters (inches)



SG206D: Green diffused plastic lens.
SG206T : Green clear plastic lens.

1. Anode
2. Cathode

* Soldering conditions are at 260°C or less within 5sec. at 3 mm or farther from the case.

FEATURES

- Small size.
- Bright.
- Easilly assembled in arrays.
- Compatible with integrated circuits.
- Fast switching time.

APPLICATIONS

- Visual Displays.
- Panel indicators.
- Desk top calculator readout.
- Portable equipment readout.
- Camera readout.

ABSOLUTE MAXIMUM RATINGS

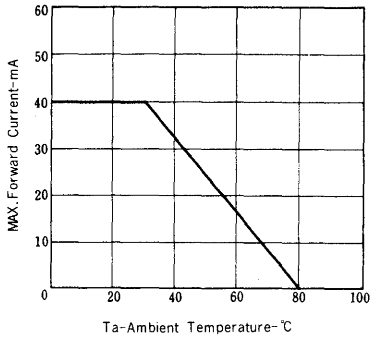
Maximum Power Dissipation (Ta = 25°C)	P	100	mW
Maximum Forward Current (Ta = 25°C)	I_F	40	mA
Maximum Reverse Voltage (Ta = 25°C)	V_R	4.0	V
Maximum Temperatures			
Junction Temperature	T_j	80	°C
Storage Temperature	T_{stg}	-30 to +80	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25°C)

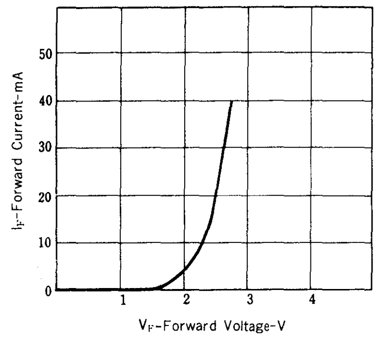
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.4	2.8	V	I_F = 20mA
Reverse Current	I_R		0.01	50	μA	V_R = 3.5V
Capacitance	C_t			100	pF	V = 0, f = 1.0MHz
Peak Emission Wavelength	λ_{peak}		565		nm	I_F = 20mA
Spectral Line Half Width	$\Delta\lambda$		30		nm	I_F = 20mA
Luminous Intensity	I_V		1.5		mcd	I_F = 20mA

TYPICAL CHARACTERISTICS (Ta = 25°C)

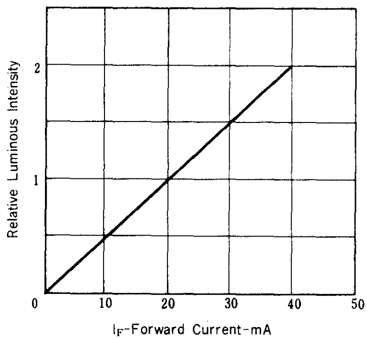
MAX. FORWARD CURRENT vs.
AMBIENT TEMPERATURE



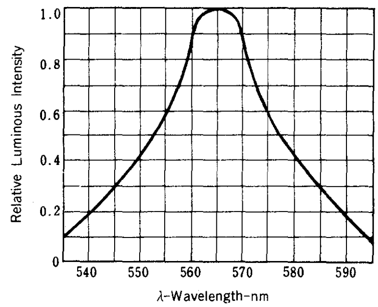
FORWARD CURRENT vs.
FORWARD VOLTAGE



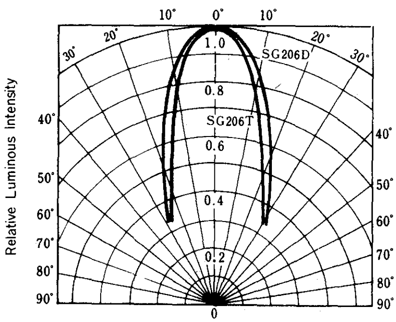
RELATIVE LUMINOUS INTENSITY vs.
FORWARD CURRENT



SPECTRAL DISTRIBUTION



SPATIAL DISTRIBUTION



8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SG231D

GaP FASHION LED
Green

—NEPOC SERIES—

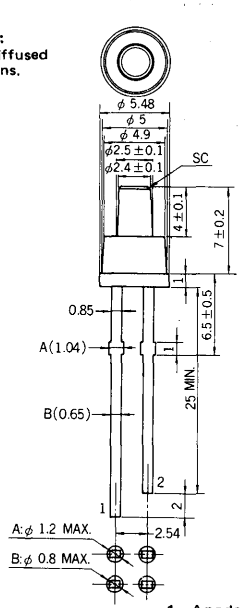
DESCRIPTION

The SG231D is a full resin-molded LED lamp and has a circular flat face which emits brilliant green light uniformly. It is especially suitable for such electronic equipments as for audio uses which require some fancy looking displays.

PACKAGE DIMENSIONS

in millimeters

SG231D:
Green Diffused
Plastic lens.



1. Anode
2. Cathode

FEATURES

- Circular flat face type
- Low cost.
- Long lead.
- Bright green.
- Compatible with Integrated Circuits.
- Red (SR531D) and amber (SY431D) LED's are available in the same pkg.

APPLICATIONS

- Visual displays.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

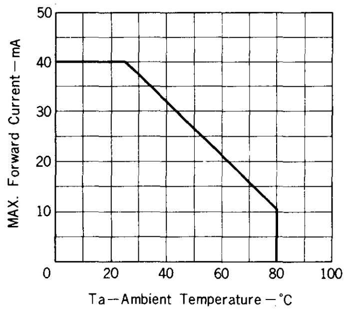
Maximum Power Dissipation (Ta=25 °C)	P	100	mW
Maximum Forward Current (Ta=25 °C)	I_F	40	mA
Maximum Reverse Voltage (Ta=25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	−40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

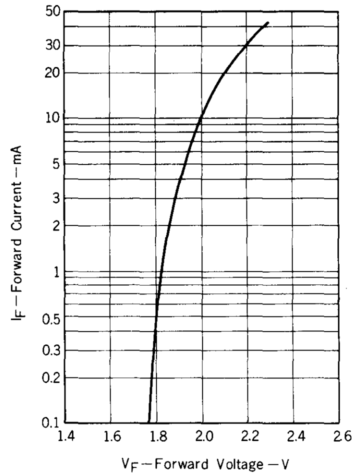
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.5	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		60		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λpeak		565		nm	I_F = 10 mA
Spectral Line Half Width	Δλ		35		nm	I_F = 10 mA
Luminous Intensity	I_V	0.1	0.3		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

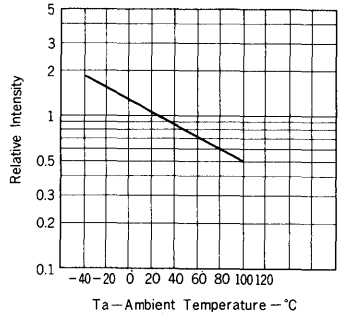
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



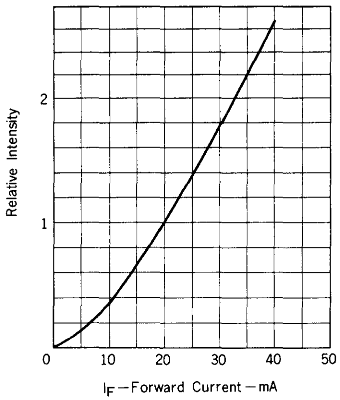
FORWARD CURRENT vs. FORWARD VOLTAGE



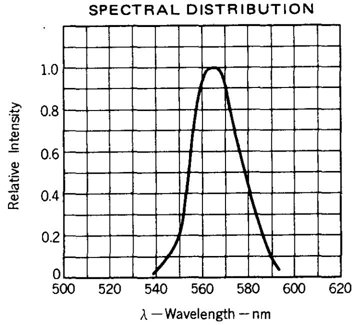
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

8

NEC
ELECTRON DEVICE

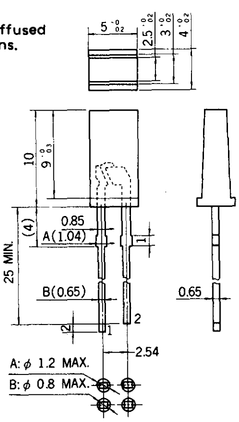
LIGHT EMITTING DIODE
SG232D

GaP FASHION LED
Green

—NEPOC SERIES—

DESCRIPTION
The SG232D is a full resin-molded LED lamp and has a rectangular flat face which emits brilliant green light uniformly. It is especially suitable for such electronic equipments as for audio uses which require some fancy looking displays.

PACKAGE DIMENSIONS
in millimeters



1. Anode
2. Cathode

FEATURES
- Rectangular flat face type
- Low cost.
- Long lead.
- Bright green.
- Compatible with Integrated Circuits.
- Red (SR632D) and amber (SY432D) LED's are available in the same pkg.

APPLICATIONS
- Visual displays.
- Peak level indicator.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

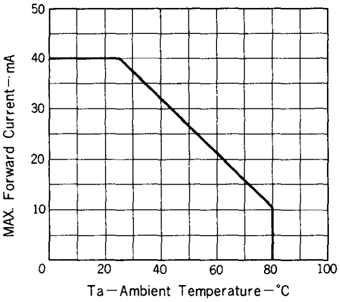
Maximum Power Dissipation (Ta=25 °C)	P	100	mW
Maximum Forward Current (Ta=25 °C)	I_F	40	mA
Maximum Reverse Voltage (Ta=25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	–40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

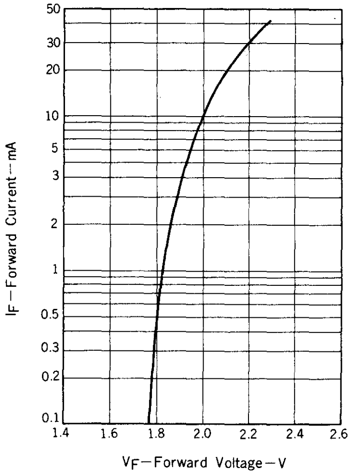
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.5	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λpeak		565		nm	I_F = 10 mA
Spectral Line Half Width	Δλ		40		nm	I_F = 10 mA
Luminous Intensity	I_V	0.2	0.5		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

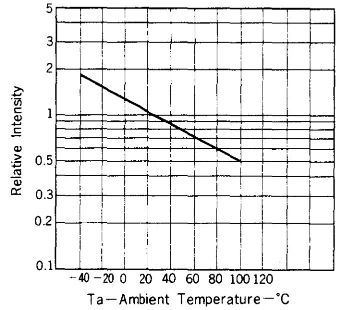
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



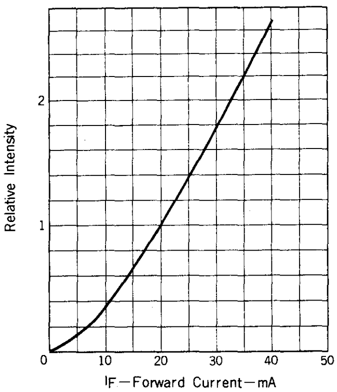
FORWARD CURRENT vs. FORWARD VOLTAGE



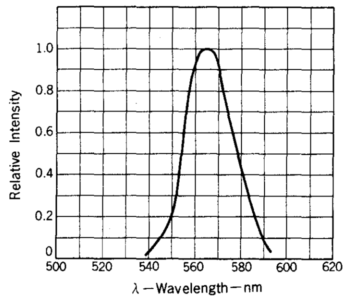
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SG235D

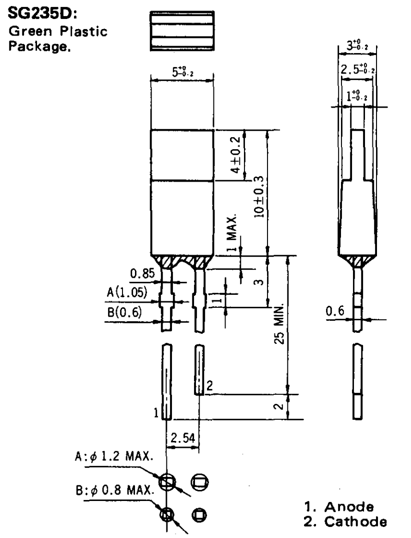
FASHION LAMP
Green

—NEPOC SERIES—

DESCRIPTION

The SG235D is a full resin-molded LED lamp and has a rectangular flat face which emits brilliant green light uniformly. It is especially suitable for such electronic equipments as for audio uses which require some fancy looking displays.

PACKAGE DIMENSIONS
in millimeters



FEATURES

- Rectangular flat face type.
- Low cost.
- Long lead.
- Bright green.
- Compatible with Integrated Circuits.
- Red (SR535D) and amber (SY435D) LED's are available in the same pkg.

APPLICATIONS

- Visual displays.
- Peak level indicator.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

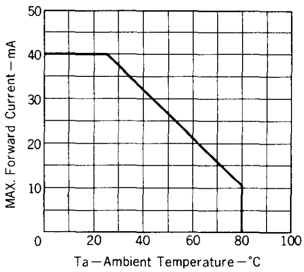
Maximum Power Dissipation (Ta = 25 °C)	P	100	mW
Maximum Forward Current (Ta = 25 °C)	I_F	40	mA
Maximum Reverse Voltage (Ta = 25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	−40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

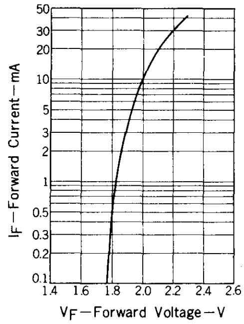
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.5	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		565		nm	I_F = 10 mA
Spectral Line Half Width	Δλ		40		nm	I_F = 10 mA
Luminous Intensity	I_V	0.2	0.5		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

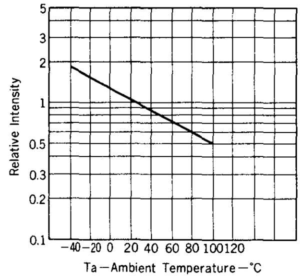
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



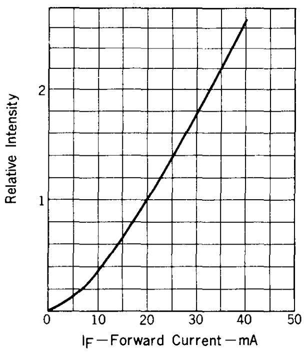
FORWARD CURRENT vs. FORWARD VOLTAGE



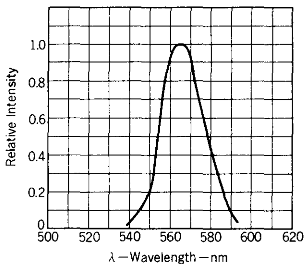
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SG238D

FASHION LAMP
Green

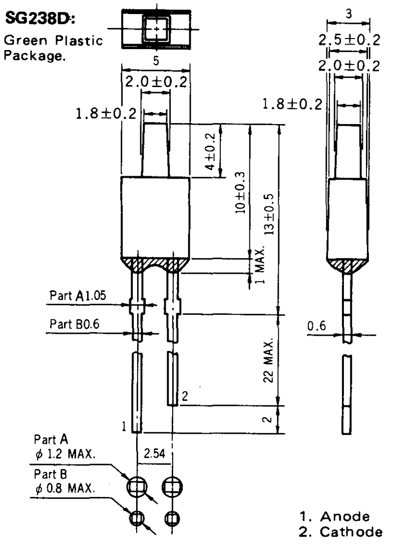
—NEPOC SERIES—

DESCRIPTION

The SG238D is a full resin-molded LED lamp and has a rectangular flat face which emits brilliant green light uniformly. It is especially suitable for such electronic equipments as for audio uses which require some fancy looking displays.

PACKAGE DIMENSIONS

in millimeters



FEATURES

- Rectangular flat face type.
- Low cost.
- Long lead.
- Bright green.
- Compatible with Integrated Circuits.
- Red (SR538D) and amber (SY438D) LED's are available in the same pkg.

APPLICATIONS

- Visual displays.
- Peak level indicator.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

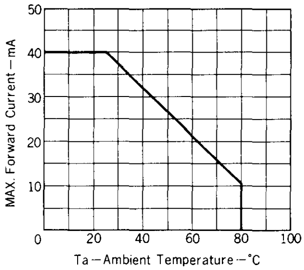
Maximum Power Dissipation (Ta = 25 °C)	P	100	mW
Maximum Forward Current (Ta = 25 °C)	I_F	40	mA
Maximum Reverse Voltage (Ta = 25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	−40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

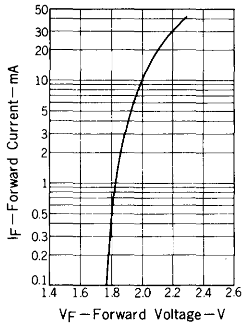
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.5	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		565		nm	I_F = 10 mA
Spectral Line Half Width	$\Delta\lambda$		40		nm	I_F = 10 mA
Luminous Intensity	I_V	0.2	0.5		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

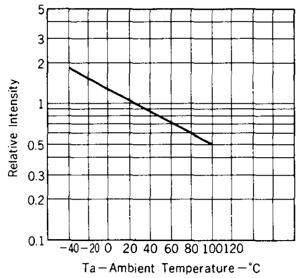
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



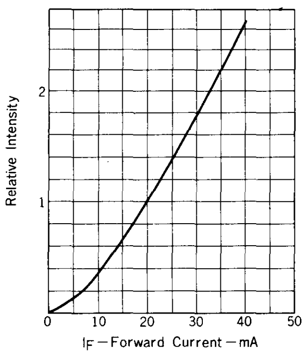
FORWARD CURRENT vs. FORWARD VOLTAGE



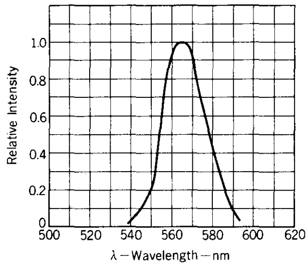
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SG239D

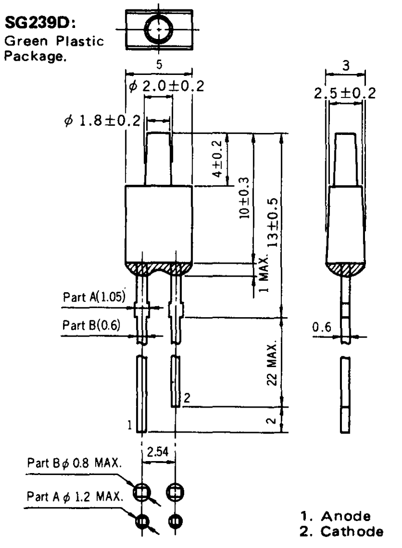
FASHION LAMP
Green

—NEPOC SERIES—

DESCRIPTION

The SG239D is a full resin-molded LED lamp and has a rectangular flat face which emits brilliant green light uniformly. It is especially suitable for such electronic equipments as for audio uses which require some fancy looking displays.

PACKAGE DIMENSIONS
in millimeters



FEATURES

- Rectangular flat face type.
- Low cost.
- Long lead.
- Bright green.
- Compatible with Integrated Circuits.
- Red (SR539D) and amber (SY439D) LED's are available in the same pkg.

APPLICATIONS

- Visual displays.
- Peak level indicator.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

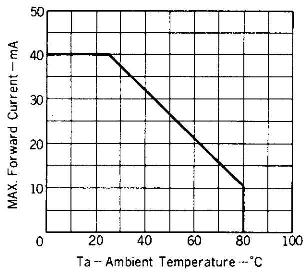
Maximum Power Dissipation (Ta = 25 °C)	P	100	mW
Maximum Forward Current (Ta = 25 °C)	I_F	40	mA
Maximum Reverse Voltage (Ta = 25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	−40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

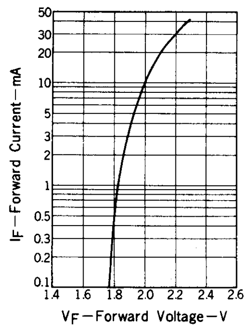
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.5	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		565		nm	I_F = 10 mA
Spectral Line Half Width	Δλ		40		nm	I_F = 10 mA
Luminous Intensity	I_V	0.2	0.5		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

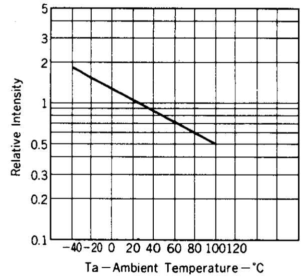
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



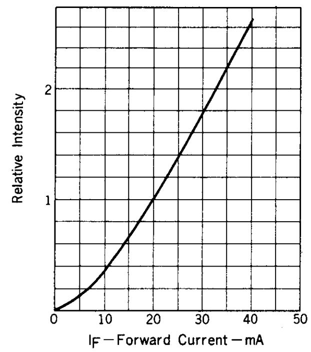
FORWARD CURRENT vs. FORWARD VOLTAGE



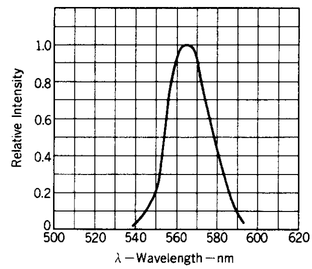
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SR106CA

GaAsP LIGHT EMITTING DIODE
RED

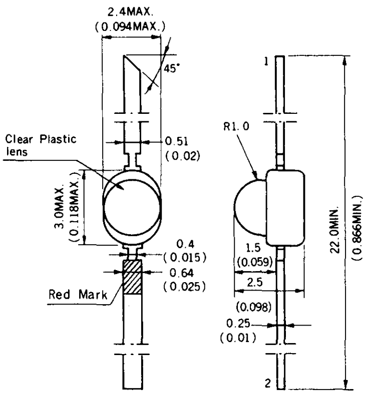
– NEPOC SERIES –

DESCRIPTION

The SR106CA is a GaAsP (Gallium Arsenide Phosphide) Light Emitting Diode which is mounted on the lead frames and molded in clear plastic. It is ideally suited for front panel indicator applications.

PACKAGE DIMENSIONS

in millimeters (inches)



1. Anode
2. Cathode

* Soldering conditions are at 260°C or less Within 5sec. at 3 mm or farther from the case.

FEATURES

- Small size.
- 30° Viewing Angle at 60% Brightness.
- Bright.
- Easily assembled in arrays.
- Compatible with Integrated Circuits.
- Fast switching time.

APPLICATIONS

- Visual displays.
- Dial indicators.
- Portable equipment readout.
- Camera readout.
- Desk top Calculator readout.

ABSOLUTE MAXIMUM RATINGS

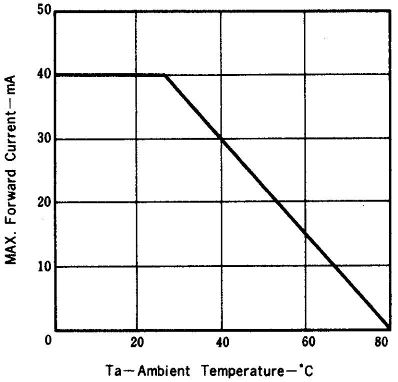
Maximum Power Dissipation (Ta = 25°C)	P	80	mW
Maximum Forward Current (Ta = 25°C)	I_F	40	mA
Maximum Reverse Voltage (Ta = 25°C)	V_R	3	V
Maximum Temperatures			
Junction Temperature	T_j	80	°C
Storage Temperature	T_{stg}	-30 to +80	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25°C)

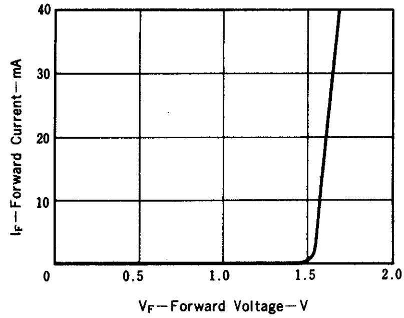
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		1.6	1.95	V	I_F = 20 mA
Reverse Current	I_R		0.01	50	μA	V_R = 3.0V
Capacitance	C_t		50		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		660		nm	I_F = 20 mA
Spectral Line Half Width	Δλ		35		nm	I_F = 20 mA
Luminous Intensity	I_V	0.5	2.5		mcd	I_F = 20 mA

TYPICAL CHARACTERISTICS (Ta = 25°C)

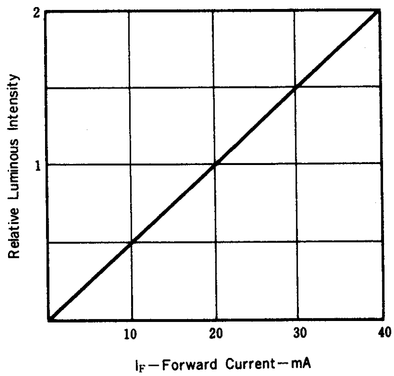
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



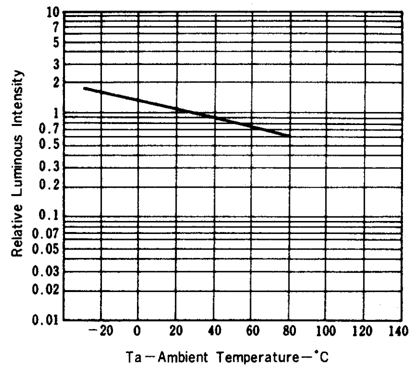
FORWARD CURRENT vs. FORWARD VOLTAGE



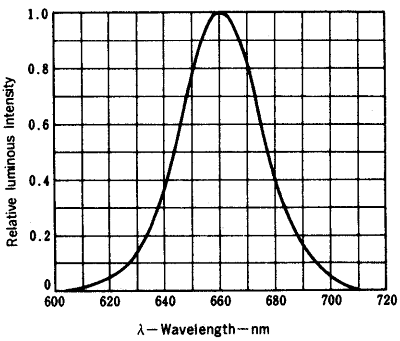
RELATIVE LUMINOUS INTENSITY vs. FORWARD CURRENT



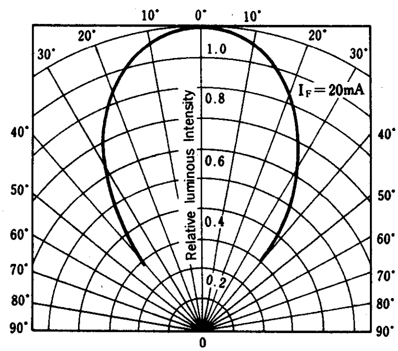
RELATIVE LUMINOUS INTENSITY vs. AMBIENT TEMPERATURE



SPECTRAL DISTRIBUTION



SPATIAL DISTRIBUTION



8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODES
SR106D, SR106C

GaAsP LIGHT EMITTING DIODE (RED)

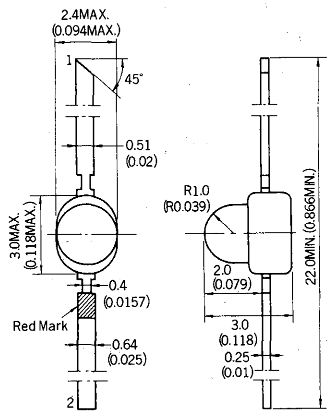
— NEPOC SERIES —

DESCRIPTION

The SR106D, SR106C are GaAsP (Gallium Arsenide Phosphide) Light Emitting Diodes which are mounted on the lead frames and molded in red diffused, clear plastic respectively. They are ideally suited for front panel indicator applications.

PACKAGE DIMENSIONS

in millimeters (inches)



SR106D: Red Diffused plastic lens.
SR106C: Clear plastic lens.

1. Anode
2. Cathode

* Soldering conditions are at 260°C or less Within 5sec. at 3 mm or farther from the case.

FEATURES

- Small size.
- Low cost.
- Bright.
- Easily assembled in arrays.
- Compatible with Integrated Circuits.
- Fast switching time.

APPLICATIONS

- Visual displays.
- Dial indicators.
- Portable equipment readout.
- Camera readout.
- Desk top Calculator readout.

ABSOLUTE MAXIMUM RATINGS

Maximum Power Dissipation (Ta = 25°C)	P	80	mW
Maximum Forward Current (Ta = 25°C)	I_F	40	mA
Maximum Reverse Voltage (Ta = 25°C)	V_R	3.0	V
Maximum Temperatures			
Junction Temperature	T_j	80	°C
Storage Temperature	T_{stg}	-30 to +80	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		1.6	2.0	V	I_F = 20 mA
Reverse Current	I_R		0.01	50	μA	V_R = 3.0V
Capacitance	C_t		50		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		660		nm	I_F = 20 mA
Spectral Line Half Width	$\Delta\lambda$		35		nm	I_F = 20 mA
Luminous Intensity	I_V		1.5		mcd	I_F = 20 mA

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODES
SR503D, SR503C, SR503W

Gap HIGH INTENSITY LED
Red

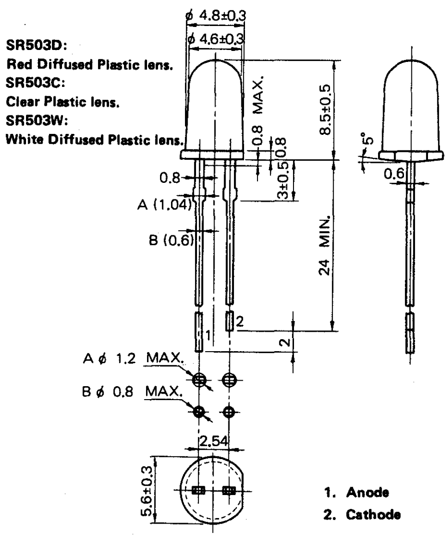
—NEPOC SERIES—

DESCRIPTION

The SR503D, SR503C and SR503W are full resin-molded LED lamps which emit brilliant red light at comparably low current. They are especially suitable for such electronic equipments as battery-driven equipments, audio equipments etc. which require low power displays.

PACKAGE DIMENSIONS

in millimeters



FEATURES

- Low cost.
- High intensity with low current.
- Compatible with integrated circuits.
- Long lead.
- Wide view angle.
- Bright red.

APPLICATIONS

- Visual displays.
- Guard system.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.
- Optical switching light source.

ABSOLUTE MAXIMUM RATINGS

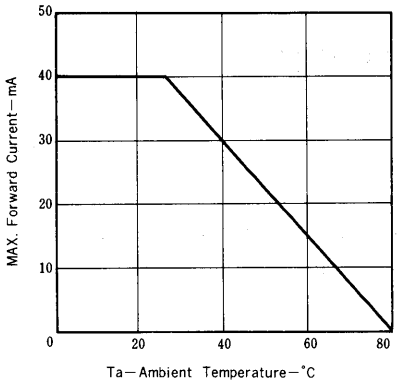
Maximum Power Dissipation (Ta=25 °C)	P	60	mW
Maximum Forward Current (Ta=25 °C)	I_F	30	mA
Maximum Reverse Voltage (Ta=25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	Tstg	−40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

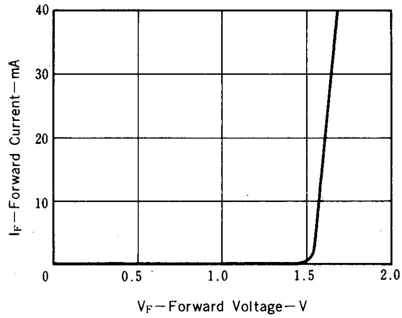
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.5	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ peak		695		nm	I_F = 10 mA
Spectral Line Half Width	Δλ		100		nm	I_F = 10 mA
Luminous Intensity (SR503D, 503W)	I_V	1.5	5		mcd	I_F = 10 mA
Luminous Intensity (SR503C)	I_V	4	10		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25°C)

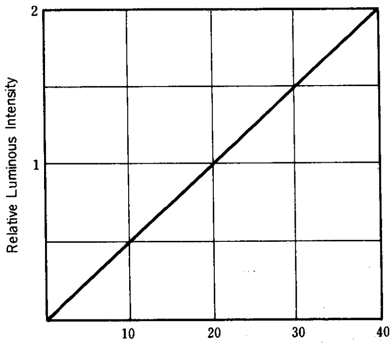
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



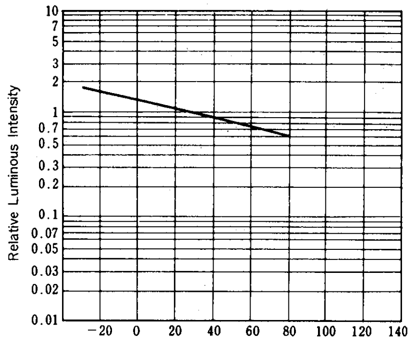
FORWARD CURRENT vs. FORWARD VOLTAGE



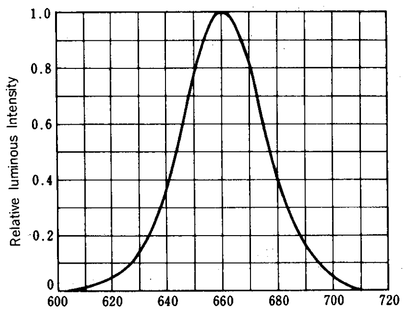
RELATIVE LUMINOUS INTENSITY vs. FORWARD CURRENT



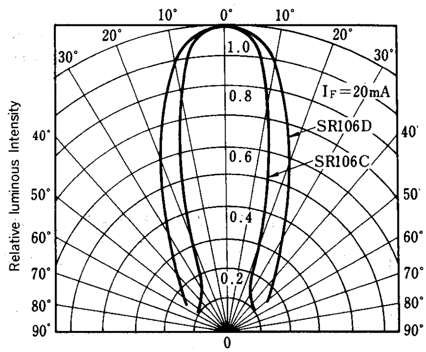
RELATIVE LUMINOUS INTENSITY vs. CASE TEMPERATURE



SPECTRAL DISTRIBUTION



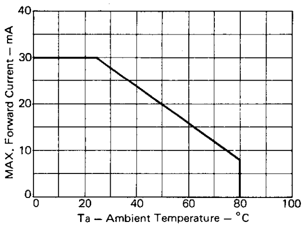
SPATIAL DISTRIBUTION



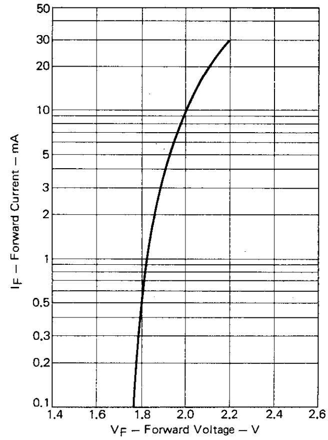
8

TYPICAL CHARACTERISTICS (Ta = 25 °C)

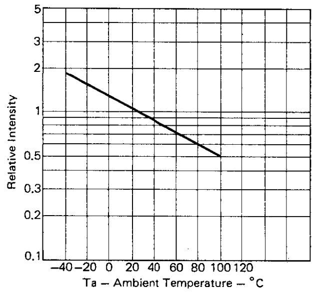
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



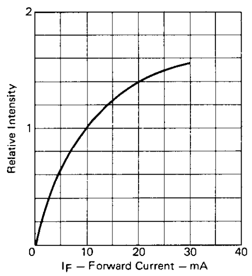
FORWARD CURRENT vs. FORWARD VOLTAGE



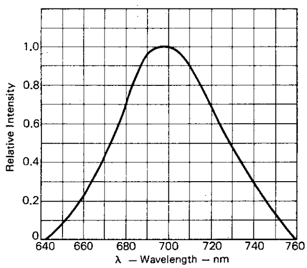
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



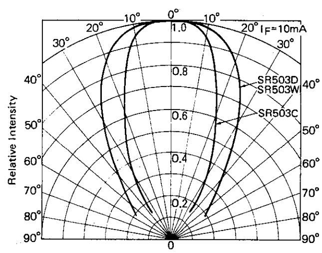
RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



SPATIAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.
2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.

      Freon TE, Freon TF, Ethanol, Methanol Difron-solvent, Isopropyl-alcohol

   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODES
SR505D, SR505C, SR505W

Gap HIGH INTENSITY LED
Red

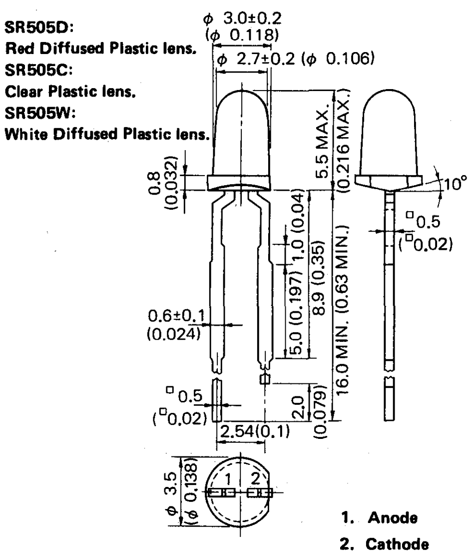
—NEPOC SERIES—

DESCRIPTION

The SR505D, SR505C and SR505W full resin-molded medium-size LED lamps which emit brilliant red light at comparably low current. They are especially suitable for such electronic equipments as battery-driven equipments, audio equipments etc. which require low power displays.

PACKAGE DIMENSIONS

in millimeters (inches)



FEATURES

- Low cost.
- High intensity with low current.
- Compatible with integrated circuits.
- Bright red.

APPLICATIONS

- Radio, Stereo equipment readout.
- Visual displays.
- Guard system.
- Measuring instrument, terminal.
- Optical switching light source.

ABSOLUTE MAXIMUM RATINGS

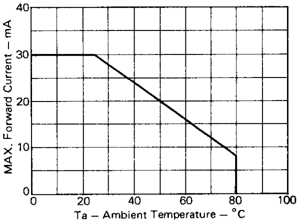
Maximum Power Dissipation (Ta=25 °C)	P	60	mW
Maximum Forward Current (Ta=25 °C)	I_F	30	mA
Maximum Reverse Voltage (Ta=25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	Tstg	−40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

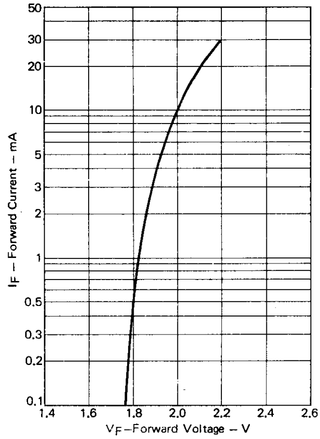
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.5	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		50		pF	V = 0, f = 1.0 MHZ
Peak Emission Wavelength	λ peak		695		nm	I_F = 10 mA
Spectral Line Half Width	Δ λ		100		nm	I_F = 10 mA
Luminous Intensity (SR505D,SR505W)	I_V	1	3.5		mcd	I_F = 10 mA
Luminous Intensity (SR505C)	I_V	2	6		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

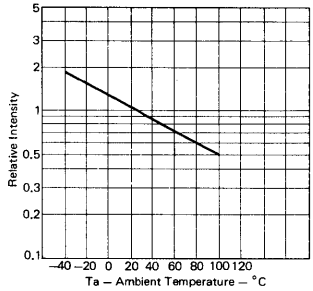
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



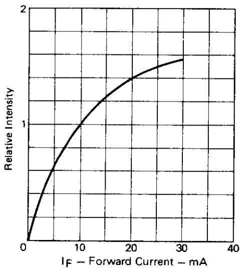
FORWARD CURRENT vs. FORWARD VOLTAGE



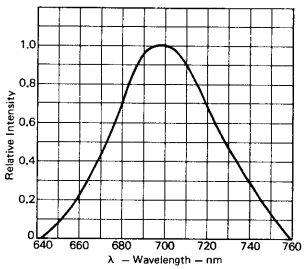
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



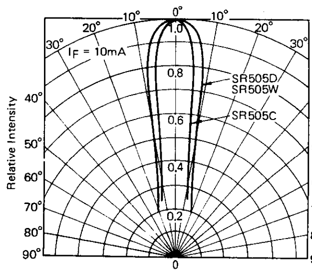
RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



SPATIAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.
2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SR531D

FASHION LAMP
Red

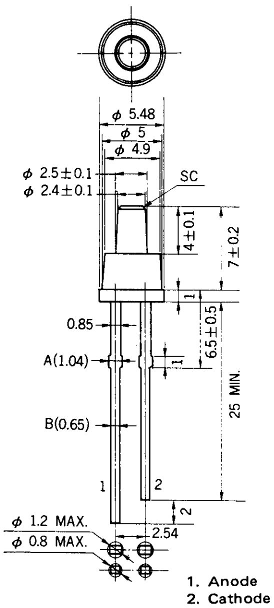
—NEPOC SERIES—

DESCRIPTION

The SR531D is a full resin-molded LED lamp and has a circular flat face which emits brilliant red light uniformly. It is especially suitable for such electronic equipments as for audio uses which require some fancy looking displays.

PACKAGE DIMENSIONS
in millimeters

SR531D:
Red Diffused Plastic lens.



FEATURES

- Circular flat face type.
- Low cost.
- Long lead.
- Bright red.
- Compatible with Integrated Circuits.
- Green (SG231D) and amber (SY431D) LED's are available in the same pkg.

APPLICATIONS

- Visual displays.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

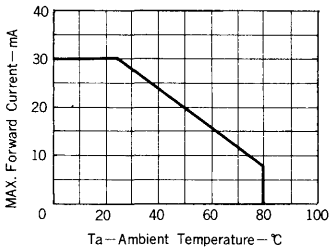
Maximum Power Dissipation (Ta=25 °C)	P	60	mW
Maximum Forward Current (Ta=25 °C)	I_F	30	mA
Maximum Reverse Voltage (Ta=25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	−40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

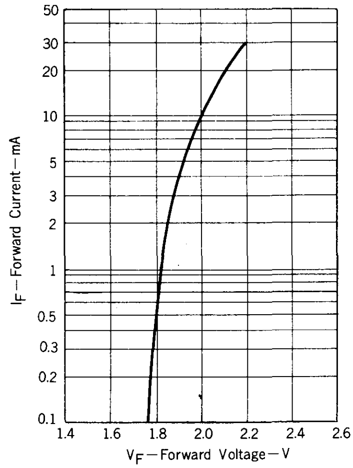
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2	2.5	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		695		nm	I_F = 10 mA
Spectral Line Half Width	$\Delta\lambda$		100		nm	I_F = 10 mA
Luminous Intensity	I_V	0.2	0.5		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

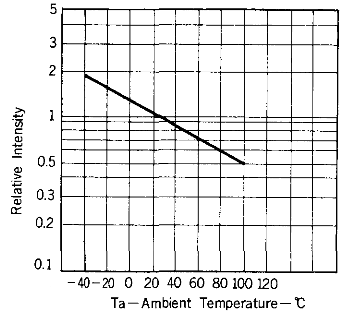
MAX. FORWARD CURRENT vs.
AMBIENT TEMPERATURE



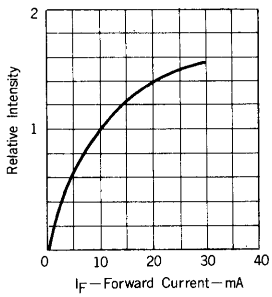
FORWARD CURRENT vs.
FORWARD VOLTAGE



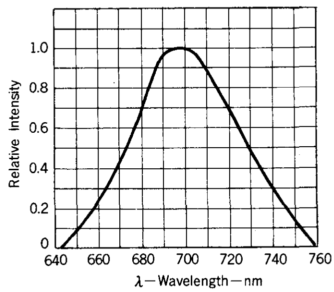
RELATIVE INTENSITY vs.
AMBIENT TEMPERATURE



RELATIVE INTENSITY vs.
FORWARD CURRENT



SPECTRAL DISTRIBUTION



8

HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.
2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol Difron-solvent, Isopropy-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and teh mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SR535D

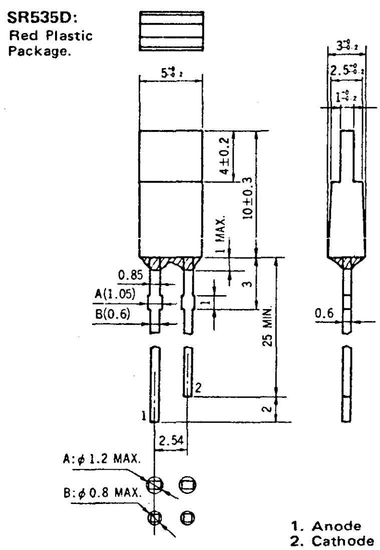
FASHION LAMP
Red

—NEPOC SERIES—

DESCRIPTION

The SR535D is a full resin-molded LED lamp and has a rectangular flat face which emits brilliant red light uniformly. It is especially suitable for such electronic equipments as for audio uses which require some fancy looking.displays.

PACKAGE DIMENSIONS
in millimeters



FEATURES

- Rectangular flat face type.
- Low cost.
- Long lead.
- Bright red.
- Compatible with Integrated Circuits.
- Green (SG235D) and amber (SY435D) LED's are available in the same pkg.

APPLICATIONS

- Visual displays.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

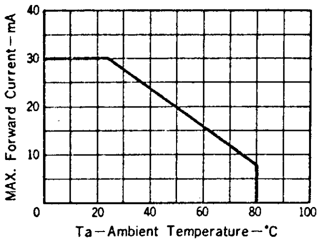
Maximum Power Dissipation (Ta = 25 °C)	P	60	mW
Maximum Forward Current (Ta = 25 °C)	I_F	30	mA
Maximum Reverse Voltage (Ta = 25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	−40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

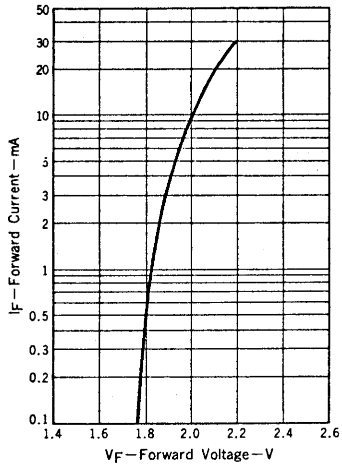
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.5	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		695		nm	I_F = 10 mA
Spectral Line Half Width	$\Delta\lambda$		100		nm	I_F = 10 mA
Luminous Intensity	I_V	0.2	0.5		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

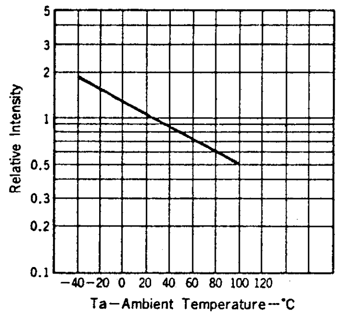
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



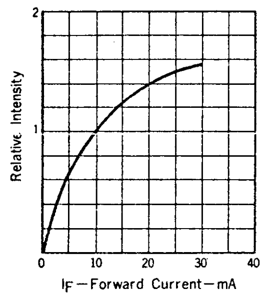
FORWARD CURRENT vs. FORWARD VOLTAGE



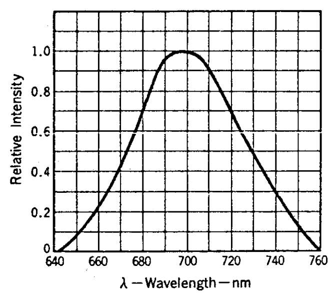
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   - (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   - (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   - (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
     Freon TE, Freon TF, Ethanol, Methanol
     Difron-solvent, Isopropyl-alcohol
   - (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SR538D

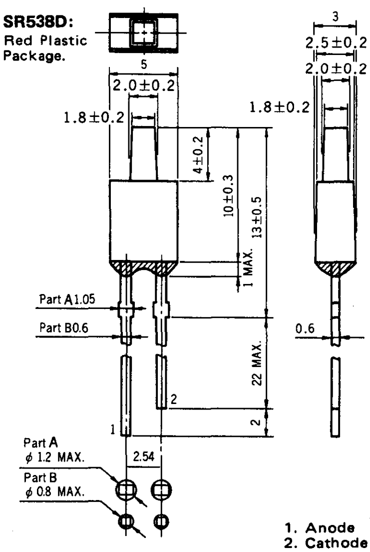
FASHION LAMP
Red

—NEPOC SERIES—

DESCRIPTION

The SR538D is a full resin-molded LED lamp and has a rectangular flat face which emits brilliant red light uniformly. It is especially suitable for such electronic equipments as for audio uses which require some fancy looking.displays.

PACKAGE DIMENSIONS
in millimeters



FEATURES

- Rectangular flat face type.
- Low cost.
- Long lead.
- Bright red.
- Compatible with Integrated Circuits.
- Green (SG238D) and amber (SY438D) LED's are available in the same pkg.

APPLICATIONS

- Visual displays.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

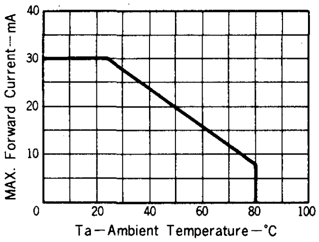
Maximum Power Dissipation (Ta = 25 °C)	P	60	mW
Maximum Forward Current (Ta = 25 °C)	I_F	30	mA
Maximum Reverse Voltage (Ta = 25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	−40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

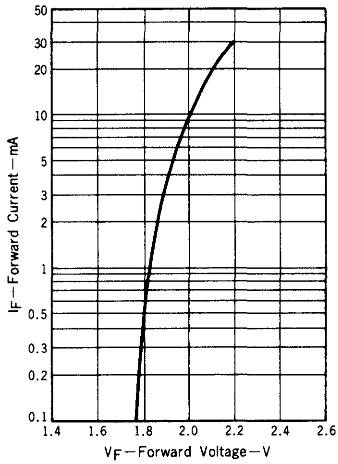
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.5	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		695		nm	I_F = 10 mA
Spectral Line Half Width	Δλ		100		nm	I_F = 10 mA
Luminous Intensity	I_V	0.2	0.5		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

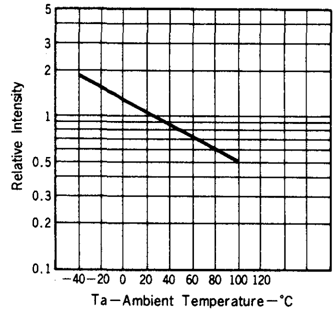
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



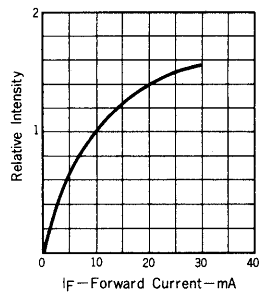
FORWARD CURRENT vs. FORWARD VOLTAGE



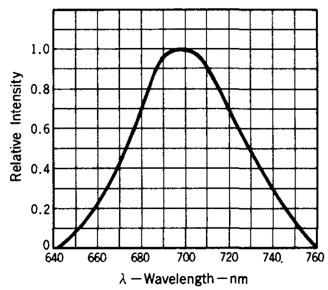
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODES
SR603D, SR603C, SR603W

GaAsP(N) HIGH INTENSITY LED
Red

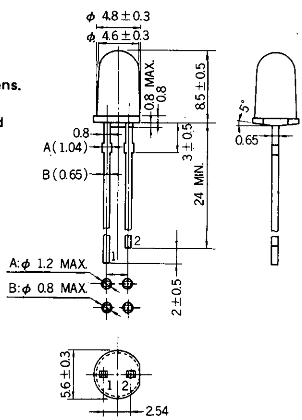
—NEPOC SERIES—

DESCRIPTION

The SR603D, SR603C and SR603W are full resin-molded LED lamps which emit brilliant and uniform red light proportional with the forward current (I_F). They are especially suitable for such electronic equipments as for audio uses which require bright, vivid displays.

PACKAGE DIMENSIONS
in millimeters

SR603D: Red Diffused Plastic lens.
SR603C: Clear Plastic lens.
SR603W: White Diffused Plastic lens.



1. Anode
2. Cathode

FEATURES

- Low cost.
- High intensity.
- Compatible with Integrated Circuits.
- Long lead.
- Wide view angle.
- Bright red

APPLICATIONS

- Visual displays.
- Guard system.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.
- Optical switching light source.

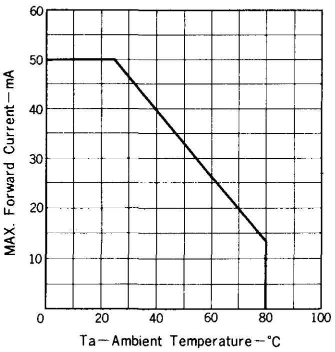
ABSOLUTE MAXIMUM RATINGS

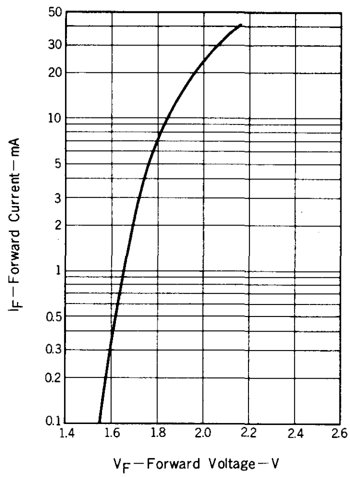
Maximum Power Dissipation (Ta=25 °C)	P	100	mW
Maximum Forward Current (Ta=25 °C)	I_F	50	mA
Maximum Reverse Voltage (Ta=25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	–40 to +100	°C

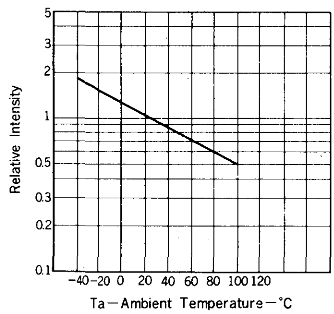
ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

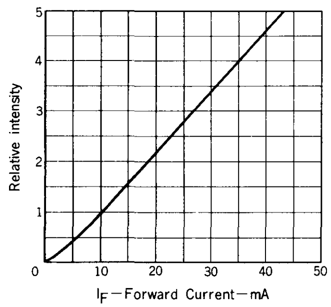
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.4	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		630		nm	I_F = 10 mA
Spectral Line Half Width	$\Delta\lambda$		40		nm	I_F = 10 mA
Luminous Intensity (SR603D, SR603W)	I_V	1	3		mcd	I_F = 10 mA
Luminous Intensity (SR603C)	I_V	3	6		mcd	I_F = 10 mA

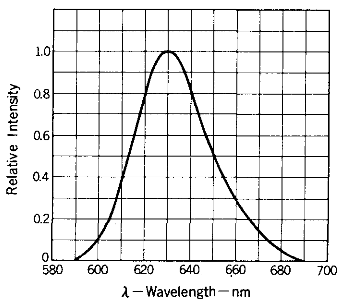
TYPICAL CHARACTERISTICS (Ta = 25 °C)

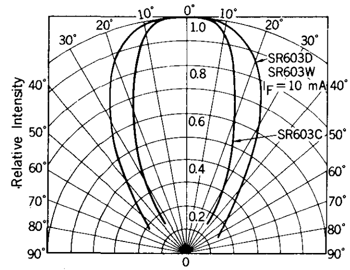












HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the poing 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODES
SR605D, SR605C, SR605W

GaAsP(N) HIGH INTENSITY LED

Red

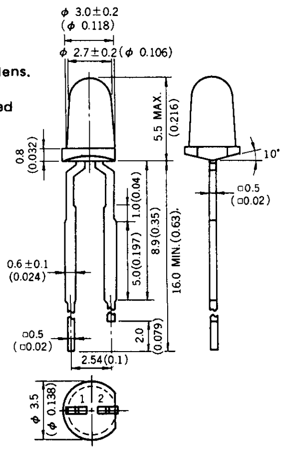
—NEPOC SERIES—

DESCRIPTION

The SR605D, SR605C and SR605W are full resin-molded medium size LED lamps which emit brilliant and uniform red light proportional with the forward current (I_F). They are especially suitable for such electronic equipments as for audio uses which require bright, vivid displays.

PACKAGE DIMENSIONS
in millimeters (inches)

SR605D:
Red Diffused Plastic lens.
SR605C:
Clear Plastic lens.
SR605W:
White Diffused Plastic lens.



1. Anode
2. Cathode

FEATURES

- Low cost.
- High intensity.
- Compatible with Integrated Circuits.
- Bright red.

APPLICATIONS

- Visual displays.
- Guard system.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.
- Optical switching light source.

ABSOLUTE MAXIMUM RATINGS

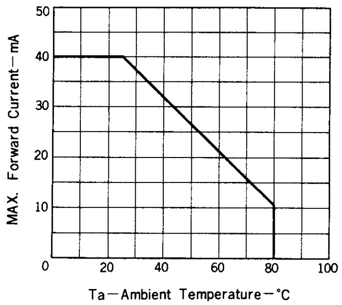
Maximum Power Dissipation (Ta=25 °C)	P	80	mW
Maximum Forward Current (Ta=25 °C)	I_F	40	mA
Maximum Reverse Voltage (Ta=25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	−40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

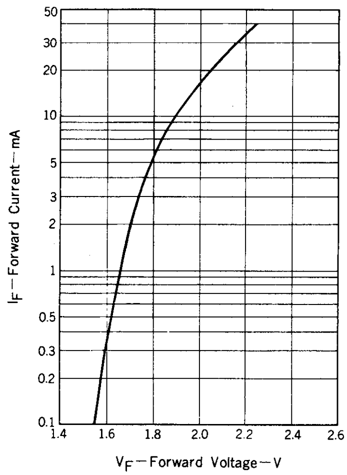
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.4	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		630		nm	I_F = 10 mA
Spectral Line Half Width	Δλ		40		nm	I_F = 10 mA
Luminous Intensity (SR605D, SR605W)	I_V	1.5	5		mcd	I_F = 10 mA
Luminous Intensity (SR605C)	I_V	3	10		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

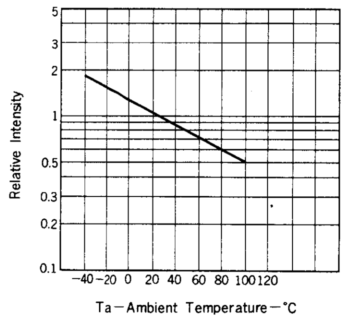
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



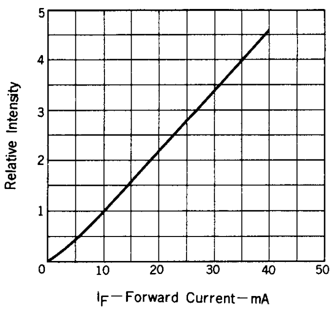
FORWARD CURRENT vs. FORWARD VOLTAGE



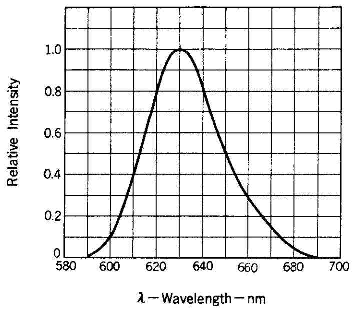
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



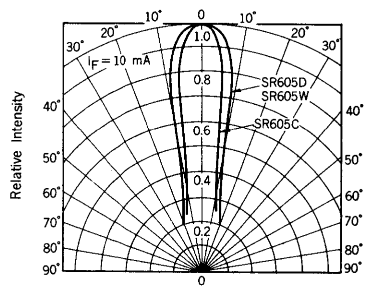
RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



SPATIAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SR632D

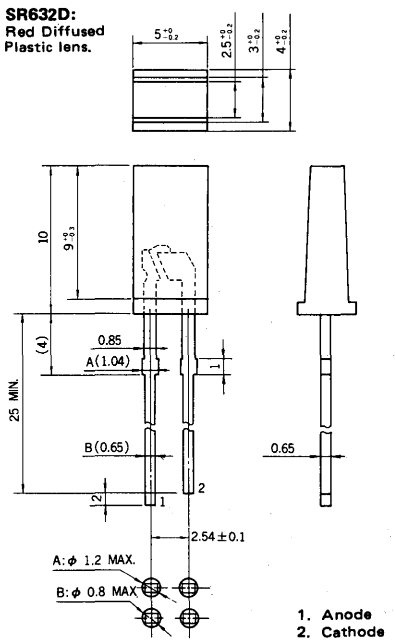
GaAsP(N) FASHION LED
Red

—NEPOC SERIES—

DESCRIPTION

The SR632D is a full resin-molded LED lamp and has a rectangular flat face which emits brilliant red light uniformly. It is especially suitable for such electronic equipments as for audio uses which require some fancy looking displays.

PACKAGE DIMENSIONS
in millimeters



FEATURES

- Rectangular flat face type.
- Low cost.
- Long lead.
- Bright red.
- Compatible with Integrated Circuits.
- Green (SG232D) and amber (SY432D) LED's are available in the same pkg.

APPLICATIONS

- Visual displays.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

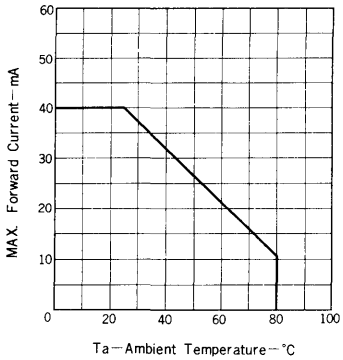
Maximum Power Dissipation (Ta=25 °C)	P	100	mW
Maximum Forward Current (Ta=25 °C)	I_F	40	mA
Maximum Reverse Voltage (Ta=25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	−40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

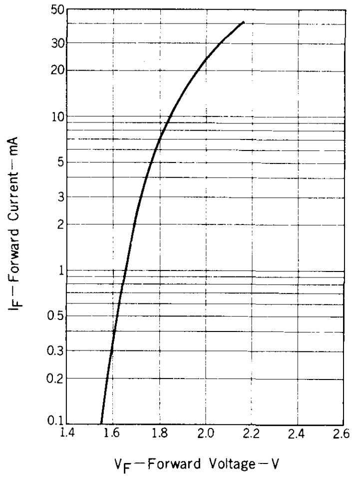
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.4	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λpeak		630		nm	I_F = 10 mA
Spectral Line Half Width	Δλ		40		nm	I_F = 10 mA
Luminous Intensity	I_V	0.2	0.5		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

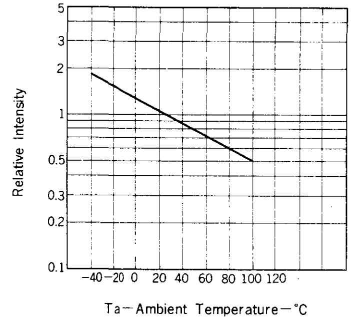
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



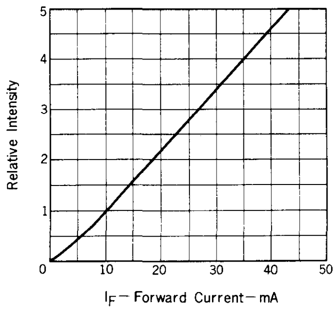
FORWARD CURRENT vs. FORWARD VOLTAGE



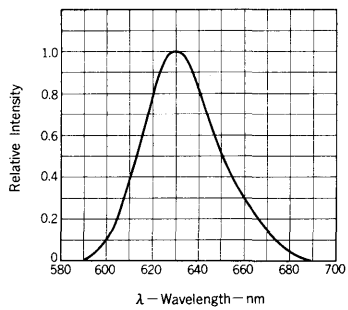
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODES
SY403DA, SY403TA

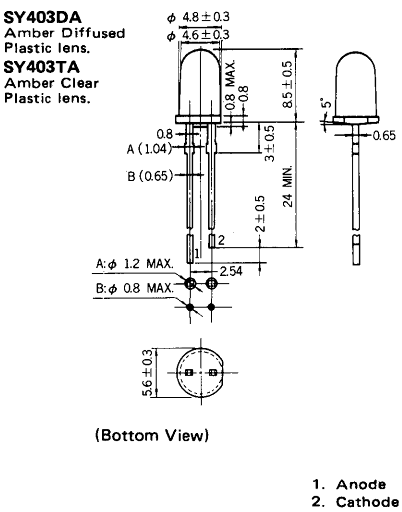
GaAsP HIGH INTENSITY LED
Amber

–NEPOC SERIES–

DESCRIPTION

The SY403DA, SY403TA are full resin-molded LED lamps and emit bright and vivid amber light. They are especially suitable for such electronic equipments as for audio uses which require high brightness displays.

PACKAGE DIMENSIONS
in millimeters



FEATURES

- High intensity.
- Wide angle.
- Long lead.
- Good sensitivity – 590 nm.
- Low cost.
- Compatible with integrated circuits.

APPLICATIONS

- Visual displays.
- Guard system.
- Mobile equipment readout.
- Stereo equipment readout.
- Transceiver readout.

ABSOLUTE MAXIMUM RATINGS

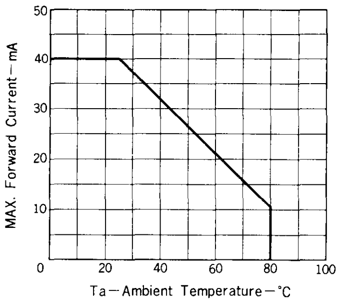
Maximum Power Dissipation (Ta=25 °C)	P	100	mW
Maximum Forward Current (Ta=25 °C)	I_F	40	mA
Maximum Reverse Voltage (Ta=25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	–40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

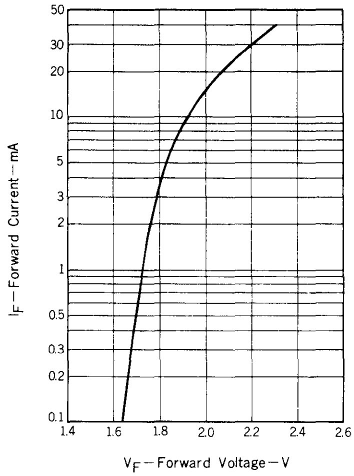
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.1	2.5	V	I_F = 20 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		60		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λpeak		590		nm	I_F = 20 mA
Spectral Line Half Width	Δλ		40		nm	I_F = 20 mA
Luminous Intensity (SY403DA)	I_V	1.5	5		mcd	I_F = 20 mA
Luminous Intensity (SY403TA)	I_V	4.5	10		mcd	I_F = 20 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

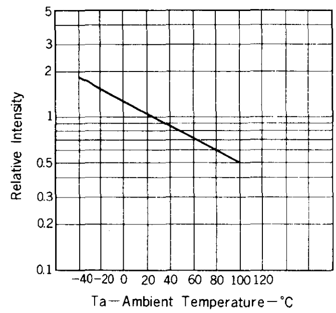
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



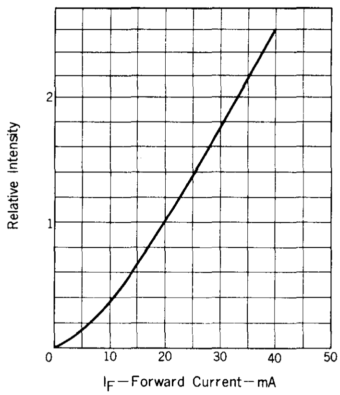
FORWARD CURRENT vs. FORWARD VOLTAGE



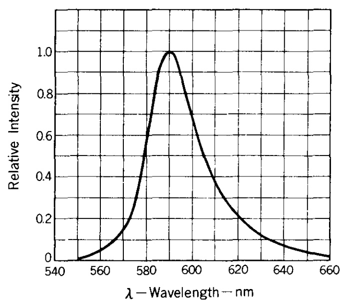
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



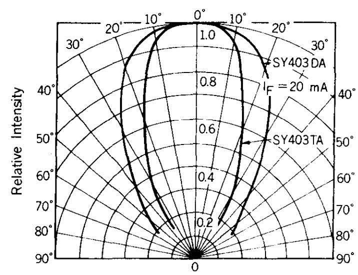
RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



SPATIAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODES
SY405D, SY405T

GaAsP LIGHT EMITTING DIODE
AMBER

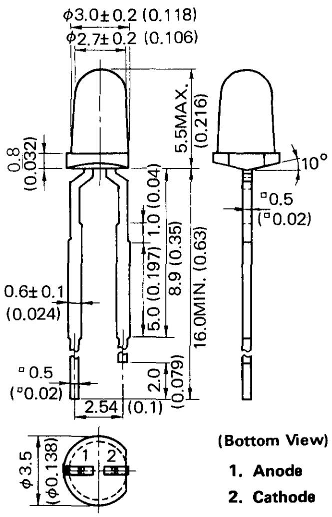
—NEPOC SERIES—

DESCRIPTION

The SY405D, SY405T are GaAsP (Gallium Arsenide Phosphide) Light Emitting Diodes which are mounted on the lead frames and molded in Amber diffused, Amber clear plastic respectively. They are ideally suited for front panel indicator applications.

PACKAGE DIMENSIONS

in millimeters (inches)



* **Soldering conditions are at 260°C or less Within 5sec. at 5 mm or farther from the case.**

FEATURES

- Good sensitivity – 590nm
- Long life – solid state reliability.
- Low cost.
- High intensity with low current.
- Versatile mounting on PC board or panel.
- Compatible with Integrated Circuits.
- Fast Switching Time.

APPLICATIONS

- Visual displays.
- Guard System.
- Radio, Stereo equipment Readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

Maximum Power Dissipation (Ta=25°C)	P	100	mW
Maximum Forward Current (Ta=25°C)	I_F	40	mA
Maximum Reverse Voltage (Ta=25°C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	80	°C
Storage Temperature	Tstg	–30 to +80	°C

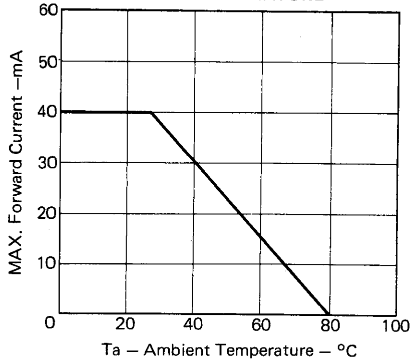
ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.2	2.5	V	I_F = 20mA
Reverse Current	I_R		0.01	50	μA	V_R = 4.5V
Capacitance	C_t		60		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λpeak		590		nm	I_F = 20mA
Spectral Line Half Width	Δλ		35		nm	I_F = 20 mA
Luminous Intensity	I_{V1}/I_{V2}*	1/2	3/5		mcd	I_F = 20 mA

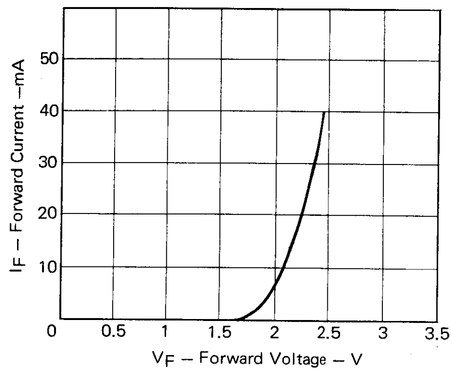
* I_{V1}/I_{V2} : Luminous Intensity of SY405D/Luminous Intensity of SY405T.

TYPICAL CHARACTERISTICS (Ta = 25 °C)

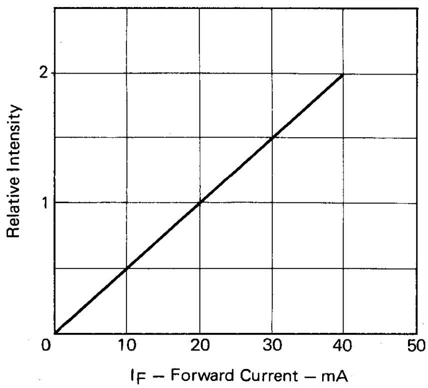
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



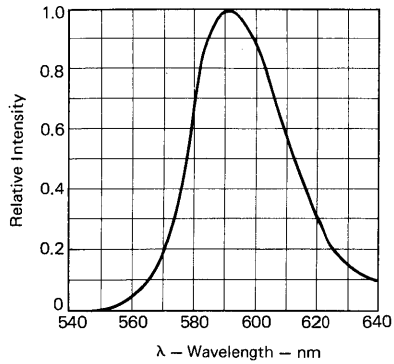
FORWARD CURRENT vs. FORWARD VOLTAGE



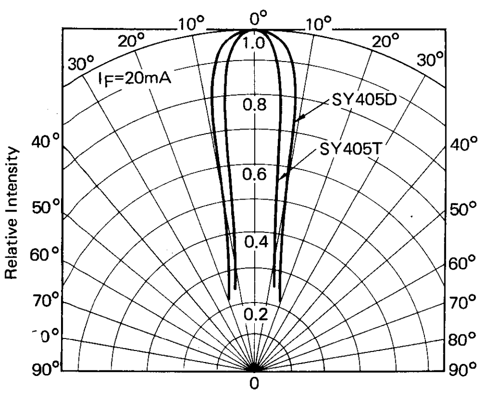
RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



SPATIAL DISTRIBUTION



8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SY431D

GaAsP FASHION LED
Amber

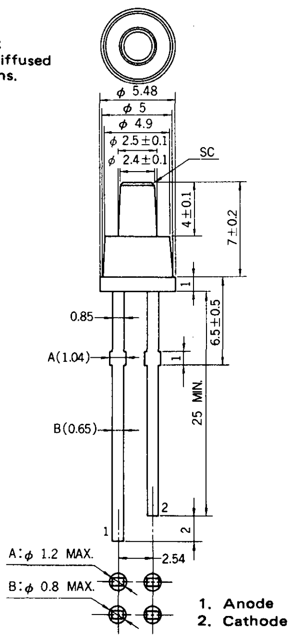
—NEPOC SERIES—

DESCRIPTION

The SY431D is a full resin-molded LED lamp and has a circular flat face which emits brilliant amber light uniformly. It is especially suitable for such electronic equipments as for audio uses which require some fancy looking displays.

PACKAGE DIMENSIONS
in millimeters

SY431D:
Amber Diffused
Plastic lens.



FEATURES

- Circular flat face type.
- Low cost.
- Long lead.
- Bright amber.
- Compatible with Integrated Circuits.
- Red (SR531D) and green (SG231D) LED's are available in the same pkg.

APPLICATIONS

- Visual displays.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

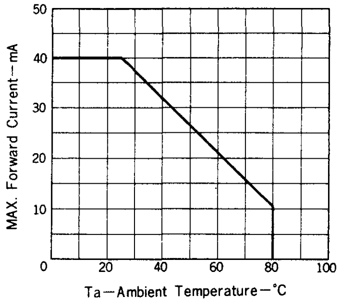
Maximum Power Dissipation (Ta=25 °C)	P	100	mW
Maximum Forward Current (Ta=25 °C)	I_F	40	mA
Maximum Reverse Voltage (Ta=25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	–40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

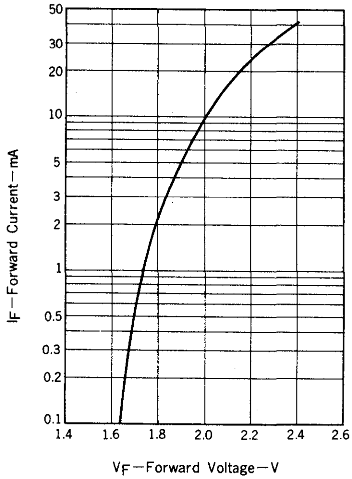
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.4	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		60		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λpeak		590		nm	I_F = 10 mA
Spectral Line Half Width	Δλ		40		nm	I_F = 10 mA
Luminous Intensity	I_V	0.1	0.3		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

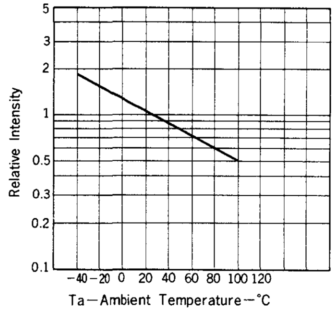
MAX. FORWARD CURRENT vs.
AMBIENT TEMPERATURE



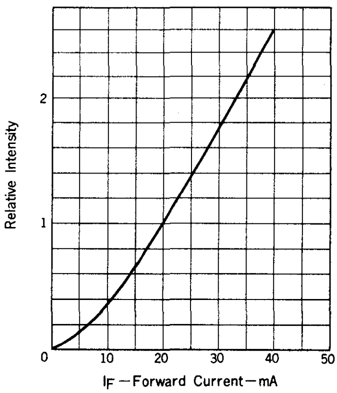
FORWARD CURRENT vs.
FORWARD VOLTAGE



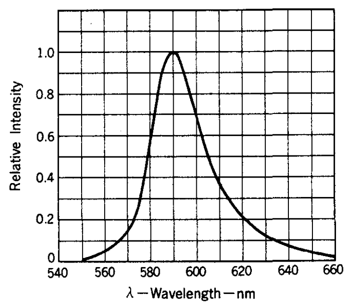
RELATIVE INTENSITY vs.
AMBIENT TEMPERATURE



RELATIVE INTENSITY vs.
FORWARD CURRENT



SPECTRAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SY432D

FASHION LAMP
Amber

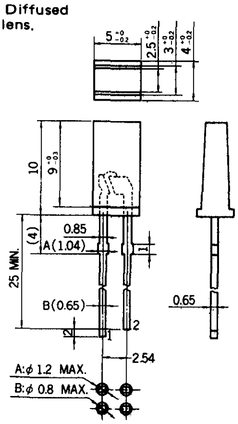
—NEPOC SERIES—

DESCRIPTION

The SY432D is a full resin-molded LED lamp and has a rectangular flat face which emits brilliant amber light uniformly. It is especially suitable for such electronic equipments as for audio uses which require some fancy looking displays.

PACKAGE DIMENSIONS
in millimeters

SY432D:
Amber Diffused Plastic lens.



1. Anode
2. Cathode

FEATURES

- Rectangular flat face type.
- Low cost.
- Long lead.
- Bright amber.
- Compatible with Integrated Circuits.
- Red (SR632D) and green (SG232D) LED's are available in the same pkg.

APPLICATIONS

- Visual displays.
- Peak level indicator.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

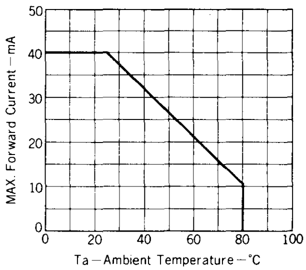
Maximum Power Dissipation (Ta=25 °C)	P	100	mW
Maximum Forward Current (Ta=25 °C)	I_F	40	mA
Maximum Reverse Voltage (Ta=25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	–40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

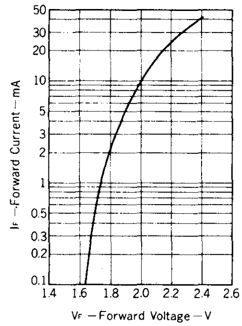
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.4	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λpeak		590		nm	I_F = 10 mA
Spectral Line Half Width	Δλ		40		nm	I_F = 10 mA
Luminous Intensity	I_V	0.2	0.5		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

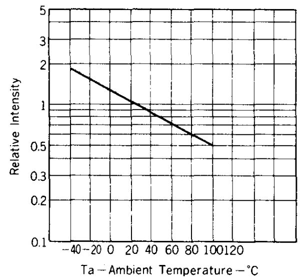
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



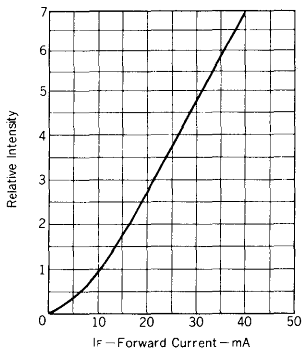
FORWARD CURRENT vs. FORWARD VOLTAGE



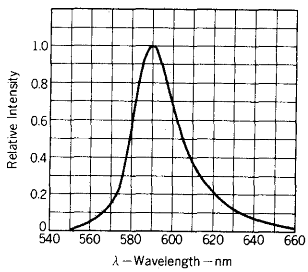
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PWB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SY435D

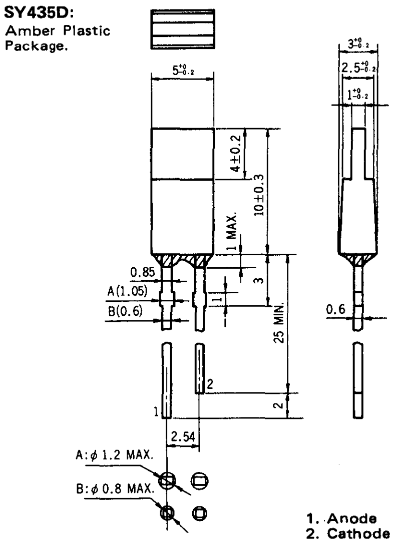
FASHION LAMP
Amber

—NEPOC SERIES—

DESCRIPTION

The SY435D is a full resin-molded LED lamp and has a rectangular flat face which emits brilliant amber light uniformly. It is especially suitable for such electronic equipments as for audio uses which require some fancy looking displays.

PACKAGE DIMENSIONS
in millimeters



FEATURES

- Rectangular flat face type.
- Low cost.
- Long lead.
- Bright amber.
- Compatible with Integrated Circuits.
- Red (SR535D) and green (SG235D) LED's are available in the same pkg.

APPLICATIONS

- Visual displays.
- Peak level indicator.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

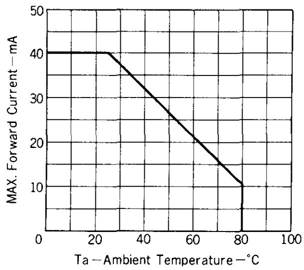
Maximum Power Dissipation (Ta = 25 °C)	P	100	mW
Maximum Forward Current (Ta = 25 °C)	I_F	40	mA
Maximum Reverse Voltage (Ta = 25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	−40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

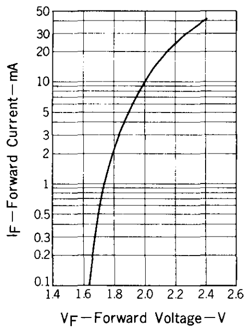
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.4	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		590		nm	I_F = 10 mA
Spectral Line Half Width	$\Delta\lambda$		40		nm	I_F = 10 mA
Luminous Intensity	I_V	0.2	0.5		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

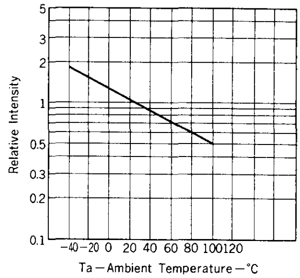
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



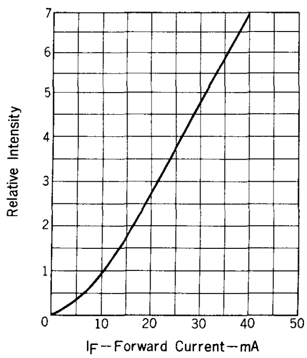
FORWARD CURRENT vs. FORWARD VOLTAGE



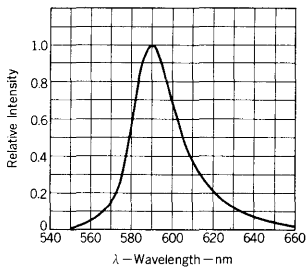
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-semiconductor devices as they have less additives. Therefore please note on the following points.
   - (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and with
   - (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the pc that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   - (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
     Freon TE, Freon TF, Ethanol, Methanol
     Difron-solvent, Isopropyl-alcohol
   - (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

8

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SY438D

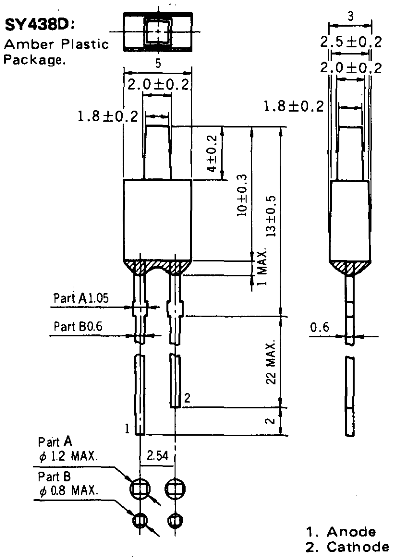
FASHION LAMP
Amber

—NEPOC SERIES—

DESCRIPTION

The SY438D is a full resin-molded LED lamp and has a rectangular flat face which emits brilliant amber light uniformly. It is especially suitable for such electronic equipments as for audio uses which require some fancy looking displays.

PACKAGE DIMENSIONS
in millimeters



FEATURES

- Rectangular flat face type.
- Low cost.
- Long lead.
- Bright amber.
- Compatible with Integrated Circuits.
- Red (SR538D) and green (SG238D) LED's are available in the same pkg.

APPLICATIONS

- Visual displays.
- Peak level indicator.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

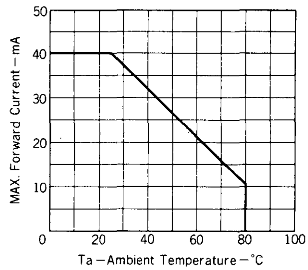
Maximum Power Dissipation (Ta = 25 °C)	P	100	mW
Maximum Forward Current (Ta = 25 °C)	I_F	40	mA
Maximum Reverse Voltage (Ta = 25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	−40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

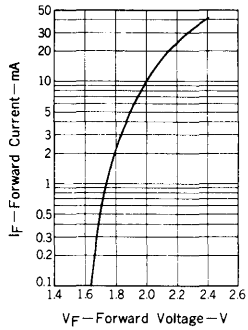
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.4	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		590		nm	I_F = 10 mA
Spectral Line Half Width	$\Delta\lambda$		40		nm	I_F = 10 mA
Luminous Intensity	I_V	0.2	0.5		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

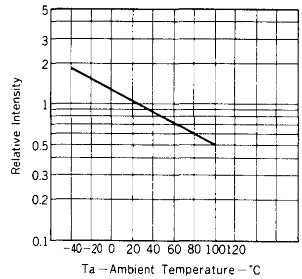
MAX. FORWARD CURRENT vs.
AMBIENT TEMPERATURE



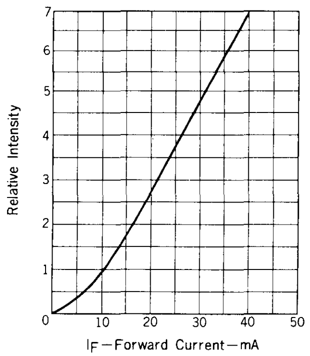
FORWARD CURRENT vs.
FORWARD VOLTAGE



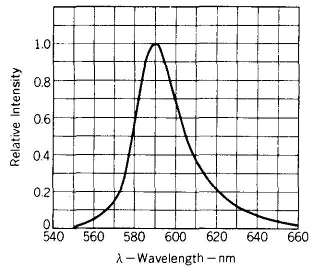
RELATIVE INTENSITY vs.
AMBIENT TEMPERATURE



RELATIVE INTENSITY vs.
FORWARD CURRENT



SPECTRAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

NEC
ELECTRON DEVICE

LIGHT EMITTING DIODE
SY439D

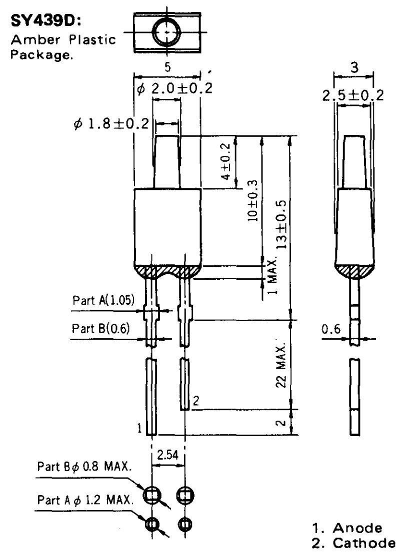
FASHION LAMP
Amber

—NEPOC SERIES—

DESCRIPTION

The SY439D is a full resin-molded LED lamp and has a rectangular flat face which emits brilliant amber light uniformly. It is especially suitable for such electronic equipments as for audio uses which require some fancy looking displays.

PACKAGE DIMENSIONS
in millimeters



FEATURES

- Rectangular flat face type.
- Low cost.
- Long lead.
- Bright amber.
- Compatible with Integrated Circuits.
- Red (SR539D) and green (SG239D) LED's are available in the same pkg.

APPLICATIONS

- Visual displays.
- Peak level indicator.
- Radio, Stereo equipment readout.
- Measuring instrument, terminal.

ABSOLUTE MAXIMUM RATINGS

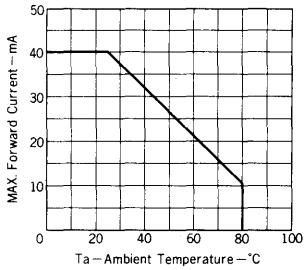
Maximum Power Dissipation (Ta = 25 °C)	P	100	mW
Maximum Forward Current (Ta = 25 °C)	I_F	40	mA
Maximum Reverse Voltage (Ta = 25 °C)	V_R	5	V
Maximum Temperatures			
Junction Temperature	T_j	100	°C
Storage Temperature	T_{stg}	−40 to +100	°C

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25 °C)

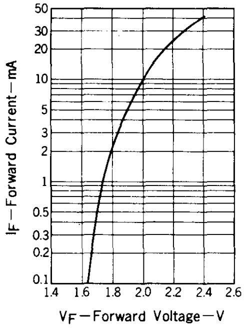
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Forward Voltage	V_F		2.0	2.4	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		590		nm	I_F = 10 mA
Spectral Line Half Width	Δλ		40		nm	I_F = 10 mA
Luminous Intensity	I_V	0.2	0.5		mcd	I_F = 10 mA

TYPICAL CHARACTERISTICS (Ta = 25 °C)

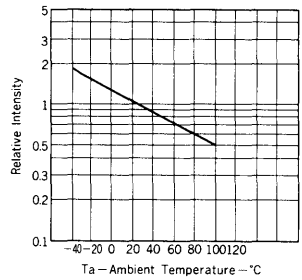
MAX. FORWARD CURRENT vs. AMBIENT TEMPERATURE



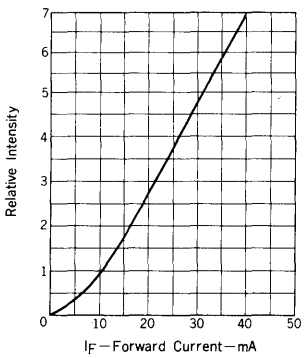
FORWARD CURRENT vs. FORWARD VOLTAGE



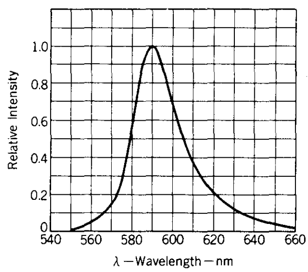
RELATIVE INTENSITY vs. AMBIENT TEMPERATURE



RELATIVE INTENSITY vs. FORWARD CURRENT



SPECTRAL DISTRIBUTION



HANDLING PRECAUTIONS:

1. The full resin-molded LED lamps have generally a little less mechanical and thermal strength than other resin-molded semiconductor devices as they have less additives. Therefore please note on the following points.
   (a) Soldering of leads should be made at the point 5 mm or more from the root of the leads at 260 °C and within 5 s.
   (b) If the temperature of the molded portion rises in addition to the residual stress between the leads, the possibility that open or short circuit occurs due to the deformation or destruction of the resin will increase.

2. On cleaning the device:
   (a) Cleaning with unsuitable solvent may impair the resin of the package and the following solvents should be used at the temperature of less than 45 °C and for less than 3 minutes of immersion time.
   Freon TE, Freon TF, Ethanol, Methanol
   Difron-solvent, Isopropyl-alcohol
   (b) Ultrasonic cleaning will add some stress on devices. The degree of the stress differs depending on the oscillation output power, the size of the PCB and the mounting methods of the devices, therefore it should be confirmed by making an experiment at actual conditions that the cleaning does not have any problem on the devices.

Contents

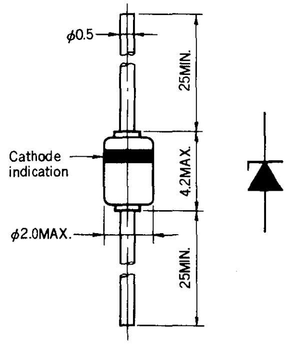
Rectifier Products

NEC
ELECTRON DEVICE

400mw ZENER DIODE
1N746A~1N759A

1N746A ~ 1N759A are DHD (Double Heatsink Diode) construction planar type zener diodes possessing an allowable power dissipation of 400m watt.

OUTLINE DRAWING
(Unit : mm)



FEATURES
- DHD (Double Heatsink Diode) Construction
- Planar process
- DO-35 Glass sealed package

APPLICATIONS

Circuits for,
Constant Voltage, Constant Current,
Wave form clipper, Surge absorber, etc.

MAXIMUM RATINGS

Power Dissipation (P) . . . . 400mW (See Fig. 1)
Junction Temperature (T_j) . . . . 175°C
Storage Temperature (T_{stg}) . . . . -65 to +175°C

ELECTRICAL CHARACTERISTICS (Ta = 25 ± 2°C)

Type	Zener Voltage V_Z (V) I_Z = 20mAdc		Maximum Reverse Current I_R (μA) V_R = 1V		Maximum Dinamic Impedance Z_Z (Ω) I_Z = 20mAdc iac = 1mA	Typical Temperature Coefficient z(% / °C)
	Min.	Max.	Ta = 25°C	Ta = 150°C		
1N746A	3.135	3.465	10	30	28	-0.060
1N747A	3.420	3.780	10	30	24	-0.055
1N748A	3.705	4.095	10	30	23	-0.050
1N749A	4.085	4.515	2	30	22	-0.035
1N750A	4.465	4.935	2	30	19	-0.015
1N751A	4.845	5.355	1	20	17	+0.005
1N752A	5.320	5.880	1	20	11	+0.020
1N753A	5.890	6.510	0.1	20	7	+0.030
1N754A	6.460	7.140	0.1	20	5	+0.040
1N755A	7.125	7.875	0.1	20	6	+0.045
1N756A	7.790	8.610	0.1	20	8	+0.050
1N757A	8.645	9.555	0.1	20	10	+0.055
1N758A	9.500	10.500	0.1	20	17	+0.060
1N759A	11.400	12.600	0.1	20	30	+0.065

Fig. 1 MAXIMUM POWER DISSIPATION

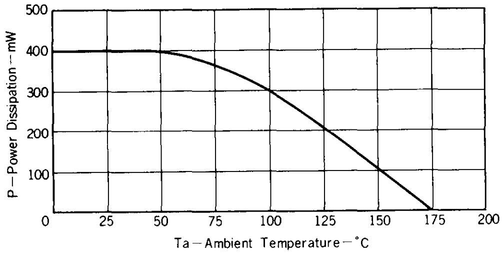


Fig. 2 P_{RSM} Rating

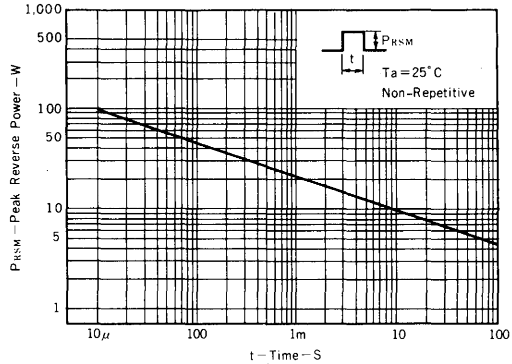


Fig. 3 Dynamic Impedance vs. Zener Voltage

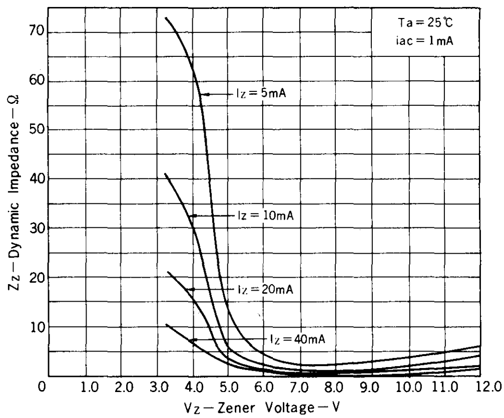


Fig. 4 Zener Temperature Coefficient vs. Zener Voltage

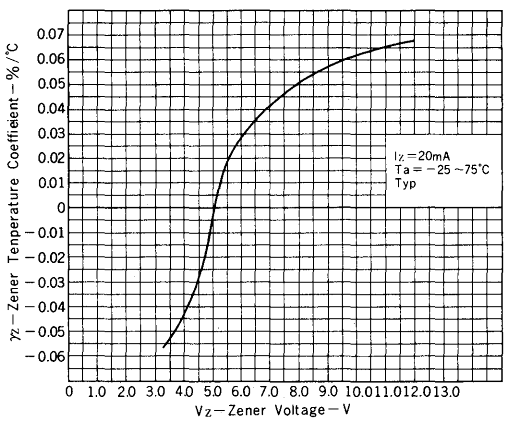
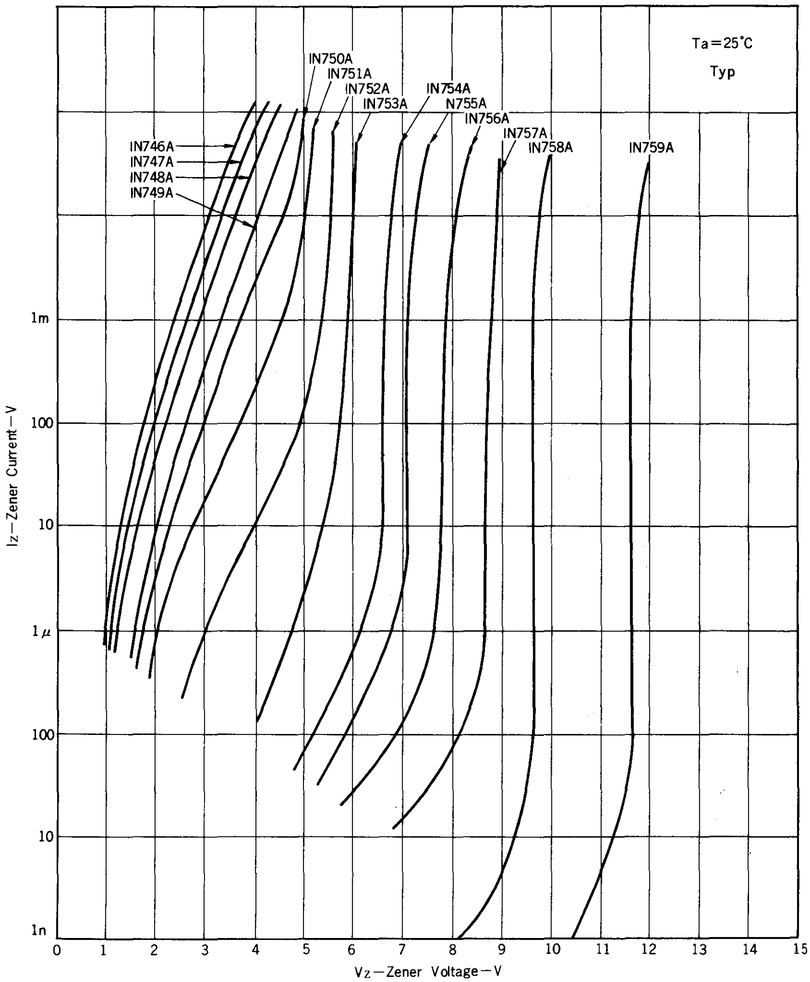


Fig. 5 Zener Voltage vs. Zener Current



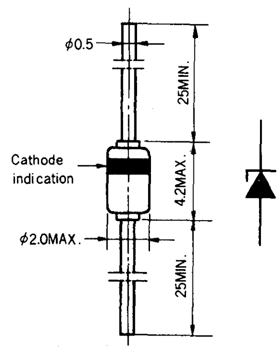
9

NEC
ELECTRON DEVICE

500mw ZENER DIODE
1N5221B thru 1N5271B

NEC Type 1N5221B through 1N5271B Series are DHD (Double Heatsink Diode) construction planar type zener diodes possessing an allowable power dissipation of 500m watt.

Outline Drawing (Unit : mm)



FEATURES

- DHD (Double Heatsink Diode) Construction
- Planar process
- DO-35 Glass sealed package

APPLICATIONS

Circuits for,
Constant Voltage, Constant Current,
Waveform clipper, Surge absorber, etc.

MAXIMUM RATINGS

Power Dissipation (P)	500mW (@T_L = 75°C, Lead·Length = 9.5mm)
Junction Temperature (T_j)	200°C
Storage Temperature (T_{stg})	- 65 to +200°C
Surge Power (P_{RSM})	10W (Non-recurrent square wave @ t = 8.3ms, T_j = 55°C, See Fig. 10)

TYPE NUMBER	Regulator Voltage (V_Z)	Test Current (I_Z)	Maximum Dynamic Impedance (Z_Z)	Maximum Reverse Current (I_R) 25°C	I_R Test Voltage (V_R) (For B Suffix)	Maximum Regulator Current (I_{ZM})	Maximum Dynamic Knee Impedance (Z_{ZK})	Maximum Temperature Coefficient
	V	madc	ohms	μa	V	ma	ohms	%/°C
1N5221B	2.4	20	30	100	1.0	191	1200	-.085
1N5222B	2.5	20	30	100	1.0	182	1250	-.085
1N5223B	2.7	20	30	75	1.0	168	1300	-.080
1N5224B	2.8	20	30	75	1.0	162	1400	-.080
1N5225B	3.0	20	29	50	1.0	151	1600	-.075
1N5226B	3.3	20	28	25	1.0	138	1600	-.070
1N5227B	3.6	20	24	15	1.0	126	1700	-.065
1N5228B	3.9	20	23	10	1.0	115	1900	-.060
1N5229B	4.3	20	22	5	1.0	106	2000	±.055
1N5230B	4.7	20	19	5	2.0	97	1900	±.055
1N5231B	5.1	20	17	5	2.0	89	1600	±.030
1N5232B	5.6	20	11	5	3.0	81	1600	+.038
1N5233B	6.0	20	7	5	3.5	76	1600	+.038
1N5234B	6.2	20	7	5	4.0	73	1000	+.045
1N5235B	6.8	20	5	3	5.0	67	750	+.050
1N5236B	7.5	20	6	3	6.0	61	500	+.058
1N5237B	8.2	20	8	3	6.5	55	500	+.062
1N5238B	8.7	20	8	3	6.5	52	600	+.065
1N5239B	9.1	20	10	3	7.0	50	600	+.068
1N5240B	10	20	17	3	8.0	45	600	+.075
1N5241B	11	20	22	2	8.4	41	600	+.076
1N5242B	12	20	30	1	9.1	38	600	+.077
1N5243B	13	9.5	13	0.5	9.9	35	600	+.079
1N5244B	14	9.0	15	0.1	10	32	600	+.082
1N5245B	15	8.5	16	0.1	11	30	600	+.082
1N5246B	16	7.8	17	0.1	12	28	600	+.083
1N5247B	17	7.4	19	0.1	13	27	600	+.084
1N5248B	18	7.0	21	0.1	14	25	600	+.085
1N5249B	19	6.6	23	0.1	14	24	600	+.086
1N5250B	20	6.2	25	0.1	15	23	600	+.086
1N5251B	22	5.6	29	0.1	17	21	600	+.087
1N5252B	24	5.2	33	0.1	18	19.1	600	+.088
1N5253B	25	5.0	35	0.1	19	18.2	600	+.089
1N5254B	27	4.6	41	0.1	21	16.8	600	+.090
1N5255B	28	4.5	44	0.1	21	16.2	600	+.091
1N5256B	30	4.2	49	0.1	23	15.1	600	+.091
1N5257B	33	3.8	58	0.1	25	13.8	700	+.092
1N5258B	36	3.4	70	0.1	27	12.6	700	+.093
1N5259B	39	3.2	80	0.1	30	11.5	800	+.094
1N5260B	43	3.0	93	0.1	33	10.6	900	+.095
1N5261B	47	2.7	105	0.1	36	9.7	1000	+.095
1N5262B	51	2.5	125	0.1	39	8.9	1100	+.096
1N5263B	56	2.2	150	0.1	43	8.1	1300	+.096
1N5264B	60	2.1	170	0.1	46	7.6	1400	+.097
1N5265B	62	2.0	185	0.1	47	7.3	1400	+.097
1N5266B	68	1.8	230	0.1	52	6.7	1600	+.097
1N5267B	75	1.7	270	0.1	56	6.1	1700	+.098
1N5268B	82	1.5	330	0.1	62	5.5	2000	+.098
1N5269B	87	1.4	370	0.1	68	5.2	2200	+.099
1N5270B	91	1.4	400	0.1	69	5.0	2300	+.099
1N5271B	100	1.3	500	0.1	76	4.5	2600	+.110

Fig. 1 Power Temperature Derating Curve

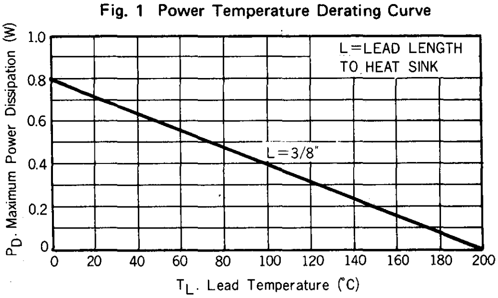


Fig. 2 V_Z — I_Z Characteristic

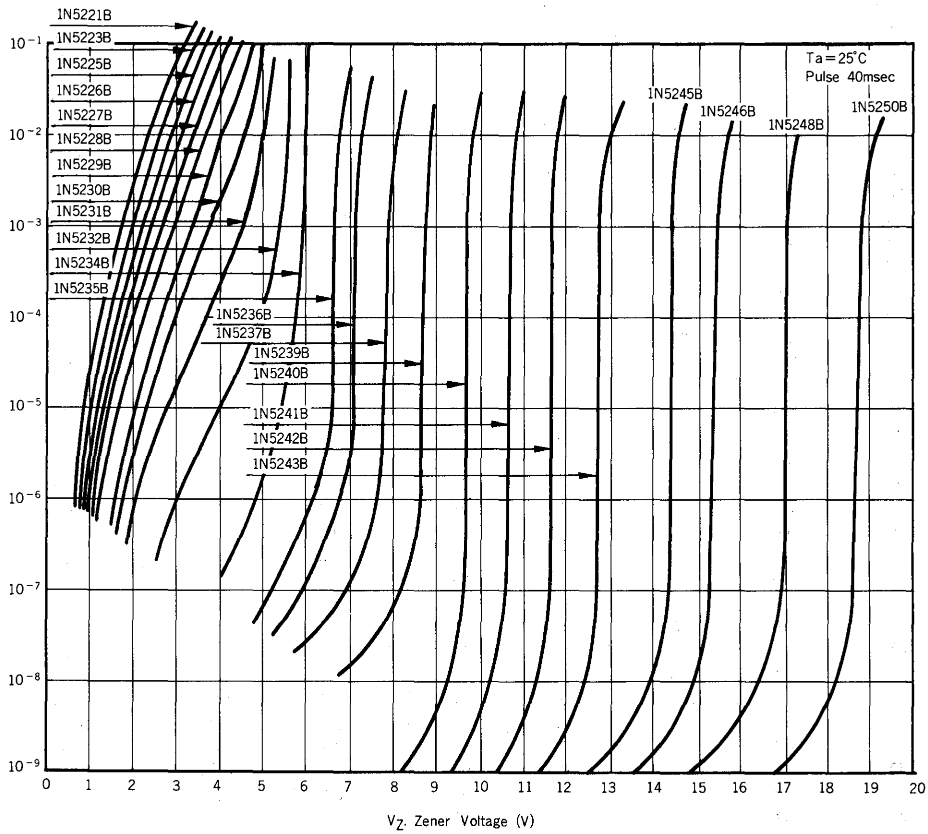


Fig. 3 $V_Z - I_Z$ Characteristic

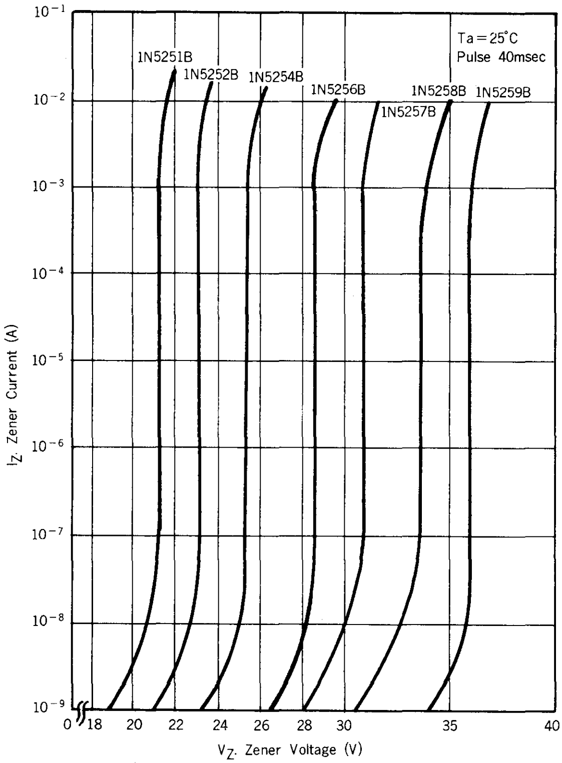


Fig. 4 $V_Z - I_Z$ Characteristic

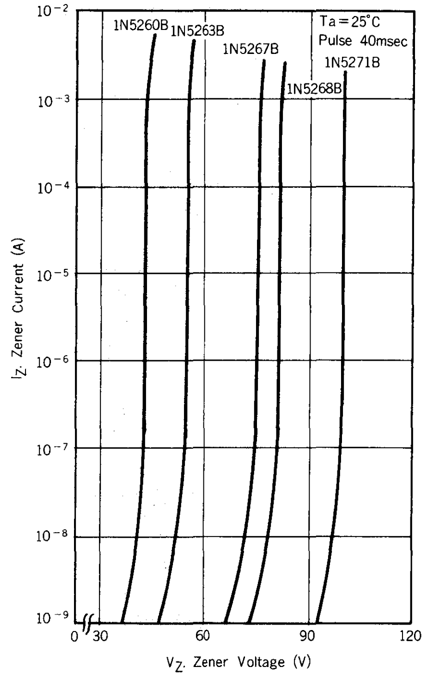


Fig. 5 Temperature Coefficient

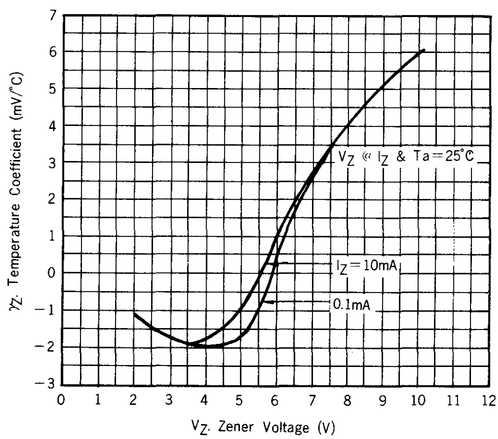
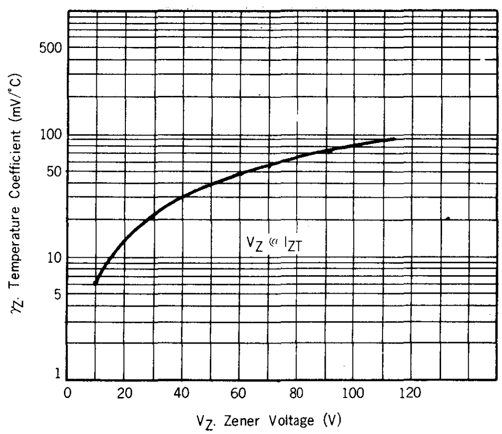


Fig. 6 Temperature Coefficient



9

Fig. 7 Voltage Regulation

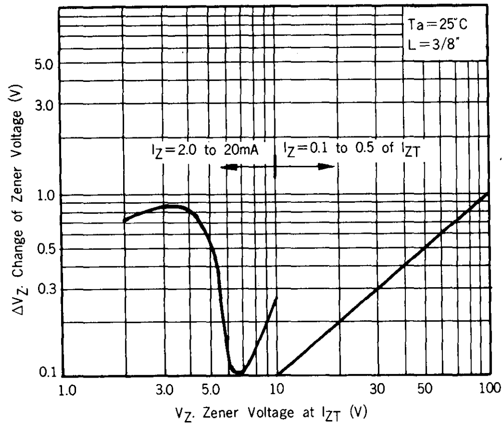


Fig. 8 Z_Z — V_Z Characteristic

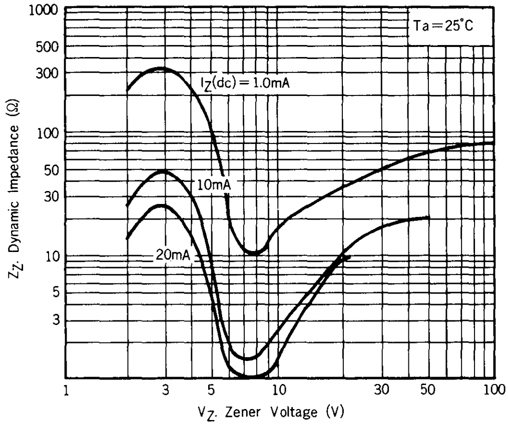


Fig. 9 Typical Thermal Resistance

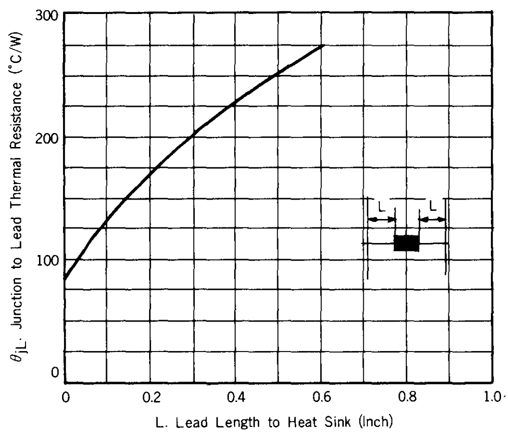
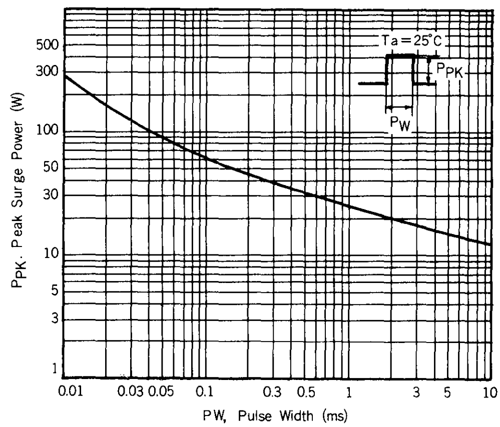


Fig. 10 Maximum Non-Repetitive Surge Power

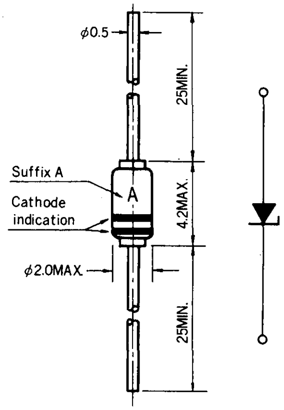


NEC
ELECTRON DEVICE

REFERENCE DIODE
1SZ45A ~ 1SZ48

NEC Type 1SZ45A ~ 1SZ48 are DHD (Double Heatsink Diode) construction planar type high stability refference diodes.

OUTLINE DRAWING (Unit : mm)



FEATURES

- DHD (Double Heatsink Diode) Construction
- Planar process
- High Stability and High Reliability
- Low zener current (I_Z = 1mA)
- DO-35 Glass sealed package

APPLICATIONS Circuits for,

Constant Voltage, Constant Current

Color Code

Black	Red	Green	Blue
1SZ45A	1SZ46A	1SZ47A	—
—	—	1SZ47	1SZ48

MAXIMUM RATINGS

Power Dissipation (P) .... 250mW (See Fig. 1)
Junction Temperature (T_j) .... 175°C
Storage Temperature (T_{stg}) .... −65 ~ +175°C

ELECTRICAL CHARACTERISTICS (Ta = 25 ± 2°C)

Type	Zener Voltage V_Z (V)		Zener Impedance Z_Z (Ω)	Zener Current	V_Z Temperature Coefficient γ_Z (%/°C)	Temperature Range
	Min.	Max.	Max.	I_Z (mA)	Max.	Ta (°C)
1SZ45A	6.1	6.7	100	1	±0.01	−40 ~ 100
1SZ46A					±0.005	
1SZ47A					±0.002	
1SZ47					±0.002	−10 ~ 60
1SZ48					±0.001	

9

Fig. 1 P-Ta Rating

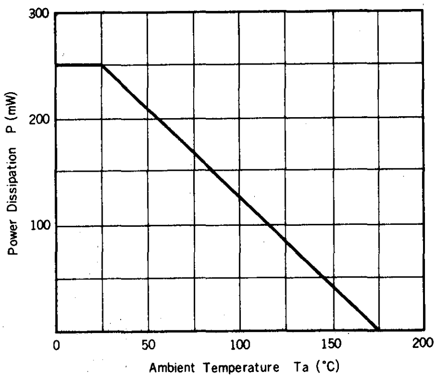


Fig. 2 γ_Z - V_Z Characteristic

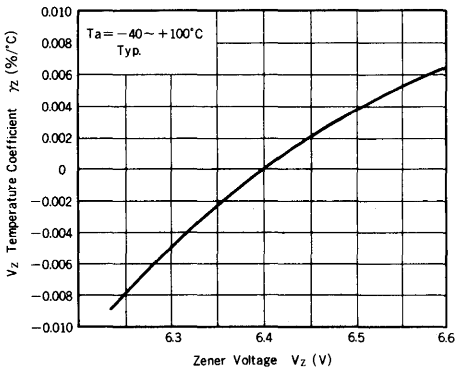


Fig. 3 γ_Z - I_Z Characteristic

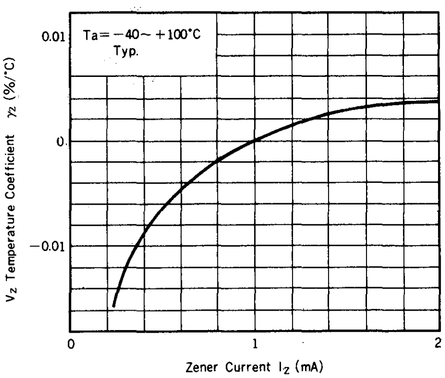


Fig. 4 Z_Z - I_Z Characteristic

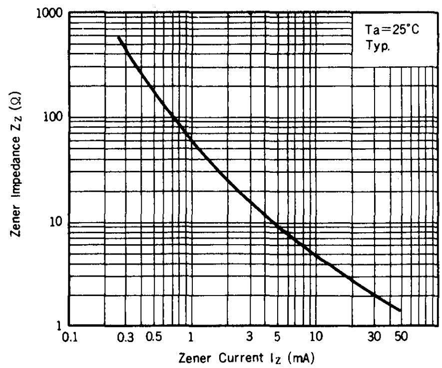
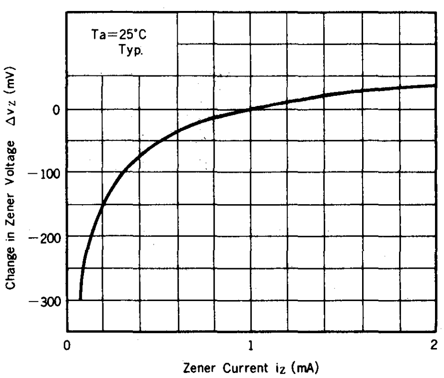


Fig. 5 Δv_Z - i_Z Characteristic

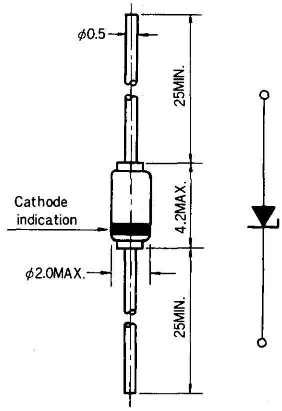


NEC
ELECTRON DEVICE

REFERENCE DIODE
1SZ50 ~ 1SZ53

NEC Type 1SZ50 ~ 1SZ53 are DHD (Double Heatsink Diode) construction planar type high stability refference diodes.

OUTLINE DRAWING (Unit : mm)



FEATURES

- DHD (Double Heatsink Diode) Construction
- Planar process
- High Stability and High Reliability
- DO-35 Glass sealed package

APPLICATIONS Circuits for,
Constant Voltage, Constant Current

Color Code

Black	Red	Green	Blue
1SZ50	1SZ51	1SZ52	1SZ53

MAXIMUM RATINGS

Power Dissipation (P) . . . . 250mW (See Fig. 1)
Junction Temperature (T_j) . . . . . 175°C
Storage Temperature (T_{stg}) . . . . −65 ~ +175°C

ELECTRICAL CHARACTERISTICS (Ta = 25 ± 2°C)

Type	Zener Voltage V_Z (V)		Zener Impedance Z_Z (Ω)	Zener Current I_Z (mA)	V_Z Temperature Coefficient γ_Z (%/°C)	Temperature Range Ta (°C)
	Min.	Max.	Max.		Max.	
1SZ50	5.9	6.5	15	7.5	±0.01	−25 ~ 75
1SZ51					±0.005	
1SZ52					±0.002	
1SZ53					±0.001	0 ~ 75

9

Fig. 1 P-Ta Rating

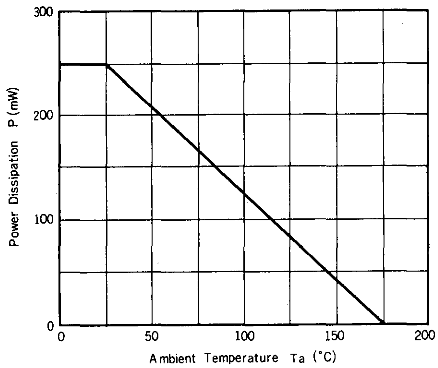


Fig. 2 $\gamma_Z - V_Z$ Characteristic

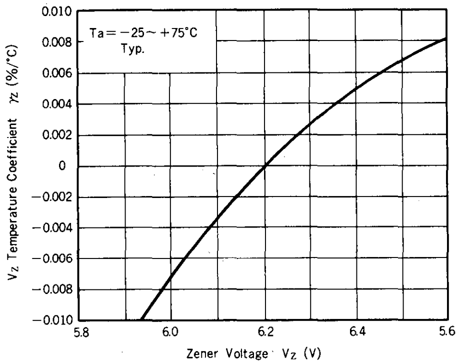


Fig. 3 $\gamma_Z - I_Z$ Characteristic

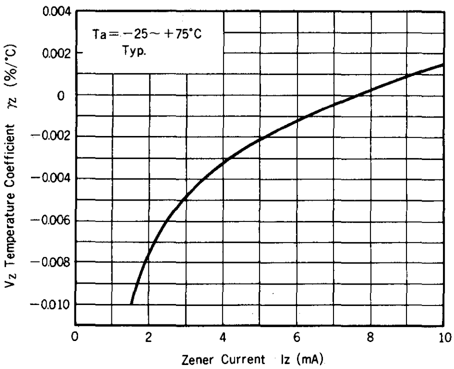


Fig. 4 $Z_Z - I_Z$ Characteristic

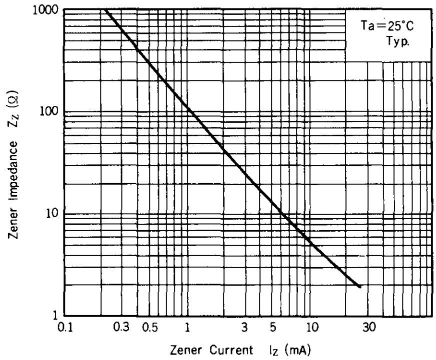
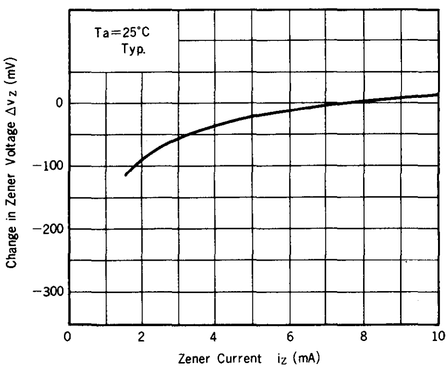


Fig. 5 $\Delta v_Z - i_Z$ Characteristic

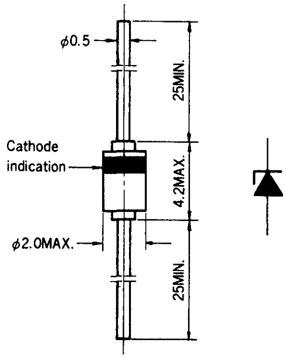


NEC
ELECTRON DEVICE

500mw ZENER DIODE
BZY88-C2V7 ~ BZY88-C33

NEC Type BZY88- Series are DHD (Double Heatsink Diode) construction planar type zener diodes possessing an allowable power dissipation of 500m watt.

OUTLINE DRAWING (Unit : mm)



FEATURES

- DHD (Double Heatsink Diode) Construction.
- Planar process.
- DO35 Glass sealed package.

APPLICATIONS

Circuits for,
Constant Voltage, Constant Current,
Waveform clipper, Surge absorber, etc.

MAXIMUM RATINGS

Power Dissipation (P)	500mW (See Fig. 1)
Junction Temperature (T_j)	175°C
Storage Temperature (T_{stg})	-65 to +175°C
Thermal Resistance ($R_{th(j-a)}$)	300°C/W*

*Valid provided that leads are kept at ambient temperature at a distance of 8mm from case.

ELECTRICAL CHARACTERISTICS ($T_a = 25°C$)

Type Number	*Zener Voltage V_Z (V) at $I_Z = 5mA$		Dynamic Impedance Z_Z (Ω) at $I_Z = 5mA$	Dynamic Knee Impedance Z_{zk} (Ω) at $I_z = 1mA$	Reverse Voltage (V) V_R (V) at $I_r = 100nA$	Temp. Coeff. of V_Z $\gamma z (10^{-4}/°C)$
	Min.	Max.	Max.	Max.	Min.	Nominal
BZY88-C2V7	2.5	2.9	83	500	–	-6.0
-C3V0	2.8	3.2	90	500	–	-6.0
-C3V3	3.1	3.5	90	500	–	-5.5
-C3V6	3.4	3.8	90	500	–	-5.0
-C3V9	3.7	4.1	90	500	–	-3.5
-C4V3	4.0	4.6	90	500	–	-1.0
-C4V7	4.4	5.0	78	500	–	+1.0
-C5V1	4.8	5.4	60	480	0.8	+2.0
-C5V6	5.2	6.0	40	400	1.0	+2.5
-C6V2	5.8	6.6	10	200	2.0	+3.0
-C6V8	6.4	7.2	8	150	3.0	+4.0
-C7V5	7.0	7.9	7	50	5.0	+5.0
-C8V2	7.7	8.7	7	50	6.0	+5.5
-C9V1	8.5	9.6	10	50	7.0	+6.0
-C10	9.4	10.6	15	70	7.5	+6.5
-C11	10.4	11.6	20	70	8.5	+7.0
-C12	11.4	12.7	20	90	9.0	+7.0
-C13	12.4	14.1	25	110	10.0	+7.0
-C15	13.8	15.6	30	110	11.0	+7.5
-C16	15.3	17.1	40	170	12.0	+7.5
-C18	16.8	19.1	50	170	14.0	+8.0
-C20	18.8	21.2	50	220	15.0	+8.0
-C22	20.8	23.3	55	220	17.0	+8.0
-C24	22.8	25.6	80	220	18.0	+8.0
-C27	25.1	28.9	80	250	20.0	+8.0
-C30	28.0	32.0	80	250	22.5	+8.0
-C33	31.0	35.0	80	250	25.0	+8.0

Note : *tested with pulse

Fig. 1 P — Ta Rating

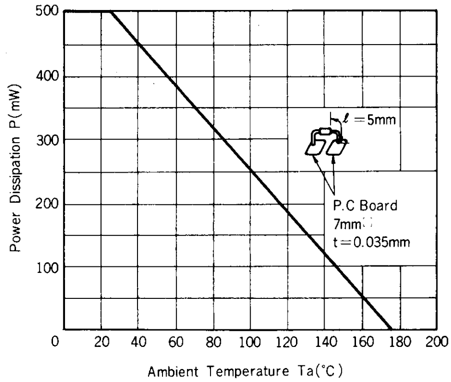


Fig. 2 R_{th} — S Characteristic

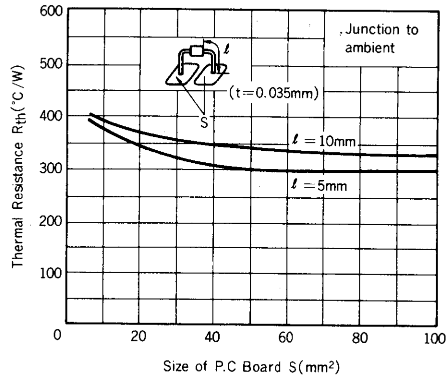


Fig. 3 v_Z — i_Z Characteristic

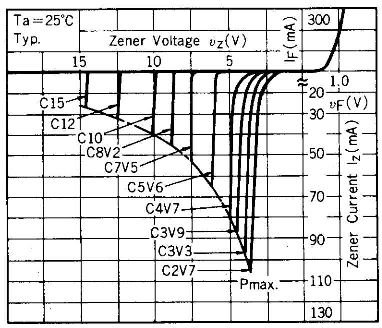


Fig. 4 v_Z — i_Z Characteristic

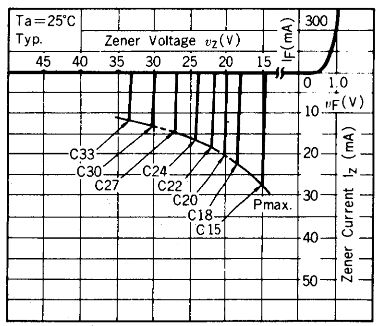


Fig. 5 Z_Z — I_Z Characteristic

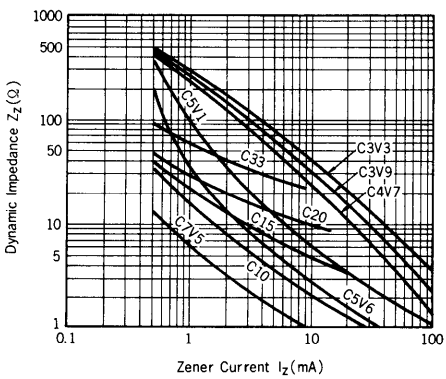
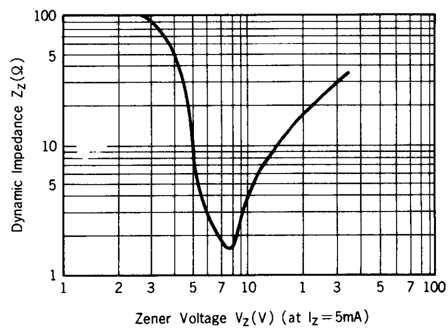


Fig. 6 Z_Z — V_Z Characteristic



9

Fig. 7 γ_{zth} − V_Z Characteristic

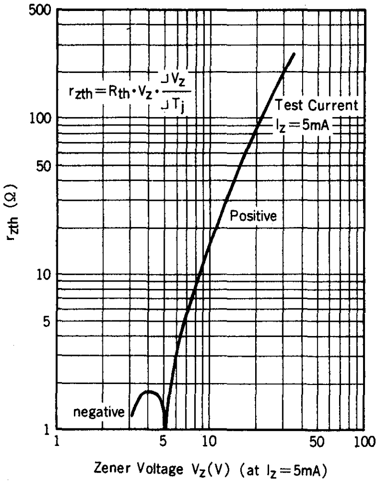


Fig. 8 γ_Z − V_Z Characteristic

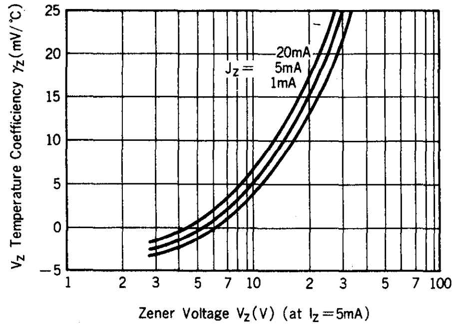


Fig. 9 ΔV_Z − Ta Characteristic

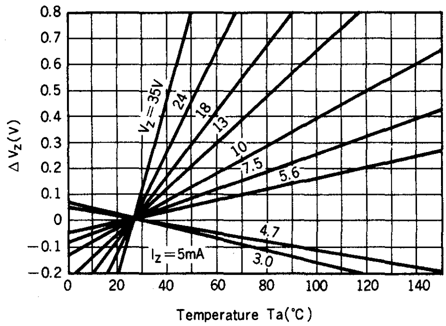


Fig. 10 ΔV_Z − V_Z Characteristic

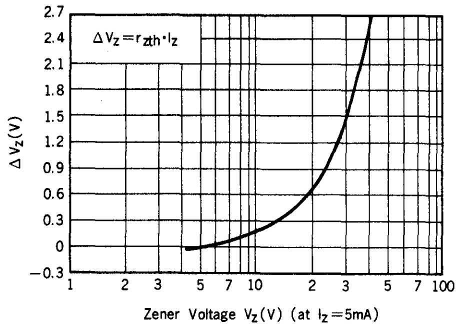


Fig. 11 P_{RSM} Rating

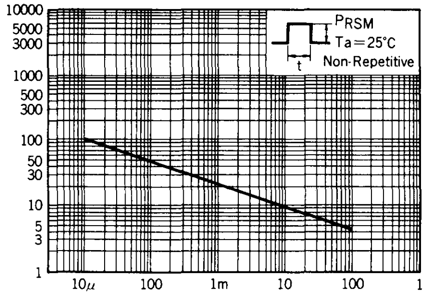


Fig. 12 Z_{th} Characteristic

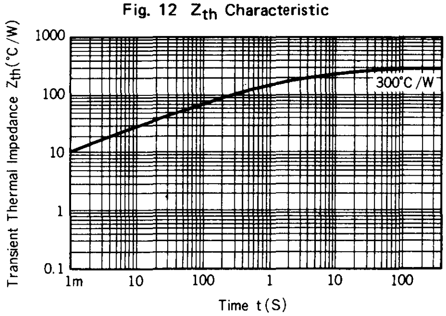
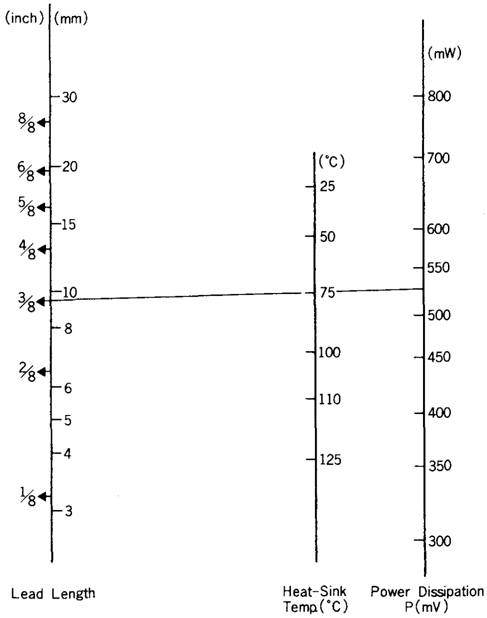


Fig. 13 Power Dissipation Nomogram



Example of use of power dissipation nomogram

Given : Lead length = 8 (mm)
Heat sink temperature = 25°C

Problem : Determine power dissipation of the zener diode

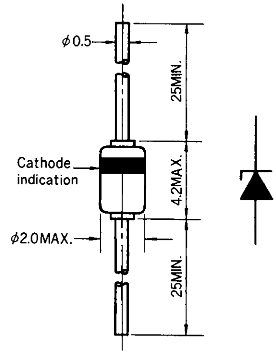
Solution : As shown on dashed line on nomogram, P = 525 (mW)

9

NEC
ELECTRON DEVICE

500mw ZENER DIODE
RD2.0E~RD100E

Outline Drawing (Unit: mm)



NEC Type RD ⌐⌙ E Series are DHD (Double Heatsink Diode) construction planar type zener diodes possessing an allowable power dissipation of 500 m watt.

FEATURES
- DHD (Double Heatsink Diode) Construction
- Planar process
- V_Z: Applied E24 standard
- DO-35 Glass sealed package

APPLICATIONS

Circuits for
Constant Voltage, Constant Current,
Wave form clipper, Surge absorber, etc.

MAXIMUM RATINGS

Power Dissipation (P)...................... 500 mW (See Fig. 1)
Junction Temperature (T_j)........... 175°C
Storage Temperature (T_{stg}).......... –65~+175°C

ELECTRICAL CHARACTERISTICS (Ta = 25±2°C)

Type	Suffix	Zener Voltage Vz (V)** Min.	Max.	Iz (mA)	Dynamic Impedance Zz (Ω)* Max.	Iz (mA)	Knee Dynamic Impedance Zzk (Ω)* Max.	Iz (mA)	Reverse Current IR (μA) Max.	VR (V)
RD2.0E	K	1.88	2.24	20	140	20	2,000	1	120	0.5
	B	1.88	2.12							
	C	2.00	2.24							
RD2.2E	K	2.08	2.45	20	120	20	2,000	1	120	0.7
	B	2.08	2.33							
	C	2.20	2.45							
RD2.4E	K	2.28	2.70	20	100	20	2,000	1	120	1,0
	B	2.28	2.56							
	C	2.40	2.70							
RD2.7E	B	2.5	2.9	20	100	20	2,000	1	100	1.0
	C	2.7	3.1							
RD3.0E	B	2.8	3.2	20	80	20	1,700	1	50	1.0
	C	3.0	3.4							
RD3.3E	B	3.1	3.5	20	70	20	1,500	1	20	1.0
	C	3.3	3.7							
RD3.6E	B	3.4	3.8	20	60	20	1,300	1	10	1.0
	C	3.6	4.0							
RD3.9E	B	3.7	4.1	20	50	20	1,200	1	10	1.0
	C	3.9	4.4							
RD4.3E	B	4.0	4.5	20	40	20	1,000	1	10	1.0
	C	4.3	4.8							
RD4.7E	B	4.4	4.9	20	35	20	900	1	10	1.0
	C	4.7	5.2							
RD5.1E	B	4.8	5.4	20	30	20	800	1	5	1.0
	C	5.1	5.7							
RD5.6E	B	5.3	6.0	20	25	20	500	1	5	1.5
	C	5.6	6.3							
RD6.2E	B	5.8	6.6	20	20	20	300	1	5	3.0
	C	6.2	7.0							
RD6.8E	B	6.4	7.2	20	10	20	150	0.5	2	3.5
	C	6.8	7.7							
RD7.5E	B	7.0	7.9	20	10	20	150	0.5	2	4.0
	C	7.5	8.4							
RD8.2E	B	7.7	8.7	20	10	20	150	0.5	2	5.0
	C	8.2	9.3							
RD9.1E	B	8.5	9.6	20	10	20	150	0.5	2	6.0
	C	9.1	10.2							
RD10E	B	9.4	10.6	20	10	20	150	0.5	2	7.0
	C	10.0	11.2							
RD11E	B	10.4	11.6	10	15	10	150	0.5	2	7.0
	C	11.0	12.3							
RD12E	B	11.4	12.6	10	20	10	150	0.5	2	9.0
	C	12.0	13.5							
RD13E	B	12.4	14.1	10	25	10	150	0.5	2	10
	C	13.3	15.0							
RD15E	B	13.8	15.6	10	30	10	150	0.5	2	11
	C	14.7	16.5							
RD16E	B	15.3	17.1	10	35	10	150	0.5	2	12
	C	16.2	18.3							
RD18E	B	16.8	19.1	10	45	10	200	0.5	2	13
	C	18.0	20.3							

Type		Zener Voltage Vz (V)**			Dynamic Impedance Zz (Ω)*		Knee Dynamic Impedance Zzk (Ω)*		Reverse Current IR (μA)	
	Suffix	Min.	Max.	Iz (mA)	Max.	Iz (mA)	Max.	Iz (mA)	Max.	VR (V)
RD20E	B	18.8	21.2	10	55	10	200	0.5	2	15
	C	20.0	22.4							
RD22E	B	20.8	23.3	5	60	5	200	0.5	2	17
	C	22.0	24.5							
RD24E	B	22.8	25.6	5	75	5	300	0.5	2	19
	C	24.0	27.6							
RD27E	B	25.1	28.9	5	95	5	300	0.5	2	21
	C	27.0	30.8							
RD30E	B	28.0	32.0	5	130	5	300	0.5	2	23
	C	30.0	34.0							
RD33E	B	31.0	35.0	5	160	5	400	0.5	2	25
	C	33.0	37.0							
RD36E	B	34.0	38.0	5	200	5	400	0.5	2	27
	C	36.0	40.0							
RD39E	B	37.0	41.0	5	250	5	400	0.5	2	30
	C	39.0	43.0							

* Z_Z is measured at I_Z by given a very small AC current signal.
** Narrow V_Z device is abailable if required.

ELECTRICAL CHARACTERISTICS (Ta = 25±2°C)

Type Name		Zener Voltage Vz (V)***			Dynamic Impedance Zz (Ω)*		Reverse Current IR (μA)	
	Suffix	Min.	Max.	Iz (mA)	Max.	Iz (mA)	Max.	VR (V)
RD43E	B	40	45	5	90	5	1	33
RD47E	B	44	49	5	90	5	1	36
RD51E	B	48	54	5	110	5	1	39
RD56E	B	53	60	5	110	5	1	43
RD62E	B	58	66	2	200	2	1	47
RD68E	B	64	72	2	200	2	1	52
RD75E	B	70	79	2	300	2	1	57
RD82E	B	77	87	2	300	2	1	63
RD91E	B	85	96	2	400	2	1	69
RD100E	B	94	106	2	400	2	1	76

*** tested with pulse (40 msec)

Fig. 1 P—Ta Rating

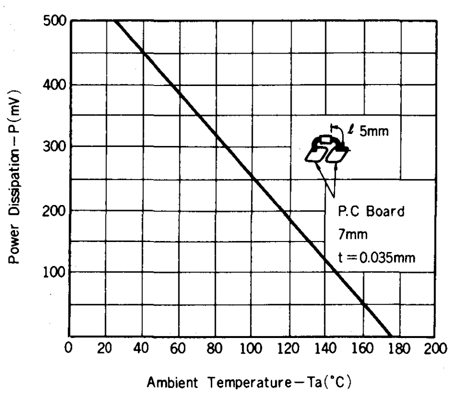


Fig. 2 v_Z–i_Z Characteristic

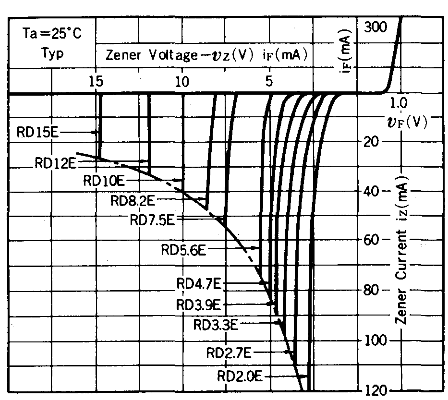


Fig. 3 $v_Z - i_Z$ Characteristic

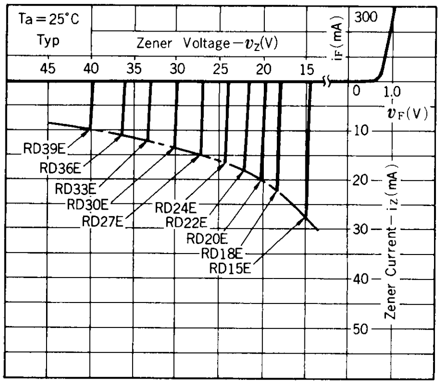


Fig. 4 $v_Z - i_Z$ Characteristic

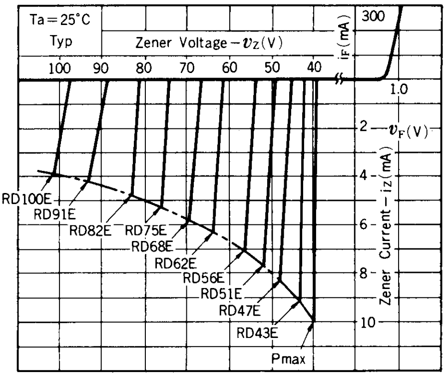


Fig. 5 $\gamma_Z - v_Z$ Characteristic

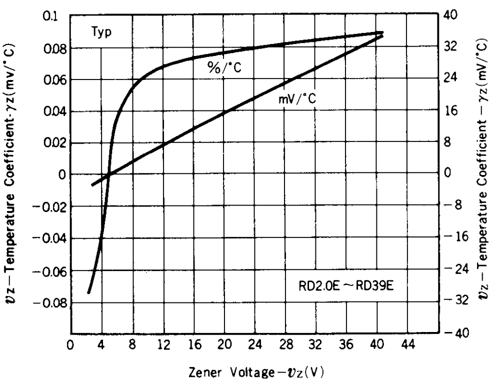


Fig. 6 $\gamma_Z - v_Z$ Characteristic

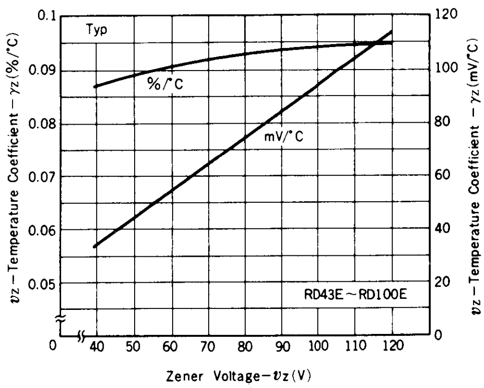


Fig. 7 $Z_Z - i_Z$ Characteristic

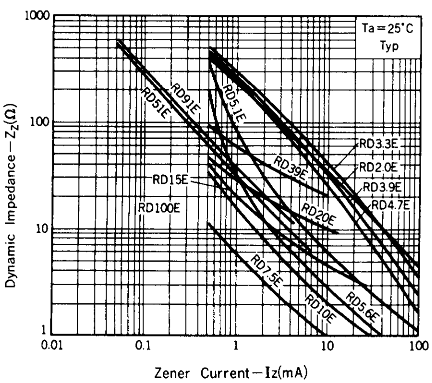
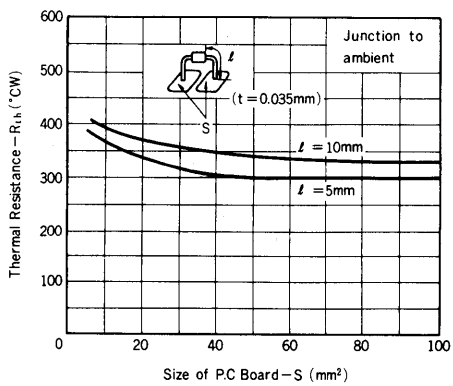


Fig. 8 Rth－S Characteristic



9

Fig. 9 PRSM Rating

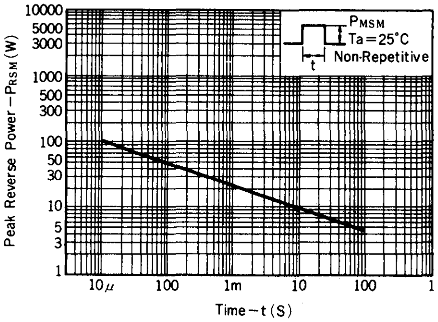
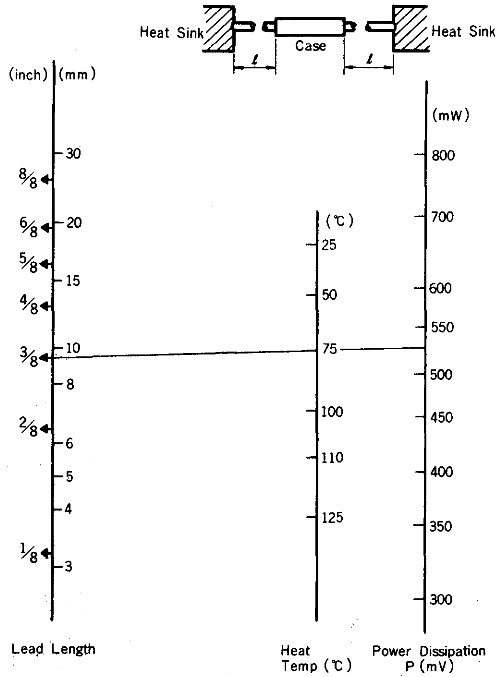


Fig. 10 Power Dissipation Nomogram



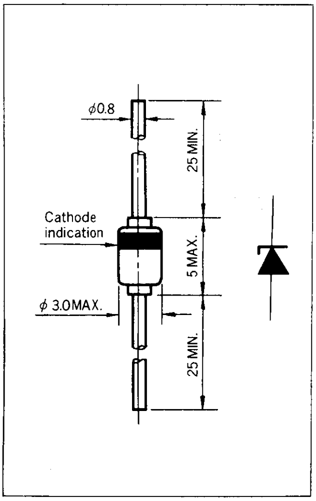
Example of use of power dissipation nomogram

Given : Lead length = 3/8 inch
Heat sink temperature = 75°C
Problem : Determine power dissipation of the zener diode
Solution : As shown on dashed line on nomogram, P = 525 (mW)

NEC
ELECTRON DEVICE

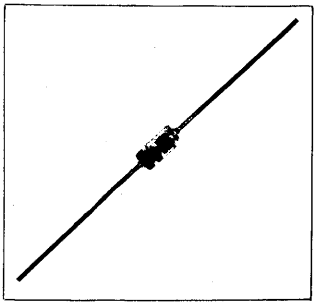
1W ZENER DIODE
RD2.0F～RD82F

NEC Type RD ⌐┘ F Series are DHD (Double Heatsink Diode) Construction planar type zener diodes possessing an allowable power dissipation of 1 watt.



FEATURES

- DHD (Double Heatsink Diode) Construction
- Planar process
- V_Z: Applied E24 standard
- DO-41 Glass sealed package



APPLICATIONS

Circuits for,
Constant Voltage, Constant Current,
Wave form clipper, Surge absorber, etc.

MAXIMUM RATINGS

Power Dissipation (P)	1W (See Fig. 1)
Junction Temperature (Tj)	175°C
Storage Temperature (T_{stg})	−65～+175°C

9

ELECTRICAL CHARACTERISTICS (Ta = 25 ± 2°C)

Type Number		Zener Voltage V_Z (V)*			Dinamic Impedance Z_Z (Ω)*		Reverse Current I_R (μA)	
	Suffix	Min.	Max.	I_Z (mA)	Max.	I_Z (mA)	Max.	V_R (V)
RD2.0F	B	1.88	2.12	40	25	40	200	0.5
	C	2.0	2.24					
RD2.2F	B	2.08	2.33	40	20	40	200	0.7
	C	2.2	2.45					
RD2.4F	B	2.28	2.56	40	15	40	200	1.0
	C	2.40	2.70					
RD2.7F	B	2.5	2.9	40	15	40	150	1.0
	C	2.7	3.1					
RD3.0F	B	2.8	3.2	40	15	40	100	1.0
	C	3.0	3.4					
RD3.3F	B	3.1	3.5	40	15	40	80	1.0
	C	3.3	3.7					
RD3.6F	B	3.4	3.8	40	15	40	60	1.0
	C	3.6	4.0					
RD3.9F	B	3.7	4.1	40	15	40	40	1.0
	C	3.9	4.4					
RD4.3F	B	4.0	4.5	40	15	40	20	1.0
	C	4.3	4.8					
RD4.7F	B	4.4	4.9	40	10	40	20	1.0
	C	4.7	5.2					
RD5.1F	B	4.8	5.4	40	8	40	20	1.0
	C	5.1	5.7					
RD5.6F	B	5.3	6.0	40	8	40	20	1.5
	C	5.6	6.3					
RD6.2F	B	5.8	6.6	40	6	40	20	3.0
	C	6.2	7.0					
RD6.8F	B	6.4	7.2	40	6	40	20	3.5
	C	6.8	7.7					
RD7.5F	B	7.0	7.9	40	4	40	20	4.0
	C	7.5	8.4					
RD8.2F	B	7.7	8.7	40	4	40	20	5.0
	C	8.2	9.3					
RD9.1F	B	8.5	9.6	40	6	40	20	6.0
	C	9.1	10.2					
RD10F	B	9.4	10.6	40	6	40	10	7.0
	C	10.0	11.2					
RD11F	B	10.4	11.6	20	8	20	10	8.0
	C	11.0	12.3					
RD12F	B	11.4	12.6	20	8	20	10	9.0
	C	12.0	13.5					
RD13F	B	12.4	14.1	20	10	20	10	10
	C	13.3	15.0					
RD15F	B	13.8	15.6	20	10	20	10	11
	C	14.7	16.5					
RD16F	B	15.3	17.1	20	12	20	10	12
	C	16.2	18.3					
RD18F	B	16.8	19.1	20	12	20	10	13
	C	18.0	20.3					
RD20F	B	18.8	21.2	20	14	20	10	15
	C	20.0	22.4					
RD22F	B	20.8	23.3	10	14	10	10	17
	C	22.0	24.5					
RD24F	B	22.8	25.6	10	16	10	10	19
	C	23.0	27.6					
RD27F	B	25.1	28.9	10	16	10	10	21
	C	27.0	30.8					
RD30F	B	28.0	32.0	10	18	10	10	23
	C	30.0	34.0					
RD33F	B	31.0	35.0	10	18	10	10	25
	C	33.0	37.0					
RD36F	B	34.0	38.0	10	20	10	10	27
	C	36.0	40.0					
RD39F	B	37.0	41.0	10	20	10	10	30
	C	39.0	43.0					

Type Number		Zener Voltage V_Z (V)*			Dinamic Impedance Z_Z (Ω)**		Reverse Current I_R (μA)	
	Suffix	Min.	Max.	I_Z (mA)	Max.	I_Z (mA)	Max.	V_R (V)
RD43F	B	40	45	10	50	10	5	33
RD47F	B	44	49	10	50	10	5	36
RD51F	B	48	54	10	50	10	5	39
RD56F	B	53	60	10	50	10	5	43
RD62F	B	58	66	10	50	10	5	47
RD68F	B	64	72	10	75	10	5	52
RD75F	B	70	79	10	90	10	5	57
RD82F	B	77	87	10	90	10	5	63

* RD2.0FB～RD39FB: tested with D.C.
RD43FB～RD82FB: tested with pulse (40msec.)
** Z_Z is measured at I_Z by given a very small A.C. current signal.

Fig. 1 P—Ta Rating

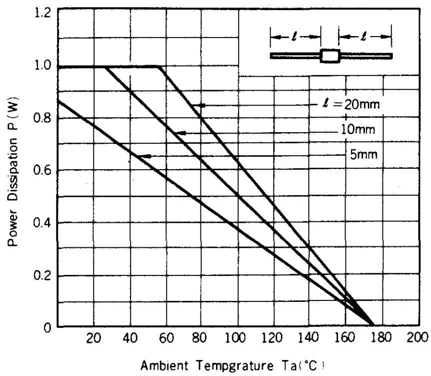


Fig. 2 v_Z—i_Z Characteristic

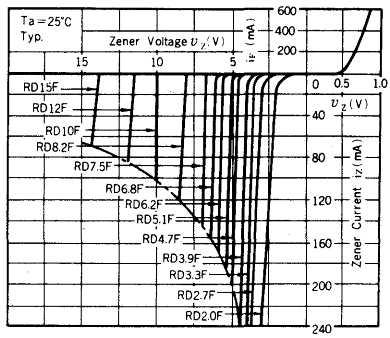


Fig. 3 v_Z—i_Z Characteristic

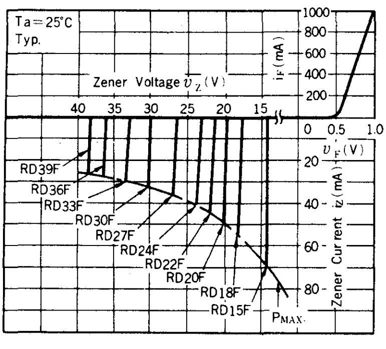


Fig. 4 v_Z—i_Z Characteristic

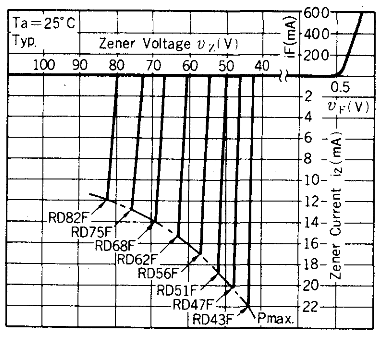


Fig. 5 γ_Z–V_Z Characteristic

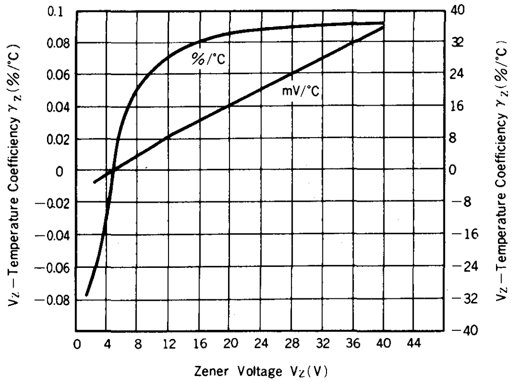


Fig. 6 γ_Z–V_Z Characteristic

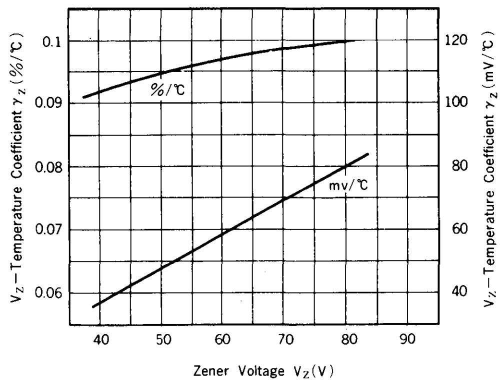


Fig. 7 Z_Z–I_Z Characteristic

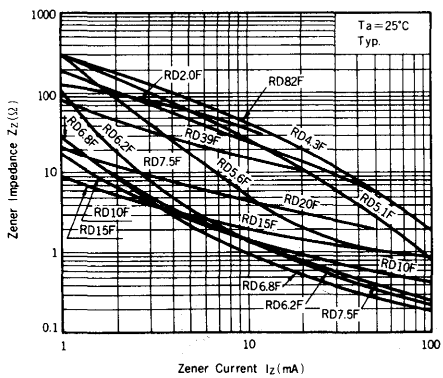


Fig. 8 Rth– S Characteristic

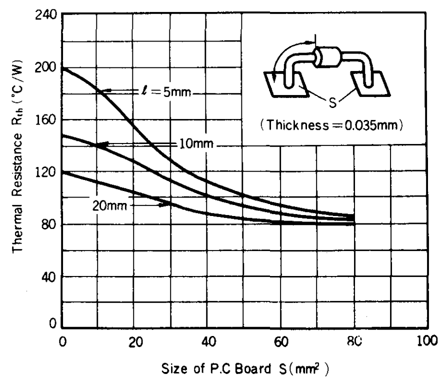


Fig. 9 PRSM Rating

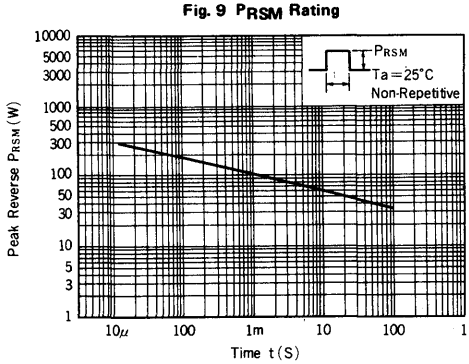


Fig. 10 Zth Characteristic

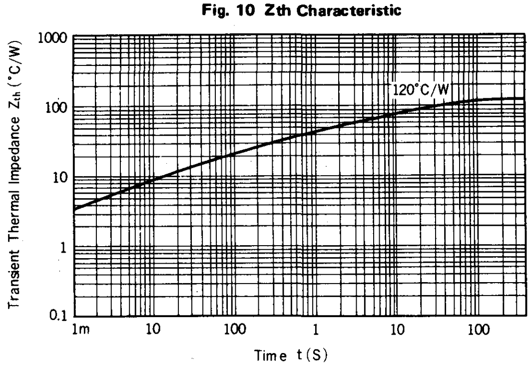
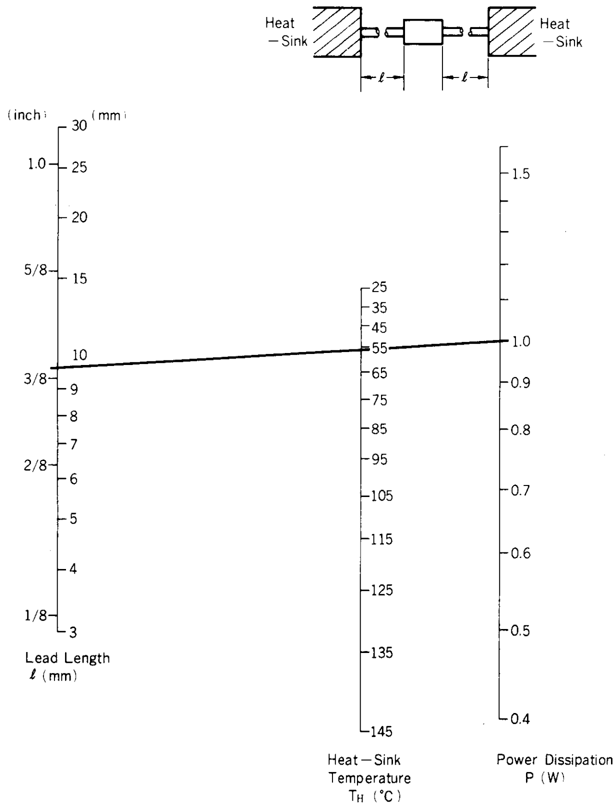


Fig. 11 Power Dissipation Nomogram



9

NEC
ELECTRON DEVICE

RD4.7JB ~ RD39JB

Low noise, Sharp Breakdown characteristics
400mw Zener Diode.

NEC Type RD[]J series are DHD (Double Heatsink Diode) construction planar type Zener diode possessing an allowable power dissipation of 400mW, featuring low noise and sharp breakdown characteristic. They are intend for use in audio equipment and instrument equipment.

FEATURES

- Low noise
- Sharp Breakdown characteristic
- DHD (Double Heatsink Diode) construction
- Planar process
- Vz Applied E24 standard
- D0-35 Glass sealed package

APPLICATIONS

Circuits for,

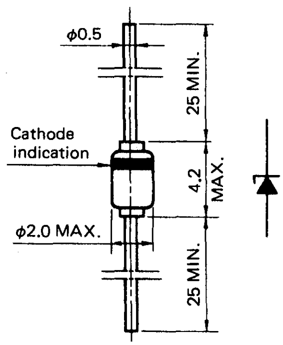
Constant Voltage, Constant Current, Wave form clipper, etc.

MAXIMUM RATINGS

Power Dissipation (P) . . . . 400mW (See Fig. 1)
Junction Temperature (Tj) . . . . 175°C
Storage Temperature (Tstg) . . . . −65 ~ +175°C

OUTLINE DRAWING

(Unit: mm)



Marking color: Blue

ELECTRICAL CHARACTERISTICS (T_a=25±2°C)

Type Number	Zener Voltage Vz (V)*			Dynamic Impedance Zz (Ω)**		Knee Dynamic Impedance Zzk (Ω)**		Reverse Current I_R (μA)	
	MIN.	MAX.	Iz(mA)	MAX.	Iz(mA)	MAX.	Iz(mA)	MAX.	V_R(V)
RD4.7JB	4.4	4.9	5	100	5	800	0.5	2	1.0
RD5.1JB	4.8	5.4	5	80	5	500	0.5	2	1.5
RD5.6JB	5.3	6.0	5	60	5	200	0.5	1	2.5
RD6.2JB	5.8	6.6	5	60	5	100	0.5	1	3.0
RD6.8JB	6.4	7.2	5	40	5	60	0.5	0.5	3.5
RD7.5JB	7.0	7.9	5	30	5	60	0.5	0.5	4.0
RD8.2JB	7.7	8.7	5	30	5	60	0.5	0.5	5.0
RD9.1JB	8.5	9.6	5	30	5	60	0.5	0.5	6.0
RD10JB	9.4	10.6	5	30	5	60	0.5	0.1	7.0
RD11JB	10.4	11.6	5	30	5	60	0.5	0.1	8.0
RD12JB	11.4	12.6	5	30	5	80	0.5	0.1	9.0
RD13JB	12.4	14.1	5	37	5	80	0.5	0.1	10
RD15JB	13.8	15.6	5	42	5	80	0.5	0.1	11
RD16JB	15.3	17.1	5	50	5	80	0.5	0.1	12
RD18JB	16.8	19.1	5	65	5	80	0.5	0.1	13
RD20JB	18.8	21.2	5	85	5	100	0.5	0.1	15
RD22JB	20.8	23.3	5	100	5	100	0.5	0.1	17
RD24JB	22.8	25.6	5	120	5	120	0.5	0.1	19
RD27JB	25.1	28.9	5	150	5	150	0.5	0.1	21
RD30JB	28.0	32.0	5	200	5	200	0.5	0.1	23
RD33JB	31.0	35.0	5	250	5	250	0.5	0.1	25
RD36JB	34.0	38.0	5	300	5	300	0.5	0.1	27
RD39JB	37.0	41.0	5	360	5	360	0.5	0.1	30

* tested with pulse (40 ms).
** Zz & Zzk are measured at Iz by given a very small A.C. current signal.

Fig. 1 P—Ta Rating

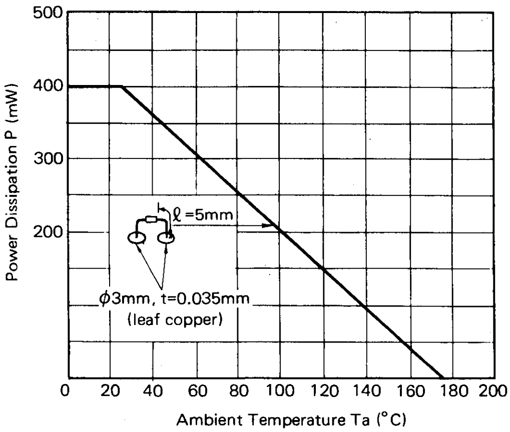


Fig. 2 v_Z—i_Z Characteristic

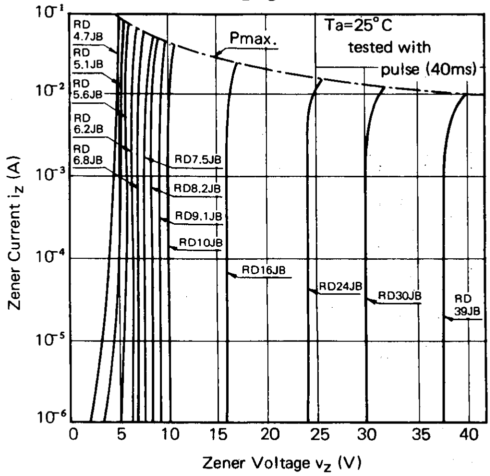


Fig. 3 γ_Z—v_Z Characteristic

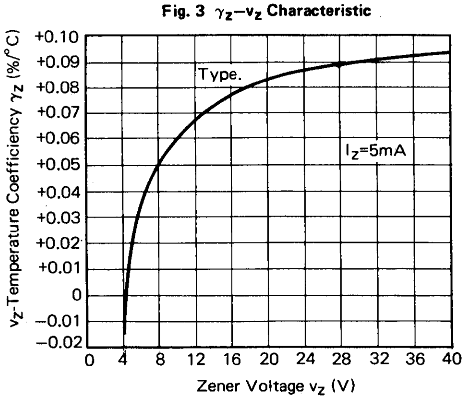
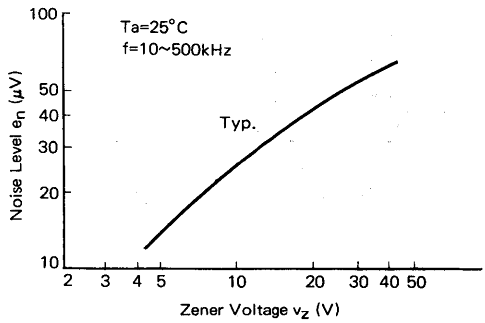


Fig. 4 e_n—v_Z Characteristic



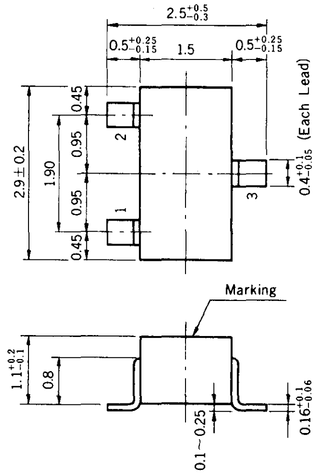
NEC
ELECTRON DEVICE

150mW ZENER DIODE
RD2.4M ~ RD24M

PLANAR TYPE ZENER DIODE

NEC Type RD2.4M through RD24M Series are planar type zener diodes possessing an allowable power dissipation of 150 m Watt.

Outline Drawing (Unit : mm)



1. NC
2. Anode
3. Cathode

FEATURES

- Vary small size to assure good space factor in hybrid IC applications.
- Planar process
- Vz; Applied E24 standard.

MAXIMUM RATINGS

Power Dissipation (P) .... 150 mW
Junction Temperature (Tj) .... 125°C
Storage Temperature (T_{stg}) .... –50~125°C

9

ELECTRICAL CHARACTERISTICS (Ta=25°C)

Type Number	Suffix	Zener Voltage Vz (V)* (at Iz=5mA)		Maximum Dynamic Impedance Zz (Ω)** (at Iz=5mA)	Maximum Reverse Current I_R (μA)	I_R Test Voltage V_R (V)
		MIN.	MAX.			
RD2.4M	B	2.2	2.6	100	120	1.0
RD2.7M	B	2.4	2.9	110	120	1.0
RD3.0M	B	2.7	3.2	120	50	1.0
RD3.3M	B	3.0	3.5	130	20	1.0
RD3.6M	B	3.3	3.8	130	10	1.0
RD3.9M	B	3.6	4.2	130	10	1.0
RD4.3M	B	4.0	4.6	130	10	1.0
RD4.7M	B	4.4	5.0	130	10	1.0
RD5.1M	B	4.8	5.4	130	5	1.5
RD5.6M	B	5.2	6.0	80	5	2.5
RD6.2M	B	5.8	6.6	50	2	3.0
RD6.8M	B	6.4	7.2	30	2	3.5
RD7.5M	B	7.0	7.9	30	2	4.0
RD8.2M	B	7.7	8.7	30	2	5.0
RD9.1M	B	8.5	9.6	30	2	6.0
RD10M	B	9.4	10.6	30	2	7.0
RD11M	B	10.4	11.6	30	2	8.0
RD12M	B	11.4	12.6	35	2	9.0
RD13M	B	12.4	14.1	35	2	10.0
RD15M	B	13.9	15.6	40	2	11.0
RD16M	B	15.4	16.8	40	2	12.0
RD18M	B	16.6	18.9	45	2	13.0
RD20M	B	18.7	20.0	50	2	15.0
RD22M	B	19.8	23.1	55	2	17.0
RD24M	B	22.9	25.2	60	2	19.0

* Tested with pulse (40ms).
** Zz is measured at Iz by given a very small A.C. current signal.

Fig. 1 P — Ta Rating

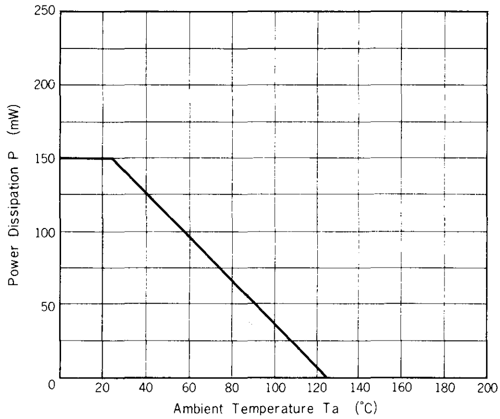


Fig. 2 Vz—iz Characteristic

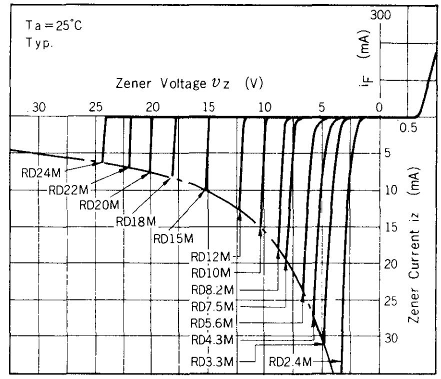


Fig. 3 Zz — Iz Characteristic

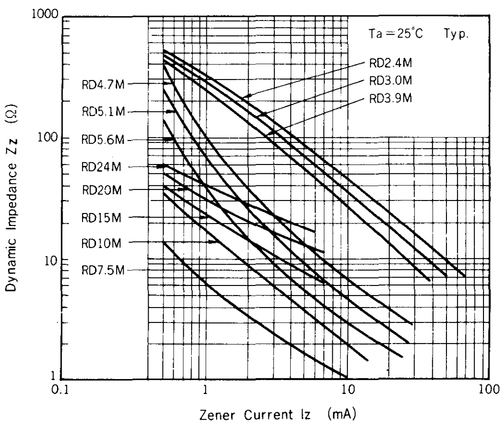
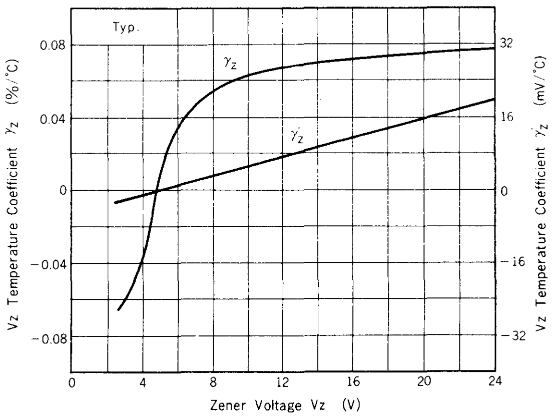


Fig. 4 Vz — γz Characteristic



9

PRELIMINARY SPECIFICATIONS

NEC
NEC ELECTRON

P-GATE ALL DIFFUSED MOLD TYPE THYRISTOR

03P4MGC, 03P5MGC

The 03P4MGC~03P5MGC are P-gate all diffused mold type SCR rated at 0.8 Amps RMS maximum on-state current, with rated voltages up to 600 volts.

FEATURES

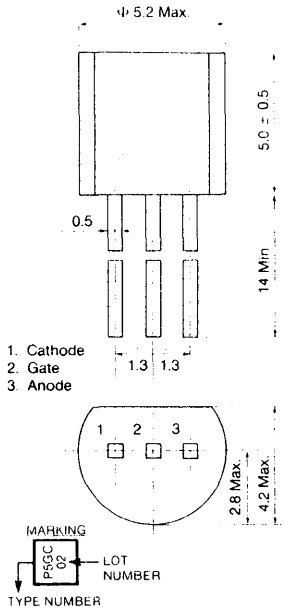
- Plastic TO-92 package
- 50μA gate sensitivity
- 5 mA holding current
- 8 A surge current
- 400 through 500V selection
  Special selection to 600V available

APPLICATIONS

Cassette tape recorder, Television
Automobile equipment
Strobe flasher
Automatic gas lighter,
Solid-state relay
Light display equipment
Motor, solenoid and temperature control etc.

1. OUTLINE DRAWING

JEDEC TO-92



2. MAXIMUM RATINGS

ITEM	SYMBOL	03P4MGC	03P5MGC	UNIT
Non-Repetitive Peak Reverse Voltage*	V_{RSM}	700	700	V
Non-Repetitive Peak Off-State Voltage*	V_{DSM}	700	700	V
Repetitive Peak Reverse Voltage*	V_{RRM}	400	500	V
Repetitive Peak Off-State Voltage*	V_{DRM}	400	500	V
On-State Current	$I_{T(AV)}$	0.5		A
	$I_{T(RMS)}$	0.8		A
Surge On-State Current	I_{TSM}	8 (50H_z Non-rep.)		A
Peak Gate Power Dissipation	P_{GM}	100		mW
Average Gate Power Dissipation	$P_{G(AV)}$	10		mW
Peak Gate Forward Current	I_{FGM}	100		mA
Peak Gate Reverse Voltage	V_{RGM}	6		V
Junction Temperature	T_j	125		°C
Storage Temperature	T_{stg}	−40 ~ 125		°C

*R_{GK} = 1KΩ

3. ELECTRIC CHARACTERISTICS [T_j = 25°C (UNLESS OTHERWISE SPECIFIED), R_{GK} = 1KΩ]

ITEM	SYMBOL	CONDITIONS	SPECIFICATIONS			UNIT
			MIN.	TYP.	MAX.	
Peak Off-State Current	I_{DRM}	T_j = 125°C, $V_{DM} = V_{DRM}$	—	—	100	μA
Peak Reverse Current	I_{RRM}	T_j = 125°C, $V_{RM} = V_{RRM}$	—	—	100	μA
On-State Voltage	V_{TM}	I_{TM} = 4A	—	—	2.2	V
Gate Trigger Voltage	V_{GT}	V_{DM} = 6V, R_L = 100Ω	—	—	0.8	V
Gate Trigger Current	I_{GT}	V_{DM} = 6V, R_L = 100Ω	—	—	50	μA
Gate Non-Trigger Voltage	V_{GD}	$V_{DM} = \frac{V_{DRM}}{2}$, T_j = 125°C	0.2	—	—	V
Critical Rate-of-Rise Off-State Voltage	dv/dt	T_j = 125°C, $V_{DM} = V_{DRM}$	10	—	—	V/μs
Holding Current	I_H	V_D = 24V	—	—	5	mA
Circuit Commutated Turn-Off Time	t_q	T_j = 125°C, V_R = 25V I_{TM} = 0.2A, di_R/dt = 15A/μs $V_{DM} = \frac{2V_{DRM}}{3}$, dv/dt = 10V/μs	—	120	—	μs
Thermal Resistance	R_{th}	Junction to Ambient	—	—	230	°C/W
Thermal Resistance	R_{th}	Junction to Case	—	—	75	°C/W

9

NEC
ELECTRON DEVICE

GLASS PASSIVATED
2A(4Arms)MOLD THYRISTOR
2P05M, 2P1M, 2P2M, 2P4M, 2P5M, 2P6M

The 2PO5M ~ 2P6M are P-gate all diffused mold type SCR granted average on-state current 2Amps (Tc = 54°C). Being applied glassivation technique to pellets' surface, they feature a quite high reliability.

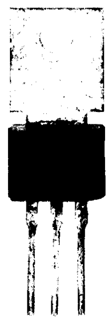
FEATURES

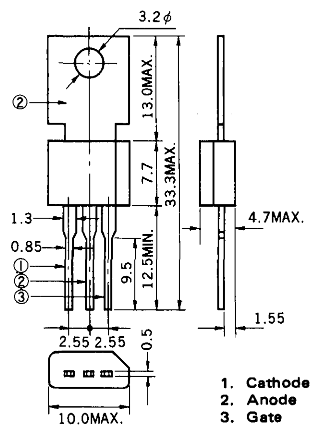
- The pellet surface is quite stable physically and electrically by applying glassivation technique.
- Easy installation by its miniature size and thin electrode leads.
- Less holding current distribution provides free application design.
- Low cost because of mass-production.

APPLICATIONS

Electric blanket, Electronic jar, Various temperature control.
Electric sewing machine, Speed control of miniature type motor.
Light display equipment, Lamp dimmer such as a display for entertainment.
Automatic gas lighter, Battery charger.
Solid state static switches etc.

Outline Drawing (Unit: mm)





MAXIMUM RATINGS

Item	Symbol	2P05M	2P1M	2P2M	2P4M	2P5M	2P6M	Unit	Note
Non-Repetitive Peak Reverse Voltage*	V_{RSM}	75	150	300	500	600	700	V	R_{GK}=1kΩ
Non-Repetitive Peak Off-state Voltage*	V_{DSM}	75	150	300	500	600	700	V	R_{GK}=1kΩ
Repetitive Peak Reverse Voltage*	V_{RRM}	50	100	200	400	500	600	V	R_{GK}=1kΩ
Repetitive Peak Off-state Voltage*	V_{DRM}	50	100	200	400	500	600	V	R_{GK}=1kΩ
On-state Current	$I_{T(AV)}$	2 (T_C=54°C, θ=180° Single phase 1/2 wave)						A	See Fig. 3, Fig. 4
Surge Non-Repetitive On-state Current	I_{TSM}	20						A	See Fig. 10
Peak Gate Power Dissipation	P_{GM}	0.5 (f ≧ 50 Hz, duty ≦ 10%)						W	
Average Gate Power Dissipation	$P_{G(AV)}$	0.1						W	
Peak Gate Fowrard Current	I_{FGM}	0.2 (f ≧ 50 Hz, duty ≦ 10%)						A	
Peak Gate Reverse Voltage	V_{RGM}	6						V	
Junction Temperature	T_j	-40 ~ +110						°C	
Storage Temperature	T_{stg}	-40 ~ +150						°C	
Weight		1.4						g	

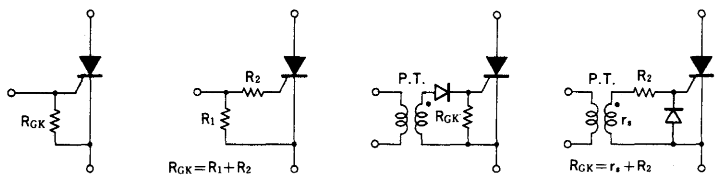
T_C : Case Temperature is measured at 1.5 mm from the neck of Tablet.

ELECTRICAL CHARACTERISTICS (T_j = 25°C)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit	Note
Repetitive Peak Reverse Current*	I_{RRM}	$V_{RM} = V_{RRM}$, T_j = 110°C R_{GK} = 1 kΩ	–	–	100	μA	
Repetitive Peak Off-state Current*	I_{DRM}	$V_{DM} = V_{DRM}$, T_j = 110°C R_{GK} = 1 kΩ	–	–	100	μA	
On-state Voltage	V_{TM}	I_{TM} = 4 A	–	–	2.2	V	See Fig. 1
Gate-Trigger Current*	I_{GT}	V_{DM} = 6V, R_L = 100 Ω R_{GK} = 1 kΩ	–	–	200	μA	See Fig. 5, Fig. 7
Gate-Trigger Voltage*	V_{GT}	V_{DM} = 6V, R_L = 100 Ω R_{GK} = 1 kΩ	–	–	0.8	V	See Fig. 6, Fig. 8
Gate Non-Trigger Voltage*	V_{GD}	V_{DM} = ½V_{DRM}, T_j = 110°C R_L = 100Ω, R_{GK} = 1 kΩ	0.2	–	–	V	
Critical Rate-of-Rise of Off-state Voltage	dv/dt	$V_{DM} = V_{DRM}$, T_j = 110°C R_{GK} = 1 kΩ	10	1 **	–	V/μS	** 2P5M, 2P6M
Holding Current*	I_H	V_D = 24V, R_{GK} = 1 kΩ I_{ON} = 40 mA (τ = 10 ms)	–	1	3	mA	See Fig. 9
Thermal Resistance	$R_{th\ (j\text{-}c)}$	Junction to Case	–	–	10	°C/W	See Fig. 11
	$R_{th\ (j\text{-}a)}$	Junction to Ambient	–	–	75		See Fig. 11

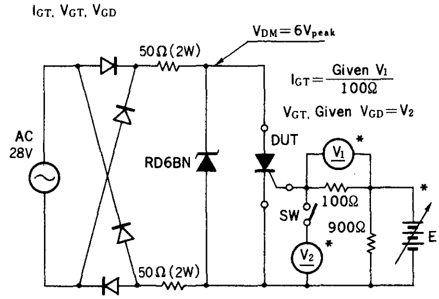
** Note: Insert a resistance less than 1 kΩ between gate and cathode, because the items indicated are guaranteed by connecting short resistance between gate and cathode (R_{GK} = 1 kΩ).

EXAMPLE OF R_{GK} INSERTION

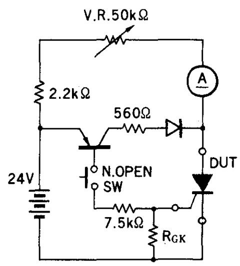


MEASUREMENT CIRCUIT

I_{GT}, V_{GT}, V_{GD}



I_H



V_1: more than 100 kΩ at I_{GT} ≦ 10 μA
V_2: more than 1 MΩ SW open
* Inner Resistance E : more than 20 kΩ

9

Fig. 1 I_{TM} - V_{TM} Characteristics

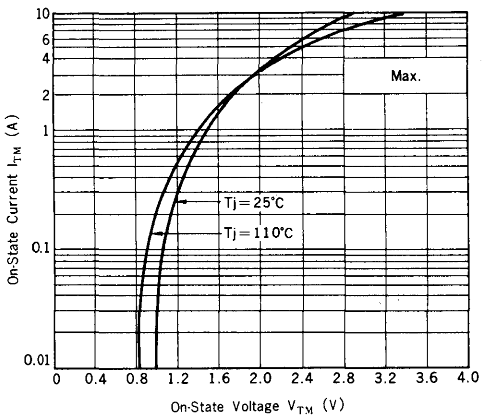


Fig. 2 $P_{T(AV)}$ - $I_{T(AV)}$ Characteristics

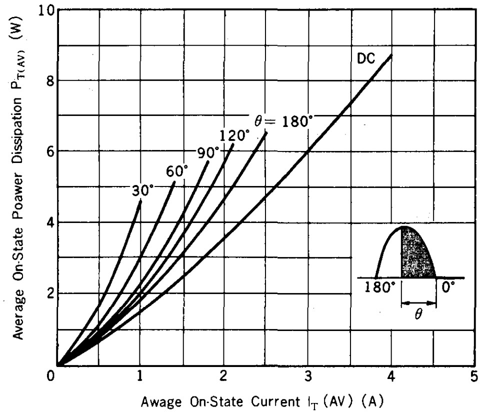


Fig. 3 T_C - $I_{T(AV)}$ Ratings

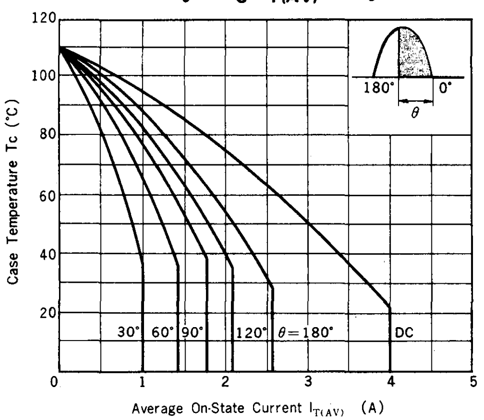


Fig. 4 Ta - $I_{T(AV)}$ Ratings

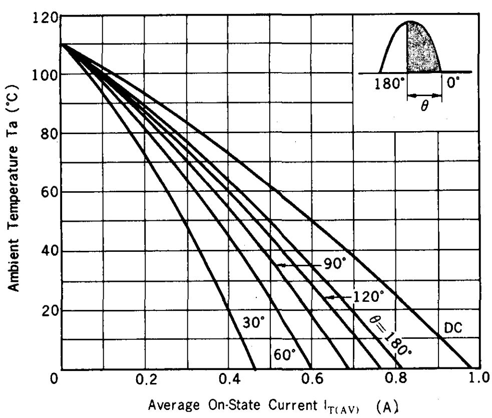


Fig. 5 I_{GT} - Ta Typical Distribution

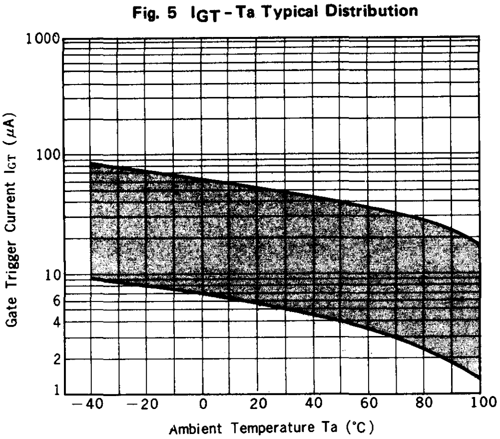


Fig. 6 V_{GT} - Ta Typical Distribution

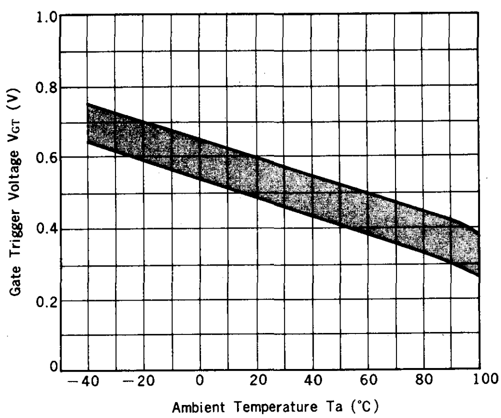


Fig. 7 I_{GT} - τ_G Typical Distribution

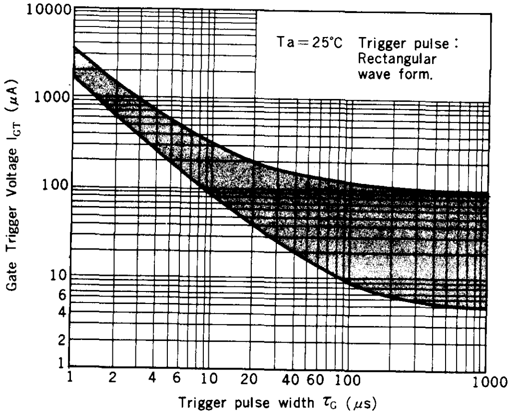


Fig. 8 V_{GT} - τ_G Typical Distribution

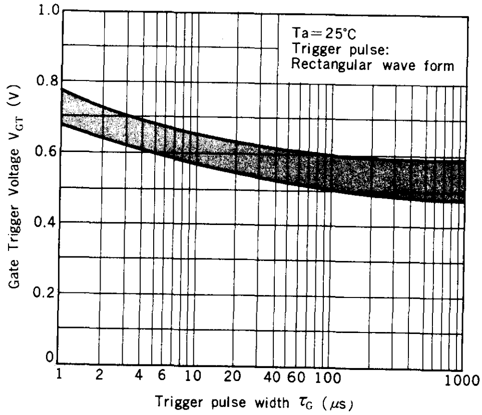


Fig. 9 I_H - Ta Typical Distribution

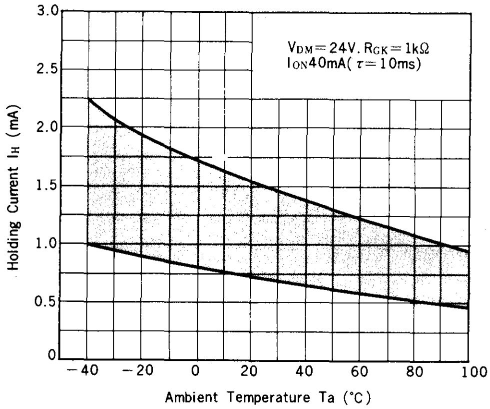


Fig. 10 I_{TSM} Ratings

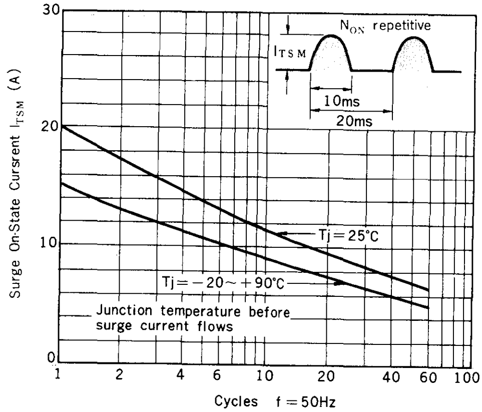
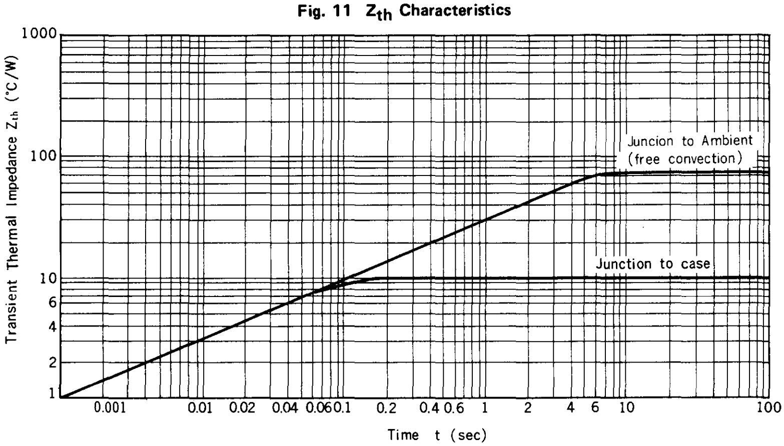


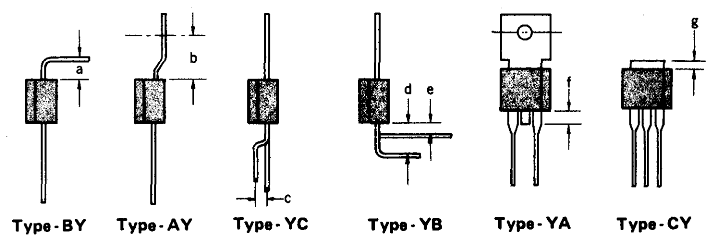
Fig. 11 Z_{th} Characteristics



9

NOTICE FOR INSTALLATION

1. Electrode leads (especially heat sink tablet) are not granted to be bent because of wet-proof. However in case it is required inevitably, a mechanical stress should not be put on mold. Fix tightly between the mold case and the area to be formed or bent.
2. Electrode leads should not to be bent more than twice over 90°. Avoid the bending within 1.5 mm from the neck of mold case.
3. Special lead and heat tab formings as indicated below are available at an additional cost.



Measurement (mm)	
a	3 ± 0.3
b	9 ± 0.2
c	2.5 ± 0.2
d	5.5 ± 0.2
e	2.5 ± 0.2
f	1.5 ± 0.3
g	1.0 ± 0.2

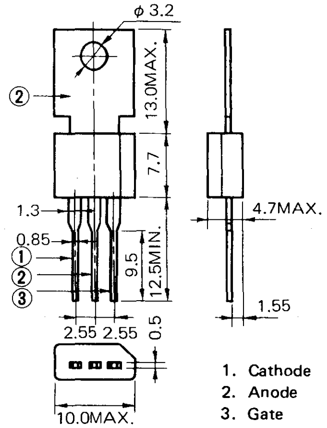
4. The surface of heat sink for thermal radiator is to be smooth without any foreign matter.
5. Suitable torque value is 4 ~ 5 kg.cm.
6. Soldering
   - ○ Recommended solder: PbSu (4 : 6)
     Melting point 180°C
   - ○ Dimension from the neck of leads to dipping points . . . . 4 ~ 6 mm
   - ○ Soldering temperature and period
     250°C . . . . less than 5 μsec.
     230°C . . . . less than 10 μsec.

NEC
ELECTRON DEVICE

HIGH SPEED SWITCHING 2A(4Arms)MOLD THYRISTOR
2S2M, 2S3M, 2S4M

The 2S2M ~ 2S4M are P-gate all diffused mold type SCR granted RMS on-state current 4 Amps and repetitive peak on-state current 15 Amps (Tc=65°C, f=10KPPS, tp=10μs).

OUTLINE DRAWING (Unit: mm)



1. Cathode
2. Anode
3. Gate

FEATURES

- Designed for Inverter, Pulse modulator, and other high frequency applications.
- Insured turn-off time of less than 15μs.
- 300μA gate sensitivity
- 200 through 400 V selection

APPLICATIONS

- Automatic gas lighter
- Speed control of miniature type motor
- Electric sewing machine
- Battery charger
- TV
- Solenoid operation
- Inverter

MAXIMUM RATINGS

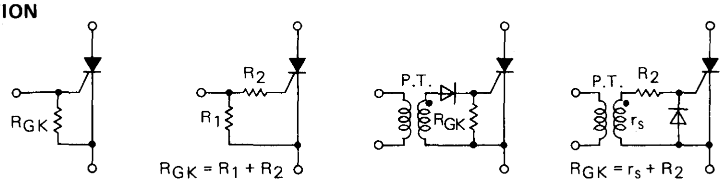
Item	Symbol	2S2M	2S3M	2S4M	Unit	Note
Non-Repetitive Peak Reverse Voltage	V_{RSM}	300	400	500	V	R_{GK}=1kΩ
Non-Repetitive Peak Off-State Voltage	V_{DSM}	300	400	500	V	R_{GK}=1kΩ
Repetitive Peak Reverse Voltage	V_{RRM}	200	300	400	V	R_{GK}=1kΩ
Repetitive Peak Off-State Voltage	V_{DRM}	200	300	400	V	R_{GK}=1kΩ
On-State Current	$I_{T(AV)}$	2 (T_C=54°C, θ=180° Single phase 1/2 wave)			A	See Fig. 3, Fig. 4
Repetitive Peak On-State Current	I_{TM}	15 (T_C=65°C, f=10KPPS, tp=10μs)			A	See Fig. 3, Fig. 4
Surge Non-Repetitive On-State Current	I_{TSM}	20			A	See Fig. 2
Peak Gate Power Dissipation	P_{GM}	0.5 (f ≧ 50 Hz, duty ≦ 10%)			W	
Average Gate Power Dissipation	$P_{G(AV)}$	0.1			W	
Peak Gate Forward Current	I_{FGM}	0.2 (f ≧ 50 Hz, duty ≦ 10%)			A	
Peak Gate Reverse Voltage	V_{RGM}	6			V	
Junction Temperature	Tj	−40 ~ +110			°C	
Storage Temperature	Tstg	−40 ~ +150			°C	
Weight		1.4			g	

T_C: Case Temperature is measured at 1.5mm from the neck of Tablet.

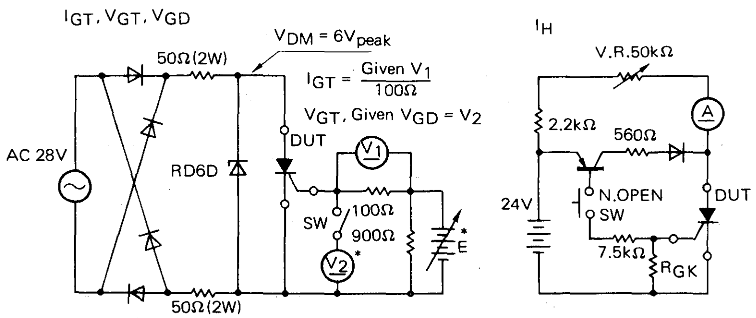
CHARACTERISTICS (T_j=25°C)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit	Note
Repetitive Peak Reverse Current	I_{RRM}	$V_{RM}=V_{RRM}$, T_j=110°C R_{GK}=1kΩ	–	–	100	μA	
Repetitive Peak Off-State Current	I_{DRM}	$V_{DM}=V_{DRM}$, T_j=110°C R_{GK}=1kΩ	–	–	100	μA	
On-State Voltage	V_{TM}	I_{TM}=4A	–	–	2.2	V	See Fig. 1
Gate Trigger Current	I_{GT}	V_{DM}=6V, R_L=100Ω R_{GK}=1kΩ	–	–	300	μA	See Fig. 8
Gate Trigger Voltage	V_{GT}	V_{DM}=6V, R_L=100Ω R_{GK}=1kΩ	–	–	0.8	V	See Fig. 9
Gate Non-Trigger Voltage	V_{GD}	V_{DM}=½V_{DRM}, T_j=110°C R_L=100Ω, R_{GK}=1kΩ	0.2	–	–	V	
Critical Rate-of-Rise of Off-State Voltage	dv/dt	V_{DM}=2/3V_{DRM}, T_j=110°C R_{GK}=1kΩ	10	–	–	V/μs	
Holding Current	I_H	V_D=24V, R_{GK}=1kΩ	–	–	10	mA	See Fig. 10
Circuit Commutated Turn-Off Time	t_q	V_{DM}=2/3V_{DRM}, T_j=110°C dv/dt=10V/μs, V_R=50V I_T=2A, R_{GK}=1kΩ	–	–	15	μs	
Turn-On Time	t_{gt}	V_{DM}=2/3V_{DRM}, I_{TM}=30A I_G=5mA, t_{IG}=5μs	–	–	2	μs	
Thermal Resistance	$R_{th(j-c)}$	Junction to Case	–	–	10	°C/W	See Fig. 11
	$R_{th(j-a)}$	Junction to Ambient	–	–	75		See Fig. 11

EXAMPLE OF R_{GK} INSERTION



MEASUREMENT CIRCUIT



* Inner Resistance

V_1: more than 100 kΩ at $I_{GT} \leq$ 10 μA
V_2: more than 1 MΩ SW open
E: more than 20 kΩ

Fig. 1 $I_{TM}-V_{TM}$ Characteristics

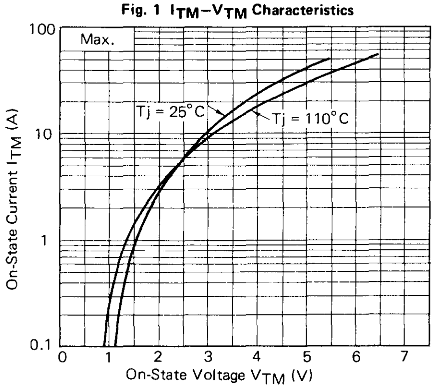


Fig. 2 I_{TSM} Rating

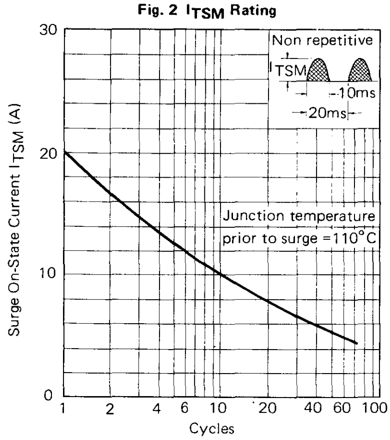


Fig. 3 $I_{TM}-t_p$ Ratings

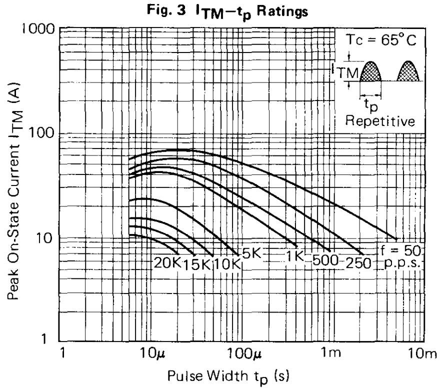


Fig. 4 $I_{TM}-t_p$ Ratings

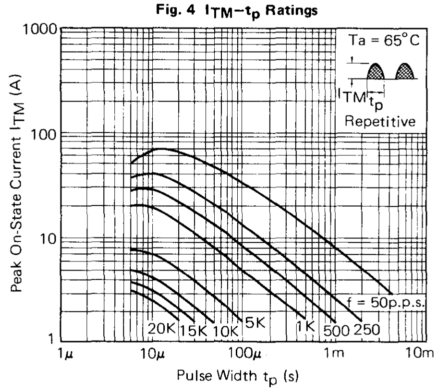


Fig. 5 $P_{T(AV)}-I_{T(AV)}$ Characteristics

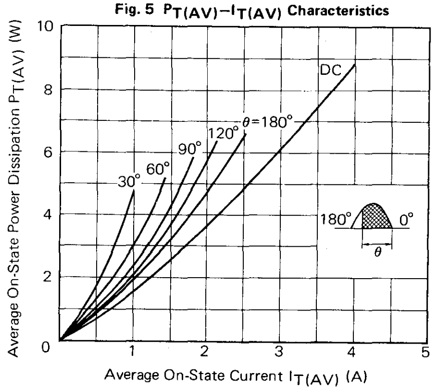
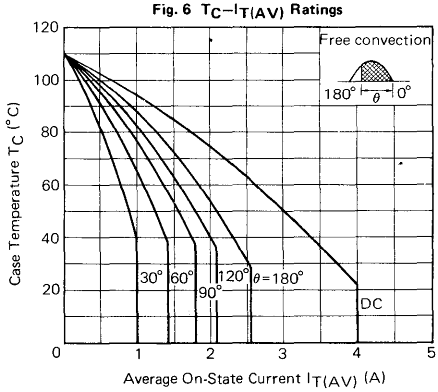


Fig. 6 $T_C-I_{T(AV)}$ Ratings



9

Fig. 7 Ta–$I_{T(AV)}$ Ratings

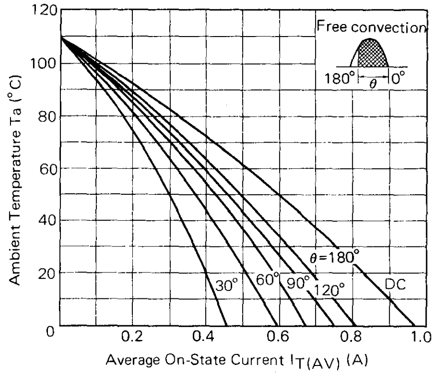


Fig. 8 I_{GT}–Ta Typical Distribution

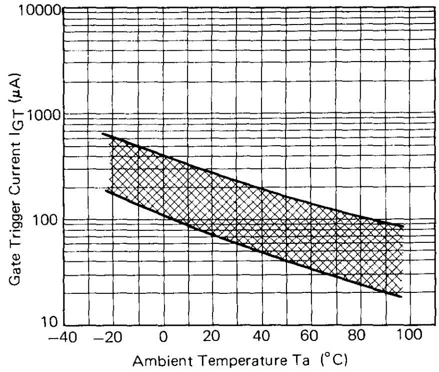


Fig. 9 V_{GT}–Ta Typical Distribution

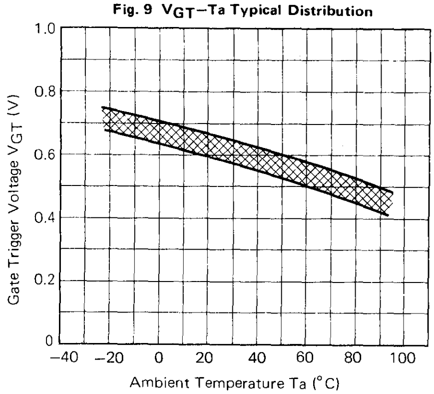


Fig. 10 I_H–Ta Typical Distribution

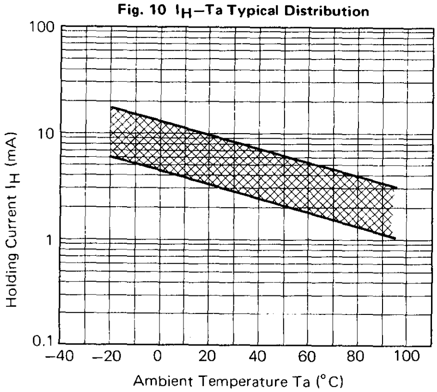
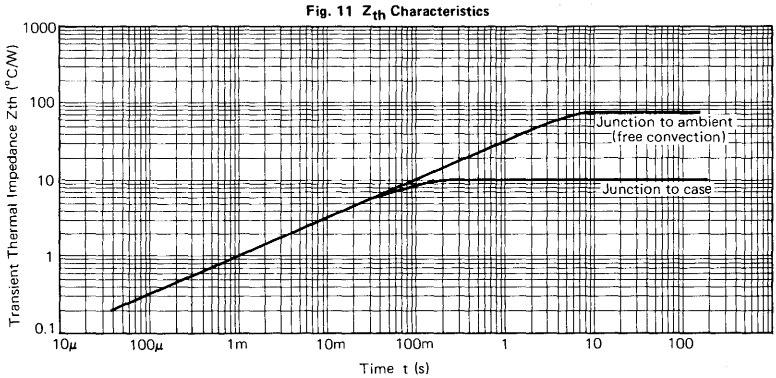
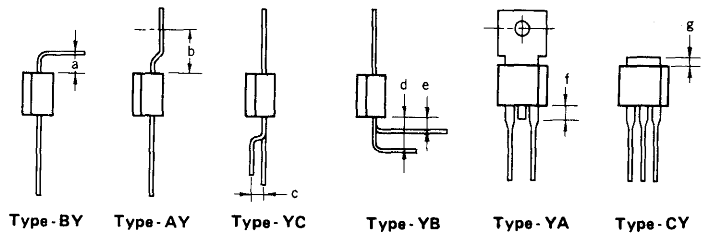


Fig. 11 Z_{th} Characteristics



NOTICE FOR INSTALLATION

1. Electrode leads (especially heat sink tablet) are not granted to be bent because of wet-proof. However in case it is required inevitably, a mechanical stress should not be put on mold. Fix tightly between the mold case and the area to be formed or bent.
2. Electrode leads should not to be bent more than twice over 90°. Avoid the bending within 1.5 mm from the neck of mold case.
3. Special lead and heat tab formings as indicated below are available at an additional cost.



Measurement (mm)	
a	3 ± 0.3
b	9 ± 0.2
c	2.5 ± 0.2
d	5.5 ± 0.2
e	2.5 ± 0.2
f	1.5 ± 0.3
g	1.0 ± 0.2

4. The surface of heat sink for thermal radiator is to be smooth without any foreign matter.
5. Suitable torque value is 4 ~ 5 kg.cm.
6. Soldering
   - ○ Recommended solder: PbSu (4 : 6)
     Melting point 180°C
   - ○ Dimension from the neck of leads to dipping points . . . . 4 ~ 6 mm
   - ○ Soldering temperature and period
     - 250°C . . . . less than 5 μsec.
     - 230°C . . . . less than 10 μsec.

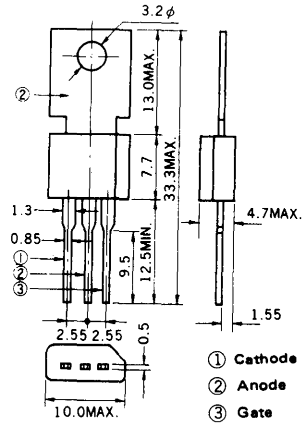
NEC
ELECTRON DEVICE

GLASS PASSIVATED 3A(4.7Arms)MOLD SCR

3P1M,3P2M,3P4M,3P5M,3P6M

The 3P1M~3P6M are P-gate all diffused mold type SCR granted average on-state current 3 Amps (T_C=87°C). Being applied glassivation technique to pellet's surface, they feature a quite high reliability.

OUTLINE DRAWING (Unit : mm)



FEATURES

- The pellet surface is quite stable physically and electrically by applying glassivation technique.
- High junction temperature rating provides free application design.
- Easy installation by its miniature and thin electrode leads.

APPLICATIONS

Various temperature control, Electronic jar.
Electric sewing machine, Automotive application such as regulator, Speed control of motor.
Various solid state relay etc.

MAXIMUM RATINGS

ITEM	SYMBOL	3P1M	3P2M	3P4M	3P5M	3P6M	UNIT	NOTE
Non-Repetitive Peak Reverse Voltage	V_{RSM}	150	300	500	600	700	V	
Non-Repetitive Peak-off Voltage	V_{DSM}	150	300	500	600	700	V	
Repetitive Reverse Voltage	V_{RRM}	100	200	400	500	600	V	
Repetitive Peak-off Voltage	V_{DRM}	100	200	400	500	600	V	
On-state Current	$I_{T(AV)}$	3(T_C=87°C, θ=180 Single Phase half wave)					A	Fig. 5 Fig. 6
	$I_{T(RMS)}$	4.7						
Surge On-state Current	I_{TSM}	65					A	Fig. 2
Critical Rate-Rise of On-state Current	di/dt	50					A/μs	
Gate Power Dissipation	P_{GM}	2(f≧50Hz, duty≦10%)					W	Fig. 3
Gate Power Dissipation	$P_{G(AV)}$	0.2					W	
Gate Forward Current	I_{FGM}	1(f≧50Hz, duty≦10%)					A	
Gate Reverse Voltage	V_{RGM}	10					V	
Junction Temperature	T_j	-40 ~ +125					°C	
Storage Temperature	T_{stg}	-40 ~ +125					°C	

ELECTRICAL CHARACTERISTICS ($T_j = 25°C$)

ITEM	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNIT	NOTE
Repetitive Peak Reverse Current	I_{RRM}	$T_j = 125°C$, $V_{RM} = V_{RRM}$	–	–	2	mA	
Repetitive Peak-off Current	I_{DRM}	$T_j = 125°C$, $V_{DM} = V_{DRM}$	–	–	2	mA	
On-state Voltage	V_{TM}	$I_{TM} = 10A$	–	–	1.6	V	Fig. 1
Gate-trigger Current	I_{GT}	$V_{DM} = 6V$, $R_L = 100\Omega$	–	–	5	mA	Fig. 3
Gate-trigger Voltage	V_{GT}	$V_{DM} = 6V$, $R_L = 100\Omega$	–	–	1.5	V	Fig. 3
Gate Non trigger Voltage	V_{GD}	$T_j = 125°C$, $V_{DM} = V_{DRM}/2$	0.2	–	–	V	
Critical Rate-of-Rise of Off-State Voltage	dv/dt	$T_j = 125°C$, $V_{DM} = 2/3 V_{DRM}$	20	40	–	V/μs	
Holding Current	I_H	$V_{DM} = 24V$	–	5	–	mA	
Termal Resistance	$R_{th(j-c)}$	Junction to Case	–	–	8	°C/W	Fig. 7
	$R_{th(j-a)}$	Junction to Ambient	–	–	75		

9

Fig. 1 $i_T - v_T$ **Characteristic**

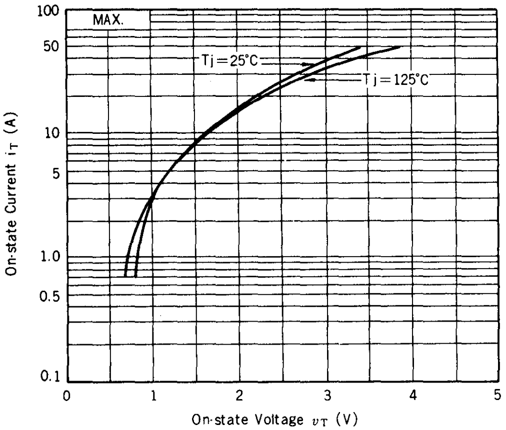


Fig. 2 I_{TSM} **Rating**

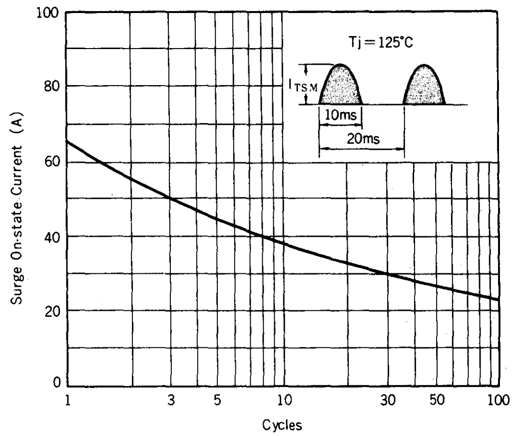


Fig. 3 Gate Characteristic

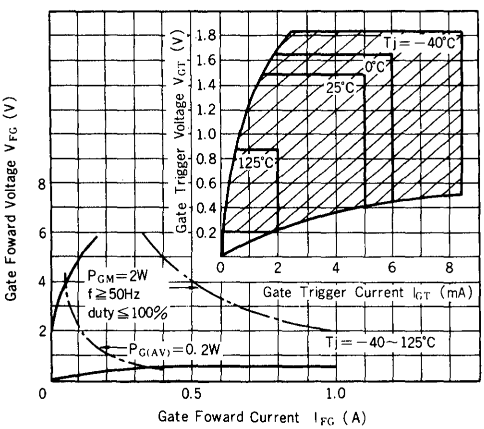


Fig. 4 $P_{T(AV)} - I_{T(AV)}$ **Characteristic**

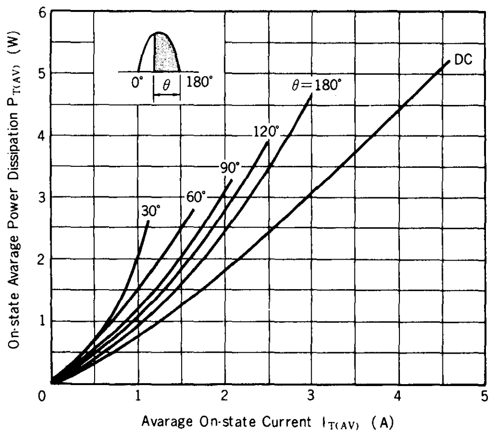


Fig. 5 $T_C - I_{T(AV)}$ **Rating**

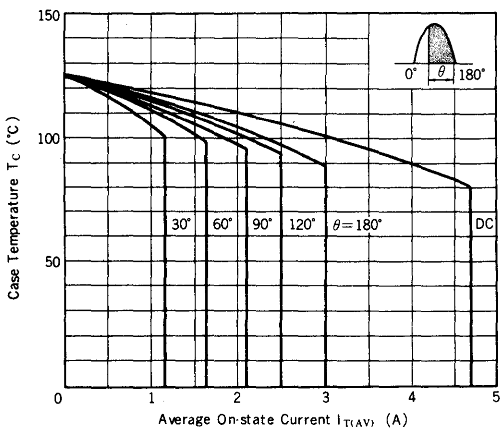


Fig. 6 $Ta - I_{T(AV)}$ **Rating**

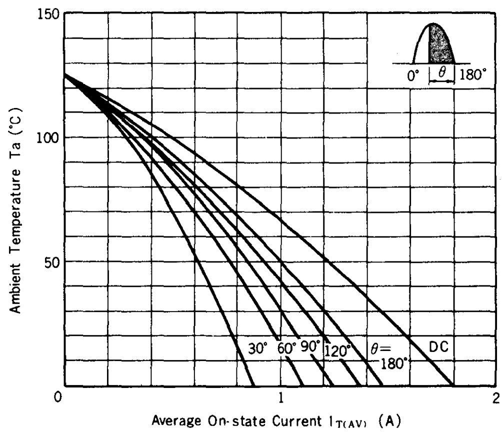
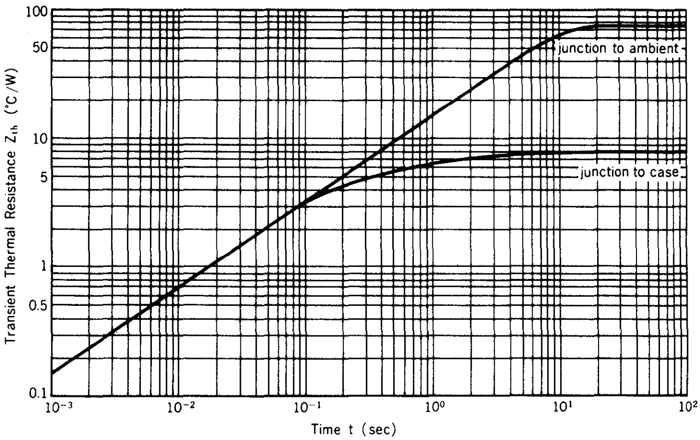


Fig. 7 Z_{th} Characteristic



9

NEC
ELECTRON DEVICE

GLASS PASSIVATED 3A(4.7Arms)MOLD SCR 3P1MH,3P2MH,3P4MH

The 3P1MH ~ 3P4MH are P-gate all diffused mold type SCR granted average on-state current 3 Amps ($T_C = 87°C$). Being applied glassivation technique to pellet's surface, they feature a quite high reliability.

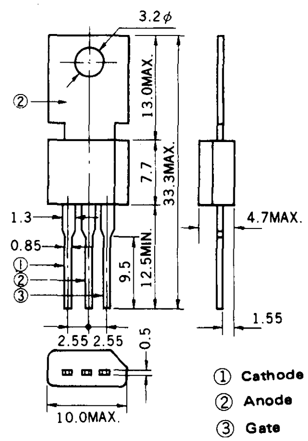
FEATURES

- The pellet surface is quite stable physically and electrically by applying glassivation technique.
- High junction temperature rating provides free application design.
- Easy installation by its miniature and thin electrode leads.

APPLICATIONS

Various temperature control, Electronic jar.
Electric sewing machine, Automotive application such as regulator, Speed control of motor.
Various solid state relay etc.

OUTLINE DRAWING (Unit : mm)



MAXIMUM RATINGS

ITEM	SYMBOL	3P1MH	3P2MH	3P4MH	UNIT	NOTE
Non-Repetitive Peak Reverse Voltage *	V_{RSM}	150	300	500	V	
Non-Repetitive PeakkOff Voltage *	V_{DSM}	150	300	500	V	
Repetitive Reverse Voltage *	V_{RRM}	100	200	400	V	
Repetitive Peak-off Voltage *	V_{DRM}	100	200	400	V	
On-state Current	$I_{T(AV)}$	3($T_C = 87°C$, $\theta = 180$ Single Phase half wave)			A	Fig. 7 Fig. 8
	$I_{T(RSM)}$	4.7				
Surge On-stage Current	I_{TSM}	65			A	Fig. 2
Critical Rate-Rise of On-State Current	di/dt	50			A/μs	
Gate Power Dissipation	P_{GM}	0.5(f ≧ 50Hz, duty ≦ 10%)			W	
Gate Power Dissipation	$P_{G(AV)}$	0.1			W	
Gate Forward Current	I_{FGM}	0.2(f ≧ 50Hz, duty ≦ 10%)			A	
Gate Reverse Voltage	V_{RGM}	10			V	
Junction Temperature	T_j	-40 ~ +125			°C	
Storage Temperature	T_{stg}	-40 ~ +125			°C	

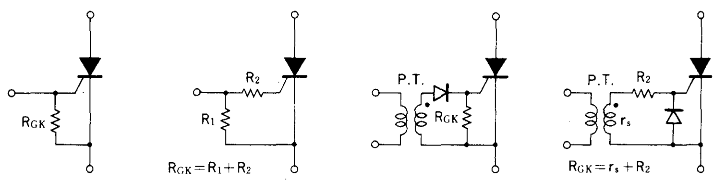
***Note :** Insert a resistance below 1 kΩ between gate and cathode, because the items are guaranteed by connecting short resistance between gate and cathod ($R_{GK} = 1$ kΩ).
T_C : Case Temperature is measured at 1.5 mm from the neck of Tablet.

Nippon Electric Co.,Ltd.

ELECTRICAL CHARACTERISTICS ($T_j = 25°C$)

ITEM	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNIT	NOTE
Repetitive Peak Reverse Current	I_{RRM}	T_j=125°C, V_{RM}=V_{RRM}, R_{GK}=1kΩ	–	–	2	mA	
Repetitive Peak-off Current	I_{DRM}	T_j=125°C, V_{DM}=V_{DRM}, R_{GK}=1kΩ	–	–	2	mA	
On-State Voltage	V_{TM}	I_{TM}=10A	–	–	1.6	V	Fig. 1
Gate-trigger Current	I_{GT}	V_{DM}=6V, R_L=100Ω, R_{GK}=1kΩ	–	–	0.2	mA	Fig. 3
Gate-trigger Voltage	V_{GT}	V_{DM}=6V, R_L=100Ω, R_{GK}=1kΩ	–	–	0.8	V	Fig. 4
Gate Non trigger Voltage	V_{GD}	T_j=125°C, V_{DM}=$V_{DRM}/2$, R_{GK}=1kΩ	0.2	–	–	V	
Critical Rate-of-Rise of Off-State Voltage	dv/dt	T_j=125°C,V_{DM}=2/3V_{DRM},R_{GK}=1kΩ	–	3	–	V/μs	
Holding Current	I_H	V_{DM}=24V, R_{GK}=1kΩ	–	1	–	mA	Fig. 5
Thermal Resistance	$R_{th(j-c)}$	Junction to Case	–	–	8	°C/W	Fig. 9
	$R_{th(j-a)}$	Junction to Ambient	–	–	75		

EXAMPLES OF R_{GK} INSERTION



9

Fig. 1 $i_T - v_T$ Characteristic

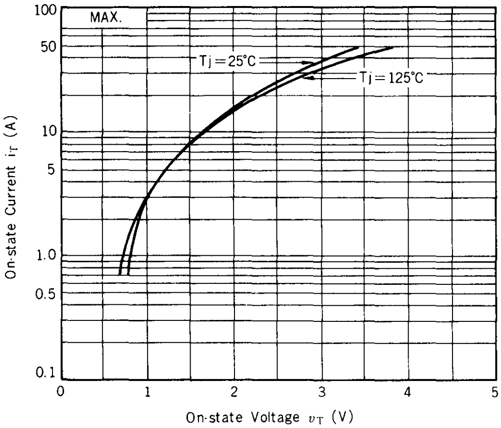


Fig. 2 I_{TSM} Rating

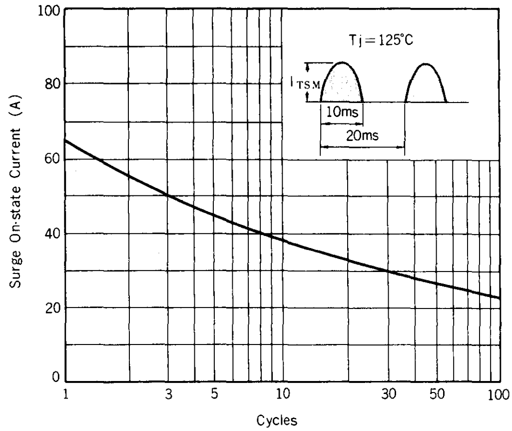


Fig. 3 I_{GT} – Ta Typical Characteristic

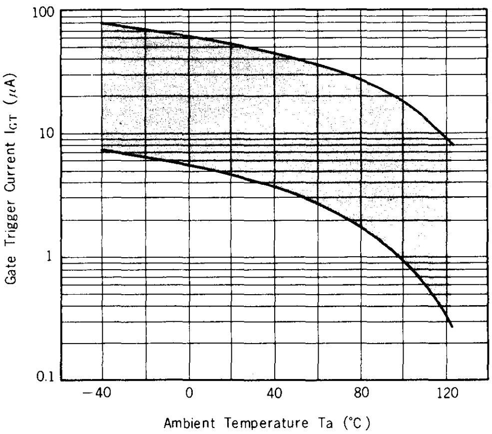


Fig. 4 V_{GT} – Ta Typical Characteristic

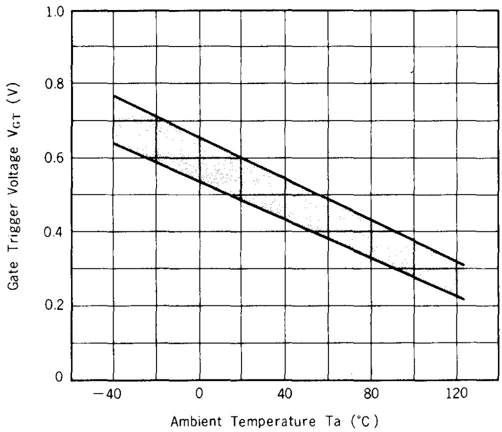


Fig. 5 I_H – Ta Typical Characteristic

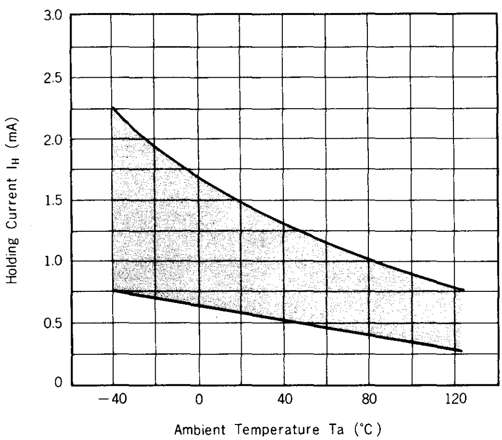


Fig. 6 $P_{T(AV)} - I_{T(AV)}$ Characteristic

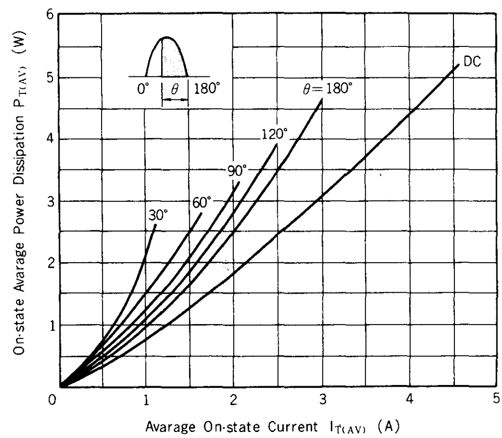


Fig. 7 $T_C - I_{T(AV)}$ Rating

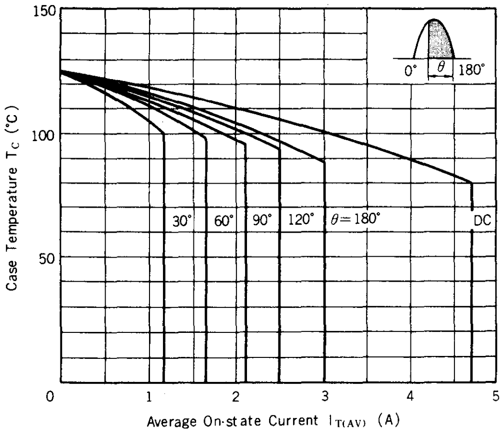


Fig. 8 $Ta - I_{T(AV)}$ Rating

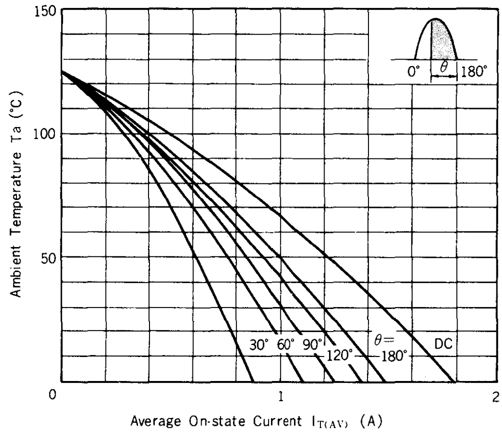
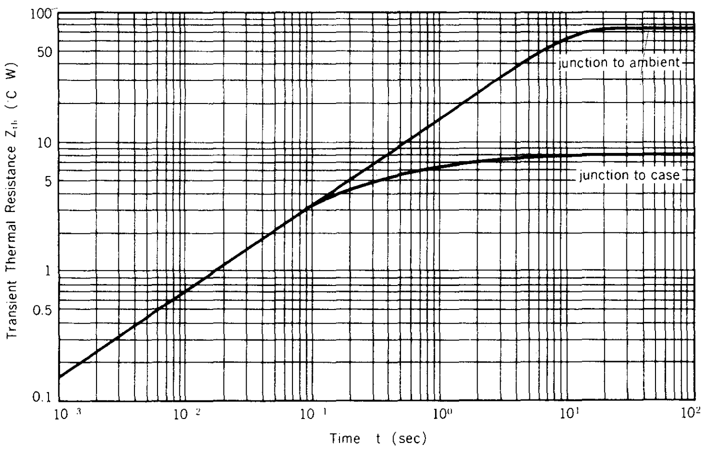


Fig. 9 Z_{th} Characteristic



9

NEC
ELECTRON DEVICE

GLASS PASSIVATED 5A(8 Arms) THYRISTOR 5P05M, 5P1M, 5P2M, 5P4M, 5P5M, 5P6M

The 5P05M ~ 5P6M are a P gate all diffused mold type Thyristor granted 5Amp On-state Average Current (Tc = 88°C). The glassivation technique applied to pellets' surface makes this series quite highly reliable.

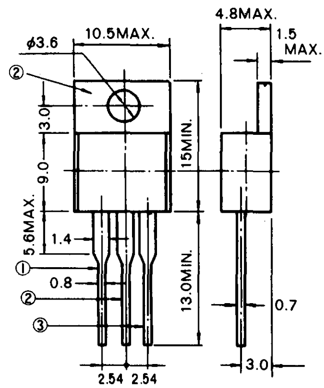
FEATURES

- Glassivated silicon chip for maximum reliability.
- Easy installation by TO-220 AB package.
- Low cost.

APPLICATIONS

- Motor speed control for household appliance.
- Temperature control for heater and constant temperature box.
- Constant voltage power source and battery charger.
- Automotive application such as regulator.
- Various solid state relay etc.

Outline Drawing (Unit : mm)



Pin Connection
① Cathode
② Anode
③ Gate

MAXIMUM RATINGS

Item	Symbol	5P05M	5P1M	5P2M	5P4M	5P5M	5P6M	Unit	Note
Non-Repetitive Peak Reverse Voltage	V_{RSM}	75	150	300	500	600	700	V	
Non-Repetitive Peak Off-State Voltage	V_{DSM}	75	150	300	500	600	700	V	
Repetitive Peak Reverse Voltage	V_{RRM}	50	100	200	400	500	600	V	
Repetitive Peak Off-State Voltage	V_{DRM}	50	100	200	400	500	600	V	
Average On-State Current	$I_{T(AV)}$	5 (Tc = 88°C, θ = 180° Single phase half wave)						A	See Fig. 5
Surge On-State Current	I_{TSM}	100						A	See Fig. 2
Fusing Current	$\int i_T^2 dt$	28 (1 ms $\leq$ t $\leq$ 10 ms)						A^2S	
Peak Gate Power Dissipation	P_{GM}	5 (f $\geq$ 50 Hz, duty $\leq$ 10 %)						W	See Fig. 3
Average Gate Power Dissipation	$P_{G(AV)}$	0.5						W	
Peak Gate Forward Current	I_{FGM}	2						A	
Peak Gate Reverse Voltage	V_{RGM}	10						V	
Junction Temperature	Tj	−40 ~ +110						°C	
Storage Temperature	T_{stg}	−40 ~ +125						°C	
Weight		2						g	

ELECTRICAL CHARACTERISTICS (Tj=25°C)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit	Note
Repetitive Peak Reverse Current	I_{RRM}	$V_{RM} = V_{RPM}$, Tj = 110°C	–	–	2	mA	
Repetitive Peak Off-State Current	I_{DRM}	$V_{DM} = V_{DRM}$, Tj = 110°C	–	–	2	mA	
On-State Voltage	V_{TM}	I_{TM} = 10 A	–	–	1.4	V	See Fig. 1
Gate-Trigger Current	I_{GT}	V_{DM} = 6V, R_L = 100Ω	–	–	15	mA	See Fig. 3
Gate-Trigger Voltage	V_{GT}	V_{DM} = 6V, R_L = 100Ω	–	–	1.5	V	
Gate Non-Trigger Voltage	V_{GD}	$V_{DM} = \frac{1}{2} V_{DRM}$, Tj = 110°C	0.2	–	–	V	
Critical Rate of Rise of Off-State Voltage	dv/dt	$V_{DM} = V_{DRM}$, Tj = 110°C	–	40	–	V/μS	
Holding Current	I_H	V_D = 24V, R_{GK} = 1Ω	–	–	10	mA	
Circuit Commuted Turn-Off Time	tq	I_{TM} = 5A, $V_R \geq$ 25V $V_{DM} = \frac{2}{3} V_{DRM}$, diR/dt = 15 A/μs dv/dt = 10V/μs, Tj = 110°C	–	70	–	μs	
Thermal Resistance	Rth	Junction to case	–	–	3	°C/W	See Fig. 7

Fig. 1 iT—vT Characteristic

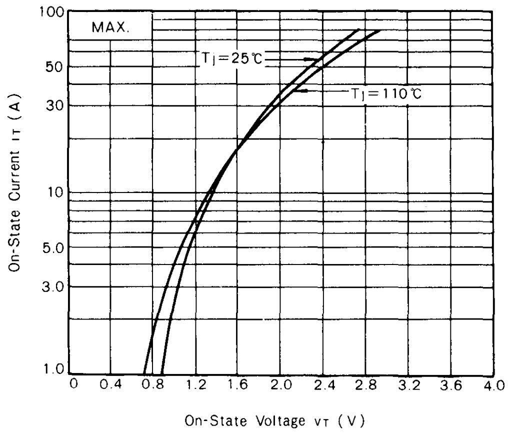


Fig. 2 ITSM Rating

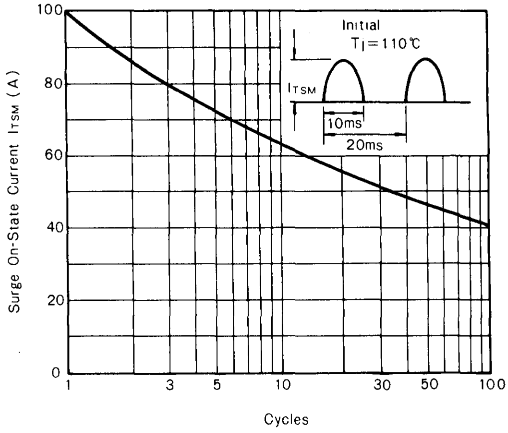


Fig. 3 Gate Characteristic

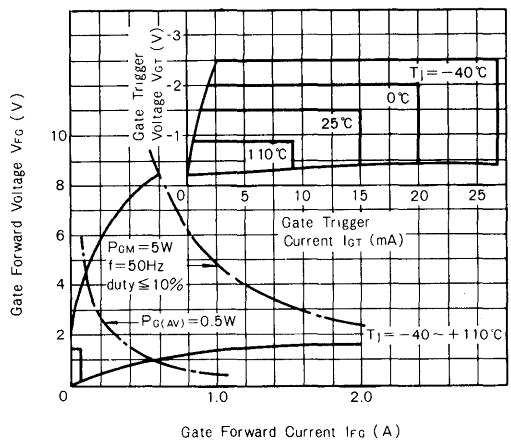


Fig. 4 PT(AV)—IT(AV) Characteristic

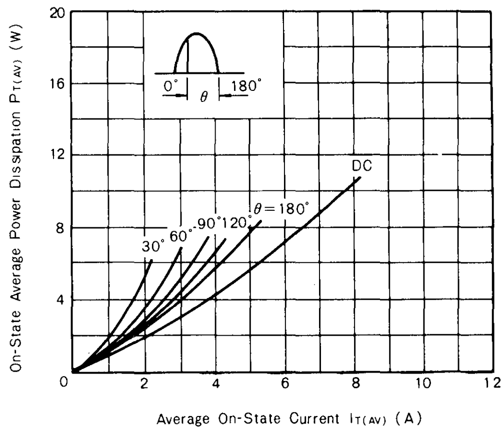


Fig. 5 Tc—IT(AV) Rating

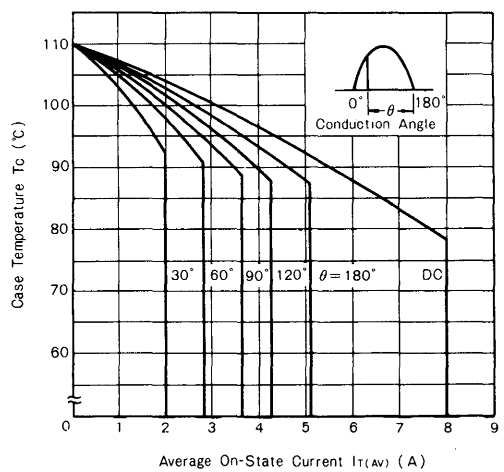


Fig. 6 IT(AV)—Ta Rating

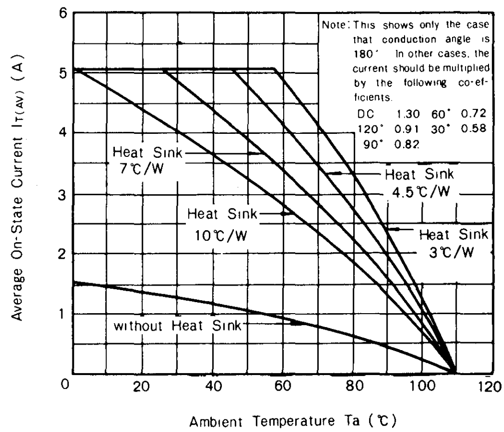
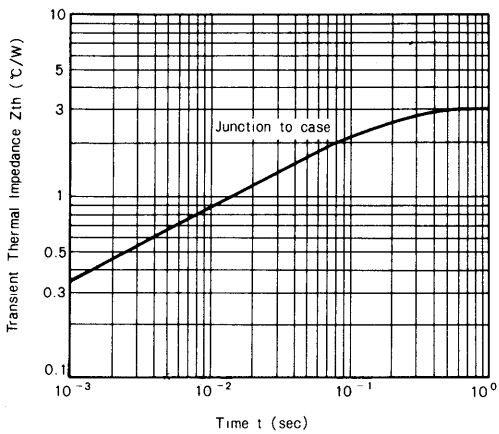


Fig. 7 Zth Characteristic



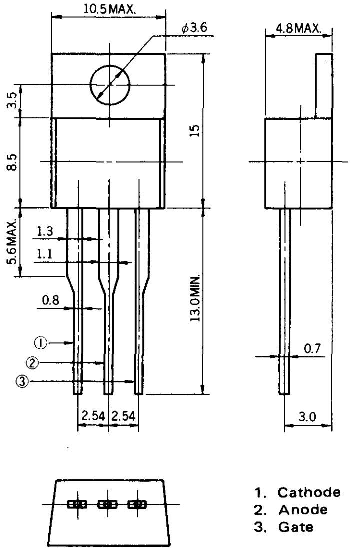
NOTICE FOR INSTALLATION

1. Electrode leads are not granted to be bent because of wet-proof. However it is required inevitably that a mechanical stress should not be put on mold case. Fix tightly between the mold case and the area to be formed or dent.
2. Electrode leads are not granted to be bent more than twice over 90° and avoid the bending within 1.5mm from the neck of the mold case.
3. The surface of heat sink for thermal radiator is to be smooth without any foreign matter.
4. Suitable torque value is around 3kg-cm.

GLASS PASSIVATED
SCR 8P1M 8P2M

The 8P1M, 8P2M are a P gate all diffused mold type Thyristor granted 12 Amp On-state Current. The glassivation technique applied to pellets surface makes this series quite highly reliable.

Outline Drawing (Unit: mm)



1. Cathode
2. Anode
3. Gate

FEATURES

- Glassivated silicon chip for maximum reliability.
- Easy installation by TO-220AB package.
- Low cost.

APPLICATION

Motor speed control for household appliance.
Temperature control for heater and constant temperature box.
Constant voltage power source and battery charger.
Automotive application such as regulator.
Various solid state relay etc.

MAXIMUM RATINGS

Item	Symbol	8P1M	8P2M	Unit	Note
Non-Repetitive Peak Reverse Voltage	V_{RSM}	200	300	V	
Non-Repetitive Peak Off-State Voltage	V_{DSM}	200	300	V	
Repetitive Peak Reverse Voltage	V_{RRM}	100	200	V	
Repetitive Peak Off-State Voltage	V_{DRM}	100	200	V	
On-State Current	$I_{T(AV)}$	8 (T_C = 90°C, Single phase half wave)		A	Fig. 5
	$I_{T(RMS)}$	12			Fig. 6
Surge On-State Current	I_{TSM}	100		A	Fig. 2
Fusing Current	$\int i_T^2 dt$	28 (1 ms $\leqq$ t $\leqq$ 10 ms)		A^2S	
Peak Gate Power Dissipation	P_{GM}	5 (f $\geqq$ 50 Hz, duty $\leqq$ 10 %)		W	Fig. 3
Average Gate Power Dissipation	$P_{G(AV)}$	0.5		W	Fig. 3
Peak Gate Forward Current	I_{FGM}	2 (f $\geqq$ 50 Hz, duty $\leqq$ 10 %)		A	
Peak Gate Reverse Voltage	V_{RGM}	10		V	
Junction Temperature	T_j	−40 ~ +125		°C	
Storage Temperature	T_{stg}	−40 ~ +125		°C	
Weight		2		g	

ELECTRICAL CHARACTERISTICS (T_j=25 °C)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit	Note
Repetitive Peak Reverse Current	I_{RRM}	$V_{RM} = V_{RRM}$, T_j = 125°C	–	–	2	mA	
Repetitive Peak Off-State Current	I_{DRM}	$V_{DM} = V_{DRM}$, T_j = 125°C	–	–	2	mA	
On-State Voltage	V_{TM}	I_{TM} = 25 A	–	–	1.4	V	See Fig. 1
Gate-Trigger Current	I_{GT}	V_{DM} = 6V, R_L = 100Ω	–	–	15	mA	
Gate-Trigger Voltage	V_{GT}	V_{DM} = 6V, R_L = 100Ω	–	–	1.5	V	
Gate Non-Trigger Voltage	V_{GD}	V_{DM} = ½V_{DRM}, T_j = 125°C	0.2	–	–	V	
Critical Rate of Rise of Off-State Voltage	dv/dt	$V_{DM} = V_{DRM}$, T_j = 125°C	–	40	–	V/μs	
Holding Current	I_H	V_D = 24V	–	–	10	mA	
Circuit Commuted Turn-Off Time	tq	I_{TM} = 5A, $V_R \geqq$ 25V V_{DM} = ⅔ V_{DRM}, diR/dt = 15A/μs dv/dt = 10V/μs, T_j = 125°C	–	100	–	μs	
Thermal Resistance	Rth	Junction to case	–	–	3	°C/W	See Fig. 7

Fig. 1 $i_T - V_T$ Characteristic

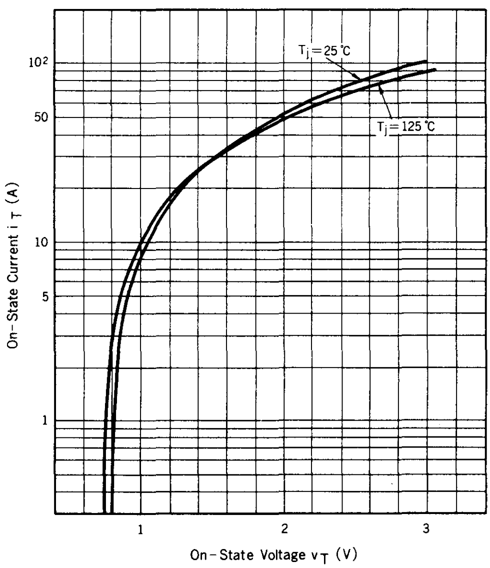
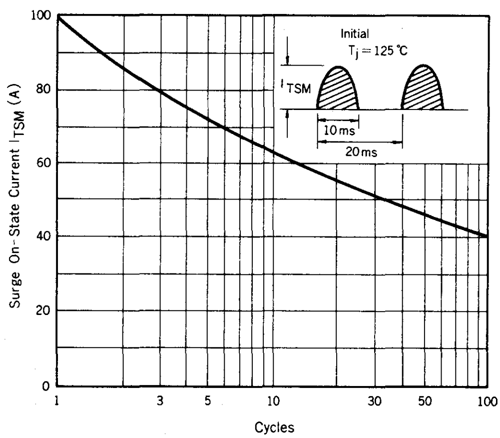


Fig. 2 I_{TSM} Rating



9

Fig. 3 Gate Characteristics

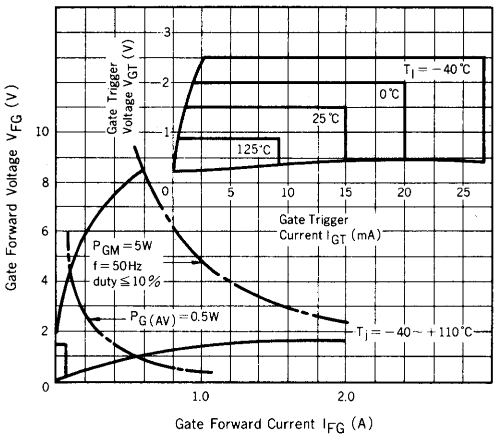


Fig. 4 PT(AV) − IT(AV) Characteristic

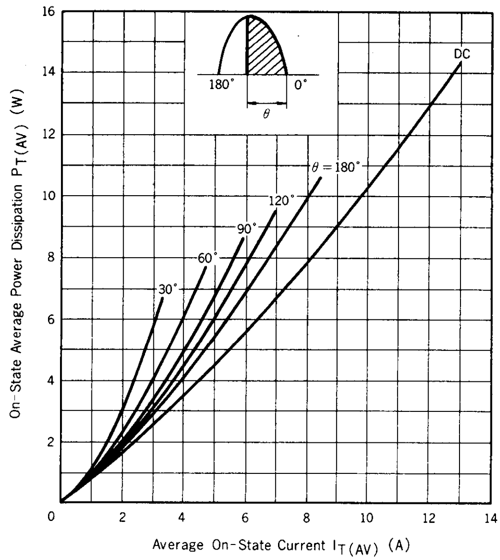


Fig. 5 TC − IT(AV) Rating

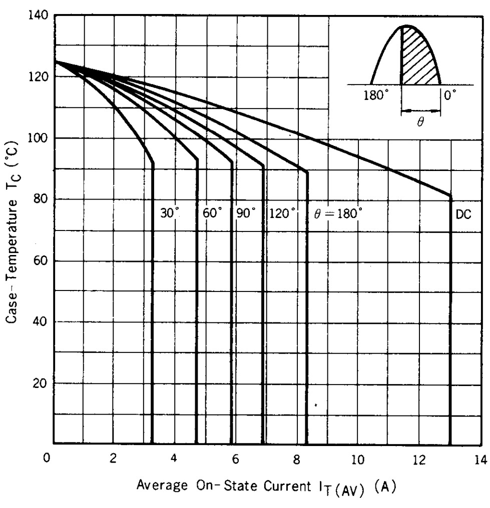


Fig. 6 IT(AV) − Ta Rating

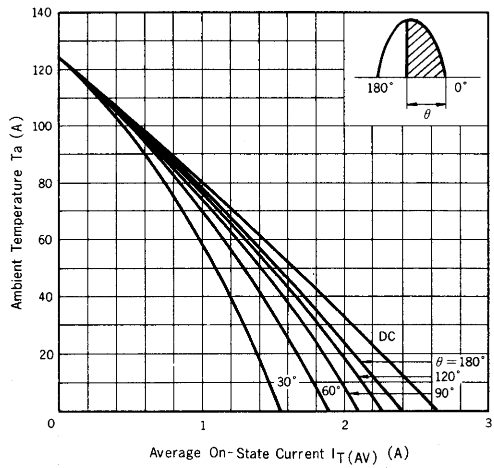
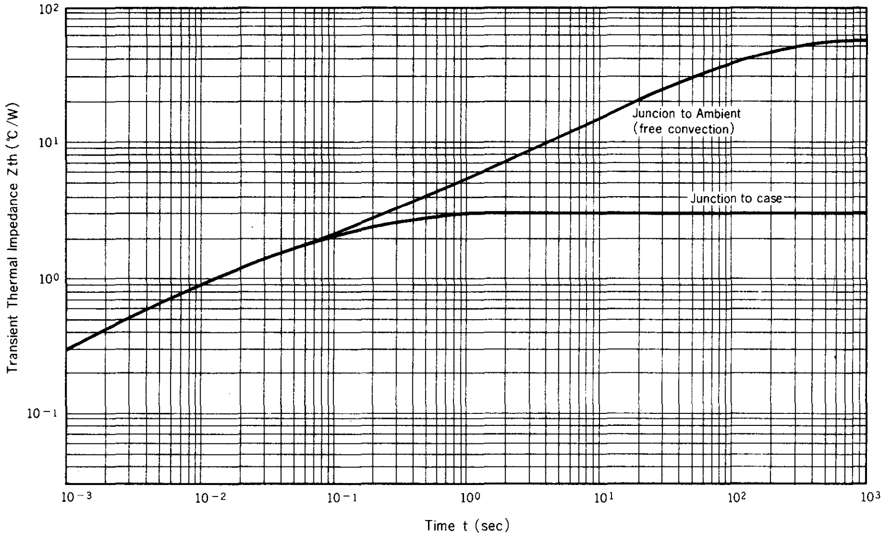


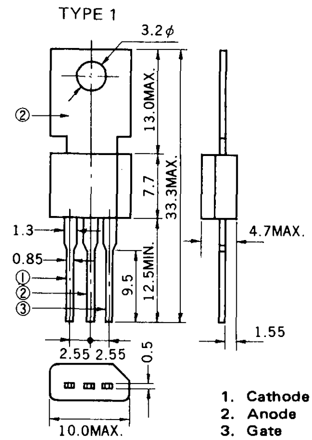
Fig. 7 Zth Characteristics



2A(4Arms)MOLD THYRISTOR
C106Q,Y,F,A,B,C,D,E,M

The C106Q ~ C106M are P-gate all diffused mold type SCR granted average on-state current 2Amps (Tc = 54°C). Being applied glassivation technique to pellets' surface, they feature a quite high reliability.

Outline Drawing (Unit: mm)



FEATURES

- The pellet surface is quite stable physically and electrically by applying glassivation technique.
- Easy installation by its miniature size and thin electrode leads.
- Less holding current distribution provides free application design.
- Low cost because of mass-production.

APPLICATIONS

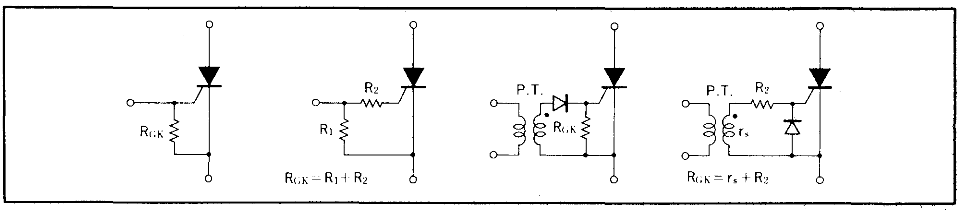
MOTOR CONTROL	Electric Model Trains Sewing Machines Movie Projectors Food Mixers Electric Fans Slot Racing Cars
LIGHT	Flame Detectors Moving-Light Signs (Chasers) Driver for Computer Readout Lights Harbor Buoy Flashers Automotive Warning Systems Nixie & Neon Drivers
TEMPERATURE	Range Surface Unit (Hybrid) Chemical Processing (Photographic, etc.) Food Warmer Tray Bearing Temperature Sensor Electric Blanket Control
PRESSURE	Auto Oil Pressure Gage Hot Water Boiler Safety Monitor
TIME	Photo Darkroom Exposure Oven Timer Vending Machine Logic Industrial Process Control
LIQUID LEVEL	Basement Sump Pump Automatic Coffee Maker Automatic Shutoff for Vending Machines
REMOTE CONTROL	Armchair TV Control Master Switching Stations for for Home Garage Door Openers Power Switch
DRYNESS	Clothes Dryness Sensor
PROXIMITY	Burglar Alarm Touch Swith Electric Door Openers
COUNTING	Low Speed Ring Counters Shift Registers
SWITCHING	Relay Replacement Solenoid Drivers Latching Relay Replacement Power Flip Flops Low Power Inverters Thyratron Tube Replacement
AMPLIFIERS	Gate Amplifier for Larger SCR's, Triacs –Blenders –Hand Tools
IGNITION	Small Gas Engines Gas Appliances
DETECTION	Voltage (Battery Charger) Current (Crowbar)

MAXIMUM RATINGS

Type	Repetitive Peak Reverse Voltage V_{RRM}	Repetitive Peak Off-state Voltage V_{DRM} $R_{GK} = 1k\Omega$
C106Q	15 Volts	15 Volts
C106Y	30 Volts	30 Volts
C106F	50 Volts	50 Volts
C106A	100 Volts	100 Volts
C106B	200 Volts	200 Volts
C106C	300 Volts	300 Volts
C106D	400 Volts	400 Volts
C106E	500 Volts	500 Volts
C106M	600 Volts	600 Volts

Item	Symbol	Maximum Ratings	Units	Note
On-state Current	$I_{T(AV)}$	2 ($T_C = 54°C$, $\theta = 180°$ Single phase 1/2 wave)	A	
	$I_{T(RMS)}$	4		
Rise of Forward Current	di/dt	50 (non-repetitive)	A/μs	
Surge On-state Current	I_{TSM}	20 (non-repetitive)	A	
Gate Power Dissipation	P_{GM}	0.5 (f ≧ 50 Hz, duty ≧ 10%)	W	
Gate Power Dissipation	$P_{G(AV)}$	0.1	W	
Gate Forward Current	I_{FGM}	0.2 (f ≧ 50 Hz, duty ≧ 10%)	A	
Gate Reverse Voltage	V_{RGM}	6	V	
Junction Temperature	T_j	−40 ~ +110	°C	
Storage Temperature	T_{sg}	−40 ~ +150	°C	
Weight		1.4	g	

EXAMPLE OF R_{GK} INSERTION

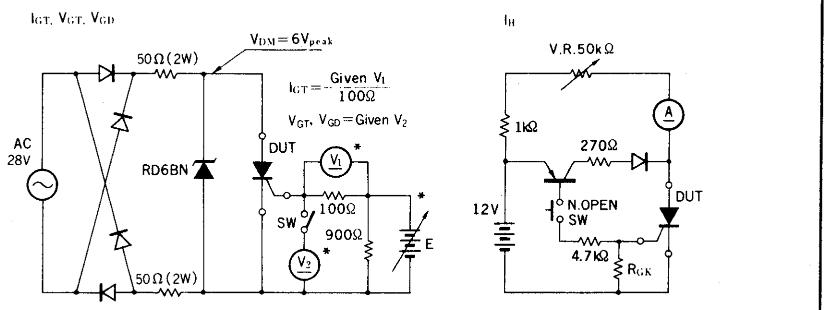


ELECTRICAL CHARACTERISTICS (T_j = 25°C)

Item	Symbol	Min.	Typ.	Max.	Units	Test Conditions
Repetitive Peak Reverse Current Repetitive Peak Off-state Current	I_{RRM} OR I_{DRM}	–	0.1	10	μA	V_{RRM} = V_{DRM} = Rated Value T_C = 25°C, R_{GK} = 1000 Ohms
		–	10	100	μA	V_{RRM} = V_{DRM} = Rated Value T_C = 110°C, R_{GK} = 1000 Ohms
Gate-Trigger Current	I_{GT}	–	30	200	μAdc	T_C = 25°C, V_D = 6Vdc, R_L = 100 Ohms R_{GK} = 1000 Ohms
		–	75	500	μAdc	T_C = −40°C, V_D = 6 Vdc, R_L = 100 Ohms R_{GK} = 1000 Ohms
Gate-Trigger Voltage	V_{GT}	0.4	0.5	0.8	Volts DC	T_C = 25°C, V_D = 6 Vdc, R_L = 100 Ohsm R_{GK} = 1000 Ohms
		0.5	0.7	1.0	Volts DC	T_C = −40°C, V_D = 6 Vdc, R_L = 100 Ohms R_{GK} = 1000 Ohms
		0.2	–	–	Volts DC	T_C = 110°C, V_D = Rated V_{DRM} Value R_L =3000 Ohms, R_{GK} = 1000 Ohms
On-state Voltage	V_{TM}	–	1.8	2.2	Volts	T_C = 25°C, I_{TM} = 4 Amperes Peak, Single Half Sine Wave Pulse, 2 Millisec. Wide
Holding Current	I_H	0.3	1.0	3.0	mAdc	T_C = 25°C, V_D = 12 Vdc, R_{GK} = 1000 Ohms
		0.4	1.5	5.0	mAdc	T_C = −40°C, V_D = 12 Vdc, R_{GK} = 1000 Ohms
		0.14	0.6	2.0	mAdc	T_C = 110°C, V_D = 12 Vdc, R_{GK} = 1000 Ohms
Latching Current	I_L	0.3	1.5	4.0	mAdc	T_C = 25°C, V_D = 12 Vdc, R_{GK} = 1000 Ohms
		0.4	2.5	7.0	mAdc	T_C = −40°C, V_D = 12 Vdc, R_{GK} = 1000 Ohms
Critical Rate-of-Rise of Off-state Voltage	dv/dt	–	8	–	Volts/ Micro-second	T_C = 110°C, V_D = Rated V_{DRM} Value R_{GK} = 1000 Ohms
Turn On Time	t_{ON}	–	1.2	–	Micro-seconds	T_C = 25°C, Rated V_{DRM} Value I_T = 1 Ampere, Gate Pulse = 4 Volts, 300 Ohms, 5 Microseconds Wide
Commutated Trun-Off Time	t_q	–	40	100	Micro-seconds	T_C = 110°C, rectangular current waveform Rate of rise of current $<$10 amps/μsec. Rate of reversal of current $<$5 amps/μsec. I_T = 1 Amp (50 μsec pulse). Repetition Rate = 60 pps. V_{RRM} = Rated V_R = 15 Volts Minimum. V_D = Rated Rate of Rise Reapplied Forward Blocking Voltage = 5 Volts/μsec. Gate Bias = 0 Volts, 100 Ohms (during turn-off time interval).

Case temperature (T_C) is measured in the center of the tab, 1.5mm from the body on Type 1 and Type 3 devices, and in the center of the anode lead, 1.5mm from the body on Type 2 devices.

MEASUREMENT CIRCUIT



* Inner Resistance

V_1 : more than 100 kΩ at I_{GT} ≦ 10 μA
V_2 : more than 1MΩ SW open
E : more than 20 kΩ

Fig. 1 I_{TM} - V_{TM} Characteristics

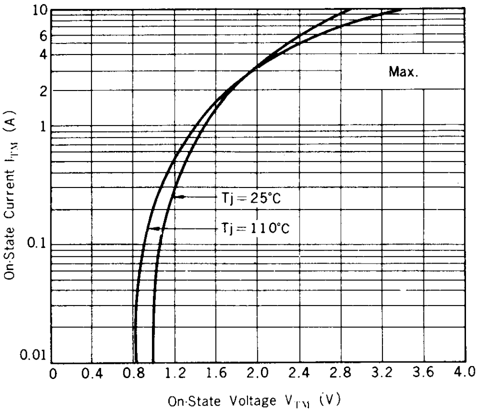


Fig. 2 $P_{T(AV)}$ - $I_{T(AV)}$ Characteristics

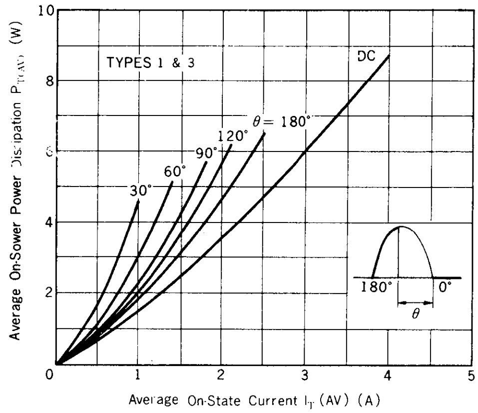


Fig. 3 T_C - $I_{T(AV)}$ Ratings

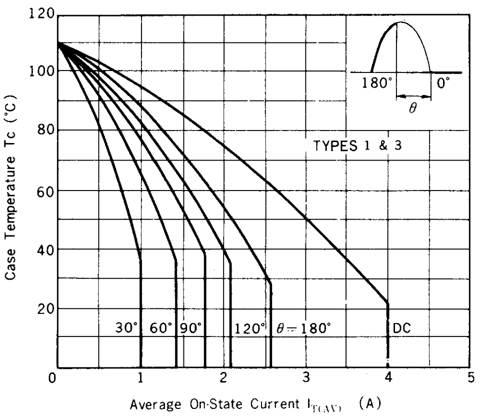


Fig. 4 Ta - $I_{T(AV)}$ Ratings

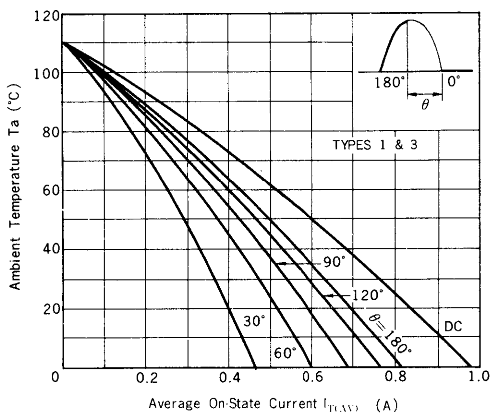


Fig. 5 I_{GT} - Ta Typical Distribution

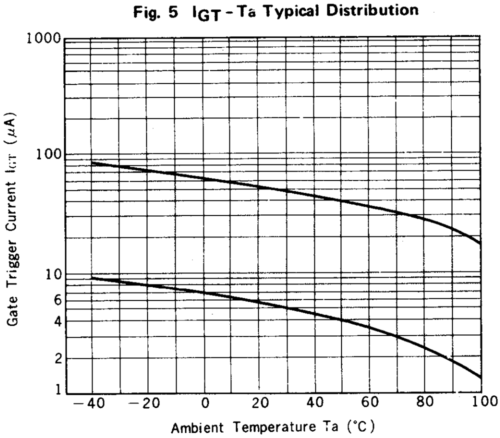
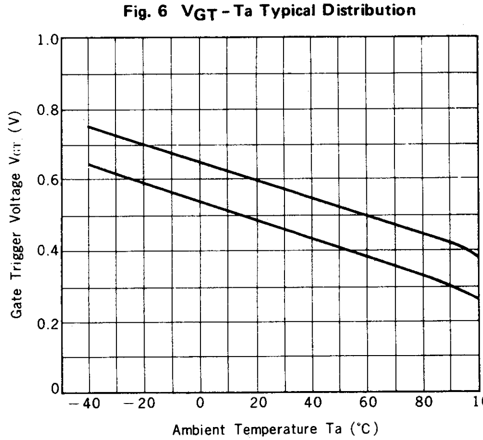


Fig. 6 V_{GT} - Ta Typical Distribution



9

Fig. 7 I_{GT} - τ_G Typical Distribution

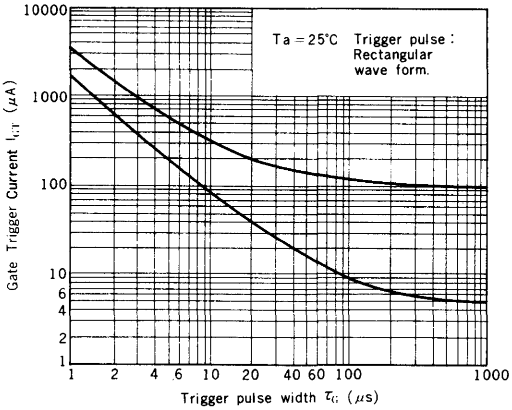


Fig. 8 V_{GT} - τ_G Typical Distribution

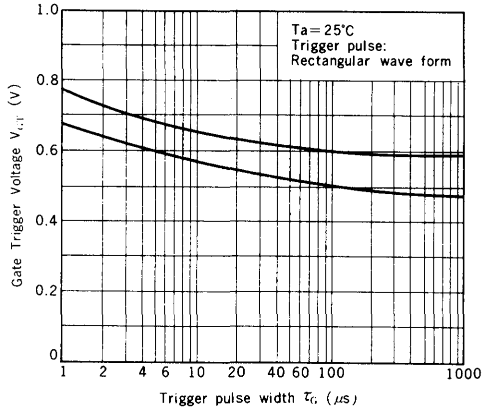


Fig. 9 I_H - Ta Typical Distribution

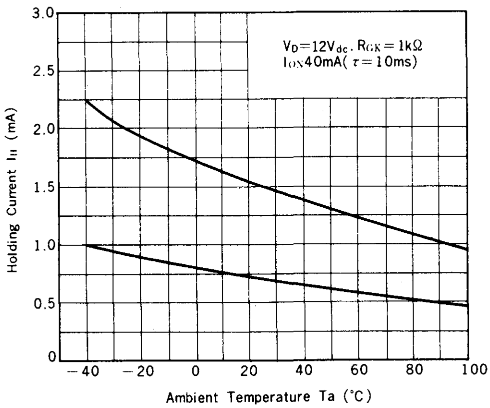


Fig. 10 I_{TSM} Ratings

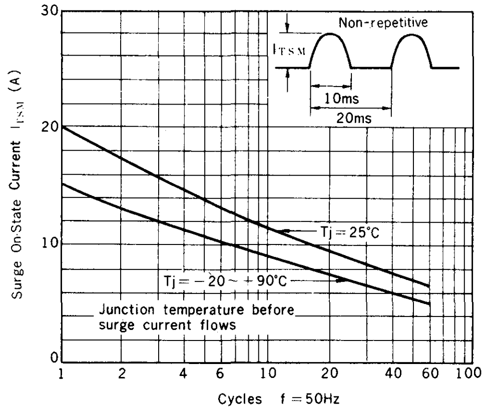
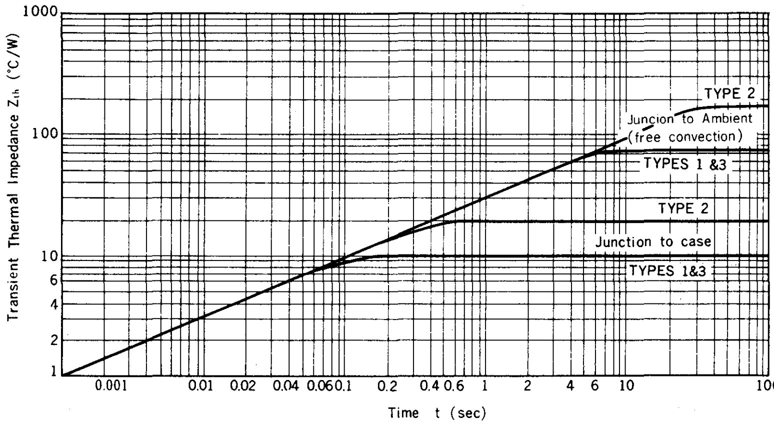
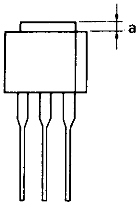


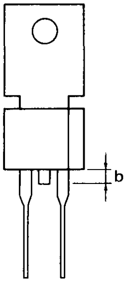
Fig. 11 Z_{th} Characteristics



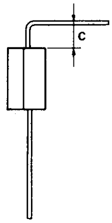
SPECIAL LEAD & HEAT TAB FORMINGS



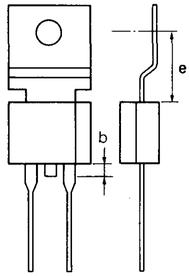
TYPE 2



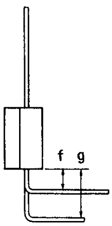
TYPE 3



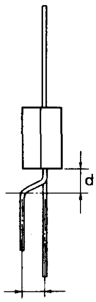
TYPE-BY



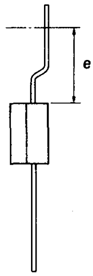
TYPE-AA



TYPE-YB



TYPE-YC



TYPE-AY

Outline Drawing (Unit: mm)			
a	1.0 ±0.2	e	9 ±0.2
b	1.5 ±0.3	f	2.5 ±0.2
c	3 ±0.3	g	5.5 ±0.2
d	3.0 ±0.3	h	2.5 ±0.5

NOTICE FOR INSTALLATION

1. Electrode leads (especially heat sink tablet) are not granted to be bent because of wet-proof. However in case it is required inevitably, a mechanical stress should not be put on mold. Fix tightly between the mold case and the area to be formed or bent.
2. Electrode leads should not to be bent more than twice over 90°. Avoid the bending within 1.5 mm from the neck of mold case.
3. The surface of heat sink for thermal radiator is to be smooth without any foreign matter.
4. Suitable torque value is 4 ~ 5 kg.cm.
5. Soldering
   - ○ Recommended solder: PbSu (4 : 6)
     Melting point 180°C
   - ○ Dimension from the neck of leads to dipping points . . . . 4 ~ 6 mm
   - ○ Soldering temperature and period
     250°C . . . . less than 5 μsec.
     230°C . . . . less than 10 μsec.

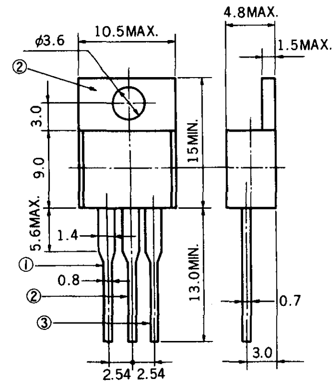
9

NEC
ELECTRON DEVICE

SCR
C122F~C122M

The C122F~C122M are a P gate all diffused mold type SCR granted 8Amp On-state Current. The glassivation technique applied to pellet's surface makes this series quite highly reliable.

Outline Drawing (Unit: mm)



Pin Connection
1. Cathode
2. Anode
3. Gate

FEATURES

- Glassivated silicon chip for maximum reliability.
- Easy installation by TO-220 AB package.
- Low cost.

APPLICATIONS

- Motor speed control for household appliance.
- Temperature control for heater and constant temperature box.
- Constant voltage power source and battery charger.
- Automotive application such as regulator.
- Various solid state relay etc.

MAXIMUM RATINGS

Item	Symbol	F	A	B	C	D	E	M	Unit	Note
Non-Repetitive Peak Reverse Voltage	V_{RSM}	75	200	300	400	500	600	700	V	
Non-Repetitive Peak Off-State Voltage	V_{DSM}	75	200	300	400	500	600	700	V	
Repetitive Peak Reverse Voltage	V_{RRM}	50	100	200	300	400	500	600	V	
Repetitive Peak Off-State Voltage	V_{DRM}	50	100	200	300	400	500	600	V	
RMS On-State Current	$I_{T(RMS)}$	8 (All conduction angles)							A	
Average On-State Current	$I_{R(AV)}$	See Fig. 4 and 6							A	
Critical Rate-Of-Rise of On-State Current	di/dt	100 (Switching from 200 Volts) 50 (Switching from 500 Volts)							A/μS	
Surge On-State Current	I_{TSM}	90 (60Hz), 82 (50Hz)							A	Fig. 2
Fusing Current	$\int i_T^2 dt$	34 (at 8.3ms), 27 (at 1.5ms)							A^2S	
Peak Gate Power Dissipation	P_{GM}	5 (10μs pulse width)							W	
Average Gate Power Dissipation	PG(AV)	0.5							W	
Peak Gate Forward Current	I_{FGM}	See Fig. 7							A	
Peak Gate Reverse Voltage	V_{RGM}	5							V	
Junction Temperature	Tj	−40 ~ +100							°C	
Storage Temperature	T_{stg}	−40 ~ +125							°C	

9

ELECTRICAL CHARACTERISTICS

Item	Symbol	Condition		Min.	Typ.	MAX.	Unit	Note
Repetitive Peak Reverse Current	I_{RRM}	$V_{RM}=V_{RRM}$	$T_C=+25°C$	–	–	0.1	mA	
			$T_C=+100°C$	–	–	0.5		
Repetitive Peak Off-State Current	I_{DRM}	$V_{DM}=V_{DRM}$	$T_C=+25°C$	–	–	0.1	mA	
			$T_C=+100°C$	–	–	0.5		
On-State Voltage	V_{TM}	$T_C=+25°C$, $I_{TM}=16A$ peak		–	–	1.83	V	Fig. 1
Gate-Trigger Current	I_{GT}	$T_C=+25°C$ $V_{DM}=6V$ $R_L=91\Omega$	$T_C=+25°C$	–	–	25	mA	Fig. 9,10
			$T_C=-40°C$	–	–	40		
Gate-Trigger Voltage	V_{GT}	$T_C=+25°C$ $V_{DM}=6V$ $R_L=91\Omega$	$T_C=+25°C$	–	–	1.5	V	Fig. 8
			$T_C=-40°C$	–	–	2.0		
Gate Non-Trigger Voltage	V_{GD}	$T_C=+100°C$, $V_{DM}=V_{DRM}$ $R_L=1\ k\Omega$		0.2	–	–	V	
Critical Rate of Rise of Off-State Voltage	dv/dt	$T_C=+100°C$, $V_{DM}=V_{DRM}$ Gate Open Circuited Linear Waveform		10	50	–	V/μs	
Holding Current	I_H	$V_{DM}=24V$	$T_C=+25°C$	–	–	30	mA	Fig. 11
			$T_C=-40°C$	–	–	60		
Latching Current	I_L	$V_{DM}=24V$	$T_C=+25°C$	–	–	60	mA	
			$T_C=-40°C$	–	–	120		
Circuit Commutated Turn-off Time	tq	$T_C=+100°C$, $I_{TM}=10A$ peak di/dt=–5A/μs, $V_D=V_{DRM}$ $V_R\geqq 12V$, dv/dt=10v/μs		–	50	–	μs	
Thermal Resistance	Rth(j–c)	Junction to case		–	–	1.8	°C/W	Fig. 12
	Rth(j–a)	Junction to Ambient		–	–	75		

Fig. 1 i_T—V_T Characteristic

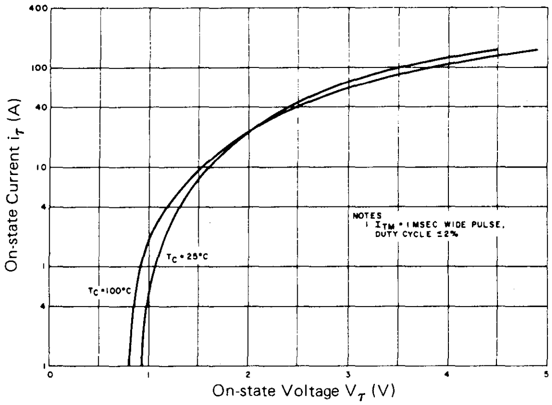


Fig. 2 I_{TSM} Rating

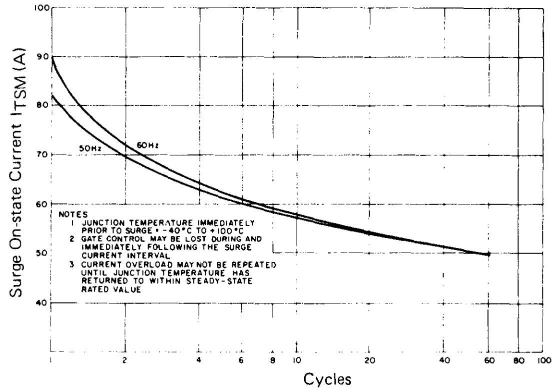


Fig. 3 P_T(AV)—I_T(AV) Characteristic
(For Half Wave)

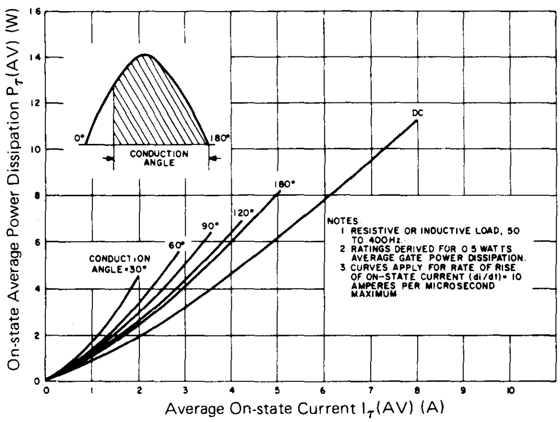


Fig. 4 T_C—I_T(AV) Rating
(For Half Wave)

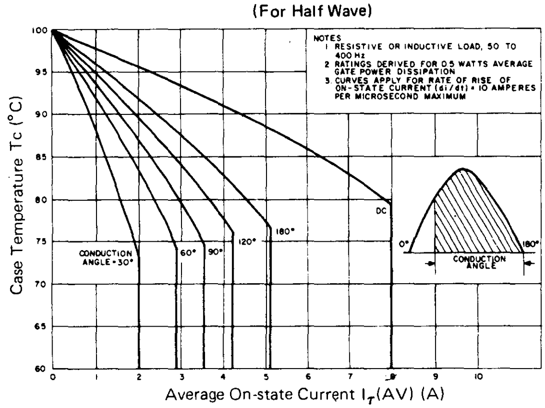


Fig. 5 P_T(AV) — I_T(AV) Characteristic
(For Full Wave)

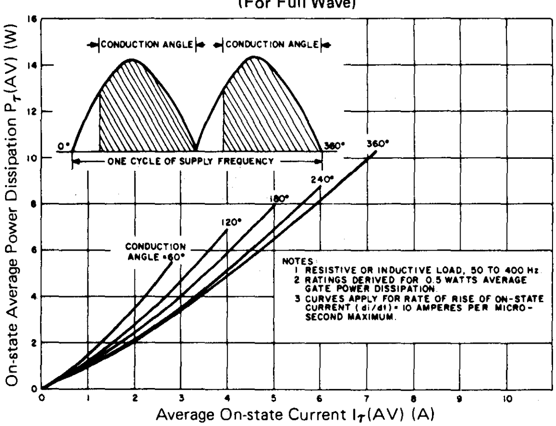


Fig. 6 T_C — I_T(AV) Rating
(For Full Wave)

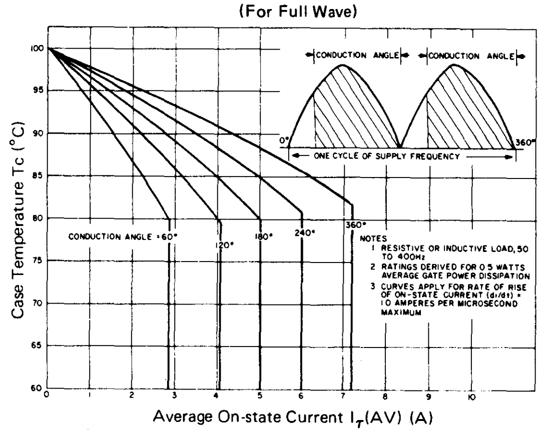


Fig. 7 Gate Characteristic

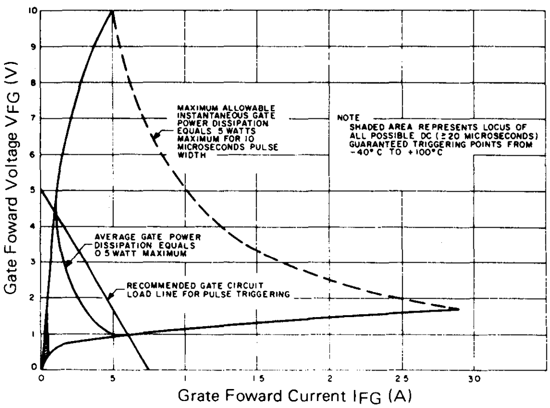


Fig. 8 VGT–Tc Characteristic

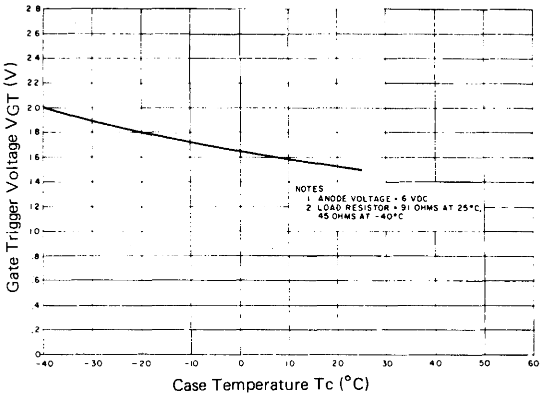


Fig. 9 IGT–Tc Characteristic

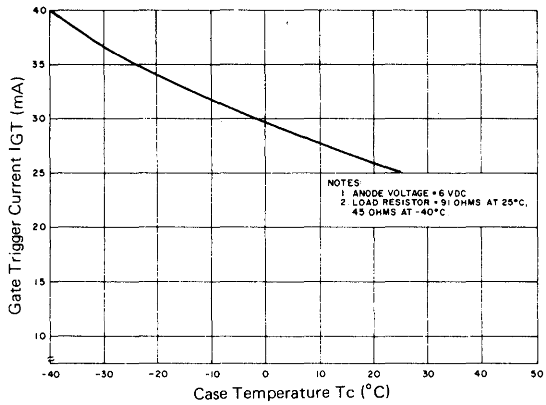


Fig. 10 Pulse IGT Characteristic

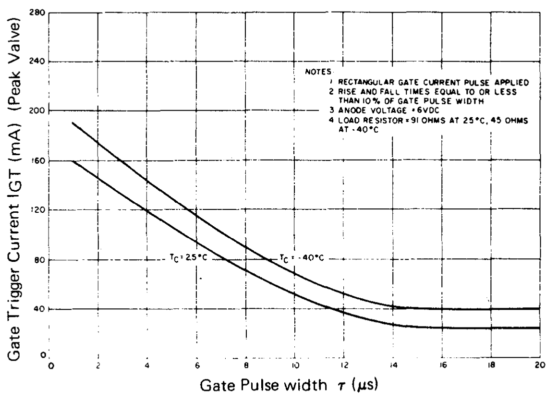


Fig. 11 IH – Tc Characteristic

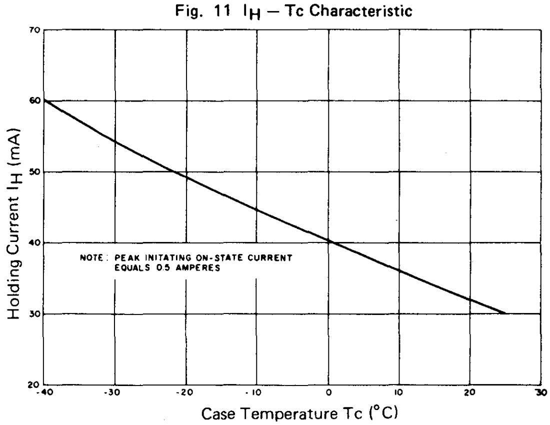
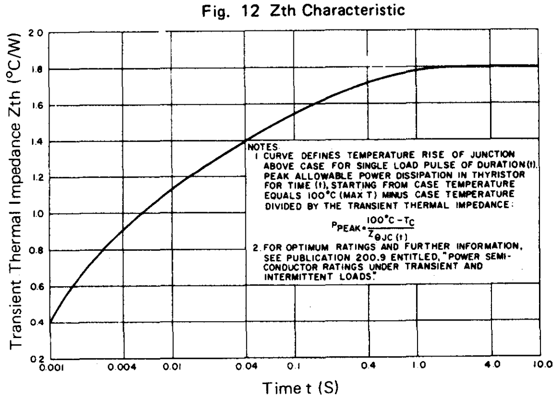


Fig. 12 Zth Characteristic

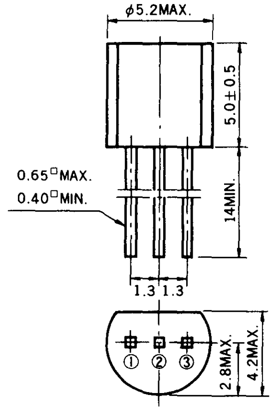


NEC
ELECTRON DEVICE

TO-92 MOLD THYRISTOR
0.8A RMS SCR
C203Y~C203D

The C203Y ~ C203D are P-gate all diffused mold type SCR rated at 0.8 Amps RMS maximum on-state current, with rated voltages up to 400 volts.

OUTLINE DRAWING (Unit : mm)



1. Cathode
2. Gate
3. Anode

FEATURES

- Plastic TO-92 package
- 200μA gate sensitivity
- 5 mA holding current
- 8 A surge current
- 30 through 400V selection

APPLICATIONS

- Cassette tape recorder, Television
- Automobile equipment
- Strobe flasher
- Automatic gas lighter
- Solid-state relay
- Light display equipment
- Motor, solenoid and temperature control etc.

MAXIMUM ALLOWABLE RATINGS

ITEM	SYMBOL	Y	YY	A	B	C	D	UNIT	NOTE
Non-Repetitive Peak Reverse Voltage	V_{RSM}	45	90	150	300	400	500	V	R_{GK} = 1 kΩ
Non-Repetitive Peak Off-State Voltage	V_{DSM}	45	90	150	300	400	500	V	R_{GK} = 1 kΩ
Repetitive Peak Reverse Voltage	V_{RRM}	30	60	100	200	300	400	V	R_{GK} = 1 kΩ
Repetitive Peak Off-State Voltage	V_{DRM}	30	60	100	200	300	400	V	R_{GK} = 1 kΩ
RMS On-State Current	$I_{T(RMS)}$	0.8 (All conduction angles)						A	
Average On-State Current	$I_{T(AV)}$	0.5 (T_C = 25°C)						A	
Surge On-State Current	I_{TSM}	8 (f = 60 Hz Non-repetitive)						A	
Peak Gate Power Dissipation	P_{GM}	1 (8.3 ms)						W	
Average Gate Power Dissipation	$P_{G(AV)}$	0.01						W	
Peak Gate Forward Current	I_{FGM}	0.5						A	
Peak Gate Reverse Voltage	V_{RGM}	8						V	
Junction Temperature	Tj	−65 ~ +125						°C	
Storage Temperature	Tstg	−65 ~ +150						°C	

CHARACTERISTICS (T_j = 25°C) (Unless Otherwise Specified)

ITEM	SYMBOL	CONDITIONS		MIN.	TYP.	MAX.	UNIT	NOTE
Peak Off-State Current	I_{DRM}	V_{DM}=V_{DRM}, R_{GK}=1kΩ	T_j= 25°C	–	–	1	μA	
			T_j=125°C	–	–	50		
Peak Reverse Current	I_{RRM}	V_{RM}=V_{RRM}, R_{GK}=1kΩ	T_j= 25°C	–	–	1	μA	
			T_j=125°C	–	–	50		
On-State Voltage	V_{TM}	I_{TM}=1A		–	–	1.5	V	See Fig. 1
Gate Trigger Voltage	V_{GT}	V_{DM}=6V, R_L=100Ω R_{GK}=1kΩ	T_j= 25°C	–	–	0.8	V	
			T_j=–65°C	–	–	1.0		
Gate Trigger Current	I_{GT}	V_{DM}=6V, R_L=100Ω R_{GK}=1kΩ	T_j= 25°C	–	–	200	μA	
			T_j=–65°C	–	–	500		
Gate Non-Trigger Voltage	V_{GD}	V_{DM}=V_{DRM}, R_L=1kΩ R_{GK}=1kΩ	T_j=125°C	0.1	–	–	V	
Critical Rate-of-Rise Off-State Voltage	dv/dt	V_{DM}=V_{DRM}, R_{GK}=1kΩ	T_j=125°C	–	20	–	V/μs	
Holding Current	I_H	V_D=12V, R_{GK}=1kΩ	T_j= 25°C	–	–	5	mA	See Fig. 8
			T_j=–65°C	–	–	10		
Circuit Commutated Turn-Off Time	tq	I_{TM}=1A, di_R/dt<5A/μs V_R≧15V, V_{DM}=V_{DRM} dv/dt=20v/μs, R_{GK}=100Ω	T_j=125°C	–	15	–	μs	
Thermal Resistance	$R_{th(j-c)}$	Junction to Case (flat side of case is temperature reference point)		–	–	125	°C/w	See Fig. 7
	$R_{th(j-a)}$	Junction to Ambient		–	–	230		

Fig. 1 I_{TM} - V_{TM} Characteristics

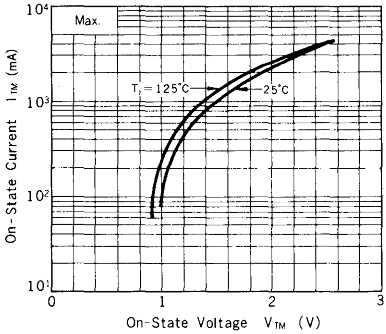


Fig. 2 I_{TSM} Rating

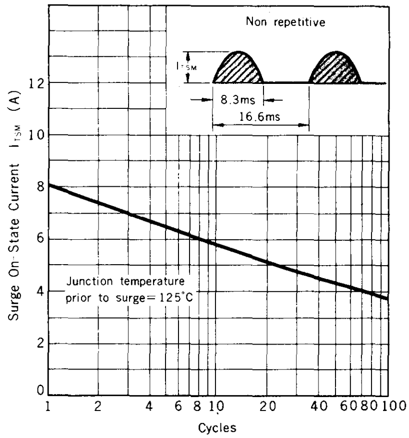


Fig. 3 $P_{T(AV)}$ - $I_{T(AV)}$ Characteristics

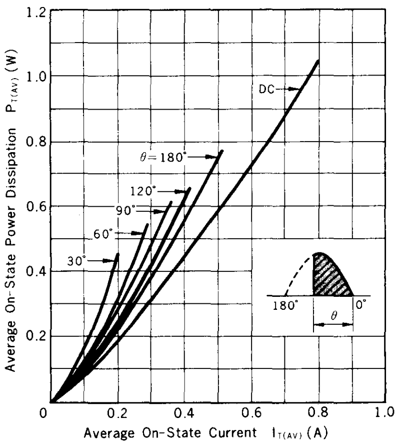


Fig. 4 T_C - $I_{T(AV)}$ Ratings

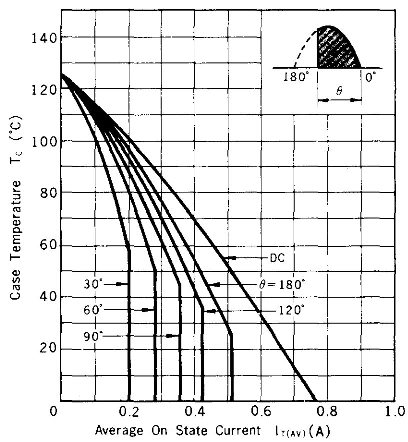


Fig. 5 Ta - $I_{T(AV)}$ Ratings

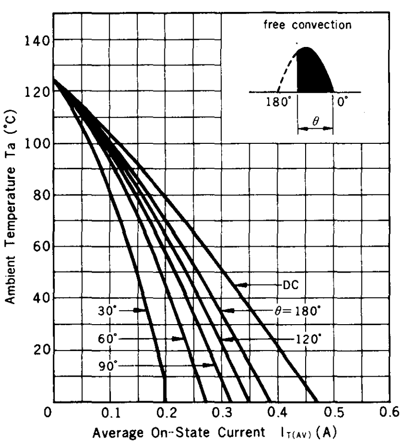


Fig. 6 Ts — I_T (AV) Characteristics

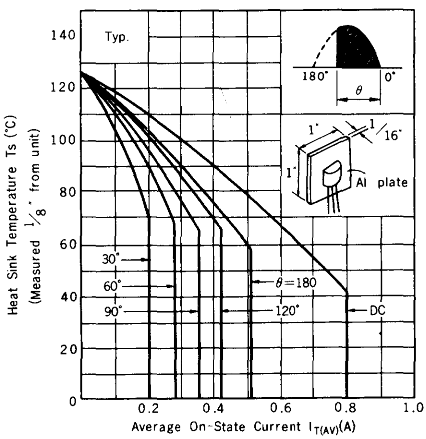


Fig. 7 Z_{th} Characteristics

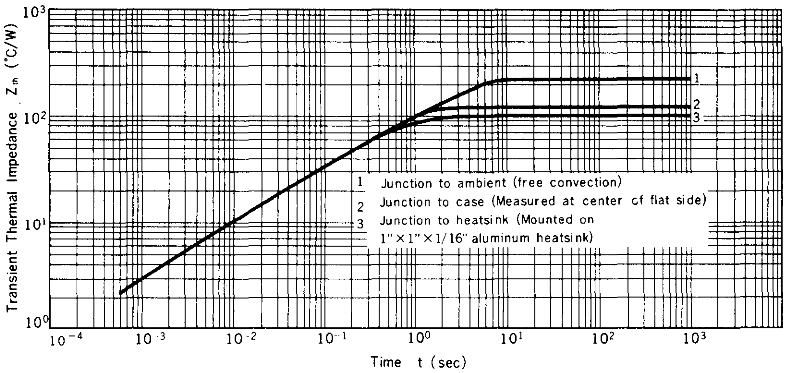
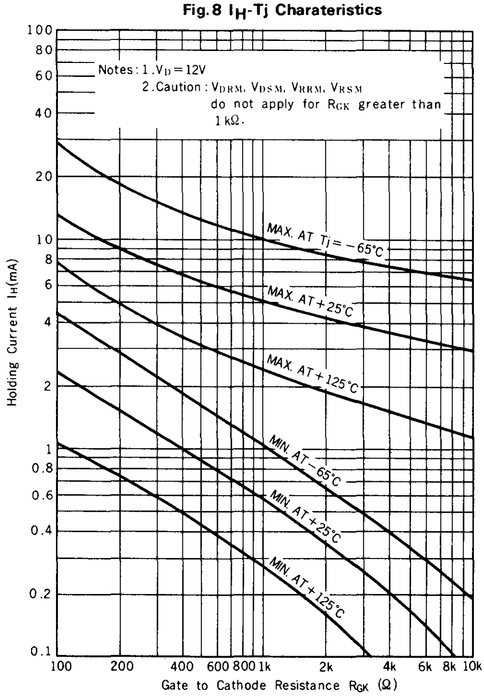


Fig.8 I_H-Tj Charateristics



NEC
ELECTRON DEVICE

TRIAC

AC0V8BGM, AC0V8DGM

The AC0V8BGM, AC0V8DGM are all diffused type TRIAC granted RMS On-state Current 0.8 Amps.
This series is designed specifically to be driven by low-level logic in any gating mode.

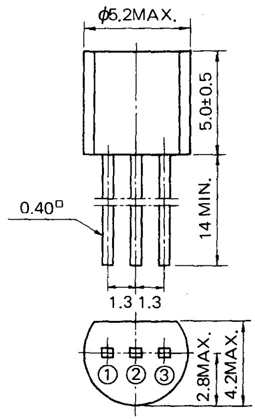
FEATURES

This series offers sensitive gate specs of 5 and 10 mA, in all four quadrants.
You can fill the gap between microprocessor controls and the power-output requirements.
This series is housed in the popular T0-92 package.
The package features excellent environmental stress and temperature cycling.

APPLICATIONS

Solid-state relays, microprocessor interfacing, TTL logic and various solid-state switch designs alone or with larger TRIAC.

OUTLINE DRAWING (Unit: mm)



1. T_1 Terminal
2. Gate
3. T_2 Terminal

MAXIMUM RATINGS

ITEM	SYMBOL	AC0V8BGM	AC0V8DGM	UNIT	NOTE
Repetitive Peak off Voltage	V_{DRM}	200	400	V	
Non-repetitive Peak off Voltage	V_{DSM}	300	500	V	
RMS On-State Current	$I_{T(RMS)}$	0.8 (T_C = 60°C)		A	
Peak Surge On-State Current	I_{TSM}	7 (50Hz), 8 (60Hz)		A	Fig. 2
Fusing Current	$\int i_T^2 dt$	0.2 (1ms ≦ t ≦ 10ms)		A^2S	
Peak Gate Power Dissipation	P_{GM}	1		W	
Average Gate Power Dissipation	$P_{G(AV)}$	0.1		W	
Peak Gate Current	I_{FGM}	1		A	
Junction Temperature	T_j	125		°C	
Storage Temperature	T_{stg}	−40 ~ +125		°C	

9

ELECTRICAL CHARACTERISTICS ($T_j = 25°C$)

ITEM		SYMBOL	TEST CONDITIONS		MIN.	TYP.	MAX.	UNIT	NOTE
Peak Off-State Current		I_{DRM}	$V_{DM} = V_{DRM}$	$T_j = 25°C$	–	–	20	μA	
				$T_j = 125°C$	–	–	100		
On-State Voltage		V_{TM}	$I_{TM} = 1.2$ A		–	–	1.5	V	Fig. 1
Critical Rate of Rise of Off-State Voltage		dv/dt	$T_j = 125°C$, $V_{DM} = V_{DRM}$ Gate Open Circuited Exponential Waveform		10	–	–	V/μs	
*DC Gate Trigger Current	I	I_{GT}	$V_{DM} = 12V$ $R_L = 100\Omega$	G;Positive, T_2;Positive	–	–	5	mA	Fig.4, 5
	II			G;Positive, T_2;Negative	–	–	10		
	III			G;Negative, T_2;Negative	–	–	5		
	IV			G;Negative, T_2;Positive	–	–	10		
DC Gate Trigger Voltage	I	V_{GT}	$V_{DM} = 12V$ $R_L = 100\Omega$	G;Positive, T_2;Positive	–	–	1.0	V	Fig.4, 5
	II			G;Positive, T_2;Negative	–	–	1.5		
	III			G;Negative, T_2;Negative	–	–	1.0		
	IV			G;Negative, T_2;Positive	–	–	1.5		
Gate Non-Trigger Voltage		V_{GD}	$T_j = 125°C$ $V_{DM} = ½ V_{DRM}$		0.1	–	–	V	
DC Holding Current		I_H	$V_D = 24V$		–	5	10	mA	
Critical Rate of Rise of Commutating Off-State Voltage		(dv/dt)c	$T_j = 125°C$, $I_{TM} = 1.2A$ $(di_T/dt)c = -0.5$ A/ms $V_{DM} = V_{DRM}$		1	–	–	V/μs	
Steady State Thermal Resistance		Rth(j–c)	Junction-to-Case		–	–	75	°C/W	
		Rth(j–a)	Junction-to-Ambient		–	–	200	°C/W	Fig. 9

*All four quadrants: 5 mA Max. Selected types available from factory.

Fig. 1 i_T–V_T Characteristic

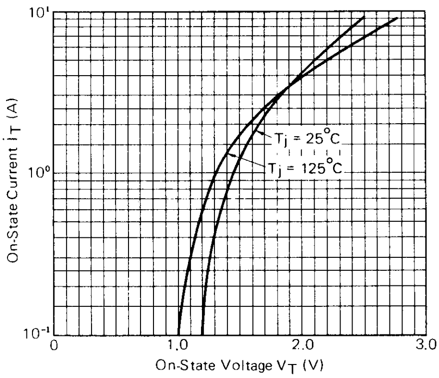


Fig. 2 I_{TSM} Rating

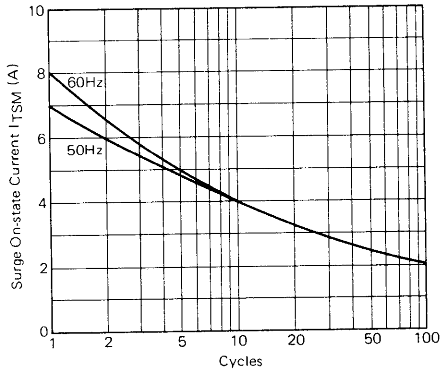


Fig. 3 $P_{T(AV)}$–$I_{T(RMS)}$ Characteristic

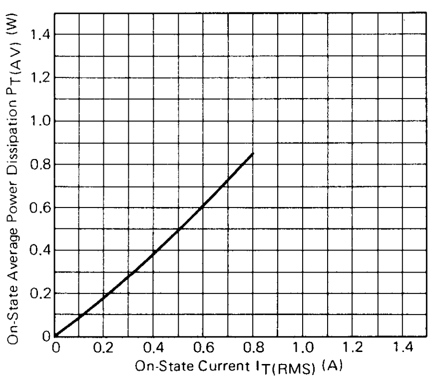


Fig. 4 Gate Characteristic

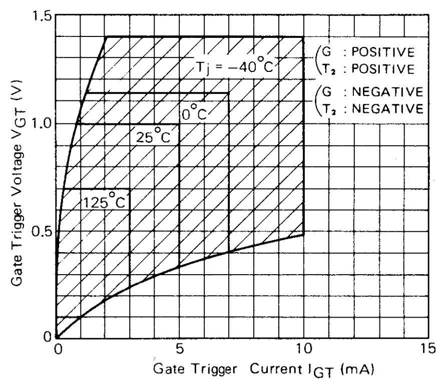


Fig. 5 Gate Characteristic

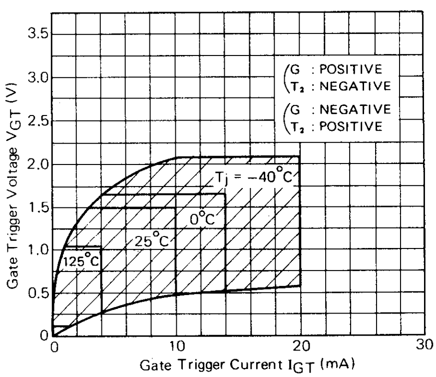


Fig. 6 T_C–$I_{T(RMS)}$ Rating

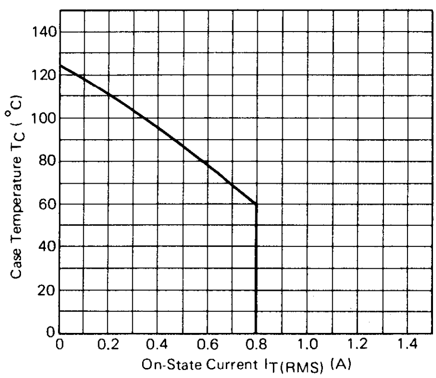


Fig. 7 $T_a - I_{T(RMS)}$ Rating

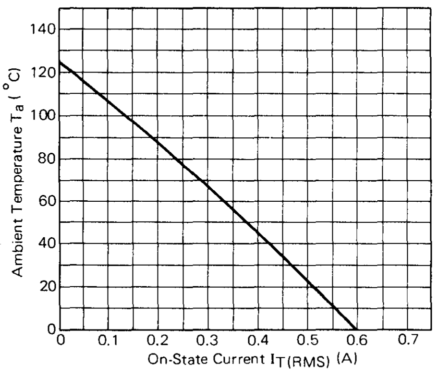


Fig. 8 Pulse I_{GT} Characteristic

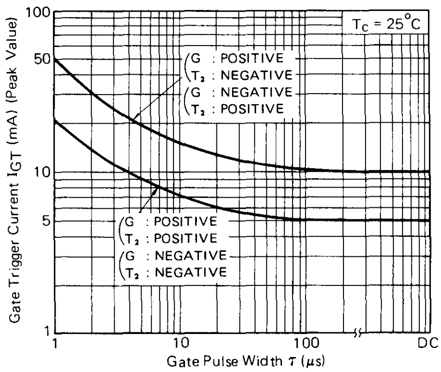
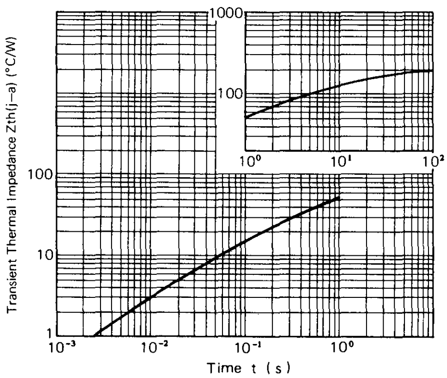


Fig. 9 Zth(j—a) Characteristic



NEC
ELECTRON DEVICE

TRIAC
AC03BGM ~ AC03FGM

The AC03BGM ~ AC03FGM are all diffused mold type triac granted RMS On-state current 3 Amps.
The glassivation technique applied to pellets' surface makes this series quite highly reliable.

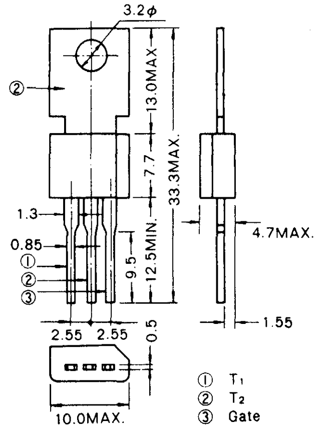
FEATURES

- The pellet surface is quite stable physically and electrically by applying glassivation technique.
- Easy installation by its miniature size and thin electrode leads.
- Less holding current distribution provides free application design.
- Low cost because of mass-production.

APPLICATIONS

Temperature Control, Light Dimmer Control, AC Motor Speed Control Electric Jar, Electric Lamp Starter, Various Solid State Switch.

Outline Drawing (Unit : mm)



MAXIMUM RATINGS

Item	Symbol	AC03BGM	AC03DGM	AC03EGM	AC03FGM	Unit	Note
Repetitive Peak off Voltage	V_{DRM}	200	400	500	600	V	
Non-repetitive Peak off Voltage	V_{DSM}	300	500	600	700	V	
RMS On-State Current	$I_{T\ (RMS)}$	3 (T_C = 77°C, θ = 180°C)				A	See Fig. 5
Surge On-State Current	I_{TSM}	30 (50Hz 1 cycle)				A	See Fig. 2
Fusing Current	$\int i_T^2 dt$	4.0				A^2S	
Peak Gate Power Dissipation	P_{GM}	3 (f ≧ 50Hz, duty ≦ 10%)				W	
Average Gate Power Dissipation	$P_{G\ (AV)}$	0.3				W	
Peak Gate Current	I_{GM}	±0.5 (f ≧ 50Hz, duty ≦ 10%)				A	
Junction Temperature	T_j	-40 ~ +110				°C	
Storage Temperature	T_{stg}	-40 ~ +125				°C	

* T_C: case temperature is measured at 1.5 mm from the neck of tablet

9

ELECTRICAL CHARACTERISTICS ($T_j = 25°C$)

Item		Symbol	Test Conditions	MIN.	TYP.	MAX.	Unit	Note
Peak Off-State Current		I_{DRM}	$V_{DM} = V_{DRM}$, $T_j = -40 \sim 110°C$	–	–	1	mA	
On-State Voltage		V_{TM}	$I_{TM} = 5A$	–	–	1.8	V	See Fig. 1
Gate-trigger Current	Trigger Mode I	I_{GT}	$V_{DM} = 12V$, $R_L = 100\Omega$	–	–	15	mA	See Fig. 3
	II			–	–	–		
	III			–	–	15		
	IV			–	–	15		
Gate-trigger Voltage	Trigger Mode I	V_{GT}	$V_{DM} = 12V$, $R_L = 100\Omega$	–	–	2	V	See Fig. 3
	II			–	–	–		
	III			–	–	2		
	IV			–	–	2		
Gate Non-Trigger Voltage		V_{GD}	$T_j = 110°C$, $V_{DM} = ½V_{DRM}$	0.2	–	–	V	
Commutating dV/dt *		(dv/dt) C	$T_j = 110°C$, $(di_T/dt)\ C = -1.6A/m\ sec$, $V_{DM} = 200V$ (AC03BGM)	–	4	–	V/μs	R; for resistive loads
			400V (AC03DGM ~ AC03FGM)	10	–	–		L; for inductive loads
Holding Current		I_H	$V_D = 24V$	–	5	–	mA	
Thermal Resistance		$R_{th(j-c)}$	Junction to Case	–	–	10	°C/W	See Fig. 7
		$R_{th(j-l)}$	Junction to Lead	–	–	20		
		$R_{th(j-a)}$	Junction to Ambient, Standard	–	–	75	°C/W	See Fig. 7
			Junction to Ambient, without Tablet	–	–	150		

* Add R or L to the end of type number according to applications.

Trigger Mode & Test circuit

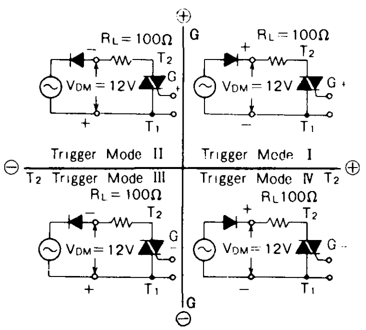


Fig. 1 $i_T - V_T$ Characteristic

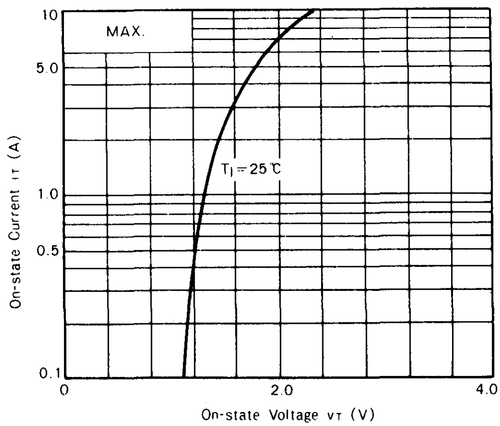


Fig. 2 I_{TSM} Rating

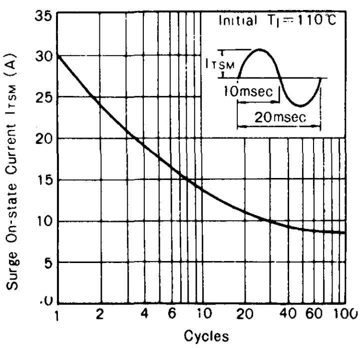


Fig. 3 $V_{GT} - I_{GT}$ Characteristic

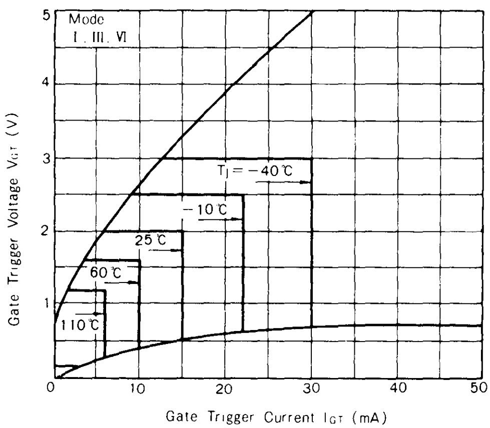


Fig. 4 $P_{T(AV)} - I_{T(RMS)}$ Characteristic

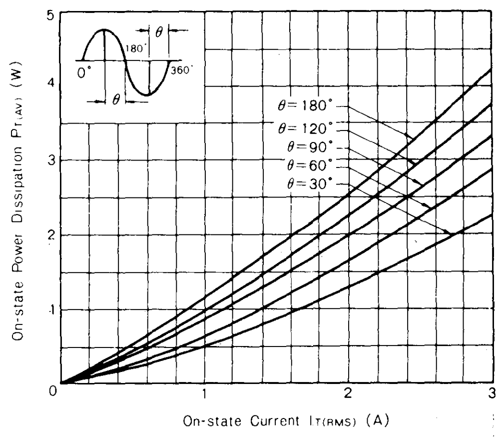


Fig. 5 $T_c - I_{T(RMS)}$ Characteristic

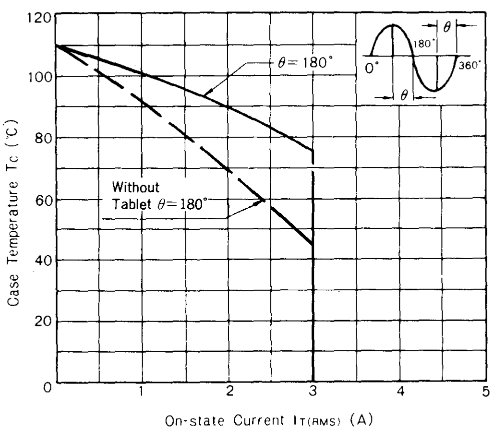


Fig. 6 Ta $- I_{T(RMS)}$ Characteristic

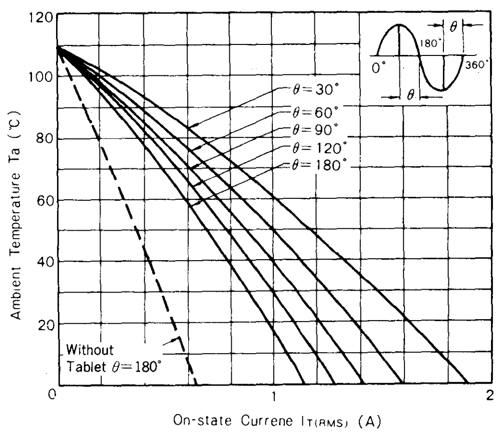
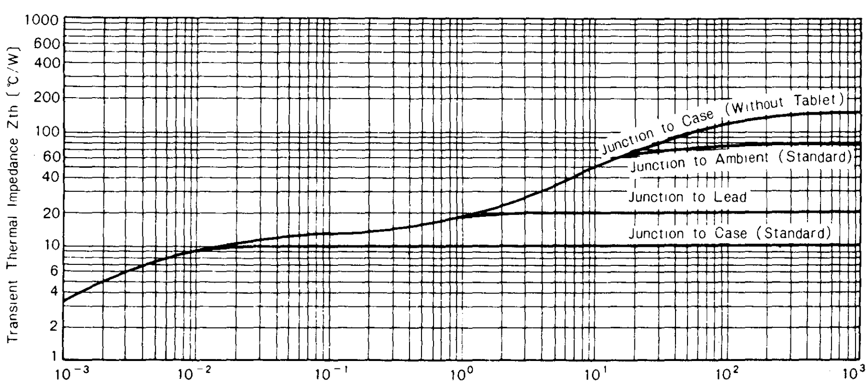


Fig. 7 Z_{th} Characteristic

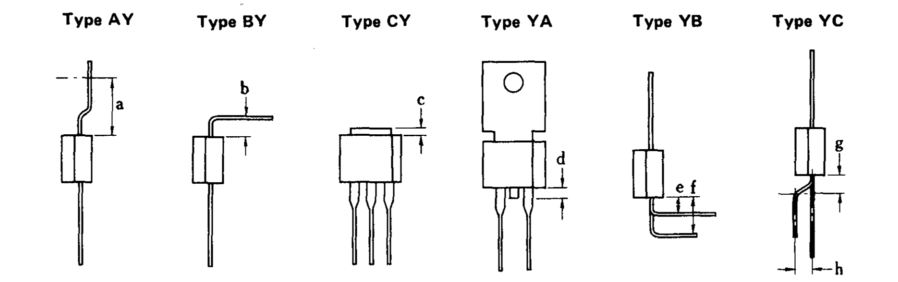


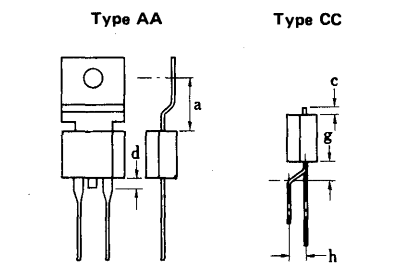
NOTICE FOR INSTALLATION

1. Electrode leads (especially heat sink tablet) are not granted to be bent because of wet-proof. However it is required inevitably that a mechanical stress should not be put on mold case. Fix tightly between the mold case and the area to be formed or bent.

2. Electrode leads are not granted to be bent more than twice over 90° and avoid the bending within 1.5mm from the neck of the mold case.

3. Special lead and heat tab formings as indicated below are available at an additional cost.





Measurement (mm)			
a	9 ± 0.2	e	2.5 ± 0.2
b	3 ± 0.3	f	5.5 ± 0.2
c	1.0 ± 0.2	g	3.0 ± 0.3
d	1.5 ± 0.3	h	2.5 ± 0.5

4. The surface of heat sink for thermal radiator is to be smooth without any foreign matter.

5. Suitable torque value is 4–5kg.cm.

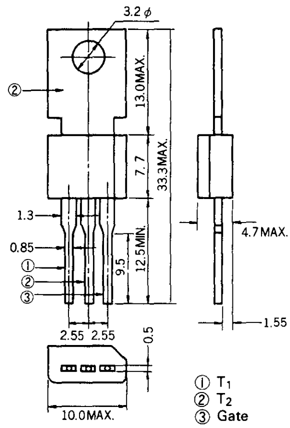
6. Soldering
   - Recommended solder: , PbSu (4 : 6)
     Melting point 180°C
   - Dimension from the neck of leads to dipping points .... 4~6 mm
   - Soldering temperature and period
     250°C .... less than .5 sec.
     230°C .... less than 10 sec.

NEC
ELECTRON DEVICE

TRIAC
AC04BGM～AC04FGM

The AC04BGM～AC04FGM are all diffused mold type triac granted RMS On-state current 4 Amps.
The glassivation technique applied to pellets' surface makes this series quite highly reliable.

Outline Drawing (Unit : mm)



FEATURES

- The pellet surface is quite stable physically by applying glassivation technique.
- Easy installation by its miniature size and thin electrode leads.
- Less holding current distribution provides free application design.
- Low cost because of mass-production.

APPLICATIONS

Temperature Control, Light Dimmer Control, AC Motor Speed Control, Electric Lamp Starter, Various Solid State Switch.

MAXIMUM RATINGS

Item	Symbol	AC04BGM	AC04DGM	AC04EGM	AC04FGM	Unit	Note
Repetitive Peak off Voltage	V_{DRM}	200	400	500	600	V	
Non-repetitive Peak off Voltage	V_{DSM}	300	500	600	700	V	
RMS On-State Current	$I_{T\ (RMS)}$	4 (T_C = 80°C, θ = 180°C)				A	See Fig. 5
Surge On-State Current	I_{TSM}	30 (50Hz 1 cycle)				A	See Fig. 2
Fusing Current	$\int i_T{}^2 dt$	4.0				A^2S	
Peak Gate Power Dissipation	P_{GM}	1 (f ≧ 50Hz, duty ≦ 10%)				W	
Average Gate Power Dissipation	$P_{G\ (AV)}$	0.3				W	
Peak Gate Current	I_{GM}	±0.5 (f ≧ 50Hz, duty ≦ 10%)				A	
Junction Temperature	T_j	–40 ~ +125				°C	
Storage Temperature	T_{stg}	–40 ~ +125				°C	

* T_C: case temperature is measured at 1.5 mm from the neck of tablet

ELECTRICAL CHARACTERISTICS (T_j=25°C)

Item		Symbol	Test Conditions	MIN.	TYP.	MAX.	Unit	Note
Peak Off-State Current		I_{DRM}	V_{DM} = V_{DRM}, T_j = –40 ~ 125°C	–	–	1	mA	
On-State Voltage		V_{TM}	I_{TM} = 5A	–	–	1.8	V	See Fig. 1
Gate-trigger Current	Trigger Mode I	I_{GT}	V_{DM} = 12V, R_L = 100Ω	–	–	15	mA	See Fig. 3
	II			–	–	–		
	III			–	–	15		
	IV			–	–	15		
Gate-trigger Voltage	Trigger Mode I	V_{GT}	V_{DM} = 12V, R_L = 100Ω	–	–	2	V	See Fig. 3
	II			–	–	–		
	III			–	–	2		
	IV			–	–	2		
Gate Non-Trigger Voltage		V_{GD}	T_j = 125°C, V_{DM} = ½V_{DRM}	0.2	–	–	V	
Commutating dV/dt *		(dv/dt) C	T_j = 125°, (di_T/dt) C = –1.6 A/m sec, V_{DM} = 200V (AC04BGM), 400V (AC04DGM ~ AC04FGM)	–	4	–	V/µs	R; for resistive loads
				10	–	–		L; for inductive loads
Holding Current		I_H	V_D = 24V	–	5	–	mA	
Thermal Resistance		$R_{th\ (j-c)}$	Junction to Case	–	–	10	°C/W	See Fig. 6
		$R_{th\ (j-l)}$	Junction to Lead	–	–	20		
		$R_{th\ (j-a)}$	Junction to Ambient: Standard	–	–	75	°C/W	See Fig. 6
			Junction to Ambient: without Tablet	–	–	150		

* Add R or L to the end of type number according to applications..

Trigger Mode & Test circuit

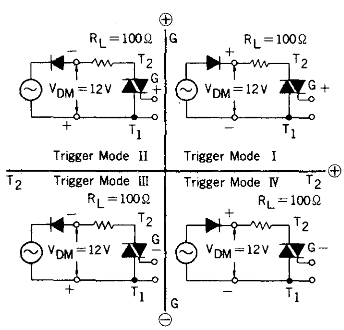


Fig. 1 iT – vT Characteristic

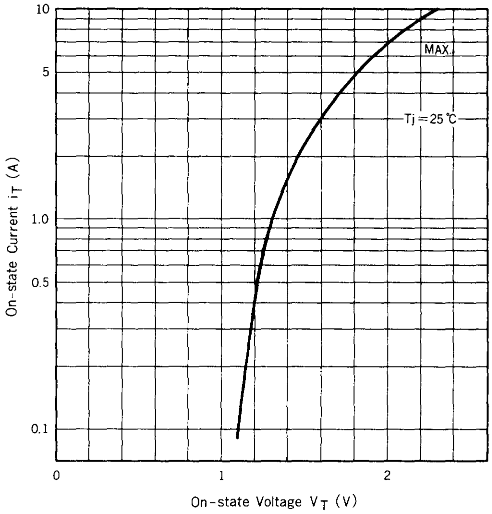


Fig. 2 ITSM Rating

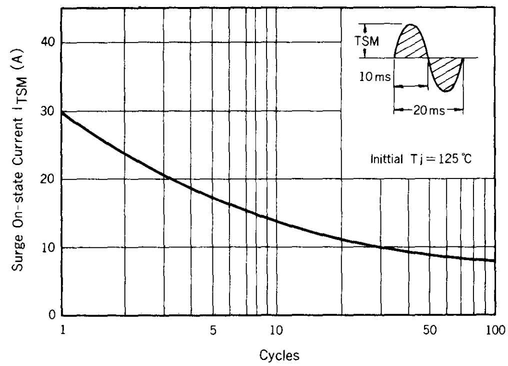


Fig. 3 VGT – IGT Characteristic

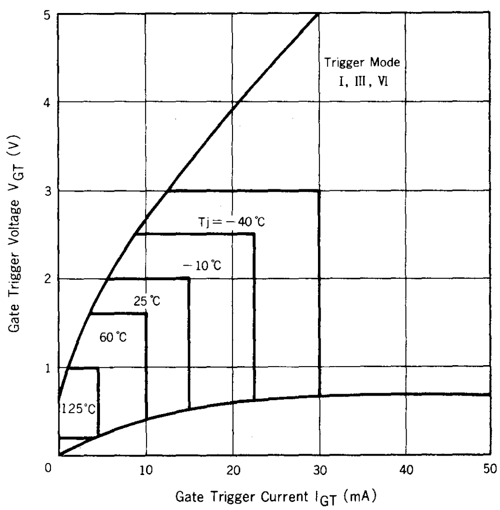
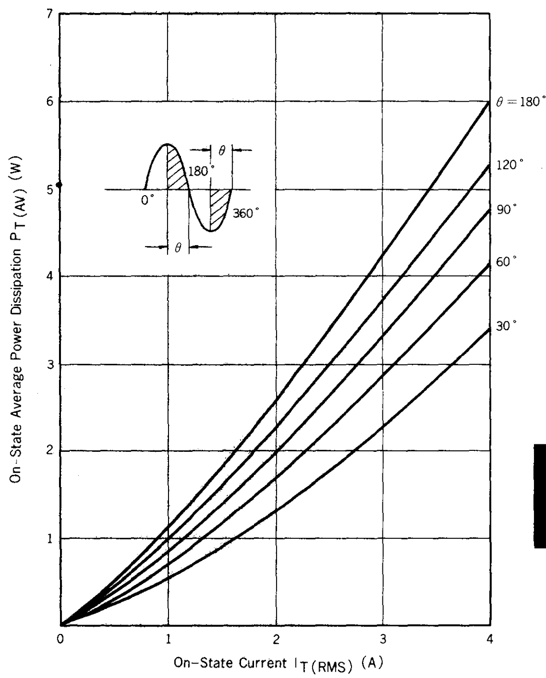


Fig. 4 PT(AV) – IT(RMS) Characteristics



9

Fig. 5 T_C – $I_{T(RMS)}$ Characteristics

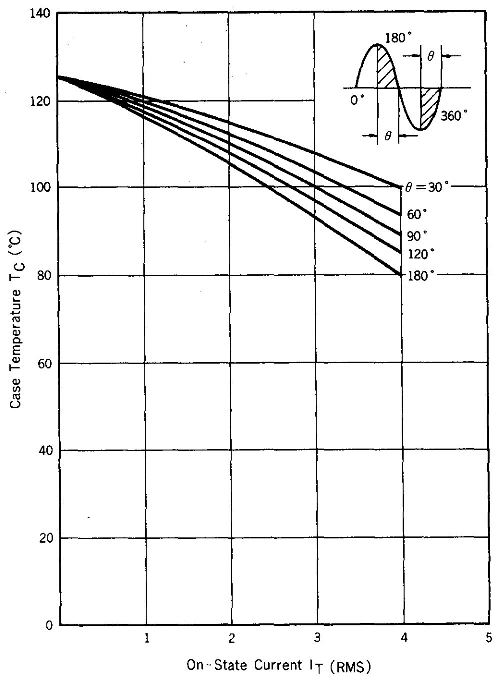
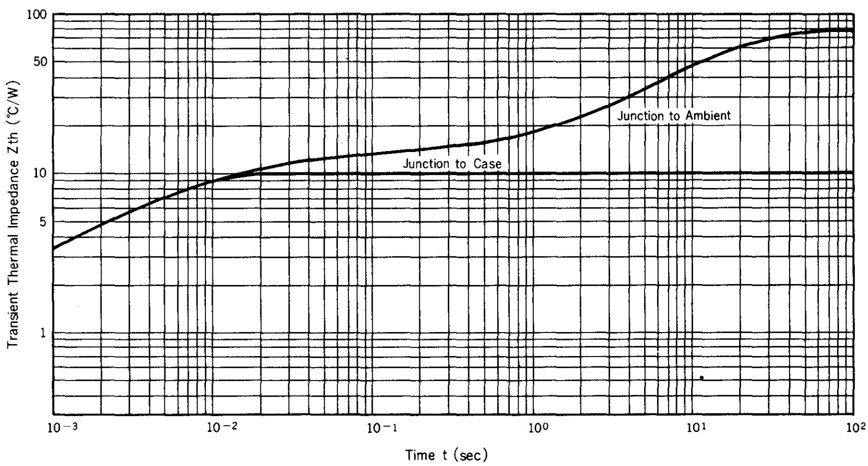


Fig. 6 Zth Characteristic



NEC
ELECTRON DEVICE

TRIAC
AC08BGM ~ AC08FGM

The AC08BGM ~ AC08FGM are all diffused mold type triac granted RMS On-state current 8Amps.
The glassivation technique applied to pellets' surface makes this series quite highly reliable.

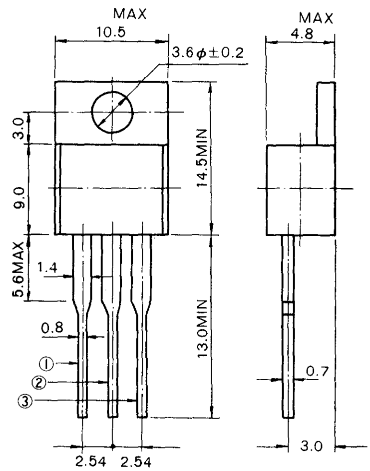
FEATURES

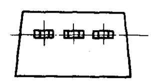
- Glassivated silicon chip for maximum reliability
- TO-220AB mold package
- Low cost

APPLICATIONS

Motor speed control,
Lamp dimmer, Temperature controllers,
Various solid state switches, etc.

Outline Drawing (Unit:mm)





Pin Connection
① T1 Termnal
② T2 Terminal
③ Gate

MAXIMUM RATINGS

Item	Symbol	AC08BGM	AC08DGM	AC08EGM	AC08FGM	Unit	Note
Repetitive Peak off Voltage	V_{DRM}	200	400	500	600	V	
Non-repetitive Peak off Voltage	V_{DSM}	300	500	600	700	V	
RMS On-State Current	$I_{T\ (RMS)}$	8 (T_C = 82°C)				A	See Fig. 6
Peak Surge On-State Current	I_{TSM}	80 (50Hz)				A	See Fig. 2
Fusing Current	$\int i_T^2 dt$	28 (1 ms ≦ t ≦ 10 ms)				A^2S	
Peak Gate Power Dissipation	P_{GM}	5.0				W	
Average Gate Power Dissipation	$P_{G\ (AV)}$	0.5				W	
Peak Gate Current	I_{FGM}	±3				A	
Junction Temperature	T_j	110				°C	
Storage Temperature	T_{stg}	-40 ~ +125				°C	

ELECTRICAL CHARACTERISTICS ($T_j = 25°C$)

Item		Symbol	Test Conditions	MIN	TYP	MAX	Unit	Note
Peak off-State Current		I_{DRM}	$T_j = 110°C$, $V_{DM} = V_{DRM}$	–	–	2	mA	
On-State Voltage		V_{TM}	$I_{TM} = 10A$	–	–	1.6	V	See Fig. 1
Gate Trigger Current	Mode I	I_{GT}	$V_{DM} = 12A$ $R_L = 30\Omega$	–	–	50	mA	See Fig. 4 Fig. 5
	II			–	–	–		
	III			–	–	50		
	IV			–	–	75		
Gate Trigger Voltage	Mode I	V_{GT}	$V_{DM} = 12A$ $R_L = 30\Omega$	–	–	3	V	See Fig. 4 Fig. 5
	II			–	–	–		
	III			–	–	3		
	IV			–	–	3		
Gate Non-Trigger Voltage		V_{GD}	$T_j = 110°C$, $V_{DM} = 12V$, $R_L = 30\Omega$	0.3	–	–	V	
Commutating dv/dt *		(dv/dt) C	$T_j = 110°C$ (di_T/dt) C = 4A/ms V_D = 200V (AC08BGM) 400V (AC08DGM ~ AC08FGM)	–	4	–	V/μs	R; for resistive loads
				10	–	–		L; for inductive loads
Holding Current		I_H	$V_D = 12A$	–	30	–	mA	
Thermal Resistance		$R_{th\,(j-c)}$	Junction to Case, DC	–	–	3.0	°C/W	See Fig. 8

* Add R or L to the end of type number according to applications.

Ex. AC08BGM R
Type No. Spec.

Fig. 1 $i_T - v_T$ Characteristic

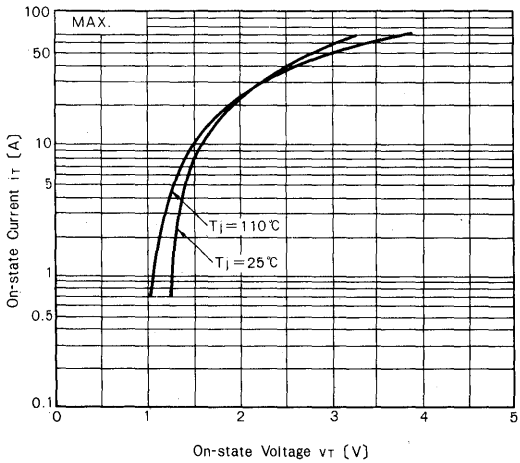


Fig. 2 I_{TSM} Rating

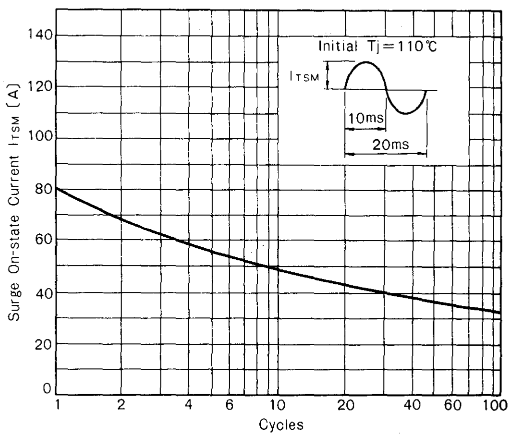


Fig. 3 $P_{T(AV)}-I_{T(RMS)}$ Characteristic

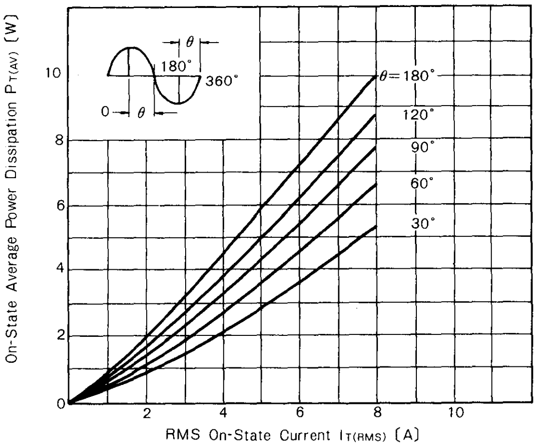


Fig. 4 $V_{GT}-I_{GT}$ Characteristic

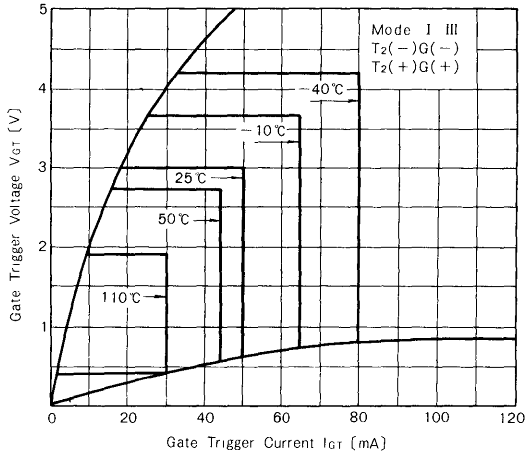


Fig. 5 $V_{GT}-I_{GT}$ Characteristic

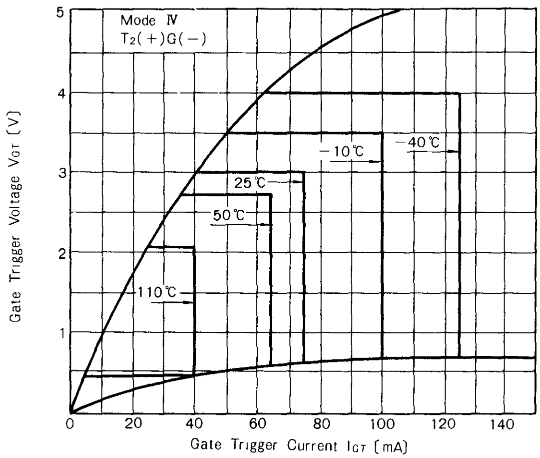


Fig. 6 $T_C-I_{T(RMS)}$ Rating

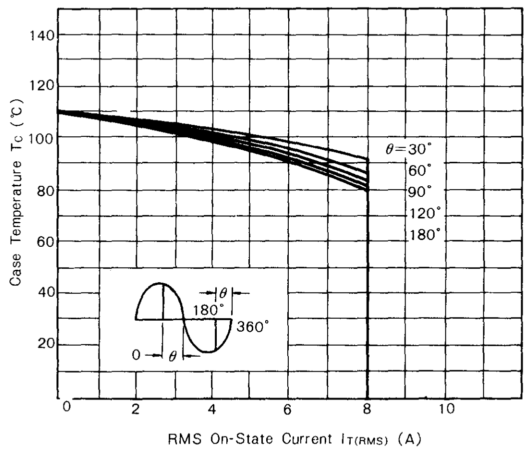


Fig. 7 $Ta-I_{T(RMS)}$ Rating

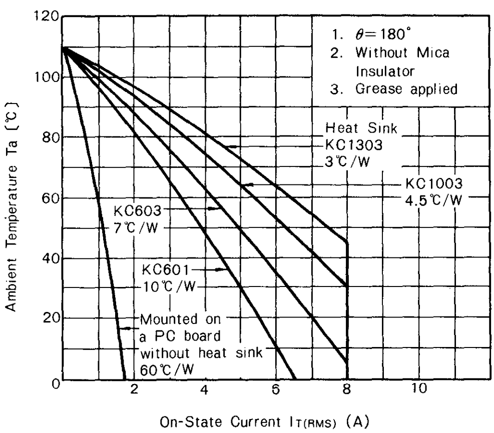
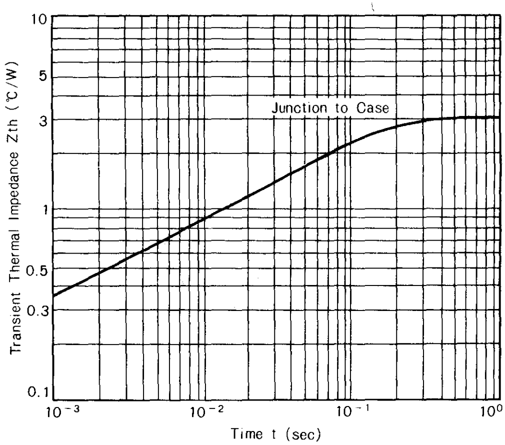


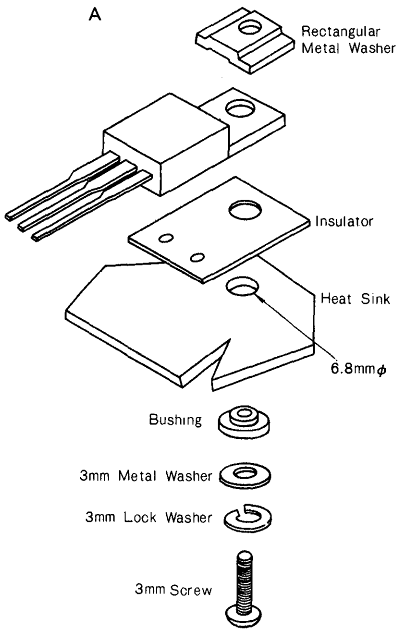
Fig. 8 Zth Characteristic



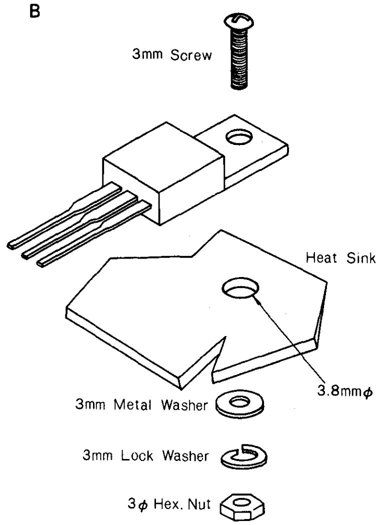
9

1. Mounting Methods

A

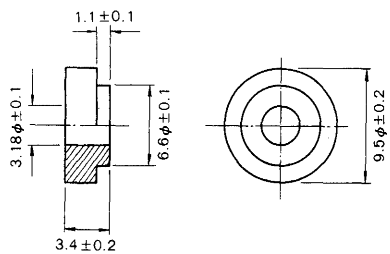


B

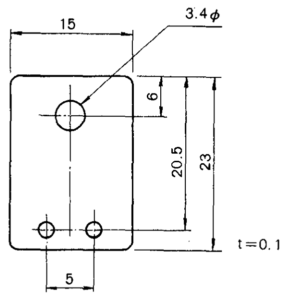


2. Outline Drawing

Bushing

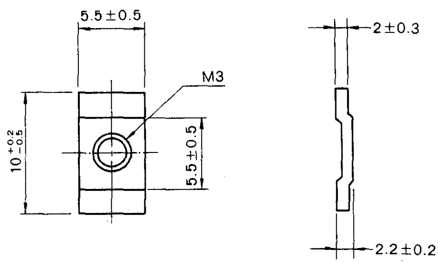


Insulator



Rth 1.0℃/W

Rectangular Metal Washer



3. Note

(1) Suitable torque value is around 3 kg·cm.

(2) Apply silicon grease between case and heat sink for thermal conduction.

(3) Electrode leads are not to be bent within 3mm from the neck of mold case.

NEC
ELECTRON DEVICE

TRIAC
AC10BGM ~ AC10FGM

The AC10BGM ~ AC10FGM are all diffused mold type triac granted RMS On-state current 10 Amps.
The glassivation technique applied to pellets' surface makes this series quite highly reliable.

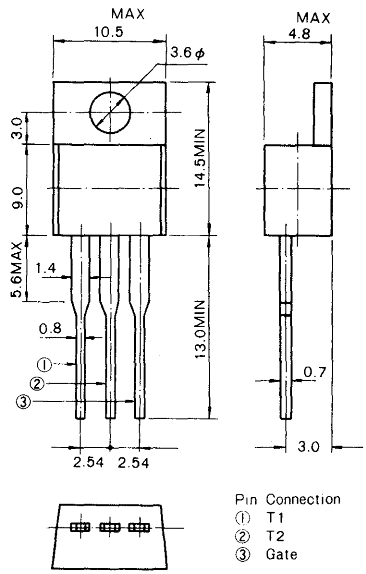
FEATURES

- Glassivated silicon chip for maximum reliability
- TO-220AB mold package
- Low cost

APPLICATIONS

Motor speed control,
Lamp dimmer, Temperature controllers,
Various solid state switches, etc.

Outline Drawing (Unit : mm)



MAXIMUM RATINGS

Item	Symbol	AC10BGM	AC10DGM	AC10EGM	AC10FGM	Unit	Note
Repetitive Peak off Voltage	V_{DRM}	200	400	500	600	V	
Non-repetitive Peak off Voltage	V_{DSM}	300	500	600	700	V	
RMS On-State Current	$I_{T(RMS)}$	10 ($T_C \fallingdotseq 76°C$)				A	See Fig. 6
Peak Surge On-State Current	I_{TSM}	80 (50Hz, T_j = 110°C)				A	See Fig. 2
Fusing Current	$\int i^2 dt$	28 (1ms ≦ t ≦ 10ms)				A^2S	
Peak Gate Power Dissipation	P_{GM}	5				W	
Average Gate Power Dissipation	$P_{G(AV)}$	0.5				W	
Peak Gate Current	I_{FGM}	±3				A	
Junction Temperature	T_j	110				°C	
Storage Temperature	T_{stg}	−40 ~ +125				°C	

ELECTRICAL CHARACTERISTICS (Tj = 25°C)

Item		Symbol	Test Conditions	MIN	TYP	MAX	Unit	Note
Peak off-State Current		I_{DRM}	T_j=110°C V_{DM} = V_{DRM}	–	–	2	mA	
On-State Voltage		V_{TM}	I_{TM} = 10A	–	–	1.4	V	See Fig. 1
Gate Trigger Current	Trigger Mode I	I_{GT}	V_{DM} = 12V R_L = 30Ω	–	–	50	mA	See Fig. 4 Fig. 5
	II			–	–	–		
	III			–	–	50		
	IV			–	–	75		
Gate Trigger Voltage	Trigger Mode I	V_{GT}	V_{DM} = 12V R_L = 30Ω	–	–	3	V	See Fig. 4 Fig. 5
	II			–	–	–		
	III			–	–	3		
	IV			–	–	3		
Gate Non-Trigger Voltage		V_{GD}	T_j = 110°C, V_{DM} = ½V_{DRM}	0.3	–	–	V	
Commutating dv/dt *		(dv/dt) C	T_j = 110°C (di$_T$/dt) C = −4A/ms V_D = 200V (AC10BGM) 400V (AC10DGM ~ AC10FGM)	–	4	–	V/μs	R; for resistive loads
				10	–	–		L; for inductive loads
Holding Current		I_H	V_D = 12V	–	30	–	mA	
Thermal Resistance		$R_{th\,(j-c)}$	Junction to Case	–	–	3.0	°C/W	See Fig. 8

* Add R or L to the end of type number according to applications.

Ex. AC10BGM R
Type No. Spec.

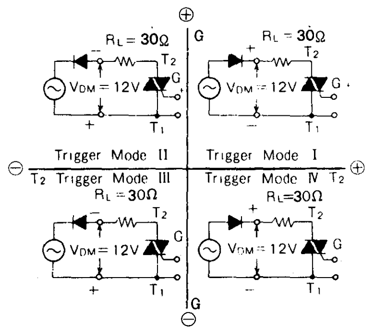


Fig. 1 $i_T - v_T$ Characteristic

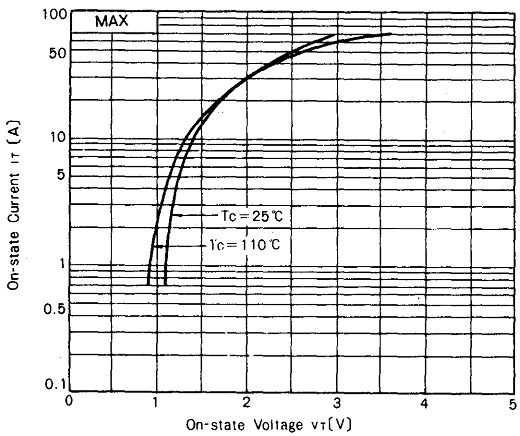


Fig. 2 I_{TSM} Rating

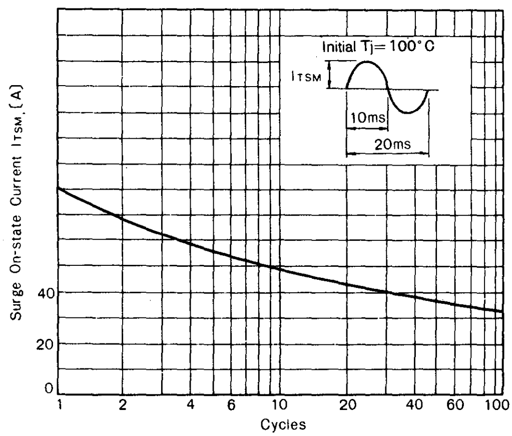


Fig. 3 $P_{T(AV)}-I_{T(RMS)}$ Characteristic

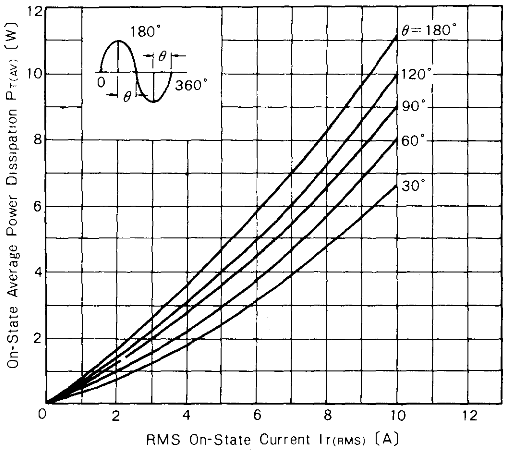


Fig. 4 $V_{GT}-I_{GT}$ Characteristic

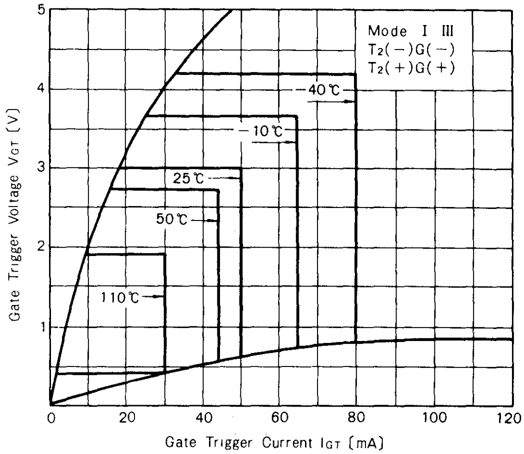


Fig. 5 $V_{GT}-I_{GT}$ Characteristic

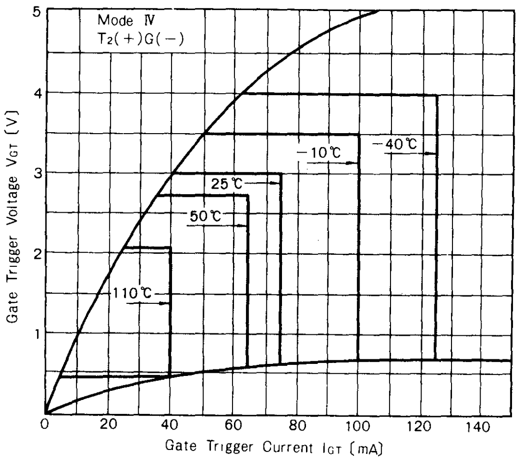


Fig. 6 $T_C-I_{T(RMS)}$ Rating

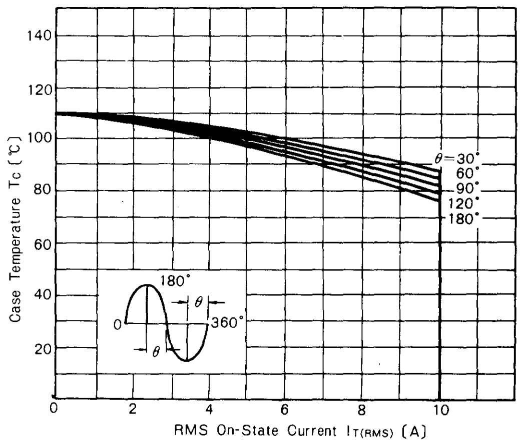


Fig. 7 $Ta-I_{T(RMS)}$ Rating

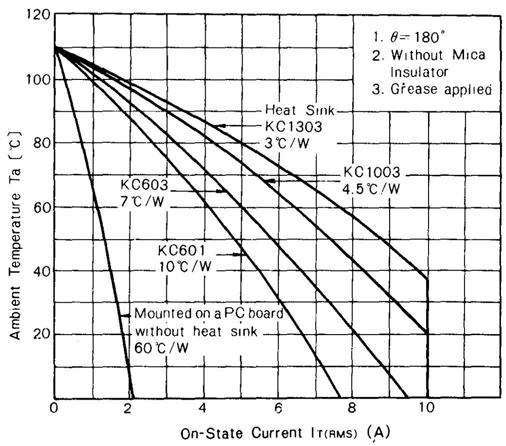
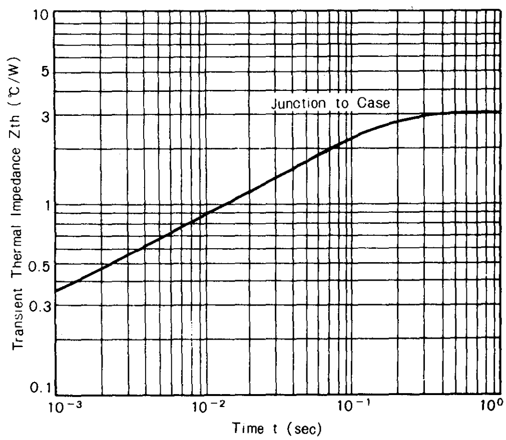
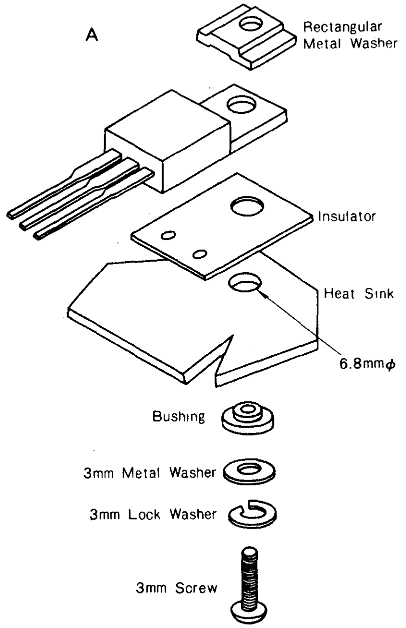


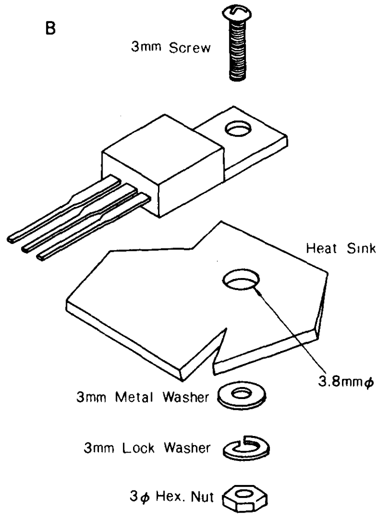
Fig. 8 Zth Characteristic



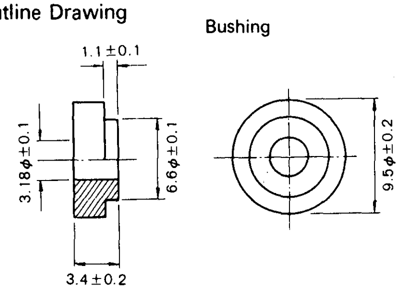
9

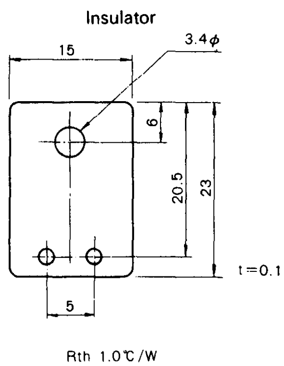
1. Mounting Methods

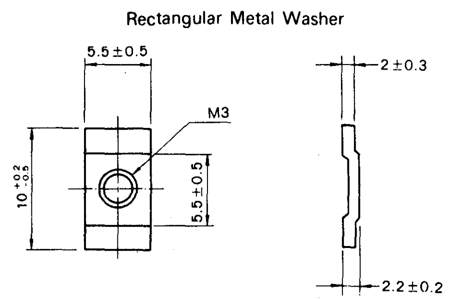




2. Outline Drawing







3. Note

(1) Suitable torque value is around 3 kg·cm

(2) Apply silicon grease between case and heat sink for thermal conduction.

(3) Electrode leads are not to be bent within 3mm from the neck of mold case.

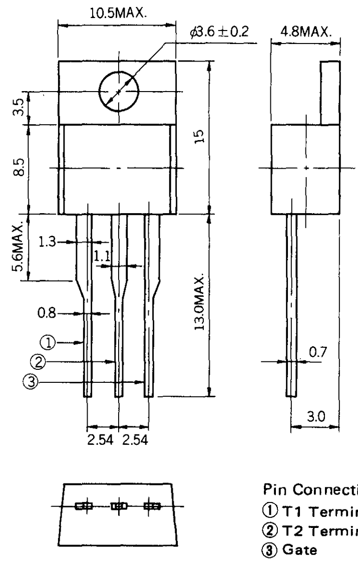
NEC
ELECTRON DEVICE

TRIAC

AC16BGM～AC16FGM

The AC16BGM～AC16FGM are all diffused mold type TRIAC granted RMS On-state current 16 Amps.
The glassivation technique applied to pellets' surface makes this series quite highly reliable.

OUTLINE DRAWING (Unit : mm)



Pin Connection
① T1 Terminal
② T2 Terminal
③ Gate

FEATURES

- Glassivated silicon chip for maximum reliability
- TO-220AB mold package
- Low cost

APPLICATIONS

Motor speed control,
Lamp dimmer, Temperature controllers,
Various solid state switches, etc.

MAXIMUM RATINGS

Item	Symbol	AC16BGM	AC16CGM	AC16DGM	AC16EGM	AC16FGM	Unit	Note
Repetitive Peak-off Voltage	V_{DRM}	200	300	400	500	600	V	
Non-Repetitive Peak-off Voltage	V_{DSM}	300	400	500	600	700	V	
RMS On-state Current	$I_{T(RMS)}$	16 (T_C=80°C)					A	See Fig. 6
Surge On-state Current	I_{TSM}	165 (60Hz 1 cycle) 150 (50Hz 1 cycle)					A	See Fig. 2
I^2t For Fusing	I^2t	100					A^2S	
Peak Gate Power Dissipation	P_{GM}	5					W	
Avarage Gate Power Dissipation	$P_{G(AV)}$	0.5					W	
Peak Gate Current	I_{GM}	±3					A	
Junction Temperature	T_j	125					°C	
Storage Temperature	T_{stg}	-40 ～ +125					°C	

9

ELECTRICAL CHARACTERISTICS ($T_j = 25°C$)

Item		Symbol	Condition	Min.	Typ.	Max.	Unit	Note
Peak Off-state Current		I_{DRM}	T_j=125°C, V_{DM}=V_{DRM}	–	–	2	mA	
On-state Voltage		V_{TM}	I_{TM}=25A	–	–	1.4	V	See Fig. 1
Gate-trigger Current	Trigger Mode I	I_{GT}	V_{DM}=12V, R_L=30Ω	–	–	50	mA	See Fig. 3 Fig. 4
	II			–	–	–		
	III			–	–	50		
	IV			–	–	50		
Gate-trigger Voltage	Trigger Mode I	V_{GT}	V_{DM}=12V, R_L=30Ω	–	–	3	V	
	II			–	–	–		
	III			–	–	3		
	IV			–	–	3		
Gate Non-trigger Voltage		V_{GD}	T_j=125°C, V_{DM}=12V, R_L=30Ω	0.3	–	–	V	
Holding Current		I_H	V_{DM}=12V	–	40	–	mA	
Critical rate of rise of commutating off-state voltage	TYPE R*	(dv/dt)c	T_j=125°C, I_{TM}=22A, $(dI_T/dt)c$=8A/ms, V_{DM}=200V (AC16BGM, AC16CGM) 400V (AC16DGM~AC16FGM)	1	–	–	V/μs	R : For resistive loads. L : For inductive loads.
	TYPE L*			10	–	–		
Thermal Resistance		$R_{th(j-C)}$	Junction to case	–	–	2.5	°C/W	See Fig. 8
		$R_{th(j-a)}$	————	–	–	–		

*Add R or L to the end of type number according to application

Ex.: AC16FGM L
Type No. Spec.

Fig. 1 $i_T - V_T$ Characteristic

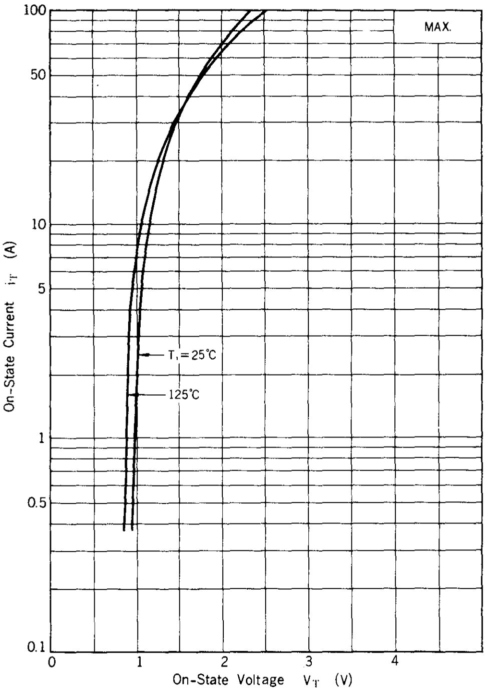


Fig. 2 I_{TSM} Rating

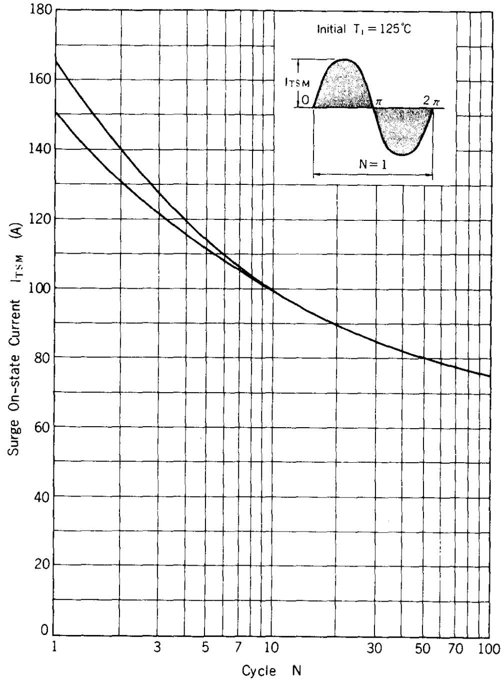


Fig. 3 Gate Rating

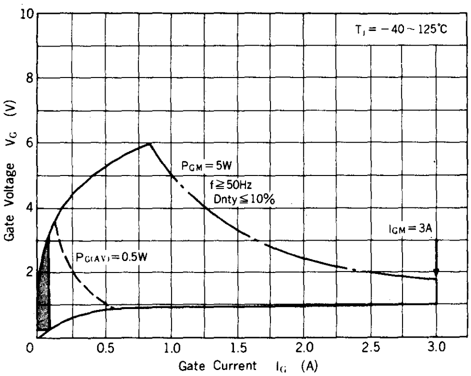
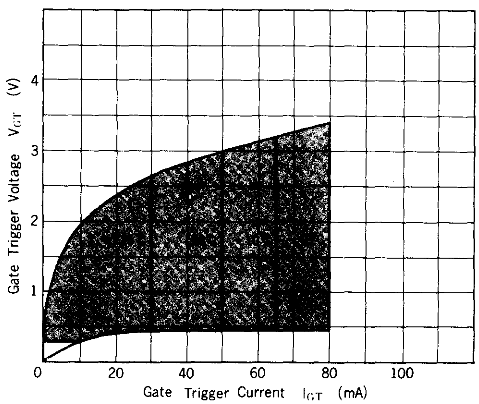


Fig. 4 $V_{GT} - I_{GT}$ Characteristic



9

Fig. 5 $P_{T(AV)} - I_{T(RMS)}$ Characteristic

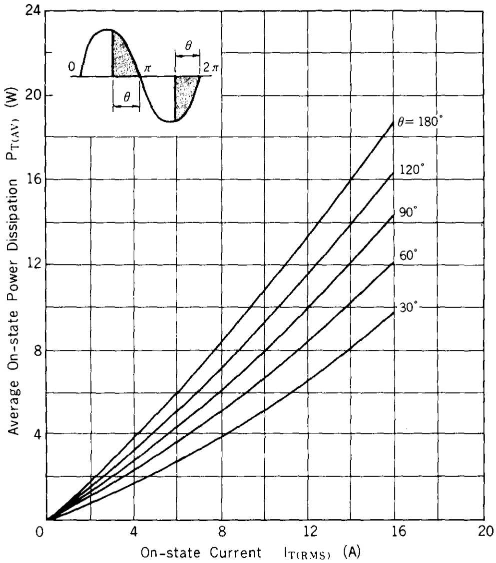


Fig. 6 $T_C - I_{T(RMS)}$ Rating

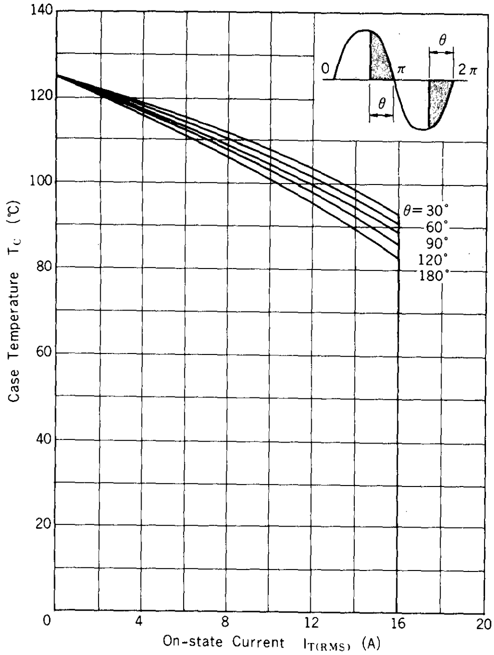


Fig. 7 Ta − $I_{T(RMS)}$ Rating

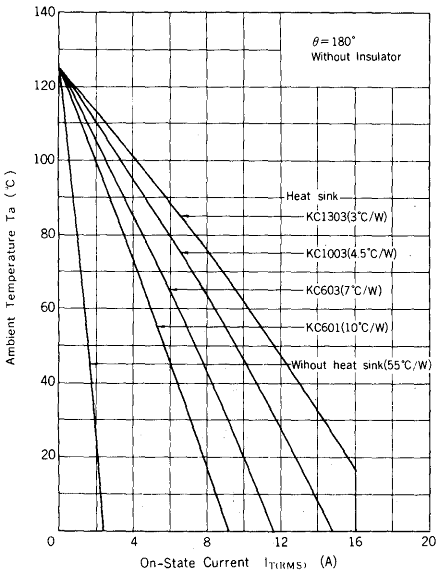
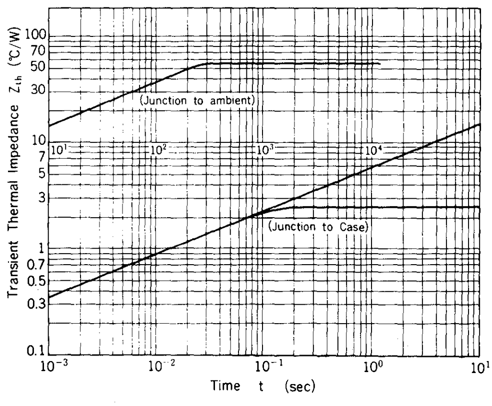
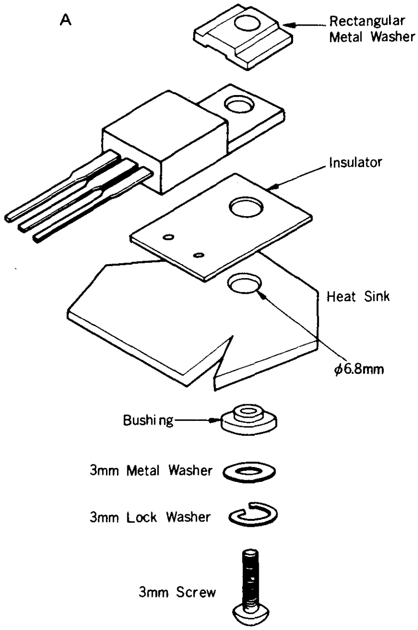


Fig. 8 Z_{th} Characteristic

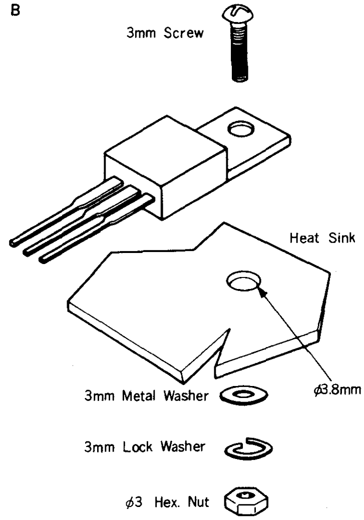


1. Mounting Methods

A

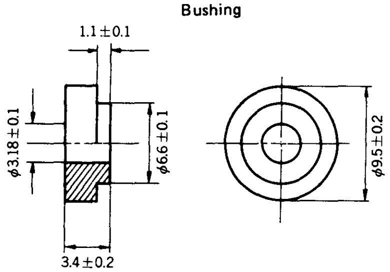


B

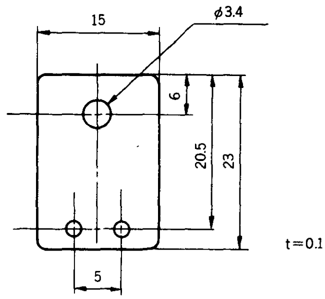


2. Outline Drawing

Bushing

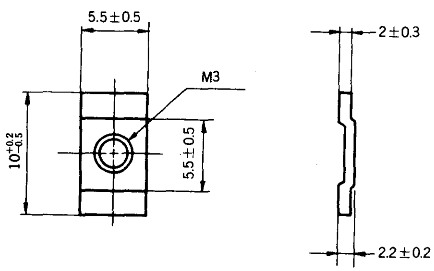


Insulator



Rth 1.0°C/W

Rectangular Metal Washer



3. Note

(1) Suitable torque value is around 3 kg-cm
(2) Apply silicon grease between case and heat sink for thermal conduction
(3) Electrode leads are not to be bent within 3 mm from the neck of mold case.

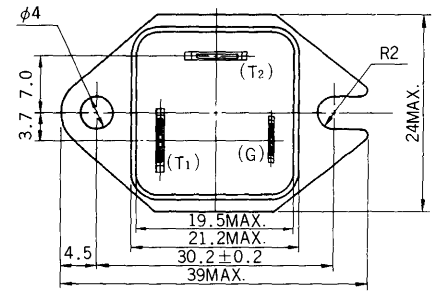
9

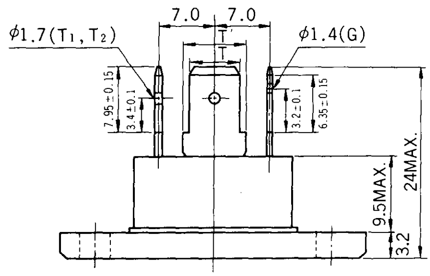
NEC
ELECTRON DEVICE

TRIAC
AC16BIF~AC16FIF

The AC16BIF~AC16FIF are fast-on terminal isolated modified TO-3 flange type triac granted RMS On-state current 16 amps. The glassivation technique applied to pellet's surface makes this series quite highly reliable.

Outline Drawing (Unit : mm)





	T	T'	t
T1 terminal	6.35 ± 0.1	8.25MIN.	0.8
T2 terminal	6.35 ± 0.1	8.25MIN.	0.8
Gate terminal	4.75 ± 0.1	5.7MIN.	0.5

FEATURES

- Isolated type.
- Fast-on terminal.
- Modified TO-3 flange.
- Glassivated silicon chip.

APPLICATIONS

- Microwave oven control.
- Temperature controllers.
- Lamp dimmer.
- Various solid state switches.

MAXIMUM RATINGS

Item	Symbol	AC16BIF	AC16DIF	AC16IEIF	AC16FIF	Unit	Note
Repetitive Peak Off-state Voltage	V_{DRM}	200	400	500	600	V	
Non-repetitive Peak Off-state Voltage	V_{DSM}	300	500	600	720	V	
RMS On-state Current	$I_{T(RMS)}$	16 (Tc=75°C)				A	See Fig.6
Surge On-state Current	I_{TSM}	150 (Initial T_j=125°C, 50Hz 1 cycle) 165 (Initial T_j=125°C, 60Hz 1 cycle)				A	See Fig.2
Fusing Current	$\int i_T^2 dt$	100				A^2S	
Critical Rate of Rise of On-state Current	dI_T/dt	50				A/μs	
Peak Gate Power Dissipation	P_{GM}	5 (f≧50Hz, Duty≦10%)				W	
Avarage Gate Power Dissipation	$P_{G(AV)}$	0.5				W	
Peak Gate Current	I_{GM}	3 (f≧50Hz, Duty≦10%)				A	
Junction Temperature	T_j	125				°C	
Strage Temperature	T_{stg}	−40 ~ 125				°C	

ELECTRICAL CHARACTERISTICS (T_j=25°C)

Item		Symbol	Test Condition	MIN.	TYP.	MAX.	Unit	Note
Peak Off-state Current		I_{DRM}	T_j=125°C, $V_{DM}=V_{DRM}$	–	–	2	mA	
On-state Voltage		V_{TM}	I_{TM}=25A	–	–	1.4	V	See Fig.1
Gate Trigger Voltage	Made I	V_{GT}	V_{DM} = 12V R_L = 30Ω	–	–	3	V	See Fig.3, Fig.4
	II			–	–	–		
	III			–	–	3		
	IV			–	–	3		
Gate Trigger Current	Mode I	I_{GT}	V_{DM} = 12V R_L = 30Ω	–	–	50	mA	See Fig.3, Fig.4
	II			–	–	–		
	III			–	–	50		
	IV			–	–	50		
Gate Non-Trigger Voltage		V_{GD}	T_j=125°C, V_D=1/2V_{DRM}	0.3	–	–	V	
Thermal Resistance		$R_{th(j-c)}$	Junction to case	–	–	3.0	°C/W	See Fig.8
Dielectric Strength		V_I	T_2, T_1, G each Terminal to flange 1 min.	AC 1500	–	–	V	
			T_2, T_1 G each Terminal to flange 1 sec.	AC 1800	–	–		
Holding Current		I_H	I_{TM}=25A	–	40	–	mA	
Cirtical Rate of Rise of Commutating Off-state Voltage (*1)		$(dV_D/dt)_C$	T_j=125°C I_{TM}=22A $(dI_T/dt)_C$=8A/ms, V_{DM} = (*2)V	10	–	–	V/μs	L
				1	–	–		R

(*1) Add L or R to the end of type number according to applications.
Ex. AC16FIF L
Type No. Spec.

(*2) AC16BIF : 200V
AC16DIF ~ FIF : 400V

9

Fig. 1 iT − vT Characteristic

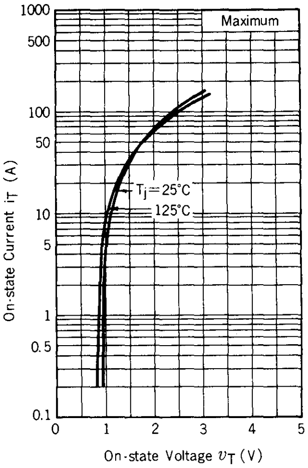


Fig. 2 ITSM Rating

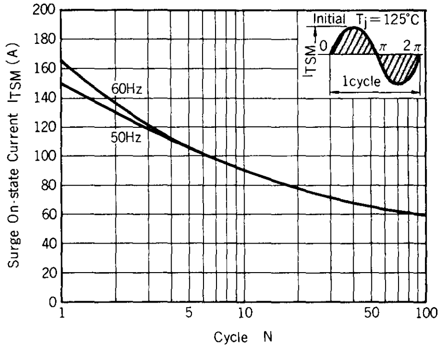


Fig. 3 Gate Rating

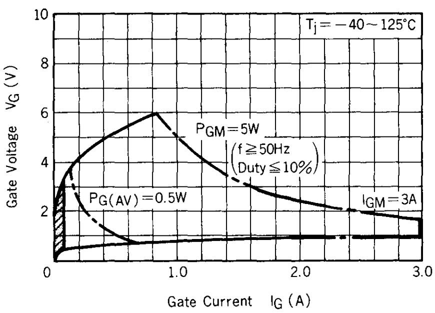


Fig. 4 Gate Characteristic

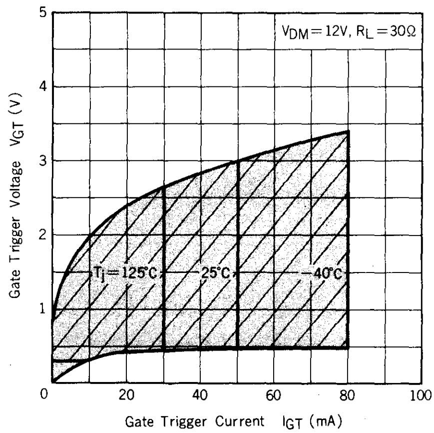


Fig. 5 PT(AV) − IT(RMS) Characteristic

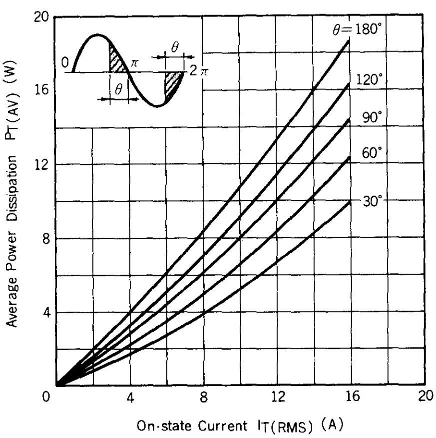


Fig. 6 Tc − IT(RMS) Rating

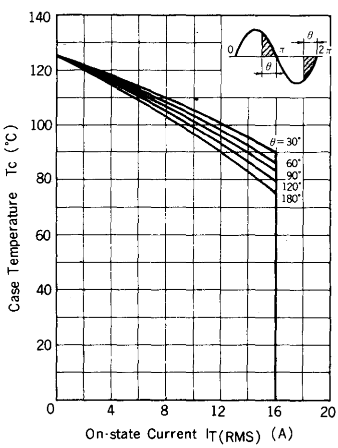


Fig. 7 Ta — IT(RMS) Rating

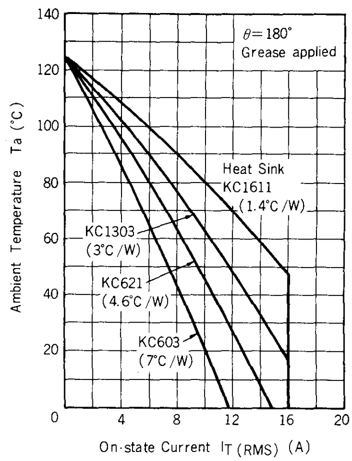
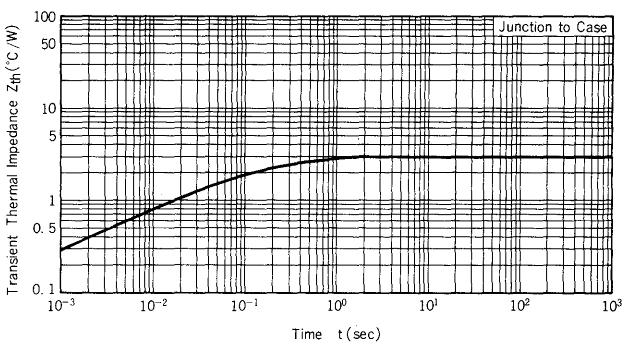


Fig. 8 Zth Characteristic



NEC
ELECTRON DEVICE

TRIAC
SC141B~SC141M

The SC141B ~ SC141M are all diffused mold type triac granted RMS On-state current 6 Amps.
The glassivation technique applied to pellets' surface makes this series quite highly reliable.

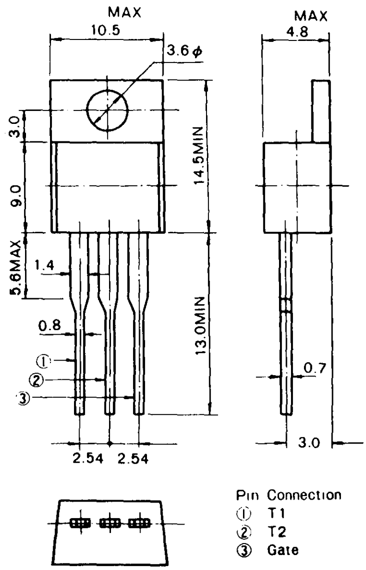
FEATURES

- Glassivated silicon chip for maximum reliability
- TO-220AB mold package
- Low cost

APPLICATIONS

Motor speed control,
Lamp dimmer, Temperature controllers,
Various solid state switches, etc.

Outline Drawing (Unit:mm)



MAXIMUM RATINGS

Item	Symbol	B	D	E	M	Unit	Note
Repetitive Peak off voltage	V_{DRM}	200	400	500	600	V	
Non-repetitive Peak off Voltage	V_{DSM}	300	500	600	700	V	
RMS On-State Current	$I_{T(RMS)}$	6 (T_c = 80°C, 360° Condition)				A	Fig. 5
Peak Surge On-State Current	I_{TSM}	80 (60Hz), 74 (50Hz)				A	Fig. 2
Fusing Current	$\int i_t^2 dt$	26.5 (8.3ms)				A^2S	
Peak Gate Power Dissipation	P_{GM}	10 (10μs Pulse Width)				W	
Average Gate Power Dissipation	$P_{G(AV)}$	0.5				W	
Peak Gate Current	I_{FGM}	See Fig. 4				A	
Junction Temperature	T_j	−40 ~ +100				°C	
Storage Temperature	T_{stg}	−40 ~ +125				°C	

ELECTRICAL CHARACTERISTICS

Item		Symbol	Test Conditions		MIN.	TYP.	MAX.	Unit	Note
Peak Off-State Current		I_{DRM}	$V_{DM} = V_{DRM}$	T_C = +25°C	–	–	100	μA	
				T_C = +110°C	–	–	500		
On-State Voltage		V_{TM}	T_C = +25°C I_{TM} = 8.5 A Peak		–	–	1.83	V	Fig. 1
Critical Rate of Rise of Off-state Voltage		dv/dt	T_C = 100°C, VDM = V_{CRM} Gate Open Circuited Exponential Wareform		30	100	–	V/μs	
Critical Rate of Rise of Commutating Off-State Voltage		$(dv/dt)_c$	$I_{T(RMS)}$ = 6A $V_{DM} = V_{DRM}$		4	–	–	V/μs	
DC Gate Trigger Current	* I	I_{GT}	V_{DM} = 12V R_L = 50Ω	T_C = +25°C	–	–	50	mA	Fig. 6, 8
	* III				–	–	50		
	* IV				–	–	50		
	* I			T_C = –40°C	–	–	80		
	* III				–	–	80		
	* IV				–	–	80		
DC Gate Trigger Voltage	* I	V_{GT}	V_{CM} = 12V R_L = 50Ω	T_C = +25°C	–	–	2.5	V	Fig. 7
	* III				–	–	2.5		
	* IV				–	–	2.5		
	* I			T_C = –40°C	–	–	3.5		
	* III				–	–	3.5		
	* IV				–	–	3.5		
DC Holding Current		I_H	V_D = 24V	T_C= +25°C	–	–	50	mA	Fig. 9
				T_C= –40°C	–	–	100		
DC Latching Current	* I	I_L	$_D$ = 24V Gate Trigger Source = 15V 100Ω, 50μsec 5 μsec rise times	T_C= +25°C	–	–	100	mA	
	* III				–	–	100		
	* IV				–	–	200		
	* I			T_C= –40°C	–	–	200		
	* III				–	–	200		
	* IV				–	–	400		
Steady State Thermal Resistance		$Rth_{(j-c)}$	Junction-to-case For acceptance test.		–	–	3.0	°C/W	
Apparent Thermal Resistance		$Rth_{(j-c)}$ (AC)	Junction-to-case For calculation of T_j.		–	–	2.22		Fig. 10

Trigger Mode & Test circuit

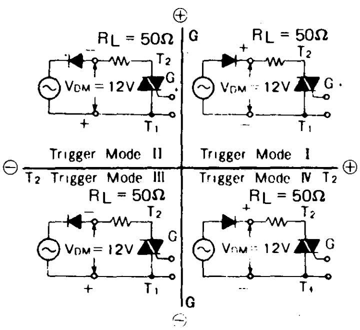


Fig. 1 $i_T - V_T$ Characteristic

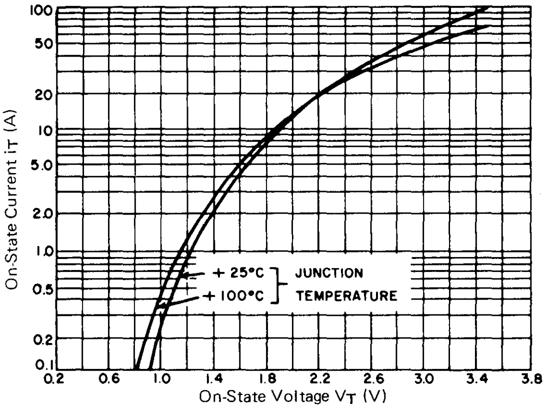


Fig. 2 I_{TSM} Rating

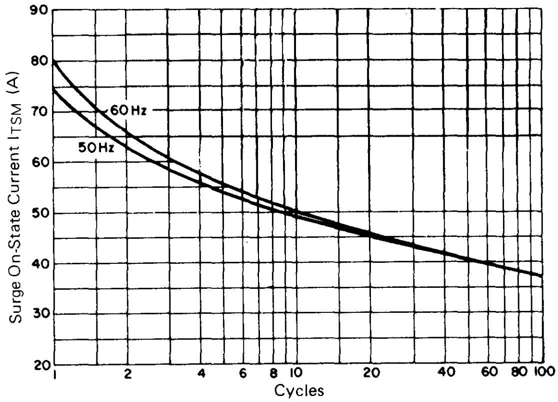


Fig. 3 $P_{T(AV)} - I_{T(RMS)}$ Characteristic

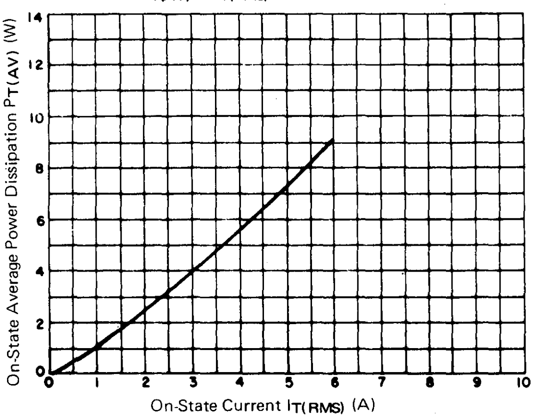


Fig. 4 Gate Characteristic and Rating

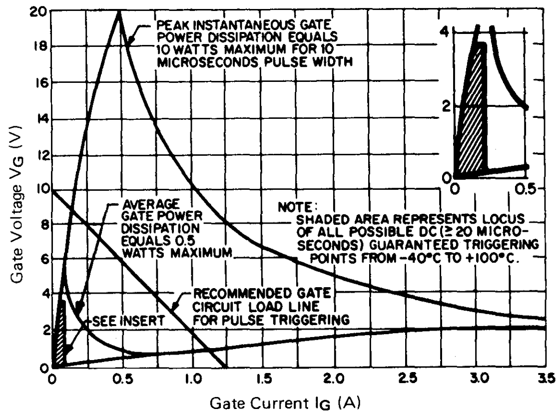


Fig. 5 $T_C - I_{T(RMS)}$ Rating

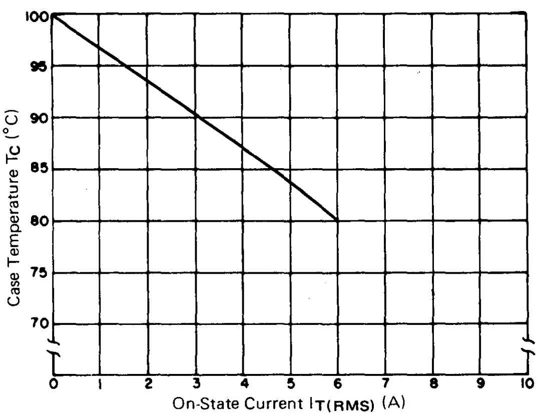


Fig. 6 $I_{GT} - T_C$ Characteristic

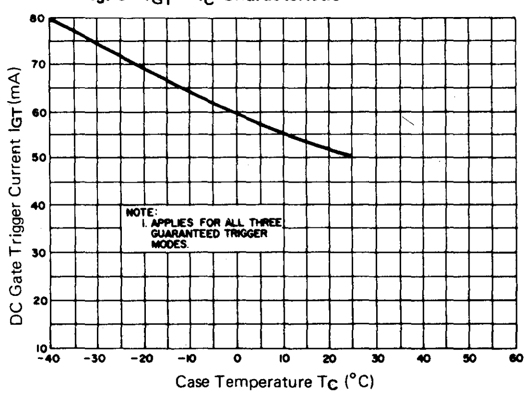


Fig. 7 $V_{GT} - T_C$ Characteristic

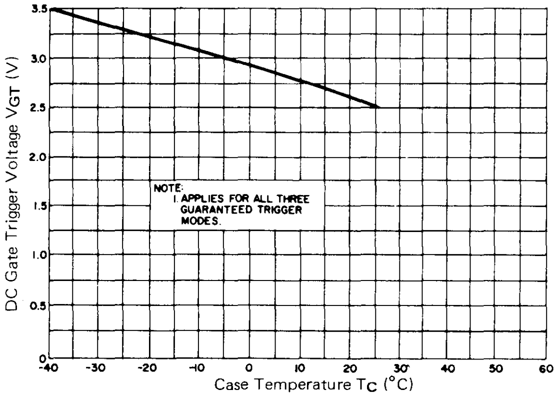


Fig. 8 Pulse I_{GT} Characteristic

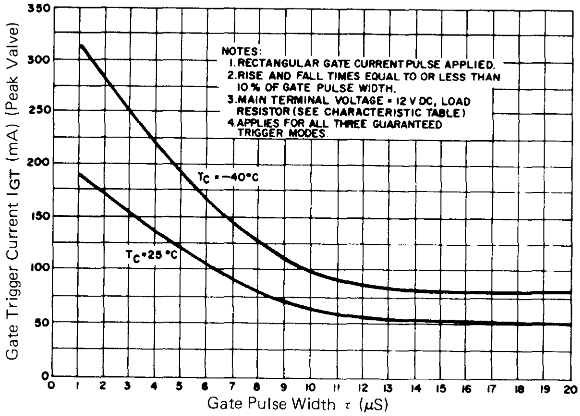


Fig. 9 $I_H - T_C$ Characteristic

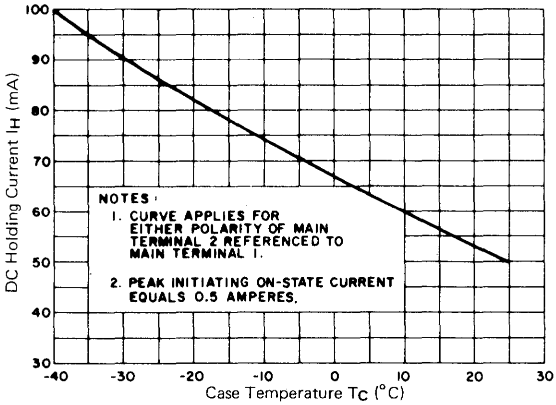
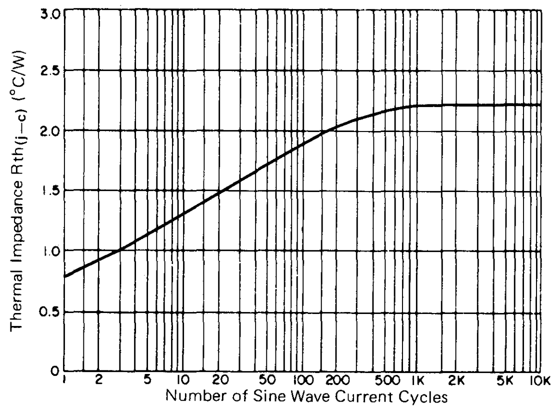


Fig. 10 $Rth_{(j-c)}$ Characteristic

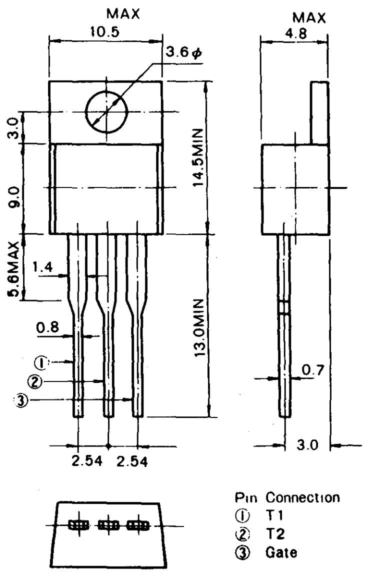


TRIAC
SC143B～SC143M

NEC
ELECTRON DEVICE

The SC143B ~ SC143M are all diffused mold type triac granted RMS On-stage current 8Amps.
The glassivation technique applied to pellets' surface makes this series quite highly reliable.

Outline Drawing (Unit: mm)



Pin Connection
① T1
② T2
③ Gate

FEATURES

- Glassivated silicon chip for maximum reliability
- TO-220AB mold package
- Low cost

APPLICATIONS

Motor speed control,
Lamp dimmer, Temperature controllers,
Various solid state switches etc.

MAXIMUM RATINGS

Item	Symbol	B	D	E	M	Unit	Note
Repetitive Peak off Voltage	V_{DRM}	200	400	500	600	V	
Non-repetitive Peak off Voltage	V_{DSM}	300	500	600	700	V	
RMS On-State Current	$I_{T(RMS)}$	8 (T_C = 80°C, 360° Condition)				A	Fig. 5
Peak Surge On-State Current	I_{TSM}	120 (60Hz), 110 (50Hz)				A	Fig. 2
Fusing Current	$\int i_t^2 dt$	60 (8.3ms)				A^2S	
Peak Gate Power Dissipation	P_{GM}	10 (10μs Pulse Width)				W	
Average Gate Power Dissipation	$P_{G(AV)}$	0.5				W	
Peak Gate Current	I_{FGM}	See Fig. 4				A	
Junction Temperature	T_j	−40 ~ +100				°C	
Storage Temperature	T_{stg}	−40 ~ +125				°C	

ELECTRICAL CHARACTERISTICS

Item		Symbol	Test Conditions		MIN.	TYP.	MAX.	Unit	Note
Peak Off-State Current		I_{DRM}	$V_{DM} = V_{DRM}$	$T_C = +25°C$	–	–	100	μA	
				$T_C = +110°C$	–	–	500		
On-State Voltage		V_{TM}	$T_C = +25°C$, $I_{TM} = 11.5A$ peak		–	–	1.55	V	Fig. 1
Critical Rate of Rise of Off-state Voltage		dv/dt	$T_C = +100°C$, $V_{DM} = V_{DRM}$ Gate Open Circuited Exponential Waveform		50	150	–	V/μs	
Critical Rate of Rise of Commutating Off-State Voltage		(dv/dt)c	$I_{T(RMS)} = 8A$ $V_{DM} = V_{DRM}$		4	–	–	V/μs	
DC Gate Trigger Current	* I	I_{GT}	$V_{DM} = 12V$ $R_L = 50\Omega$	$T_C = +25°C$	–	–	50	mA	Fig. 6, 8
	* III				–	–	50		
	* IV				–	–	50		
	* I			$T_C = -40°C$	–	–	80		
	* III				–	–	80		
	* IV				–	–	80		
DC Gate Trigger Voltage	* I	V_{GT}	$V_{DM} = 12V$ $R_L = 50\Omega$	$T_C = +25°C$	–	–	2.5	V	Fig. 7
	* III				–	–	2.5		
	* IV				–	–	2.5		
	* I			$T_C = -40°C$	–	–	3.5		
	* III				–	–	3.5		
	* IV				–	–	3.5		
DC Holding Current		I_H	$V_D = 24V$	$T_C = +25°C$	–	–	50	mA	Fig. 9
				$T_C = -40°C$	–	–	100		
DC Latching Current	* I	I_L	$V_D = 24V$ Gate Trigger Source = 15V 100Ω, 50μsec 5μsec rise Times	$T_C = +25°C$	–	–	100	mA	
	* III				–	–	100		
	* IV				–	–	200		
	* I			$T_C = -40°C$	–	–	200		
	* III				–	–	200		
	* IV				–	–	400		
Steady State Thermal Resistance		$Rth_{(j-C)}$	Junction-to-Case For acceptance Test		–	–	3.2	°C/W	
Apparent Thermal Resistance		$Rth_{(j-C)}$ (AC)	Junction-to-Case For calculation of T_j		–	–	1.97		Fig. 10

* Trigger Mode & Test Circuit

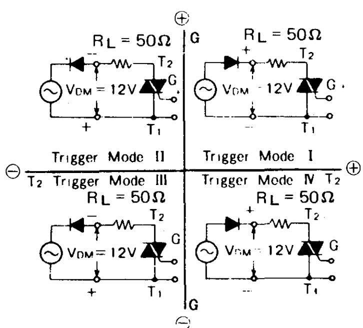


Fig. 1 $i_T - v_T$ Characteristic

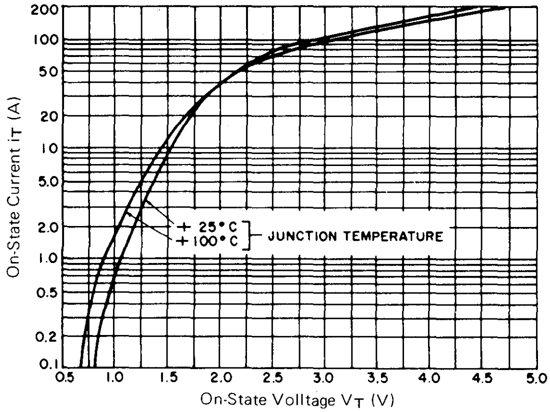


Fig. 2 I_{TSM} Rating

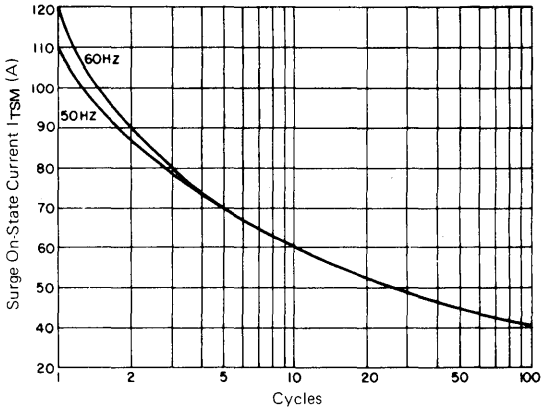


Fig. 3 $P_{T(AV)} - I_{T(RMS)}$ Characteristic

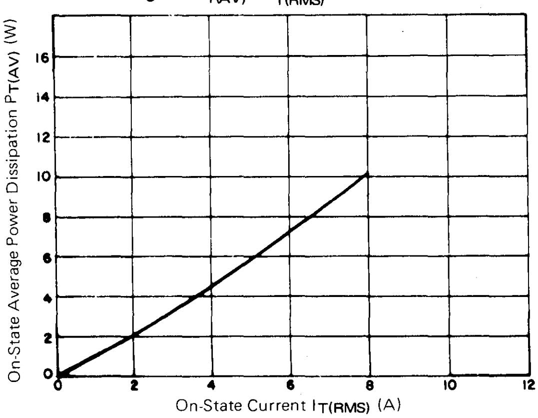


Fig. 4 Gate Characteristic and Rating

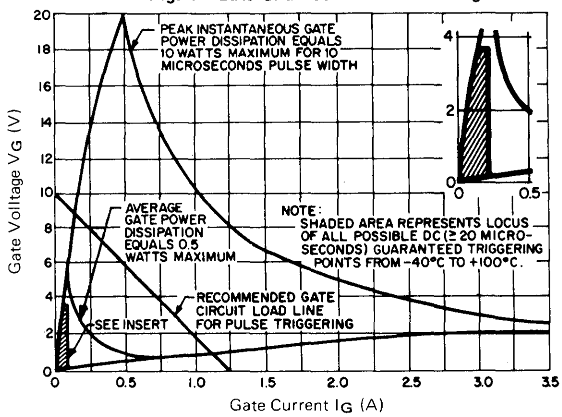


Fig. 5 $T_C - I_{T(RMS)}$ Rating

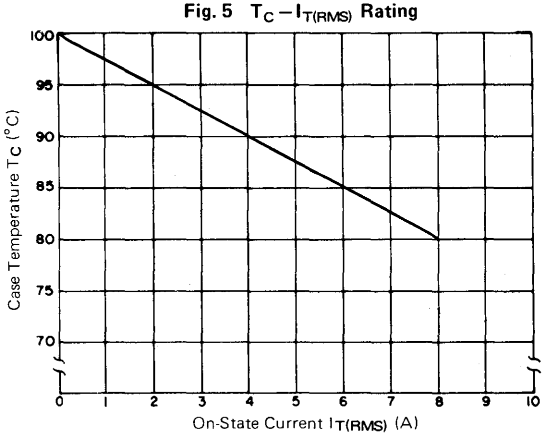


Fig. 6 $I_{GT} - T_C$ Characteristic

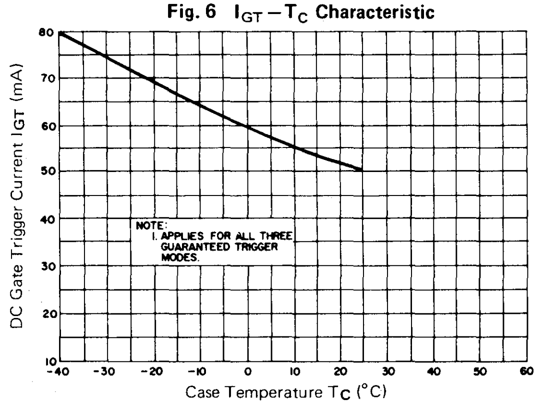


Fig. 7 $V_{GT} - T_C$ Characteristic

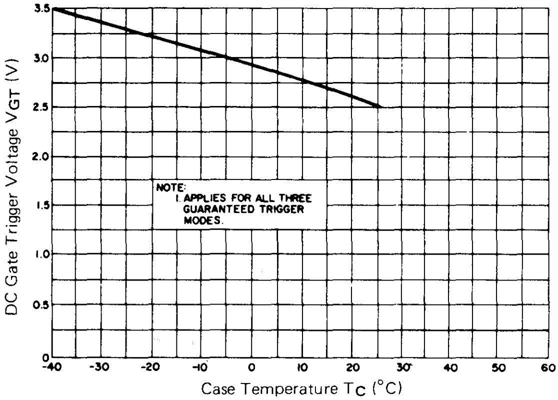


Fig. 8 Pulse I_{GT} Characteristic

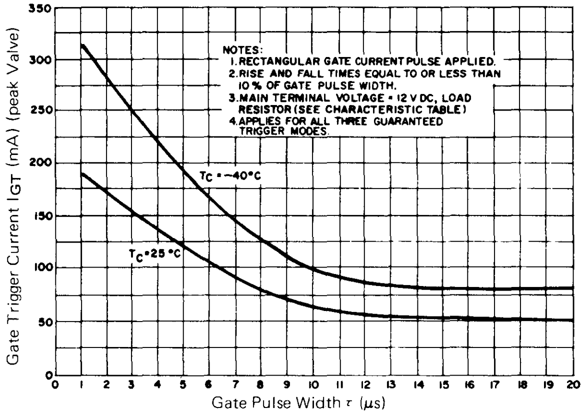


Fig. 9 $I_H - T_C$ Characteristic

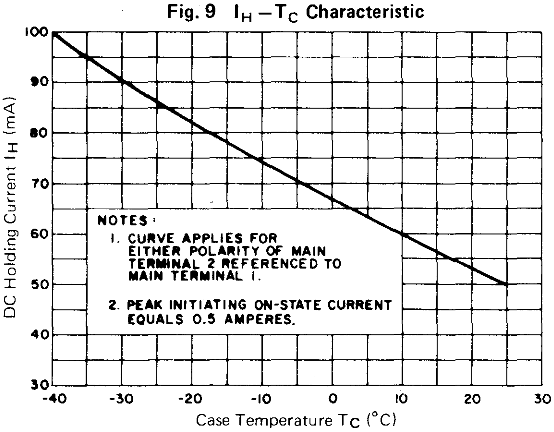
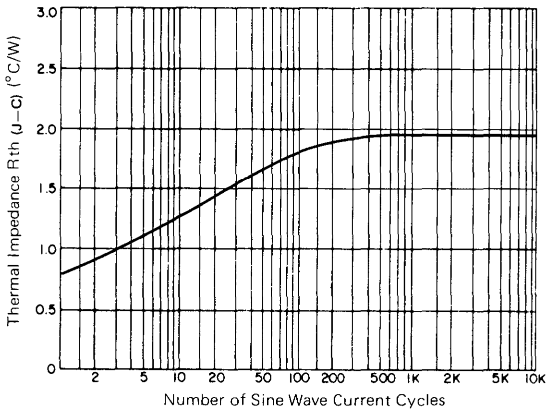


Fig. 10 $Rth_{(J-C)}$ Characteristic



NEC
ELECTRON DEVICE

TRIAC
SC146B～SC146M

The SC146B ~ SC146M are all diffused mold type triac granted RMS On-state current 10 Amps.
The glassivation technique applied to pellets' surface makes this series quite highly reliable.

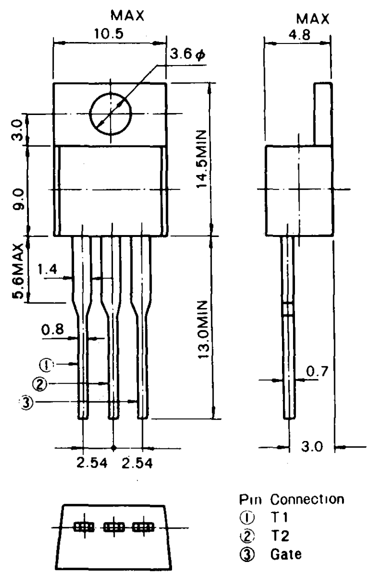
FEATURES

- Glassivated silicon chip for maximum reliability
- TO-220AB mold package
- Low cost

APPLICATIONS

Motor speed control,
Lamp dimmer, Temperature controllers,
Various solid state switches, etc.

Outline Drawing (Unit:mm)



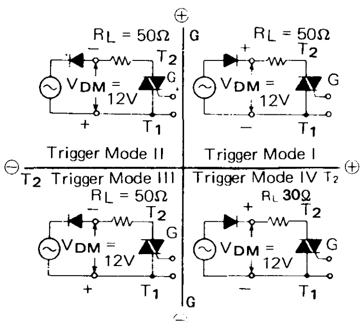
MAXIMUM RATINGS

Item	Symbol	B	D	E	M	Unit	Note
Repetitive Peak off voltage	V_{DRM}	200	400	500	600	V	
Non-repetitive Peak off Voltage	V_{DSM}	300	500	600	700	V	
RMS On-State Current	$I_{T(RMS)}$	10 (T_c = 80°C, 360° Condition)				A	Fig. 5
Peak Surge On-State Current	I_{TSM}	120 (60Hz), 110 (50Hz)				A	Fig. 2
Fusing Current	$\int i_t^2 dt$	60 (8.3ms)				A^2S	
Peak Gate Power Dissipation	P_{GM}	10 (10μs Pulse Width)				W	
Average Gate Power Dissipation	$P_{G(AV)}$	0.5				W	
Peak Gate Current	I_{FGM}	See Fig. 4				A	
Junction Temperature	T_j	−40 ~ +100				°C	
Storage Temperature	T_{stg}	−40 ~ +125				°C	

ELECTRICAL CHARACTERISTICS

Item		Symbol	Test Conditions		MIN.	TYP.	MAX.	Unit	Note
Peak Off-State Current		I_{DRM}	$V_{DM} = V_{DRM}$	T_C = +25°C	–	–	100	μA	
				T_C = +110°C	–	–	500		
On-State Voltage		V_{TM}	T_C = +25°C I_{TM} = 14 A Peak		–	–	1.65	V	Fig. 1
Critical Rate of Rise of Off-state Voltage		dv/dt	T_C = +100°C, $V_{DM} = V_{DRM}$ Gate Open Circuited Exponential Wareform		100	150	–	V/μs	
Critical Rate of Rise of Commutating Off-State Voltage		(dv/dt)c	$I_{T(RMS)}$ = 10A $V_{DM} = V_{DRM}$		4	–	–	V/μs	
DC Gate Trigger Current	* I	I_{GT}	V_{DM} = 12V R_L = 50Ω	T_C = +25°C	–	–	50	mA	Fig. 6, 8
	* III				–	–	50		
	* IV				–	–	50		
	* I			T_C = –40°C	–	–	80		
	* III				–	–	80		
	* IV				–	–	80		
DC Gate Trigger Voltage	* I	V_{GT}	V_{CM} = 12V R_L = 50Ω	T_C = +25°C	–	–	2.5	V	Fig. 7
	* III				–	–	2.5		
	* IV				–	–	2.5		
	* I			T_C = –40°C	–	–	3.5		
	* III				–	–	3.5		
	* IV				–	–	3.5		
DC Holding Current		I_H	V_D = 24V	T_C = +25°C	–	–	50	mA	Fig. 9
				T_C = –40°C	–	–	100		
DC Latching Current	* I	I_L	V_D = 24V Gate Trigger Source = 15V 100Ω, 50μsec, 5μsec Rise Times	T_C = +25°C	–	–	100	mA	
	* III				–	–	100		
	* IV				–	–	200		
	* I			T_C = –40°C	–	–	200		
	* III				–	–	200		
	* IV				–	–	400		
Steady State Thermal Resistance		$Rth_{(j-c)}$	Junction-to-case For acceptance test.		–	–	2.2	°C/W	
Apparent Thermal Resistance		$Rth_{(j-c)}$ (AC)	Junction-to-case For calculation of T_j		–	–	1.50		Fig. 10

Trigger Mode & Test circuit



9

Fig. 1 $i_T - V_T$ Characteristic

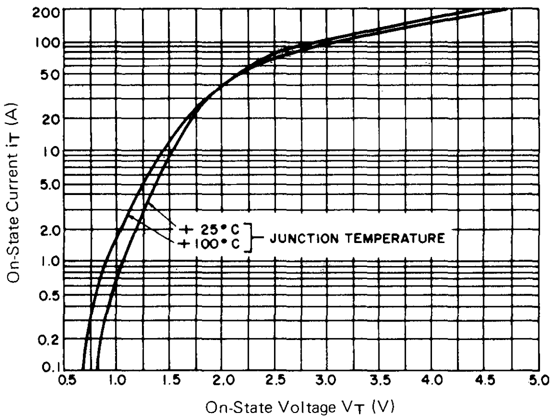


Fig. 2 I_{TSM} Rating

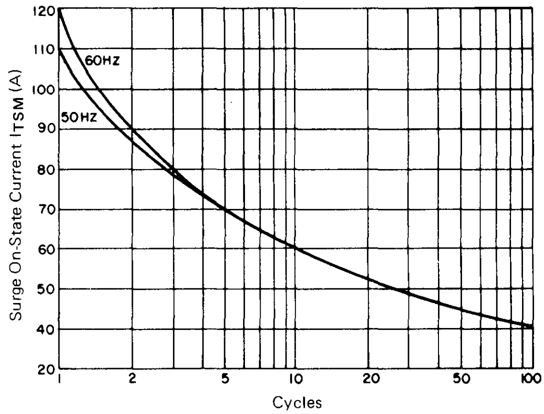


Fig. 3 $P_{T(AV)} - I_{T(RMS)}$ Characteristic

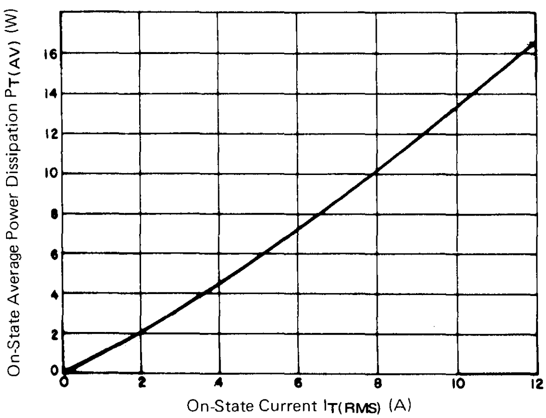


Fig. 4 Gate Characteristic and Rating

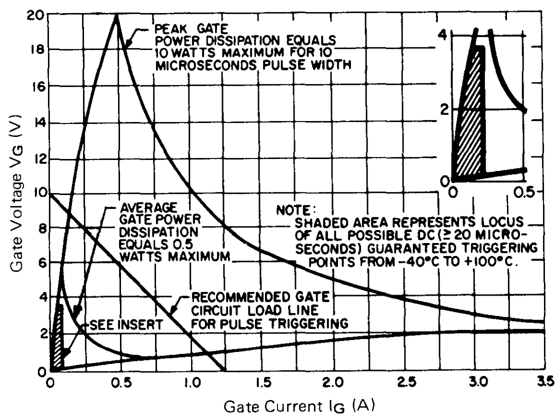


Fig. 5 $T_C - I_{T(RMS)}$ Rating

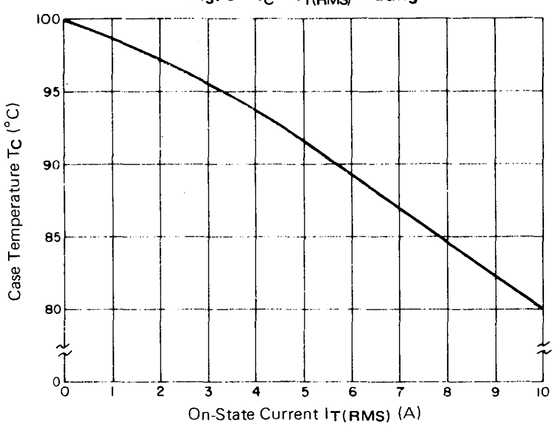


Fig. 6 $I_{GT} - T_C$ Characteristic

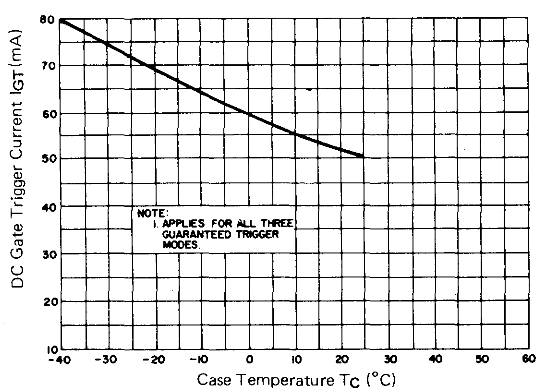


Fig. 7 $V_{GT}-T_C$ Characteristic

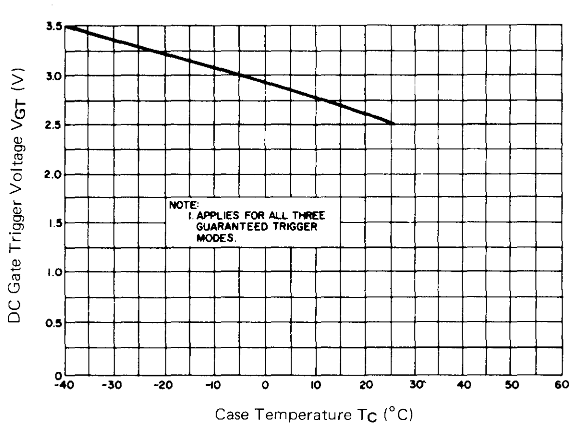


Fig. 8 Pulse I_{GT} Characteristic

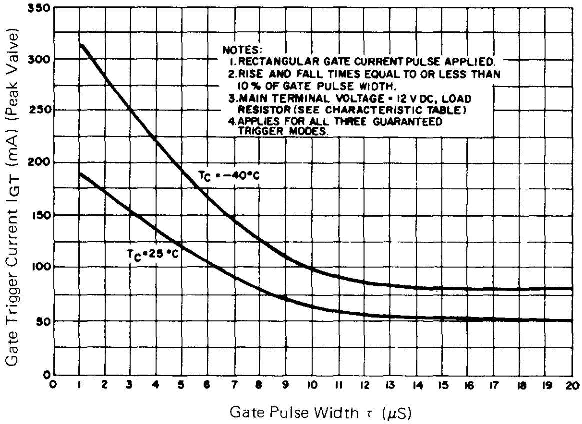


Fig. 9 I_H-T_C Characteristic

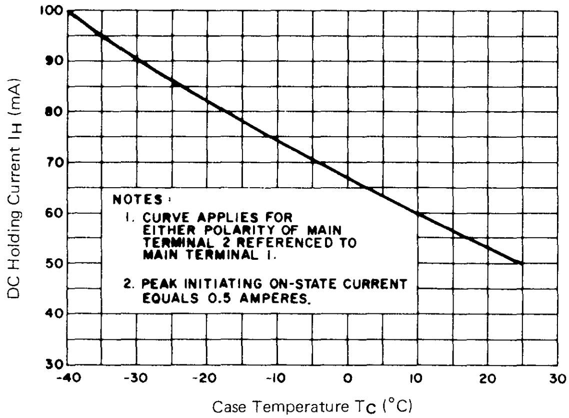
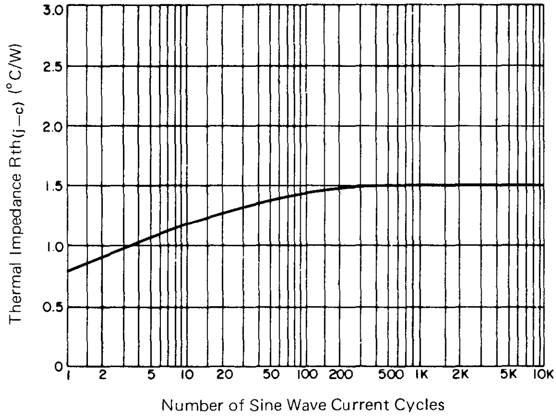


Fig. 10 $Rth_{(j-c)}$ Characteristic



9

NEC
ELECTRON DEVICE

TRIAC
SC149B~SC149M

The SC149B ~ SC149M are all diffused mold type triac granted RMS On-state current 12 Amps.
The glassivation technique applied to pellets' surface makes this series quite highly reliable.

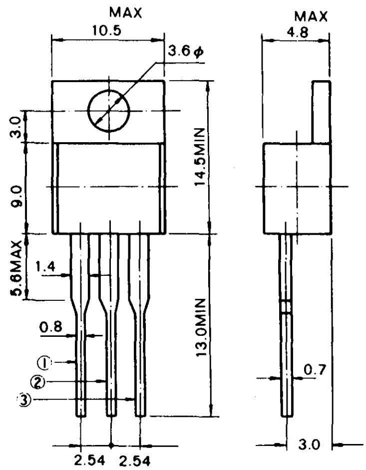
FEATURES

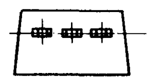
- Glassivated silicon chip for maximum reliability
- TO-220AB mold package
- Low cost

APPLICATIONS

Motor speed control,
Lamp dimmer, Temperature controllers,
Various solid state switches, etc.

Outline Drawing (Unit:mm)





Pin Connection
① T1
② T2
③ Gate

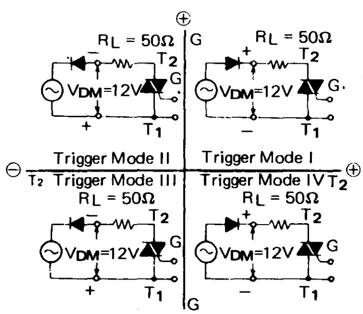
MAXIMUM RATINGS

Item	Symbol	B	D	E	M	Unit	Note
Repetitive Peak off voltage	V_{DRM}	200	400	500	600	V	
Non-repetitive Peak off Voltage	V_{DSM}	300	500	600	700	V	
RMS On-State Current	$I_{T(RMS)}$	12 (T_c = 75°C, 360° Condition)				A	Fig. 5
Peak Surge On-State Current	I_{TSM}	120 (60Hz), 110 (50Hz)				A	Fig. 2
Fusing Current	$\int i_t^2 dt$	60 (8.3ms)				A^2S	
Peak Gate Power Dissipation	P_{GM}	10 (10μs Pulse Width)				W	
Average Gate Power Dissipation	$P_{G(AV)}$	0.5				W	
Peak Gate Current	I_{FGM}	See Fig. 4				A	
Junction Temperature	T_j	−40 ~ +100				°C	
Storage Temperature	T_{stg}	−40 ~ +125				°C	

ELECTRICAL CHARACTERISTICS

Item		Symbol	Test Conditions		MIN.	TYP.	MAX.	Unit	Note
Peak Off-State Current		I_{DRM}	$V_{DM} = V_{DRM}$	$T_C = +25°C$	–	–	100	μA	
				$T_C = +110°C$	–	–	500		
On-State Voltage		V_{TM}	$T_C = +25°C$, $I_{TM} = 17$ A Peak		–	–	1.65	V	Fig. 1
Critical Rate of Rise of Off-state Voltage		dv/dt	$T_C = +100°C$, $V_{DM} = V_{DRM}$ Gate Open Circuited Exponential Wareform		100	200	–	V/μs	
Critical Rate of Rise of Commutating Off-State Voltage		$(dv/dt)_c$	$I_{T(RMS)} = 12A$ $V_{DM} = V_{DRM}$		4	–	–	V/μs	
DC Gate Trigger Current	* I	I_{GT}	$V_{DM} = 12V$ $R_L = 50Ω$	$T_C = +25°C$	–	–	50	mA	Fig. 6, 8
	* III				–	–	50		
	* IV				–	–	50		
	* I			$T_C = -40°C$	–	–	80		
	* III				–	–	80		
	* IV				–	–	80		
DC Gate Trigger Voltage	* I	V_{GT}	$V_{DM} = 12V$ $R_L = 50Ω$	$T_C = +25°C$	–	–	2.5	V	Fig. 7
	* III				–	–	2.5		
	* IV				–	–	2.5		
	* I			$T_C = -40°C$	–	–	3.5		
	* III				–	–	3.5		
	* IV				–	–	3.5		
DC Holding Current		I_H	$V_D = 24V$	$T_C = +25°C$	–	–	50	mA	Fig. 9
				$T_C = -40°C$	–	–	100		
DC Latching Current	* I	I_L	$V_D = 24V$ Gate Trigger Source = 15V 100Ω, 50μsec. 5 μsec rise times	$T_C = +25°C$	–	–	100	mA	
	* III				–	–	100		
	* IV				–	–	200		
	* I			$T_C = -40°C$	–	–	200		
	* III				–	–	200		
	* IV				–	–	400		
Steady State Thermal Resistance		$Rth_{(j-c)}$	Junction-to-case For acceptance test.		–	–	2.0	°C/W	
Apparent Thermal Resistance		$Rth_{(j-c)}$ (AC)	Junction-to-case For calculation of T_j		–	–	1.52		Fig. 10

* Trigger Mode & Test circuit



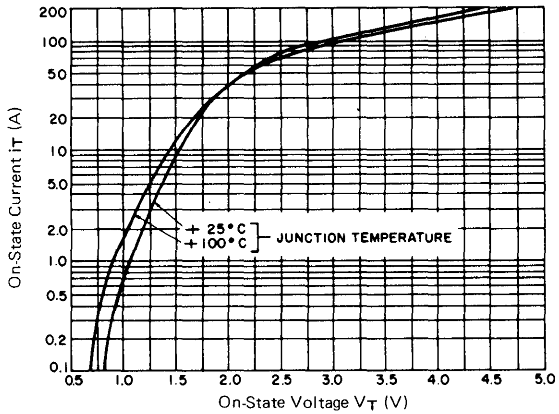


Fig. 1 $i_T - V_T$ **Characteristic**

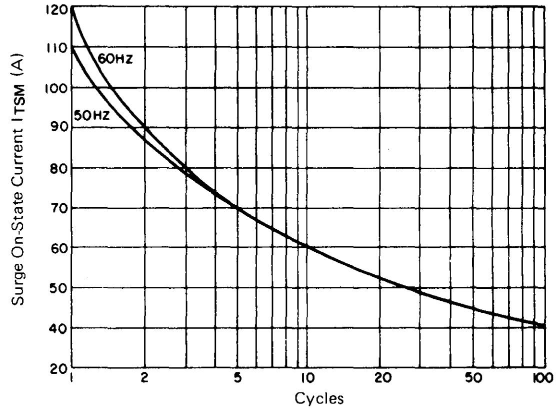


Fig. 2 I_{TSM} **Rating**

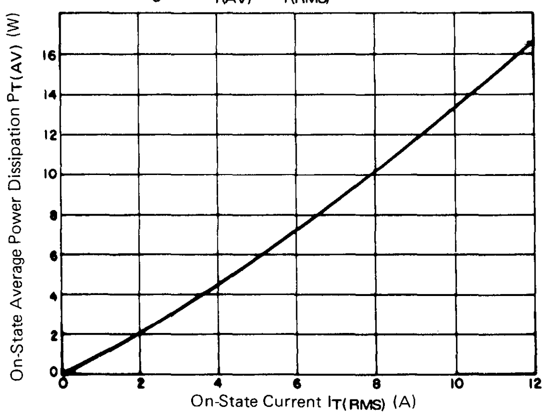


Fig. 3 $P_{T(AV)} - I_{T(RMS)}$ **Characteristic**

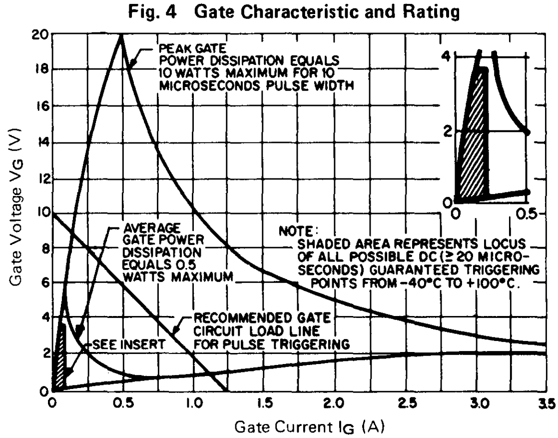


Fig. 4 Gate Characteristic and Rating

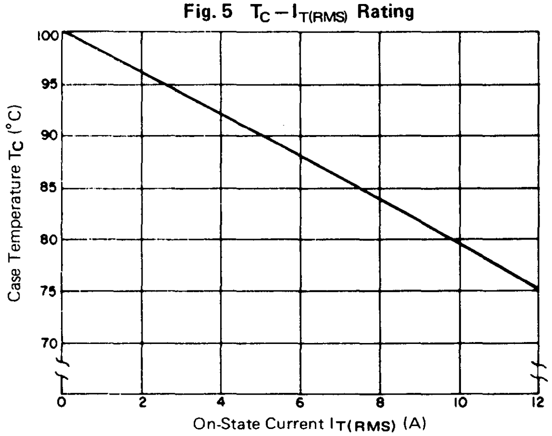


Fig. 5 $T_C - I_{T(RMS)}$ **Rating**

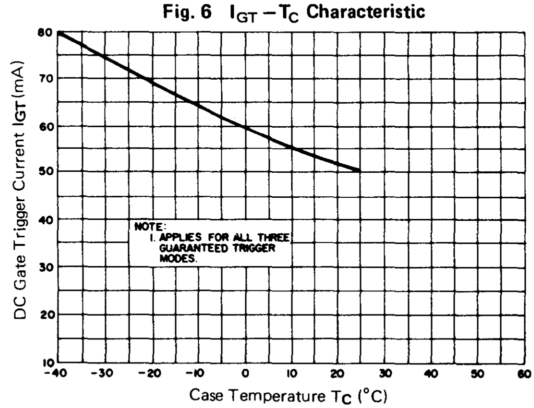


Fig. 6 $I_{GT} - T_C$ **Characteristic**

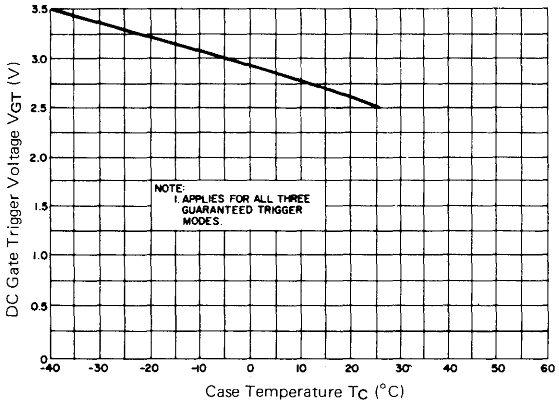


Fig. 7 $V_{GT} - T_C$ Characteristic

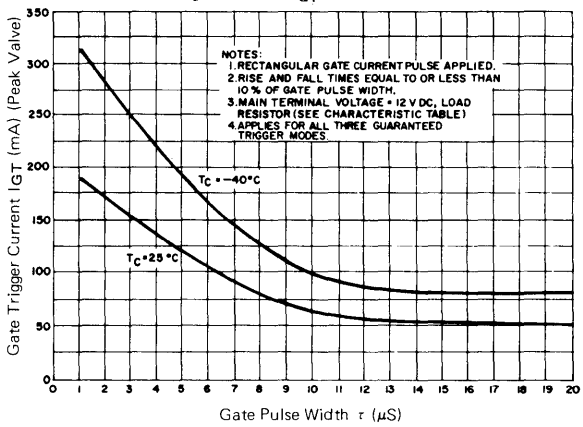


Fig. 8 Pulse I_{GT} Characteristic

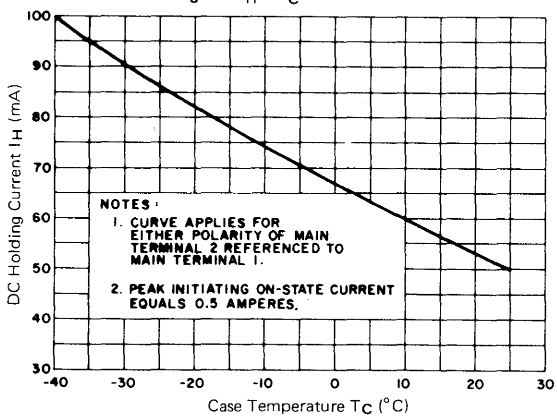


Fig. 9 $I_H - T_C$ Characteristic

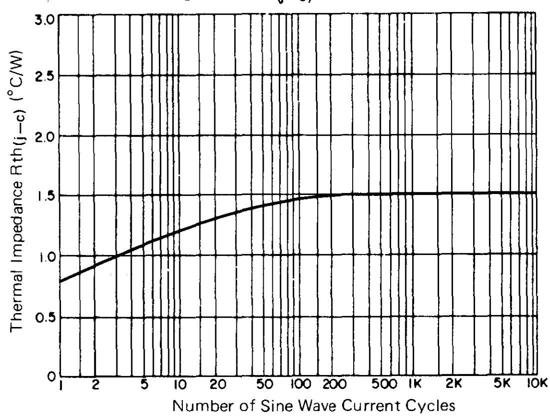


Fig. 10 $Rth_{(j-c)}$ Characteristic

9

NEC
ELECTRON DEVICE

TRIAC
SC151B～SC151M

The SC151B ~ SC151M are all diffused mold type triac granted RMS On-state current 15 Amps.
The glassivation technique applied to pellets' surface makes this series quite highly reliable.

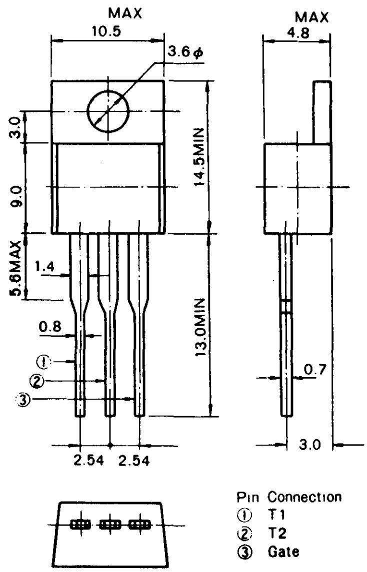
FEATURES

- Glassivated silicon chip for maximum reliability
- TO-220AB mold package
- Low cost

APPLICATIONS

Motor speed control,
Lamp dimmer, Temperature controllers,
Various solid state switches, etc.

Outline Drawing (Unit: mm)



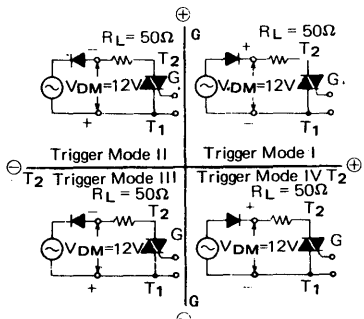
MAXIMUM RATINGS

Item	Symbol	B	D	E	M	Unit	Note
Repetitive Peak off Voltage	V_{DRM}	200	400	500	600	V	
Non-repetitive Peak off Voltage	V_{DSM}	300	500	600	700	V	
RMS On-State Current	$I_{T(RMS)}$	15 (T_C = 80°C, 360° Condition)				A	Fig. 5
Peak Surge On-State Current	I_{TSM}	120 (60Hz), 110 (50Hz)				A	Fig. 2
Fusing Current	$\int i_t^2 dt$	60 (8.3ms)				A^2S	
Peak Gate Power Dissipation	P_{GM}	10 (10μs Pulse Width)				W	
Average Gate Power Dissipation	$P_{G(AV)}$	0.5				W	
Peak Gate Current	I_{FGM}	See Fig. 4				A	
Junction Temperature	T_j	–40 ~ +100				°C	
Storage Temperature	T_{stg}	–40 ~ +125				°C	

ELECTRICAL CHARACTERISTICS

Item		Symbol	Test Conditions		MIN.	TYP.	MAX.	Unit	Note
Peak Off-State Current		I_{DRM}	$V_{DM} = V_{DRM}$	$T_C = +25^{\circ}C$	–	–	100	μA	
				$T_C = +110^{\circ}C$	–	–	500		
On-State Voltage		V_{TM}	$T_C = +25^{\circ}C$, $I_{TM} = 21A$ peak		–	–	1.52	V	Fig. 1
Critical Rate of Rise of Off-state Voltage		dv/dt	$T_C = 100^{\circ}C$, $V_{DM} = V_{DRM}$ Gate Open Circuited Exponential Waveform		100	250	–	V/μs	
Critical Rate of Rise of Commutating Off-State Voltage		(dv/dt)c	$I_{T(RMS)} = 15A$ $V_{DM} = V_{DRM}$		4	–	–	V/μs	
DC Gate Trigger Current	* I	IGT	$V_{DM} = 12V$ $R_L = 50\Omega$	$T_C = +25^{\circ}C$	–	–	50	mA	Fig. 6, 8
	* III				–	–	50		
	* IV				–	–	50		
	* I			$T_C = -40^{\circ}C$	–	–	80		
	* III				–	–	80		
	* IV				–	–	80		
DC Gate Trigger Voltage	* I	V_{GT}	$V_{DM} = 12V$ $R_L = 50\Omega$	$T_C = +25^{\circ}C$	–	–	2.5	V	Fig. 7
	* III				–	–	2.5		
	* IV				–	–	2.5		
	* I			$T_C = -40^{\circ}C$	–	–	3.5		
	* III				–	–	3.5		
	* IV				–	–	3.5		
DC Holding Current		I_H	$V_D = 24V$	$T_C = +25^{\circ}C$	–	–	50	mA	Fig. 9
				$T_C = -40^{\circ}C$	–	–	100		
DC Latching Current	* I	I_L	$V_D = 24V$ Gate Trigger Source = 15V 100Ω, 150μsec. 5μsec rise Times	$T_C = +25^{\circ}C$	–	–	100	mA	
	* III				–	–	100		
	* IV				–	–	200		
	* I			$T_C = -40^{\circ}C$	–	–	200		
	* III				–	–	200		
	* IV				–	–	400		
Steady State Thermal Resistance		$Rth_{(j-c)}$	Junction-to-Case For acceptance Test		–	–	2.0	°C/W	
Apparent Thermal Resistance		$Rth_{(j-c)}$ (AC)	Junction-to-Case For claculation of T_j		–	–	1.10		Fig. 10

* Trigger Mode & Test Circuit



9

Fig. 1 $i_T - V_T$ Characteristic

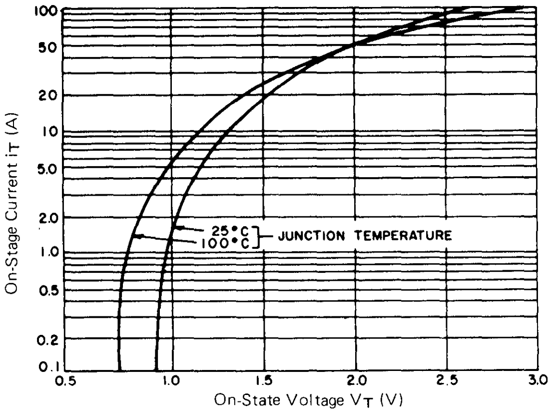


Fig. 2 I_{TSM} Rating

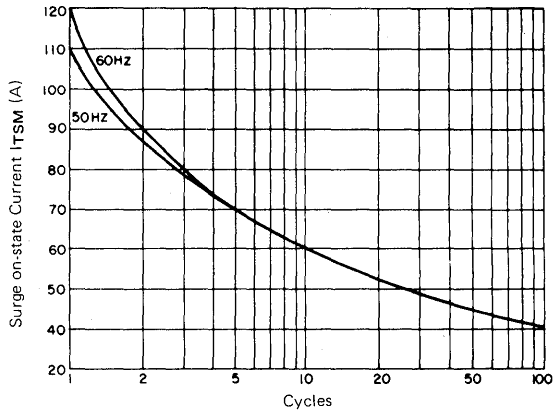


Fig. 3 $P_{T(AV)} - I_{T(RMS)}$ Characteristic

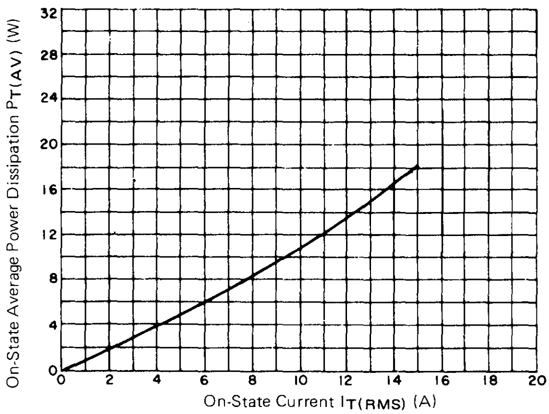


Fig. 4 Gate Characteristic and Rating

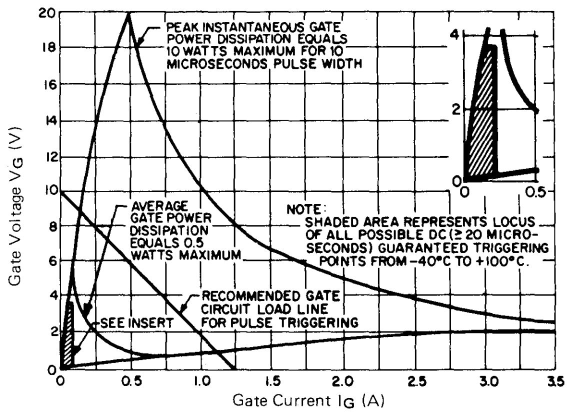


Fig. 5 $T_C - I_{T(RMS)}$ Rating

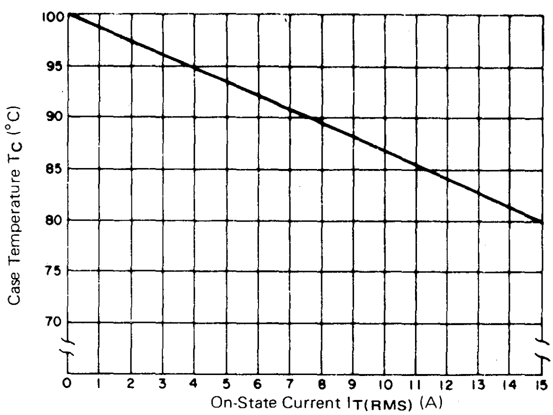


Fig. 6 $I_{GT} - T_C$ Characteristic

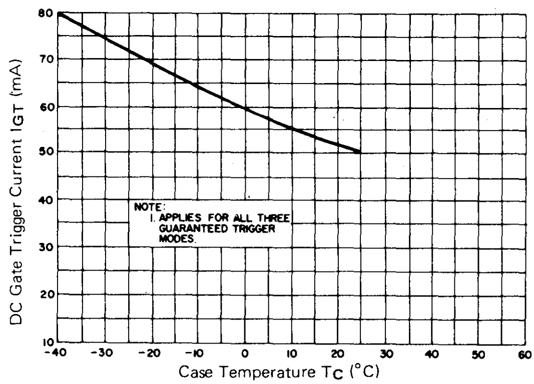


Fig. 7 $V_{GT} - T_C$ Characteristic

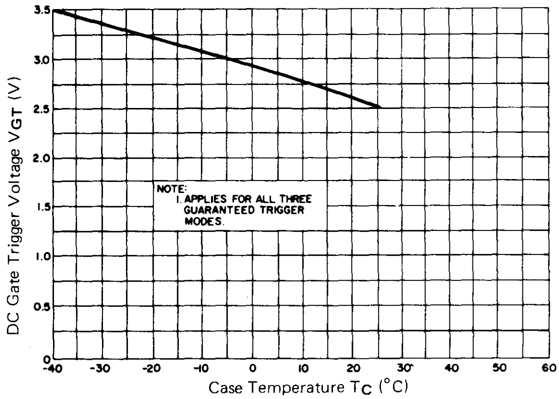


Fig. 8 Pulse I_{GT} Characteristic

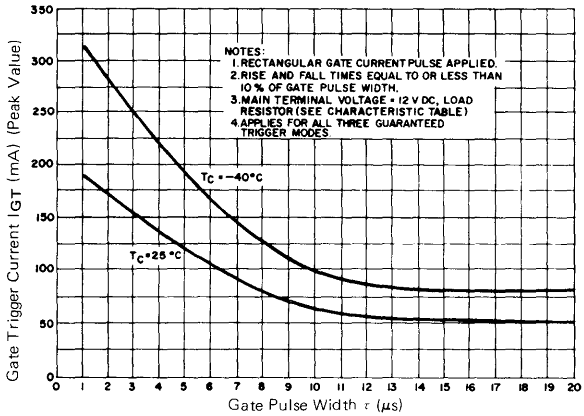


Fig. 9 $I_H - T_C$ Characteristic

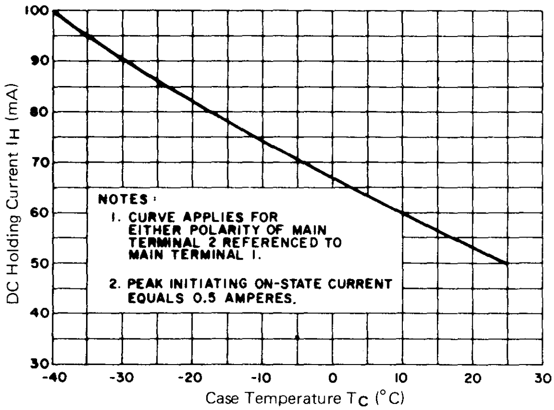
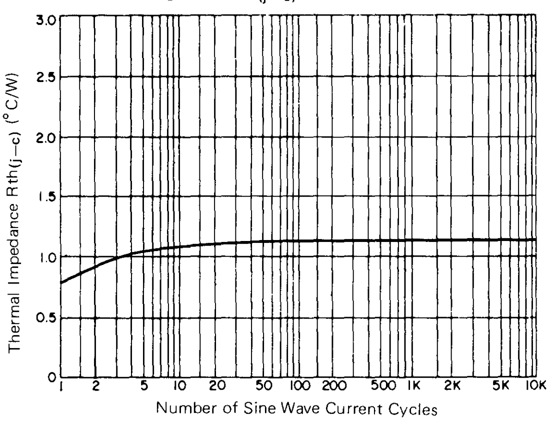


Fig. 10 $Rth_{(j-c)}$ Characteristic



9

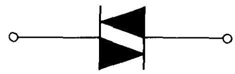
NEC
ELECTRON DEVICE

DIAC
N413

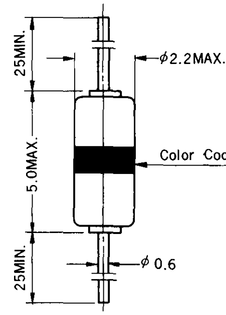
Silicon Bidirectional Trigger Diode

FEATURES

- Glassivation technique applied
- Suitable for TRIAC trigger
- DO 35 package
- Low cost



Outline Drawing (Unit: mm)



MAXIMUM ALLOWABLE RATINGS

Item	Symbol	Rating	Unit	Condition
Peak Current	I_P	±2	A	Pulse Width 10μs Repetition 120Hz
Storage Temperature	T_{stg}	−40~+125	°C	
Junction Temperature	T_j	+125	°C	

ELECTRICAL CHARACTERISTICS (Ta = 25 ± 2°C)

Item	Symbol	Specification			Unit	Note
		MIN.	TYP.	MAX.		
Break Over Voltage	V_{BO1} (V_{BO2})	26	–	40	V	See Fig. 1
Break Over Voltage Symmetry	$\Delta V_{BO} \lvert V_{BO1} - V_{BO2} \rvert$	–	–	3	V	See Fig. 1
Break Over Current	I_{BO1} (I_{BO2})	–	–	50	μA	See Fig. 1
V_{BO} Temperature Coefficiency		–	–	–	%/°C	See Fig. 3
Peak Output Voltage	V_P	5	–	–	V	See Fig. 2, 4, 5

SUBDIVIDED V_{BO}

Suffix (Color Code)	V_{BO}(V)	
	MIN.	MAX.
L(Red)	26	32
M(Blue)	29	37
N(Yellow)	34	40

Fig. 1 Fundamental Characteristic

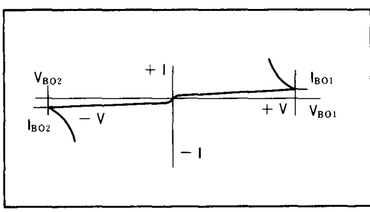
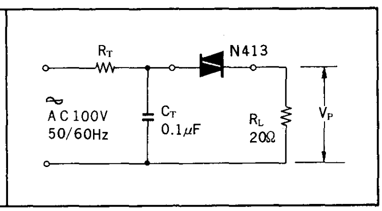


Fig. 2 Fundamental Circuit



Note: Request L, M or N, when the special selected V_{BO} is needed. Ex., N413M.

Fig. 3 Variation of V_{BO} with Ta

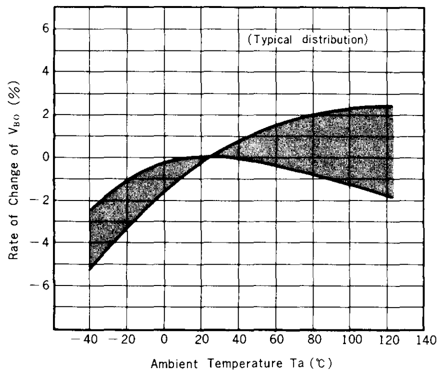


Fig. 4 V_p–Ta Characteristic

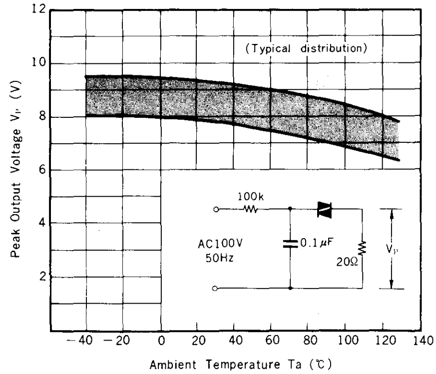


Fig. 5 V_p–C_T Characteristic (Ta = 25°C)

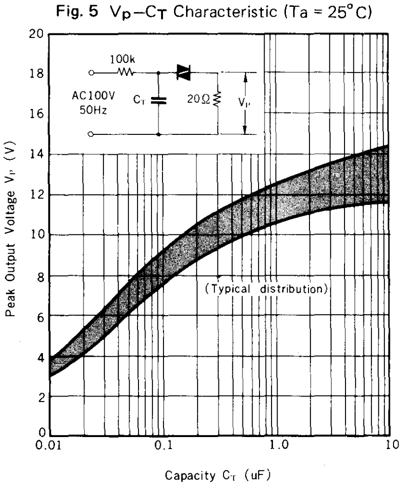
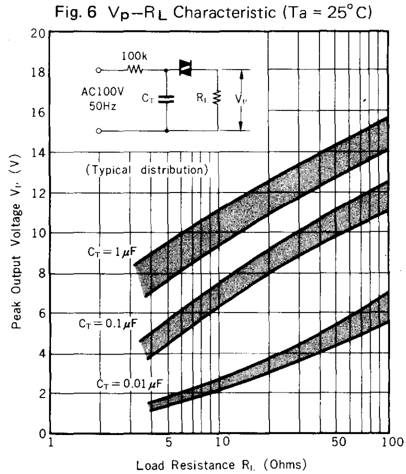


Fig. 6 V_p–R_L Characteristic (Ta = 25°C)



9

NEC
ELECTRON DEVICE

15A SHOTTKY BARRIER DIODE
15SB03S, 15SB04S

15SB03S and 15SB04S are shottky barrier diodes of which forward average current is 15A.

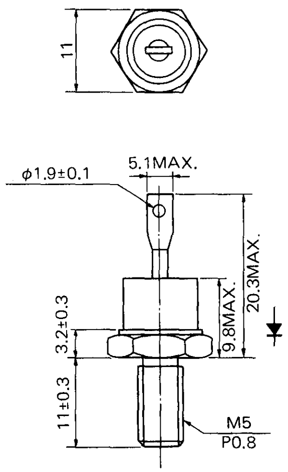
FEATURES

- Low forward voltage drop.
- Very fast recovery time.

APPLICATIONS

- Switching Regulators
- DC-DC Convertors

OUTLINE DRAWING (Unit: mm)



MAXIMUM RATINGS

Items	Symbols	15SB03S	15SB04S	Units	Notes
Repetitive Peak Reverse Voltage	V_{RRM}	30	40	V	
Non Repetitive Peak Reverse Voltage	V_{RSM}	36	48	V	
Forward Current	$I_{F(AV)}$	15 (Tc=98°C, Square wave Duty=50%)		A	Fig. 3
Surge Forward Current	I_{FSM}	250		A	
Junction Temperature	T_j	−40 ~ 125		°C	
Storage Temperature	T_{stg}	−40 ~ 125		°C	
Stud Torque		13 ~ 18		Kg-cm	

ELECTRIC CHARACTERISTICS (Tj=25°C)

Items	Symbols	Conditions	Max.	Units	Notes
Repetitive Peak Reverse Current	I_{RRM}	Tj=125°C $V_{RM}=V_{RRM}$	100	mA	
Forward Voltage	V_{FM}	I_{FM}=15A	0.6	V	Fig. 1
Thermal Resistance	$R_{j\text{-}c}$	Junction-Case	2.0	°C/W	Fig. 4

15SB03S, 15SB04S

Fig. 1 $\nu_F - i_F$ Characteristic

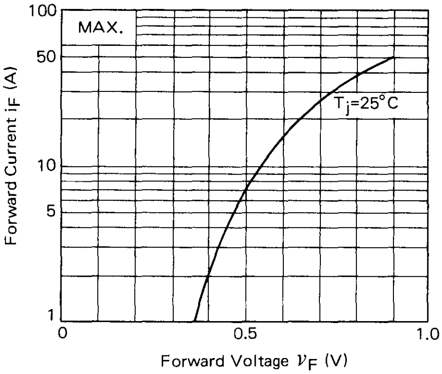


Fig. 2 $P_{F(AV)} - I_{F(AV)}$ Characteristics

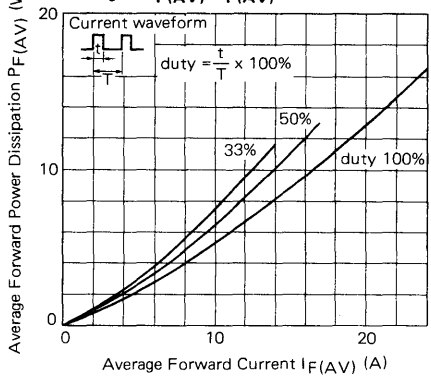


Fig. 3 $T_C - I_{F(AV)}$ Ratings

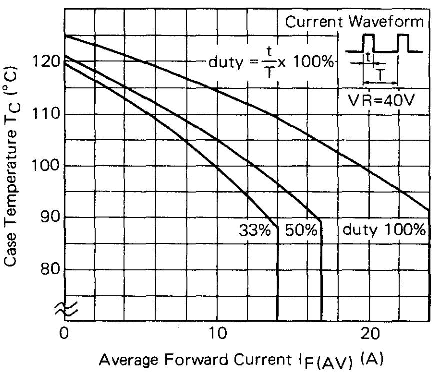
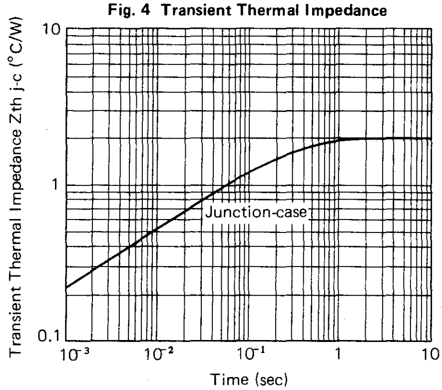


Fig. 4 Transient Thermal Impedance



NEC
ELECTRON DEVICE

15A SHOTTKY BARRIER DIODE
15SB04M

15SB04M is a shottky barrier diode of which forward average current is 15A.

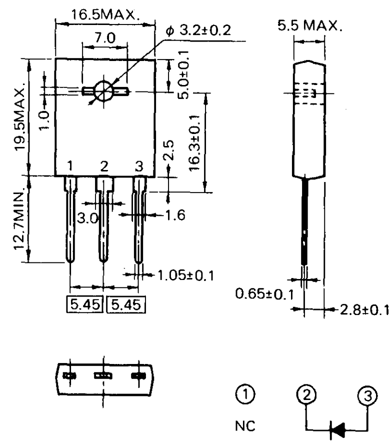
FEATURES

- Low forward voltage drop.
- Very fast recovery time.
- Easy installation.

APPLICATIONS

- Switching Regulators
- DC-DC Convertors

OUTLINE DRAWING (Unit: mm)



MAXIMUM RATINGS

ITEMS	SYMBOLS	15SB04M	UNITS	NOTES
Repetitive Peak Reverse Voltage	V_{RRM}	40	V	
Non Repetitive Peak Reverse Voltage	V_{RSM}	48	V	
Forward Current	$I_{F(AV)}$	15 (Tc=95.5°C, Square wave Duty=50%)	A	
Surge Forward Current	I_{FSM}	250	A	
Junction Temperature	T_j	−40 ~ 125	°C	
Storage Temperature	Tstg	−40 ~ 125	°C	

ELECTRICAL CHARACTERISTICS (Tj=25°C)

ITEMS	SYMBOLS	CONDITIONS	MAX.	UNITS	NOTES
Repetitive Peak Reverse Current	I_{RRM}	Tj=125°C $V_{RM}=V_{RRM}$	50	mA	
Forward Voltage	V_{FM}	I_{FM}=12A	0.6	V	
Thermal Resistance	$R_{th(j-c)}$	Junction to Case	2.5	°C/W	
Reverse Recovery Time	t_{rr}	I_{FM}=5A	50	nS	Typ.

Fig. 1 $v_F - i_F$ Characteristics

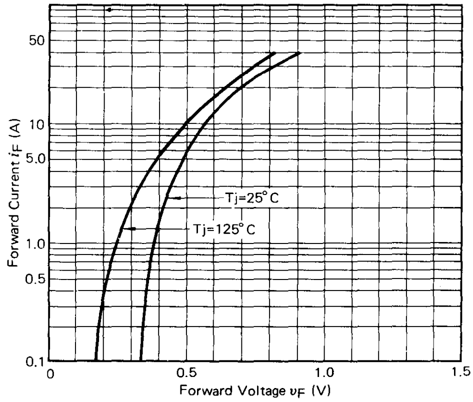


Fig. 2 $P_{F(AV)} - I_{F(AV)}$ Characteristics

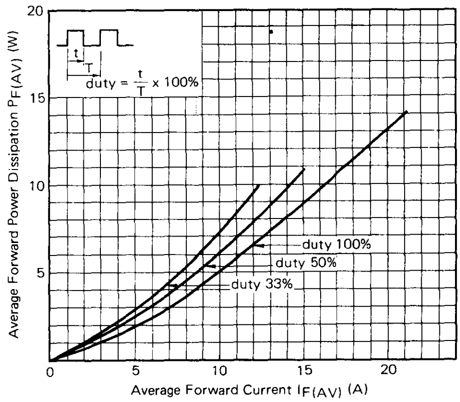


Fig. 3 $I_{F(AV)} - T_C$ Ratings

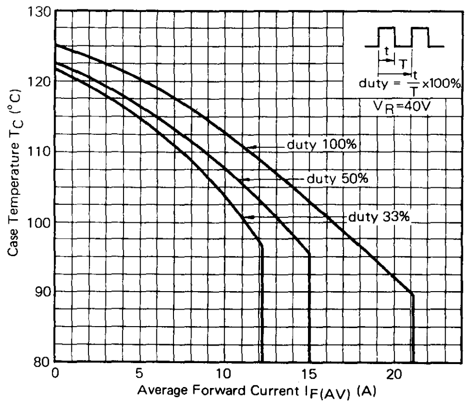


Fig. 4 $I_{F(AV)}$–Ta Ratings

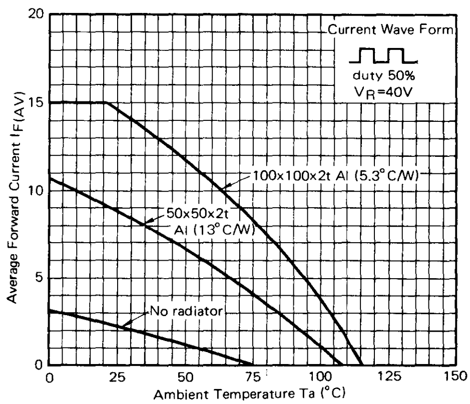
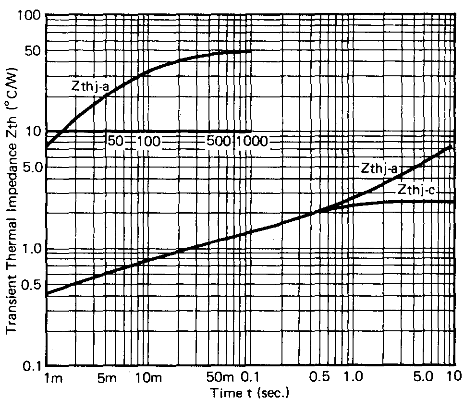


Fig. 5 Transient Thermal Impedance



9

NEC
ELECTRON DEVICE

30A SHOTTKY BARRIER DIODE
30SB03SA, 30SB04SA

30SB03SA and 30SB04SA are shottky barrier diodes of which forward average current is 30A.

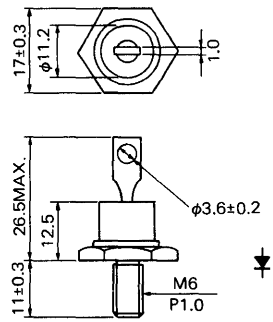
FEATURES

- Low forward voltage drop.
- Very fast recovery time.

APPLICATIONS

- Switching Regulators
- DC-DC Convertors

OUTLINE DRAWING (Unit: mm)



MAXIMUM RATINGS

Items	Symbols	30SB03SA	30SB04SA	Units	Notes
Repetitive Peak Reverse Voltage	V_{RRM}	30	40	V	
Non Repetitive Peak Reverse Voltage	V_{RSM}	36	48	V	
Forward Current	$I_{F(AV)}$	30 (Tc=82°C, Square wave Duty=50%)		A	Fig. 3
Surge Forward Current	I_{FSM}	600		A	
Junction Temperature	T_j	−40 ~ 125		°C	
Storage Temperature	T_{stg}	−40 ~ 125		°C	
Stud Torque		26 ~ 35		Kg-cm	

ELECTRIC CHARACTERISTICS (Tj=25°C)

Items	Symbols	Conditions	Max.	Units	Notes
Repetitive Peak Reverse Current	I_{RRM}	Tj=125°C $V_{RM}=V_{RRM}$	250	mA	
Forward Voltage	V_{FM}	I_{FM}=100A	0.9	V	Fig. 1
Thermal Resistance	$R_{j\text{-}c}$	Junction-Case	1.4	°C/W	Fig. 4

30SB03SA, 30SB04SA

Fig. 1 $\nu_F - i_F$ Characteristic

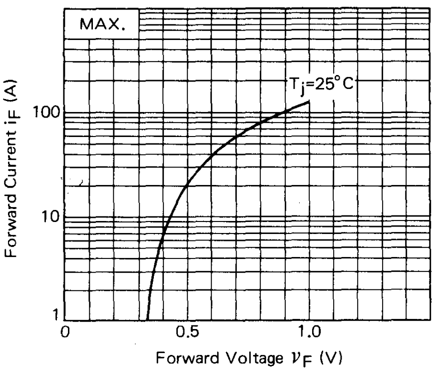


Fig. 2 $P_{F(AV)} - I_{F(AV)}$ Characteristics

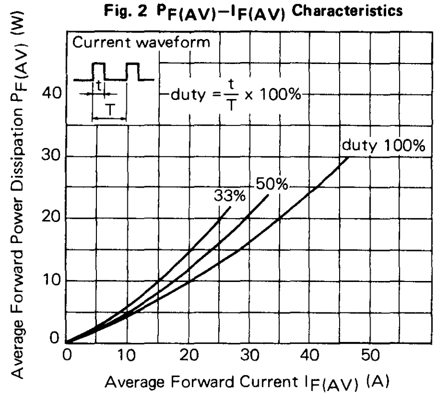


Fig. 3 $T_C - I_{F(AV)}$ Ratings

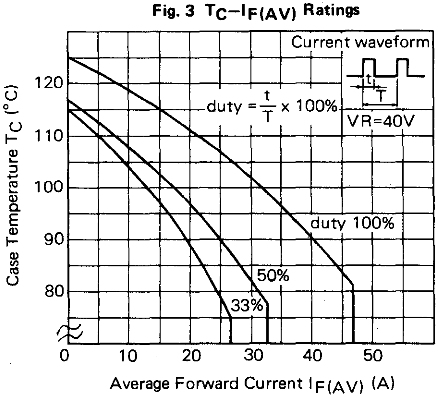
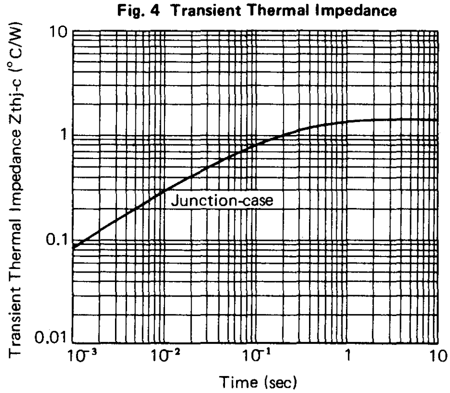


Fig. 4 Transient Thermal Impedance



9

NEC
ELECTRON DEVICE

40A SHOTTKY BARRIER DIODE
40SB03SA,40SB04SA

40SB03SA and 40SB04SA are shottky barrier diodes of which forward average current is 40A.

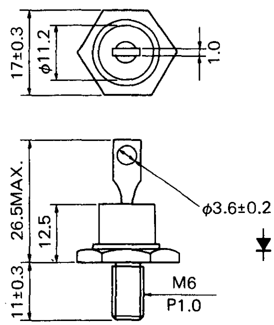
FEATURES

- Low forward voltage drop.
- Very fast recovery time.

APPLICATIONS

- Switching Regulators
- DC-DC Convertors

OUTLINE DRAWING (Unit: mm)



MAXIMUM RATINGS

Items	Symbols	40SB03SA	40SB04SA	Units	Notes
Repetitive Peak Reverse Voltage	V_{RRM}	30	40	V	
Non Repetitive Peak Reverse Voltage	V_{RSM}	36	48	V	
Forward Current	$I_{F(AV)}$	40 (Tc=81°C, Square wave Duty=50%)		A	Fig. 3
Surge Forward Current	I_{FSM}	600		A	
Junction Temperature	T_j	−40 ~ 125		°C	
Storage Temperature	T_{stg}	−40 ~ 125		°C	
Stud Torque		26 ~ 35		Kg-cm	

ELECTRIC CHARACTERISTICS (Tj=25°C)

Items	Symbols	Conditions	Max.	Units	Notes
Repetitive Peak Reverse Current	I_{RRM}	Tj=125°C $V_{RM}=V_{RRM}$	250	mA	
Forward Voltage	V_{FM}	I_{FM}=100A	0.9	V	Fig. 1
Thermal Resistance	R_{j-c}	Junction-Case	1.0	°C/W	Fig. 4

40SB03SA, 40SB04SA

Fig. 1 $\nu_F - i_F$ Characteristic

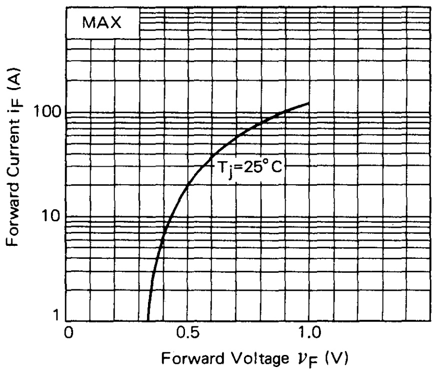


Fig. 2 $P_{F(AV)} - I_{F(AV)}$ Characteristics

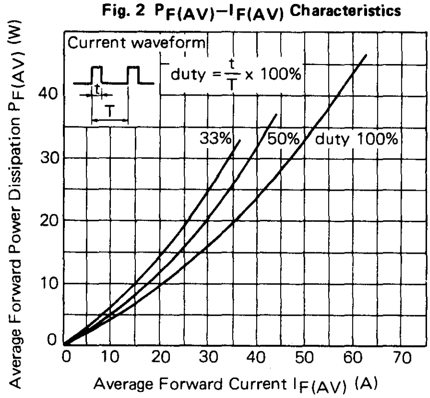


Fig. 3 $T_C - I_{F(AV)}$ Ratings

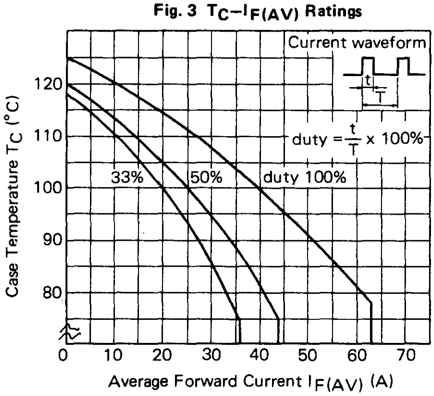
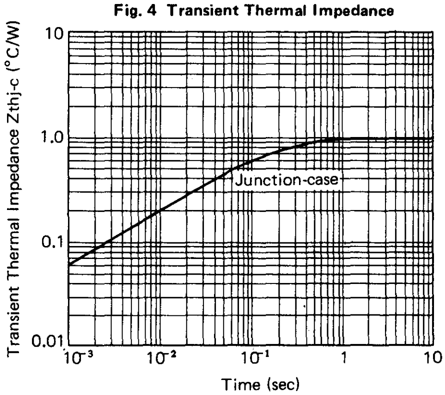


Fig. 4 Transient Thermal Impedance



9

NEC
ELECTRON DEVICE

60A SHOTTKY BARRIER DIODE
60SB03S, 60SB04S

60SB03S and 60SB04S are shottky barrier diodes of which forward average current is 60A.

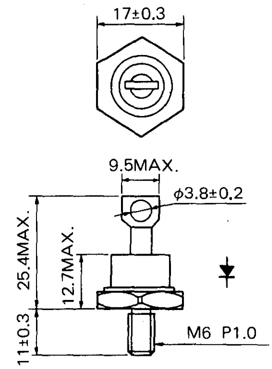
FEATURES

- Low forward voltage drop.
- Very fast recovery time.

APPLICATIONS

- Switching Regulators
- DC-DC Convertors

OUTLINE DRAWING (Unit: mm)



MAXIMUM RATINGS

Items	Symbols	60SB03S	60SB04S	Units	Notes
Repetitive Peak Reverse Voltage	V_{RRM}	30	40	V	
Non Repetitive Peak Reverse Voltage	V_{RSM}	36	48	V	
Forward Current	$I_{F(AV)}$	60 (Tc=85°C, Square wave Duty=50%)		A	Fig. 3
Surge Forward Current	I_{FSM}	850		A	
Junction Temperature	T_j	−40 ~ 125		°C	
Storage Temperature	T_{stg}	−40 ~ 125		°C	
Stud Torque		26 ~ 35		Kg-cm	

ELECTRIC CHARACTERISTICS (Tj=25°C)

Items	Symbols	Conditions	Max.	Units	Notes
Repetitive Peak Reverse Current	I_{RRM}	Tj=125°C $V_{RM}=V_{RRM}$	400	mA	
Forward Voltage	V_{FM}	I_{FM}=150A	0.8	V	Fig. 1
Thermal Resistance	$R_{j\text{-}c}$	Junction-Case	0.75	°C/W	Fig. 4

60SB03S, 60SB04S

Fig. 1 $V_F - i_F$ Characteristic

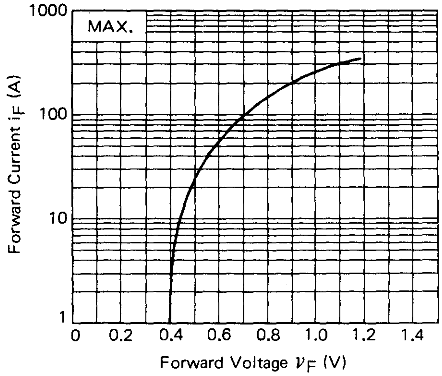


Fig. 2 $P_{F(AV)} - I_{F(AV)}$ Characteristics

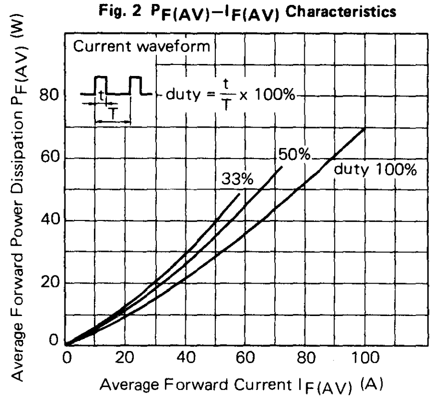


Fig. 3 $T_C - I_{F(AV)}$ Ratings

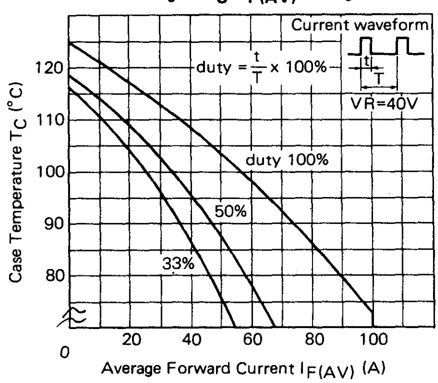
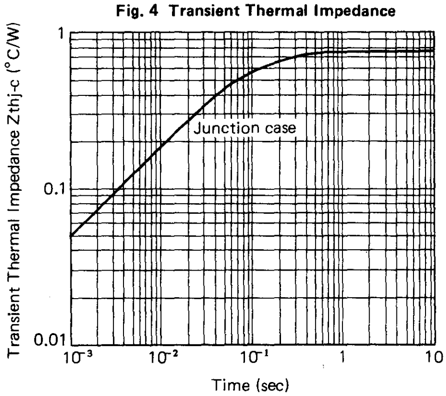


Fig. 4 Transient Thermal Impedance



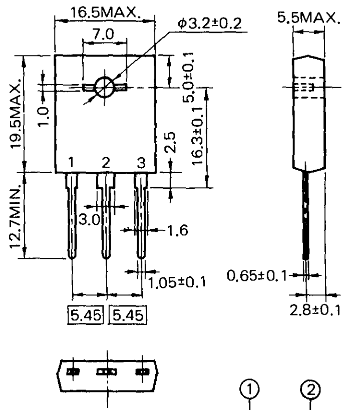
9

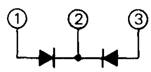
NEC
ELECTRON DEVICE

12A FAST RECOVERY DIODE MODULE
12CH1M～12CH4M

12CH1M～12CH4M are fast recovery diode centertap module of which output current is 12A.

OUTLINE DRAWING (UNIT: mm)





FEATURES

* Fast recovery time.
* High reliability (Glass passivation).
* Easy installation.

APPLICATIONS

* Switching Regulators
* DC-DC Convertors

MAXIMUM RATINGS

Items	Symbols	12CH1M	12CH2M	12CH3M	12CH4M	Units	Notes
Repetitive Peak Reverse Voltage	V_{RRM}	100	200	300	400	V	
Non Repetitive Peak Reverse Voltage	V_{RSM}	150	250	350	450	V	
Output Current	Io	12 (Tc = 132°C, Square wave Duty = 50 %)				A	
Surge Forward Current	I_{FSM}	60				A	
Junction Temperature	Tj	−40～150				°C	
Storage Temperature	Tstg	−40～150				°C	

ELECTRICAL CHARACTERISTICS (Tj = 25°C)

Items	Symbols	Conditions	Max.	Units	Notes
Repetitive Peak Reverse Current	I_{RRM}	Tj = 150 °C, V_{RM} = V_{RRM}	8.0	mA	
Forward Voltage	V_{FM}	I_{FM} = 6A	1.2	V	
Thermal Resistance	$R_{th(j\text{-}c)}$	Junction to Case	2.5	°C/W	
Reverse Recovery Time	trr	1_{FM} = 0.4A, I_{RM} = 0.8A	350	nS	

Fig. 1 $v_F - i_F$ Characteristics (per Cell)

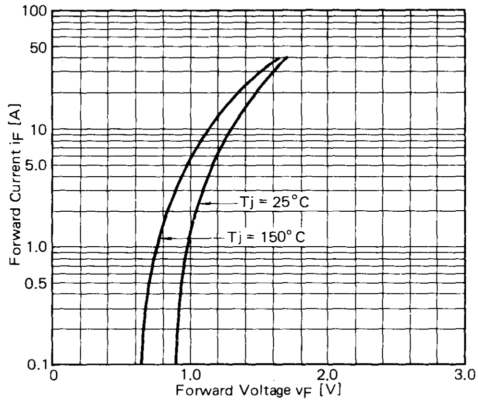
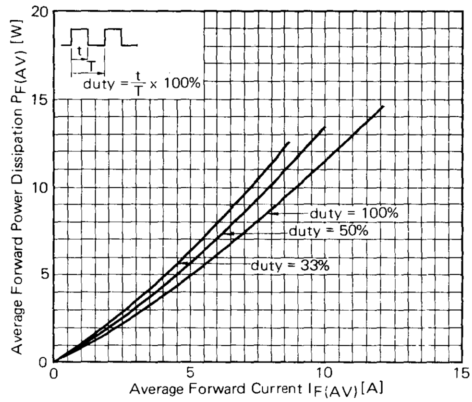


Fig. 2 $P_{F(AV)} - I_{F(AV)}$ Characteristics



Fgi. Fig. 3 $I_{O(DC)} - T_C$ Ratings

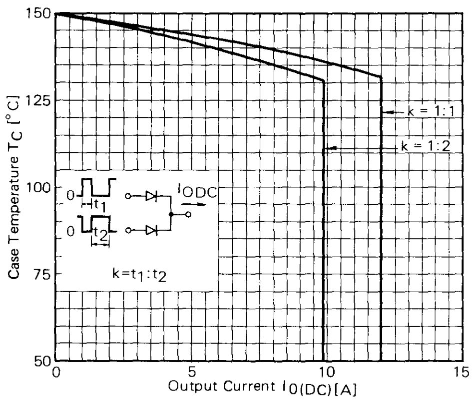


Fig. 4 $I_{F(AV)} - T_C$ Ratings (per Cell)

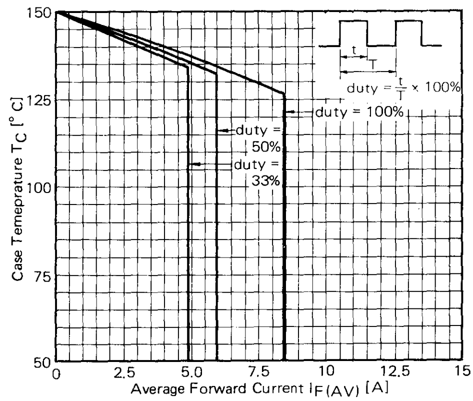


Fig. 5 $I_{O(DC)} - $ Ta Ratings

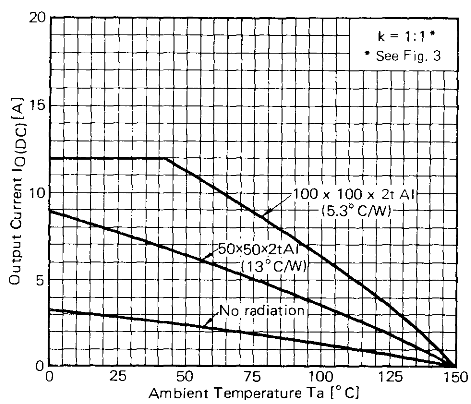
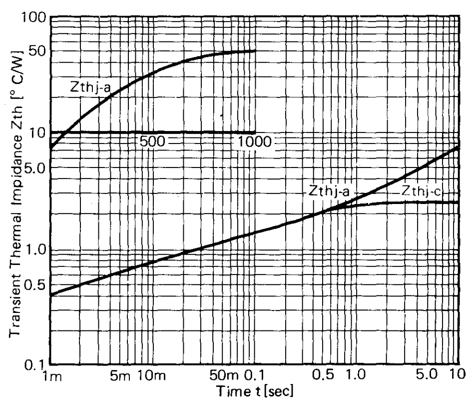


Fig. 6 Transient Thermal Impedance (per Cell)



NEC
ELECTRON DEVICE

12A FAST RECOVERY DIODE MODULE
12CH1FM～12CH4FM

12CH1FM～12CH4FM are isolated type fast recovery diode centertap module of which output current is 12A.

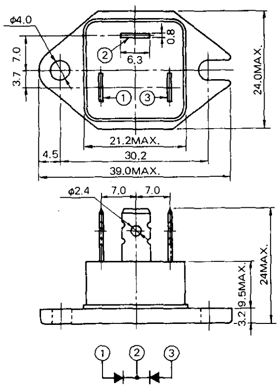
FEATURES

* Fast recovery time.
* High reliability (Glass passivation).
* Isolation type.
* Easy installation.

APPLICATIONS

* Switching Regulators
* DC-DC Convertors

OUTLINE DRAWING (UNIT: mm)



MAXIMUM RATINGS

Items	Symbols	12CH1FM	12CH2FM	12CH3FM	12CH4FM	Units	Notes
Repetitive Peak Reverse Voltage	V_{RRM}	100	200	300	400	V	
Non Repetitive Peak Reverse Voltage	V_{RSM}	150	250	350	450	V	
Output Current	Io	12 (Tc = 121 °C, Square wave Duty = 50 %)				A	
Surge Forward Current	I_{FSM}	60				A	
Junction Temperature	Tj	–40～150				°C	
Storage Temperature	Tstg	–40～150				°C	
Isolation Voltage	Visol	AC 1500				V	

ELECTRICAL CHARACTERISTICS (Tj = 25° C)

Items	Symbols	Conditions	Max.	Units	Notes
Repetitive Peak Reverse Current	I_{RRM}	Tj = 150° C, $V_{RM} = V_{RRM}$	8.0	mA	
Forward Voltage	V_{FM}	I_{FM} = 6A	1.2	V	
Thermal Resistance	$R_{th(j\text{-}c)}$	Junction to Case	4.0	°C/W	
Reverse Recovery Time	t_{rr}	I_{FM} = 0.4A	350	nS	

Fig. 1 $v_F - i_F$ Characteristics (per Cell)

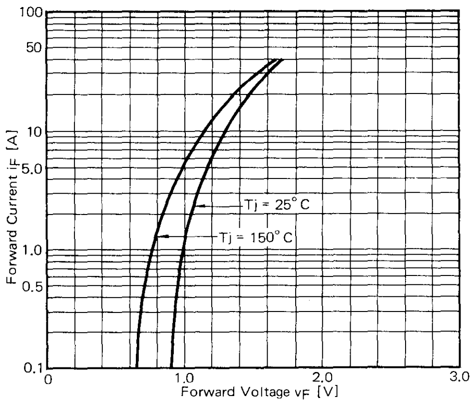


Fig. 2 $P_{F(AV)} - I_{F(AU)}$ – Chracteristics (per Cell)

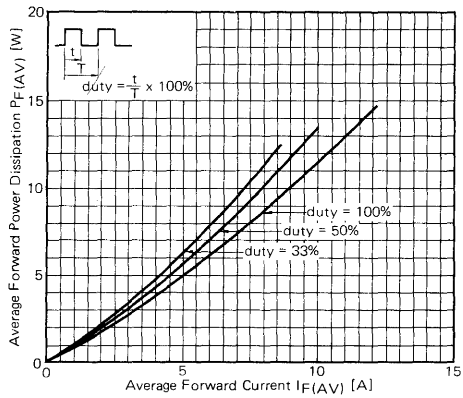


Fig. 3 $I_{O(DC)} - T_C$ Ratings

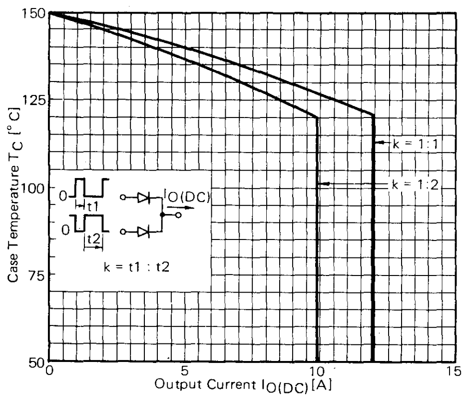


Fig. 4 $I_{F(AV)} - T_C$ Ratings (cer Cell) (per Cell)

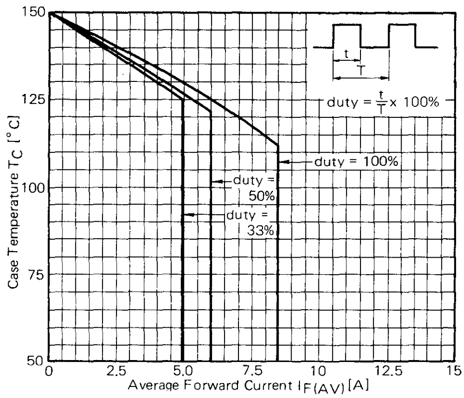


Fig. 5 $I_{O(DC)}$ – Ta Ratings

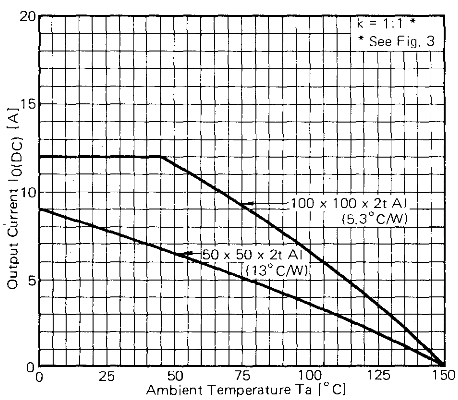
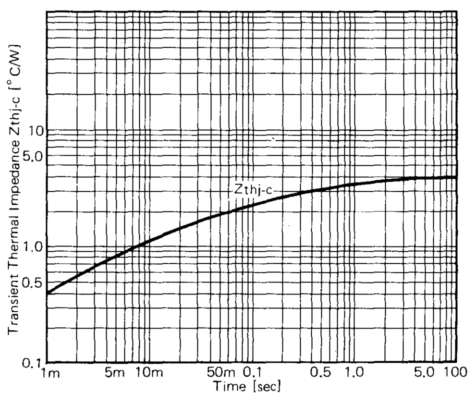


Fig. 6 Transient Thermal Impedance (per Cell)



9

NEC
ELECTRON DEVICE

20A SHOTTKY BARRIER DIODE MODULE
20CS04M

20CS04M is a shottky barrier diode centertap module of which output current is 20A.

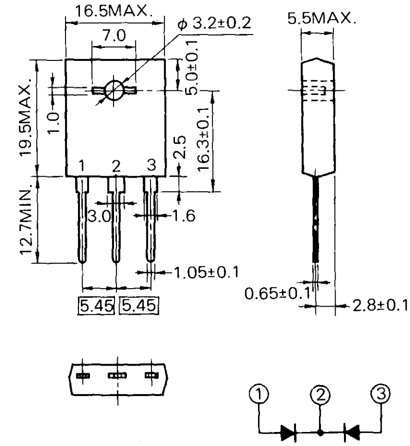
FEATURES

- Low forward voltage drop.
- Very fast recovery time.
- Easy installation.

APPLICATIONS

- Switching Regulators
- DC-DC Convertors

OUTLINE DRAWING (Unit: mm)



MAXIMUM RATINGS

ITEMS	SYMBOLS	20CS04M	UNITS	NOTES
Repetitive Peak Reverse Voltage	V_{RRM}	40	V	
Non Repetitive Peak Reverse Voltage	V_{RSM}	48	V	
Output Current	I_o	20 (Tc=106°C, Square wave Duty=50%)	A	
Surge Forward Current	I_{FSM}	250	A	
Junction Temperature	Tj	−40 ~ 125	°C	
Storage Temperature	Tstg	−40 ~ 125	°C	

ELECTRICAL CHARACTERISTICS (Tj=25°C)

ITEMS	SYMBOLS	CONDITIONS	MAX.	UNITS	NOTES
Repetitive Peak Reverse Current	I_{RRM}	Tj=125°C $V_{RM}=V_{RRM}$	50	mA	
Forward Voltage	V_{FM}	I_{FM}=10A	0.6	V	
Thermal Resistance	$R_{th(j-c)}$	Junction to Case	2.5	°C/W	
Reverse Recovery Time	t_{rr}	I_{FM}=5A	50	nS	Typ.

Fig. 1 $v_F - i_F$ Characteristics (per Cell)

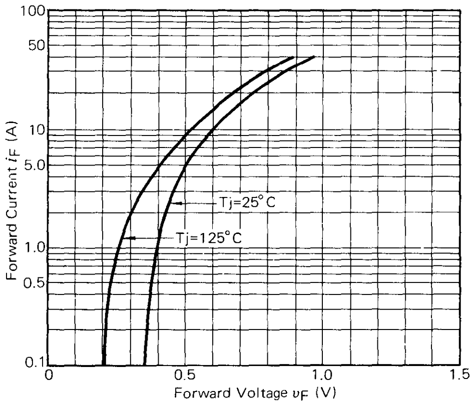


Fig. 2 $P_{F(AV)} - I_{F(AV)}$ Characteristics (per Cell)

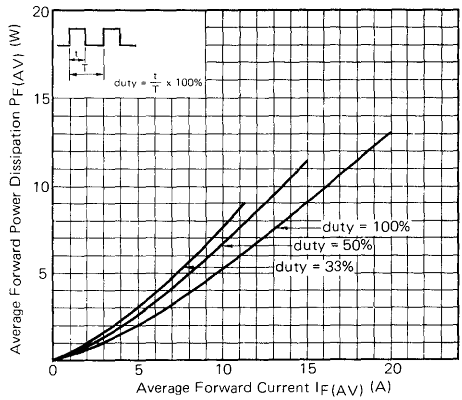


Fig. 3 $I_{O(DC)} - T_C$ Ratings

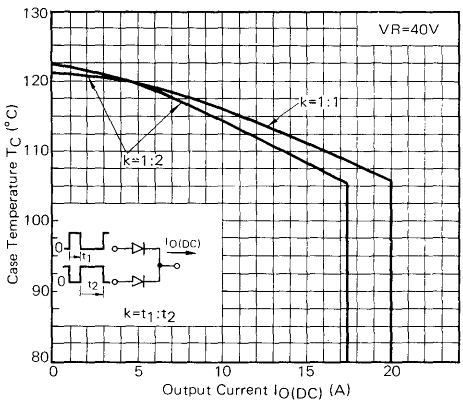


Fig. 4 $I_{F(AV)} - T_C$ Ratings (per Cell)

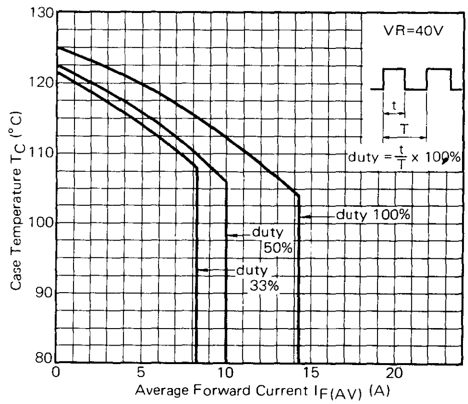


Fig. 5 $I_{O(DC)} - T_a$ Ratings

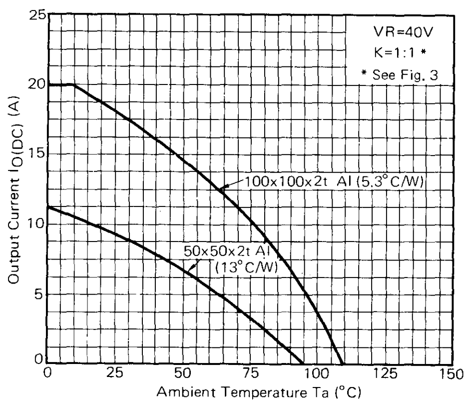
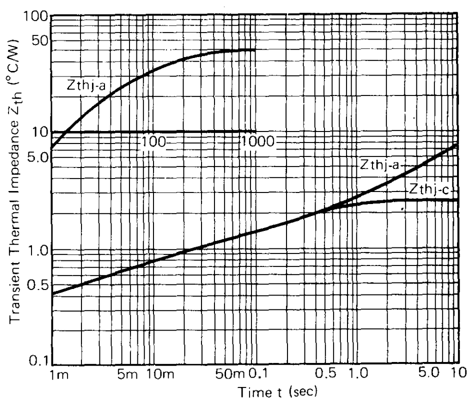


Fig. 6 Transient Thermal Impedance (per Cell)



9

20A SHOTTKY BARRIER DIODE MODULE

20CS04FM

NEC
ELECTRON DEVICE

20CS04FM is a isolated type shottkey barrier diode centertap module of which output current is 20A.

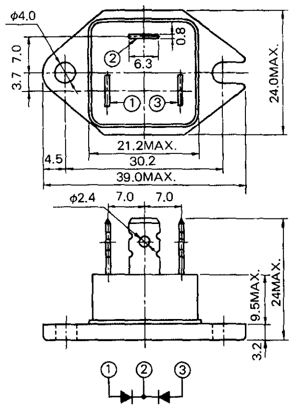
FEATURES

* Low forward voltage drop.
* Very fast recovery time.
* Isolated type.
* Easy installation.

APPLICATIONS

* Switching Regulators
* DC-DC Convertors

OUTLINE DRAWING (UNIT: mm)



MAXIMUM RATINGS

Items	Symbols	20CS04FM	Units	Notes
Repetitive Peak Reverse Voltage	V_{RRM}	40	V	
Non Repetitive Peak Reverse Voltage	V_{RSM}	48	V	
Output Current	Io	20 (Tj = 102°C, Square wave Duty = 50 %)	A	
Surge Forward Current	I_{FSM}	250	A	
Junction Temperature	Tj	−40~125	°C	
Storage Temperature	Tstg	−40~125	°C	
Isolation Voltage	Visol	AC 1500	V	

ELECTRICAL CHARACTERISTICS (Tj = 25°C)

Items	Symbols	Conditions	Max.	Units	Notes
Repetitive Peak Reverse Current	I_{RRM}	Tj=125°C, $V_{RM} = V_{RRM}$	50	mA	
Forward Voltage	V_{FM}	I_{FM} = 10A	0.6	V	
Thermal Resistance	$R_{th(j-c)}$	Junction to Case	3.0	°C/W	
Reverse Recovery Time	t_{rr}	I_{FM} = 5A	50	nS	Typ.

Fig. 1 $v_F - i_F$ Characteristics (per Cell)

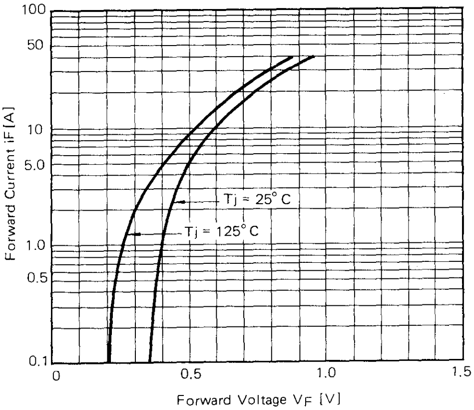


Fig. 2 PF(AV) – IF(AV) Characteristics (per Cell)

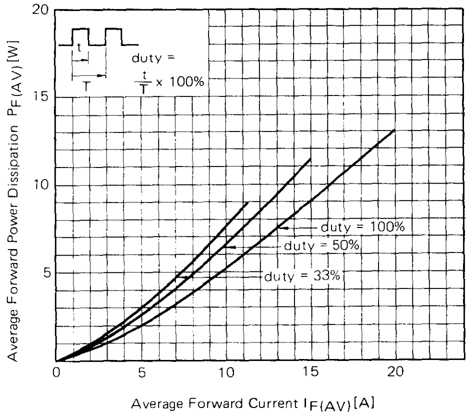


Fig. 3 Io(pc) – Tc Ratings

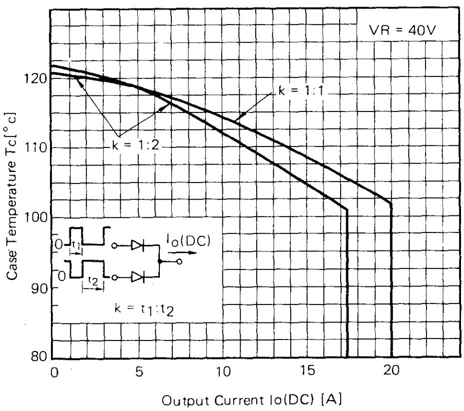


Fig. 4 IF(AV) – Tc Ratings (per Cell)

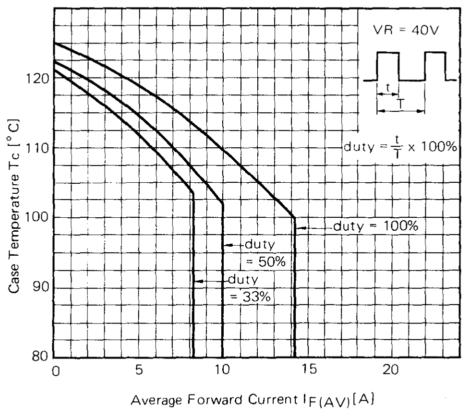


Fig. 5 Io(DC) – Ta Ratings

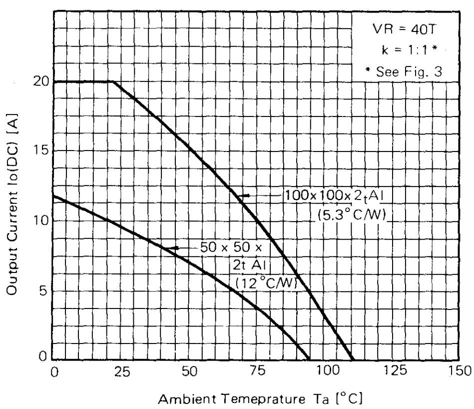
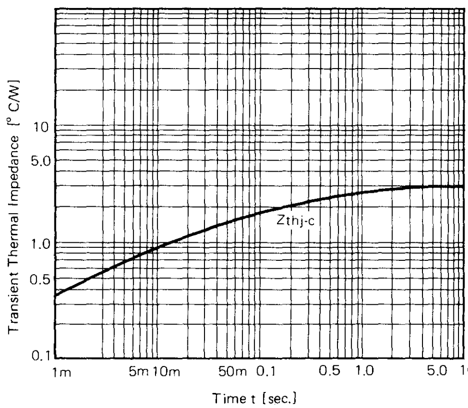


Fig. 6 Transient Thermal Impedance (per Cell)



NEC
ELECTRON DEVICE

24A FAST RECOVERY DIODE MODULE
24CH1FM ~ 24CH4FM

24CH1FM ~ 24CH4FM are isolated type fast recovery diode centertap module of which output current is 24A.

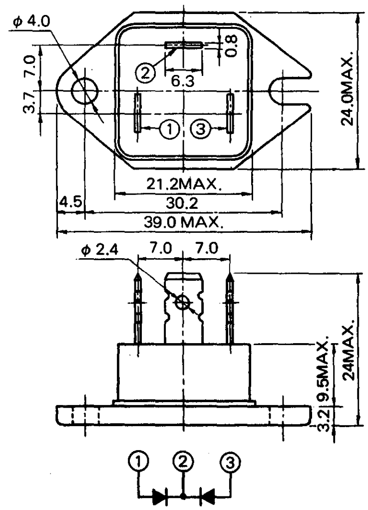
FEATURES

- Fast recovery time.
- High reliability (Glass passivation).
- Isolation type.
- Easy installation.

APPLICATIONS

- Switching Regulators
- DC-DC Convertors

OUTLINE DRAWING (Unit: mm)



MAXIMUM RATINGS

ITEMS	SYMBOLS	24CH 1FM	24CH 2FM	24CH 3FM	24CH 4FM	UNITS	NOTES
Repetitive Peak Reverse Voltage	V_{RRM}	100	200	300	400	V	
Non Repetitive Peak Reverse Voltage	V_{RSM}	150	250	350	450	V	
Output Current	I_o	24 (Tc=99°C Square wave Duty=50%)				A	
Surge Forward Current	I_{FSM}	120				A	
Junction Temperature	Tj	−40 ~ 150				°C	
Storage Temperature	Tstg	−40 ~ 150				°C	
Isolation Voltage	Visol	AC 1500				V	

ELECTRICAL CHARACTERISTICS (Tj=25°C)

ITEMS	SYMBOLS	CONDITIONS	MAX.	UNITS	NOTES
Repetitive Peak Reverse Current	I_{RRM}	Tj=150°C $V_{RM}=V_{RRM}$	8.0	mA	
Forward Voltage	V_{FM}	I_{FM}=12A	1.3	V	
Thermal Resistance	$R_{th(j-c)}$	Junction to Case	3.0	°C/W	
Reverse Recovery Time	t_{rr}	I_{FM}=0.4A I_{RM}=0.8A	350	nS	

Fig. 1 $v_F - i_F$ Characteristics (per Cell)

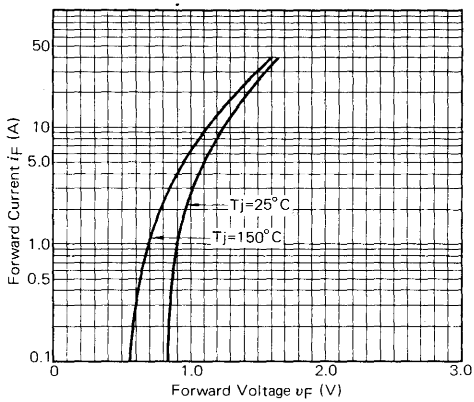


Fig. 2 $P_{F(AV)} - I_{F(AV)}$ Characteristics (per Cell)

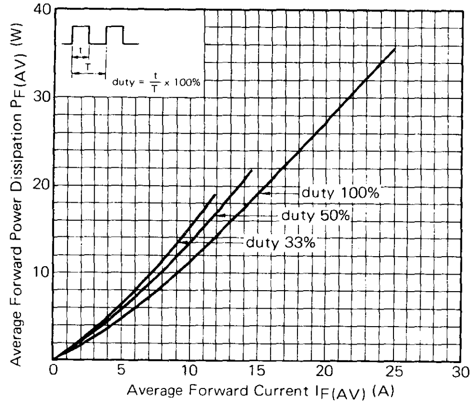


Fig. 3 $I_{O(DC)} - T_C$ Ratings

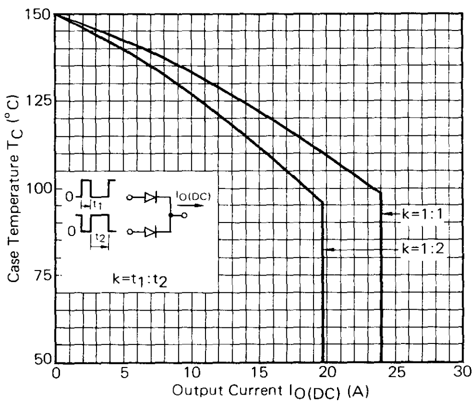


Fig. 4 $I_{F(AV)} - T_C$ Ratings (per Cell)

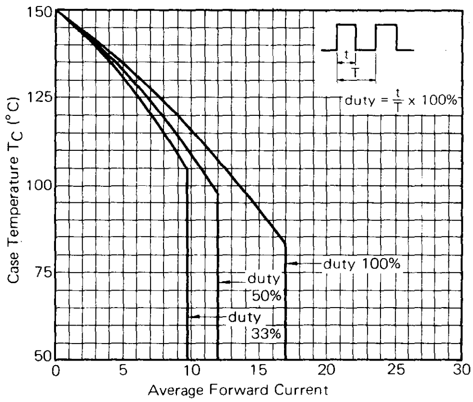


Fig. 5 $I_{O(DC)} - Ta$ Ratings

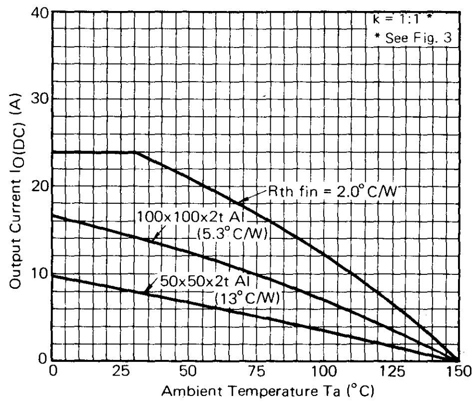
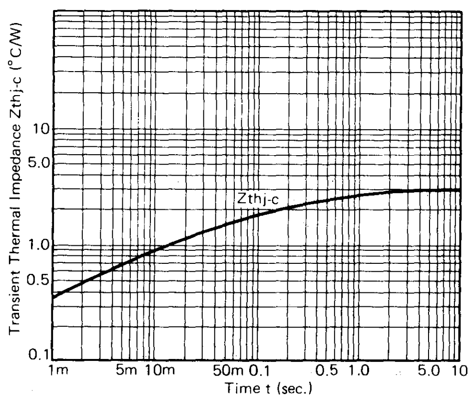


Fig. 6 Transient Thermal Impedance (per Cell)



9

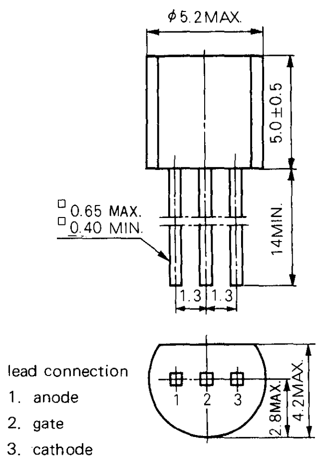
NEC
ELECTRON DEVICE

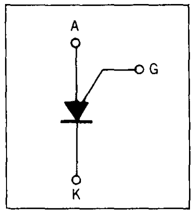
PUT
N13T1, N13T2

PROGRAMMABLE UNIJUNCTION TRANSISTOR
Silicon Planar Type N-gate Thyristor

The N13T1, T2 are planar type PUT for the industrial use. The designer can select the resistance values to program the characteristics such as R_{BB}, η, I_V, and I_P to meet his particular needs.
Application of the N13T includes thyristor trigger, timing circuits, oscillator, pulse generator, sensing circuit and other N-gate thyristors.

Outline Drawing (Unit : mm)





FEATURES

- N gate SCR which has high gate sensitivity.
- Low leakage current.
- Wide changeability R_{BB}, η, I_p, I_v.
- Low in I_v and small power operation.
- Fast, High Energy Trigger Pulse.
- Low cost.

MAXIMUM ALLOWABLE RATINGS (Ta = 25°C)

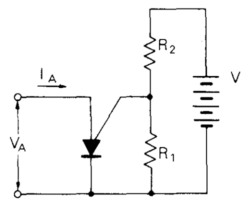
Items	Symbols	Specifications	Unit
Gate-Cathode Forward Voltage	V_{GKF}	40	V
Gate-Cathode Reverse Voltage	V_{GKR}	5	V
Gate-Anode Reverse Voltage	V_{GAR}	40	V
Anode-Cathode Voltage	V_{AK}	±40	V
DC Anode Current *1	I_T	150	mA
DC Gate Current *1	I_G	±20	mA
Peak Anode Recurrent *2 Pulse width 100μs, duty 1% Pulse width 20μs, duty 1%	I_{TRM}	 1.0 2.0	 A A
Peak Anode Non-recurrent Pulse width 10μs	I_{TSM}	5.0	A
Total Average Power *1	P_T	300	mW
Operation Ambient Temperature Range	T_{opt}	−50 ~ +100	°C
Junction Temperature	T_j	125	°C
Capacitive Discharge Power *3	E	250	μJ

Note: Please refer to Application Note No. 3; PUT application.
*1 Derate currents and powers 1%/°C above 25°C
*2 Rectangular wave.
*3 $E = 1/2\ CV^2$ capacitor discharge energy no current limiting.

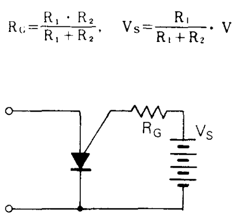
ELECTRICAL CHARACTERISTICS ($T_a = 25°C$)

Items		Symbol	Fig. No.	Type No.	MIN.	TYP.	MAX.	Unit
Peak Current	R_G = 1MΩ	I_P	Fig.1 Fig.2, Fig.3 Fig.6 Fig.9	N12T1 N13T2			2 0.15	μA
(V_S = 10V)	R_G = 10KΩ			N13T1 N13T2			5 1.0	
Offset Voltage	R_G = 1MΩ	V_T	Fig.1	N13T1 N13T2	0.2 0.2		1.6 0.6	V
(V_S = 10V)	R_G = 10KΩ		Fig.10	N13T1 N13T2	0.2 0.2		0.6 0.6	
Valley Current	R_G = 1MΩ	I_V	Fig.1 Fig.4, Fig.5 Fig.7 Fig.8	N13T1 N13T2			50 25	μA
(V_S = 10V)	R_G = 10KΩ			N13T1 N13T2	70 25			
Gate-Anode Leakage Current (K Open, V_S = 40V)		I_{GAO}	Fig.12			0.03	10	nA
Gate-Cathode Leakage Current (A–K Short, V_S = 40V)		I_{GKS}	Fig.12			0.3	100	nA
Forward Voltage (I_F = 50mA)		V_F	Fig.1, Fig.17			1	1.5	V
Pulse Out-put Voltage (V = 20V, C = 0.2μF)		V_O	Fig.14, Fig.15		6	10		V
Pulse Voltage Rate of Rise (V = 20V, C = 0.2μF)		t_r	Fig.1			50	80	ns

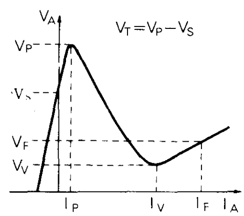
Fig. 1 Definition of Electrical Characteristic



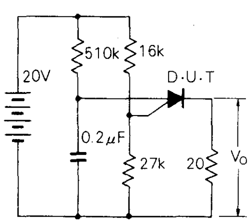
(1a) Equivalent UJT which is connected Program resistance.



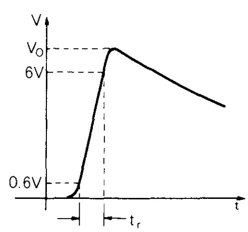
(1b) The definition of equivalent circuit of (1a) and V_S, R_G.



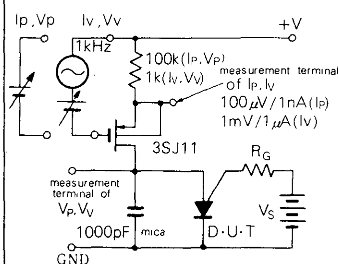
(1c) Characteristic model of V_A–I_A and the definition of measurement point.



(1d) Vo, t_r measurement circuit.



(1e) The definition of output pulse wave and measurement point.



(1f) Measurement method of I_P, V_P, I_V, V_V (Please refer to Application Note No. 3)

9

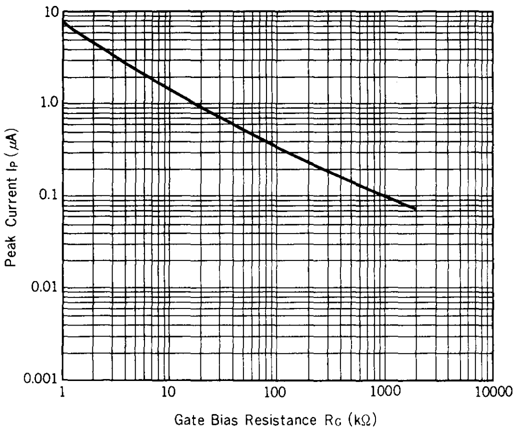


Fig. 2 N13T1 IP–RG Typical Characteristic (VS=10V)

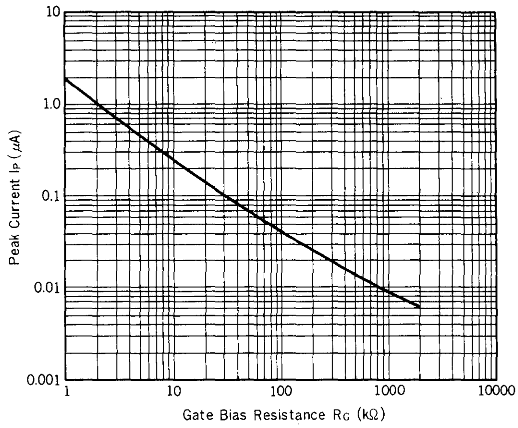


Fig. 3 N13T2 IP–RG Typical Characteristic (VS=10V)

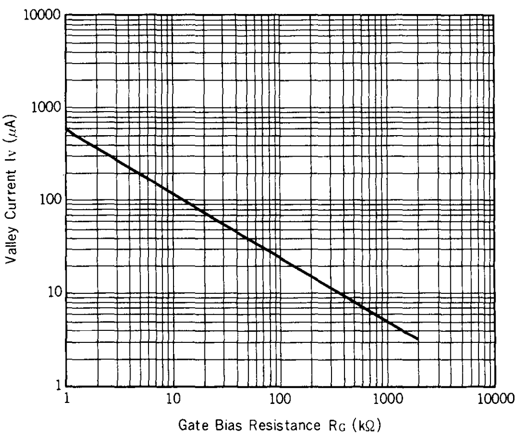


Fig. 4 N13T1 IV–RG Typical Characteristic

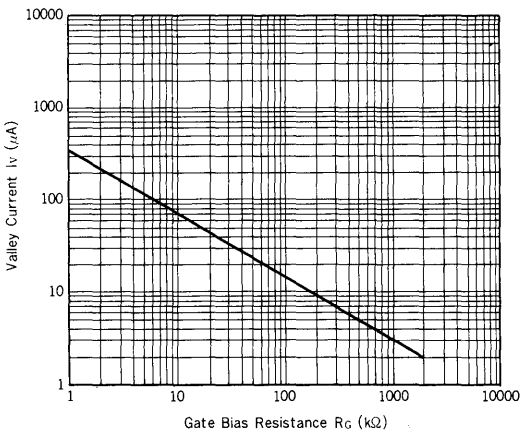


Fig. 5 IV–RG Typical Characteristic

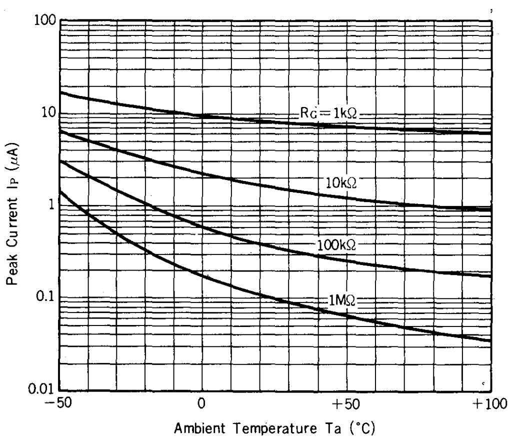


Fig. 6 IP–Ta–RG Typical Characteristic (VS=10V)

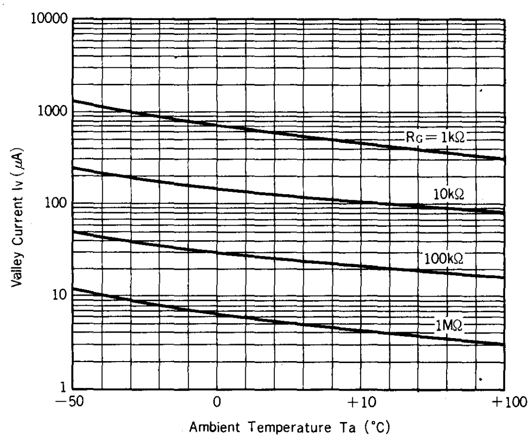


Fig. 7 IV–Ta–RG Typical Characteristic (VS=10V)

Fig. 8 I_V–V_S–R_G Typical Characteristic

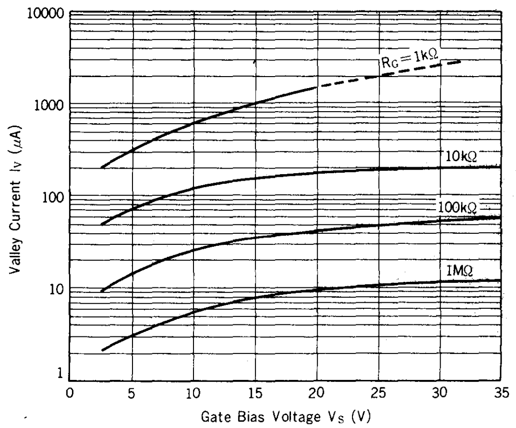


Fig. 9 I_P–V_S–R_G Typical Characteristic

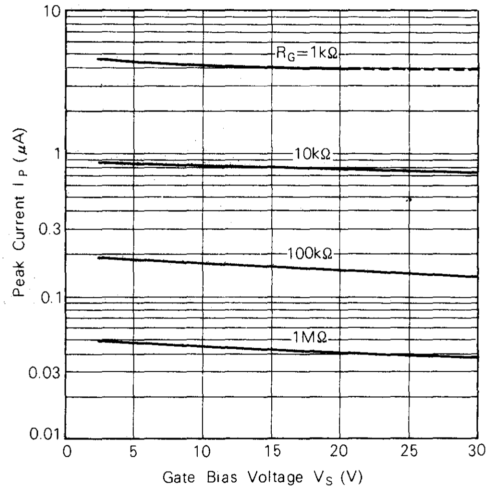


Fig. 10 V_T–R_G–Ta Typical Characteristic (V_S=10V)

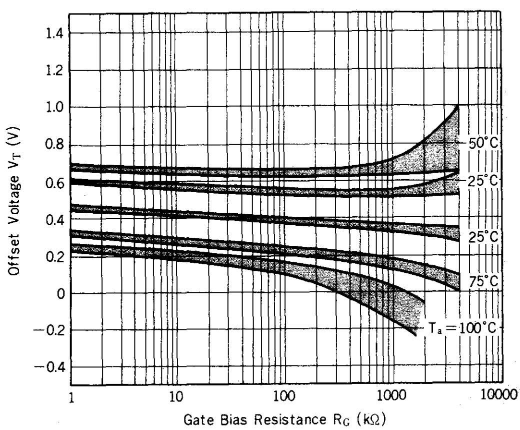


Fig. 11 V_V–Ta–R_G Typical Characteristic (V_S=10V)

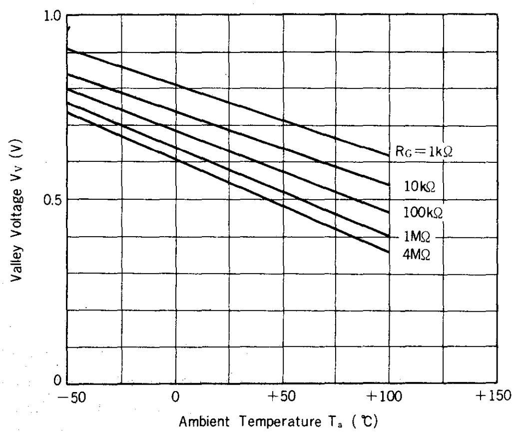


Fig. 12 I_{leak}–Ta Typical Characteristic (V_S=40V)

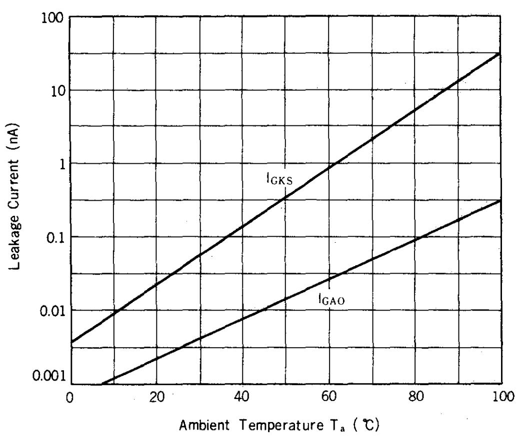
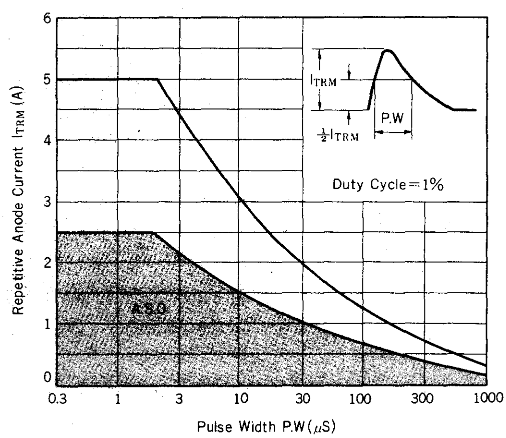


Fig. 13 I_{TRM}–P・W Maximum Rating



9

Fig. 14 V_O–C–V Typical Characteristic

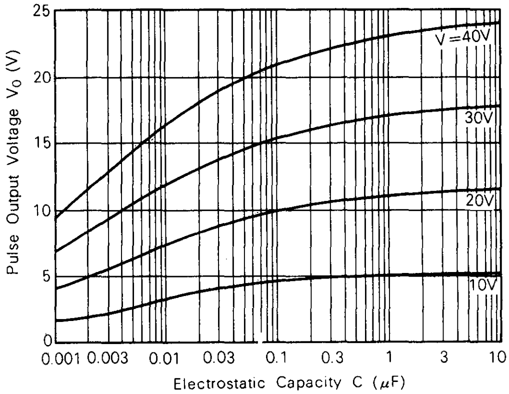


Fig. 15 V_O–V–C Typical Rating

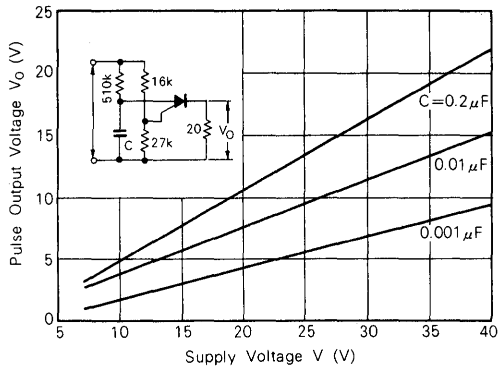


Fig. 16 Derating Wave

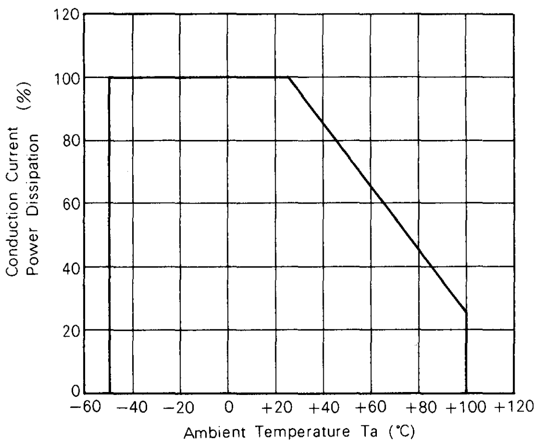


Fig. 17 I_F–V_F Typical Characteristic

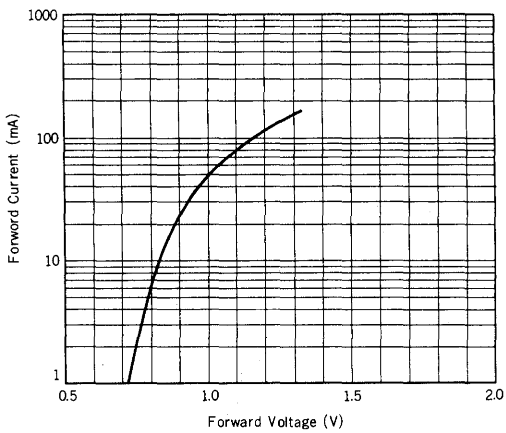
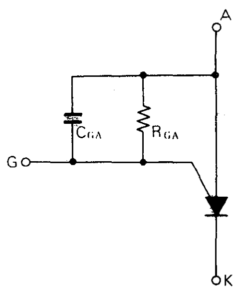


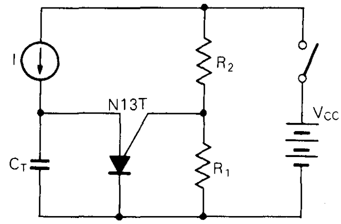
Fig. 18



When the N13T1 is used as a N-gate "SCR" Connect C_{GA} and R_{GA} as Fig. 18 shows.

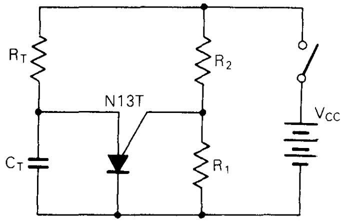
R_{GA}	C_{GA}
less than 5kΩ	3300pF
less than 10kΩ	4700pF

Approximate Design Equations for Timer



$$\tau = \frac{C_T}{I} \cdot V_P$$

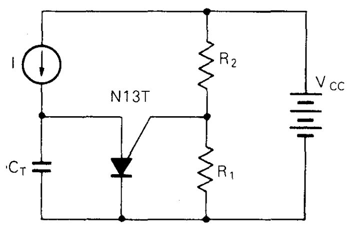
$$\begin{cases} V_P = \dfrac{R_1}{R_1 + R_2} \cdot V_{CC} + V_T \\ I_{C(leak)} + I_P \ll I \end{cases}$$



$$\tau = C_T \cdot R_T \, l_n \frac{1}{1 - \dfrac{\eta V_{CC} + V_T}{V_{CC}}}$$

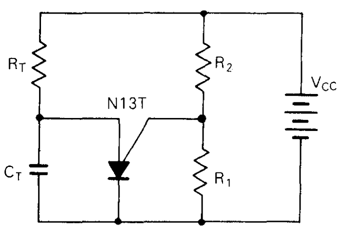
$$\begin{cases} \eta = \dfrac{R_1}{R_1 + R_2} \\ I_{C(leak)} + I_P \ll \dfrac{V_{CC} - V_P}{R_T} \end{cases}$$

Approximate Design Equations for Relaxation Oscillator circuit



$$T = \frac{C_T}{I} \cdot (V_P - V_V)$$

$$\begin{cases} V_P = \dfrac{R_1}{R_1 + R_2} \cdot V_{CC} + V_T \\ I_{C(leak)} + I_P \ll I \\ I < I_V \end{cases}$$



$$T = C_T \cdot R_T \, l_n \frac{1}{1 - \dfrac{\eta V_{CC} + V_T - V_V}{V_{CC} - V_V}}$$

$$\begin{cases} \eta = \dfrac{R_1}{R_1 + R_2} \\ I_{C(leak)} + I_P \ll \dfrac{V_{CC} - V_P}{R_T} \\ \dfrac{V_{CC} - V_V}{R_T} < I_V \end{cases}$$

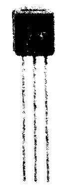
9

NEC
ELECTRON DEVICE

TRIGGER DEVICE (EUJT

2SH25

The 2SH25 is a mold type (TO-92) monolithic IC Unijunction Transistor with an equivalent function to a traditional UJT, showing outstanding temperature characteristics and long term stability as compared with traditional one.
Simple oscillation circuit with 2SH25 can be designed, which are suitable for use in phase controllers, inverters and timers.



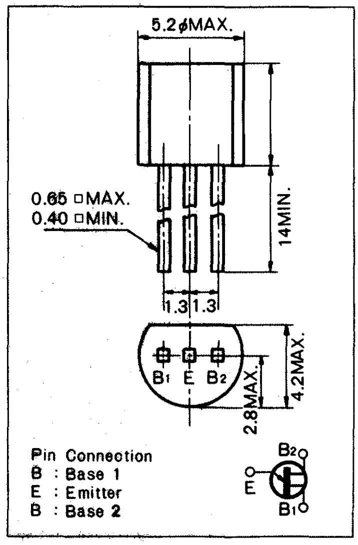
FEATURES

- Planer passivated structure
- Superior reliability and temperature stability
- Fast, high energy trigger pulse
- High interbase resistance (twice as high as traditional one)
- Constant valley point current against load resistance and bias voltage
- Small deviation of η (±5%)
- Tight instrinstic standoff ratio distribution

APPLICATIONS

- Trigger for SCR phase control circuit
- Timers
- Oscillators
- Sweep circuits
- Stable voltage
- Frequency divider

Outline Drawing (Unit : mm)



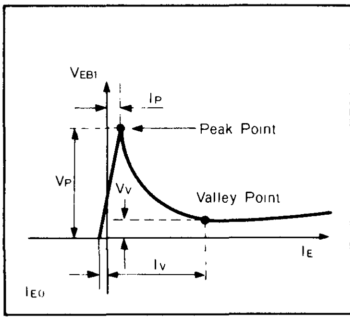
MAXIMUM RATINGS

Items	Symbol * **	Specifications	Units	Notes
Power Dissipation	P	300	mW	Ta=25°C
Emitter Reverse Voltage	V_{B2E}	30	V	
Interbase Voltage	V_{BB}	30	V	
Peak Emitter Current	I_{EM}	1	A	Pulse width 20μs
DC Emitter Current	I_E	75	mA	
Junction Temperature	T_j	125	°C	
Storage Temperature	T_{stg}	−40~150	°C	

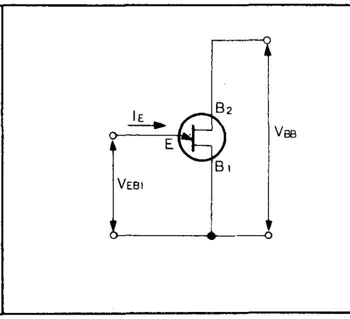
ELECTRICAL CHARACTERISTICS

Items	Symbol * **	Test Conditions	Specifications			Units
			MIN.	TYP.	MAX.	
Interbase Resistance	R_{BB}	V_{BB}=30V, I_E=0	8	15.5	20	kΩ
Emitter Reverse Current	I_{EO}	V_{BB}=30V, V_{B1}=0	–	0.01	0.2	μA
Emitter Saturation Voltage	V_{EB1}(sat)	V_{BB}=20V, I_E=50mA	–	3.3	4.0	V
Instrinsic Stand-off Ratio	η	V_{BB}=20V	0.58	0.61	0.64	–
Peak Point Emitter Current	Ip	V_{BB}=20V	–	1	2.0	μA
Valley Point Current	I_V	V_{BB}=20V	7	18	25	mA
Valley Point Voltage	V_V	V_{BB}=20V	–	2.5	3.0	V
Base-one Peak Pulse Voltage	V_{OB1}	R_{B1}=20Ω, C_T=0.2μF ***	4	5.5	–	V

*Static Emitter Characteristic



**Symbol



***Basic Oscillation Circuit

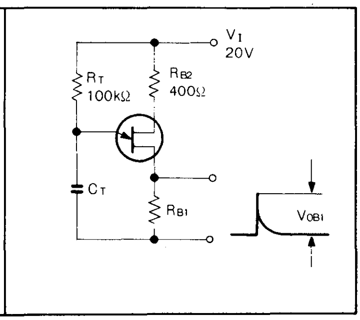


Fig. 1 $I_V - R_{B1}$ Characteristic

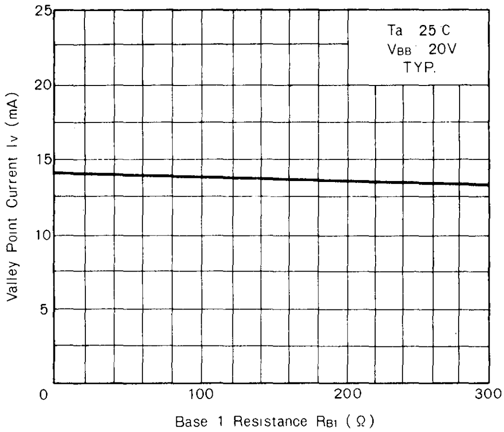


Fig. 2 $I_V - V_{BB}$ Characteristic

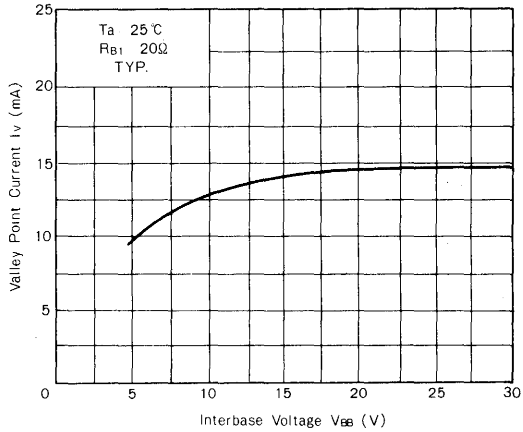


Fig. 3 $I_V - Ta$ Characteristic

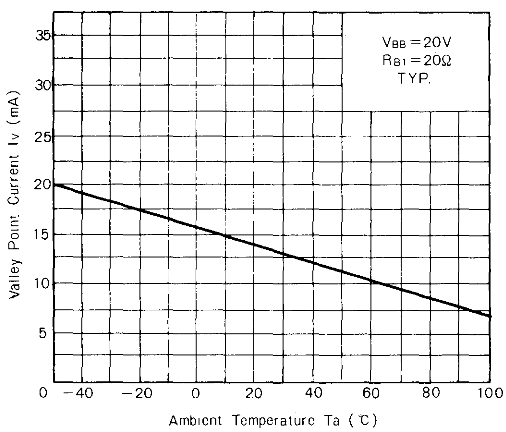


Fig. 4 $V_{OB1} - R_{B1}$ Characteristic

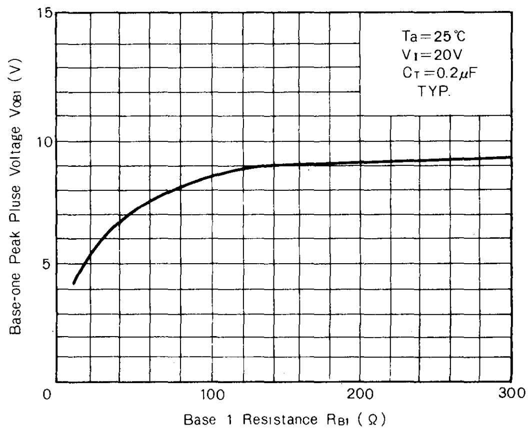


Fig. 5 $V_{OB1} - C_T$ Characteristic

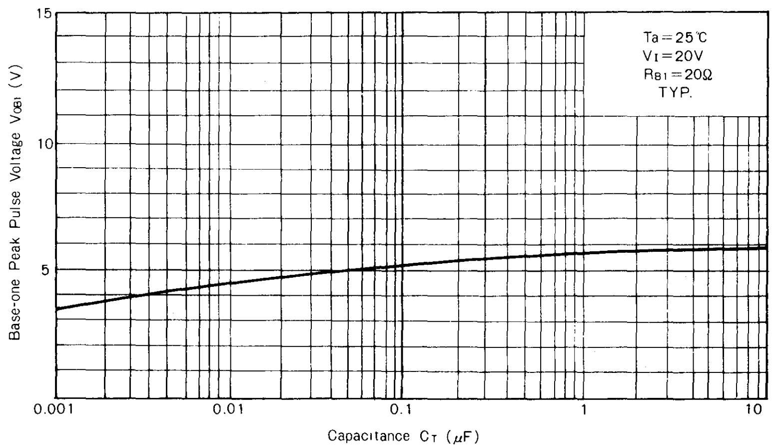


Fig. 6 $I_P - V_{BB}$ Characteristic

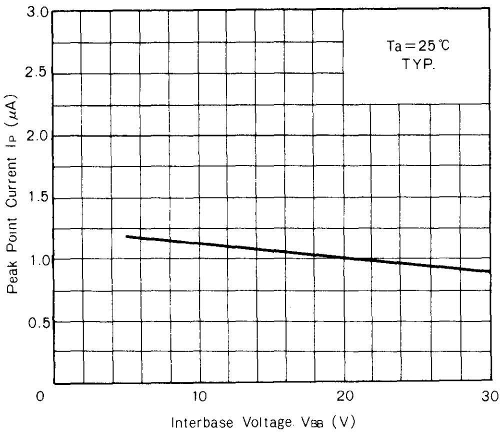
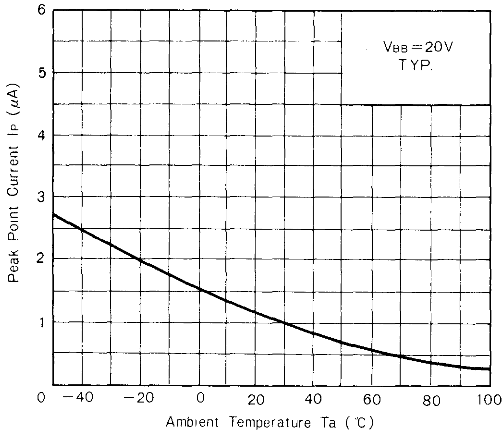


Fig. 7 $I_P - Ta$ Characteristic



MATTERS TO BE ATTENDED ON USE

(1) Modulation base current

Modulation base current of 2SH25 is about 3mA, while that of a traditional UJT is about 15mA. Therefore in the circuit as shown in Fig. 8-a, which catches signals from B_2 unsufficient output pulse can be gained. In this case it is recommendable to use the circuits shown in Fig. 8-b and Fig. 8-c.

(2) R_{B1} and R_{BB}

In the circuits of larger R_{B1} (more than 200Ω) or of using pulse transformer with turn ratio of more than 2 to 1, the discharge current from C_T might not be reached to I_V (see Fig. 9). Or in case bias voltage V_I is 5 to 6 volts, careful consideration should be required for replacing traditional UJT to 2SH25. It is possible to amplify output pulse in the circuit shown in Fig. 11 as well as one in Fig. 10.

(3) Series resistance

Small emitter saturation voltage and internal resistance of 2SH25 require to insert a series resistance of more than 5Ω in the discharge circuit loop of oscillation capacitor as shown in Fig. 12 to suppress peak current.

9

Fig. 8-a Circuit obtained Signal from B2 Terminal (unrecommendable)

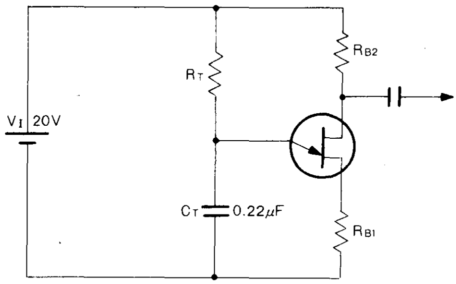


Fig. 8-b An Example 1 of improved circuit of Fig. 8-a

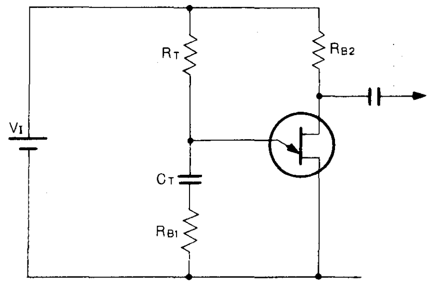


Fig. 8-c An Example 2 of improved circuit of Fig. 8-a

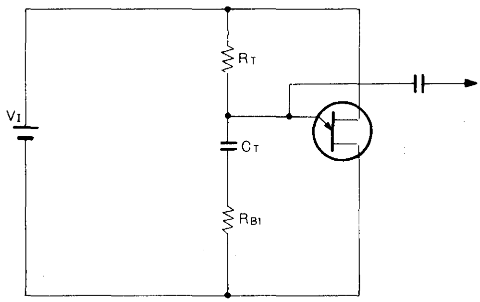


Fig. 9 An Example of improved circuit with Pulse Transformer

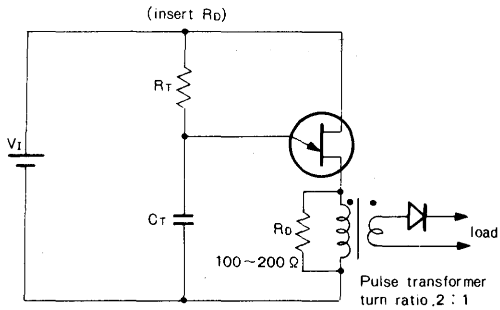
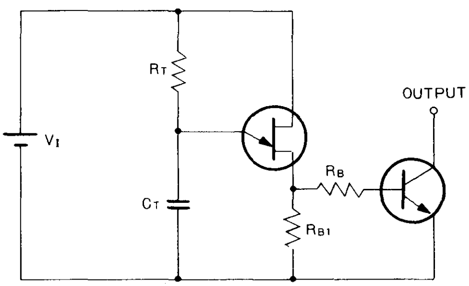
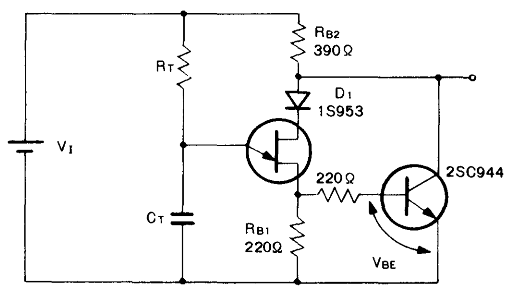


Fig. 10 Pulse amplifier circuit



$\frac{V_{OB1}}{R_{B1}/R_B} < I_V < \frac{V_I - V_V}{R_T}$ $\quad \because \frac{R_{B1}}{R_{B1}+R_{BB}} V_I < V_{BE}$

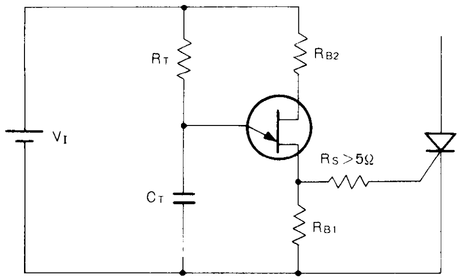
Fig. 11 Pulse amplifier circuit



$I_V \fallingdotseq \frac{V_{BE}}{R_{B1}}$

$\because \frac{R_{B1}}{R_T \,/\!/\, R_{BB}} V_I < V_{BE}$

Fig. 12 Insertion of series resistance



NEC
ELECTRON DEVICE

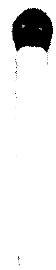
SILICON VARISTOR 1S1209 ~ 1S1212 VD1120 ~ VD1223

FEATURES

- Suitable for voltage and temperature compensation of B-class push-pull amplifier.
- Two different out-forms having the same characteristic. Optional device can be selected in your mounting.
- Low cost

Silicon Diode Varistor for Voltage and Temperature Compensation of Transistor

Type A



Type B

RATING AND CHARACTERISIC

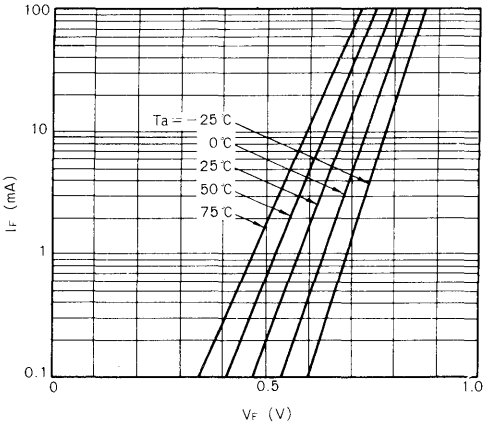
Type No.	Power Dissipation P (mW)	Forward Current I_F (mA)	Junction Temperature T_j (°C)	Storage Temperature T_{stg} (°C)	Forward Voltage V_F (V)		Forward Voltage Temperature Co-efficient (mV/°C)		Condition
					MIN.	MAX.	MIN.	TYP.	
1S1209	100	100	90	-30 ~ +90	0.63	0.69	-1.5	-1.9	I_F=10mA, Ta=25°C
1S1210	50	60	90	-30 ~ +90	0.56	0.61	-1.5	-1.8	I_F=1.5mA, Ta=25°C
1S1211	50	60	90	-30 ~ +90	0.59	0.64	-1.5	-1.8	I_F=1.5mA, Ta=25°C
1S1212	50	60	90	-30 ~ +90	0.62	0.67	-1.5	-1.8	I_F=1.5mA, Ta=25°C
VD1120	50	60	120	-30 ~ +120	0.56	0.61	-1.5	-1.8	I_F=1.5mA, Ta=25°C
VD1121	50	60	120	-30 ~ +120	0.59	0.64	-1.5	-1.8	I_F=1.5mA, Ta=25°C
VD1122	50	60	120	-30 ~ +120	0.62	0.67	-1.5	-1.8	I_F=1.5mA, Ta=25°C
VD1123	100	100	120	-30 ~ +120	0.63	0.69	-1.5	-1.9	I_F=10mA, Ta=25°C
VD1124	100	100	120	-30 ~ +120	0.62	0.67	-1.5	-1.9	I_F=1.5mA, Ta=25°C
VD1210	50	30	90	-30 ~ +90	1.12	1.22	-3.0	-3.6	I_F=1.5mA, Ta=25°C
VD1211	50	30	90	-30 ~ +90	1.18	1.28	-3.0	-3.6	I_F=1.5mA, Ta=25°C
VD1212	50	30	90	-30 ~ +90	1.24	1.34	-3.0	-3.6	I_F=1.5mA, Ta=25°C
VD1213	100	50	90	-30 ~ +90	1.26	1.38	-3.0	-3.8	I_F=10mA, Ta=25°C
VD1220	50	30	120	-30 ~ +120	1.12	1.22	-3.0	-3.6	I_F=1.5mA, Ta=25°C
VD1221	50	30	120	-30 ~ +120	1.18	1.28	-3.0	-3.6	I_F=1.5mA, Ta=25°C
VD1222	50	30	120	-30 ~ +120	1.24	1.34	-3.0	-3.6	I_F=1.5mA, Ta=25°C
VD1223	100	50	120	-30 ~ +120	1.26	1.38	-3.0	-3.8	I_F=10mA, Ta=25°C

Forward Voltage Temperature Coefficient ...... $\dfrac{(V_F \text{ (at } 0°C) - V_F \text{ (at } 50°C)) \text{ (mV)}}{-50 \text{ (°C)}}$

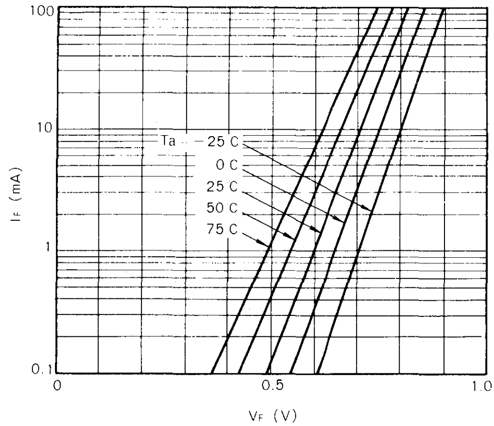
☐ Type A

☐ Type B

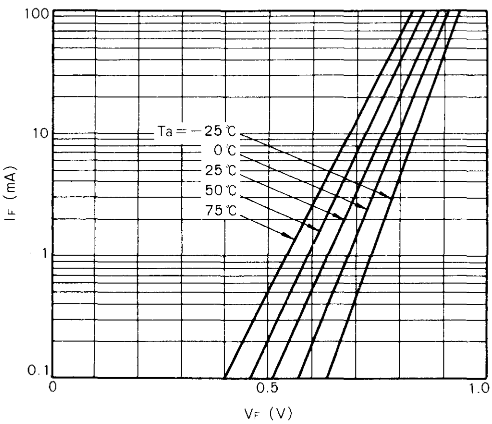
1S1210 VD1120 $I_F - V_F$ Characteristic



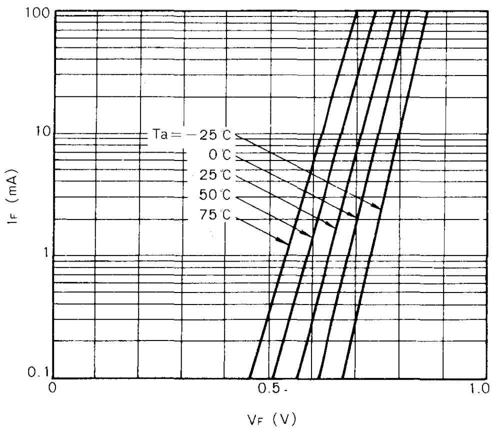
1S1211 VD1121 $I_F - V_F$ Characteristic



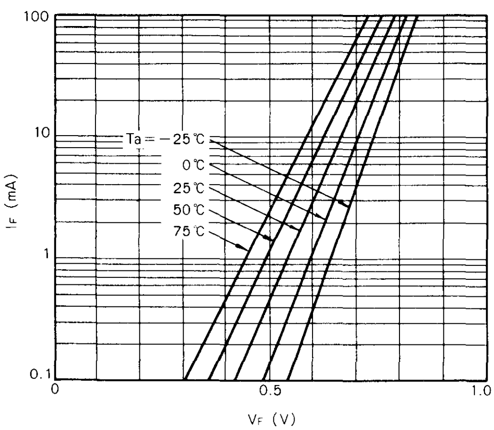
1S1212 VD1122 $I_F - V_F$ Characteristic



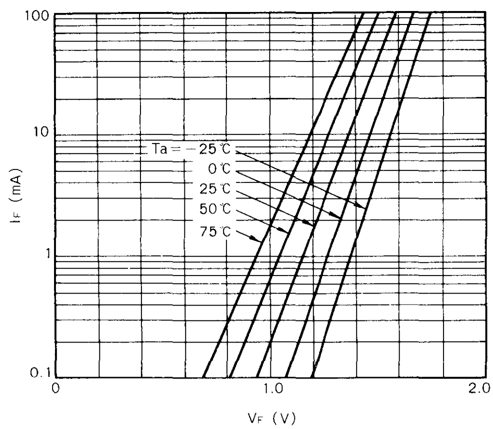
VD1124 $I_F - V_F$ Characteristis



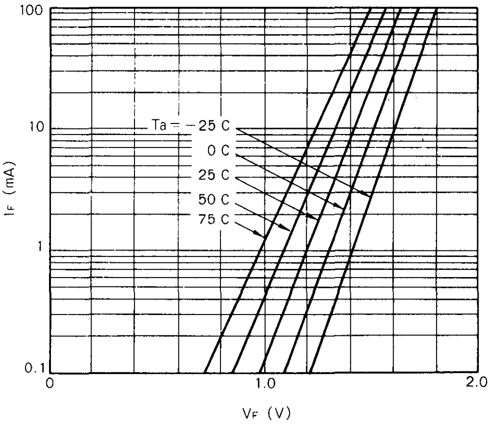
1S1209 VD1123 $I_F - V_F$ Characteristic



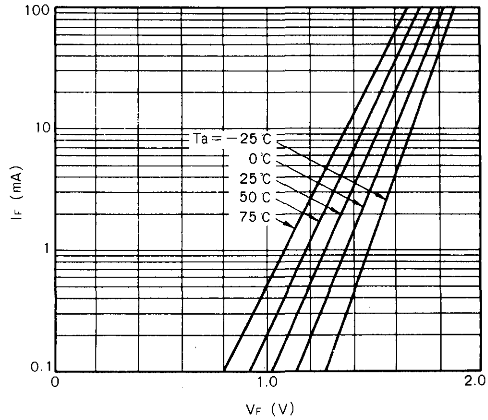
VD1210 VD1220 $I_F - V_F$ Characteristic



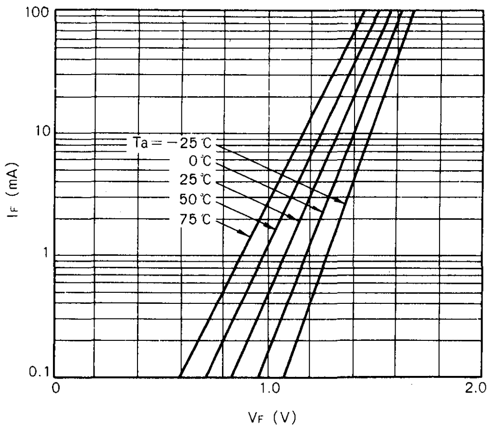
VD1211
VD1221 $I_F - V_F$ Characteristic



VD1212
VD1222 $I_F - V_F$ Characteristic

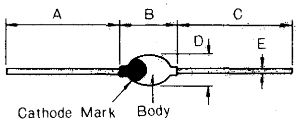


VD1213
VD1223 $I_F - V_F$ Characteristic



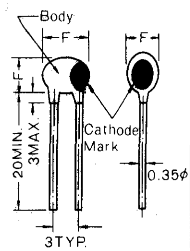
Outline Drawing and Color-code (Unit : mm)

		Type No.	A MIN.	B MAX.	C MIN.	D MAX.	E ϕ
Brown	White	1S1210	13.0	3.0	13.0	2.5	0.25
	Yellow	1S1211	13.0	3.0	13.0	2.5	0.25
	Green	1S1212	13.0	3.0	13.0	2.5	0.25
	Blue	–	–	–	–	–	–
	Black	1S1209	30.0	5.0	30.0	3.5	0.4
	Pink	VD1210	13.0	4.0	13.0	3.5	0.25
	Blue	VD1211	13.0	4.0	13.0	3.5	0.25
	Grey	VD1212	13.0	4.0	13.0	3.5	0.25
	Light Blue	VD1213	30.0	5.0	30.0	4.0	0.4
Body Color	Cathode Color-code	Type A					



Type A

		Type No.	F MAX.
Brown	White	VD1120	5.0
	Yellow	VD1121	5.0
	Green	VD1122	5.0
	Blue	VD1124	5.0
	Black	VD1123	5.0
Black	Pink	VD1220	5.0
	Blue	VD1221	5.0
	Grey	VD1222	5.0
	Light Blue	VD1223	6.0
Body Color	Cathode Color-code	Type B	



Type B

Notice on Using

Solder dip should be done according to the conditions below mentioned.

	Dipping Extent Limit	Solder Temp.	Dipping Time
Type A (Double end)	More than 10 mm from the base of electrode	220 ±5°C	Within 5 seconds
Type B (Single end)	More than 1.6 mm from the base of electrode	250 ±5°C	Within 5 seconds

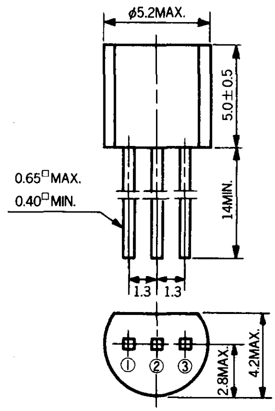
9

NEC
ELECTRON DEVICE

PNPN SWITCH
NFD15

The NFD15 is a unilateral switch consist of PNPN structure.
Fundamental characteristic is same to SCR without gate lead.

OUTLINE DRAWING (Unit : mm)



1. Anode
2. NC
3. Cathode

FEATURES

- Break over voltage V_{BO} = 96 to 152V
- Small break over current (Negative resistance characteristic).
- Plastic TO-92 package.
- Shortest turn on time.
- Low cost because of mass-production.

APPLICATIONS

- Gas, Oil ignitor.
- Fluorescent lamp starter.
- Various pulse generator.

MAXIMUM RATINGS (T_a = 25°C)

Item	Symbol	Rating	Unit
Repetitive Peak Anode Current	I_{TRM}	10 (Pulse Width = 100μs, duty = 0.1%, Ta = 50°C) 50 (Pulse Width = 20μs, duty = 0.1%, Ta = 50°C)	A
Non Repetitive Peak Anode Current	I_{TSM}	70 (Pulse Width = 10μs, Ta = 50°C)	A
Rate of rise of On State Current	di_T/dt	20	A/μs
On State Current	$I_{T(AV)}$	0.25	A
Operating Temperature	T_{opt}	−20 to +80	°C
Storage Temperature	T_{stg}	−40 to +125	°C

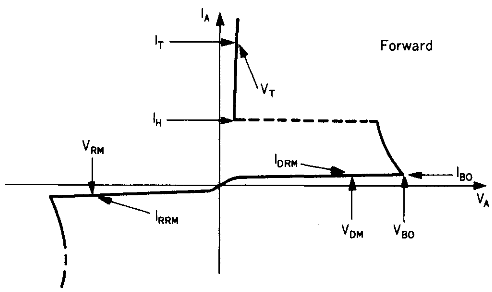
ELECTRICAL CHARACTERISTICS (Unless Otherwise Specified)

Item	Symbol	Test Condition Ta = 25°C	Characteristics Min.	Max.	Unit
Breakover Voltage	V_{BO}		96	152*	V
Breakover Current	I_{BO}		–	100	μA
Repetitive Peak-off Current	I_{DRM}	V_{DM} = 80V	–	5.0	μA
On State Voltage	V_T	I_T = 0.25A	–	1.2	V
Peak On State Voltage	V_{TM}	I_{TM} = 10A	–	4.0	V
Holding Current	I_H		Typical 20		mA
Breakover Voltage Temperature Coefficiency	γV_{BO}		Typical ±0.1		%/°C

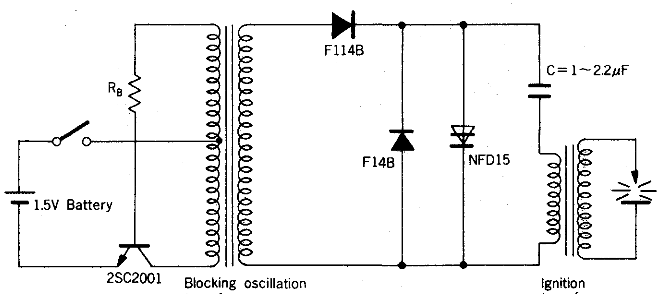
*Subdivided V_{BO}

A	B	C	D	E
96 – 115V	111 – 128V	124 – 138V	134 – 146V	142 – 152V

Fundamental Characteristic



Continuous Electric Discharge Type Gas Ignition Circuit



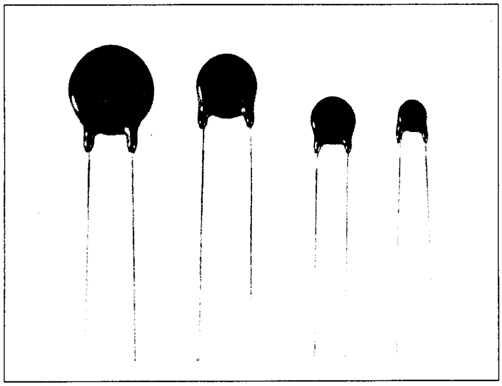
9

NEC
ELECTRON DEVICE

SURGE SUPPRESSOR METAL OXIDE VARISTOR
NEC-MOV SERIES
(LOW VOLTAGE SERIES)

NV022D05 ~ NV082D05
NV022D07 ~ NV082D07
NV022D10 ~ NV068D10
NV022D14 ~ NV068D14

The NEC-MOV series are the best device for transient voltage protection. When exposed to high transient voltage the NEC-MOV's impedance changes from a very high value to a very low conducting value thus clamping the transient voltage to a safe level. Therefore NEC-MOV protects many electric equipment from surge voltage and keep a safe drive.



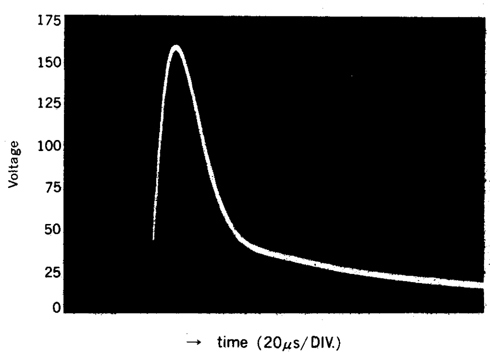
FEATURES

- Excellent transient voltage suppression characteristics.
- High surge current.
- Fast response time. (< 50 ns)
- V-I characteristics are the same in both polarity.

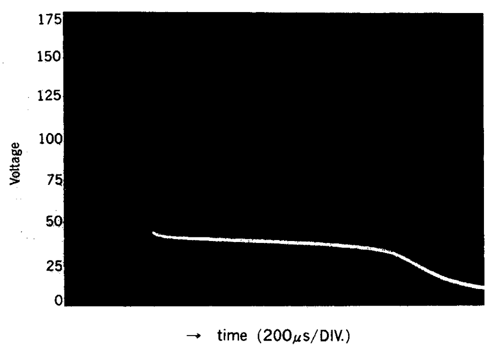
APPLICATIONS

- Protects equipment against failures by transient surge voltage.

Transient Voltage



Clipped Voltage (By NV033D14)



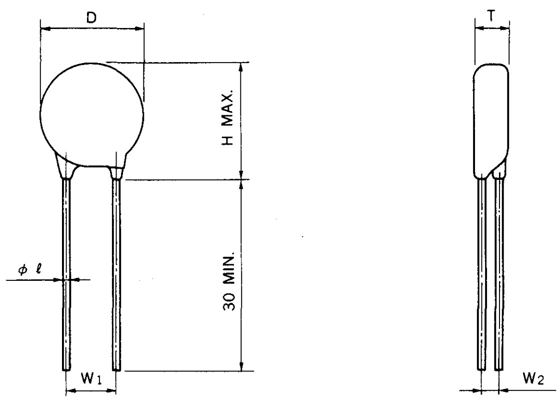
Outline Drawing (Unit : mm)

Type Number	D MAX.	T MAX.	W_1	H MAX.	W_2	ℓ
NV022D05	7.0	4.2		10.0	1.1	
NV027D05	7.0	4.3		10.0	1.2	
NV033D05	7.0	4.3		10.0	1.3	
NV039D05	7.0	4.4	5±1	10.0	1.4	φ 0.6
NV047D05	7.0	4.6		10.0	1.6	
NV056D05	7.0	5.0		10.0	1.7	
NV068D05	7.0	5.3		10.0	1.9	
NV082D05	7.0	5.3		10.0	2.0	

Type Number	D MAX.	T MAX.	W_1	H MAX.	W_2	ℓ
NV022D07	9.0	4.2		12.0	1.1	
NV027D07	9.0	4.3		12.0	1.2	
NV033D07	9.0	4.3		12.0	1.3	
NV039D07	9.0	4.4	5±1	12.0	1.4	φ 0.6
NV047D07	9.0	4.6		12.0	1.6	
NV056D07	9.0	5.0		12.0	1.7	
NV068D07	9.0	5.3		12.0	1.9	
NV082D07	9.0	5.3		12.0	2.0	

Type Number	D MAX.	T MAX.	W_1	H MAX.	W_2	ℓ
NV022D10	12.0	4.3		15.0	1.3	
NV027D10	12.0	4.3		15.0	1.4	
NV033D10	12.0	4.3		15.0	1.5	
NV039D10	12.0	4.4	7.5±1	15.0	1.6	φ 0.8
NV047D10	12.0	4.7		15.0	1.8	
NV056D10	12.0	5.0		15.0	1.9	
NV068D10	12.0	5.3		15.0	2.1	

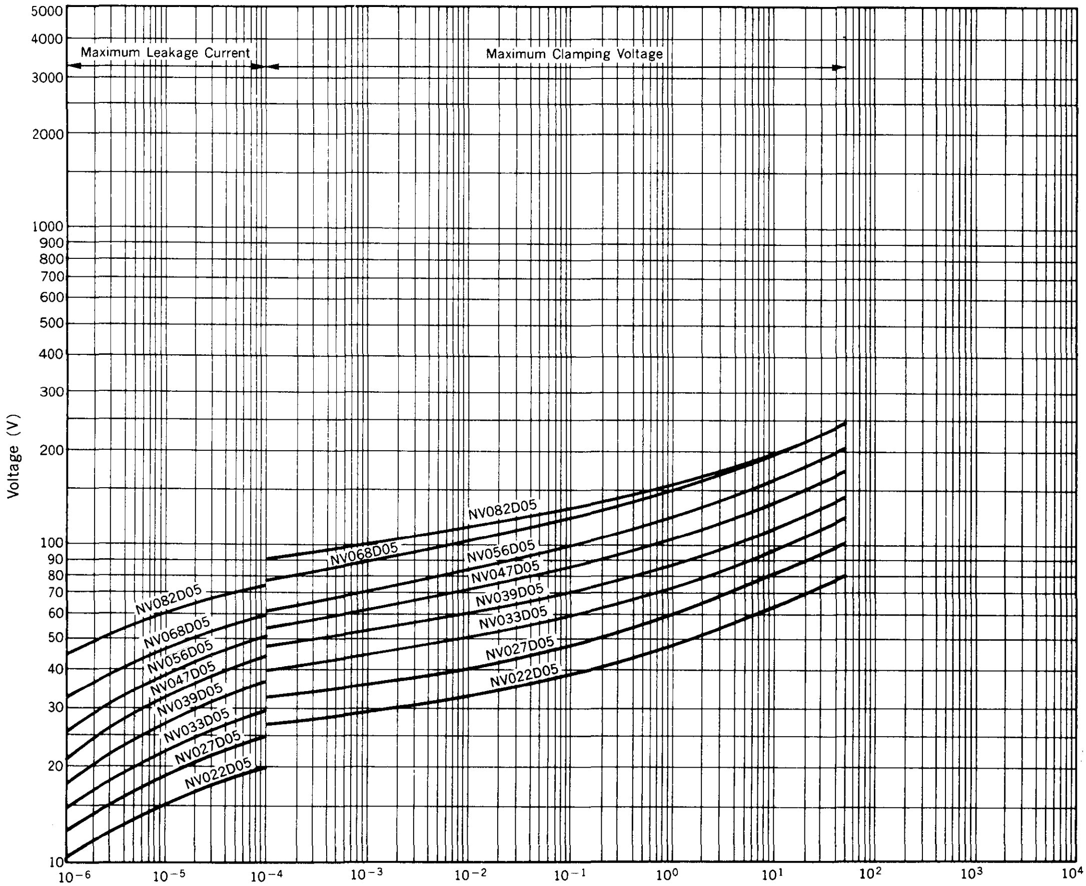
Type Number	D MAX.	T MAX.	W_1	H MAX.	W_2	ℓ
NV022D14	16.0	4.3		21	1.3	
NV027D14	16.0	4.3		21	1.4	
NV033D14	16.0	4.3		21	1.5	
NV039D14	16.0	4.4	7.5±1	21	1.6	φ 0.8
NV047D14	16.0	4.7		21	1.8	
NV056D14	16.0	5.0		21	1.9	
NV068D14	16.0	5.3		21	2.1	



RATINGS AND CHARACTERISTICS (NV022D05 ~ NV082D05)

Type Number	Varistor Voltage	Maximum Allowable Voltage		Clamping Voltage	Energy	Peak Current	Operating Ambient Temperature	Storage Temperature	Capacitance (reference value)
	V0.1mA (V)	ACrms (V)	DC (V)	V_{1A} (V)	(J)	8x20 μs (A)	Topt (°C)	Tstg (°C)	1 k ~ 1 MHz (pF)
NV022D05	20 ~ 27	14	18	48	0.4	50	−40 ~ 85	−40 ~ 125	300 ~ 3000
NV027D05	25 ~ 32	17	22	60	0.5				
NV033D05	30 ~ 39	20	26	73	0.6				
NV039D05	37 ~ 47	25	31	86	0.8				
NV047D05	45 ~ 54	30	38	104	1.0				
NV056D05	52 ~ 62	35	45	123	1.0				
NV068D05	60 ~ 76	40	56	150	1.2				
NV082D05	74 ~ 90	50	65	155	1.7				

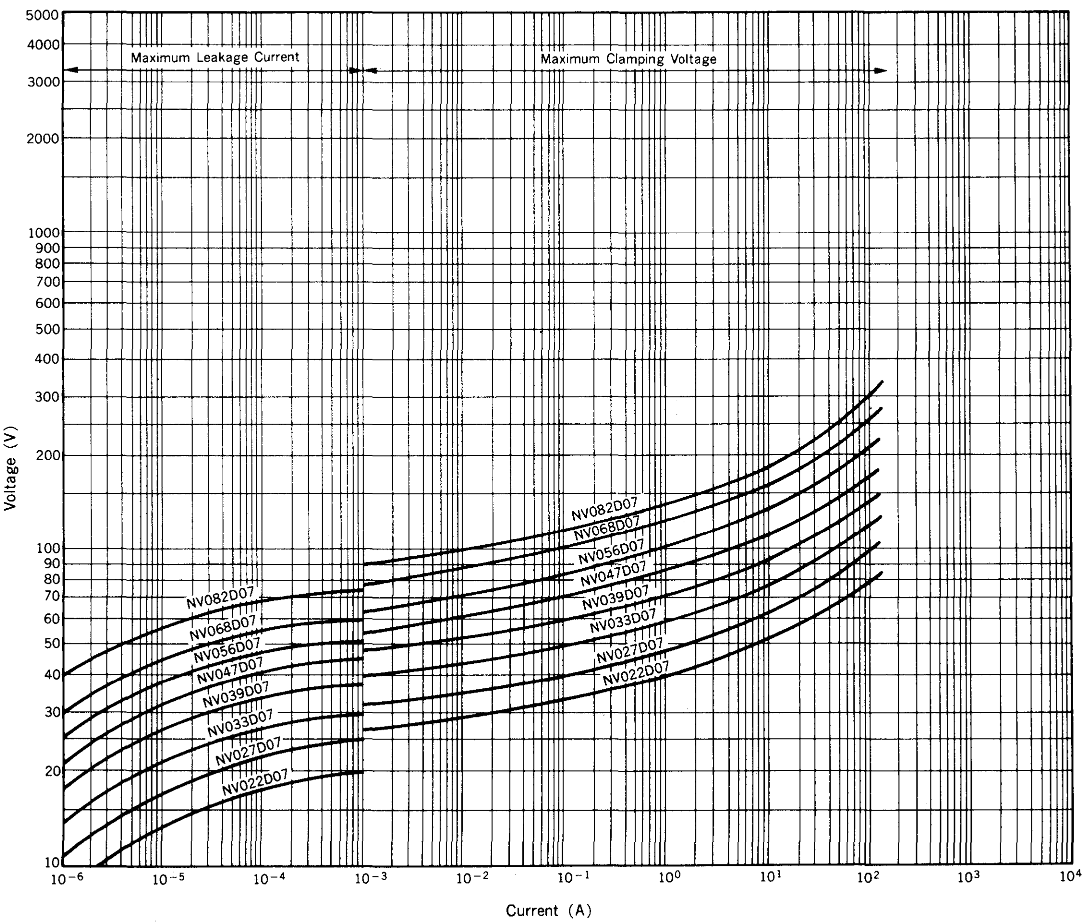
Fig. 1 V-I Characteristics



RATINGS AND CHARACTERISTICS (NV022D07 ~ NV082D07)

Type Number	Varistor Voltage	Maximum Allowable Voltage		Clamping Voltage	Energy	Peak Current	Operating Ambient Temperature	Storage Temperature	Capacitance (reference value)
	V1mA (V)	ACrms (V)	DC (V)	$V_{2.5A}$ (V)	(J)	8×20 μs (A)	Topt (°C)	Tstg (°C)	1 k ~ 1 MHz (pF)
NV022D07	20 ~ 27	14	18	43	0.9	125	−40 ~ 85	−40 ~ 125	500 ~ 5000
NV027D07	25 ~ 32	17	22	53	1.0				
NV033D07	30 ~ 39	20	26	65	1.2				
NV039D07	37 ~ 49	25	31	77	1.5				
NV047D07	45 ~ 54	30	38	93	1.8				
NV056D07	52 ~ 62	35	45	110	2.2				
NV068D07	60 ~ 76	40	56	135	2.5				
NV082D07	74 ~ 90	50	65	150	3.5				

Fig. 2 V-I Characteristics

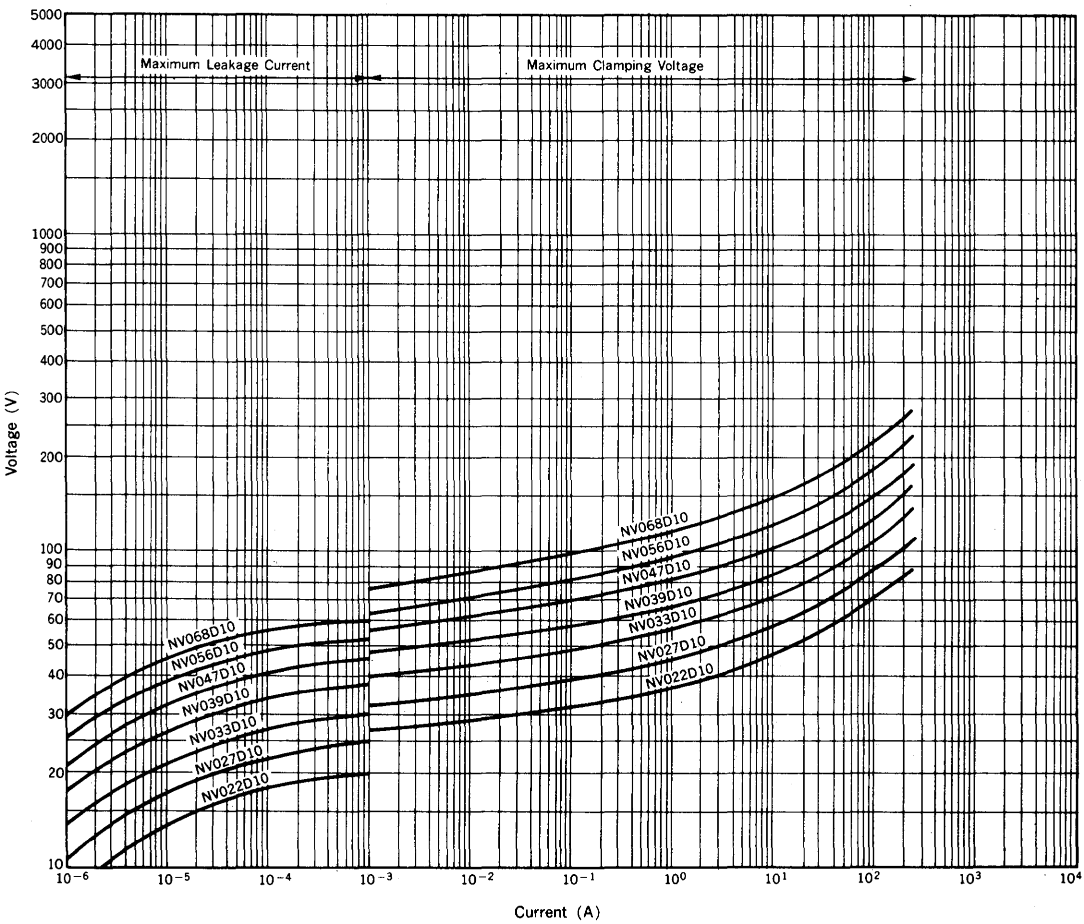


9

RATINGS AND CHARACTERISTICS (NV022D10 ~ NV068D10)

Type Number	Varistor Voltage	Maximum Allowable Voltage		Clamping Voltage	Energy	Peak Current	Operating Ambient Temperature	Storage Temperature	Capacitance (reference value)
	V1mA (V)	ACrms (V)	DC (V)	V5A (V)	(J)	8×20 μs (A)	Topt (°C)	Tstg (°C)	1 k ~ 1 MHz (pF)
NV022D10	20 ~ 27	14	18	43	2.0	250	−40 ~ 85	−40 ~ 125	1000 ~ 5000
NV027D10	25 ~ 32	17	22	53	2.5				
NV033D10	30 ~ 39	20	26	65	3.0				
NV039D10	37 ~ 47	25	31	77	3.5				
NV047D10	45 ~ 54	30	38	93	4.5				
NV056D10	52 ~ 62	35	45	110	5.5				
NV068D10	60 ~ 76	40	56	135	6.5				

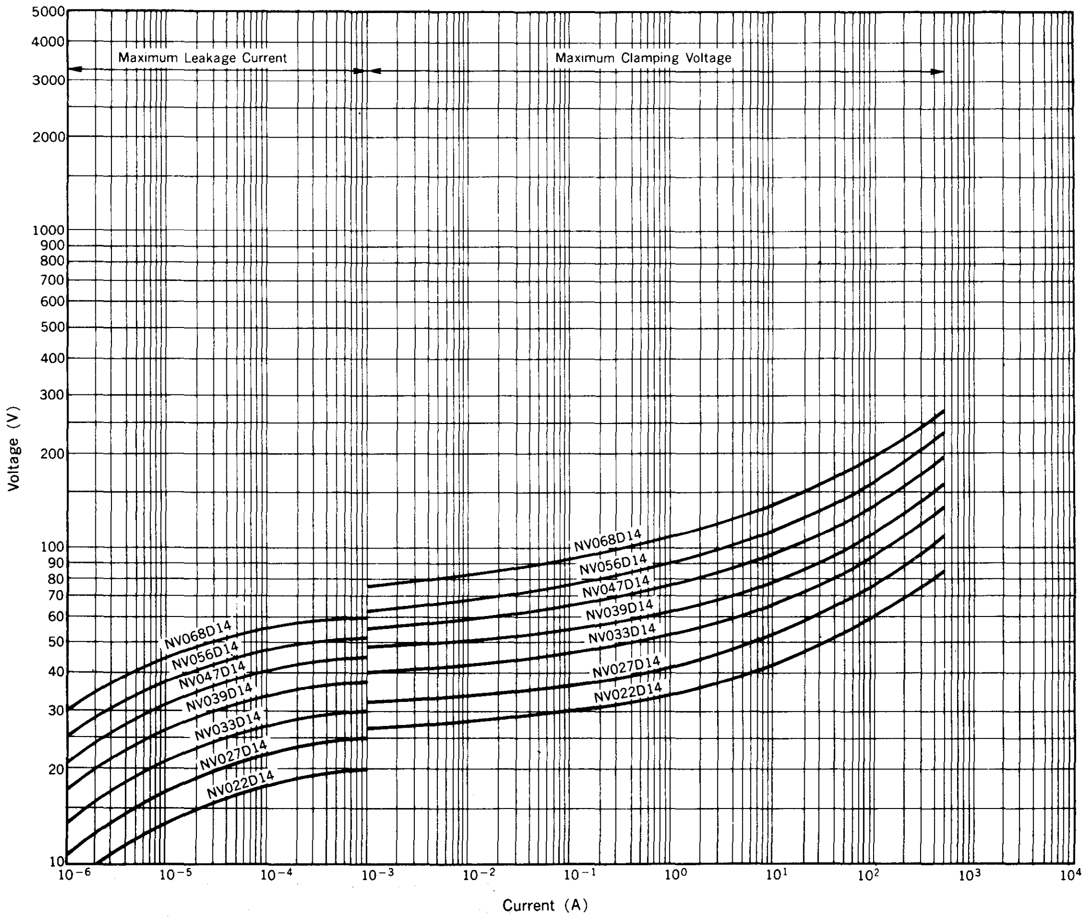
Fig. 3 V-I Characteristics



RATINGS AND CHARACTERISTICS (NV022D14 ~ NV068D14)

Type Number	Varistor Voltage	Maximum Allowable Voltage		Clamping Voltage	Energy	Peak Current	Operating Ambient Temperature	Storage Temperature	Capacitance (reference value)
	V1mA (V)	ACrms (V)	DC (V)	V_{10A} (V)	(J)	8x20 μs (A)	Topt (°C)	Tstg (°C)	1 k ~ 1 MHz (pF)
NV022D14	20 ~ 27	14	18	43	4.0	500	−40 ~ 85	−40 ~ 125	3000 ~ 10000
NV027D14	25 ~ 32	17	22	53	5.0				
NV033D14	30 ~ 39	20	26	65	6.0				
NV039D14	37 ~ 47	25	31	77	7.0				
NV047D14	45 ~ 54	30	38	93	8.5				
NV056D14	52 ~ 62	35	45	110	10.0				
NV068D14	60 ~ 76	40	56	135	12.0				

Fig. 4 V-I Characteristics



9

Fig. 6 Peak Current-Pulse Width Rating (Impulse Number N=2)

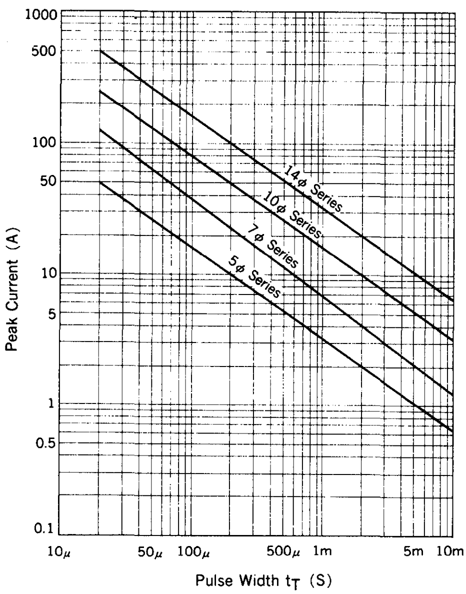
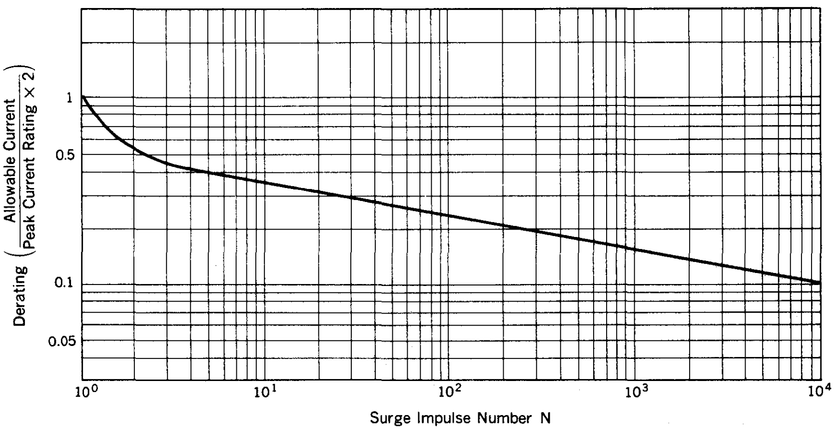


Fig. 7 Derating Curve

ex. 14φ Series
Pulse width t_T=200 μs Impulse number $N=10^4$
I (at t_T=200 μs)=100 A (See Fig. 6)
Derating (at $N=10^4$)=0.1 (See Fig. 7)
Allowable current I= 100x2x0.1 = 20A



NOTICE

- Applied voltage should not be over the maximum ratings.
- Should the NEC-MOV be subjected to surge current and energy levels in excess of maximum ratings, it may physically fail by package rupture or explosion of material. It is recommended that protective fusing be used in a circuit.
- When the NEC-MOV are used in a high frequency circuit, notice it's capacitance and avoid to fever.

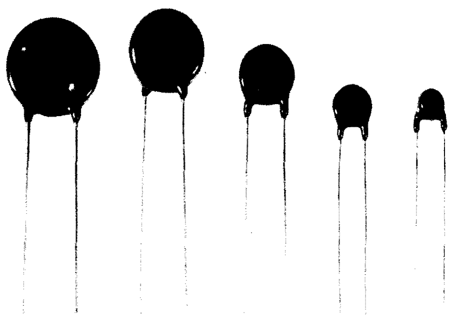
NEC
ELECTRON DEVICE

SURGE SUPPRESSOR METAL OXIDE VARISTOR

NEC-MOV SERIES

NV100D05～NV470D05
NV100D07～NV470D07
NV082D10～NV910D10
NV082D14～NV910D14
NV100D19～NV910D19

The NEC-MOV series are the best device for transient voltage protection. When exposed to high transient voltage the NEC-MOV's impedance changes from a very high value to a very low conducting value thus clamping the transient voltage to a safe level. Therefore NEC-MOV protects many electric equipment from surge voltage and keep a safe drive.



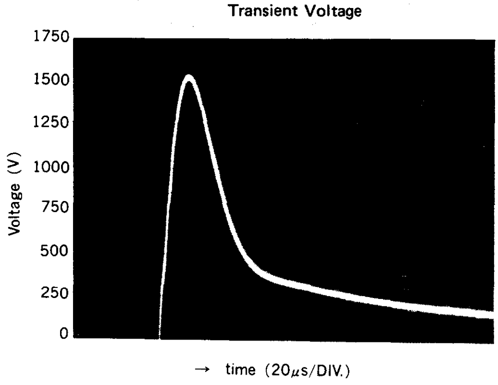
FEATURES

- Excellent transient voltage suppression characteristics.
- High surge current.
- Fast response time. (< 50 ns)
- V-I characteristics are the same in both polarity.

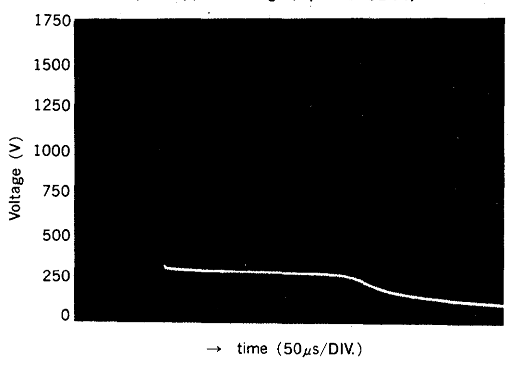
APPLICATIONS

- Protects equipment against failures by transient surge voltage.

Transient Voltage



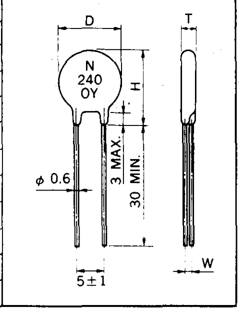
Clipped Voltage (By NV240D14)



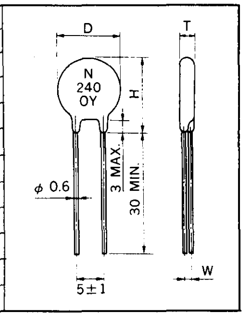
9

Outline Drawing (Unit : mm)

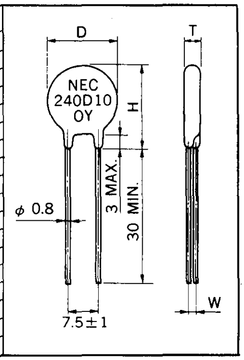
Type Number	D(MAX.)	H(MAX.)	T(MAX.)	W
NV100D05	7.0	10.0	4.3	1.2
NV120D05	7.0	10.0	4.3	1.3
NV150D05	7.0	10.0	4.5	1.5
NV200D05	7.0	10.0	5.0	1.7
NV220D05	7.0	10.0	5.0	1.8
NV240D05	7.0	10.0	5.3	1.9
NV270D05	7.0	10.0	5.3	2.1
NV360D05	7.5	10.5	6.0	2.6
NV390D05	7.5	10.5	6.0	2.7
NV430D05	7.5	10.5	6.5	2.9
NV470D05	7.5	10.5	6.5	3.1



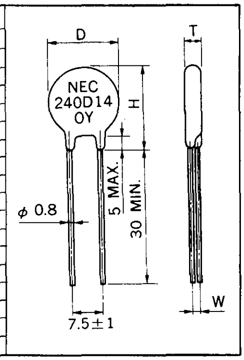
Type Number	D(MAX.)	H(MAX.)	T(MAX.)	W
NV100D07	9.0	12.0	4.3	1.2
NV120D07	9.0	12.0	4.3	1.3
NV150D07	9.0	12.0	4.5	1.5
NV200D07	9.0	12.0	5.0	1.7
NV220D07	9.0	12.0	5.0	1.8
NV240D07	9.0	12.0	5.3	1.9
NV270D07	9.0	12.0	5.3	2.1
NV360D07	9.5	12.5	6.0	2.6
NV390D07	9.5	12.5	6.0	2.7
NV430D07	9.5	12.5	6.5	2.9
NV470D07	9.5	12.5	6.5	3.1



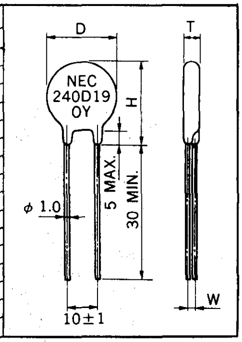
Type Number	D(MAX.)	H(MAX.)	T(MAX.)	W
NV082D10	12.0	15.0	3.5	1.3
NV100D10	12.0	15.0	4.3	1.4
NV120D10	12.0	15.0	4.3	1.5
NV150D10	12.0	15.0	4.5	1.7
NV200D10	12.0	15.0	5.0	1.9
NV220D10	12.0	15.0	5.0	2.0
NV240D10	12.0	15.0	5.3	2.1
NV270D10	12.0	15.0	5.3	2.3
NV360D10	12.5	15.5	6.0	2.8
NV390D10	12.5	15.5	6.0	2.9
NV430D10	12.5	15.5	6.5	3.1
NV470D10	12.5	15.5	6.5	3.3
NV620D10	12.5	15.5	7.5	4.1
NV680D10	12.5	15.5	8.0	4.5
NV750D10	12.5	15.5	8.5	4.8
NV780D10	12.5	15.5	8.5	5.0
NV820D10	12.5	15.5	9.0	5.2
NV910D10	12.5	15.5	9.5	5.6



Type Number	D(MAX.)	H(MAX.)	T(MAX.)	W
NV082D14	16.0	21.0	3.5	1.3
NV100D14	16.0	21.0	4.3	1.4
NV120D14	16.0	21.0	4.3	1.5
NV150D14	16.0	21.0	4.5	1.7
NV200D14	16.0	21.0	5.0	1.9
NV220D14	16.0	21.0	5.0	2.0
NV240D14	16.0	21.0	5.3	2.1
NV270D14	16.0	21.0	5.3	2.3
NV360D14	16.5	21.5	6.0	2.8
NV390D14	16.5	21.5	6.0	2.9
NV430D14	16.5	21.5	6.5	3.1
NV470D14	16.5	21.5	6.5	3.3
NV620D14	16.5	21.5	7.5	4.1
NV680D14	16.5	21.5	8.0	4.5
NV750D14	16.5	21.5	8.5	4.8
NV780D14	16.5	21.5	8.5	5.0
NV820D14	16.5	21.5	9.0	5.2
NV910D14	16.5	21.5	9.5	5.6



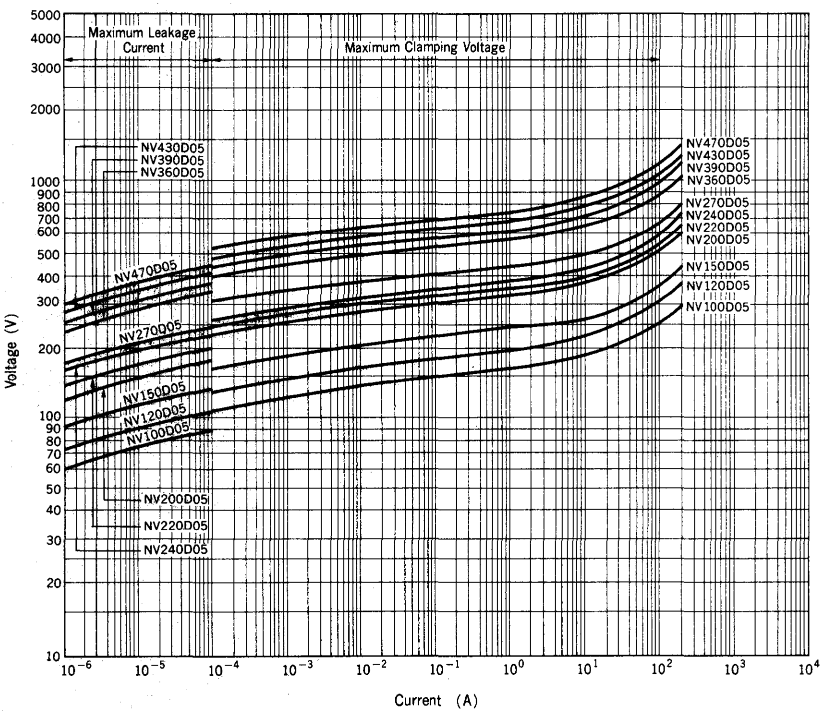
Type Number	D(MAX.)	H(MAX.)	T(MAX.)	W
NV100D19	20.0	25.0	4.8	1.6
NV120D19	20.0	25.0	4.8	1.7
NV150D19	20.0	25.0	5.0	1.9
NV200D19	20.0	25.0	5.4	2.1
NV220D19	20.0	25.0	5.4	2.2
NV240D19	20.0	25.0	5.7	2.3
NV270D19	20.0	25.0	5.7	2.5
NV360D19	21.0	26.0	6.3	3.0
NV390D19	21.0	26.0	6.3	3.1
NV430D19	21.0	26.0	6.8	3.3
NV470D19	21.0	26.0	6.8	3.5
NV620D19	21.0	26.0	7.6	4.3
NV680D19	21.0	26.0	8.0	4.7
NV750D19	21.0	26.0	8.5	5.0
NV780D19	21.0	26.0	8.5	5.2
NV820D19	21.0	26.0	9.0	5.4
NV910D19	21.0	26.0	9.5	5.8



RATINGS AND CHARACTERISTICS (NV100D05 ~ NV470D05)

Type Number	Varistor Voltage	Maximum Allowable Voltage		Clamping Voltage	Energy	Peak Current	Operating Ambient Temperature	Storage Temperature	Capacitance (reference value)
	V 0.1mA (±10%) (V)	ACrms (V)	DC (V)	V_{25A} (V)	(J)	8×20 μs (A)	Topt (°C)	Tstg (°C)	1 k~1 MHz (pF)
NV100D05	100	60	85	175	2.0	200	−40~85	−40~125	40~150
NV120D05	120	75	100	210	2.5				
NV150D05	150	95	125	260	3.0				
NV200D05	200	130	170	355	4.0				
NV220D05	220	140	180	380	4.5				
NV240D05	240	150	200	415	5.0				
NV270D05	270	175	225	475	6.0				
NV360D05	360	230	300	620	7.5				
NV390D05	390	250	320	675	8.0				
NV430D05	430	275	350	745	9.0				
NV470D05	470	300	385	810	10.0				

Fig. 1 V-I Characteristics

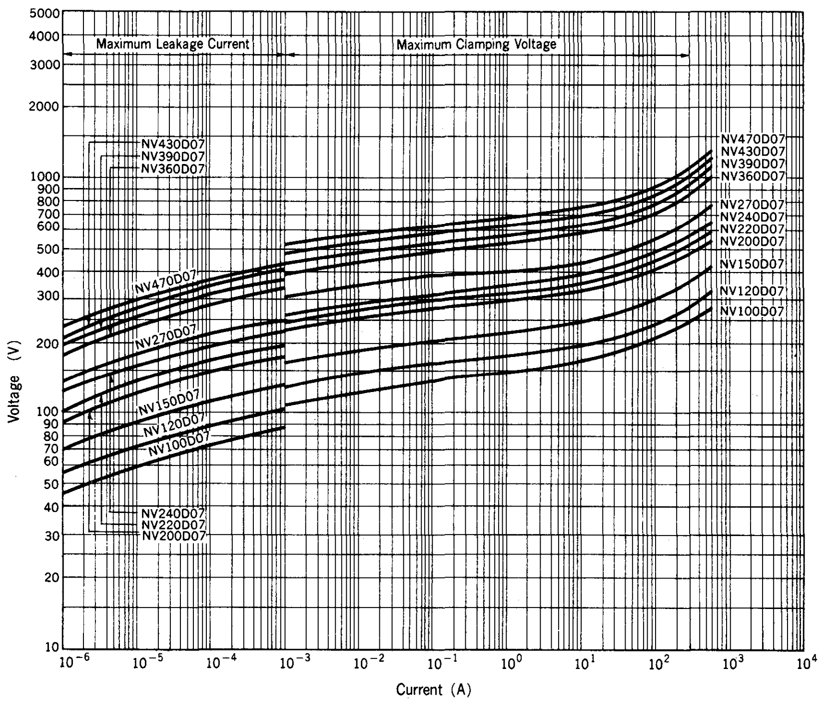


9

RATINGS AND CHARACTERISTICS (NV100D07 ~ NV470D07)

Type Number	Varistor Voltage	Maximum Allowable Voltage		Clamping Voltage	Energy	Peak Current	Operating Ambient Temperature	Storage Temperature	Capacitance (reference value)
	V1mA (±10%) (V)	ACrms (V)	DC (V)	V_{50A} (V)	(J)	8×20 μs (A)	Topt (°C)	Tstg (°C)	1 k ~ 1 MHz (pF)
NV100D07	100	60	85	165	4.5				
NV120D07	120	75	100	200	5.0				
NV150D07	150	95	125	250	6.0				
NV200D07	200	130	170	340	10.0				
NV220D07	220	140	180	360	10.0				
NV240D07	240	150	200	395	10.0	600	−40 ~ 85	−40 ~ 125	70 ~ 250
NV270D07	270	175	225	455	12.0				
NV360D07	360	230	300	595	15.0				
NV390D07	390	250	320	650	17.0				
NV430D07	430	275	350	710	20.0				
NV470D07	470	300	385	775	20.0				

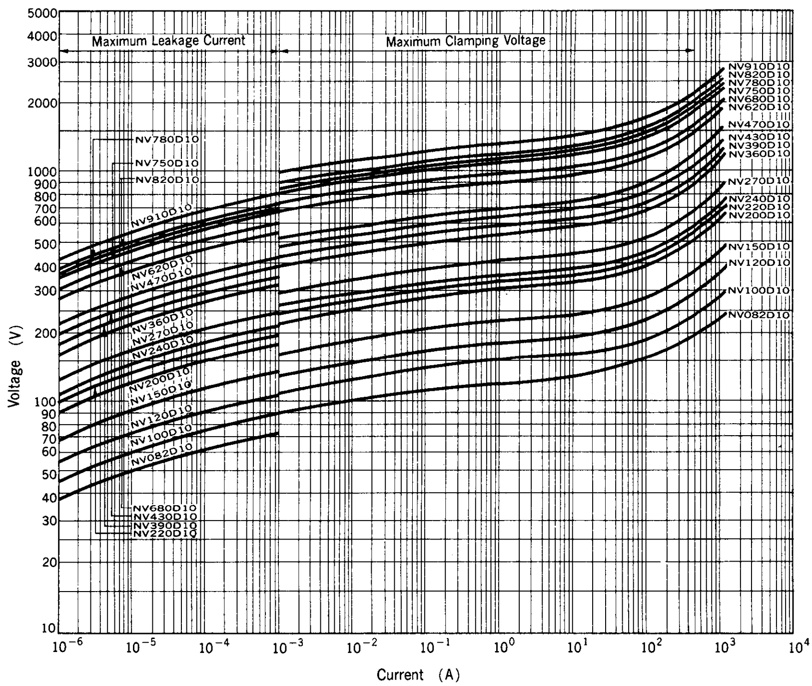
Fig. 2 V-I Characteristics



RATINGS AND CHARACTERISTICS (NV082D10 ~ NV910D10)

Type Number	Varistor Voltage	Maximum Allowable Voltage		Clamping Voltage	Energy	Peak Current	Operating Ambient Temperature	Storage Temperature	Capacitance (reference value)
	V1mA (±10%) (V)	ACrms (V)	DC (V)	V25A (V)	(J)	8×20 μs (A)	Topt (°C)	Tstg (°C)	1 k ~ 1 MHz (pF)
NV082D10	82	50	65	135	8	1250	−40~85	−40~125	250~800
NV100D10	100	60	85	165	10				
NV120D10	120	75	100	200	12				
NV150D10	150	95	125	250	16				
NV200D10	200	130	170	340	20				
NV220D10	220	140	180	360	23				
NV240D10	240	150	200	395	25				
NV270D10	270	175	225	455	30				
NV360D10	360	230	300	595	35				
NV390D10	390	250	320	650	40				
NV430D10	430	275	350	710	45				
NV470D10	470	300	385	775	45				
NV620D10	620	385	505	1025	45				
NV680D10	680	420	560	1120	45				
NV750D10	750	460	615	1240	50				
NV780D10	780	485	640	1290	50				
NV820D10	820	510	670	1355	55				
NV910D10	910	550	745	1500	60				

Fig. 3 V-I Characteristics

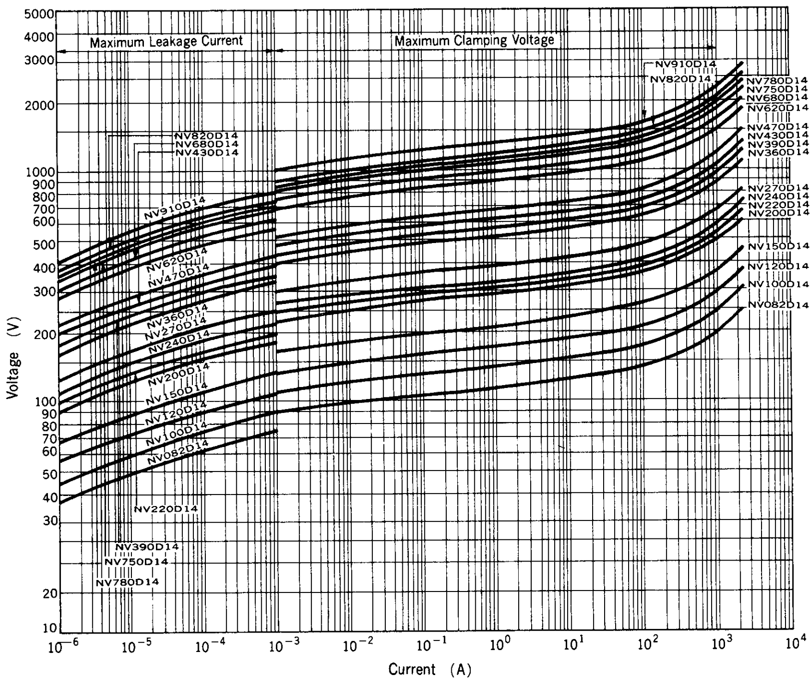


9

RATINGS AND CHARACTERISTICS (NV082D14 ~ NV910D14)

Type Number	Varistor Voltage	Maximum Allowable Voltage		Clamping Voltage	Energy	Peak Current	Operating Ambient Temperature	Storage Temperature	Capacitance (reference value)
	V1mA (±10%) (V)	ACrms (V)	DC (V)	V_{50A} (V)	(J)	8×20 μs (A)	Topt (°C)	Tstg (°C)	1 k ~ 1 MHz (pF)
NV082D14	82	50	65	135	14	2500	−40 ~ 85	−40 ~ 125	100 ~ 1000
NV100D14	100	60	85	165	18				
NV120D14	120	75	100	200	20				
NV150D14	150	95	125	250	25				
NV200D14	200	130	170	340	35				
NV220D14	220	140	180	360	40				
NV240D14	240	150	200	395	40				
NV270D14	270	175	225	455	50				
NV360D14	360	230	300	595	65				
NV390D14	390	250	320	650	70				
NV430D14	430	275	350	710	75				
NV470D14	470	300	385	775	80				
NV620D14	620	385	505	1025	85				
NV680D14	680	420	560	1120	90				
NV750D14	750	460	615	1240	100				
NV780D14	780	485	640	1290	105				
NV820D14	820	510	670	1355	110				
NV910D14	910	550	745	1500	120				

Fig. 4 V-I Characteristics



RATINGS AND CHARACTERISTICS (NV100D19 ~ NV910D19)

Type Number	Varistor Voltage	Maximum Allowable Voltage		Clamping Voltage	Energy	Peak Current	Operating Ambient Temperature	Storage Temperature	Capacitance (reference value)
	V1mA (±10%) (V)	ACrms (V)	DC (V)	V_{100A} (V)	(J)	8×20 μs (A)	Topt (°C)	Tstg (°C)	1 k ~ 1 MHz (pF)
NV100D19	100	60	85	165	19	3000	−40 ~ 85	−40 ~ 125	300 ~ 2000
NV120D19	120	75	100	200	21				
NV150D19	150	95	125	250	27				
NV200D19	200	130	170	340	37				
NV220D19	220	140	180	360	42				
NV240D19	240	150	200	395	42				
NV270D19	270	175	225	455	52				
NV360D19	360	230	300	595	68				
NV390D19	390	250	320	650	73				
NV430D19	430	275	350	710	80				
NV470D19	470	300	385	775	90				
NV620D19	620	385	505	1025	100				
NV680D19	680	420	560	1120	110				
NV750D19	750	460	615	1240	120				
NV780D19	780	485	640	1290	130				
NV820D19	820	510	670	1355	140				
NV910D19	910	550	745	1500	150				

Fig. 5 V-I Characteristics

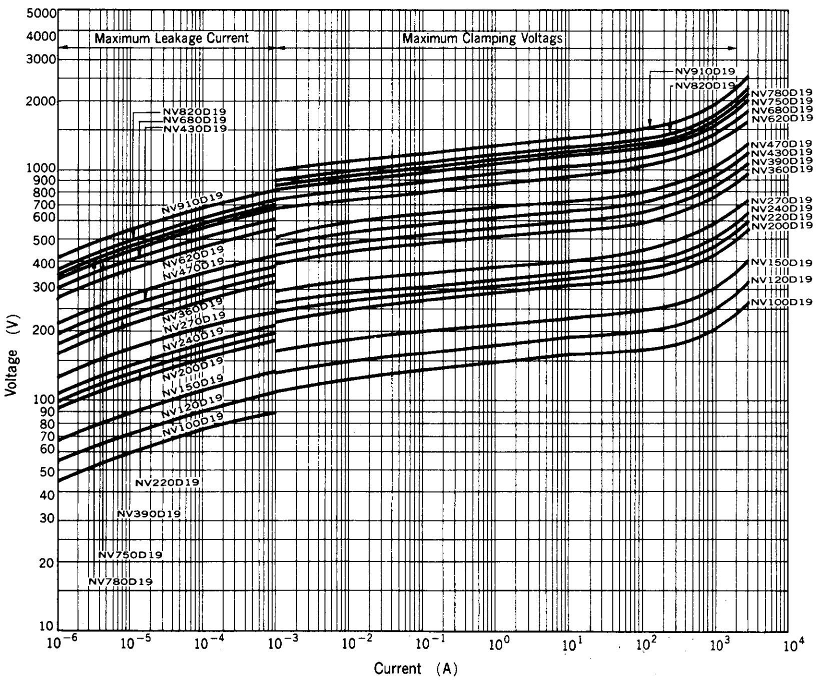


Fig. 6 Peak Current-Pulse Width Rating (Impulse Number N=2)

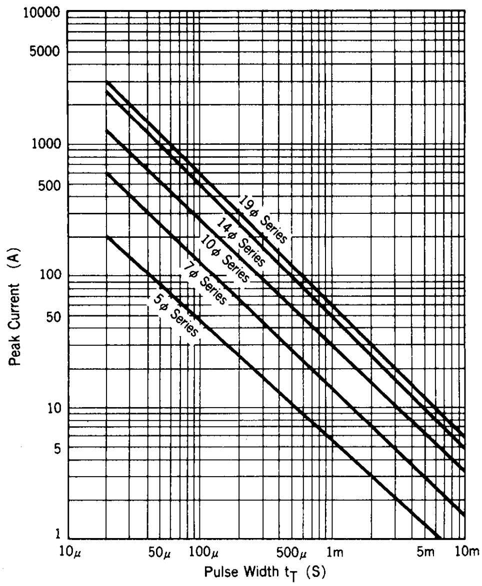
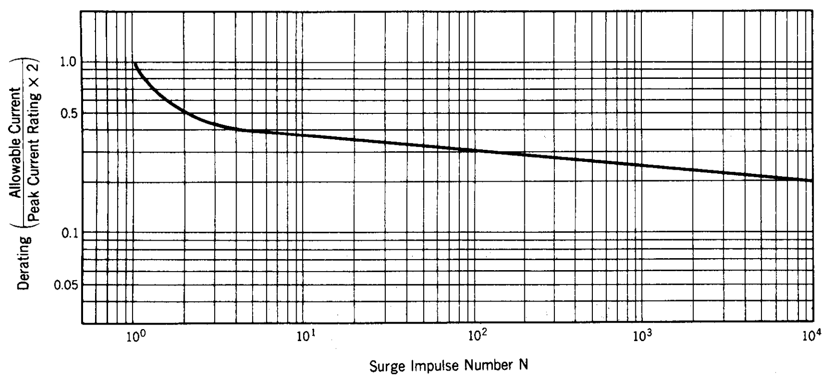


Fig. 7 Derating Curve

ex. 14 φ Series
Pulse width t_T=200 μs, Impulse number N=10^4
I (at t_T=200 μs)=250A (See Fig. 6)
Derating (at N=10^4)=0.2 (See Fig. 7)
Allowable current I=250x2x0.2=100A



NOTICE

- Applied voltage should not be over the maximum ratings.
- Should the NEC-MOV be subjected to surge current and energy levels in excess of maximum ratings, it may physically fail by package rupture or explosion of material. It is recommended that protective fusing be used in a circuit.
- When the NEC-MOV are used in a high frequency circuit, notice it's capacitance and avoid to fever.

Contents

Cross Reference Information

Photo Coupler Cross Reference

Photo Couplers

Type No.	Manu-facturer	PKG	Maximum Ratings (Ta=25°C)					Electrical Characteristics				Remarks Classification (CTR)
			I_F (mA)	P_C (mW)	V_{CE} (V)	I_C (mA)	T_{OPT} (°C)	V_{1-2} (kV_{DC})	CTR Min. (%)	t_r Typ. (μs)	I_{CEO} Max. (nA)	
PS1001	NEC	TO-5 can	60	100	30	50	-55~ +100	1.0	20[*2]	5[**10]	200[+1]	
*PS2001B	"	6DIP	"	"	"	"	"	2.5	30[*2]	"	"	K:90% L:50%~ 100% M:30%~ 60%
*PS2008B	"	"	"	"	"	"	"	"	"	"	"	o(") o NO BASE LEAD
*PS2002B	"	"	50	"	40	"	"	2.5	100[*12]	120[**11]	400[+1]	oK:250% L:150% 300% M: 100% 200% o NO BASE LEAD
*PS2003B	"	"	40	"	30	"	"	2.5	30[*2]	5[**10]	200[+1]	K:90% L:50~ 100% M:30~ 60%
*PS2009B	"	"	"	"	"	"	"	"	"	"	"	o(") o NO BASE LEAD
PS2004B	"	"	50	"	"	200	"	2.5	1300[*12]	250[**11]	400[+1]	
PS2005B	"	"	150	200	"	50	"	2.5	10[*13]	5[**8]	200[+1]	

1. NEC will change type numbers from PS2001-PS2009 to PS2001B-PS2009B in June 1979.
2. PS2001A-PS2005A will not be changed.

10

(1) Photo Transistor Output

Type No.	Manu-facturer	PKG.	Maximum Ratings (Ta=25°C) I_F (mA)	P_C (mW)	V_{CE} (V)	I_C (mA)	T_{OPT} (°C)	Electrical Characteristics V_{1-2} (kV_{DC})	CTR Min. (%)	t_r Typ. (μs)	I_{CEO} Max. (nA)	NEC No.	Remarks ( ): advantage	Code
4N25		6DIP	80	150	30	100	-55-100	2.5	20^{*1}	2^{**1}	50^{+1}	PS2001B	I_F, I_C	B
4N25A		"	"	"	"	"	"	1.775RMS (1 sec)	"	"	"	PS2001B	I_F, I_C (V_{1-2})	B
4N26		"	"	"	"	"	"	1.5	"	"	"	PS2001B	"	B
4N27		"	"	"	"	"	"	"	10^{*1}	"	"	PS2001B	"	B
4N28		"	"	"	"	"	"	0.5	"	"	100^{+1}	PS2001B	"	B
4N29		6DIP	80	150	30	100	-55-100	2.5	100^{*1}	40MAX^{**9}	100^{+1}	PS2004B	I_F(I_C, CTR)	B
4N29A		"	"	"	"	"	"	2.5 (1.775RMS)	"	"	"	PS2004B	I_F(I_C, CTR, V_{1-2})	B
4N30		"	"	"	"	"	"	1.5	"	"	"	PS2004B	"	B
4N31		"	"	"	"	"	"	"	50^{*1}	"	"	PS2004B	"	B
4N32		"	"	"	"	"	"	2.5	500^{*1}	100MAX^{**1}	"	PS2004B	I_F(I_C, CTR)	B
4N32A		"	"	"	"	"	"	(1.775RMS)	"	"	"	PS2004B	I_F(I_C, CTR, V_{1-2})	B
4N33		"	"	"	"	"	"	1.5	"	"	"	PS2004B	"	B
4N35		6DIP	60	300	30	100	-55-100	3.55 (2.5RMS)	100^{*1}	5TYP^{**1} 10MAX	50^{+1}	NONE	under developement	-
4N36		"	"	"	"	"	"	2.5 (1.75RMS)	"	"	"	PS2001B (K)	I_C (V_{1-2})	B
4N37		"	"	"	"	"	"	1.5 (1.05RMS)	"	"	"	PS2001B (K)	"	B
4N38		6DIP	80	150	80	100	-55-100	1.5	10^{+1}	5^{**1}	50^{+5}	NONE	I_F, I_C(CTR) V_{1-2})	-
4N38A		"	"	"	"	"	"	2.5 (1.775RMS)	"	"	"	NONE	I_F, I_C(CTR	-
4N22		TO-5 (6PIN)	40	300	35	50	-55-125	1.0	25^{*1}	15	-	PS1001	V_{CE}, CTR (I_F, I_C)	B
4N22A		"	"	"	"	"	"	"	"	"	-	PS1001	"	B
4N23		"	"	"	"	"	"	"	60^{*1}	"	-	PS1001	"	C
4N23A		"	"	"	"	"	"	"	"	"	-	PS1001	"	C
4N24		"	"	"	"	"	"	"	100^{*1}	20	-	NONE	-	-
4N24A		"	"	"	"	"	"	"	"	"	-	NONE	-	-
4N47		TO-5 (6PIN)	40	300	35	50	-55-125	1.0	100	20	-	NONE	-	-
4N48		"	"	"	"	"	"	"	200	"	-	NONE	-	-
4N49		"	"	"	"	"	"	"	400	"	-	NONE	-	-

Type No.	Manu-facturer	PKG.	Maximum Ratings (Ta=25°C)					Electrical Characteristics				NEC No.	Remarks ( ): advantage	Code
			I_F (mA)	P_C (mW)	V_{CE} (V)	I_C (mA)	T_{OPT} (°C)	V_{1-2} (kV_{DC})	CTR Min. (%)	t_r Typ. (μs)	I_{CEO} Max. (nA)			
JAN 4N22	TI	6DIP	40	300	35	-	-55-100	1.0	25*1	15	-	PS2001B PS2003B	V_{CE}, CTR (V_{1-2})	B
JAN 4N23	"	"	"	"	"	-	"	"	60*1	"	-	PS2001B (K)	"	B
JAN 4N24	"	"	"	"	"	-	"	"	100*1	20	-	PS2001B (K)	"	B
JAN 4N22A	OPI	"	"	"	"	-	"	"	25*1	15	-	PS2001B PS2003B	"	B
JAN 4N23A	"	"	"	"	"	-	"	"	60*1	20	-	PS2001B (K)	"	B
JAN 4N24A	"	"	"	"	"	-	"	"	100*1	"	-	PS2001B (K)	"	B

Code
A = Direct Replacement
B = Minor Electrical Difference
C = Significant Electrical Difference

10

Type No.	Manu- factu- rer	PKG.	Maximum Ratings (Ta=25°C)					Electrical Characteristics				NEC No.	Remarks ( ): advantage	Code
			I_F (mA)	P_C (mW)	V_{CE} (V)	I_C (mA)	T_{OPT} (°C)	V_{1-2} (kV_{DC})	CTR Min. (%)	t_r Typ. (μ s)	I_{CEO} Max. (nA)			
H11A1	GE.	6DIP	60	150	30	100	-55-100	2.5 (1.77RMS)	50^{*1}	2^{**1}	50^{+1}	PS2001B (L, K)	I_C	B
H11A2	"	"	"	"	"	"	"	1.5 (1.06RMS)	20^{*1}	2^{**1}	"	PS2001B	I_C (V_{1-2})	B
H11A3	"	"	"	"	"	"	"	2.5 (1.77RMS)	20^{+1}	2^{**1}	"	PS2001B	I_C	B
H11A4	"	"	"	"	"	"	"	1.5 (1.06RMS)	10^{*1}	2^{**1}	"	PS2001B	I_C (V_{1-2})	B
H11A5	"	"	"	"	"	"	"	1.5 (1.06RMS)	30*1	2^{**1}	100^{+1}	PS2001B	"	B
H11A10	"	"	50	300	"	"	"	1.5 (1.06RMS)	10^{*1}	5(ton)**7	-	PS2001B	I_C(I_F, V_{1-2}, CTR	B
H11A520	"	"	60	"	"	"	"	5.656 (4RMS)	20^{*1}	10MAX**1	50^{+1}	NONE	High V_{1-2}	-
H11A550	"	"	"	"	"	"	"	"	50^{*1}	10MAX**1	"	NONE	"	-
H11A5100	"	"	"	"	"	"	"	"	100^{*1}	10MAX**1	"	NONE	"	-
H11B1	"	"	"	150	25	"	"	2.5 (1.77RMS)	500^{*7}	125(ton)**3	100^{+1}	PS2004B	I_C, (CTR)	B
H11B2	"	"	"	"	"	"	"	1.5 (1.06RMS)	200^{*7}	"	"	PS2004B	I_C, (V_{1-2}, CTR)	B
H11B3	"	"	"	"	"	"	"	"	100^{*7}	"	"	PS2004B	"	B
H11B255	"	"	"	210	55	"	"	1.5 (1.06RMS)	100^{*3}	"	"	PS2004B	V_{CE} (")	C
H11EX522	"	"	"	150	25	"	"	2.5 (1.7RMS)	200^{*8}	(1~3ns)	(10μ A)	PS2004B	I_C, (CTR)	B
H74A1	"	"	"	300	15	50	0-70	1.5 (1.06RMS)	-	-	-	NONE	TTLUsage	
H11AA1	"	"	"	"	30	100	-55-100	1.5 (1.06RMS)	20^{*1}	-	100^{*1}	NONE	Dual Diodes	
H11AA2	"	"	"	"	"	"	"	"	10^{*1}	-	"	NONE	"	
H11D1	"	"	"	"	300	"	"	2.5 (1.77RMS)	20^{*1}	5^{**1}	"+4	NONE	High V_{CEO}	
H11D2	"	"	"	"	"	"	"	1.5 (1.06RMS)	"	"	"	NONE	"	
H11D3	"	"	"	"	200	"	"	"	"	"	"	NONE	"	
H11D4	"	"	"	"	"	"	"	"	10^{*1}	"	"	NONE	"	
H211A1	"	12DIP	"	150	30	"	"	2.5	50^{*1}	2^{**1}	"	NONE	Dual	
H211A2	"	"	"	"	"	"	"	1.5	20^{*1}	"	"	NONE	"	

Type No.	Manu-facturer	PKG.	Maximum Ratings (Ta=25°C)					Electrical Characteristics				NEC No.	Remarks ( ): advantage	Code
			I_F (mA)	P_C (mW)	V_{CE} (V)	I_C (mA)	T_{OPT} (°C)	V_{1-2} (kV_{DC})	CTR Min. (%)	t_r Typ. (μs)	I_{CEO} Max. (nA)			
H211B1	GE.	12DIP	60	150	30	100	-55 100	2.5	500^{*7}	125^{**3}	100^{+4}	NONE	Dual	-
H211B2	"	"	"	"	"	"	"	1.5	200^{*7}	"	"	NONE	"	-
MCT2	MON	6DIP	60	200	"	50	"	1.5	20^{*1}	2.5^{**1}	50^{+1}	PS2001B	CTR(V_{1-2})	B
MCT2E	"	"	"	"	"	"	"	2.5	"	"	"	PS2001B	CTR	B
MCT26	"	"	"	"	"	"	"	1.5	6^{*2}	2^{**1}	100^{*2}	PS2001B	(V_{1-2}, CTR)	A
MCT4	"	TO-18	"	"	"	-	"	1.0	15	-	-	NONE	-	-
MCT4R	"	"	-	-	"	-	-	1.0	15	-	-	NONE	-	-
MCT6	"	8DIP	60	150	30	-	-55-100	1.5	20^{*1}	2.4^{**1}	100^{+1}	NONE	Dual	-
MCT66	"	"	"	"	"	-	"	1.5	6^{*1}	2.4^{**1}	100^{+2}	NONE	"	-
MCA230	"	6DIP	"	210	"	125	"	1.5	100^{*3}	10 (ton)^{**2}	100^{+1}	PS2004B	I_F I_C (V_{1-2}, CTR)	C
MCA231	"	"	"	275	"	100	"	1.5 (AC)	-	80^{**3}	100^{+1}	PS2004B	"	C
MCA255	"	"	60	210	55	125	"	3.55	100^{*3}	10 (ton)^{**2}	100^{+1}	NONE	-	-
MCD2	"	6DIP	100	-	50	-	"	1.5	0.15	-	-	NONE	Diode	-
MCD4	"	TO-18	"	100	"	-	-55-125	1	0.1	-	-	NONE	"	-
MCD4R	"	"	-	-	"	-	"	1	0.1		-	NONE	"	-
MCT2F	"	6DIP	75	100	30	10	-55-100	2	10^{*1}	0.8 Max^{**1}	10^{+1}	PS2008B	I_F, t_r (I_C, CTR)	C
MCA2200	"	"	60	-	200	30	"	1.5	5^{*9}	-	100^{+1}	NONE	High V_{CEO}	-
MCD2-M	"	"	60	-	30	-	-55-125	1.5	0.1	-	-	NONE	Diode	-

10

Type No.	Manu-facturer	PKG.	Maximum Ratings (Ta=25°C) I_F (mA)	P_C (mW)	V_{CE} (V)	I_C (mA)	T_{OPT} (°C)	Electrical Characteristics V_{1-2} (kV_{DC})	CTR Min. (%)	t_r, tf Typ. (μ s)	I_{CEO} Max. (nA)	NEC No.	Remarks ( ): advantage	Code
TIL102	TI	TO-5 Can	40	300	35	50	-55-125	1	25^{*3}	3^{**4}	100^{+3}	PS1001	V_{CE}, CTR (I_F)	
TIL103	"	"	"	"	"	"	"	"	100^{*3}	6^{**4}	"	NONE	-	
TIL111	"	6DIP	100	150	30	-	-	1.5	12.5^{*4}	$5MAX^{**1}$	50^{+1}	PS2001B	I_F, (V_{1-2}, CTR)	
												PS2005B	(I_F), CTR	
TIL114	"	"	"	"	"	-	-	2.5	12.5^{*4}	"	"	PS2001B	L_F, (CTR)	
												PS2005B	(I_F)CTR	
TIL116	"	"	"	"	"	-	-	"	20^{*1}	$7MAX^{**1}$		PS2001B	I_F, (CTR)	
												PS2005B	(I_F)CTR	
TIL117	"	"	"	"	"	-	-	"				PS2001B (L, K)	I_F, (CTR)	
												PS2005B	(I_F)CTP	
TIL112	"	"	"	"	20	-	-	1.5	2^{*3}	$15MAX^{**1}$	100^{+2}	PS2005B	(V_{CE}, V_{1-2}, CTR)	
TIL115	"	"	"	"	"	-	-	2.5	2^{*3}	"	"	PS2005B	(CTR)	
TIL118	"	"	"	"	"	-	-	1.5	10^{*3}	"	"	PS2005B	(V_{CE}, V_{1-2} CTR)	
TIL113	"	"	"	"	"	30		1.5	300^{*5}	50^{**5}	100^{+1}	PS2004B	I_F, (V_{1-2}, CTR)	
TIL119	"	"	"	"	"	"		"	300^{*6}	50^{**6}	100^{+1}	PS2002B (K)	I_F, (V_{VE}, V_{1-2} NO BASE LEAD	
TIL107	"	Tubular	50	150	35	-	-55-150	1	3.3^{*10}	5^{**7}	25^{+4}	NONE	-	
TIL108	"	"	"	"	"	-	"	"	11^{*10}	5^{**7}	"	"	-	
TIXL113	"	6DIP	60	150	30	-	-	1.5	100^{*11}	50^{**6}	100^{+1}	PS2004B	(V_{1-2}, CTR)	

CROSS-REFERENCE GUIDE FOR NEC HIGH SPEED SWITCHING POWER TRANSISTORS

PART—I (U.S.A. TYPE)

TYPE NO.	MANUFAC-TURERS	POLARITY	PACKAGE	MAXIMUM RATINGS (Ta=25°C) P_T(W) (Tc=25°C)	$I_{C(DC)}$(A)	V_{CEO}(V)	ELECTRICAL CHARACTERISTICS (Ta=25°C) h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX.	f_T(MHz) MIN.	NEC TYPE NO.	NOTE
2N2033	STC	N	3	5.0	3.0	60	20 (4/0.5)	800 m	t_{on} 1.0, t_{off} 1.5	1.0	NTC1860	
2N2034	STC	N	3	5.0	3.0	60	20 (4/1)	300 m	1.0, 1.5	1.0	NTC1860	
2N3418	TII	N	3	1.0 (Ta=25°C)	3.0	60	20 (2/1)	–	0.3, 1.2	40	NTC1860	
2N3419	TII	N	3	1.0 (Ta=25°C)	3.0	80	20 (2/1)	–	0.3, 1.2	40	NTC1860	
2N3420	TII	N	3	1.0 (Ta=25°C)	3.0	60	40 (2/1)	–	0.3, 1.2	40	NTC1860	*
2N3421	TII	N	3	1.0 (Ta=25°C)	3.0	80	40 (2/1)	–	0.3, 1.2	40	NTC1860	*
2N3445	MOTA	N	1	115	7.5	60	20 (5/3)	500 m	t_{on} 0.35, t_{stg} 2.0, t_f 0.35	10	NTC1866	
2N3446	MOTA	N	1	115	7.5	80	20 (5/3)	500 m	0.35, 2.0, 0.35	10	NTC1866	
2N3447	MOTA	N	1	115	7.5	60	40 (5/5)	300 m	0.35, 2.0, 0.35	10	NTC1869	*
2N3448	MOTA	N	1	115	7.5	80	40 (5/5)	300 m	0.35, 2.0, 0.35	10	NTC1869	*
2N3902	DEL	N	1	100	2.5	400	10(5/2.5)	800 m	t_{on} 0.8, t_{off} 1.7	4.0†	NTC1868	
2N4000	TII	N	3	1.0 (Ta=25°C)	1.0	80	30(2/0.5)	500 m	0.3, 2.0	40	NTC1860	
2N4001	TII	N	3	1.0 (Ta=25°C)	1.0	100	40(2/0.5)	500 m	0.3, 2.0	40	NTC1860	
2N4240	MOTA	N	2	35	5.0	300	10(2/0.75)	1.3 m	t_r 0.5, t_{stg} 6.0, t_f 3.0	15	NTC1865	
2N4395	SOD	N	1	63	5.0	40	50(1/2)	180 m	t_{on} 0.8, t_{off} 1.7	4.0	NTC1866	*
2N4396	SOD	N	1	63	5.0	60	40(1/2)	180 m	1.0, 2.0	4.0	NTC1866	*
2N5038	RCA	N	1	140	20	$V_{CEO(SUS)}$ 90	20(5/10)	125 m	t_{on} 0.5, t_{stg} 1.5, t_f 0.5	60	NTC1869	*
2N5039	RCA	N	1	140	20	$V_{CEO(SUS)}$ 75	20(5/12)	125 m	0.5, 1.5, 0.5	60	NTC1869	*
2N5050	MOTA	N	2	40	2.0	125	25(5/0.75)	–	t_r 0.3, t_{stg} 3.5, t_f 1.2	10	NTC1864	
2N5051	MOTA	N	2	40	2.0	150	25(5/0.75)	–	0.3, 3.5, 1.2	10	NTC1864	
2N5052	MOTA	N	2	40	2.0	200	25(5/0.75)	–	0.3, 3.5, 1.2	10	NTC1864	
2N5157	DEL	N	1	100	3.5	500	30(5/1)	710 m	t_{on} 0.8, t_{off} 1.7	2.8	2N6545	
2N5202	RCA	N	2	35	4.0	75	10(1.2/4)	300 m	t_r 0.4, t_{stg} 1.2, t_f 0.4	60	NTC1863	
2N5241	DEL	N	1	125	5.0	400	15(5/2.5)	500 m	t_{on} 0.8, t_{off} 1.7	2.5	NTC1868	
2N5660	UNI	N	2	20	1.0	200	15(5/1)	–	0.25, 0.85	20	NTC1864	

PACKAGE (JEDEC)
1:TO-3
2:TO-66
3:TO-5 or TO-39

* Lower h_{FE}
†: typical

TYPE NO.	MANUFAC-TURERS	POLALITY	PACKAGE	MAXIMUM RATINGS(T_a=25°C) P_T(W) (T_c=25°C)	I_C(DC)(A)	V_{CEO}(V)	ELECTRICAL CHARACTERISTICS (T_a=25°C) h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX.			f_T(MHz) MIN.	NEC TYPE NO.	NOTE
2N5661	UNI	N	2	20	1.0	300	15(5/1)	–	t_{on} 0.25		t_{off} 1.2	20	NTC1865	
2N5662	UNI	N	3	15	1.0	200	15(5/1)	–	0.25		0.85	20	NTC1861	
2N5663	UNI	N	3	15	1.0	300	15(5/1)	–	0.25		1.2	20	NTC1862	
2N5664	UNI	N	2	30	3.0	200	15(5/3)	–	0.25		1.5	20	NTC1864	
2N5665	UNI	N	2	30	3.0	300	15(10/3)	–	0.25		2.0	20	NTC1865	
2N5666	UNI	N	3	15	3.0	200	15(5/3)	–	0.25		1.5	20	NTC1861	
2N5667	UNI	N	3	15	3.0	300	15(10/3)	–	0.25		2.0	20	NTC1862	
2N5671	RCA	N	1	140	30	120	20(2/15)	50 m	t_r 0.5	t_{stg} 1.5	t_f 0.5	50	NTC1870	*
2N5672	RCA	N	1	140	30	150	20(2/15)	50 m	0.5	1.5	0.5	50	NTC1870	*
2N5734	SLD KER	N	1	150	30	V_{CEX} 80	30(2/10)	60 m	0.7	3.0	1.0	30	NTC1869	*
2N5804	RCA	N	1	110	5.0	300	10(4/5)	400 m	0.5†	3.5†	2.0†	15	NTC1868	*****
2N5805	RCA	N	1	110	5.0	375	10(4/5)	400 m	0.5†	3.5†	2.0†	15	NTC1868	*****
2N5838	RCA	N	1	100	3.0	275	8(2/3)	–	1.5	3.0	1.5	5.0	NTC1868	
2N5839	RCA	N	1	100	3.0	300	10(3/2)	–	1.5	3.7	1.5	5.0	NTC1868	
2N5840	RCA	N	1	100	3.0	375	10(3/2)	–	1.7	3.0	1.5	5.0	NTC1868	
2N5867	MOTA	P	1	87	5.0	60	20(4/1.5)	500 m	0.7	1.0	0.8	4.0	NTA959	
2N5868	MOTA	P	1	87	5.0	80	20(4/1.5)	500 m	0.7	1.0	0.8	4.0	NTA959	
2N5869	SPC STC TII	N	1	87	5.0	60	20(4/1.5)	500 m	0.7	1.0	0.8	4.0	NTC1866	
2N5870	SPC STC TII	N	1	87	5.0	80	20(4/1.5)	500 m	0.7	1.0	0.8	4.0	NTC1866	
2N5871	SPC STC TII	P	1	115	7.0	60	20(4/2.5)	250 m	0.7	1.0	0.8	4.0	NTA959	
2N5872	SPC STC TII	P	1	115	7.0	80	20(4/2.5)	250 m	0.7	1.0	0.8	4.0	NTA959	
2N5873	SPC STC TII	N	1	115	7.0	60	20(4/2.5)	250 m	0.7	1.0	0.8	4.0	NTC1869	
2N5874	SPC STC TII	N	1	115	7.0	80	20(4/2.5)	250 m	0.7	1.0	0.8	4.0	NTC1869	
2N5875	MOTA	P	1	150	10	60	20(4/4)	200 m	0.7	1.0	0.8	4.0	NTA959	
2N5876	MOTA	P	1	150	10	80	20(4/4)	200 m	0.7	1.0	0.8	4.0	NTA959	

PACKAGE (JEDEC)
1:TO-3
2:TO-66
3:TO-5 or TO-39

* Lower h_{FE}
***** Shorter SW time
†:typical

TYPE NO.	MANUFACTURERS	POLALITY	PACKAGE	MAXIMUM RATINGS(T_a=25°C)			ELECTRICAL CHARACTERISTICS (T_a=25°C)						NEC TYPE NO.	NOTE
				P_T(W) (T_c=25°C)	$I_{C(DC)}$(A)	V_{CEO}(V)	h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX. t_r	t_{stg}	t_f	f_T(MHz) MIN.		
2N5877	MOTA	N	1	150	10	60	20(4/4)	200 m	0.7	1.0	0.8	4.0	NTC1869	
2N5878	MOTA	N	1	150	10	80	20(4/4)	200 m	0.7	1.0	0.8	4.0	NTC1869	
2N5879	MOTA	P	1	160	15	60	20(4/6)	142 m	0.7	1.0	0.8	4.0	NTA959	
2N5880	MOTA	P	1	160	15	80	20(4/6)	142 m	0.7	1.0	0.8	4.0	NTA959	
2N5881	MOTA	N	1	160	15	60	20(4/6)	142 m	0.7	1.0	0.8	4.0	NTC1869	
2N5882	MOTA	N	1	160	15	80	20(4/6)	142 m	0.7	1.0	0.8	4.0	NTC1869	
2N5883	MOTA	P	1	200	25	60	20(4/10)	66 m	0.7	1.0	0.8	4.0	NTA959	*
2N5884	MOTA	P	1	200	25	80	20(4/10)	66 m	0.7	1.0	0.8	4.0	NTA959	*
2N5885	MOTA	N	1	200	25	60	20(4/10)	66 m	0.7	1.0	0.8	4.0	NTC1869	*
2N5886	MOTA	N	1	200	25	80	20(4/10)	66 m	0.7	1.0	0.8	4.0	NTC1869	*
2N5970	SSI STC KER	N	1	85	15	V_{CEX} 80	20(1.5/5)	–	0.6	1.4	0.5	4.0	NTC1869	
2N5971	SSI STC KER	N	1	85	15	V_{CEX} 80	15(1.5/5)	–	0.6	1.4	0.5	4.0	NTC1869	
2N5972	SSI STC KER	N	1	85	15	V_{CEX} 90	25(1.5/5)	–	0.6	1.4	0.5	4.0	NTC1869	
2N5973	SSI STC KER	N	1	85	15	V_{CEX} 100	25(1.5/0.5)	–	0.6	1.4	0.5	4.0	NTC1869	
2N6107	RCA	P	4	40	7.0	70	30(4/2)	500m	–			10	NTA1010	
2N6109	RCA	P	4	40	7.0	50	30(4/2.5)	400m	–			10	NTA1010	
2N6111	RCA	P	4	40	7.0	30	30(4/3)	333m	–			10	NTA1010	
2N6233	MOTA	N	2	50	5.0	225	25(5/0.1)	500m	t_r 0.5	t_{stg} 3.5	t_f 0.5	20	NTC1864	
2N6234	MOTA	N	2	50	5.0	275	25(5/0.1)	500m	0.5	3.5	0.5	20	NTC1865	
2N6232	GSE	N	2	15	10	100	40(2/0.5)	–	t_{on} 0.25		t_{off} 1.3	30	NTC1860	*
2N6235	MOTA	N	2	50	5.0	325	25(5/0.1)	500m	t_r 0.5	t_{stg} 3.5	t_f 0.5	20	NTC1865	
2N6249	MOTA	N	1	100	10	$V_{CEO(SUS)}$ 225	10(3/10)	150m	2.0	3.5	1.0	2.5	NTC1870	
2N6250	MOTA	N	1	100	10	$V_{CEO(SUS)}$ 300	8.0(3/10)	150m	2.0	3.5	1.0	2.5	NTC1871A	
2N6251	MOTA	N	1	100	10	$V_{CEO(SUS)}$ 375	6.0(3/10)	150m	2.0	3.5	1.0	2.5	NTC1871A	
2N6288	RCA	N	4	40	7.0	30	30(4/3)	333m	–			4	NTC2334	

PACKAGE (JEDEC)
1:TO-3
2:TO-66
4:TO-220AB

* Lower h_{FE}

10

TYPE NO.	MANUFAC-TURERS	POLALITY	PACKAGE	MAXIMUM RATINGS(Ta=25°C) P_T(W) (T_c=25°C)	I_C(DC)(A)	V_{CEO}(V)	ELECTRICAL CHARACTERISTICS (Ta=25°C) h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX. t_r	t_{stg}	t_f	f_T(MHz) MIN.	NEC TYPE NO.	NOTE
2N6290	RCA	N	4	40	7.0	50	30(4/2.5)	400m	–			4	NTC2334	
2N6292	RCA	N	4	40	7.0	70	30(4/2)	500m	–			4	NTC2334	
2N6306	MOTA	N	1	125	8.0	250	15(5/3)	–	0.6	1.6	0.4	5.0	NTC1868	
2N6307	MOTA	N	1	125	8.0	300	15(5/3)	–	0.6	1.6	0.4	5.0	2N6544	
2N6308	MOTA	N	1	125	8.0	350	12(5/3)	–	0.6	1.6	0.4	5.0	2N6545	
2N6315	MOTA	N	2	90	7.0	60	20(4/2.5)	–	0.7	1.0	0.8	4	NTC1863	
2N6316	MOTA	N	2	90	7.0	80	20(4/2.5)	–	0.7	1.0	0.8	4.0	NTC1863	
2N6317	MOTA	P	2	90	7.0	60	20(4/2.5)	–	0.7	1.0	0.8	4.0	–	
2N6318	MOTA	P	2	90	7.0	80	20(4/2.5)	–	0.7	1.0	0.8	4.0	–	
2N6338	MOTA	N	1	200	25	100	12(2/25)	–	0.3	1.0	0.25	40	NTC1869	*
2N6339	MOTA	N	1	200	25	120	12(2/25)	–	0.3	1.0	0.25	40	NTC1869	*
2N6340	MOTA	N	1	200	25	140	12(2/25)	–	0.3	1.0	0.25	40	NTC1870	*
2N6341	MOTA	N	1	200	25	150	12(2/25)	–	0.3	1.0	0.25	40	NTC1870	*
2N6436	MOTA	P	1	200	25	80	12(2/25)	–	0.3	1.0	0.25	40	NTA959	*
2N6437	MOTA	P	1	200	25	100	12(2/25)	–	0.3	1.0	0.25	40	NTA959	*
2N6438	MOTA	P	1	200	25	120	12(2/25)	–	0.3	1.0	0.25	40	NTA959	*
2N6473	RCA	N	4	40	4.0	100	15(4/1.5)	800m	–			4	NTC2333	
2N6475	RCA	P	4	40	4.0	100	15(4/1.5)	800m	–			10	NTA1008	
2N6486	RCA	N	4	75	15	40	20(4/5)	260m	–			5	NTC2334	
2N6487	RCA	N	4	75	15	60	20(4/5)	260m	–			5	NTC2334	
2N6488	RCA	N	4	75	15	80	20(4/5)	260m	–			5	NTC2334	
2N6489	RCA	P	4	75	15	40	20(4/5)	260m	–			5	NTA1010	
2N6490	RCA	P	4	75	15	60	20(4/5)	260m	–			5	NTA1010	
2N6491	RCA	P	4	75	15	80	20(4/5)	260m	–			5	NTA1010	
2N6496	RCA	N	1	140	15	$V_{CEO(SUS)}$ 130	12(2/8)	125m	0.5	1.5	0.5	60	NTC1870	

PACKAGE (JEDEC)
1:TO-3
2:TO-66
4:TO-220AB

* Lower h_{FE}

TYPE NO.	MANUFAC-TURERS	POLARITY	PACKAGE	MAXIMUM RATINGS(T_a=25°C)			ELECTRICAL CHARACTERISTICS (T_a=25°C)				NEC TYPE NO.	NOTE
				P_T(W) (T_c=25°C)	I_C(DC)(A)	V_{CEO}(V)	h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX.	f_T(MHz) MIN.		
2N6500	RCA	N	2	35	4.0	$V_{CEO(SUS)}$ 110	10(12/4)	500m	t_r t_{stg} t_f 0.4 1.0 0.5	60	NTC1864	
2N6510	RCA	N	1	120	7.0	200	10(3/3)	500m	t_r t_d t_{stg} t_f 1.5 0.2 5.0 1.5	3.0	NTC1867	
2N6511	RCA	N	1	120	7.0	250	10(3/4)	375m	1.5 0.2 5.0 1.5	3.0	NTC1867	
2N6512	RCA	N	1	120	7.0	300	10(2/4)	375m	1.5 0.2 5.0 1.5	3.0	NTC1868	
2N6513	RCA	N	1	120	7.0	350	10(3/4)	375m	1.5 0.2 5.0 1.5	3.0	NTC1868	
2N6514	RCA	N	1	120	7.0	300	10(3/5)	300m	1.5 0.2 5.0 1.5	3.0	NTC1868	
2N6542	MOTA	N	1	100	5.0	$V_{CEO(SUS)}$ 300	12(2/1.5)	1.0	0.7 0.05 4.0 0.8	24†	2N6544	
2N6543	MOTA	N	1	100	5.0	$V_{CEO(SUS)}$ 400	12(2/1.5)	1.0	0.7 0.05 4.0 0.8	24†	2N6545	
2N6544	MOTA	N	1	125	10	$V_{CEO(SUS)}$ 300	7(3/5)	300m	1.0 0.05 4.0 1.0	24†	2N6544	
2N6545	MOTA	N	1	125	10	$V_{CEO(SUS)}$ 400	7(3/5)	300m	1.0 0.05 4.0 1.0	24†	2N6545	
2N6546	MOTA	N	1	175	15	$V_{CEO(SUS)}$ 300	6(2/10)	150m	1.0 0.05 4.0 0.7	24†	2N6546	
2N6547	MOTA	N	1	175	15	$V_{CEO(SUS)}$ 400	6(2/10)	150m	1.0 0.05 4.0 0.7	24†	2N6547	
2N6561	SOD	N	1	220	10	$V_{CEO(SUS)}$ 300	10(2/10)	75m	0.5 0.1 1.2 0.5	15	NTC1871A	*
2N6569	MOTA	N	1	100	12	$V_{CEO(SUS)}$ 40	15(3/4)	333m	1.5 0.4 5.0 1.5	15	NTC1866	
2N6573	DEL	N	1	125	10	250	5(5/10)	214m	0.9 0.15 2.5 0.7	15	2N6544	
2N6574	DEL	N	1	125	10	275	5(5/10)	214m	0.9 0.15 2.5 0.7	15	2N6545	
2N6575	DEL	N	1	125	10	300	5(5/10)	214m	0.9 0.15 2.5 0.7	15	NTC1868	
2N6579	TRW	N	1	125	10	$V_{CEO(SUS)}$ 350	7(3/5)	300m	0.5 0.05 2.0 0.5	25	NTC1871A	
2N6580	TRW	N	1	125	10	$V_{CEO(SUS)}$ 400	7(3/5)	300m	0.5 0.05 2.0 0.5	25	NTC1871A	
2N6581	TRW	N	1	125	10	$V_{CEO(SUS)}$ 450	7(3/5)	300m	0.5 0.05 2.0 0.5	25	NTC1871A	
2N6582	TRW	N	1	125	10	$V_{CEO(SUS)}$ 350	7(3/7)	214m	0.5 0.05 2.0 0.5	25	NTC1871A	
2N6583	TRW	N	1	125	10	$V_{CEO(SUS)}$ 400	7(3/7)	214m	0.5 0.05 2.0 0.5	25	NTC1871A	
2N6584	TRW	N	1	125	10	$V_{CEO(SUS)}$ 450	7(3/7)	214m	0.5 0.05 2.0 0.5	25	NTC1871A	
2N6594	MOTA	P	1	100	12	$V_{CEO(SUS)}$ 40	15(3/4)	375m	1.5 0.5 5.0 1.5	2.5	NTA959	
2N6669	RCA	N	5	40	10	$V_{CEO(SUS)}$ 30	20(2/5)	200m	0.3 0.05 0.5 0.5	10	NTC2334	*

PACKAGE (JEDEC)
1:TO-3
2:TO-66

* Lower h_{FE}
†: typical

10

TYPE NO.	MANUFAC-TURERS	POLALITY	PACKAGE	MAXIMUM RATINGS (T_a=25°C) P_T(W) (T_c=25°C)	$I_{C(DC)}$(A)	V_{CEO}(V)	ELECTRICAL CHARACTERISTICS (T_a=25°C) h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX.	f_T(MHz) MIN.	NEC TYPE NO.	NOTE
2N6671	RCA	N	1	150	8.0	$V_{CEO(SUS)}$ 300	10(3/5)	300m	0.5 0.1 2.5 0.4	15	NONE	
2N6672	RCA	N	1	150	8.0	$V_{CEO(SUS)}$ 350	10(3/5)	300m	0.5 0.1 2.5 0.4	15	NONE	
2N6773	RCA	N	1	150	8.0	$V_{CEO(SUS)}$ 400	10(3/5)	300m	0.5 0.1 2.5 0.4	15	NONE	
2N6674	RCA	N	1	175	15	$V_{CEO(SUS)}$ 300	8(2/10)	333m	0.6 0.1 2.5 0.5	15	NONE	
2N6675	RCA	N	1	175	15	$V_{CEO(SUS)}$ 400	8(2/10)	333m	0.6 0.1 2.5 0.5	15	NONE	
2N6676	RCA	N	1	175	15	$V_{CEO(SUS)}$ 300	8(3/15)	100m	0.6 0.1 2.5 0.5	15	NONE	
2N6677	RCA	N	1	175	15	$V_{CEO(SUS)}$ 350	8(3/15)	100m	0.6 0.1 2.5 0.5	15	NONE	
2N6678	RCA	N	1	175	15	$V_{CEO(SUS)}$ 400	8(3/15)	100m	0.6 0.1 2.5 0.5	15	NONE	
1843–2005	SSI	N	1	150	30	200	20(5/5)	200m	t_{on} t_{stg} t_f 0.5 1.5 1.0	25	NTC1870	
2010	SSI	N	1	150	30	200	15(5/10)	125m	0.5 1.5 1.0	25	NTC1870	
1843–2020	SSI	N	1	150	30	200	10(5/20)	87m	t_{on} t_{stg} t_f 0.5 1.5 1.0	25	NTC1870	*
2205	SSI	N	1	150	30	225	20(5/5)	200m	0.5 1.5 1.0	25	NTC1870	
2210	SSI	N	1	150	30	225	15(5/10)	125m	0.5 1.5 1.0	25	NTC1870	
2220	SSI	N	1	150	30	225	10(5/20)	87m	0.5 1.5 1.0	25	NTC1870	*
2505	SSI	N	1	150	30	250	20(5/5)	200m	0.5 1.5 1.0	25	NTC1870	
2510	SSI	N	1	150	30	250	15(5/10)	125m	0.5 1.5 1.0	25	NTC1870	
2520	SSI	N	1	150	30	250	10(5/20)	87m	0.5 1.5 1.0	25	NTC1870	*
2705	SSI	N	1	150	30	250	20(5/5)	200m	0.5 1.5 1.0	25	NTC1870	
2710	SSI	N	1	150	30	275	15(5/10)	125m	0.5 1.5 1.0	25	NTC1871A	*
2720	SSI	N	1	150	30	275	10(5/20)	87m	0.5 1.5 1.0	25	NTC1871A	*
3005	SSI	N	1	150	30	275	20(5/5)	200m	0.5 1.5 1.0	25	NTC1871A	*
3010	SSI	N	1	150	30	300	15(5/10)	125m	0.5 1.5 1.0	25	NTC1871A	*
3020	SSI	N	1	150	30	300	10(5/20)	87m	0.5 1.5 1.0	25	NTC1871A	*
3205	SSI	N	1	150	30	300	20(5/5)	200m	0.5 1.5 1.0	25	NTC1871A	*
3210	SSI	N	1	150	30	325	15(5/10)	125m	0.5 1.5 1.0	25	NTC1871A	*

PACKAGE (JEDEC)
1:TO-3

* Lower h_{FE}

TYPE NO.	MANUFAC-TURERS			MAXIMUM RATING (Ta=25°C)			ELECTRICAL CHARACTERISTICS (Ta=25°C)				NEC TYPE NO.	NOTE
				P_T(W) (T_c=25°C)	$I_{C(DC)}$(A)	V_{CEO}(V)	h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX.	f_T(MHz) MIN.		
3220	SSI	N	1	150	30	325	10(5/20)	87m	0.5 1.5 1.0	25	NTC1871A	*
3505	SSI	N	1	150	30	325	20(5/5)	200m	0.5 1.5 1.0	25	NTC1871A	*
3510	SSI	N	1	150	30	350	15(5/10)	125m	0.5 1.5 1.0	25	NTC1871A	*
3520	SSI	N	1	150	30	350	10(5/20)	87m	0.5 1.5 1.0	25	NTC1871A	*
3705	SSI	N	1	150	30	375	20(5/5)	200m	0.5 1.5 1.0	25	NTC1871A	*
3710	SSI	N	1	150	30	375	15(5/10)	125m	0.5 1.5 1.0	25	NTC1871A	*
3720	SSI	N	1	150	30	375	10(5/20)	87m	0.5 1.5 1.0	25	NTC1871A	*
MJ3771	MOTA	N	1	200	30	40	15(4/15)	66m	0.5 1.5 1.0	25	NTC1869	*
MJ3772	MOTA	N	1	200	20	60	15(4/10)	80m	0.7 1.0 0.8	2.0	NTC1869	
MJ3773	MOTA	N	1	200	16	140	15(4/8)	100m	1.5 2.0 1.8	1.0	NTC1870	
MJ7160	MOTA	N	1	140	8.0	300	25(5/3)	333m	t_{on} t_{stg} t_f 0.2 2.0 0.3	30	NTC1868	*
MJ7161	MOTA	N	1	140	8.0	400	25(5/3)	333m	0.2 2.0 0.3	30	NTC1868	*
MJ7260	MOTA	N	1	175	15	300	25(5/5)	200m	0.2 2.0 0.3	30	NTC1871A	*
MJ7261	MOTA	N	1	175	15	400	25(5/5)	200m	0.2 2.0 0.3	30	NTC1871A	*
MJE340	MOTA	N	5		0.5	300	30(10/50m)				NT340	
MJE350	MOTA	P	5		0.5	300	30(10/50m)				NT350	
MJE13005	MOTA	N	4	80	8.0	300	8(5/2)	500m	t_r t_d t_{stg} t_f 1.0 0.1 3.0 0.7	4	NTC2335	** V_{CEV}:600V
MJE13006	MOTA	N	4	80	8.0	400	8(5/2)	500m	1.0 0.1 3.0 0.7	4	NTC2335	** V_{CEV}:700V
MJE13007	MOTA	N	4	100	12	300	8(5/5)	200m	1.0 0.1 3.0 0.7	4	NTC2335	** V_{CEV}:600V
MJE13008	MOTA	N	4	100	12	400	8(5/5)	200m	1.0 0.1 3.0 0.7	4	NTC2335	** V_{CEV}:700V
PTC174RT	MAL	P	1	250	30	100	20(2/4)	–	t_r t_f 0.7 1.1	2.0†	2SA959	
PTC175RT	MAL	N	1	250	30	100	20(2/4)	–	0.7 1.1	2.0†	NTC1869	
RCA410	RCA	N	1	125	7.0	$V_{CEO(SUS)}$ 200	10(5/2.5)	800m	t_r t_{stg} t_f 0.35 1.4 0.15	4.0	NTC1867	
RCA411	RCA	N	1	125	7.0	$V_{CEO(SUS)}$ 300	10(5/2.5)	800m	0.35 1.4 0.15	2.5	NTC1868	
RCA412	RCA	N	1	125	7.0	$V_{CEO(SUS)}$ 325	15(5/1.0)	800m	0.35 1.4 0.15	4.0	NTC1868	
TA8427A	RCA	P	1	175	15	$V_{CEO(SUS)}$ 50	20(2/20)	100m	1.0 2.0 1.0	4.0	NTA959	*
TA8427B	RCA	P	1	175	15	$V_{CEO(SUS)}$ 60	20(2/20)	100m	1.0 2.0 1.0	4.0	NTA959	*

PACKAGE (JEDEC)
1: TO-3 4: TO-220AB 5: TO-126

* Lower h_{FE}
†: typical

10

TYPE NO.	MANUFAC-TURERS	POLALITY	PACKAGE	MAXIMUM RATINGS(T_a=25°C) P_T(W) (T_c=25°C)	$I_{C(DC)}$(A)	V_{CEO}(V)	ELECTRICAL CHARACTERISTICS (T_a=25°C) h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (µs) MAX.	f_T(MHz) MIN.	NEC TYPE NO.	NOTE
TA8427C	RCA	P	1	175	15	$V_{CEO(SUS)}$ 70	20(2/20)	100m	1.0 2.0 1.0	4.0	NTA959	*
TA8662A	RCA	N	1	175	15	$V_{CEO(SUS)}$ 50	10(2/20)	67m	1.0 2.0 1.0	4.0	NTC1869	*
TA8662B	RCA	N	1	175	15	$V_{CEO(SUS)}$ 60	10(2/20)	67m	1.0 2.0 1.0	4.0	NTC1869	*
TA8662C	RCA	N	1	175	15	$V_{CEO(SUS)}$ 70	10(2/20)	67m	1.0 2.0 1.0	4.0	NTC1869	*
TA8767A	RCA	N	1	150	10	$V_{CEO(SUS)}$ 300	12(3/6)	210m	0.3 1.7 0.3	4.0	NTC1871A	
TA8767B	RCA	N	1	150	10	$V_{CEO(SUS)}$ 350	12(3/6)	210m	0.3 1.7 0.3	4.0	NTC1871A	
TA8767C	RCA	N	1	150	10	$V_{CEO(SUS)}$ 400	12(3/6)	210m	0.3 1.7 0.3	4.0	NTC1871A	
RCS564	SPC	N	1	175	10	$V_{CEO(SUS)}$ 200	5(3/10)	250m	2.0 3.5 1.0	8.0†	NTC1870	
RCS579	RCA	N	1	125	8.0	$V_{CEO(SUS)}$ 250	12(5/3)	180m	0.6 2.0 0.4	—	NTC1867	
DTS103	STI	N	1	125	15	60	20(1.5/5)	150m	0.55† 1.0† 0.35†	4.0	NTC1869	
DTS104	STI	N	1	125	15	60	50(1.5/5)	180m	t_r t_{stg} t_f 0.55† 1.0† 0.35†	4.0	NTC1869	*
DTS105	STI	N	1	125	15	80	20(1.5/5)	180m	0.55† 1.0† 0.35†	4.0	NTC1869	
DTS106	STI	N	1	125	15	90	20(1.5/5)	180m	0.55† 1.0† 0.35†	4.0	NTC1869	
DTS107	STI	N	1	125	15	100	20(1.5/5)	180m	0.55† 1.0† 0.35†	4.0	NTC1869	
DTS410	DEL	N	1	100	35	$V_{CEO(SUS)}$ 200	30(5/1)	800m	0.25† 0.6† 0.15†	2.0	NTC1867	
DTS515	DEL	N	1	125	10	$V_{CEO(SUS)}$ 250	15(5/3)	600m	0.4† 1.0† 0.25†	5.0†	NTC1871A	
DTS516	DEL	N	1	125	10	$V_{CEO(SUS)}$ 250	20(5/3)	500m	0.4† 1.0† 0.25†	5.0†	NTC1871A	
DTS517	DEL	N	1	125	10	$V_{CEO(SUS)}$ 250	20(5/3)	400m	0.4† 1.0† 0.25†	5.0†	NTC1871A	
DTS518	DEL	N	1	125	10	$V_{CEO(SUS)}$ 275	25(5/3)	333m	0.4† 1.0† 0.25†	5.0†	2N6544	
DTS519	DEL	N	1	125	10	$V_{CEO(SUS)}$ 300	25(5/3)	333m	0.4† 1.0† 0.25†	5.0†	2N6545	
SDT7731	PPC SSI SOD	N	1	125	10	40	20(5/5)	100m	t_{on} t_{off} 0.4† 0.6†	5.0	NTC1869	
SDT7732	PPC SSI SOD	N	1	125	10	60	20(5/5)	100m	0.4† 0.6†	5.0	NTC1869	
SDT7733	PPC SSI SOD	N	1	125	10	80	20(5/5)	100m	0.4† 0.6†	5.0	NTC1869	
SDT7734	PPC SSI SOD	N	1	125	10	100	20(5/5)	100m	0.4† 0.6†	5.0	NTC1869	
SDT7735	PPC SSI SOD	N	1	125	10	125	20(5/5)	100m	0.4† 0.6†	5.0	NTC1870	

PACKAGE (JEDEC)
1: TO-3

* Lower h_{FE}
†: typical

TYPE NO.	MANUFAC-TURERS	POLARITY	PACKAGE	MAXIMUM RATINGS(T_a=25°C) P_T(W) (T_c=25°C)	I_C(DC)(A)	V_{CEO}(V)	ELECTRICAL CHARACTERISTICS (T_a=25°C) h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX.	f_T(MHz) MIN.	NEC TYPE NO.	NOTE
SDT7736	PPC SSI SOD	N	1	125	10	150	20(5/5)	100m	0.4† 0.6†	5.0	NTC1870	
SDT7741	PPC SSI SOD	N	2	35	10	40	20(5/5)	100m	0.4† 0.6†	5.0	NTC1863	*
SDT7742	PPC SSI SOD	N	2	35	10	60	20(5/5)	100m	0.4† 0.6†	5.0	NTC1863	*
SDT7743	PPC SSI SOD	N	2	35	10	80	20(5/5)	100m	0.4† 0.6†	5.0	NTC1863	*
SDT7744	PPC SSI SOD	N	2	35	10	100	20(5/5)	100m	0.4† 0.6†	5.0	NTC1863	*
SDT7745	PPC SSI SOD	N	2	35	10	125	20(5/5)	100m	0.4† 0.6†	5.0	NTC1864	*
SDT7746	PPC SSI SOD	N	2	35	10	150	20(5/5)	100m	0.4† 0.6†	5.0	NTC1864	*
SPT4624	SSI	N	1	87	10	350	30(5/2)	214m	t_r t_{stg} t_f 0.5 1.2 0.7	50	NTC1868	*
SPT4625	SSI	N	1	87	10	400	30(5/2)	214m	0.5 1.2 0.7	50	NTC1868	*
SPT5303	SSI	N	1	200	20	100	15(2/10)	100m	1 2 1	2.0	NTC1869	*
SSP3302	UNI	N	1	150	20	80	15(5/20)	70m	t_{on} t_{off} 0.5 2.0	40	NTC1869	*
SSP3303	UNI	N	1	150	20	60	15(5/20)	70m	0.5 2.0	40	NTC1869	
STA8309	STC	N	1	125	5.0	200	20(5/3)	333m	t_r 0.5 –	15	NTC1867	
STA8341	STC	N	1	100	10	400	10(5/10)	100m	2.0 –	2.5	NTC1871A	
16AJ101	SOD	N	2	44	10	200	5(5/5)	200m	t_{on} t_{stg} t_f 0.6† 0.5† 0.2†	–	NTC1864	
16SE101	SOD	N	1	177	10	200	5(5/5)	200m	0.6† 0.5† 0.2†	–	NTC1867	
D44C1	GESI	N	4	30	4.0	30	10(1/1)	500m	0.1† 0.5† 0.075†	50†	NTC2331	
D44C2	GESI	N	4	30	4.0	30	20(1/1)	500m	0.1† 0.5† 0.075	50†	NTC2331	
D44C3	GESI	N	4	30	4.0	30	20(1/2)	500m	0.1† 0.5† 0.075	50†	NTC2516	
D44C4	GESI	N	4	30	4.0	45	10(1/1)	500m	0.1† 0.5† 0.075	50†	NTC2331	
D44C5	GESI	N	4	30	4.0	45	20(1/1)	500m	0.1† 0.5† 0.075†	50†	NTC2331	
D44C6	GESI	N	4	30	4.0	45	20(1/2)	500m	0.1† 0.5† 0.075†	50†	NTC2516	
D44C7	GESI	N	4	30	4.0	60	10(1/1)	500m	0.1† 0.5† 0.075†	50†	NTC2331	
D44C8	GESI	N	4	30	4.0	60	20(1/1)	500m	0.1† 0.5† 0.075†	50†	NTC2331	
D44C9	GESI	N	4	30	4.0	60	20(1/2)	500m	0.1† 0.5† 0.075†	50†	NTC2516	

PACKAGE (JEDEC)
1:TO-3
2:TO-66
4:TO-220AB

* Lower h_{FE}
†: typical

10

TYPE NO.	MANUFAC-TURERS	POLALITY	PACKAGE	MAXIMUM RATINGS(T_a=25°C)			ELECTRICAL CHARACTERISTICS (T_a=25°C)				NEC TYPE NO.	NOTE
				P_T(W) (T_c=25°C)	$I_{C(DC)}$(A)	V_{CEO}(V)	h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX.	f_T(MHz) MIN.		
D44C10	GESI	N	4	30	4.0	80	10(1/1)	500m	0.1† 0.5† 0.075†	50†	NTC2331	
D44C11	GESI	N	4	30	4.0	80	20(1/1)	500m	0.1† 0.5† 0.075†	50†	NTC2331	
D44C12	GESI	N	4	30	4.0	80	20(1/2)	500m	0.1† 0.5† 0.075†	50†	NTC2516A	
D44H1	GESI	N	4	50	10	30	20(1/4)	125m	0.3† 0.5† 0.1†	50†	NTC2334	
D44H2	GESI	N	4	50	10	30	40(1/4)	125m	0.3† 0.5† 0.14†	50†	NTC2334	*
D44H4	GESI	N	4	50	10	45	20(1/4)	125m	0.3† 0.5† 0.14†	50†	NTC2334	
D44H5	GESI	N	4	50	10	45	40(1/4)	125m	0.3† 0.5† 0.14†	50†	NTC2334	*
D44H7	GESI	N	4	50	10	60	20(1/4)	125m	0.3† 0.5† 0.14†	50†	NTC2334	
D44H8	GESI	N	4	50	10	60	40(1/4)	125m	0.3† 0.5† 0.14†	50†	NTC2334	*
D44H10	GESI	N	4	50	10	80	20(1/4)	125m	0.3† 0.5† 0.14†	50†	NTC2334	
D44H11	GESI	N	4	50	10	80	40(1/4)	125m	t_{on} t_{stg} t_f 0.3† 0.5† 0.14†	50†	NTC2334	*
D44Q1	GESI	N	4	31.25	4.0	125	20(10/2)	500m	t_{stg} 2.0	50†	NTC2333	*
D44Q3	GESI	N	4	31.25	4.0	175	20(10/2)	500m	2.0	50†	NTC2333	*
D44Q5	GESI	N	4	31.25	4.0	225	20(10/2)	500m	2.0	50†	NTC2333	*
D44R1	GESI	N	4	31.25	1.0	$V_{CEO(SUS)}$ 250	30(10/0.5)	3.33	t_{on} t_{stg} t_f 3.7† 0.6† 1.9†	40†	NTC2333	*
D44R2	GESI	N	4	31.25	1.0	$V_{CEO(SUS)}$ 250	75(10/0.5)	3.33	3.7† 0.6† 1.9†	40†	NTC2333	*
D44R3	GESI	N	4	31.25	1.0	$V_{CEO(SUS)}$ 300	30(10/0.5)	3.33	3.7† 0.6† 1.9†	40†	NTC2333	*
D44R4	GESI	N	4	31.25	1.0	$V_{CEO(SUS)}$ 300	75(10/0.5)	3.33	3.7† 0.6† 1.9†	40†	NTC2333	*
D44R5	GESI	N	4	31.25	1.0	$V_{CEO(SUS)}$ 250	30(10/0.5)	3.33	3.7† 0.6† 1.9†	40†	NTC2333	*
D44R6	GESI	N	4	31.25	1.0	$V_{CEO(SUS)}$ 300	30(10/0.5)	3.33	3.7† 0.6† 1.9†	40†	NTC2333	*
D44R7	GESI	N	4	31.25	1.0	$V_{CEO(SUS)}$ 250	150(10/0.5)	3.33	3.7† 0.6† 1.9†	40†	NTC2333	*
D44R8	GESI	N	4	31.25	1.0	$V_{CEO(SUS)}$ 300	150(10/0.5)	3.33	3.7† 0.6† 1.9†	40†	NTC2333	*
D44T1	GESI	N	4	31.2	2.0	250	30(10/0.5)	2.0	–	45†	NTC2333	*
D44T2	GESI	N	4	31.2	2.0	250	75(10/0.5)	2.0	–	45†	NTC2333	*
D44T3	GESI	N	4	31.2	2.0	300	30(10/0.5)	2.0	–	45†	NTC2333	*
D44T4	GESI	N	4	31.2	2.0	300	75(10/0.5)	2.0	–	45†	NTC2333	*
D44T5	GESI	N	4	31.2	2.0	250	30(10/0.5)	3.33	–	45†	NTC2333	*

PACKAGE (JEDEC)
4: TO-220AB

* Lower h_{FE}
†: typical

TYPE NO.	MANUFAC-TURERS	POLALITY	PACKAGE	MAXIMUM RATINGS (Ta=25 °C)			ELECTRICAL CHARACTERISTICS (Ta=25 °C)				NEC TYPE NO.	NOTE
				P_T(W) (Tc=25 °C)	I_C(DC) (A)	V_{CEO}(V)	h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX.	f_T(MHz) MIN.		
D44T6	GESI	N	4	31.2	2.0	300	30(10/0.5)	3.33	–	45†	NTC2333	*
D44T7	GESI	N	4	31.2	2.0	250	150(10/0.5)	2.0	–	45†	NTC2333	*
D44T8	GESI	N	4	31.2	2.0	300	150(10/0.5)	2.0	–	45†	NTC2333	*
D45C1	GESI	P	4	30	4.0	30	10(1/1)	500m	t_{on} t_{stg} t_f 0.05† 0.5† 0.05†	40†	NTA1008	
D45C2	GESI	P	4	30	4.0	30	20(1/1)	500m	0.05† 0.5† 0.05†	40†	NTA1008	
D45C3	GESI	P	4	30	4.0	30	20(1/2)	500m	0.05† 0.5† 0.05†	40†	NTA1069	*
D45C4	GESI	P	4	30	4.0	45	10(1/1)	500m	0.05† 0.5† 0.05†	40†	NTA1008	
D45C5	GESI	P	4	30	4.0	45	20(1/1)	500m	0.05† 0.5† 0.05†	40†	NTA1008	
D45C6	GESI	P	4	30	4.0	45	20(1/2)	500m	0.05† 0.5† 0.05†	40†	NTA1069	*
D45C7	GESI	P	4	30	4.0	60	10(1/1)	500m	0.05† 0.5† 0.05†	40†	NTA1008	
D45C8	GESI	P	4	30	4.0	60	20(1/1)	500m	0.05† 0.5† 0.05†	40†	NTA1008	
D45C9	GESI	P	4	30	4.0	60	20(1/2)	500m	0.05† 0.5† 0.05†	40†	NTA1069	*
D45C10	GESI	P	4	30	4.0	80	10(1/1)	500m	t_{on} t_{stg} t_f 0.05† 0.5† 0.05†	40†	NTA1008	
D45C11	GESI	P	4	30	4.0	80	20(1/1)	500m	0.05† 0.5† 0.05†	40†	NTA1008	
D45C12	GESI	P	4	30	4.0	80	20(1/2)	500m	0.05† 0.5† 0.05†	40†	NTA1069A	*
D45H1	GESI	P	4	50	10	30	20(1/4)	125m	0.135† 0.5† 0.1†	40†	NTA1010	
D45H2	GESI	P	4	50	10	30	40(1/4)	125m	0.135† 0.5† 0.1†	40†	NTA1010	*
D45H4	GESI	P	4	50	10	45	20(1/4)	125m	0.135† 0.5† 0.1†	40†	NTA1010	
D45H5	GESI	P	4	50	10	45	40(1/4)	125m	0.135† 0.5† 0.1†	40†	NTA1010	*
D45H7	GESI	P	4	50	10	60	20(1/4)	125m	0.135† 0.5† 0.1†	40†	NTA1010	
D45H8	GESI	P	4	50	10	60	40(1/4)	125m	0.135† 0.5† 0.1†	40†	NTA1010	*
D45H10	GESI	P	4	50	10	80	20(1/4)	125m	0.135† 0.5† 0.1†	40†	NTA1010	
D45H11	GESI	P	4	50	10	80	40(1/4)	125m	0.135† 0.5† 0.1†	40†	NTA1010	*
TIP29	TII	N	4	30	1.0	40	15(4/1)	700m	t_{on} t_{off} 0.5† 2.0†	3	NTC2331	
TIP29A	TII	N	4	30	1.0	60	15(4/1)	700m	0.5† 2.0†	3	NTC2331	
TIP29B	TII	N	4	30	1.0	80	15(4/1)	700m	0.5† 2.0†	3	NTC2331	
TIP29C	TII	N	4	30	1.0	100	15(4/1)	700m	0.5† 2.0†	3	NTC2331	
TIP30	TII	P	4	30	1.0	40	15(4/1)	700m	0.3† 1.0†	3	NTA1008	
TIP30A	TII	P	4	30	1.0	60	15(4/1)	700m	0.3† 1.0†	3	NTA1008	

PACKAGE (JEDEC)
4: TO-220AB

* Lower h_{FE}
†: typical

10

TYPE NO.	MANUFAC-TURERS	POLARITY	PACKAGE	MAXIMUM RATINGS (Ta=25°C)			ELECTRICAL CHARACTERISTICS (Ta=25°C)					NEC TYPE NO.	NOTE
				P_T(W) (T_c=25°C)	I_C(DC) (A)	V_{CEO}(V)	h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX. t_{on}	t_{off}	f_T(MHz) MIN.		
TIP30B	TII	P	4	30	1.0	80	15(4/1)	700m	0.3†	1.0†	3	NTA1008	
TIP30C	TII	P	4	30	1.0	100	15(4/1)	700m	0.3†	1.0†	3	NTA1008	
TIP31	TII	N	4	40	3.0	40	10(4/3)	400m	0.5†	2.0†	3	NTC2516	
TIP31A	TII	N	4	40	3.0	60	10(4/3)	400m	0.5†	2.0†	3	NTC2516	
TIP31B	TII	N	4	40	3.0	80	10(4/3)	400m	0.5†	2.0†	3	NTC2516A	
TIP31C	TII	N	4	40	3.0	100	10(4/3)	400m	0.5†	2.0†	3	NTC2334	
TIP32	TII	P	4	40	3.0	40	10(4/3)	400m	0.3†	1.0†	3	NTA1069	
TIP32A	TII	P	4	40	3.0	60	10(4/3)	400m	0.3†	1.0†	3	NTA1069	
TIP32B	TII	P	4	40	3.0	80	10(4/3)	400m	0.3†	1.0†	3	NTA1069A	
TIP32C	TII	P	4	40	3.0	100	10(4/3)	400m	0.3†	1.0†	3	NTA1010	
TIP41	TII	N	4	65	6.0	40	15(4/3)	250m	0.6†	1.0†	3	NTC2334	
TIP41A	TII	N	4	65	6.0	60	15(4/3)	250m	0.6†	1.0†	3	NTC2334	
TIP41B	TII	N	4	65	6.0	80	15(4/3)	250m	t_{on} 0.6†	t_{off} 1.0†	3	NTC2334	
TIP41C	TII	N	4	65	6.0	100	15(4/3)	250m	0.6†	1.0†	3	NTC2334	
TIP42	TII	P	4	65	6.0	40	15(4/3)	250m	0.4†	0.7†	3	NTA1010	
TIP42A	TII	P	4	65	6.0	60	15(4/3)	250m	0.4†	0.7†	3	NTA1010	
TIP42B	TII	P	4	65	6.0	80	15(4/3)	250m	0.4†	0.7†	3	NTA1010	
TIP42C	TII	P	4	65	6.0	100	15(4/3)	250m	0.4†	0.7†	3	NTA1010	
TIP47	TII	N	4	40	1.0	250	10(10/1)	1.0	0.2†	2.0†	10	NTC2333	*
TIP48	TII	N	4	40	1.0	300	10(10/1)	1.0	0.2†	2.0†	10	NTC2333	*
TIP49	TII	N	4	40	1.0	350	10(10/1)	1.0	0.2†	2.0†	10	NTC2333	*
TIP50	TII	N	4	40	1.0	400	10(10/1)	1.0	0.2†	2.0†	10	NTC2333	*

PACKAGE (JEDEC)
4: TO-220AB

* Lower h_{FE}
†: typical

CROSS-REFERENCE GUIDE FOR NEC HIGH SPEED SWITCHING POWER TRANSISTORS PART–2 (EUROPIAN TYPE)

TYPE NO.	MANUFAC-TURERS	POLALITY	PACKAGE	MAXIMUM RATINGS(T_a=25°C) P_T(W) (T_c=25°C)	I_C(DC)(A)	V_{CEO}(V)	ELECTRICAL CHARACTERISTICS (T_a=25°C) h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX.	f_T(MHz) MIN.	NEC TYPE NO.	NOTE
BDX91	ELMA PHIN RTCF VALG	N	1	90	8.0	60	20(2/3)	266 m	t_{on} 1.0 t_{off} 2.0	4.0	NTC1866	
BDX92	ELMA PHIN RTCF VALG	P	1	90	8.0	60	20(2/3)	266 m	1.0 2.0	4.0	NTA959	
BDX93	ELMA PHIN RTCF VALG	N	1	90	8.0	80	20(2/3)	266 m	1.0 2.0	4.0	NTC1866	
BDX94	ELMA PHIN RTCF VALG	P	1	90	8.0	80	20(2/3)	266 m	1.0 2.0	4.0	NTA959	
BDX95	ELMA PHIN RTCF VALG	N	1	90	8.0	100	20(2/3)	266 m	1.0 2.0	4.0	NTC1866	
BDX96	ELMA PHIN RTCF VALG	P	1	90	8.0	100	20(2/3)	266 m	1.0 2.0	4.0	NTA959	
BDY42	ALGG	N	1	60	5.0	250	10(2/1)	300 m	t_{on} 2.0 t_f 1.0	10	NTC1868	
BDY43	ALGG	N	1	60	5.0	300	10(2/1)	300 m	2.0 1.0	10	2N6544	
BDY44	ALGG	N	1	60	5.0	350	10(2/1)	300 m	2.0 1.0	10	2N6545	
BDY45	ALGG	N	1	95	15	250	20(2/2)	100 m	3.0 1.0	10	NTC1871A	
BDY46	ALGG	N	1	95	15	300	20(2/2)	100 m	3.0 1.0	10	2N6546	
BDY47	ALGG	N	1	95	15	350	20(2/2)	100 m	3.0 1.0	10	2N6547	
BDY90	MULB NASB PHIN RTCF	N	1	80	10	100	30(5/5)	150 m	t_{on} 0.35 t_{stg} 1.3 t_f 0.2	70†	NTC1869	*
BDY91	VALG	N	1	80	10	80	30(5/5)	150 m	0.35 1.3 0.2	70†	NTC1869	*
BDY92	VALG	N	1	80	10	60	30(5/5)	100 m	0.35 1.3 0.2	70†	NTC1869	*
BDY93	VALG	N	1	40	3.0	350	15(5/1)	1.0	0.5 3.0 0.6	8.0†	NTC1868	
BDY93/01	MULB	N	1	75	4.0	400	30†(5/1)	600 m	0.5 3.0 0.4†	10†	NTC1868	
BDY94	APX.MULB PHIN RTCF VALG	N	1	40	3.0	300	25(5/1)	1.0	0.5 3.5 1.0	8.0†	NTC1868	*
BDY94/01	MULB	N	1	75	4.0	300	30†(5/1)	600 m	0.5 3.5 0.5†	10†	NTC1868	
BDY96	MULB PHIN RTCF VALG	N	1	62	10	350	15(5/2)	200 m	0.5 3.0 0.4	10†	NTC1868	
BDY96/01	MULB	N	1	100	10	400	30†(5/2)	300 m	0.5 3.0 0.3†	10†	NTC1868	

PACKAGE (JEDEC)
1:TO-3

* Lower h_{FE}
†: typical

10

TYPE NO.	MANUFACTURERS	POLARITY	PACKAGE	MAXIMUM RATINGS(Ta=25°C) P_T(W) (T_c=25°C)	I_C(DC)(A)	V_{CEO}(V)	ELECTRICAL CHARACTERISTICS (Ta=25°C) h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX.	f_T(MHz) MIN.	NEC TYPE NO.	NOTE
BDY97	APX, VALG MULB PHIN RTCF	N	1	62	10	300	25(5/2)	300 m	t_{on} 0.5 t_{stg} 3.0 t_f 0.9	10†	NTC1868	*
BDY97/01	MULB	N	1	62	10	300	30†(5/2)	300 m	0.5 3.5 0.4†	10†	NTC1868	
BDY98	APX	N	1	100	10	250	25(5/2)	300 m	0.5 4.0 0.9	10†	NTC1868	*
BFX34	ALGG MULB NASB PHIN VALG	N	1	50	5.0	60	40(2/2)	–	t_{on} 0.6 t_{off} 1.2	70	NTC1868	*
BLY47	TIIB	N	1	40	3.0	75	30(10/1)	–	1.0 3.0	15	NTC1866	*
BLY47A	TIIB	N	2	40	3.0	75	30(10/1)	–	1.0 3.0	15	NTC1863	*
BLY48	TIIB	N	1	40	3.0	75	60(10/1)	–	1.0 3.0	15	NTC1866	*
BLY48A	TIIB	N	2	40	3.0	75	60(10/1)	–	1.0 3.0	15	NTC1863	*
BLY49	TIIB	N	1	40	3.0	150	30(10/1)	–	1.0 3.0	15	NTC1867	*
BLY49A	TIIB	N	2	40	3.0	150	30(10/1)	–	1.0 3.0	15	NTC1864	*
BLY50	TIIB	N	1	40	3.0	150	60(10/1)	–	1.0 3.0	15	NTC1867	*
BLY50A	TIIB	N	2	40	3.0	150	60(10/1)	–	1.0 3.0	15	NTC1864	*
BSV64	MULB PHIC PHIN RTCF TADI	N	3	5.0	2.0	60	40(2/2)	200 m	0.6 1.2	100†	NTC1860	*
BSW65	MULB VALG	N	3	5.0	1.0	80	15(5/1)	1.0	0.5† 10†	80†	NTC1860	
BUX10	MISI NPC THCF	N	1	150	25	$V_{CEO(SUS)}$ 125	20(2/10)	60 m	t_{on} 1.5 t_{stg} 1.2 t_f 0.2	8.0	NTC1869	*
BUX11	MISI NPC THCF SSCF	N	1	150	20	$V_{CEO(SUS)}$ 200	20(2/6)	100 m	1.5 1.2 0.5	8.0	NTC1870	*
BUX12	MISI NPC THCF SSCF	N	1	150	20	$V_{CEO(SUS)}$ 250	20(4/5)	200 m	1.5 1.2 0.5	8.0	NTC1870	
BUX13	MISI NPC THCF SSCF	N	1	150	15	$V_{CEO(SUS)}$ 325	15(4/5)	200 m	2.0 1.5 1.0	8.0	NTC1871A	
BUX14	MISI NPC THCF SSCF	N	1	150	10	$V_{CEO(SUS)}$ 400	15(4/3.5)	171 m	2.0 2.0 1.0	8.0	NTC1871A	
BUX15	MISI NPC THCF SSCF	N	1	150	10	$V_{CEO(SUS)}$ 500	15(4/2.5)	240 m	2.0 2.5 1.5	8.0	NTC1868	**
BUX17	RCAB	N	1	150	10	$V_{CEO(SUS)}$ 150	20(3/4)	200 m	2.0 3.5 1.0	2.5	NTC1870	
BUX17A	RCAB	N	1	150	10	$V_{CEO(SUS)}$ 250	20(3/4)	200 m	2.0 3.5 1.0	2.5	NTC1870	

PACKAGE (JEDEC)
1:TO-3
2:TO-66
3:TO-5 or TO-39

* Lower h_{FE}
** Lower $V_{CEO(SUS)}$
†: typical

TYPE NO.	MANUFAC-TURERS	POLALITY	PACKAGE	MAXIMUM RATINGS(Ta=25°C) P_T(W) (T_c=25°C)	$I_{C(DC)}$(A)	V_{CEO}(V)	ELECTRICAL CHARACTERISTICS (Ta=25°C) h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX. t_{on}	t_{stg}	t_f	f_T(MHz) MIN.	NEC TYPE NO.	NOTE
BUX17B	RCAB	N	1	150	10	$V_{CEO(SUS)}$ 300	15(3/4)	250 m	2.0	3.5	1.0	2.5	NTC1871A	
BUX17C	RCAB	N	1	150	10	$V_{CEO(SUS)}$ 350	15(3/4)	250 m	2.0	3.5	1.0	2.5	NTC1871A	
BUX20	MISI NPC THCF	N	1	250	50	$V_{CEO(SUS)}$ 125	20(2/20)	30 m	1.5	1.2	0.2	8.0	NTC1870	*
BUX21	MISI NPC THCF SSCF	N	1	250	40	$V_{CEO(SUS)}$ 200	20(2/12)	60 m	1.5	1.2	0.5	8.0	NTC1870	*
BUX22	MISI NPC THCF SSCF	N	1	250	40	$V_{CEO(SUS)}$ 250	20(4/10)	75 m	1.5	1.5	0.5	8.0	NTC1870	*
BUX23	MISI NPC SSCF THCF	N	1	250	30	$V_{CEO(SUS)}$ 325	20(4/10)	50 m	2.0	1.5	1.0	8.0	NTC1871A	*
BUX24	MISI NPC SSCF THCF	N	1	250	20	$V_{CEO(SUS)}$ 400	15(4/10)	66 m	2.0	2.0	1.0	8.0	NTC1871A	*
BUX25	MISI NPC SSCF THCF	N	1	250	20	$V_{CEO(SUS)}$ 500	15(4/7)	120 m	2.0	2.5	1.5	8.0	NTC1871A	**
BUX39	MISI NPC THCF	N	1	120	30	$V_{CEO(SUS)}$ 90	20(4/10)	80 m	1.5	1.0	0.2	8.0	NTC1869	*
BUX40	MISI NPC THCF	N	1	120	20	$V_{CEO(SUS)}$ 125	15(4/10)	106 m	1.2	1.0	0.25	8.0	NTC1869	
BUX41	MISI NPC THCF SSCF	N	1	120	15	$V_{CEO(SUS)}$ 200	15(4/4)	200 m	1.5	1.5	0.8	8.0	NTC1867	
BUX42	MISI NPC THCF SSCF	N	1	120	12	$V_{CEO(SUS)}$ 250	15(4/4)	266 m	1.5	1.5	1.0	8.0	NTC1867	
BUX43	MISI NPC THCF SSCF	N	1	120	10	$V_{CEO(SUS)}$ 325	15(4/3)	320 m	1.5	1.5	1.0	8.0	NTC1868	
BUX44	MISI NPC THCF SSCF	N	1	120	8.0	$V_{CEO(SUS)}$ 400	15(4/2)	400 m	2.0	1.5	1.0	8.0	NTC1868	
BUX45	MISI NPC THCF SSCF	P	1	120	5.0	$V_{CEO(SUS)}$ 500	15(4/1.5)	533 m	2.0	2.0	1.5	8.0	–	
BUX46	THCF	N	1	85	3.5	400	5(5.0/3.5)	600 m	1.0	3.0	0.8	–	2N6545	
BUX48	THCF	N	1	125	12	400	5(5.0/12)	167 m	1.0	3.0	0.8	–	2N6547	
BUX66	RCAB	P	1	35	2.0	$V_{CEO(SUS)}$ 150	10(5/1)	–	0.6	2.5	0.6	20	–	
BUX66A	RCAB	P	1	35	2.0	$V_{CEO(SUS)}$ 250	10(5/1)	–	0.6	2.5	0.6	20	–	
BUX66B	RCAB	P	1	35	2.0	$V_{CEO(SUS)}$ 300	10(5/1)	–	0.6	2.5	0.6	20	–	
BUX66C	RCAB	P	1	35	2.0	$V_{CEO(SUS)}$ 350	10(5/1)	–	0.6	2.5	0.6	20	–	

PACKAGE (JEDEC)
1:TO-3

* Lower h_{FE}
** Lower $V_{CEO(SUS)}$, V_{CEX}

TYPE NO.	MANUFAC-TURERS	POLALITY	PACKAGE	MAXIMUM RATINGS(T_a=25°C) P_T(W) (T_c=25°C)	$I_{C(DC)}$(A)	V_{CEO}(V)	ELECTRICAL CHARACTERISTICS (T_a=25°C) h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (µs) MAX.	f_T(MHz) MIN.	NEC TYPE NO.	NOTE
BUX67	RCAB	N	2	35	2.0	$V_{CEO(SUS)}$ 150	15(5/1)	–	t_{on} t_{stg} t_f 3.0 4.0 3.0	10	NTC1864	
BUX67A	RCAB	N	2	35	2.0	$V_{CEO(SUS)}$ 250	15(5/1)	–	3.0 4.0 3.0	10	NTC1864	
BUX67B	RCAB	N	2	35	2.0	$V_{CEO(SUS)}$ 300	15(5/1)	–	3.0 4.0 2.0	10	NTC1865	
BUX67C	RCAB	N	2	35	2.0	$V_{CEO(SUS)}$ 350	15(5/1)	–	3.0 4.0 3.0	10	NTC1865	
BUX80	PHIC RTCF VALG	N	1	100	10	400	–	300 m	0.5 3.5 0.8	8.0†	NTC1868	
BUX82	PHIC RTCF VALG	N	1	60	5.0	400	–	600 m	0.5 3.5 1.0	8.0†	NTC1868	
BUX84	PH1C RTCF VALG	N	4	40	2.0	400	–	2.0	t_r t_{stg} t_f 0.5 3.5 0.3†	–	NTC2333	
BUX97	SGAI	N	1	120	6.0	350	10(5/1)	1.0	0.6 2.0 0.5	20†	NTC1868	
BUX97A	SGAI	N	1	120	6.0	400	10(5/1)	1.0	0.6 2.0 0.5	20†	NTC1868	
BUX97B	SGAI	N	1	120	6.0	450	10(5/1)	1.0	0.6 2.0 0.5	20†	NTC1868	**
BUY20	TIIB	N	1	85	10	200	20(5/3)	–	1.0 3.0 1.0	15	NTC1867	
BUY21	TIIB	N	1	85	10	300	20(5/3)	–	1.0 3.0 1.0	15	NTC1871A	
BUY22	TIIB	N	1	85	10	450	20(5/3)	–	1.0 3.0 1.0	15	NTC1871A	**
BUY23	TIIB	N	1	100	10	250	20(5/2.5)	–	1.0 3.0 1.0	25	2N6544	
BUY23A	TIIB	N	1	100	10	300	20(5/2.5)	–	1.0 3.0 1.0	25†	2N6545	
BUY49S	SGAI	N	3	1.0 (T_a=25°C)	1.5	200	40(5/0.5)	400 m	t_{on} t_{off} 0.5† 1.0†	80†	NTC1861	*
BUY55	SIEG	N	1	84	10	125	8(1.5/7)	214 m	t_{on} t_{stg} t_{off} 2.0 1.2 2.0	20†	NTC1870	
BUY56	SIEG	N	1	84	10	160	8(1.5/7)	214 m	2.0 1.2 2.0	20†	NTC1870	
BUY72	SIEG	N	1	84	10	280	8(1.5/7)	214 m	2.0 1.2 2.0	20†	NTC1871A	
BUY86	MULB	N	1	62	7.0	100	50(5/1)	142 m	t_{on} t_{off} 0.35 1.5	45	NTC1866	*
BUY87	MULB	N	1	62	7.0	150	30(5/2)	185 m	0.35 1.5	45	NTC1867	*
BUY88	MULB	N	1	62	7.0	150	30(5/1)	185 m	t_{on} t_{stg} t_{off} 0.5 1.0 1.3	45	NTC1868	*
BU104	MISI NPC THCF	N	1	85	7.0	V_{CEX} 400	10(3.5/5)	360 m	–	10†	NTC1868	

PACKAGE (JEDEC)
1:TO-3
2:TO-66
3:TO-5 or TO-39
4:TO-220AB

* Lower h_{FE}
** Lower V_{CBO}, V_{CEO}
†: typical

TYPE NO.	MANUFAC-TURERS	POLALITY	PACKAGE	MAXIMUM RATINGS (Ta=25 °C)			ELECTRICAL CHARACTERISTICS (Ta=25 °C)				NEC TYPE NO.	NOTE
				P_T(W) (Tc=25 °C)	I_C(DC) (A)	V_{CEO}(V)	h_{FE} MIN. (V_{CE}(V)/I_C(A))	MAX. SAT RES. (Ω)	SW-time (μs) MAX.	f_T(MHz) MIN.		
BU109	MISI NPC THCF	N	1	85	7.0	330	15(1.5/5)	285m	–	10†	NTC1868	•
BU406	SGAI	N	4	60	7.0	200	10(1/5)	200m	–	–	NTC2335	•
BU406D	SGAI	N	4	60	7.0	200	8.3(1/5)	200m	–	–	NTC2335	•
BU407	SGAI	N	4	60	7.0	200	10(1/5)	200m	–	–	NTC2335	•
BU407D	SGAI	N	4	60	7.0	200	8.3(1/5)	200m	–	–	NTC2335	•
BU408	SGAI	N	4	60	7.0	200	5(1/6)	167m	–	–	NTC2335	•
BU408D	SGAI	N	4	60	7.0	200	5(1/6)	167m	–	–	NTC2335	•
BU409	SGAI	N	4	60	7.0	200	7.5(1/3)	333m	–	–	NTC2335	

PACKAGE (JEDEC)
1:TO-3
4:TO-220AB

• Lower h_{FE}
†: typical

10

TYPE NO.	MANU-FACTURER	POLALITY	PACKAGE	MAXIMUM RATINGS (Ta=25°C)				ELECTRICAL CHARACTERISTICS (Ta=25°C)						NEC TYPE NO.	NOTE
				P_{T}(W) Tc=25°C	$I_{C(DC)}$(A)	V_{CBO}(V)	V_{CEO}(V)	h_{FE}			V_{CE}(V)/ I_C(A)	$V_{CE(sat)}$			
								MIN.	TYP.	MAX.		MAX.(V)	I_C(A)/ I_B(mA)		
2N6058	MOTA	N	1	150	12	80	80	750		18K	3/6	2	6/24	NTD411	
2N6059	MOTA	N	1	150	12	100	100	750		18K	3/6	2	6/24	NTD411	
2N6282	MOTA	N	1	160	20	60	60	750		18K	3/10	2	10/40	NTD412	
2N6283	MOTA	N	1	160	20	80	80	750		18K	3/10	2	10/40	NTD412	
2N6284	MOTA	N	1	160	20	100	100	750		18K	3/10	2	10/40	NTD412	
2N6285	MOTA	P	1	160	20	60	60	750		18K	3/10	2	10/40	NONE	
2N6286	MOTA	P	1	160	20	80	80	750		18K	3/10	2	10/40	NONE	
2N6287	MOTA	P	1	160	20	100	100	750		18K	3/10	2	10/40	NONE	
2N6294	MOTA	N	2	50	4.0	60	60	750		18K	3/2	2	2/8	NTD409	
2N6295	MOTA	N	2	50	4.0	80	80	750		18K	3/2	2	2/8	NTD409	
2N6296	MOTA	P	2	50	4.0	60	60	750		18K	3/2	2	2/8	NONE	
2N6297	MOTA	P	2	50	4.0	80	80	750		18K	3/2	2	2/8	NONE	
2N6298	MOTA	P	2	75	8.0	60	60	750		18K	3/4	2	4/16	NONE	
2N6299	MOTA	P	2	75	8.0	80	80	750		18K	3/4	2	4/16	NONE	
2N6300	MOTA	N	2	75	8.0	60	60	750		18K	3/4	2	4/16	NTD409	
2N6301	MOTA	N	2	75	8.0	60	80	750		18K	3/4	2	4/16	NTD409	
2N6383	RCA	N	1	100	10	40	40	1K		20K	3/5	2	5/10	NTD411	
2N6384	RCA	N	1	100	10	60	60	1K		20K	3/5	2	5/10	2SD411	
2N6385	RCA	N	1	100	10	80	80	1K		20K	3/5	2	5/10	NTD411	
2N6386	RCA	N	5	65	8	40	40	1K		20K	3/3	2	3/6	NTD560	
2N6387	RCA	N	5	65	10	60	60	1K		20K	3/5	2	5/10	NTD560	

PACKAGE (JEDEC)
1. TO-3
2. TO-66
5. TO-220

TYPE NO.	MANU-FACTURER	POLALITY	PACKAGE	MAXIMUM RATINGS (T_a=25°C) P_T(W) T_c=25°C				ELECTRICAL CHARACTERISTICS (T_a=25°C) h_{FE}						NEC TYPE NO.	NOTE
				P_T(W) T_c=25°C	$I_{C(DC)}$(A)	V_{CBO}(V)	V_{CEO}(V)	h_{FE} MIN.	TYP.	MAX.	V_{CE}(V)/ I_C(A)	$V_{CE(sat)}$ MAX.(V)	I_C(A)/ I_B(mA)		
2N6388	RCA	N	5	65	10	80	80	1K		20K	3/5	2	5/10	NTD560	
2N6530	RCA	N	5	65	8.0	80	80	1K		10K	3/5	2	5/10	NTD560	
2N6531	RCA	N	5	65	8.0	100	100	500		10K	3/3	3	3/6	NTD560	
2N6532	RCA	N	5	65	8.0	100	100	1K		10K	3/5	2	5/10	NTD560	
2N6533	RCA	N	5	65	8.0	120	120	1K		10K	3/3	2	3/6	NTD560	**
2N6534	RCA	N	2	36	8.0	80	80	1K		10K	3/5	2	5/10	NTD409	
2N6535	RCA	N	2	36	8.0	100	100	500		10K	3/3	3	3/6	NTD409	
2N6536	RCA	N	2	36	8.0	100	100	1K		10K	3/5	2	5/10	NTD409	
2N6537	RCA	N	2	36	8.0	120	130	1K		10K	3/3	2	3/6	NTD410	
BDX33	RCA	N	5	70	10		45	750			3/4	2.5	4/8	NTD560	
BDX33A	RCA	N	5	70	10		60	750			3/4	2.5	4/8	NTD560	
BDX33B	RCA	N	5	70	10		80	750			3/3	2.5	3/6	NTD560	
BDX33C	RCA	N	5	70	10		100	750			3/3	2.5	3/6	NTD560	
BDX33D	RCA	N	5	70	10		120	750			3/3	2.5	3/6	NTD560	**
BDX34	RCA	P	5	70	10		45	750			3/4	2.5	4/8	NTB601	
BDX34A	RCA	P	5	70	10		60	750			3/4	2.5	4/8	NTB601	
BDX34B	RCA	P	5	70	10		80	750			3/3	2.5	3/6	NTB601	
BDX34C	RCA	P	5	70	10		100	750			3/3	2.5	3/6	NTB601	
BDX83	RCA	N	1	125	10		45	1K			3/5	2.0	5/10	NTD411	
BDX83A	RCA	N	1	125	10		60	1K			3/5	2.0	5/10	NTD411	
BDX 83B	RCA	N	1	125	10		80	1K			3/5	2.0	5/10	NTD411	

PACKAGE (JEDEC)
1. TO-3
2. TO-66
5. TO-220

** Lower V_{CEO}

10

TYPE NO.	MANU-FACTURER	POLALITY	PACKAGE	MAXIMUM RATINGS (Ta=25°C) $P_{T(W)}$ Tc=25°C	$I_{C(DC)}(A)$	$V_{CBO}(V)$	$V_{CEO}(V)$	ELECTRICAL CHARACTERISTICS (Ta=25°C) h_{FE} MIN.	TYP.	MAX.	$V_{CE}(V)$/ $I_C(A)$	$V_{CE(sat)}$ MAX.(V)	$I_C(A)$/ $I_B(mA)$	NEC TYPE NO.	NOTE
BDX83C	RCA	N	1	125	10		100	1K			3/5	2.0	5/10	NTD411	••
D40C1	GESY	N	(6')	6.25	0.5	30	30	10K		60K	5/0.2	1.5	0.5/0.5	NTD558	• ••
D40C2	GESY	N	(6')	6.25	0.5	30	30	40K			5/0.2	1.5	0.5/0.5	NTD558	• •••
D40C3	GESY	N	(6')	6.25	0.5	30	30	90K			5/0.2	1.5	0.5/0.5	NTD558	• •••
D40C4	GESY	N	(6')	6.25	0.5	40	40	10K		60K	5/0.2	1.5	0.5/0.5	NTD558	• •••
D40C5	GESY	N	(6')	6.25	0.5	40	40	40K			5/0.2	1.5	0.5/0.5	NTD558	• •••
D40C7	GESY	N	(6')	6.25	0.5	50	50	10K		60K	5/0.2	1.5	0.5/0.5	NTD558	• •••
D40C8	GESY	N	(6')	6.25	0.5	50	50	40K			5/0.2	1.5	0.5/0.5	NTD558	• •••
D40K1	GESY	N	(6')	10	1.5	30	30	10K			5/0.2	1.5	1.5/3	NTD558	• •••
D40K2	GESY	N	(6')	10	1.5	50	50	10K			5/0.2	1.5	1.5/3	NTD558	• •••
D40K3	GESY	N	(6')	1.6	1.5	30	30	10K			5/0.2			NTD558	• •••
D40K4	GESY	N	(6')	1.6	1.5	50	50	10K			5/0.2			NTD558	• •••
D41K1	GESY	P	(6')	10	1.5	30	30	10K			5/0.2			NONE	
D41K2	GESY	P	(6')	10	1.5	50	50	10K			5/0.2			NONE	
D41K3	GESY	P	(6')	10	1.5	30	30	10K			5/0.2			NONE	
D41K4	GESY	P	(6')	10	1.5	50	50	10K			5/0.2			NONE	
D42D1	GESY	N	(6')	12	4.0	50	50	5K	20K		2/1			NTD560	• •••
D42D2	GESY	N	(6')	12	4.0	50	50	5K	20K		2/1			NTD560	• •••
D42D3	GESY	N	(6')	12	4.0	70	70	5K	20K		2/1			NTD560	• •••
D42D4	GESY	N	(6')	12	4.0	70	70	5K	20K		2/1			NTD560	• •••
D42D5	GESY	N	(6')	12	4.0	90	90	5K	20K		2/1			NTD560	• •••

PACKAGE (JEDEC)
1. TO-3
6. TO-221

• Lower h_{FE}
•• Lower V_{CEO}
••• Different pin configuration

TYPE NO.	MANU-FACTURER	POLALITY	PACKAGE	MAXIMUM RATINGS (Ta=25°C)				ELECTRICAL CHARACTERISTICS (Ta=25°C)						NEC TYPE NO.	NOTE
				$P_{T(W)}$ Tc=25°C	$I_{C(DC)}(A)$	$V_{CBO}(V)$	$V_{CEO}(V)$	h_{FE} MIN.	h_{FE} TYP.	h_{FE} MAX.	$V_{CE}(V)/I_C(A)$	$V_{CE(sat)}$ MAX.(V)	$I_C(A)/I_B(mA)$		
D42D6	GESY	N	(6')	12	4.0	50	50	2K	10K		2/1			NTB601	• •••
D43D1	GESY	P	(5)	12	4.0	50	50	2K	10K		2/1			NTB601	• •••
D43D2	GESY	P	(5)	12	4.0	50	50	2K	10K		2/1			NTB601	• •••
D43D3	GESY	P	(5)	12	4.0	70	70	2K	10K		2/1			NTB601	• •••
D43D4	GESY	P	(5)	12	4.0	70	70	2K	10K		2/1			NTB601	• •••
D43D5	GESY	P	(5)	12	4.0	90	90	2K	10K		2/1			NTB601	• •••
D43D6	GESY	P	(5)	12	4.0	90	90	2K	10K		2/1			NTB601	• •••
D44D1	GESY	N	5	30	6.0		50	5K	20K		2/1			NTD560	•
D44D2	GESY	N	5	30	6.0		50	5K	20K		2/1			NTD560	•
D44D3	GESY	N	5	30	6.0		70	5K	20K		2/1			NTD560	•
D44D4	GESY	N	5	30	6.0		70	5K	20K		2/1			NTD560	•
D44D5	GESY	N	5	30	6.0		90	5K	20K		2/1			NTD560	•
D44D6	GESY	N	5	30	6.0		90	5K	20K		2/1			NTD460	•
D44E1	GESY	N	5	50	10		40	1.0K			5/5			NTD560	
D44E2	GESY	N	5	50	10		60	1.0K			5/5			NTD560	
D44E3	GESY	N	5	50	10		80	1.0K			5/5			NTD560	
D45D1	GESY	P	5	30	6.0		50	2.0K	10K		2/1			NTB601	•
D45D2	GESY	P	5	30	6.0		50	2.0K	10K			2/1		NTB601	•
D45D3	GESY	P	5	30	6.0		70	2.0K	10K			2/1		NTB601	•
D45D4	GESY	P	5	30	6.0		70	2.0K	10K		2/1			NTB601	•
D45D5	GESY	P	5	30	6.0		90	2.0K	10K		2/1			NTB601	•

PACKAGE (JEDEC)
5. TO-220
6. TO-221

• Lower h_{FE}
••• Different pin configuration

10

TYPE NO.	MANU-FACTURER	POLALITY	PACKAGE	MAXIMUM RATINGS (Ta=25°C) $P_{T}(W)$ Tc=25°C	$I_{C(DC)}(A)$	$V_{CBO}(V)$	$V_{CEO}(V)$	ELECTRICAL CHARACTERISTICS (Ta=25°C) h_{FE} MIN.	TYP.	MAX.	$V_{CE}(V)/I_{C}(A)$	$V_{CE(sat)}$ MAX.(V)	$I_{C}(A)/I_{B}(mA)$	NEC TYPE NO.	NOTE
D45D6	GESY	P	5	30	6.0		90	2.0K	10K		2/1			NTB601	*
D45E1	GESY	P	5	50	10		40	1.0K			5/5			NTB601	
D45E2	GESY	P	5	50	10		60	1.0K			5/5			NTB601	
D45E3	GESY	P	5	50	10		80	1.0K			5/5			NTB601	
MJ900	MOTA	P	1	90	8.0	60	60	1K			3/3	2.0	3/12	NONE	
MJ901	MOTA	P	1	90	8.0	80	80	1K			3/3	2.0	3/12	NONE	
MJ1000	MOTA	N	1	90	8.0	60	60	1K			3/3	2.0	3/12	NTD411	
MJ1001	MOTA	N	1	90	8.0	80	80	1K			3/3	2.0	3/12	NTD411	
MJ4030	MOTA	P	1	150	16	60	60	1K			3/10	2.5	10/40	NONE	
MJ4031	MOTA	P	1	150	16	80	80	1K			3/10	2.5	10/40	NONE	
MJ4032	MOTA	P	1	150	16	100	100	1K			3/10	2.5	10/40	NONE	
MJ4033	MOTA	N	1	150	16	60	60	1K			3/10	2.5	10/40	NTD412	
MJ4034	MOTA	N	1	150	16	80	80	1K			3/10	2.5	10/40	NTD412	
MJ4035	MOTA	N	1	150	16	100	100	1K			3/10	2.5	10/40	NTD412	
MJ11011	MOTA	P	1	200	30	60	60	1K			5/20	3.0	20/200	NONE	
MJ11012	MOTA	N	1	200	30	60	60	1K			5/20	3.0	20/200	NONE	
MJ11013	MOTA	P	1	200	30	90	90	1K			5/20	3.0	20/200	NONE	
MJ11014	MOTA	N	1	200	30	90	90	1K			5/20	3.0	20/200	NONE	
MJ11015	MOTA	P	1	200	30	120	120	1K			5/20	3.0	20/200	NONE	
MJ11016	MOTA	N	1	200	30	120	120	1K			5/20	3.0	20/200	NONE	
MJE700	MOTA	P	7	40	4.0	60	60	750			3/1.5	2.5	1.5/30	(V103)	

PACKAGE (JEDEC)
1. TO-3
5. TO-220
7. TO-126 (MAXI)

* Lower h_{FE}

TYPE NO.	MANU-FACTURER	POLALITY	PACKAGE	MAXIMUM RATINGS (Ta=25°C)				ELECTRICAL CHARACTERISTICS (Ta=25°C)						NEC TYPE NO.	NOTE
				P_{T}(W) Tc=25°C	$I_{C(DC)}$(A)	V_{CBO}(V)	V_{CEO}(V)	h_{FE} MIN.	TYP.	MAX.	V_{CE}(V)/ I_{C}(A)	$V_{CE(sat)}$ MAX.(V)	I_{C}(A)/ I_{B}(mA)		
MJE701	MOTA	P	7	40	4.0	60	60	750			3/2.0	2.8	2/40	(V103)	
MJE702	MOTA	P	7	40	4.0	80	80	750			3/1.5	2.5	1.5/30	(V103)	
MJE703	MOTA	P	7	40	4.0	80	80	750			3/2.0	2.8	2/40	(V103)	
MJE800	MOTA	N	7	40	4.0	60	60	750			3/1.5	2.5	1.5/30	NTD985	••
MJE801	MOTA	N	7	40	4.0	60	60	750			3/2.0	2.8	2/40	NTD985	••
MJE802	MOTA	N	7	40	4.0	80	80	750			3/1.5	2.5	1.5/30	NTD986	••
MJE803	MOTA	N	7	40	4.0	80	80	750			3/2.0	2.8	2/40	NTD986	••
MJE1090	MOTA	P	7	70	5.0	60	60	750			3/3	2.5	3/12	NTB601	•••
MJE1091	MOTA	P	7	70	5.0	60	60	750			3/4	2.8	4/16	NTB601	•••
MJE1092	MOTA	P	7	70	5.0	80	80	750			3/3	2.5	3/12	NTB601	•••
MJE1093	MOTA	P	7	70	5.0	80	80	750			3/4	2.8	4/16	NTB601	•••
MJE1100	MOTA	N	7	70	5.0	60	60	750			3/3	2.5	3/12	NTD560	•••
MJE1101	MOTA	N	7	70	5.0	60	60	750			3/4	2.8	4/16	NTD560	•••
MJE1102	MOTA	N	7	70	5.0	80	80	750			3/3	2.5	3/12	NTD560	•••
MJE1103	MOTA	N	7	70	5.0	80	80	750			3/4	2.8	4/16	NTD560	•••
MJE2090	MOTA	P	7	70	5.0	60	60	750			3/3	2.5	3/12	NTB601	•••
MJE2091	MOTA	P	7	70	5.0	60	60	750			3/4	2.8	4/16	NTB601	•••
MJE2092	MOTA	P	7	70	5.0	80	80	750			3/3	2.5	3/12	NTB601	•••
MJE2093	MOTA	P	7	70	5.0	80	80	750			3/4	2.8	4/16	NTB601	•••
MJE2100	MOTA	N	7	70	5.0	60	60	750			3/3	2.5	3/12	NTD560	•••
MJE2101	MOTA	N	7	70	5.0	60	60	750			3/4	2.8	4/16	NTD560	•••

PACKAGE (JEDEC)
7. TO-126 (MAXI)

••• Different pin configuration
•• Narrow S.O.A.

10

TYPE NO.	MANU-FACTURER	POLALITY	PACKAGE	MAXIMUM RATINGS (T_a=25°C) $P_{T}(W)$ T_c=25°C	$I_{C(DC)}(A)$	$V_{CBO}(V)$	$V_{CEO}(V)$	ELECTRICAL CHARACTERISTICS (T_a=25°C) h_{FE} MIN.	h_{FE} TYP.	h_{FE} MAX.	$V_{CE}(V)$/ $I_C(A)$	$V_{CE(sat)}$ MAX.(V)	$I_C(A)$/ $I_B(mA)$	NEC TYPE NO.	NOTE
MJE2102	MOTA	N	7	70	5.0	80	80	750			3/3	2.5	3/12	NTD560	***
MJE2103	MOTA	N	7	70	5.0	80	80	750			3/4	2.8	4/16	NTD560	***
MJE6040	MOTA	P	7	75	8	60	60	1K	20K		4/4	2.0	4/16	NTB601	***
MJE6041	MOTA	P	7	75	8	80	80	1K	20K		4/4	2.0	4/16	NTB601	***
MJE6042	MOTA	P	7	75	8	100	100	1K	20K		4/3	2.0	3/12	NTB601	***
MJE6043	MOTA	N	7	75	8	60	60	1K	20K		4/4	2.0	4/16	NTD560	***
MJE6044	MOTA	N	7	75	8	80	80	1K	20K		4/4	2.0	4/16	NTD560	***
MJE6045	MOTA	N	7	75	8	100	100	1K	20K		4/3	2.0	3/12	NTD560	***
RCA120	RCA	N	5	65	8	60	60	1K			3/3	2.0	3/12	NTD560	
RCA121	RCA	N	5	65	8	80	80	1K			3/3	2.0	3/12	NTD560	
RCA122	RCA	N	5	65	8	100	100	1K			3/3	2.0	3/12	NTD560	
RCA125	RCA	P	5	65	8	60	60	1K			3/3	2.0	3/12	NTB601	
RCA126	RCA	P	5	65	8	80	80	1K			3/3	2.0	3/12	NTB601	
RCA127	RCA	P	5	65	8	100	100	1K			3/3	2.0	3/12	NTB601	
RCA1000	RCA	N	1	90	8	60	60	1K			3/3	2.0	3/12	NTD411	
RCA1001	RCA	N	1	90	8	80	80	1K			3/3	2.0	3/12	NTD411	
RCA8203	RCA	P	5	65	8	40	40	1K		20K	3/3	2.0	3/6	NTB601	
RCA8203A	RCA	P	5	65	10	60	60	1K		20K	3/5	2.0	5/10	NTB601	
RCA8203B	RCA	P	5	65	10	80	80	1K		20K	3/5	2.0	5/10	NTB601	
RCA8350	RCA	P	1	70	10	40	40	1K		20K	3/5	2.0	5/10	NONE	
RCA8350A	RCA	P	1	70	10	60	60	1K		20K	3/5	2.0	5/10	NONE	

PACKAGE (JEDEC)
1. TO-3
5. TO-220
7. TO-126 (MAXI)

*** Different pin configuration

TYPE NO.	MANU-FACTURER	POLALITY	PACKAGE	MAXIMUM RATINGS (T_a=25°C)				ELECTRICAL CHARACTERISTICS (T_a=25°C)						NEC TYPE NO.	NOTE
				P_T(W) T_c=25°C	$I_{C(DC)}$(A)	V_{CBO}(V)	V_{CEO}(V)	h_{FE} MIN.	h_{FE} TYP.	h_{FE} MAX.	V_{CE}(V)/ I_C(A)	$V_{CE(sat)}$ MAX.(V)	I_C(A)/ I_B(mA)		
RCA8350B	RCA	P	1	70	10	80	80	1K		20K	3/5	2.0	5/10	NONE	
TIP110	TII	N	5	50	2	60	60	1K			4/1			NTD558	
TIP111	TII	N	5	50	2	80	80	1K			4/1			NTD558	** ***
TIP112	TII	N	5	50	2	100	100	1K			4/1			NTD558	** ***
TIP115	TII	P	5	50	2	60	60	1K			4/1			NTB601	
TIP116	TII	P	5	50	2	80	80	1K			4/1			NTB601	
TIP117	TII	P	5	50	2	100	100	1K			4/1			NTB601	
TIP120	TII	N	5	65	5	60	60	1K			3/3			NTD560	
TIP121	TII	N	5	65	5	80	80	1K			3/3			NTD560	
TIP122	TII	N	5	65	5	100	100	1K			3/3			NTD560	
TIP125	TII	P	5	65	5	60	60	1K			3/3			NTB601	
TIP126	TII	P	5	65	5	80	80	1K			3/3			NTB601	
TIP127	TII	P	5	65	5	100	100	1K			3/3			NTB601	
TIP140	TII	N	4	125	10	60	60	1K			4/5			NONE	
TIP141	TII	N	4	125	10	80	80	1K			4/5			NONE	
TIP142	TII	N	4	125	10	100	100	1K			4/5			NONE	
TIP145	TII	P	4	125	10	60	60	1K			4/5			NONE	
TIP146	TII	P	4	125	10	80	80	1K			4/5			NONE	
TIP147	TII	P	4	125	10	100	100	1K			4/5			NONE	
TIP640	TII	N	1	175	10	60	60	1K			4/5			NTD411	
TIP641	TII	N	1	175	10	80	80	1K			4/5			NTD411	

PACKAGE (JEDEC)
1. TO-3
4. TOP-3 (MP-80)
5. TO-220

** Lower V_{CEO}
*** Different pin configuration

10

TYPE NO.	MANU-FACTURER	POLALITY	PACKAGE	MAXIMUM RATINGS (Ta=25°C)				ELECTRICAL CHARACTERISTICS (Ta=25°C)						NEC TYPE NO.	NOTE
				P_T(W) Tc=25°C	$I_{C(DC)}$(A)	V_{CBO}(V)	V_{CEO}(V)	h_{FE} MIN.	h_{FE} TYP.	h_{FE} MAX.	V_{CE}(V)/ I_C(A)	$V_{CE(sat)}$ MAX.(V)	I_C(A)/ I_B(mA)		
TIP642	TII	N	1	175	10	100	100	1K			4/5			NTD411	**
TIP645	TII	P	1	175	10	60	60	1K			4/5			NONE	
TIP646	TII	P	1	175	10	80	80	1K			4/5			NONE	
TIP647	TII	P	1	175	10	100	100	1K			4/5			NONE	

PACKAGE (JEDEC)
1. TO-3

** Lower V_{CEO}

TO-92 Type Cross Reference Information

TYPE No.		Package	Electrical Characteristics	Recommended NEC device

TYPE No.: Other Manufacturer's Type Number

Electrical Characteristics:

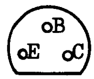
◎ Equivalent Characteristics

Without Note: Different Measuring Conditions

Package:

◎ Same Package (TO-92 Pin Configuration C.B.E.)

○ Little different package almost all are triangle pin configuration



△ Almost same package different pin configuration (Pin Configuration E C B)

Without Note Can case Tr.

Type No.	Package	Elec-trically	Recommended NEC Device
A5T718A	O		2N4400
A5T2192	O		NT2222A
A5T2193	O		2N4400
A5T2222	O	◎	NT2222
A5T2907	O	◎	NT2907
A5T3391	O		2N4124
A5T3391A	O		2N4124
AST3504	O		NT2907A
A5T3505	O		NT2907A
A5T3638	O		NT2907
A5T3638A	O		NT2907A
A5T3644	O		NT2907A
A5T3645	O		NT2907A
A5T3903	O	◎	2N3903
A5T3904	O	◎	2N3904
A5T3905	O	◎	2N3905
A5T3906	O	◎	2N3906
A5T4123	O	◎	2N4123
A5T4124	O	◎	2N4124
A5T4125	O	◎	2N4125
A5T4126	O	◎	2N4126
A5T4402	O	◎	2N4402
A5T4403	O	◎	2N4403
A5T5220	O		NT2222
A5T5221	O		NT2907
A5T5226	O		NT2907
A8T3391	◎		2N4124
A8T3391A	◎		2N4124
A8T3702	◎		2N4403
A8T3703	◎		2N4402
A8T3705	◎		2N4400, 1
A8T3706	◎		2N4401

Type No.	Package	Elec-trically	Recommended NEC Device
BC115			NT2222
BC116			NT2907
BC116A			NT2907
BC119			2N4400
BC125			NT2222
BC136	O		NT2222
BC137			NT2907
BC138			2N4400
BC139			2N4402
BC204			2N3905
BC204A			2N3906
BC204B			2N3906
BC205			2N4125
BC205A	O		2N4126
BC221	O		NT2907
BC222	O		NT2222
BC231	O		2N4403
BC232	O		2N4402
BCY42			2N4400
BCY43			NT2222
BCY58			2N3904
BCY59			2N3904
BCY65E			2N3904
BFW29			NT2222A
BFW31			NT2907
BFW32			NT2222
BFW68			NT2222A
BFX29			NT2907A
BFX30			NT2907A
BFX45			NT2222

Type No.	Package	Elec-trically	Recommended NEC Device
BFX50			NT2222A
BFX51			2N4400
BFX52			NT2222A
BFX68			NT2222
BFX68A			NT2222
BFX69			2N4400
BFX75			2N4402
BFX88			2N4402
BFX94			2N4400
BFX95			NT2222
BFX96			2N4400
BFX97			NT2222
BFY64			NT2907
BFY72			2N4400
BSW21			2N4402
BSW22			NT2907
BSW23			2N4402
BSW58	○		NT2369A
BSW59	○		NT2369A
BSW24			2N4402
BSW72			2N4402
BSW73			NT2907
BSW74			2N4402
BSW75			NT2907
BSW82			2N4400
BSW83			NT2222
BSW84			2N4400
BSW85			NT2222
BSX19			NT2369A
BSX20			NT2369A

Type No.	Package	Elec-trically	Recommended NEC Device
BSX26			NT2369A
BSX28			NT2369A
BSX36			2N4402
BSX87		◎	NT2369A
BSX87A		◎	NT2369A
BSX88			NT2369A
BSX88A			NT2369A
BSX89			NT2369A
BSX90			NT2369A
BSX91			NT2369A
BSX92			NT2369A
BSX93			NT2369A
BSY17			NT2369A
BSY19			NT2369A
BSY21			NT2369A
BSY26		◎	NT2369A
BSY27		◎	NT2369A
BSY28		◎	NT2369A
BSY38		◎	NT2369A
BSY39		◎	NT2369A
BSY62			NT2369A
BSY62A			NT2369A
BSY63			NT2369A
BSY70			NT2369A
BSY78			NT2222
BSY95			NT2369A
BSY95A			NT2369A
D29E1	△		2N4402
D29E1J1	△		2N4402
D29E2	△		2N4403
D29E2J1	△		2N4403

10

Type No.	Package	Electrically	Recommended NEC Device
D29E4	△		2N4402
D29E4K1	△		2N4402
D29E5	△		2N4403
D29E5J1	△		2N4403
D29E6	△		2N4403
D29E6J1	△		2N4403
D29E7	△		2N4403
D29E7J1	△		2N4403
D29F1	△		2N3905
D29F2	△		2N3905
D29F3	△		2N3906
D32P2	O		2N4123
D32P2	O		2N4123
D32P4	O		2N4124
D33D21	△		2N4400
D33D21J1	△		2N4400
D33D22	△		2N4401
D33D22J1	△		2N4401
D33D24	△		2N4400
D33D24J1	△		2N4400
D33D25	△		2N4401
D33D25J1	△		2N4401
D33D26	△		2N4401
D33D26J1	△		2N4401
D33D27	△		2N4401
D33D27J1	△		2N4401
EN697	O		2N4400
EN706	O	◎	NT2369A
EN708	O	◎	NT2369A
EN718A	O		2N4400

Type No.	Package	Electrically	Recommended NEC Device
EN722	O		2N4402
EN744	O	◎	NT2369A
EN915	O		2N3903
EN916	O		2N3903
EN956	O		NT2222
EN1132	O		2N4402
EN1613	O		2N4400
EN1711	O		NT2222A
EN2219	O	◎	NT2222
EN2222	O	◎	NT2222
EN2369	O	◎	NT2369
EN2369A	O	◎	NT2369A
EN2905	O	◎	NT2907
EN2907	O	◎	NT2907
EN3011	O	◎	NT2369A
EN3250	O		2N3905
EN3502	O		NT2907A
EN3504	O		NT2907A
EN3903	O	◎	2N3903
EN3904	O	◎	2N3904
EN3905	O	◎	2N3905
EN3906	O	◎	2N3906
EN4123	O	◎	2N4123
EN4124	O	◎	2N4124
EN4125	O	◎	2N4125
EN4126	O	◎	2N4126
GET2221	O		2N4400
GET2221A	O		2N4400
GET2222	O	◎	NT2222
GET2222A	O	◎	NT2222A
GET2904	O		2N4402
GET2905	O	◎	NT2907

Type No.	Package	Electrically	Recommended NEC Device
GET2906	O		2N4402
GET2907	O		NT2907
GET3638	O		2N4402
GET3638A	O		2N4403
GES2221	◎		2N4400
GES2221A	◎		2N4400
GES2222	◎	◎	NT2222
GES2222A	◎	◎	NT2222A
GES2906	◎		2N4402
GES2907	◎	◎	NT2907
GES3566	◎		NT2222
GES3567	◎		2N4400
GES3569	◎		2N4400
GES4121	◎		2N3905
GES4122	◎		2N3905
GES5368	◎		2N4400
GES5369	◎		2N4401
GES5370	◎		NT2222
GES5371	◎		2N4400
GES5372	◎		2N4403
GES5373	◎		2N4403
GES5375	◎		2N4402
GES5447	◎		2N4403
GES5448	◎		2N4402
GES5449	◎		2N4401
GES5450	◎		2N4401
GES5451	◎		2N4401
GES5810	◎		2N4403
GES5811	◎		2N4123
GES5824	◎		2N4123
GES5825	◎		2N4123
GES5826	◎		2N4124

Type No.	Package	Electrically	Recommended NEC Device
GES5827	◎		2N4124
GES6000	◎		2N4401
GES6001	◎		2N4402
GES6004	◎		2N4401
GES6005	◎		2N4402
GES6010	◎		2N4401
GES6011	◎		2N4402
MM2193A			2N4400
MM3903		◎	2N3903
MM3904		◎	2N3904
MM3905		◎	2N3905
MM3906		◎	2N3906
MM4400		◎	2N4400
MM4401		◎	2N4401
MM4402		◎	2N4402
MM4403		◎	2N4403
MPS706	◎	◎	NT2369A
MPS708	◎	◎	NT2369
MPS753	◎	◎	NT2369
MPS834	◎	◎	NT2369
MPS2222	◎	◎	NT2222
MPS835	◎	◎	NT2369A
MPS2222A	◎	◎	NT2222A
MPS2369	◎	◎	NT2369
MPS2369A	◎	◎	NT2369A
MPS2711	◎		2N4123
MPS2712	◎		2N4124
MPS2713	◎		2N4400
MPS2714	◎		2N4401
MPS2907	◎	◎	NT2907
MPS2907A	◎	◎	NT2907A

Type No.	Package	Elec-trically	Recommended NEC Device
MPS2923	◎		2N4123
MPS2924	◎		2N4124
MPS2925	◎		2N4124
MPS2926	◎		2N4123,4
MPS3390	◎		2N4124
MPS3391	◎		2N4124
MPS3391A	◎		2N4124
MPS3392	◎		2N4124
MPS3393	◎		2N4124
MPS3394	◎		2N4123
MPS3395	◎		2N4124
MPS3402	◎		2N4123
MPS3403	◎		2N4124
MPS3569	◎		2N4400
MPS3638	◎		NT2907
MPS3638A	◎		NT2907
MPS3641	◎		2N4400
MPS3644	◎		NT2907A
MPS3645	◎		NT2907A
MPS3693	◎		2N3903
MPS3694	◎		2N3903
MPS3702	◎		2N4403
MPS3703	◎		2N4402
MPS3704	◎		2N4401
MPS3705	◎		2N4400
MPS3706	◎		2N4400
MPS3903	◎	◎	2N3903
MPS3904	◎	◎	2N3904
MPS3905	◎	◎	2N3905
MPS3906	◎	◎	2N3906
MPS4274	◎		NT2369A
MPS4275	◎		NT2369A
MPS5128	◎		NT2222

Type No.	Package	Elec-trically	Recommended NEC Device
MPS5129	◎		NT2222
MPS5135	◎		NT2222
MPS5136	◎		NT2222
MPS5137	◎		NT2222
MPS5142	◎		NT2907
MPS5143	◎		NT2907
MPS5172	◎		2N3904
MPS6512	◎		2N4123
MPS6513	◎		2N4123
MPS6514	◎		2N4124
MPS6515	◎		2N4124
MPS6516	◎		2N4125
MPS6517	◎		2N4125
MPS6518	◎		2N4126
MPS6519	◎		2N4126
MPS6520	◎		2N4124
MPS6521	◎		2N4124
MPS6522	◎		2N4126
MPS6523	◎		2N4126
MPS6530	◎		2N4400
MPS6531	◎		2N4401
MPS6532	◎		2N4400
MPS6533	◎		2N4402
MPS6533M	◎		2N4402
MPS6534	◎		2N4403
MPS6534M	◎		2N4403
MPS6535	◎		2N4402
MPS6535M	◎		2N4402
MPS6560	◎		2N4401
MPS6561	◎		2N4401
MPS6562	◎		2N4403
MPS6563	◎		2N4403

Type No.	Package	Elec-trically	Recommended NEC Device
PN2218	◎		2N4400
PN2218A	◎		2N4400
PN2219	◎	◎	NT2222
PN2219A	◎	◎	NT2222A
PN2221	◎		2N4400
PN2221A	◎		2N4400
PN2222	◎		NT2222
PN2222A	◎		NT2222A
PN2369	◎		NT2369
PN2369A	◎		NT2369A
PN2904	◎		2N4402
PN2904A	◎		2N4402
PN2905	◎		NT2907
PN2905A	◎		NT2907A
PN2906	◎		2N4402
PN2907	◎		NT2907
PN2907A	◎	◎	NT2907A
PN3565	◎	◎	2N3904
PN3566	◎		2N3904
PN3641	◎		2N4400
PN3643	◎		NT2222
PN3644	◎		NT2907A
PN3645	◎		NT2907
PN4916	◎		2N3905
PN4917	◎		2N3906
PN5128	◎		NT2222
PN5129	◎		NT2222
PN5134	O	◎	NT2369
PN5135	◎		NT2222
PN5136	◎		NT2222
PN5137	◎		NT2222
PN5142	◎		NT2907
PN5143	◎		NT2907

Type No.	Package	Elec-trically	Recommended NEC Device
TIS37	△		2N3905
TIS38	△		2N3905
TIS90	△		2N4401
TIS90M	△		2N4401
TIS91	△		2N4403
TIS91M	△		2N4403
TIS92	O		2N4401
TIS92M	O		2N4401
TIS93	O		2N4403
TIS93M	O		2N4403
TIS109	O		NT2222
TIS110	O	◎	2N4400
TIS111	O	◎	2N4401
TIS112	O	◎	NT2907A
TIS137	O		2N3905
TIS138	O		2N3906
TP3638	O		NT2907
TP3638A	O		NT2907A
TP4123	O	◎	2N4123
TP4124	O	◎	2N4124
TP4125	O	◎	2N4125
TP4126	O	◎	2N4126
2N160			2N4400
2N160A			2N4400
2N161			2N4400
2N161A			2N4400
2N162			2N4400
2N162A			2N4400
2N163			2N4400
2N163A			2N4400
2N258			2N4402

Type No.	Package	Elec-trically	Recommended NEC Device
2N259			2N4402
2N260			2N4402
2N260A			2N4402
2N261			2N4402
2N262			2N4402
2N262A			2N4402
2N263			NT2907
2N264			2N4402
2N327			2N4402
2N327A			2N4402
2N327B			2N4402
2N328			2N4402
2N328A			2N4402
2N328B			2N4402
2N329			2N4402
2N329A			2N4402
2N330			2N4402
2N330A			2N4402
2N332			2N4400
2N332A			2N4400
2N333			2N4400
2N333A			2N4400
2N334			2N4400
2N334A			2N4400
2N334B			2N4400
2N335			2N4400
2N335A			2N4400
2N335B			2N4400
2N336			2N4400
2N336A			2N4400
2N337			2N4400
2N337A			2N4400
2N338			2N4400

Type No.	Package	Elec-trically	Recommended NEC Device
2N338A			2N4400
2N354			2N4402
2N355			2N4402
2N470			2N4400
2N471			2N4400
2N471A			2N4400
2N472			2N4400
2N472A			2N4400
2N473			2N4400
2N474			2N4400
2N474A			2N4400
2N475			2N4400
2N475A			2N4400
2N476			2N4400
2N477			2N4400
2N478			2N4400
2N479			2N4400
2N479A			2N4400
2N480			2N4400
2N480A			2N4400
2N541			2N4400
2N541A			2N4400
2N542			2N4400
2N542A			2N4400
2N543			2N4400
2N543A			2N4400
2N552			2N4400
2N619			2N4400
2N620			2N4400
2N621			2N4400
2N696			2N4400
2N696A			2N4400
2N697			2N4400

Type No.	Package	Electrically	Recommended NEC Device
2N697A			2N4400
2N702			2N3903
2N703			2N3903
2N715			2N4400
2N716			2N4400
2N717			2N4400
2N718			2N4400
2N718A			2N4400
2N721			2N4402
2N721A			2N4402
2N722			2N4402
2N722A			2N4402
2N730			2N4400
2N731			2N4400
2N744		◎	NT2369A
2N744A		◎	NT2369A
2N745			2N4400
2N746			2N4400
2N747			2N4400
2N748			2N4400
2N749			2N4400
2N751			2N4400
2N752			2N4400
2N753		◎	NT2369
2N783		◎	NT2369A
2N784		◎	NT2369A
2N784A		◎	NT2369A
2N789			2N3903
2N790			2N3903
2N791			2N3903
2N792			2N3903
2N793			2N3903
2N834		◎	NT2369A

Type No.	Package	Electrically	Recommended NEC Device
2N835		◎	NT2369A
2N839			2N3903
2N840			2N3903
2N841			2N3904
2N842			2N3903
2N843			2N3903
2N847		◎	NT2369A
2N850		◎	NT2369A
2N852		◎	NT2369A
2N858			NT4402
2N859			2N4402
2N860			2N4402
2N861			2N4402
2N862			2N4402
2N863			2N4402
2N864			2N4402
2N864A			2N4402
2N865			2N4402
2N865A			2N4402
2N866			2N4402
2N867			2N4402
2N902			2N4400
2N903			2N4400
2N904			2N4400
2N905			2N4400
2N906			2N4400
2N907			2N4400
2N908			2N4400
2N909			NT2222
2N915			2N3903
2N915A			2N3903
2N916			2N3903
2N916A			2N3903

10

Type No.	Package	Elec-trically	Recommended NEC Device
2N916B			2N3903
2N919		◎	NT2369A
2N920		◎	NT2369A
2N921		◎	NT2369A
2N922		◎	NT2369A
2N923			2N4402
2N924			2N4402
2N925			2N4402
2N926			2N4402
2N927			2N4402
2N928			2N4402
2N935			2N4402
2N936			2N4402
2N937			2N4402
2N938			2N4402
2N939			2N4402
2N940			2N4402
2N941			2N4402
2N942			2N4402
2N943			2N4402
2N944			2N4402
2N945			2N4402
2N946			2N4402
2N956			NT2222
2N958		◎	NT2369A
2N959		◎	NT2369A
2N978			2N4402
2N988			2N4400
2N989			2N4400
2N1051			2N4400
2N1074			2N4400
2N1075			2N4400
2N1076			2N4400

Type No.	Package	Elec-trically	Recommended NEC Device
2N1077			2N4400
2N1081			2N4400
2N1082			2N4400
2N1131			2N4402
2N1131A			2N4402
2N1132			2N4402
2N1132A			2N4402
2N1132B			2N4402
2N1139			2N3903
2N1149			2N4400
2N1150			2N4400
2N1151			2N4400
2N1152			2N4400
2N1153			2N4400
2N1228			2N4402
2N1229			2N4402
2N1230			2N4402
2N1231			2N4402
2N1335			2N4400
2N1336			2N4400
2N1337			2N4400
2N1338			2N4400
2N1386			NT2222
2N1387			NT2222
2N1388			NT2222
2N1389			NT2222A
2N1390			NT2222
2N1420			NT2222
2N1420A			NT2222
2N1441			2N4402
2N1442			2N4402
2N1443			2N4402
2N1469			2N4402

Type No.	Package	Elec-trically	Recommended NEC Device
2N1491			2N4400
2N1492			2N4400
2N1505			2N4400
2N1506			2N4400
2N1506A			2N4400
2N1507			NT2222
2N1528			2N4400
2N1586			2N3903
2N1587			2N3903
2N1588			2N3903
2N1589			2N3903
2N1590			2N3903
2N1591			2N3903
2N1592			2N3903
2N1593			2N3903
2N1594			2N3903
2N1613			2N4400
2N1613A			2N4400
2N1704			2N4400
2N1711			NT2222A
2N1711A			NT2222A
2N1711B			NT2222A
2N1837			2N4400
2N1837A			2N4400
2N1837B			2N4400
2N1838			2N4400
2N1839			2N4400
2N1840			2N4400
2N1941			2N4400
2N1944			NT2222
2N1945			NT2222
2N1946			NT2222A
2N1953			2N4400

Type No.	Package	Elec-trically	Recommended NEC Device
2N1972			NT2222
2N1983			NT2222
2N1984			2N4400
2N1985			2N4400
2N1986			2N4400
2N1987			2N4400
2N1988			2N4400
2N1989			2N4400
2N1991			2N4402
2N1992			2N4400
2N2049			NT2222A
2N2192			NT2222A
2N2192A			NT2222A
2N2192B			NT2222A
2N2193			2N4400
2N2193A			2N4400
2N2193B			2N4400
2N2194			2N4400
2N2194A			2N4400
2N2194B			2N4400
2N2195			2N4400
2N2195A			2N4400
2N2195B			2N4400
2N2217			2N4400
2N2218			2N4400
2N2218A			2N4400
2N2219		◎	NT2222
2N2219A		◎	NT2222A
2N2220			2N4400
2N2221			2N4400
2N2221A			2N4400
2N2222		◎	NT2222
2N2222A		◎	NT2222A

10

Type No.	Package	Elec-trically	Recommended NEC Device
2N222B			NT222A
2N2236			2N4400
2N2237			2N4400
2N2240			2N4400
2N2241			NT2222
2N2272			NT2222
2N2303			NT2907
2N2309			2N4400
2N2314			2N4400
2N2315			2N4400
2N2350			NT2222A
2N2350A			NT2222A
2N2351			2N4400
2N2352			2N4400
2N2352A			2N4400
2N2353			2N4400
2N2353A			2N4400
2N2369		◎	NT2369
2N2369A		◎	NT2369A
2N2380			2N4400
2N2380A			2N4400
2N2393			2N4402
2N2394			2N4402
2N2395			2N4400
2N2396			2N4400
2N2413			2N4400
2N2478			2N4400
2N2479			2N4400
2N2595			2N4402
2N2596			2N4402
2N2597			2N4402
2N2601			2N4402
2N2602			2N4402

Type No.	Package	Elec-trically	Recommended NEC Device
2N2603			2N4402
2N2618			2N4400
2N2645			2N4400
2N2695			2N4402
2N2696			2N4402
2N2709			2N4402
2N2711	△		2N4123
2N2712	△		2N4124
2N2713	△		2N4400
2N2714	△		2N4401
2N2787			2N4400
2N2788			2N4400
2N2789			NT2222A
2N2790			2N4400
2N2791			2N4400
2N2792			NT2222A
2N2801			NT2907A
2N2831			2N4400
2N2837			2N4402
2N2838			NT2907A
2N2863			2N4400
2N2864			2N4400
2N2886			2N4400
2N2904			2N4402
2N2905		◎	NT2907
2N2905A		◎	NT2907A
2N2906			2N4402
2N2907		◎	NT2907
2N2907A		◎	NT2907A
2N2909			2N4400
2N2922	△		2N4124
2N2923	△		2N4123
2N2924	△		2N4124

Type No.	Package	Elec-trically	Recommended NEC Device
2N2925	△		2N4124
2N2926			2N4123, 4
2N2927			2N4402
2N2938			NT2369A
2N2960			NT2222
2N2961			NT2222
2N3011		◎	NT2369A
2N3115			2N4400
2N3116			NT2222
2N3120			2N4402
2N3121			2N4402
2N3122			NT2222
2N3123			NT2222
2N3133			2N4402
2N3135			2N4402
2N3136			NT2907
2N3241			NT2222
2N3241A			NT2222
2N3242			NT2222
2N3242A			NT2222
2N3250			2N3905
2N3251			2N3906
2N3299			2N4400
2N3300			NT2222
2N3301			2N4400
2N3302			NT2222
2N3326			2N4400
2N3390	△		2N4124
2N3391	△		2N4124
2N3391A	△		2N4124
2N3402	△		2N4123
2N3403	△		2N4124
2N3464	△		NT2222A

Type No.	Package	Elec-trically	Recommended NEC Device
2N3485			2N4402
2N3486			NT2907
2N3486A			NT2907A
2N3502			NT2907A
2N3503			NT2907A
2N3504			NT2907A
2N3505			NT2907A
2N3566	○		NT2222
2N3567	○		2N4400
2N3569	○		2N4400
2N3605	△		NT2369A
2N3605A	△		NT2369A
2N3606	△		NT2369A
2N3606A	△		NT2369A
2N3607	△		NT2369A
2N3638	○		NT2907
2N3638A	○		NT2907A
2N3641	○		2N4400
2N3643	○		NT2222
2N3644	○		NT2907A
2N3645	○		NT2907A
2N3671			NT2907A
2N3672			NT2907A
2N3673			NT2907A
2N3702	△		2N4403
2N3703	△		2N4402
2N3704	△		2N4401
2N3705	△		2N4400, 1
2N3706	△		2N4401
2N3830			2N4400
2N3831			2N4400
2N3843	△		2N4124
2N3843A	△		2N4124

Type No.	Package	Elec-trically	Recommended NEC Device
2N3844	△		2N4124
2N3844A	△		2N4124
2N3845	△		2N4124
2N3845A	△		2N4123
2N3854	△		2N4123
2N3854A	△		2N4123
2N3855	△		2N4123
2N3855A	△		2N4123
2N3856	△		2N4123
2N3856A	△		2N4123
2N3858	△		2N4123
2N3859	△		2N4123
2N3860	△		2N4124
2N3862	△		2N3903
2N3903	◎	◎	2N3903
2N3904	◎	◎	2N3904
2N3905	◎	◎	2N3905
2N3906	◎	◎	2N3906
2N3945			2N4400
2N3946		◎	2N3903
2N3947		◎	2N3904
2N3973	△		2N4400
2N3974	△		2N4401
2N3975	△		2N4400
2N3976	△		2N4401
2N3981			2N4400
2N3982			2N4400
2N4086	△		2N4124
2N4087	△		2N4124
2N4087A	△		2N4124
2N4121	○		2N3905
2N4122	○		2N3905
2N4123	◎	◎	2N4123

Type No.	Package	Elec-trically	Recommended NEC Device
2N4124	◎	◎	2N4124
2N4125	◎	◎	2N4125
2N4126	◎	◎	2N4126
2N4140	○		2N4400
2N4141	○		2N4401
2N4142	○		2N4402
2N4143	○		2N4403
2N4227	○		2N4400
2N4228	○		2N4402
2N4256	△		2N3904
2N4274	○		NT2369A
2N4275	○		NT2369A
2N4286	△		2N4124
2N4294	△		NT2369A
2N4400	◎	◎	2N4400
2N4401	◎	◎	2N4401
2N4402	◎	◎	2N4402
2N4403	◎	◎	2N4403
2N4436	○		2N4400
2N4437	○		2N4401
2N4450			NT2222
2N4452			NT2907
2N4890			2N4402
2N4944	○		2N4400
2N4951			2N4400
2N4952			NT2222
2N4953			NT2222
2N4954			2N4400
2N4969	○		2N4400
2N4970	○		2N4401
2N4971	○		2N4402
2N4972	○		2N4403
2N5106			NT2222

Type No.	Package	Elec-trically	Recommended NEC Device
2N5107			NT2222
2N5128	○		NT2222
2N5129	○		NT2222
2N5134	○	◎	NT2369
2N5135	○		NT2222
2N5136	○		NT2222
2N5137	○		NT2222
2N5142	○		NT2907
2N5143	○		NT2907
2N5219	◎		2N4123
2N5220	◎		NT2222
2N5221	◎		NT2907
2N5223	◎		2N4124
2N5225	◎		NT2222
2N5226	◎		NT2907
2N5227	◎		2N3906
2N5354	△		NT2907
2N5355	△		NT2907A
2N5365	△		NT2907A
2N5366	△		NT2907A
2N5368	○		2N4400
2N5369	○		2N4401
2N5370	○		NT2222
2N5371	○		2N4400
2N5372	○		2N4402
2N5373	○		2N4403
2N5375	○		2N4402
2N5380	○		2N3903
2N5381	○		2N3904
2N5382	○		2N3905
2N5383	○		2N3906
2N5418	△		2N4400
2N5419	△		2N4401

Type No.	Package	Elec-trically	Recommended NEC Device
2N5420	△		NT2222
2N5447	○		2N4403
2N5448	○		2N4402
2N5449	○		2N4401
2N5450	○		2N4401
2N5451	○		2N4401
2N5763			NT2907A
2N5769	◎	◎	NT2369A
2N5810	○		2N4401
2N5811	○		2N4403
2N5824	○		2N4123
2N5825	○		2N4123
2N5826	○		2N4124
2N5827	○		2N4124
2N6000	○		2N4401
2N6001	○		2N4402
2N6004	○		2N4401
2N6005	○		2N4402
2N6010	○		2N4401
2N6011	○		2N4402
2N6223	○		NT2907

10

Cross Performance Guide to TO-92 Transistor

Motorola	NEC	Selection	Motorola	NEC	
MPS-A09	JE9014	$BV_{CEO} \geqq 50V$	MPS6523	JE9015	NF ≦ 3 dB
MPS-A18	JE9014		MPS6539	2SC1393	
MPS-A20	JE9014		MPS6540	2SC1393	
MPS-A70	JE9015		MPS6560	JE9013	
MPS-H17	2SC2352	f_T, NF	MPS6562	JE9012	
MPS-H20	2SC1393	BVCBO ≧ 40V	MPS8097	JE9014	NF ≦ 3 dB
MPS-H24	2SC1393	BVCBO ≧ 40V	MPS8098	JE9014	$BV_{CEO} \geqq 60V$
MPS-H32	2SC1393	BVCBO ≧ 40V	MPS8598	JE9015	$BV_{CEO} \geqq 60V$
MPS 918	JE9018		2N3903	2N3903	
MPS2222	NT2222		2N3904	2N3904	
MPS2907	NT2907		2N3905	2N3905	
MPS3563	JE9018		2N3906	2N3906	
MPS3693	JE9014		2N4123	2N4123	
MPS3694	JE9014		2N4124	2N4124	
MPS3702	JE9015		2N4125	2N4125	
MPS3704	JE9015		2N4126	2N4126	
MPS4249	JE9015	BV_{CEO}, NF	2N4400	2N4400	
MPS4250	JE9015	NF	2N4401	2N4401	
MPS4250A	JE9015	BVCEO, NF	2N4402	2N4402	
MPS5172	JE9014		2N4403	2N4403	
MPS5179	2SC2026		2N5086	JE9015	NF ≦ 3 dB
MPS6513	JE9014	NF ≦ 2 dB	2N5087	JE9015	NF ≦ 2 dB
MPS6514	JE9014	NF ≦ 2 dB	2N5209	JE9014	NF ≦ 3 dB
MPS6515	JE9014	NF ≦ 2 dB	2N5210	JE9014	NF ≦ 2 dB
MPS6517	JE9015	NF ≦ 2 dB	2N5222	JE9016	
MPS6518	JE9015	NF ≦ 2 dB	2N6428	JE9014	NF
MPS6519	JE9015	NF ≦ 2 dB	2N6428A	JE9014	NF
MPS6520	JE9014	NF ≦ 3 dB	2N6429	JE9014	NF
MPS6521	JE9014	NF ≦ 3 dB	2N6429A	JE9014	NF
MPS6522	JE9015	NF ≦ 3 dB			

ZENER DIODES
SILICON CONTROLLED RECTIFIERS
(SCRS, TRIACS)

TRIGGER DEVICES

CROSS REFERENCE LIST

Nippon Electric Co., Ltd.

Tokyo, Japan

1980 February

10

1. ZENER DIODES

1) Zener Diodes 500 mW, 1W

SPECIFICATIONS			TYPE NO.				
P (W)	Nominal Voltage Vz(V)	Test Current Iz(mA)	EIA/JEDEC Number	Motorola Number	NEC Number	Replace-ability	Feature of NEC Products and Remarks
0.4	2.4	20	1N4370	·4M2.4AZ	RD2.4E	◎	Vz test conditions are not equal selection is required
	2.7	20	1N4371	·4M2.7AZ	RD2.7E	◎	
	3.0	20	1N4372	·4M3.0AZ	RD3.0E	◎	
	3.3	20	1N746	·4M3.3AZ	1N746	◎	
	3.6	20	1N747	·4M3.6AZ	1N747	◎	
	3.9	20	1N748	·4M3.9AZ	1N748	◎	
	4.3	20	1N749	·4M4.3AZ	1N749	◎	
	4.7	20	1N750	·4M4.7AZ	1N750	◎	
	5.1	20	1N751	·4M5.1AZ	1N751	◎	
	5.6	20	1N752	·4M5.6AZ	1N752	◎	
	6.2	20	1N753	·4M6.2AZ	1N753	◎	
	6.8	20	1N754	·4M6.8AZ	1N754	◎	
	6.8	18.5	1N957	·4M6.8Z	RD6.8E	◎	
	7.5	20	1N755	·4M7.5AZ	1N755	◎	
	7.5	16.5	1N958	·4M7.5Z	RD7.5E	◎	
	8.2	20	1N756	·4M8.2AZ	1N756	◎	
	8.2	15	1N959	·4M8.2Z	RD8.2E	◎	
	9.1	20	1N757	·4M9.1AZ	1N757	◎	
	9.1	14	1N960	·4M9.1Z	RD9.1E	◎	
	10	20	1N758	·4M10AZ	1N758	◎	
	10	12.5	1N961	·4M10Z	RD10E	◎	
	11	11.5	1N962	·4M11Z	RD11E	◎	
	12	20	1N759	·4M12AZ	1N759	◎	
	12	10.5	1N963	·4M12Z	RD12E	◎	
	13	9.5	1N964	·4M13Z	RD13E	◎	
	15	8.5	1N965	·4M15Z	RD15E	◎	
	16	7.8	1N966	·4M16Z	RD16E	◎	
	18	7.0	1N967	·4M18Z	RD18E	◎	
	20	6.2	1N968	·4M20Z	RD20E	◎	
	22	5.6	1N969	·4M22Z	RD22E	◎	
	24	5.2	1N970	·4M24Z	RD24E	◎	

SPECIFICATIONS			TYPE NO.		NEC Number	Replace-ability	Feature of NEC Products and Remarks
P (W)	Nominal Voltage Vz(V)	Test Current Iz(mA)	EIA/JEDEC Number	Motorola Number			
0.4	27	4.6	1N971	·4M27Z	RD27E	◎	
	30	4.2	1N972	·4M30Z	RD30E	◎	
	33	3.8	1N973	·4M33Z	RD33E	◎	
	36	3.4	1N974	·4M36Z	RD36E	◎	
	39	3.2	1N975	·4M39Z	RD39E	◎	
	43	3.0	1N976	·4M43Z	RD43E	◎	
	47	2.7	1N977	·4M47Z	RD47E	◎	
	51	2.5	1N978	·4M51Z	RD51E	◎	
	56	2.2	1N979	·4M56Z	RD56E	◎	
	62	2.0	1N980	·4M62Z	RD62E	◎	
	68	1.8	1N981	·4M68Z	RD68E	◎	
	75	1.7	1N982	·4M75Z	RD75E	◎	
	82	1.5	1N983	·4M82Z	RD82E	◎	
	91	1.4	1N984	·4M91Z	RD91E	◎	
	100	1.3	1N985	·4M100Z	RD100E	◎	
	≀	≀	≀	≀	–	–	
	200	0.31	1N992	·4M200Z	–	–	

10

SPECIFICATIONS			TYPE NO.		NEC Number	Replace-ability	Feature of NEC Products and Remarks
P (W)	Nominal Voltage Vz(V)	Test Current Iz(mA)	EIA/JEDEC Number	Motorola Number			
0.5	2.7	5	BZX55-C2V7	ZPD2.7	RD2.7EB	◎	
	3.0	5	BZX55-C3V0	ZPD3.0	RD3.0EB	◎	
	3.3	5	BZX55-C3V3	ZPD3.3	RD3.3EB	◎	
	3.6	5	BZX55-C3V6	ZPD3.6	RD3.6EB	◎	
	3.9	5	BZX55-C3V9	ZPD3.9	RD3.9EB	◎	
	4.3	5	BZX55-C4V3	ZPD4.3	RD4.3EB	◎	
	4.7	5	BZX55-C4V7	ZPD4.7	RD4.7EB	◎	
	5.1	5	BZX55-C5V1	ZPD5.1	RD5.1EB	◎	
	5.6	5	BZX55-C5V6	ZPD5.6	RD5.6EB	◎	
	6.2	5	BZX55-C6V2	ZPD6.2	RD6.2EB	◎	
	6.8	5	BZX55-C6V8	ZPD6.8	RD6.8EB	◎	
	7.5	5	BZX55-C7V5	ZPD7.5	RD7.5EB	◎	
	8.2	5	BZX55-C8V2	ZPD8.2	RD8.2EB	◎	
	9.1	5	BZX55-C9V1	ZPD9.1	RD9.1EB	◎	
	10	5	BZX55-C10	ZPD10	RD10EB	◎	
	11	5	BZX55-C11	ZPD11	RD11EB	◎	
	12	5	BZX55-C12	ZPD12	RD12EB	◎	
	13	5	BZX55-C13	ZPD13	RD13EB	◎	
	15	5	BZX55-C15	ZPD15	RD15EB	◎	
	16	5	BZX55-C16	ZPD16	RD16EB	◎	
	18	5	BZX55-C18	ZPD18	RD18EB	◎	
	20	5	BZX55-C20	ZPD20	RD20EB	◎	
	22	5	BZX55-C22	ZPD22	RD22EB	◎	
	24	5	BZX55-C24	ZPD24	RD24EB	◎	
	27	5	BZX55-C27	ZPD27	RD27EB	◎	
	30	5	BZX55-C30	ZPD30	RD30EB	◎	
	33	5	BZX55-C33	ZPD33	RD33EB	◎	
	36	5	BZX55-C36	ZPD36	RD36EB	◎	
	39	5	BZX55-C39	ZPD39	RD39EB	◎	
	43	5	BZX55-C43	ZPD43	RD43EB	◎	

SPECIFICATIONS			TYPE NO.		NEC Number	Replace-ability	Feature of NEC Products and Remarks
P (W)	Nominal Voltage Vz(V)	Test Current Iz(mA)	EIA/JEDEC Number	Motorola Number			
0.5	47	5	BZX55-C47	ZPD47	RD47EB	◎	
	51	5	BZX55-C51	ZPD51	RD51EB	◎	

10

SPECIFICATIONS			TYPE NO.		NEC Number	Replace-ability	Feature of NEC Products and Remarks
P (W)	Nominal Voltage Vz(V)	Test Current Iz(mA)	EIA/JEDEC Number	Motorola Number			
0.5	2.4	20	1N5221	•5M2.4ZS	1N5221	◎	Vz test conditions are not equal so selection is required
	2.5	20	1N5222	•5M2.5ZS	1N5222	◎	
	2.7	20	1N5223	•5M2.7ZS	1N5223	◎	
	2.8	20	1N5224	•5M2.8ZS	1N5224	◎	
	3.0	20	1N5225	•5M3.0ZS	1N5225	◎	
	3.3	20	1N5226	•5M3.3ZS	1N5226	◎	
	3.6	20	1N5227	•5M3.6ZS	1N5227	◎	
	3.9	20	1N5228	•5M3.9ZS	1N5228	◎	
	4.3	20	1N5229	•5M4.3ZS	1N5229	◎	
	4.7	20	1N5230	•5M4.7ZS	1N5230	◎	
	5.1	20	1N5231	•5M5.1ZS	1N5231	◎	
	5.6	20	1N5232	•5M5.6ZS	1N5232	◎	
	6.0	20	1N5233	•5M6.0ZS	1N5233	◎	
	6.2	20	1N5234	•5M6.2ZS	1N5234	◎	
	6.8	20	1N5235	•5M6.8ZS	1N5235	◎	
	7.5	20	1N5236	•5M7.5ZS	1N5236	◎	
	8.2	20	1N5237	•5M8.2ZS	1N5237	◎	
	8.7	20	1N5238	•5M8.7ZS	1N5238	◎	
	9.1	20	1N5239	•5M9.1ZS	1N5239	◎	
	10	20	1N5240	•5M10ZS	1N5240	◎	
	11	20	1N5241	•5M11ZS	1N5241	◎	
	12	20	1N5242	•5M12ZS	1N5242	◎	
	13	9.5	1N5243	•5M13ZS	1N5243	◎	
	14	9	1N5244	•5M14ZS	1N5244	◎	
	15	8.5	1N5245	•5M15ZS	1N5245	◎	
	16	7.8	1N5246	•5M16ZS	1N5246	◎	
	17	7.4	1N5247	•5M17ZS	1N5247	◎	
	18	7.0	1N5248	•5M18ZS	1N5248	◎	
	19	6.6	1N5249	•5M19ZS	1N5249	◎	
	20	6.2	1N5250	•5M20ZS	1N5250	◎	
	22	5.6	1N5251	•5M22ZS	1N5251	◎	

SPECIFICATIONS			TYPE NO.		NEC Number	Replace-ability	Feature of NEC Products and Remarks
P (W)	Nominal Voltage Vz(V)	Test Current Iz(mA)	EIA/JEDEC Number	Motorola Number			
0.5	24	5.2	1N5252	.5M24ZS	1N5252	◎	
	25	5.0	1N5253	.5M25ZS	1N5253	◎	
	27	4.6	1N5254	.5M27ZS	1N5254	◎	
	28	4.5	1N5255	.5M28ZS	1N5255	◎	
	30	4.2	1N5256	.5M30ZS	1N5256	◎	
	33	3.8	1N5257	.5M33ZS	1N5257	◎	
	36	3.4	1N5258	.5M36ZS	1N5258	◎	
	39	3.3	1N5259	.5M39ZS	1N5259	◎	
	43	3.0	1N5260	.5M43ZS	1N5260	◎	
	47	2.7	1N5261	.5M47ZS	1N5261	◎	
	51	2.5	1N5262	.5M51ZS	1N5262	◎	
	56	2.2	1N5263	.5M56ZS	1N5263	◎	
	60	2.1	1N5264	.5M60ZS	1N5264	◎	
	62	2.0	1N5265	.5M62ZS	1N5265	◎	
	68	1.8	1N5266	.5M68ZS	1N5266	◎	
	75	1.7	1N5267	.5M75ZS	1N5267	◎	
	82	1.5	1N5268	.5M82ZS	1N5268	◎	
	87	1.4	1N5269	.5M87ZS	1N5269	◎	
	91	1.4	1N5270	.5M91ZS	1N5270	◎	
	100	1.3	1N5271	.5M100ZS	1N5271	◎	
	~	~	~	~	-	-	
	200	0.65	1N5281	.5M200ZS	-	-	

10

SPECIFICATIONS			TYPE NO.				NEC Number	Replace-ability	Feature of NEC Products and Remarks
P (W)	Nominal Voltage Vz(V)	Test Current Iz(mA)	EIA JEDEC Number	EIA Number	EIA Number	Motorola Number			
1.0	3.3	76	1N4728	1N3821	–	1M3.3AZ 1M3.3ZS	RD3.3F	◎	Vz test conditions are not equal so selection is required
	3.6	69	1N4729	1N3822	–	1M3.6AZ 1M3.6ZS	RD3.6F	◎	
	3.9	64	1N4730	1N3823	–	1M3.9AZ 1M3.9ZS	RD3.9F	◎	
	4.3	58	1N4731	1N3824	–	1M4.3AZ 1M4.3ZS	RD4.3F	◎	
	4.7	53	1N4732	1N3825	–	1M4.7AZ 1M4.7ZS	RD4.7F	◎	
	5.1	49	1N4733	1N3826	–	1M5.1AZ 1M5.1ZS	RD5.1F	◎	
	5.6	45	1N4734	1N3827	–	1M5.6AZ 1M5.6ZS	RD5.6F	◎	
	6.2	41	1N4735	1N3828	–	1M6.2AZ 1M6.2ZS	RD6.2F	◎	
	6.8	37	1N4736	1N3829	1N3016	1M6.8AZ 1M6.8Z 1M6.8ZS	RD6.8F	◎	
	7.5	34	1N4737	1N3830	1N3017	1M7.5AZ 1M7.5Z 1M7.5ZS	RD7.5F	◎	
	8.2	31	1N4738	–	1N3018	1M8.2Z 1M8.2ZS	RD8.2F	◎	
	9.1	28	1N4739	–	1N3019	1M9.1AZ 1M9.1ZS	RD9.1F	◎	
	10	25	1N4740	–	1N3020	1M10AZ 1M10ZS	RD10F	◎	
	11	23	1N4741	–	1N3021	1M11AZ 1M11ZS	RD11F	◎	
	12	21	1N4742	–	1N3022	1M12AZ 1M12ZS	RD12F	◎	
	13	19	1N4743	–	1N3032	1M13AZ 1M13ZS	RD13F	◎	
	15	17	1N4744	–	1N3024	1M15AZ 1M15ZS	RD15F	◎	
	16	15.5	1N4745	–	1N3025	1M16AZ 1M16ZS	RD16F	◎	
	18	14	1N4746	–	1N3026	1M18AZ 1M18ZS	RD18F	◎	
	20	12.5	1N4747	–	1N3027	1M20AZ 1M20ZS	RD20F	◎	
	22	11.5	1N4748	–	1N3028	1M22AZ 1M22ZS	RD22F	◎	
	24	10.5	1N4749	–	1N3029	1M24AZ 1M24ZS	RD24F	◎	
	27	9.5	1N4750	–	1N3030	1M27AZ 1M27ZS	RD27F	◎	
	30	8.5	1N4751	–	1N3031	1M30AZ 1M30ZS	RD30F	◎	

SPECIFICATIONS			TYPE NO.				NEC Number	Replace-ability	Feature of NEC Products and Remarks
P (W)	Nominal Voltage Vz(V)	Test Current Iz(mA)	EIA JEDEC Number	EIA Number	EIA Number	Motorola Number			
1.0	33	7.5	1N4752	-	1N3032	1M33AZ 1M33ZS	RD33F	◎	
	36	7.0	1N4753	-	1N3033	1M36AZ 1M36ZS	RD36F	◎	
	39	6.5	1N4754	-	1N3034	1M39AZ 1M39ZS	RD39F	◎	
	43	6	1N4755	-	1N3035	1M43Z 1M43ZS	RD43F	◎	
	47	5.5	1N4756	-	1N3036	1M47Z 1M47ZS	RD47F	◎	
	51	5	1N4757	-	1N3037	1M51Z 1M51ZS	RD51F	◎	
	56	4.5	1N4758	-	1N3038	1M56Z 1M56ZS	RD56F	◎	
	62	4	1N4759	-	1N3039	1M62Z 1M62ZS	RD62F	◎	
	68	3.7	1N4760	-	1N3040	1M68Z 1M68ZS	RD68F	◎	
	75	3.3	1N4761	-	1N3041	1M75Z 1M75ZS	RD75F	◎	
	82	3	1N4762	-	1N3042	1M82Z 1M82ZS	RD82F	◎	
	∫	∫	∫		∫	∫			
	100	2.5	1N4764	-			-	-	
	∫	∫	∫						
	200	1.2	-	-	1N3051	1M200Z	-	-	

10

SPECIFICATIONS				TYPE NO.		NEC Number	Replace-ability	Feature of NEC Products and Remarks
P (W)	Nominal Voltage Vz(V)	Test Current Iz (mA)		Sescosem Number	ITT Number			
		(ITT)	(Sescosem)					
1.3	3.9	100	60	BZX85-C3V9	ZPY3.9	RD3.9F	◎	Vz test conditions are not equal, so selection is required
	4.3	100	50	BZX85-C4V3	ZPY4.3	RD4.3F	◎	
	4.7	100	45	BZX85-C4V7	ZPY4.7	RD4.7F	◎	
	5.1	100	45	BZX85-C5V1	ZPY5.1	RD5.1F	◎	
	5.6	100	45	BZX85-C5V6	ZPY5.6	RD5.6F	◎	
	6.2	100	35	BZX85-C6V2	ZPY6.2	RD6.2F	◎	
	6.8	100	35	BZX85-C6V8	ZPY6.8	RD6.8F	◎	
	7.5	100	35	BZX85-C7V5	ZPY7.5	RD7.5F	◎	
	8.2	100	25	BZX85-C8V2	ZPY8.2	RD8.2F	◎	
	9.1	50	25	BZX85-C9V1	ZPY9.1	RD9.1F	◎	
	10	50	25	BZX85-C10	ZPY10	RD10F	◎	
	11	50	20	BZX85-C11	ZPY11	RD11F	◎	
	12	50	20	BZX85-C12	ZPY12	RD12F	◎	
	13	50	20	BZX85-C13	ZPY13	RD13F	◎	
	15	50	15	BZX85-C15	ZPY15	RD15F	◎	
	16	25	15	BZX85-C16	ZPY16	RD16F	◎	
	18	25	15	BZX85-C18	ZPY18	RD18F	◎	
	20	25	10	BZX85-C20	ZPY20	RD20F	◎	
	22	25	10	BZX85-C22	ZPY22	RD22F	◎	
	24	25	10	BZX85-C24	ZPY24	RD24F	◎	
	27	25	8	BZX85-C27	ZPY27	RD27F	◎	
	30	25	8	BZX85-C30	ZPY30	RD33F	◎	
	33	25	8	BZX85-C33	ZPY33	RD33F	◎	
	36	10	8	BZX85-C36	ZPY36	RD36F	◎	
	39	10	6	BZX85-C39	ZPY39	RD39F	◎	
	43	10	6	BZX85-C43	ZPY43	RD43F	◎	
	47	10	4	BZX85-C47	ZPY47	RD47F	◎	
	51	10	4	BZX85-C51	ZPY51	RD51F	◎	
	56	10	4	BZX85-C56	ZPY56	RD56F	◎	
	62	10	4	BZX85-C62	ZPY62	RD62F	◎	
	68	10	3.7	BZX85-C68	ZPY68	RD68F	◎	
	75	10	3.3	BZX85-C75	ZPY75	RD75F	◎	
	82	10	3	BZX85-C82	ZPY82	RD82F	◎	
	91	5	2.8	BZX85-C91	ZPY91	RD91F	◎	
	100	5	2.5	BZX85-C100	ZPY100	RD100F	◎	

2) Voltage Reference Diodes (Temperature Compensated)

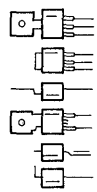
SPECIFICATIONS				TYPE NO.			NEC Number	Replace-ability	Feature of NEC Products and Remarks
P (W)	Nominal Voltage Vz(V)	Test Current Iz(mA)	Temperature Coefficient γ_z(%/°C)	EIA/JEDEC Number		Sescosem Number			
0.25	6.2	7.5	0.01	1N821	1N3500	BZV27	1SZ50	◎	DO-35 Package
			0.005	1N823	1N3496	BZV28	1SZ51	◎	Temperature Range
			0.002	1N825	1N3497	BZV29	1SZ52	◎	-25 ~ 75°C
			0.001	1N827	1N3498	BZV30	1SZ53	◎	1SZ53 0 ~ 75°C
			0.0005	1N829	1N3499	BZV31	-	-	
0.25	6.4	1	0.01	1N4570			1SZ45A	◎	DO-35 Package
			0.005	1N4571			1SZ46A	◎	Temperature Range
			0.002	1N4572			1SZ47	◎	-10 ~ 60°C
			0.001	1N4573			1SZ48	◎	
			0.0005	1N4574			-		
			0.01	1N4570A			1SZ45A		Suffix A Type
			0.005	1N4571A			1SZ46A		-40 ~ 100°C
			0.002	1N4572A			1SZ47A		
			0.001	1N4573A			-		
			0.0005	1N4574A			-		

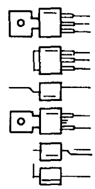
10

Type No.	Main Specification			Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	I_T(A)	V_{DRM} V_{RRM} (V)	Others				
MOTOROLA							
2N5060	0.5	30	$I_{GT} \leqq 0.2$mA		N203YY	○	
2N5061	0.8(RMS)	60	$I_H \leqq 5$mA	TO-92'	N203YY	○	△0.51A
2N5062	(T_C=67°C)	100	$I_{GT} \leqq 0.35$A		N203A	○	at T_C=25°C
2N5063		150	(at T_C=−65°C)		N203B	○	
2N5064		200			N203B	○	
TECCOR (ECC)	0.5						
EC103Y	0.8(RMS)	30	$I_{GT} \leqq 0.2$mA		N203YY	○	△0.51A
EC103A	(T_C=67°C)	100	$I_H \leqq 5$mA	TO-92	N203A	○	at T_C=25°C
EC103B		200	dv/dt >4V/μS		N203B	○	
EC103D		400			N203D	○	
2N5060	0.5	30	$I_{GT} \leqq 0.2$mA		N203YY	○	
	0.8(RMS)		$I_{GT} \leqq 0.35$mA				△0.51A
2N5062	(T_C=67°C)	100	(at T_C=−65°C)	TO-92	N203A	○	at T_C=25°C
			$I_H \leqq 5$mA				
2N5064		200	$I_H \leqq 10$mA		N203B	○	
			(at T_C=−65°C)				
TRANSITRON							
2N5060	255m	30	$I_H \leqq 0.35$mA		N203YY	○	△0.51A
2N5061	(T_C=102°C)	50	$I_H \leqq 10$mA	TO-92	N203YY	○	at T_C=25°C
2N5062		100	(at T_C=−65°C)		N203A	○	
2N5063		150			N203B	○	
2N5064		200			N203B	○	
RTJ103		30			N203YY	○	
RTJ106	400m	60	$I_{GT} \leqq 100$μA		N203YY	○	△0.51A
RTJ110	(T_C=80°C)	100	$I_H \leqq 5$mA	TO-92	N203A	○	at T_C=25°C
RTJ120		200	I_{TSM}=5A		N203B	○	
RTJ130		300			N203C	○	
RTJ140		400			N203D	○	
RTJ103-1		30			–		
RTJ106-1		60	$I_{GT} \leqq 2$μA		–		
RTJ110-1	400m	100	$I_H \leqq 5$mA	TO-92	–		
RTJ120-1	(T_C=80°C)	200	I_{TSM}=5A		–		
RTJ130-1		300					
RTJ140-1		400			–		

Type No.	Main Specification			Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	I_T(A)	VDRM VRRM (V)	Others				
TRANSITRON							
RTJ103-2		30	$I_{GT} \geqq 5\mu A$		N203YY	○	
RTJ106-2	400m	60	$I_H \leqq 5mA$	TO-92	N203YY	○	△0.51A
RTJ110-2	($Tc=80^oC$)	100	$I_{TSM}=5A$		N203A	○	at $Tc=25^oC$
RTJ120-2		200			N203B	○	
RTJ130-2		300			N203C	○	
RTJ140-2		400			N203D	○	
TEXAS INSTRUMENTS			$I_{GT} \leqq 0.2mA$				
T1C 45	300m	60	$I_H \leqq 5mA$	RD-26	N203YY	◎	○0.3A
T1C 46	($Ta=25^oC$)	100	$I_{TSM}=6A$	NEC	N203A	◎	at $Ta=35^oC$
T1C 47		200	(repetitive)	TO-92	N203B	◎	
UNITRODE							
2N5060		30			N203YY	○	
2N5061	255m	60	$I_{GT} \leqq 0.35mA$	TO-92	N203YY	○	△0.51A
2N5062	($Tc=102^oC$)	100	$I_H \leqq 10mA$		N203A	○	at $Tc=25^oC$
2N5063		150	(at $Tc=-65^oC$)		N203B	○	
2N5064		200			N203B	○	
2N6564	510m	300	$I_{GT} \leqq 350\mu A$		N203C	○	△0.51A
			$I_H \leqq 10mA$				at $Tc=25^oC$
2N6565	($Tc=70^oC$)	400	(at $Tc=-65^oC$)		N203D	○	
GE							
C103Y		30		MOLD	C203Y	○	
C103YY	0.8(RMS)	60	$-65\sim125^oC$	TO-18	C203YY	○	
C103A		100	$I_{GT} \leqq 200\mu A$	NEC	C203A	○	
C103B		200		TO-92	C203B	○	
C203Y		30			C203Y	◎	
C203YY		60			C203YY	◎	
C203A	0.8(RMS)	100	$I_{GT} \leqq 500\mu A$		C203A	◎	
C203B		200	$I_H \leqq 10mA$	TO-92	C203B	◎	
C203C		300	(at $Tc=-65^oC$)		C203C	◎	
C203D		400			C203D	◎	

10

Type No.	Main Specification			Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	I_T(A)	VDRM VRRM (V)	Others				
RCA							
S122F		50	I_{TSM}=100A		C122F	◎	Almost equivalent ratings
S122A		100	(60Hz)		C122A	◎	
S122B	5	200	di/dt=100A/µS	JEDEC	C122B	◎	
S122C	(Tc=80°C)	300	dv/dt ≧10V/µS	TO-220AB	C122C	◎	
S122D		400	tgt ≦2.5µS		C122D	◎	
S122E		500	tq ≦ 35µS		C122E	◎	
S122M		600	I_{GT} ≦ 25mA		C122M	◎	
S122S		700					
S2800F		50			C122F	○	
S2800A		100	I_{TSM}=100A		C122A	○	Almost equivalent ratings
S2800B	6.4	200	(60Hz)		C122B	○	
S2800C	(Tc=75°C)	300	di/dt=100A/µS	JEDEC	C122C	○	
S2800D		400	t_{gt} ≦2.5µS	TO-220AB	C122D	○	
S2800E		500	tq ≦35µS		C122E	○	
S2800M		600	I_{GT} ≦15mA		C122M	○	
S2800S		700					
GE							Forming (BASIC TYPES)
C107Q1		15	Tj V_{TM}		C106Q1	○	
C107Q2		15		MOLD	C106Q2	○	
C107Q3	4.0(RMS)	15	-40 ~ 110°C		C106Q3	○	 TYPE 1 2 AY 3 CC BY
C107Q4		15			–		
C107Y		30	2.5V		C106Y「」	○	
C107F		50	I_T=4A		C106F「」	○	
C107A		100			C106A「」	○	
C107B		200			C106B「」	○	
C107C		300	Note		C106C「」	○	
C107D		400	I_{GT}≦500µA		C106D「」	○	

Type No.	Main Specification			Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	I_T(A)	VDRM VRRM (V)	Others				
C106Q1		15	Tj V_{TM}		C106Q1	◎	
C106Q2		15	↑ ↑		C106Q2	◎	Forming (BASIC TYPES)
C106Q3		15			C106Q3	◎	
C106Q4	4.0(RMS)	15	-40 ~ 110°C	MOLD	C106Q4	-	TYPE
C106Y		30			C106Y「」	◎	 1
C106F		50			C106F「」	◎	2
C106A		100	2.2V		C106A「」	◎	AY
C106B		200	I_T=4A		C106B「」	◎	3
C106C		300			C106C「」	◎	CC
C106D		400	↓ ↓		C106D「」	◎	BY
			I_{GT} ≦ 200µA				
MOTOROLA			(60Hz)				
2N4441	5.1	50	I_{TSM}=80A	MISCEL	C122F	○	higher ratings
2N4442	(Tc=75°C)	200	I_{GT} ≦ 60mA	LANEOUS	C122B	○	I_{TSM}=90A
2N4443		400	Tj=-40~100°C		C122D	○	low I_{GT}(≦ 25mA)
2N4444		600		MV10	C122M	○	Package (TO-220AB)
2N6394		50	I_{TSM}=100A		C122F	◎	I_T(RMS)=8A
2N6395	7.6	100	(60Hz)	JEDEC	C122A	◎	I_{GT}(≦25mA)
2N6396	(Tc=94°C)	200	I_{GT} ≦ 30mA	TO-220AB	C122B	◎	
2N6397		400	Tj=-40~125°C		C122D	◎	
2N6398		600			C122M	◎	
2N6399		800			-		
HUTSON							
1S08		50			C122F	△	
1S18		100	I_{TSM}=100A	MISCEL-	C122A	△	Non Isolated Type
1S28	5	200	(60Hz)	LANEOUS	C122B	△	
1S38	8(RMS)	300	I_{GT} ≦ 25mA		C122C	△	
1S48		400			C122D	△	
1S58		500			C122E	△	
1S68		600			C122M	△	

10

Type No.	Main Specification			Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	I_T(A)	VDRM VRRM (V)	Others				
TECCOR							
S0306L		30	I_{TSM}=100A		C122F	△	High Ratings
S0506L		50	(60Hz)		C122F	△	Non Isolated
S1006L	3.8	100	$I_{GT} \leqq$ 15mA	JEDEC	C122A	△	Type
S2006L	(Tc=80°C)	200	dv/dt≧ 30V/μS	TO-220	C122B	△	
S4006L	6 (RMS)	400	Tj=-40°~100°C	AB	C122D	△	
S6006L		600	Insulated		C122M	△	
			Type				
S0308L		30	I_{TSM}=100A		C122F	△	
S0508L		50	(60Hz)		C122F	△	
S1008L	5.1	100	$I_{GT} \leqq$ 15mA	JEDEC	C122A	△	
S2008L	(Tc=80°C)	200	dv/dt≧30V/μS	TO-220	C122B	△	
S4008L	6 (RMS)	400	Tj=-40~100°C	AB	C122D	△	
S6008L		600	Insulated		C122M	△	
			Type				
S0310L		30	I_{TSM}=100A		C122F	△	Almost
S0510L		50	(60Hz)		C122F	△	equivalent
S1010L	6.4	100	$I_{GT} \leqq$ 15mA	JEDEC	C122A	△	ratings
S2010L	(Tc=80°C)	200	dv/dt≧30V/μS	TO-220	C122B	△	Non Isolated
S4010L	10 (RMS)	400	Tj=-40~100°C	AB	C122D	△	Type
S6010L		600	Insulated		C122M	△	
			Type				
GE							
C122F		50	I_{TSM}=90A		C122F	◎	Equivalent
C122A		100	(60Hz)	JEDEC	C122A	◎	ratings
C122B	5.1	200	dI_T/dt=100A/μS	TO-220	C122B	◎	
C122C	(Tc=77°C)	300	dv/dt ≧10V/μS	AB	C122C	◎	
C122D		400	$I_{GT} \leqq$ 25mA		C122D	◎	
C122E		500	$V_{GT} \leqq$ 1.5V		C122E	◎	
C122M		600	Tj=-40~100°C		C122M	◎	

3. TRIAC

1) I_T (RMS) = ~ 1A

Type No.	Main Specification			Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	I_T(A)	VDRM VRRM (V)	Others				
MOTOROLA							
MAC94-1		25			-		Almost
MAC94-2		50			-		equivalent
MAC94-3		100			ACOV8BGM	◎	I_{GT} I,III,IV
MAC94-4	0.8	200	I_{GT} I,III,IV	JEDEC	ACOV8BGM	◎	≦5mA
MAC94-5		300	≦10mA	TO-92	ACOV8DGM	◎	
MAC94-6		400			ACOV8DGM	◎	I_{GT} II
MAC94-7		500			-		≦10mA
MAC94-8		600					
MAC94A-1		25			-		Almost
MAC94A-2		50			-		equivalent
MAC94A-3		100			ACOV8BGM	◎	I_{GT} I,III,IV
MAC94A-4	0.8	200	I_{GT} I,II,III,	JEDEC	ACOV8BGM	◎	≦5mA
MAC94A-5		300	IV	TO-92	ACOV8DGM	◎	
MAC94A-6		400	≦10mA		ACOV8DGM	◎	I_{GT} II
MAC94A-7		500			-		≦10mA
MAC94A-8		600			-		
MAC95-1		25			-		Almost
MAC95-2		50			-		equivalent
MAC95-3		100			ACOV8BGM	◎	I_{GT} I,III,IV
MAC95-4	0.8	200	I_{GT} I,III,IV	JEDEC	ACOV8BGM	◎	≦5mA
MAC95-5		300	≦5mA	TO-92	ACOV8DGM	◎	
MAC95-6		400			ACOV8DGM	◎	I_{GT} II
MAC95-7		500			-		≦10mA
MAC95-8		600			-		
MAC95A-1		25			-		
MAC95A-2		50			-		
MAC95A-3		100			ACOV8BGM	○	Can be replaced
MAC95A-4	0.8	200	I_{GT} I,II,III,	JEDEC	ACOV8BGM	○	by selection
MAC95A-5		300	IV	TO-92	ACOV8DGM	○	
MAC95A-6		400	≦5mA		ACOV8DGM	○	
MAC95A-7		500			-		
MAC95A-8		600			-		

10

Type No.	Main Specification			Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	I_T(A)	VDRM VRRM (V)	Others				
MAC96-1		25			-		
MAC96-2		50			-		
MAC96-3		100			ACOV8BGM	○	Can be replaced
MAC96-4	0.8	200	I_{GT} I,III,IV	JEDEC	ACOV8BGM	○	by selection.
MAC96-5		300	≦3mA	TO-92	ACOV8DGM	○	
MAC96-6		400			ACOV8DGM	○	
MAC96-7		500			-		
MAC96-8		600			-		
UNITRODE							
IB202	0.8	200	I_{GT} I,III	JEDEC	ACOV8BGM	◎	Almost
IB204	(T_C=65°C)	400	≦5mA	TO-92	ACOV8DGM	◎	equivalent
IB206		600	I_{GT} II,IV		-		I_{GT} I,III,IV
			≦10mA				≦5mA
							I_{GT} II
							≦10mA
TECCOR							
L200E3	0.8	200	I_{GT} I,II,III,	JEDEC	ACOV8BGM	×	I_{GT} II
L400E3	(T_C=60°C)	400	IV	TO-92	ACOV8DGM	×	not guaranteed
			≦3mA				
L200E5	0.8	200	I_{GT} I,II,III,	JEDEC	ACOV8BGM	○	Can be replaced
L400E5	(T_C=60°C)	400	IV	TO-92	ACOV8DGM	○	by selection
			≦5mA				
Q200E3	0.8	200	I_{GT} I,III	JEDEC	ACOV8BGM	◎	Almost
Q400E3	(T_C=60°C)	400	≦10mA	TO-92	ACOV8DGM	◎	equivalent
							I_{GT} I,III,IV
							≦5mA
							I_{GT} II
							≦10mA
GE							Almost
			I_{GT} I,II,III				equivalent
			IV	JEDEC			I_{GT} I,III,IV
SC92	0.8	〜	≦10mA	TO-92	〜	〜	≦5mA
		400			ACOV8DGM	◎	I_{GT} II
							≦10mA

3. TRIAC

2) I_T (RMS) = 2 ~ 4A

Type No.	Main Specification I_T(A)	V_{DRM} (V) RRM	Others		Package	NEC Number	Replace-ability	Feature NEC Products and Remarks
MOTOROLA			I_{GT}	I_{TSM}				
2N6068		25	I,III	=30A		SC136B	◎	
2N6069		50	≦30mA	(60Hz)		SC136B	◎	
2N6070		100		I_{TSM}		SC136B	◎	
2N6071		200		=30A		SC136B	◎	Almost
2N6072		300	I_{GT}	(60Hz)		SC136D	◎	equivalent
2N6073		400	I,III			SC136D	◎	TO-202AA
2N6074	4	500	≦30mA	Tj=-40	MISCEL-	AC03EGM	◎	
2N6075	(Tc=85°C)	600		~110°C	LANEOUS	AC03FGM	◎	
2N6068A		25			MU47	SC136B	◎	
2N6069A		50	I_{GT}			SC136B	◎	
2N6070A		100	I,III,IV			SC136B	◎	
2N6071A		200	≦20mA			SC136B	◎	
2N6072A		300				SC136D	◎	
2N6073A		400				SC136D	◎	
2N6074A		500				AC03EGM	◎	
2N6075A		600				AC03FGM	◎	
2N6068B		25				SC136B	◎	
2N6069B		50	I_{GT}			SC136B	◎	
2N6070B		100	I,III,IV			SC136B	◎	
2N6071B		200	≦15mA			SC136B	◎	
2N6072B		300				SC136D	◎	
2N6073B		400	I_{GT} II			SC136D	◎	
2N6074B		500	≦20mA			AC03EGM	◎	
2N6075B		600				AC03FGM	◎	
TECCOR								
Q2003L3		200	I_{GT} I,III	I_{TSM}=30A		SC136B	○	△Non-isolated
Q4003L3		400	≦10mA	(60Hz)		SC136D	○	
	3.0			(dv/dt)c	JEDEC			
Q2003L4	(Tc=80°C)	200	I_{GT} I,III	≧2V/μS	TO-220AB	SC136B	○	
Q4003L4		400	≦25mA	Tj=-40		SC136D	○	
Q2003LT		200	Built-in	~100°C		SC136B	○	N413+AC03⌈ ⌋GM
Q4003LT		400	Diac	Insulated		SC136D	○	

10

Type No.	Main Specification I_T(A)	V_{DRM} (V) RRM	Others		Package	NEC Number	Replace-ability	Feature NEC Products and Remarks
Q2004L4	4.0 (Tc=80°C)	200	I_{GT} I,III ≦ 25mA	I_{TSM}=30A (60Hz) (dv/dt)c ≧2V/μS Tj=-40 ~100°C Insulated	JEDEC TO-220AB	SC141B	○	△Non-isolated
Q4004L4		400				SC141D	○	
Q5004L4		500				SC141E	○	
Q6004L4		600				SC141M	○	
Q2004LT		200	Built-in Diac			SC141B	○	N413+SC141
Q4004LT		400				SC141D	○	
Q5004LT		500				SC141E	○	
Q6004LT		500				SC141M	○	
ITT TC0420	4 (Tc=100°C)	200	I_{TSM}=40A (50Hz)			SC141B	◎	High I_T(RMS)
TC0440	4 (Tc=100°C)	400	I_{GT} I,III ≦35mA		JEDEC TO-220AB	SC141D	◎	High I_{TSM} (80A)
TC0450		500	I_{GT} IV ≦25mA			SC141E	◎	△I_{GT} II Not guaranteed
TC0460		600	I_{GT} II ≦55mA			SC141M	◎	
GE SC136B	3 (Tc=65°C)	200	I_{TSM}=30A (60Hz) (dv/dt)c ≧5V/μS I_{GT} I,III,IV ≦25mA V_{GT} I,III,IV ≦2.0V Tj=-40~110°C		JEDEC TO-202AA	SC136B	◎	Almost equivalent
SC136D		400				SC136D	◎	
SC137A	3 (Tc=65°C)	100	I_{TSM}=30A (dv/dt)c ≧5V/μS I_{GT} I,II,III,IV ≦10mA V_{GT} I,II,III,IV ≦1.5V		JEDEC TO-202AA	SC136B	◎	
SC137B		200				SC136B	◎	IGT: Selection is available
SC137D		400					◎	SC136M (600V) SC136E (500V)

3) I_T (RMS) = 6A

Type No.	Main Specification			Package	NEC Number	Replace-ability	NEC Products and Remarks
	I_T(A)	V_{DRM} (V) RRM	Others				
RCA							
T2506B	6.0	200	I_{TSM}=60A (60Hz)		SC141B	×	
T2506D	(Tc=80°C)	400	di/dt=70A/μS		SC141D	×	I_{GT} II:
			(dv/dt)c ≧4V/μS	JEDEC			Not guaranteed
			I_{GT} I,II ≦45mA	TO-220AB			
T2801B	6.0	200	I_{TSM}=80A (60Hz)	JEDEC	SC141B	◎	Almost
T2801C	(Tc=80°C)	300	di/dt=70A/μS	TO-220AB	SC141D	◎	equivalent
T2801D		400	(dv/dt)c ≧2V/μS		SC141D	◎	
T2801E		500	I_{GT} I,III ≦80mA		SC141E	◎	
T2500B	6.0	200	I_{TSM}=60A (60Hz)	JEDEC	SC141B	◎	
T2500D	(Tc=80°C)	400	di/dt=70A/μS	TO-220AB	SC141D	◎	
			(dv/dt)c ≧4V/μS				
			I_{GT} I,III ≦25mA				
			I_{GT} II,IV ≦60mA				
HUTSON							
IT06	6	50	I_{TSM}=100A (60Hz)	MISCEL-	SC141B	○	Non-isolated
IT16		100	I_{GT} I,III ≦50mA	LANEOUS	SC141B	○	
IT26		200	I_{GT} II,IV ≦80mA		SC141B	○	
IT36		300	Isolated type	MU29	SC141D	○	
IT46		400			SC141D	○	
IT56		500			SC141E	○	
IT66		600			SC141M	○	
SSC							
TXAL116	6	200	No; I_{TSM}=100A	JEDEC	SC141B	◎	
TXAL226	(Tc=80°C)	400	insulated; (60Hz)		SC141D	◎	
TXAL606		600	I_{GT} I,III	TO-220AB	SC141M	◎	
			≦50mA				
TYAL116		200	I_{GT} I,III		SC141B	○	
TYAL226		400	insulated; ≦80mA		SC141D	○	Non-isolated
TYAL606		600			SC141M	○	
TECCOR							
Q2006L4		200	I_{GT} I,III; I_{TSM}=80A		SC141B	○	Non-isolated
Q4006L4		400	≦ 25mA; (60Hz)		SC141D	○	

10

Type No.	Main Specification				Package	NEC Number	Replace-ability	Feature NEC Products and Remarks
	I_T(A)	V_{DRM} (V) RRM	Others					
TECCOR								
Q5006L4		500	I_{GT} I,III	I_{TSM}=80A	JEDEC	SC141E	○	
Q6006L4		600	≦25mA	(60Hz)	TO-220AB	SC141M	○	
	6.0			(dv/dt)c				
Q2006LT	(Tc=80°C)	200		≧2V/µS		SC141B	○	Non-isolated
Q4006LT		400		Tj=-40		SC111D	○	N413+SC141
Q5006LT		500		~100°C		SC141E	○	
Q6006LT		600		Isolated		SC141M	○	
ITT								
TC0620		200	I_{TSM}=60A		JEDEC	S141B	○	I_T(RMS): High
	6		(50Hz)					I_{TSM}: High
TC0640	(Tc=100°C)	400	I_{GT} I,III		TO-220AB	SC141D	○	(80A)
			≦35mA					I_{GT} II:
TC0650		500	I_{GT} IV≦25mA			SC141E	○	not guaranteed
TC0660		600	I_{GT} II≦55mA			SC141M	○	
			Tj=-40~120°C					
GE								
SC141B		200	I_{TSM}=80A		JEDEC	S141B	◎	
	6A		(60Hz)					
SC141D	(TC=80°C)	400	(dv/dt)c ≧4V/µS		TO-220AB	SC141D	◎	Almost
SC141E		500	I_{GT} I,III,IV			SC141E	◎	equivalent
			IV					
			≦ 50mA					
SC141M		600	V_{GT} I,III,IV			SC141M	◎	
			≦2.5V					
			Tj=-40~100°C					

4) I_T (RMS) = 8A

Type No.	Main Specification			Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	I_T(A)	V_{DRM} (V) RRM	Others				
RCA T2860B T2806D	8 (Tc=80°C)	200 400	I_{TSM}=100A (60Hz) di/dt=70A/μS (dv/dt)c ≧4V/μS I_{GT} I,II ≦45mA	JEDEC TO-220AB	SC143B SC143D	× ×	Almost equivalent Rating I_{GT} II: not guaranteed
T2850A T2850B T2850D	8 (Tc=80°C)	100 200 400	I_{TSM}=100A (60Hz) di/dt=70A/μS (dv/dt)c ≧4V/μS I_{GT} I,III ≦25mA I_{GT} II,IV ≦60mA Isolated type	JEDEC TO-220AB	SC143B SC143B SC143D	○ ○ ○	Almost equivalent Rating Non-isolated I_{GT} II: not guaranteed
T2856B T2856D	8 (Tc=80°C)	200 400	I_{TSM}=100A (60Hz) di/dt=70A/μS (dv/dt)c ≧4V/μS I_{GT} I,II ≦45mA Isolated type	JEDEC TO-220AB	SC143B SC143D	× ×	Almost equivalent Rating Non-isolated I_{GT} II: no guaranteed
T2800B T2800C T2800D T2800E T2800M	8.0 (Tc=80°C)	200 300 400 500 600	I_{TSM}=100A (60Hz) di/dt=70A/μS (dv/dt)c ≧4V/μS I_{GT} I,III≦25mA I_{GT} II,III ≦60mA	JEDEC TO-220AB	SC143B SC143D SC143D SC143E SC143M	× × × × ×	Almost equivalent Rating I_{GT} II: not guaranteed
T2802B T2802C T2802D T2802E T2802M	8.0 (Tc=80°C)	200 300 400 500 600	I_{TSM}=100A (60Hz) di/dt/70A/μS (dv/dt)c ≧4V/μS I_{GT} I,III ≦50mA	JEDEC TO-220AB	SC143B SC143D SC143D SC143E SC143M	◎ ◎ ◎ ◎ ◎	Almost equivalent Rating
MOTOROLA 2N6342 2N6343 2N6344 2N6345	8 (Tc=80°C)	200 400 600 800	I_{TSM}=100A (60Hz) I_{GT} I,III≦50mA I_{GT} II,IV≦75mA	JEDEC TO-220AB	SC143B SC143D SC143M -	◎ ◎ ◎ ×	Almost equivalent

10

Type No.	Main Specification				Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	I_T(A)	V_{DRM} (V) RRM	Others					
MAC220-2		50	I_{TSM}=100A (60Hz)		JEDEC	SC143B	◎	
MAC220-3	8	100	I_{GT} I,III,IV		TO-220AB	SC143B	◎	Almost
MAC220-5	(Tc=80°C)	300	≤50mA			SV143D	◎	equivalent
MAC220-7		500				SC143E	◎	
MAC220-9		700				SC143M	△	
HUTSON								
IT08		50	I_{TSM}=100A (60Hz)		MISCEL-	SC143B	○	
IT18		100	I_{GT} I,III≤50mA		LANEOUS	SC143B	○	
IT28	8	200	I_{GT} II,IV			SC143B	○	Non-isolated
IT38	(Tc=75°C)	300	≤80mA		MU29	SC143D	○	
IT48		400	Isolated type			SC143D	○	
IT58		500				SC143E	○	
IT68		600				SC143M	○	
SSC								
TXAL118		200	Non-	I_{TSM}=110A	JEDEC	SC143B	◎	Almost
TXAL228		400	isolated	(60Hz)	TO-220AB	SV143D	◎	equivalent
TXAL608	8	600	type	I_{GT} II,III		SC143M	◎	Rating
TYAL118	(Tc=80°C)	200	Isolated	≤50mA		SC143B	○	Non-
TYAL228		400	type	I_{GT} II,IV		SC143D	○	isolated
TYAL608		600		≤80mA		SC143M	○	
TECCOR								
Q2008L4		200	I_{GT}	I_{TSM}=100A		SC143B	○	Almost
Q4008L4	8	400	I,III	(60Hz)	JEDEC	SC143D	○	equivalent
Q5008L4	(Tc=80°C)	500	≤25mA	(dv/dt)c	TO-220AB	SC143E	○	Rating
Q6008L4		600		≥3V/μS		SC143M	○	Non-isolated
				Tj=-40				
Q2008LT		200	Diac	~100°C		SC143B	○	Almost
Q4008LT		400	Built	Isolated		SC143D	○	equivalent
Q5008LT		500	in Diac	type		SC143E	○	Rating
Q6008LT		600				SC143M	○	N413+SC143
ITT								
TC0820	8	200	I_{TSM}=65A (50Hz)		JEDEC	SC143B	◎	I_{TSM}: High
TC0840	(Tc=95°C)	400	I_{GT} I,III ≤35mA		TO-220AB	SC143D	◎	120
TC0850		500	I_{GT} IV ≤ 25mA			SC143E	◎	I_{GT}: not
TC0860		600	I_{GT} II ≤ 55mA			SC143M	◎	guaranteed
			Tj=-40~120°C					

5) I_T = 10A (RMS)

Type No.	Main Specification				Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	I_T(A)	V_{DRM} (V) RRM	Others					
MOTOROLA								
MAC11-1		25	I_{TSM}=100A (60Hz)		MISCEL-	SC146B	◎	Almost
MAC11-2	10	50	I_{GT} I,III ≦50mA		LANEOUS	SC146B	◎	equivalent
MAC11-3	(TC=75°C)	100			MU10b	SC146B	◎	ratings
MAC11-4		200				SC146B	◎	
MAC11-5		300				SC146D	◎	Package:
MAC11-6		400				SC146D	◎	JEDEC
MAC11-7		500				SC146E	◎	TO-220AB
MAC11-8		600				SC146M	◎	
2N6151		200	I_{TSM}=100A (60Hz)		MISCEL-	SC146B	◎	Almost
2N6152	10	400	I_{GT} I,III ≦50mA		LANEOUS	SC146D	◎	equivalent
2N6153	(Tc=75°C)	600	I_{GT} II,IV≦75mA		MU10	SC146M	◎	rating
2N6154		200	(2N6151~2N6153)			SC146B	◎	Package:
2N6155		400				SC146D	◎	JEDEC
2N6156		600				SC146M	◎	TO-220AB
MAC10-1		25	I_{TSM}=100A (60Hz)		MISCEL-	SC146B	◎	Almost
MAC10-2	10	50	I_{GT} I,IV≦50mA		LANEOUS	SC146B	◎	equivalent
MAC10-3	(Tc=75°C)	100	I_{GT} II,IV ≦75mA		MU10b	SC146B	◎	rating
MAC10-4		200				SC146B	◎	Package:
MAC10-5		300				SC146D	◎	JEDEC
MAC10-6		400				SC146D	◎	TO-220AB
MAC10-7		500				SC146E	◎	
MAC10-7		600				SC146M	◎	
HUTSON								
IT010		50	I_{TSM}=100A (60Hz)		MISCEL-	SC146B	○	Almost
IT110	10	100	I_{GT} I,III ≦50mA		LANEOUS	SC146B	○	equivalent
IT210	(Tc=75°C)	200	I_{GT} II,IV ≦80mA		MU29	SC146B	○	rating
IT310		300				SC146D	○	Non-Isolated
IT410		400				SC146D	○	
IT510		500				SC146E	○	
IT610		600				SC146M	○	
SSC								
TXAL1110		200	Non-	I_{TSM}=120A	JEDEC	SC146B	◎	Almost
TXAL2210	10	400	isolated	(60Hz)	TO-220AB	SC146D	◎	equivalent
TXAL610	(Tc=80°C)	600		I_{GT} I,III		SC146M	◎	rating
				≦50mA				
TYAL1110		200	Isolated	I_{GT} II,IV		SC146B	○	Non-isolated
TYAL2210		400		≦80mA		SC146D	○	type
TYAL610		600				SC146M	○	

10

Type No.	Main Specification				Package	NEC Number	Replace-ability	Featuee of NEC Products and Remarks
	I_T(A)	V_{DRM} (V) RRM	Others					
TECCOR								
Q2010L4	10	200	I_{GT} I,III ≦25mA	I_{TSM}=110A (60Hz) (dv/dt)c ≧3V/µS Tj=-40 ~100°C Isolated type	JEDEC TO-220AB	SC146B	○	Almost equivalent rating Non-isolated type
Q4010L4		400				SC146D	○	
Q5010L4	(Tc=80°C)	500				SC146M	○	
Q6010L4		600				SC146M	○	
Q2010LT		200	Built-in Diac			SC146B	○	Almost equivalent rating N413+SC146
Q4010LT		400				SC146D	○	
Q5010LT		500				SC146E	○	
Q6010LT		600				SC146M	○	
ITT								
TC1020	10	200	I_{TSM}=100A (50Hz)		JEDEC	SC146B	×	I_{GT} Mode II Not guaranteed
TC1040	(Tc=80°C)	400	I_{GT} I,III ≦35mA		TO-220AB	SC146D	×	
TC1050		500				SC146E	×	
TC1060		600	I_{GT} IV ≦25mA Tj=-40~120°C			SC146M	×	
GE								
SC146B	10A	200	I_{TSM}=100A (60Hz) (dv/dt)c ≧4V/µS		JEDEC	SC146B	◎	
SC146D	(Tc=80°C)	400	I_{GT} I,III,IV ≦50mA		TO-220AB	SC146D	◎	equivalent
SC146E		500				SC146E	◎	
SC146M		600	V_{GT} I,III,IV ≦2.5V Tj=-40~100°C			SC146M	◎	

6) I_T (RMS) = 15, 16A

Type No.	Main Specification			Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	I_T(A)	VDRM VRRM (V)	Others				
HUTSON							
IT015		50	I_{TSM}=150A		AC16BGM	◎	
IT115		100	Tj=100°C		"	◎	I_T(rms): High
IT215	15	200	I_{GT} I,III	TO-220AB	"	◎	L_{GT} Mode II
IT315	(Tc=75°C)	300	=50mA		AC16DGM	◎	Not guaranteed
			I_{GT} II,IV				
			=80mA				
IT415		400			AC16DGM	◎	Tj: High
IT515		500			AC16EGM	◎	
IT615		600			AC16FGM	◎	
ITT							
TC1620		200	I_{TSM}=115A		AC16BGM	◎	I_{TSM}: High
TC1640	16	400	Tj=-40~120°C		AC16DGM	◎	Tj: High
TC1650		500			AC16EGM	◎	
TC1660		600			AC16FGM	◎	
GE							
SC151B	15	200	I_{TSM}=120A		SC151B	◎	
SC151D	(Tc=80°C)	400	Tj=100°C	TO-220AB	SC151D	◎	Equivalent
SC151E		500	I_{GT} I,II,III		SC151E	◎	
SC151M		600	IV		SC151M	◎	
			=50mA				
TECCOR							
Q2015L5		200			SC151B	○	
Q4015L5		400	I_{TSM}=125A/150		SC151D	○	Non-Isolated
Q5015L5	15	500	(50Hz/60Hz)	TO-220AB	SC151E	○	type
Q6015L5	(Tc=70°C)	600	Tj=100°C		SC151M	○	
Q2015LT		200	$(dv_D/dt)c$		SC151B	○	
Q4015LT		400	≧3V/μS		SC151D	○	N413+SC151
Q5015LT		500			SC151E	○	
Q6015LT		600			SC151M	○	

10

4. TRIGGER DEVICES

1) PUT

Type No.	Main Specification						Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	P (mW)	V_{AK} (V)	I_{TRM} (A)	I_P (μA)	I_V (μA)	Others				
GE										
2N6027 (D13T1)	300	±40	2 (20μs d=1%)	2 (1M)	70 (10K)		TO-98	2N6027 (D13T1)	◎	○ Ip: low ○ High stability
2N6028 (D13T2)	300	±40	2 (20μs d=1%)	0.15 (1M)	25 (10K)		TO-98	2N6028 (D13T2)	◎	
D13T3	300	±100	2 (20μs d=1%)	2 (1M)	70 (10K)		To-98	TO-92		△ V_{AK}=40V
D13T4	300	±100	2 (20μs d=1%)	0.15 (1M)	25 (10K)		TO-98			
UNITRODE										
U13T1	400	±40	8 (10μs d=1%)	2 (1M)	70 (10K)	Tstg -55~150	TO-18	N13H1	◎	○ High stability △ I_{TRM}=2A (20μs)
U13T2	400	±40	8 (10μs d=1%)	0.15 (1M)	25 (10K)	Tstg -55~150	TO-18	N13H2	◎	
U13T3	400	±100	8 (10μs d=1%)	2 (1M)	70 (10K)	Tstg -55~150	TO-18			△ V_{AK}=40V
U13T4	400	±100	8 (10μs d=1%)	0.15 (1M)	25 (10K)	Tstg -55~150	TO-18			
P13T1	375	±40	5 (10μs d=1%)	2 (1M)	70 (10K)		TO-92	2N6027 (N13T1)	◎	○ Ip: low ○ High stability
P13T2	375	±40	5 (10μs d=1%)	0.15 (1M)	25 (10K)		TO-92	2N6028 (N13T2)	◎	
2N6119	400	±40	8 (10μs d=1%)	2 (1M)	70 (10K)		TO-18	N13H1	◎	○ High stability △ I_{TRM}=2A (20μs)
2N6120	400	±40	8 (10μs d=1%)	0.15 (1M)	25 (10K)		TO-18	N13H2	◎	
2N6137	400	±40	8 (10μs d=1%)	Note 1 10 (10K)	Note 2 40 (10K)	Note 1: Ta=-55°C Note 2: Ta=125°C	TO-18	N13H1	◎	△ Ip-Iv: not guaranteed at High and Low Temperature. can be replaced by NEC Type From Distribution
2N6138	400	±100	8 (10μs d=1%)	Note 1 10 (10K)	Note 2 40 (10K)	〃	TO-18			

Type No.	Main Specification						Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	P (mW)	V_{AK} (V)	I_{TRM} (A)	I_P (μA)	I_V (μA)	Others				
)TOROLA										
MPU131	300	40 V_{GK}	2 (20μs d=1%)	2 (1M)	70 (10K)		TO-92	2N6027 (N13T1)	◎	o Ip: low o High stability
MPU132	300	40 V_{GK}	2 (20μs d=1%)	0.4 (1M)	25 (10K)		TO-92	2N6028 (N13T2)	◎	
MPU133	300	40 V_{GK}	2 (20μs d=1%)	0.08	18		TO-92	2N6028 (N13T2)	○	
MPU231	250			1.2	18			2N6027 (N13T1 N13H1)		o Ip: low o High stability
MPU232	250			0.19	18			2N6028 (N13T2 N13H2)		
MPU233	250			0.08	18			2N6028 (N13T2 N13H2)		
ILEC										
TUP1A		±40		2 (1M)	70 (10K)		TO-18	N13H1	◎	o High stability
TUP2A		±40		0.2 (1M)	25 (10K)		TO-18	N13H2	◎	
TUP3				5 (10K)	70 (10K)		TO-18			
TUP3S				1 (10K)	25 (10K)		TO-18			
TUP4				5 (10K)	70 (10K)		TO-72			
IICRO ;LECTRONICS										
MEU21	300	±40	2 (20μs d=1%)	2 (1M)	70 (10K)			2N6027 (N13T1)	◎	
MEU22	300	±40	2 (20μs d=1%)	0.15 (1M)	25 (10K)			2N6028 (N13T2)	◎	

10

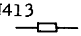
2) UJT

Type No.	Main Specification						Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	P (mW)	V_{B2E} (V)	I_{EM} (A)	I_P (μA)	I_V (mA)	η,(Others)				
GE										
2N489	450	60	2	12 6(B) 2(C)	8	R_{BBO}=4.7K ~6.8K η=0.51	TO-5	2SH24 2SH23 (B.C)	○	○ η: 0.61±0.03 ○ R_{BB}: high ○ Stable △ V_{BZE}=30V
2N490	450	60	2	12 6(B) 2(C)	8	~0.62 R_{BBO}=6.2K ~9.1K	TO-5	2SH24 2SH23 (B.C)	○	
2N491	450	60	2	12 6(B) 2(C)	8	R_{BBO}=4.7K ~6.8K η=0.56	TO-5	2SH24 2SH23 (B.C)	○	
2N492	450	60	2	12 6(B) 2(C)	8	~0.68 R_{BBO}=6.2K ~9.1K	TO-5	2SH24 2SH23 (B.C)	○	
2N493	450	60	2	12 6(B) 2(C)	8	R_{BBO}=4.7K ~6.8K η=0.62	TO-5	2SH24 2SH23 (B.C)	○	
2N494	450	60	2	12 6(B) 2(C)	8	~0.75 R_{BBO}=6.2K ~9.1K	TO-5	2SH24 2SH23 (B.C)	○	
D5E-43	300	30	2	2	6	0.68~0.82	TO-18	2SH23 2SH25	△	○η: 0.61±0.03 ○I_V: high △Package 2SH23: TO-5 2SH25: TO-92
D5E-44	300	30	2	5	4	0.68~0.82	TO-18	2SH23 2SH25	△	
D5E-45	300	30	2	2	8	0.68~0.82	TO-18	2SH23 2SH25	△	
2N1671	450	30	2	25 6(B) 2(C)	8	0.47~0.62	TO-5	2SH24 2SH23 (B.C)	◎	○η: 0.61±0.03 ○I_P: low
2N2160	450	30	2	25	8	0.47~0.80	TO-5	2SH24	◎	
2N2417	300	60	2	12 6(B)	8	R_{BBO}=4.7K ~6.8K η=0.51	TO-18	2SH23 ~2SH25	○	
2N2418	300	60	2	12 6(B)	8	~0.62 R_{BBO}=6.2K ~9.1K	TO-18	2SH23 ~2SH25	○	○η: 0.61±0.03 ○I_P: low ○Stable △V_{B2E}=30V △Package 2SH23: TO-5 2SH25: TO-92
2N2419	300	60	2	12 6(B)	8	R_{BBO}=4.7K ~6.8K η=0.58	TO-18	2SH23 ~2SH25	○	
2N2420	300	60	2	12 6(B)	8	~0.68 R_{BBO}=6.2K ~9.1K	TO-18	2SH23 ~2SH25	○	
2N2421	300	60	2	12 6(B)	8	R_{BBO}=4.7K ~6.8K η=0.62	TO-18	2SH23 ~2SH25	○	
2N2422	300	60	2	12 6(B)	8	~0.75 R_{BBO}=6.2K ~9.1K	TO-18	2SH24 2SH25	○	Power Supply Voltage: 7V MIN
2N2840	300	30	2	10	0.2		TO-18	2SH23 ~2SH25	△	○η: small deviation
2N2646	300	30	2	5	4	0.56~0.75	TO-18	2SH23 2SH25	○	○I_P: low I_V: High ○High stability (2SH23: TO-5) (2SH25: TO-92)
2N2647	300	30	2	5	4	0.68~0.82	TO-18	2SH23 2SH25	△	

Type No.	Main Specification						Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	P (mW)	V_{B2E} (V)	I_{EM} (A)	I_p (μA)	I_v (mA)	η, (Others)				
MOTOROLA										
2N4851	300	35		2	2	0.56~0.75	TO-18	2SH23 2SH25	○	oη: small deviation oIv: High oHigh stability △Package △Ip Special spec.
2N4852	300	35		2	4	0.70~0.85	TO-18	2SH23 2SH25	△	
2N4853	300	35		0.4	6	0.70~0.85	TO-18	2SH23 2SH25	△	
2N4870	300	35		5	2	0.56~0.75	TO-92	2SH25	◎	oη: 0.61±0.03 oIv: High oHigh stability
2N4871	300	35		5	4	0.70~0.85	TO-92	2SH25	△	
2N4891 (MU4891)	300			5	2	0.55~0.82	TO-92	2SH25	◎	oη: 0.61±0.03 oIv: High oHigh stability
2N4892 (MU4892)	300			2	2	0.51~0.69	TO-92	2SH25	◎	
2N4893 (MU4893)	300			2	2	055~0.82	TO-92	2SH25	◎	
2N4894 (MU4894)	300			1	2	0.74~0.86	TO-92	2SH25	△	
2N4947	300			2		~0.69	TO-18	2SH23 2SH25	○	oη: 0.61±0.03 oIv: High oHigh stability
2N4948	360			2	2	0.55~0.82	TO-18	2SH23 2SH25	○	
2N4949	360			1	2	0.74~0.86	TO-18	2SH23 2SH25	△	△Ip Special spec.
2N3980	360	35		2	1	0.68~0.82	TO-18	2SH23 2SH25	△	△Package 2SH23: TO-5 2SH25: TO-92 (Mold type) Ip Special spec.
2N5431	360	35		0.4	2	0.72~0.80	TO-18	2SH23 2SH25	△	
MU851	200	30		2			Disk	2SH25	△	△Package 2SH25: TO-92 (Mold type) △Ip Special spec.
MU852	200	30		2			Disk	2SH25	△	
MU853	200	30		0.4			Disk	2SH25	△	
SILEC										
2N3479	400	35	2	20	6	0.47~0.62	TO-5	2SH24	◎	oη:0.61±0.03 oIp: Small oIv: High oHigh Stability
2N3480	400	35	2	20	4	0.56~0.75	TO-5	2SH24	◎	
2N3481	400	35	2	20	4	~0.85	TO-5	2SH24	◎	
2N3483	400	35	2	5	4	0.60~0.72	TO-5	2SH23	◎	
2N3484	400	35	2	5	4	0.70~0.85	TO-5		△	
BB-12		30	2	1	4	0.56~0.75	TO-18	2SH23 2SH25		oη: small deviation oIp: low Iv: High oHigh stability △Package 2SH23: TO-5 2SH25: TO-92
BB-14		30	2	25	4	0.68~0.82	TO-18	2SH24 2SH25		
BB-18		30	2	25	8	0.68~0.82	TO-18	2SH24 2SH25		
2N1671AX		35		25	8	0.47~0.62	TO-5	2SH24		oη: small deviation oIp: low oHigh stability △Ip Special spec.
2N1671BP				12			TO-5	2SH24		
2N1671BX				6			TO-5	2SH23		
2N1671CX				2			TO-5	2SH23		

10

3) DIAC

Type No.	Main Specification				Package	NEC Number	Replace-ability	Feature of NEC Products and Remarks
	Ip(A)	V_{BO}(V)	I_{BO}(μA)	V_{BO}(V)				
RCA								
D3202Y (45411)	2	29~35	25	±3	DO-15	N413	○	replaceable by I_{BO} selection
D3202U (45412)	2	25~40	25	±3	DO-15	N413	○	
40583	2	27~37	50	±3	DO-26	N413	◎	
1N5411	2	29~35	50	±3	DO-26	N413	○	
TECCOR								
GT-32	1.5	27~37	50	±2	DO-7	N413	◎	
GT-35	1.5	30~40	50	±2	DO-7	N413	◎	
GT-40	1.5	38~48	50	±4	DO-7	-		
GT-50	1.5	46~58	50	±4	DO-7	-		
GT-60	1.5	56~70	50	±2	DO-7	-		
MOTOROLA								
1N5758A	2	18~22	25	±2	MU46	-		
1N5758	2	16~24	100	±4	MU46	-		
1N5759A	2	22~26	25	±2	MU46	-		
1N5759	2	20~28	100	±4	MU46	-		different package
1N5760A	2	26~30	25	±2	MU46	N413	○	(MU46 )
1N5760	2	24~32	100	±4	MU46	N413	○	
1N5761A	2	30~34	25	±2	MU46	N413	○	N413 
1N5761	2	28~36	100	±4	MU46	N413	○	
1N5762A	2	34~38	25	±2	MU46	N413	○	IN「」A
1N5762	2	32~40	100	±4	MU46	N413	○	I_{BO} special spec.
THYROTEX								
D24	2	20~29	200	±3.8	A x 1	N413	△	V_{BO}=26~32V
D30	2 at 50°C	28~36	200	±3.8	A x 1	N413	◎	(L spec)
D32	2 at 50°C	28~36	200	±3.8	A x 1	N413	◎	
D40	2	35~44	200	±3.8	A x 1	N413	○	
SILEC								
DB3		28~36	300	±3	DO-7	N413	◎	
HUTSON								
D-30	2 at 50°C	28~36	200	±3.8	DO-7	N413	◎	

METAL OXIDE VARISTOR

CROSS REFENCE LIST

SIEMENS v.s. NEC
VALVO v.s. NEC
GE v.s. NEC

10

NOTICE ON USE

1. Products are classified in accordance with TYPE and MAKERS.
2. Main Ratings of SIEMENS, VALVO and GE's products, features of NEC's products and points required by replacement are listed.
   For further comparison, refer NEC's catalogues.
3. Symbols of List are as follows.
   Varistor Voltage * ; Minimum
   Replace ability ◎ ; Superior, can be replaced without any problem.
   ○ ; Almost equivalent, can be replaced with a little caution.
   △ ; Further consideration required.
4. This material must be handled as "secret".
   Don't hand this to customers.

1/4 SIEMENS TYPE NO.	Varistor Voltage (TYP) (V)	Allowable Voltage		Peak Current 8x20μs (A)	NEC Number	Replace ability	Remarks
		RMS Voltage (V)	DC Voltage (V)				
SIOV-S05K11	18	11	14	↑			
SIOV-S05K14	22	14	18		NV022D05	○	
SIOV-S05K17	27	17	22		NV027D05	○	
SIOV-S05K20	33	20	26	100	NV033D05	○	
SIOV-S05K25	39	25	31		NV039D05	○	No. Pulses of Rated Peak Current:
SIOV0-S05K30	47	30	38		NV047D05	○	
SIOV-S05K35	56	35	45		NV056D05	○	
SIOV-S05K40	68	40	56	↓	NV068D05	○	
SIOV-S05K50	82	50	65	↑	NV082D05	△	SIEMENS: 1 pulse NEC: 2 pulses
SIOV-S05K60	100	60	85		NV100D05	○	(1 Pulse Rating is equivalent to SIEMENS TYPE (100 and 400A))
SIOV-S05K75	120	75	100		NV120D05	○	
SIOV-S05K95	150	95	125		NV150D05	○	
SIOV-S05K130	205	130	170		NV200D05	○	
SIOV-S05K140	220	140	180		NV220D05	○	△: Different 1 pulse Peak Current Rating: 100A
SIOV-S05K150	240	150	200	400	NV240D05	○	
SIOV-S05K175	270	175	225		NV270D05	○	
SIOV-S05K230	360	230	300		NV360D05	○	
SIOV-S05K250	390	250	320		NV390D05	○	
SIOV-S05K275	430	275	350		NV430D05	○	
SIOV-S05K300	470	300	385	↓	NV470D05	○	

SIOV-S07K11	18	11	14	↑			
SIOV-S07K14	22	14	18		NV022D07	○	
SIOV-S07K17	27	17	22		NV027D07	○	NO. Pulses of Rated Peak Current:
SIOV-S07K20	33	20	26	250	NV033D07	○	
SIOV-S07K25	39	25	31		NV039D07	○	
SIOV-S07K30	47	30	38		NV047D07	○	SIEMENS: 1 pulse NEC: 2 pulses
SIOV-S07K35	56	35	45		NV056D07	△	(1 Pulse Rating is equivalent to SIEMENS TYPE (250 and 1200A))
SIOV-S07K40	68	40	56	↓	NV068D07	△	
SIOV-S07K50	82	50	65	↑	NV082D07	△	
SIOV-S07K60	100	60	85		NV100D07	○	
SIOV-S07K75	120	75	100	1200	NV120D07	○	△: Different 1 pulse Peak Current Rating: 250A
SIOV-S07K95	150	95	125		MV150D07	○	
SIOV-S07K130	205	130	170	↓	NV200D07	○	

10

2/4 SIEMENS TYPE NO.	Varistor Voltage (TYP) (V)	Allowable Voltage		Peak Current 8x20μs (A)	NEC Number	Replace ability	Remarks
		RMS Voltage (V)	DC Voltage (V)				
SIOV-S07K140	220	140	180	↑	NV220D07	○	
SIOV-S07K150	240	150	200		NV240D07	○	
SIOV-S07K175	270	175	225		NV270D07	○	
SIOV-S07K230	360	230	300	1200	NV360D07	○	
SIOV-S07K250	390	250	320		NV390D07	○	
SIOV-S07K275	430	275	350		NV430D07	○	
SIOV-S07K300	470	300	385	↓	NV470D07	○	
SIOV-S10K11	18	11	14	↑			
SIOV-S10K14	22	14	18		NV022D10	○	
SIOV-S10K17	27	17	22		NV027D10	○	
SIOV-S10K20	33	20	26		NV033D10	○	
SIOV-S10K25	39	25	31	500	NV039D10	○	
SIOV-S10K30	47	30	38		NV047D10	○	
SIOV-S10K35	56	35	45		NV056D10	○	
SIOV-S10K40	68	40	56	↓	NV068D10	○	
SIOV-S10K50	82	50	65	↑	NV082D10	○	No. Pulses of Rated Peak Current:
SIOV-S10K60	100	60	85		NV100D10	○	
SIOV-S10K75	120	75	100		NV120D10	○	
SIOV-S10K95	150	95	125		NV150D10	○	SIEMENS: 1 pulse
SIOV-S10K130	205	130	170		NV200D10	○	NEC: 2 pulses
SIOV-S10K140	220	140	180		NV220D10	○	(1 Pulse Rating is equivalent to SIEMENS TYPE (500 and 2500A))
SIOV-S10K150	240	150	200		NV240D10	○	
SIOV-S10K175	270	175	225		NV270D10	○	
SIOV-S10K230	360	230	300	2500	NV360D10	○	
SIOV-S10K250	390	250	320		NV390D10	○	
SIOV-S10K275	430	275	350		NV430D10	○	
SIOV-S10K300	470	300	385		NV470D10	○	
SIOV-S10K385	620	385	505		NV620D10	○	
SIOV-S10K420	680	420	560		NV680D10	○	
SIOV-S10K460	750	460	615		NV750D10	○	
SIOV-S10K510	820	510	670		NV820D10	○	
SIOV-S10K550	910	550	745		NV910D10	○	
SIOV-S10K625	1000	625	825				
SIOV-S10K680	1100	680	895	↓			

3/4 SIEMENS TYPE NO.	Varistor Voltage (TYP) (V)	Allowable Voltage		Peak Current 8x20μs (A)	NEC Number	Replace ability	Remarks
		RMS Voltage (V)	DC Voltage (V)				
SIOV-S14K11	18	11	14	↑			No. Pulses of Rated Peak Current: SIEMENS: 1 pulse NEC: 2 pulses (1 Pulse Rating is equivalent to SIEMENS TYPE (1000 A))
SIOV-S14K14	22	14	18		NV022D14	○	
SIOV-S14K17	27	17	22		NV027D14	○	
SIOV-S14K20	33	20	26	1000	NV033D14	○	
SIOV-S14K25	39	25	31		NV039D14	○	
SIOV-S14K30	47	30	38		NV047D14	○	
SIOV-S14K35	56	35	45		NV056D14	○	
SIOV-S14K40	68	40	56	↓	NV068D14	○	
SIOV-S14K50	82	50	65	↑	NV082D14	◎	NO. Pulses of Rated Peak Current: SIEMENS: 1 pulse NEC: 2 pulses (1 Pulse Rating is superior to SIEMENS TYPE (5000 A))
SIOV-S14K60	100	60	85		NV100D14	◎	
SIOV-S14K75	120	75	100		NV120D14	◎	
SIOV-S14K95	150	95	125		NV150D14	◎	
SIOV-S14K130	205	130	170		NV200D14	◎	
SIOV-S14K140	220	140	180		NV220D14	◎	
SIOV-S14K150	240	150	200		NV240D14	◎	
SIOV-S14K175	270	175	225		NV270D14	◎	
SIOV-S14K230	360	230	300		NV360D14	◎	
SIOV-S14K250	390	250	320		NV390D14	◎	
SIOV-S14K275	430	275	350	4500	NV430D14	◎	
SIOV-S14K300	470	300	385		NV470D14	◎	
SIOV-S14K385	620	385	505		NV620D14	◎	
SIOV-S14K420	680	420	560		NV680D14	◎	
SIOV-S14K460	750	460	615		NV750D14	◎	
SIOV-S14K510	820	510	670		NV820D14	◎	
SIOV-S14K550	910	550	745		NV910D14	◎	
SIOV-S14K625	1000	625	825				
SIOV-S14K680	1100	680	895				
SIOV-S14K1000	1800	1000	1465	↓			
SIOV-S20K11	18	11	14	↑			
SIOV-S20K14	22	14	18	2000			
SIOV-S20K17	27	17	22	↓			

10

4/4 SIEMENS TYPE NO.	Varistor Voltage (TYP) (V)	Allowable Voltage		Peak Current 8x20μs (A)	NEC Number	Replace ability	Remarks
		RMS Voltage (V)	DC Voltage (V)				
SIOV-S20K20	33	20	26	↑			
SIOV-S20K25	39	25	31				
SIOV-S20K30	47	30	38	2000			
SIOV-S20K35	56	35	45				
SIOV-S20K40	68	40	56	↓			
SIOV-S20K50	82	50	65	↑			
SIOV-S20K60	100	60	85		NV100D19	△	No. Pulses of Rated Peak Current:
SIOV-S20K75	120	75	100		NV120D19	△	
SIOV-S20K95	150	95	125		NV150D19	△	
SIOV-S20K130	205	130	170		NV200D14	△	SIEMENS: 1 pulse
SIOV-S20K140	220	140	180		NV220D19	△	NEC: 2 pulses
SIOV-S20K150	240	150	200		NV240D19	△	
SIOV-S20K175	270	175	225		NV270D19	△	(1 Pulse Rating is little inferior to SIEMENS TYPE (6000 A))
SIOV-S20K230	360	230	300	6500	NV360D19	△	
SIOV-S20K250	390	250	320		NV390D19	△	
SIOV-S20K275	430	275	350		NV430D19	△	
SIOV-S20K300	470	300	385		NV470D19	△	Different diameter
SIOV-S20K385	620	385	505		NV620D19	△	
SIOV-S20K420	680	420	560		NV680D19	△	
SIOV-S20K460	750	460	615		NV750D19	△	
SIOV-S20K510	820	510	670		NV820D19	△	
SIOV-S20K550	910	550	745		NV910D19	△	
SIOV-S20K625	1000	625	825				
SIOV-S20K680	1100	680	895				
SIOV-S20K1000	1800	1000	1465	↓			

1/1 VOLVO TYPE NO.	Varistor Voltage (TYP) (V)	Allowable Voltage		Peak Current 8x20μs (A)	NEC Number	Replace ability	Remarks
		RMS Voltage (V)	DC Voltage (V)				
2322 592 18202	* 82	(Peak) 75	70		NV100D05	△	Different external form
2322 592 11012	* 100	95	85		NV120D05	△	
2322 592 11512	* 150	150	135		NV200D05	△	NEC lead pitch: 5±1 mm lead ϕ: 0.6
2322 592 11912	* 190	185	170		NV200D05	△	
2322 592 12212	* 220	210	190		NV240D05	△	
2322 592 12712	* 270	255	235		NV270D05	△	
2322 592 13312	* 330	320	290		NV360D05	△	
2322 592 13512	* 350	340	310		NV390D05	△	
2322 592 13912	* 390	380	345		NV430D05	△	
2322 592 14712	* 470	455	415		NV620D10	△	Different Characteristics, external form
2322 592 16212	* 620	605	550		NV680D10	△	
2322 592 16812	* 680	660	600		NV750D10	△	
2322 594 18202	* 82	75	70		NV100D07	△	Different external form
2322 594 11012	* 100	95	85		NV120D07	△	
2322 594 11512	* 150	150	135		NV200D07	△	NEC lead pitch: 5±1 mm lead ϕ: 0.6
2322 594 11912	* 190	185	170		NV200D07	△	
2322 594 12212	* 220	210	190		NV240D07	△	
2322 594 12712	* 270	255	235		NV270D07	△	
2322 594 13312	* 330	320	290		NV360D07	△	
2322 594 13512	* 350	340	310		NV390D07	△	
2322 594 13912	* 390	380	345		NV430D07	△	
2322 594 14712	* 470	455	415		NV620D10	△	Different Characteristics, external form.
2322 594 16212	* 620	605	550		NV680D10	△	
2322 594 16812	* 680	660	600		NV680D10	△	

10

1/3 GE TYPE NO.	Varistor Voltage (TYP) (V)	Allowable Voltage RMS Voltage (V)	DC Voltage (V)	Peak Current 8x20μs (A)	NEC Number	Replace ability	Remarks
V18ZA1	18	10	14	↑			No. Pulses of Rated Peak Current: GE: 1 pulse NEC: 2 pulses
V22ZA1	22	14	18		NV022D07	○	
V24ZA1	24	15	20		NV027D07	○	
V27ZA1	27	17	22		NV027D07	○	
V33ZA1	33	20	26		NV033D07	○	
V39ZA1	39	25	31	250	NV039D07	○	(1 Pulse Rating is equivalent to GE TYPE (250 A and 1200 A))
V47ZA1	47	30	38		NV047D07	○	
V56ZA2	56	35	45		NV056D07	○	
V68ZA2	68	40	56		NV068D07	○	Different lead pitch (5±1 mm)
V82ZA2	82	50	66		NV082D07	○	
V100ZA3	100	60	81	↓	NV100D07	○	
V120ZA1	120	75	102	↑	NV120D07	○	△: Different Varistor Voltage
V150ZA1	150	95	127	1000	NV150D07	○	
V180ZA1	180	115	153	↓	NV200D07	△	
V130LA1	* 184	130	175	500	NV200D07	○	
V130LA2	* 184	130	175	1000	NV200D07	○	
V150LA1	* 212	150	200	500	NV240D07	○	
V150LA2	* 212	150	200	1000	NV240D07	○	
V250LA2	* 354	250	330	500	NV390D07	○	
V250LA4	* 354	250	330	1000	NV390D07	○	
V275LA2	* 389	275	369	500	NV430D07	○	
V275LA4	* 389	275	369	1000	NV430D07	○	
V300LA2	* 420	300	405	500	NV470D07	○	
V300LA4	* 420	300	405	1000	NV470D07	○	
V18ZA3	18	10	14	↑			
V22ZA3	22	14	18		NV022D14	○	
V24ZA4	24	15	20		NV027D14	○	
V27ZA4	27	17	22		NV027D14	○	
V33ZA5	33	20	26	1000	NV033D14	○	
V39ZA6	39	25	31		NV039D14	○	
V47ZA7	47	30	38		NV047D14	○	
V56ZA8	56	35	45		NV056D14	○	
V68ZA10	68	40	56		NV068D14	○	
V82ZA12	82	50	66	↓	NV082D14	○	

2/3 GE TYPE NO.	Varistor Voltage (TYP) (V)	Allowable Voltage		Peak Current 8x20μs (A)	NEC Number	Replace ability	Remarks
		RMS Voltage (V)	DC Voltage (V)				
V100ZA15	100	60	81	↑	NV100D14	○	No. Pulses of Rated Peak Current:
V120ZA6	120	75	102	1000	NV120D14	○	GE: 1 pulse
V150ZA8	150	95	127		NV150D14	○	NEC: 2 pulses
V180ZA10	180	115	153	↓	NV200D14	△	
V95LA7A	* 134	95	130	↑	NV150D14	○	(1 Pulse Rating is equivalent or superior to GE TYPE (1000 and 5000 A))
V95LA7B	* 134	95	130		NV150D14	○	
V130LA10A	* 184	130	175	4000	NV200D14	○	
V150LA10A	* 212	150	200	↓	NV240D14	○	Different lead pitch (7.5±1 mm)
V250LA15A	* 354	250	330	3000	NV390D14	○	
V250LA20A	* 354	250	330	4000	NV390D14	○	
V275LA15A	* 389	275	369	3000	NV430D14	○	△: Different Varistor Voltage
V275LA20A	* 389	275	369	↑	NV430D14	○	
V320LA15A	* 462	320	420		NV620D14	△	
V420LA20A	* 610	420	560	4000	NV680D14	○	
V460LA20A	* 610	460	615	↓	NV750D14	○	
V480LA20A	* 670	480	640	3000	NV780D14	○	
V480LA40A	* 670	480	640	4000	NV780D14	○	
V510LA20A	* 735	510	675	3000	NV820D14	○	
V510LA40A	* 735	510	675	4000	NV820D14	○	
V550LA20A	* 775	550	700	3000	NV910D14	○	
V550LA40A	* 775	550	700	4000	NV910D14	○	
V575LA20A	* 805	575	730	3000			
V575LA40A	* 805	575	730	4000			
V1000LA80A	* 1425	1000	1200	4000			
V24ZA50	24	14	16	↑			
V27ZA60	27	17	21	2000			
V33ZA70	33	21	27				
V36ZA80	36	23	31	↓			
V130LA20A	* 184	130	175	6000			
V130LA20B	* 184	130	175	6000			

3/3 GE TYPE NO.	Varistor Voltage (V)	Allowable Voltage		Peak Current 8x20μs (A)	NEC Number	Replace ability	Remarks
		RMS Voltage (V)	DC Voltage (V)				
V150LA20A	* 212	150	200	↑	NV240D19	○	NO. Pulses of
V150LA20B	* 212	150	200		NV240D19	○	Rated Peak
V250LA40A	* 354	250	330		NV390D19	○	Current:
V250LA40B	* 354	250	330		NV390D19	○	GE: 1 pulse
V275LA40A	* 389	275	369		NV430D19	○	NEC: 2 pulses
V275LA40B	* 389	275	369		NV430D19	○	(1 pulse Rating
V320LA40A	* 462	320	420		NV620D19	△	is equivalent
V320LA40B	* 462	320	420		NV620D19	△	to GE TYPE (6000 A))
V420LA40A	* 610	420	560		NV680D19	○	Different
V420LA40B	* 610	420	560		NV680D19	○	external form
V460LA40A	* 640	460	615		NV750D19	○	(19 φ)
V460LA40B	* 640	460	615	6000	NV750D19	○	△: Different
V480LA80A	* 670	480	640		NV780D19	○	Varistor
V480LA80B	* 670	480	640		NV780D19	○	Voltage
V510LA80A	* 735	510	675		NV820D19	○	
V510LA80B	* 735	510	675		NV820D19	○	
V550LA80A	* 775	550	700		NV910D19	○	
V550LA80B	* 775	550	700		NV910D19	○	
V575LA80A	* 805	575	730				
V575LA80B	* 805	575	730				
V1000LA160A	*1425	1000	1200				
V1000LA160B	*1425	1000	1200	↓			

Contents

Application and Design Notes

DESIGNATION SYSTEM FOR SEMICONDUCTOR DEVICES

The designation system for semiconductor devices such as transistors, diodes, etc. is based on the standards in JIS C 7012 and is called the JIS type number. Also, it is called the EIAJ type number, because the registering of specifications and designations for individual type number is performed by the Electronic Industries Association of Japan (EIAJ).
The detail of the EIAJ designation system is specified in the SD–1, "Designation System for Discrete Semiconductor Devices," of the EIAJ Standards.
This paper is intended to inform you of the outline of the EIAJ designation system and the agreements on its registering, thereby letting you know how semiconductor devices are designated.

Scope of Applications

The SD–1 specifies the designation system for discrete semiconductor devices such as diodes, transistors, thyristors, etc. Here composite devices, such as twin transistors are included but none of integrated circuits.
Since the discrete transistors produced by the semiconducter device manufacturers joining EIAJ are subject to the obligatory registering system, those intended for any of domestic and overseas markets must have the specification and designation registered on EIAJ. As a result, the discrete transistors other than those manufactured for trial or by manufacturers outside EIAJ ought to carry the EIAJ type numbers such as 2SAOO~2SDOO
On the contrary, since diodes, FETs, thyristors, photo transistors, etc. are not subject to the obligatory registering system. There are many devices having peculiar type numbers designated by its own manufacturers. Though some registered ones carry the EIAJ type numbers.

EIAJ Type Numbers

The EIAJ type number consists of (1) a first number symbol; (2) a first letter symbol; (3) a second letter symbol; (4) a second number symbol; and (5) one or more suffix letter symbol if necessary. These symbols have the following significance.

1. First number symbol

The first number symbol consists of one digit indicating the class of the discrete semiconductor device. As a rule, letting the number of useful electrical connections or useful electrodes of a device be n, the first number symbol is n–1. Consequently, diodes or 2–electrode devices carry a number of 1, transistors or 3–electrode devices carry a number of 2, and tetrodes or 4–electrode devices carry a number of 3. Here the largest number assigned is 4 and therefore devices with more than 5 electrodes always carry a number of 4 as the first number symbol. For instance, the type number, 4SCOO, represents an NPN transistor for high frequency use but does not indicate whether five or six or more electrodes are provided (see Fig. 1). Since, however, there are very few semiconductor devices with five or more electrodes, this designation system will cause no problems in practical applications.
An effective electrode is defined as an external electrical connection which is essential to the basic operation of a semiconductor device. Such connection does not include any to shield and or case. An electrode connecting to two external leads is regarded as a single electrode. A composite device enclosing two or more independent device units in a single package carries a first number symbol corresponding to the unit with more electrodes. A composite device containing interconnected units which have no independent characteristics and act as a single device is treated as an equivalent single device. For instance, a twin transistor (with 6 external leads) comprising high-frequency NPN transistors with all independent electrodes is designated as 2SCOO. A twin transistor (with 5 external leads) with interconnected collectors is designated 2SCOO also. On the other hand, a twin transistor (with 4 external leads) with interconnected collectors and emitters is designated as 3SCOO.

If the collectors are interconnected and the first stage emitter is connected to the base of the second stage, so called Darlington Connection transistor is equivalent to a single transistor and is designated as 2SCOO. The above conditions are shown in Fig. 2.

2. First letter symbol

The first letter symbol is the capital letter S which represents a semiconductor device.

3. Second letter symbol

The second letter symbol is determined by the function or, if necessary, structure (operating form) of a semiconductor device and is specified as shown in Table 1.
In 1956, when the EIAJ designation system was started, this second letter symbol did not use and transistors were designated as 2SOO. In 1959, the designation system for semiconductor devices was changed and the second letter symbol was applied to the semiconductor device with three or more electrodes. Furthermore, in 1971, this second letter symbol was employed to identify those with two or more electrodes, as classified in Table 1. But this classification does not cover all semiconductor devices. The device already registered and designated as ISOO will not be subject to the new designation system, which covers newly registered devices.
At present, both the old and new designation systems are used. The diodes for microwave application are designated as ISTOO, ISGOO, ISVOO, or ISSOO, while the ordinary rectifier diodes and switching diodes still carry a conventional ISOO as well as the above designations.

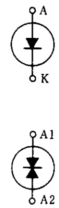
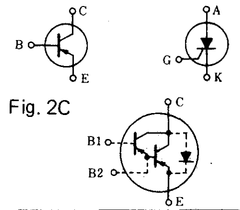
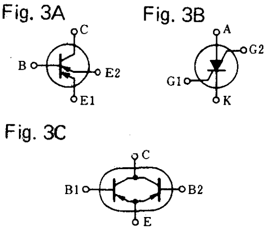
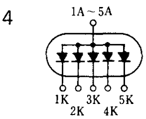
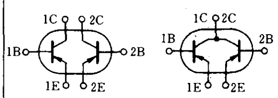
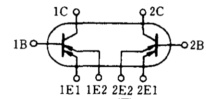
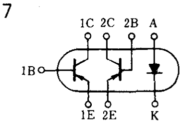
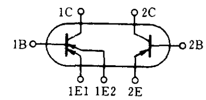
4. Second number symbol

The second number symbol starting with the number 11 indicates the order in registering. This symbol is given to each of the versions classified by the first number and the second letter symbols, and the class with many register applications by semiconductor device manufacturers includes many items. Transistors, for example, cover some 1000 items by 2SA, 700 by 2SB, 2500 by 2SC, and 700 by 2SD. However, FETs cover just over one hundred by each designation.

5. Suffix letter symbol

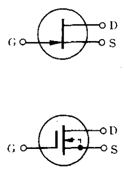
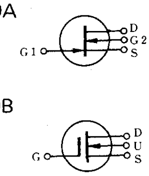
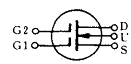
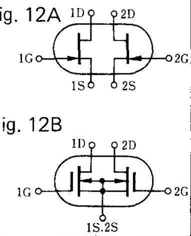
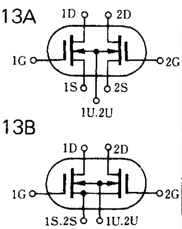
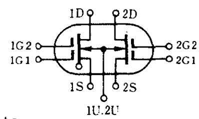
The suffix letter symbol is usually attached to the improved or modified devices which must be distinguished from previous versions. Suffix letters A, B, C, D, E, F, G, H, J and K can be used in this order indicate a later and modified version. Here the later or altered version may be substituted for any previous version but may not vice versa. For instance, 2SA708A is a version of 2SA708 with partly modified characteristic and can be substituted for 2SA708, but the reverse substitution may not always be possible.
In addition, for microwave diode, the suffix letter M issued to designate a pair of devices which are identical in outline dimensions and polarity and which have matched electrical characteristics.
A letter R is used to indicate a reverse polarity diode in an asymmetrical package which is mechanically and electrically identical to a forward polarity device.

Bipolar Device

	1S	2S	3S
Single Unit	Fig. 1A, Fig. 1B 	Fig. 2A, Fig. 2B, Fig. 2C 	Fig. 3A, Fig. 3B, Fig. 3C 
Composite Device with Identical Units	Fig. 4 	Fig. 5A, Fig. 5B 	Fig. 6 
Composite Device with Different Units		Fig. 7 	Fig. 8 

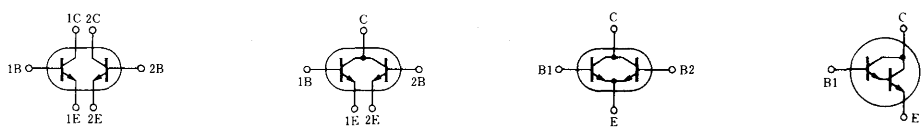
Note: Dotted line indicates terminal or part not relating to the designation.

FET

	2S	3S	4S
Single Unit	Fig. 9A, Fig. 9B 	Fig. 10A, Fig. 10B 	Fig. 11A 
Composite Device with Identical Units	Fig. 12A, Fig. 12B 	Fig. 13A, Fig. 13B 	Fig. 14  U = Substrate D = Drain G = Gate S = Source

Note: Dotted line indicates the connection not relating to the designation.

Fig. 1 Use of First Number Symbol



With two independent units 2SCOO

With interconnected collectors 2SCOO

With interconnected collectors and emitters 3SCOO

With Darlington connected units 2SCOO

Fig. 2 Composite Devices with Different Internal Connections

10

Table 1 Specification for Second Letter Symbol

Letter	Major Function
A	High-frequency transistor of PNP type or the like
B	Low-frequency transistor of PNP type or the like
C	High-frequency transistor of NPN type or the like
D	Low-frequency transistor of NPN type or the like
E	Tunnel diode
F	Reverse blocking thyristor, Reverse conducting thyristor
G	Gunn diode
H	Uni-junction transistor
J	P-channel field effect transistor
K	N-channel field effect transistor
L	
M	Bidirectional thyristor
N	
P	Light sensitive device
Q	Light emitting device
R	Rectifier diode
S	Small signal diode (mixer, detector, switching, video detection, Schottky barrier, point contact)
T	Avalanche diode (IMPATT diode, avalanche and transit time diode)
U	
V	Variable capacitance diode, Snap-off diode, PIN diode
W	
X	
Y	
Z	Voltage Regulator Diode, Voltage Reference Diode

Suffix Letter Representing Matched Pair of Microwave Diodes

The specification for matched pair of microwave diodes is shown in the attachment of the SD–1. The device treated as a pair with a matched pair characteristic is designated by the suffix letter M.
The specification for matched pair of microwave diodes is as follows:

1. Microwave mixer diode
   (a) Conversion loss unbalance, 0.3 dB maximum
   (b) Intermediate frequency impedance unbalance, 25 ohms maximum
   (c) Isolation of signal to local oscillator arm, 13 dB maximum

2. Microwave video detector diode
   (a) Figure of merit unbalance, 1 dB maximum
   where unbalance $= 10\log_{10}\frac{M_1}{M_2}$
   where M_1 and M_2 are individual figure of merit and $M_1 \geqq M_2$ to get unbalance a positive number.

   (b) The video impedance deviation of one, of the paired diodes with lower impedance is within 20% of that of the other diode.

Suffix Letter for Reverse Polarity of Diode

The paired two diodes identical in electrical characteristic and external form but opposite in electrode polarity are identified by the letter R which is suffixed to the diode of reverse polarity.
When a mounting base (stud, flange, etc.) where part of the package is used for an electrical connection, the definitions of forward and reverse polarities are given as follows:

1. Rectifier Diode

In forward-polarity devices, the mounting base is the cathode terminal. And in reverse-polarity devices, the mounting base is the anode terminal. Here, the suffix letter R is followed by a letter symbol, A, B, C, D, E, F, G, H, J, K or the like which indicates a variation of the device.

2. Voltage Regulator Diodes and Voltage Reference Diodes

The forward and reverse polarities are defined in the same way as the rectifier diode.

3. Microwave Diodes

The larger diameter terminal of the package is identified as the diode base. In forward-polarity devices, the diode base is the anode terminal. And in reverse-polarity devices, the diode base is the cathode terminal.

4. Microwave Matched Pair Diodes

The paired two microwave diodes identical in outline dimensions but different in polarity and electrical characteristic are identified by the suffix letter MR which is attached to the one with a reverse polarity.

Examples:

1S23	Forward polarity
1S23R	Reverse polarity
1S23M	A matched pair of forward polarity diode 1N23
1S23MR	A matched pair of one forward polarity diode 1N23 and one reverse polarity diode 1N23R

1S23RM A matched pair, of reverse polarity diode 1S23R

One of the suffix letters, A, B, C, D, E, F, G, H, J or K is preceded by M, R, MR or RM.

Examples:

1S23M, 1S23AM, 1S23AMR, 1S23ARM

Designation for Performance Range

The devices each consisting of group may be provided with different type number. Also, a combination of the basic type number and the following symbols, which indicates the performance range, separated by a hyphen between the basic type number may be used. This designation system is specified in SD–1 Attachment 2 as shown in the table in page 7.

Marking on Devices

It is necessary to mark the proper type numbers not only on individual devices but on the packing for each unit and the outside packing such as carton box. However, this regulation is accompanied by exceptional agreements, which permit a symbol, color code or the like on a small-sized device where marking of the type number is impossible, or permit any marking or color code specified by the customer. Also, the device without marking is permitted. In any of the above cases, the packing must carry a registered type number.

In marking on devices, deletion of the first number symbol and the first letter symbol is also permitted. For example, C1507 is marked on the 2SC1507 package.

Ownership of the Registered Designation

After the registering at EIAJ, the specification and the type number are held commonly by the industry, and manufacture of the registered goods is opened to every manufacturer. Consequently, it happens that some devices carry a type number, being manufactured by two or more manufacturers.

Although this system has been employed for electron tubes for a long time, it presents more increasing aspect as a result of the advanced manufacturing techniques intending for identical characteristics and the user's needs for compatible devices.

Manufacturers Outside EIAJ

The semiconductor devices produced by the manufacturers outside EIAJ are not subjected to the regulations of the SD–1 designation system. And, in many cases, such manufacturers are operated by foreign capitals.

However, in response to EIAJ's proposal to the registering of specification and designation, some manufacturers have started registering on EIAJ.

1. Voltage Regulator Diode

Example: 1SZ99 R – C 4V7

Basic Type Number	Polarity	Letter Indicating the Allowance of Zener Voltage	Typical Zener Voltage Indicated by Volt Unit
Designated according to the text of SD–1 specification. The polarity-suffix relationship is also determined by the text.	No polarity is indicated for the device with forward polarity where mounting base is the cathode terminal, or the device which has symmetrical package. The device with reverse polarity where mounting base is the anode terminal is identified by R.	A : 1% B : 2% C : 5% D : 10% E : 20%	Typical value of Zener voltage relating to the nominal current rating throughout the performance range. V is used in place of a decimal point if necessary.

2. Rectifier Diode, Reverse Blocking Thyristor, Bidirectional Thyristor

Examples: 1SR99 R - 100
2SF99 - 100
2SM99 - 100

Basic Type Number	Polarity	Maximum Rating of Repetitive Peak Reverse Voltage Indicated by Volt Unit
Designated according to the text of SD–1 specification The polarity-suffix relationship is also determined by the text.	No polarity is indicated for the device with forward polarity where mounting base is the cathode terminal, or the device which has symmetrical package. The device with reverse polarity where mounting base is the anode terminal is identified by R.	Thyristors are given the maximum rating of repetitive peak reverse voltage or of repetitive peak off-state voltage of which the lower value.

TECHNICAL SYMBOLS USED IN NEC'S SEMICONDUCTOR DEVICES

(Transistors, Field Effect Transistors, Diodes)

AN ITEM COMMON TO ALL DEVICES

Symbol	Term
C	Capacitance
f	Frequency
I	DC Current
i	AC Current
L	Inductance
P	Power
R	Resistance

Symbol	Term
T	Temperature
t	Time
V	DC Voltage
v	AC Voltage
Z	Impedance
η	Efficiency
λ	Wave Length

TRANSISTOR

ABSOLUTE MAXIMUM RATINGS

Symbol	Term
ASO	Safe Operating Area
I_B	Base Current
$I_{B(DC)}$	DC Base Current
$I_{B(peak)}$	Peak Base Current
$I_{B(pulse)}$	Pulse Base Current
I_C	Collector Current
$I_{C(DC)}$	DC Collector Current
$I_{C(pulse)}$	Pulse Collector Current
I_E	Emitter Current
P_C	Collector Power Dissipation
P_T	Total Power Dissipation
R_{th}	Thermal Resistance
$R_{th(j-a)}$	Thermal Resistance (Junction to Ambient)
$R_{th(j-c)}$	Thermal Resistance (Junction to Case)
T_a	Ambient Temperature
T_c	Case Temperature
T_j	Operating Junction Temperature

Symbol	Term
T_{opt}	Operating Temperature
T_{stg}	Storage Temperature
V_{CBO}	Collector to Base Voltage
V_{CEO}	Collector to Emitter Voltage
V_{CER}	Collector to Emitter Voltage ($R_{BE}=R\Omega$)
V_{CES}	Collector to Emitter Voltage (base emitter short circuited)
V_{CEX}	Collector to Emitter Voltage (base reverse biased)
V_{EBO}	Emitter to Base Voltage
V_{ECR}	Emitter to Collector Voltage ($R_{BE}=R\Omega$)
V_{ECS}	Emitter to Collector Voltage (base collector short circuited)
V_{ECX}	Emitter to Collector Voltage (base reverse biased)

ELECTRICAL CHARACTERISTICS

Symbol	Term
b_{fb}	Forward Transfer Susceptance (common base)
b_{fe}	Forward Transfer Susceptance (common emitter)
b_{ib}	Input Susceptance (common base)
b_{ie}	Input Susceptance (common emitter)
b_{ob}	Output Susceptance (common base)
b_{oe}	Output Susceptance (common emitter)
b_{rb}	Reverse Transfer Susceptance (common base)
b_{re}	Reverse Transfer Susceptance (common emitter)
BV_{CBO}	Collector to Base Breakdown Voltage
BV_{CEO}	Collector to Emitter Breakdown Voltage
BV_{CER}	Collector to Emitter Breakdown Voltage (R_{BE}=RΩ)
BV_{CES}	Collector to Emitter Breakdown Voltage (base emitter short circuited)
BV_{CEX}	Collector to Emitter Breakdown Voltage (base reverse biased)
BV_{EBO}	Emitter to Base Breakdown Voltage
BV_{ECO}	Emitter to Collector Breakdown Voltage
BV_{ECR}	Emitter to Collector Breakdown Voltage (R_{BC}=RΩ)
BV_{ECS}	Emitter to Collector Breakdown Voltage (base emitter short circuited)
BV_{ECX}	Emitter to Collector Breakdown Voltage (base reverse biased)
C_{cb}	Collector Capacitance
$C_c \cdot r_{b'b}$	Collector to Base Time Constant
C_{eb}	Emitter Capacitance
C_{ib}	Input Capacitance (common base)
C_{ie}	Input Capacitance (common emitter)
C_{ob}	Output Capacitance (common base)
C_{oe}	Output Capacitance (common emitter)
C_{re}	Feedback Capacitance
$f_{\alpha b}$	α Cutoff Frequency
$f_{\alpha e}$	β Cutoff Frequency
f_{max}	Maximum Frequency of Oscillation
f_T	Gain Bandwidth Product
G_{cb}	Conversion Gain (common base)
G_{ce}	Conversion Gain (common emitter)

Symbol	Term
g_{fb}	Forward Transfer Conductance (common base)
g_{fe}	Forward Transfer Conductance (common emitter)
g_{ib}	Input Conductance (common base)
g_{ie}	Input Conductance (common emitter)
G_{max}	Maximum Unilateral Insertion Power Gain
g_{ob}	Output Conductance
g_{oe}	Output Conductance
G_{pb}	Power Gain (common base)
G_{pe}	Power Gain (common emitter)
g_{rb}	Reverse Transfer Conductance (common base)
g_{re}	Reverse Transfer Conductance (common emitter)
G_{vb}	Voltage Gain (common base)
G_{ve}	Voltage Gain (common emitter)
h_{fb}	Current Gain (common base)
h_{FC}	DC Current Gain (common collector)
h_{FE}	DC Current Gain
h_{fe}	Current Gain (common emitter)
h_{FE1}/h_{FE2}	DC Current Gain Ratio
h_{ib}	Input Impedance (common base)
h_{ie}	Input Impedance (common emitter)
h_{ob}	Output Admittance (common base)
h_{oe}	Output Admittance (common emitter)
h_{rb}	Voltage Feedback Ratio (common base)
h_{re}	Voltage Feedback Ratio (common emitter)
I_{AGC}	AGC Current
I_{CBO}	Collector Cutoff Current
I_{CEO}	Collector Cutoff Current
I_{CER}	Collector Cutoff Current (R_{BE}=RΩ)
I_{CES}	Collector Cutoff Current (base emitter short circuited)
I_{CEX}	Collector Cutoff Current (base reverse biased)
I_{EBO}	Emitter Cutoff Current
I_{ECO}	Emitter Cutoff Current
I_{ECR}	Emitter Cutoff Current (R_{BC}=RΩ)
I_{ECS}	Emitter Cutoff Current (base emitter short circuited)
I_{ECX}	Emitter Cutoff Current (base reverse biased)

Symbol	Term
KF	Distortion
KF_2	2rd Harmonic Distortion
KF_3	3rd Harmonic Distortion
LV_{CEO}	Collector to Emitter Sustaining Voltage
MAG	Maximum Available Power Gain
NF	Noise Figure
NV	Noise Voltage
P_i	Input Power
P_o	Output Power
P_{osc}	Oscillation Power
PW	Pulse Width
$r_{bb'}$	Base Spreading Resistance
$R_{e(hie)}$	Real Part of Input Impedance
R_G	Source Resistance
r_{ib}	Input Resistance (common base)
r_{ie}	Input Resistance (common emitter)
R_L	Load Resistance
r_{ob}	Output Resistance (common base)
r_{oe}	Output Resistance (common emitter)
S_{11}	Input Reflection Coefficient
S_{12}	Reverse Insertion Gain
S_{21}	Forward Insertion Gain
S_{22}	Output Reflection Coefficient
$\|S_{21}\|^2$	Forward Insertion Gain
t_d	Delay Time
t_f	Fall Time
T.H.D.	Total Harmonic Distortion
t_{off}	Turn off Time
t_{on}	Turn on Time
t_r	Rise Time
$t_{stg}(t_s)$	Storage Time
V_{AGC}	AGC Voltage
V_{BB}	Supply Voltage
V_{BE}	Base to Emitter Voltage
$V_{BE(sat)}$	Base Saturation Voltage
V_{CC}	Supply Voltage
V_{CEK}	Knee Voltage
$V_{CE(sat)}$	Collector Saturation Voltage
V_{EE}	Supply Voltage
V_{OSC}	Oscillation Voltage
y_{fb}	Forward Transfer Admittance (common base)
y_{fe}	Forward Transfer Admittance (common emitter)
Y_G	Source Admittance
y_{ib}	Input Admittance (common base)
y_{ie}	Input Admittance (common emitter)

Symbol	Term
Y_L	Load Admittance
y_{ob}	Output Admittance (common base)
y_{oe}	Output Admittance (common emitter)
y_{rb}	Reverse Transfer Admittance (common base)
y_{re}	Reverse Transfer Admittance (common emitter)
Z_G	Source Impedance
Z_{ib}	Input Impedance (common base)
Z_{ie}	Input Impedance (common emitter)
Z_L	Load Impedance
Z_o	Characteristic Impedance
Z_{ob}	Output Impedance (common base)
Z_{oe}	Output Impedance (common emitter)
η_c	Collector Efficiency
η_{osc}	Oscillation Efficiency
η_t	Total Efficiency

FIELD EFFECT TRANSISTOR

ABSOLUTE MAXIMUM RATINGS

Symbol	Term
I_D	Drain Current
I_G	Gate Current
I_S	Source Current
P_T	Total Power Dissipation
T_a	Ambient Temperature
T_{ch}	Channel Temperature
T_j	Junction Temperature
T_{stg}	Storage Temperature
V_{DSS}	Drain to Source Voltage (gate source short circuited)

Symbol	Term
V_{DSX}	Drain to Source Voltage (gate reverse biased)
V_{GDO}	Gate to Drain Voltage
V_{GDS}	Gate to Drain Voltage (drain source short circuited)
V_{GSO}	Gate to Source Voltage
V_{GSS}	Gate to Source Voltage (drain source short circuited)

ELECTRICAL CHARACTERISTICS

Symbol	Term
b_{fs}	Forward Transfer Susceptance (common source)
b_{is}	Input Susceptance (common source)
b_{os}	Output Susceptance (common source)
b_{rs}	Reverse Transfer Susceptance (common source)
BV_{DSS}	Drain to Source Breakdown Voltage
BV_{DSX}	Drain to Source Breakdown Voltage (gate reverse biased)
BV_{GSO}	Gate to Source Breakdown Voltage
BV_{GSS}	Gate to Source Breakdown Voltage (drain source short circuited)
C_{iss}	Input Capacitance
C_{oss}	Output Capacitance
C_{rss}	Feedback Capacitance
f_{max}	Maximum Frequency of Oscillation
g_{fs}	Forward Transfer Conductance
g_{is}	Input Conductance
g_{os}	Output Conductance
G_{ps}	Power Gain (common source)

Symbol	Term
g_{rs}	Reverse Conductance
I_{DSS}	Drain Cutoff Current
I_{DSS}	Drain Leak Current
I_{GSS}	Gate Cutoff Current
I_{GSS}	Gate Leak Current
MAG	Maximum Available Power Gain
NF	Noise Figure
NV	Noise Voltage
r_{ds}	Output Resistance
$r_{ds(on)}$	Drain to Source ON Resistance
$\|S_{21s}\|^2$	Insertion Gain
U	Maximum Unilateral Insertion Power Gain
$V_{GS(off)}$	Gate to Source Cutoff Voltage
V_p	Pinch off Voltage
y_{fs}(or g_m)	Forward Transfer Admittance
y_{is}	Input Admittance
y_{os}	Output Admittance
y_{rs}	Reverse Transfer Admittance

DIODE

ABSOLUTE MAXIMUM RATINGS

Symbol	Term
I_{FM}	Peak Forward Current
$I_{F(surge)}$	Forward Surge Current
I_O	Average Rectified Current
P	Power Dissipation
R_{th}	Thermal Resistance
$R_{th(j\text{-}a)}$	Thermal Resistance (junction to ambient)
$R_{th(j\text{-}c)}$	Thermal Resistance (junction to case)
T_a	Ambient Temperature

Symbol	Term
T_C	Case Temperature
T_j	Operating Junction Temperature
T_{op}	Operating Temperature
T_{stg}	Storage Temperature
V_R	Reverse Voltage
V_{RM}	Peak Reverse Voltage
V_T	Tuning Voltage
σ_L	VSWR

ELECTRICAL CHARACTERISTICS

Symbol	Term
B_O	Burn out
C_t	Terminal Capacitance
$\Delta f/\Delta T$	Frequency Temperature Coefficient
f_c	Cutoff Frequency
Δf_e	Voltage Tuning Range
Δf_m	Mechanical Tuning Range
f_o	Center Frequency
f_{osc}	Oscillation Frequency
I_o	Rectified Current
I_{op}	Operating Current
I_p	Peak Point Current
I_p/I_v	Peak Point Current Vally Current Ratio
I_r	Reverse Recovery Current
I_v	Valley Current
L_C	Conversion Loss, Multiple Loss
L_i	Insertion Loss
N	Capacitance Ratio
NF	Noise Figure
N_{MAX}	Maximum Capacitance Ratio
P_{osc}	Oscillation Power

Symbol	Term
P_{out}	Conversion Power
Q	Figure of Merit
Q_s	Stored Charge
R_d	Differential Resistance
R_o	DC Current
R_p	RF Parallel Resistance
R_s	RF Series Resistance
t_{fr}	Forward Recovery Time
t_{rr}	Reverse Recovery Time
t_t	Transition Time
V_F	Forward Voltage
V_{op}	Operating Voltage
V_p	Peak Point Voltage
V_{pp}	Projected Peak Point Voltage
V_s	Switch Voltage
V_{th}	Threshold Voltage
V_v	Valley Voltage
η_{osc}	Oscillation Efficiency
τ	Minority Carrier Lifetime

SEMICONDUCTOR STANDARDS

1. ABSOLUTE MAXIMUM RATINGS

The ratings which are applied to semiconductor products are called Absolute Maximum Ratings and are defined as "The limiting values that must not be exceeded under any usage or testing conditions, and no two or more of these values must not be applied at the same time."

Absolute maximum ratings are given for voltage, current, power, and temperature, and are specified for continuous DC conditions at a temperature of 25 °C. However, recently pulse ratings have begun to be specified.

VOLTAGE RATINGS

Voltage ratings imply the maximum inverse voltage that may be applied between two electrodes, and is specified for the following items.

1) Diodes

- Peak inverse voltage V_{RM}:

  The peak value of the inverse voltage that may be applied. It is limited by the electron avalanche breakdown voltage.
- DC inverse voltage V_R:

  The inverse voltage that may be applied continuously. Usually, the inverse leakage current is specified at this voltage.

2) Transistors

- Collector-base voltage V_{CBO}:

  The inverse voltage between the collector and base, when the emitter is kept open. Limited by the electron avalanche breakdown voltage of the collector-base junction. Electron avalanche breakdown occurs when a field of over 10^5 V/cm is applied to a PN junction. The carrier multiplication factor of the breakdown is given by the following formula.

$$M = \frac{1}{1-(V/V_B)^m}$$

V: Voltage applied to the PN junction.

V_B: Electron avalanche breakdown voltage.

m: A constant determined from experience, in regards to which the relationship shown in Table 1 has been obtained.

Table 1

Material	N* type	P* type
Ge	m=3	m=6
Si	m=4	m=8

* The type of which V_B is to be determined is taken. (The type having higher specific resistance)

- Emitter-base voltage V_{EBO}:

  The inverse voltage between the emitter and base, when the collector is kept open. Limited by the electron avalanche breakdown or zener breakdown of the emitter-base junction.
- Collector-emitter voltage V_{CEO}:

  Inverse voltage between the collector and emitter, when the base is kept open. Determined from the V_{CBO} and h_{FE}.

$$V_{CEO} = \frac{V_{CBO}}{\sqrt[m]{1+h_{FE}}}$$

m: Refer to the paragraph on V_{CBO}

- Collector-emitter voltage V_{CER}:

  The inverse voltage between the collector and emitter when the base and emitter are connected together with a resistor. Determined by BV_{CBO} and R_{BE}.

$$V_{CER} = V_{CBO}\sqrt[m]{1-\frac{I_{CBO}(r_b+R_{BE})}{V_{TF}}}$$

V_{TF}: The forward threshold voltage between the base and emitter. About 0.5 V for Si.

- Collector-emitter voltage V_{CES}:

  The inverse voltage between the collector and emitter, when the base and emitter are shorted together (R_{BE} = 0).

$$V_{CES} = V_{CBO}\sqrt[m]{1-\frac{I_{CBO}\cdot r_b}{V_{TF}}} \approx V_{CBO}$$

- Collector-emitter voltage V_{CEX}:

  The inverse voltage between the collector and emitter, when the base-emitter is reverse biased through a resistor.

$$V_{CEX} = V_{CBO} \sqrt[m]{1 - \frac{I_{CBO}(r_b + R_{BE})}{V_{TF} + V_{BB}}}$$

- Collector-emitter voltage V_{CEC}:

  The inverse voltage between the collector and emitter, when the base-emitter is reverse biased ($R_{BE} = 0$).

$$V_{CEV} = V_{CB} \sqrt[m]{1 - \frac{I_{CBO} \cdot r_b}{V_{TF} + V_{BB}}} \approx V_{CBO}$$

  Generally, this is expressed as V_{CEX}.

The relationship between these ratings is, generally, $V_{CBO} \approx V_{CEV} \approx V_{CES} > V_{CER} > V_{CEO}$ and when shown as voltage-current characteristics have the relationship shown in Fig. 1.

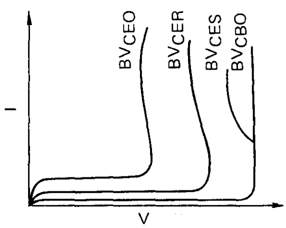


Fig. 1 Relationship of Collector Withstanding Voltages.

3) Field Effect Transistors (FETs)

- Gate-source voltage V_{GSS}:

  The voltage between the gate and source, when the drain and source are shorted. This voltage is limited by the electron avalanche breakdown in junction type FETs, and by the breakdown voltage of the gate insulating film in insulated gate type FETs. In FETs, since the gate input impedance is extremely high breakdown may occur even from static electricity, therefore great care should be exercised in their handling.

- Gate-source voltage V_{GSO}:

  The voltage between the gate and source, when the drain is kept open.

- Gate-drain voltage V_{GDS}:

  The voltage between the gate and drain, when the source and drain are shorted together. Applicable to junction type FETs only. Limited by the electron avalanche breakdown of the gate-drain junction.

- Drain-source voltage V_{DSS}:

  The voltage between the drain and source, when the gate and source are shorted together. Applicable to insulated gate type FETs only. Limited by the drain-substrate junction electron avalanche breakdown.

- Drain-source voltage V_{DSX}:

  The voltage between the drain and source, when a cutoff voltage is applied between the gate and source.

CURRENT RATINGS

Current ratings mean the maximum current that can be passed through any electrode. Current ratings are determined by either the electrical characteristics of the device, or the current carrying capacity of the internal connecting wires or the lead wires of the package.

1) Diodes

- Peak current I_{FM}:

  Limited by the power rating. Current up to this value may be repeatly passed through the device.

- Average rectified current I_O:

  The average value of the forward current, when a sine wave is rectified. DC current of this value may be passed continuously.

- Surge current $I_{F(surge)}$:

  The current that may be instantaneously passed within a specified time.

2) Transistors

- Collector current I_C:

  Hithertofore, the definition of the collector current rating has been somewhat obscure. However, in the 6th Semiconductor Technical Committee of EIAJ of 1972, on the premise that the collector current should be considered from the standpoint of initial assurance of the absolute maximum ratings, a tentative opinion of the definition of the collector current was obtained as shown in Table 2. Therefore, our company specifies the collector current in accordance with this opinion.

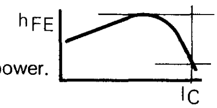
- Base current I_B:

  Generally, this current is not specified (It is inevitably determined from the current amplication factor.).

Base currents at which breakdown will not occur are as follows.

For low power use ($I_C \leqq 1A$) . . . $I_B \leqq I_C$
For high power use ($I_C > 1A$) . . . $I_B \leqq 1/2 \cdot I_C$

Table 2

	Interpretation	Supplementary explanation
1. DC collector current	1. Under a condition of T_j less than $T_{jMAX.}$, breakdown or degradation of characteristics shall not occur when $I_C \leqq I_CMAX$.	a) Degradation of characteristics means that the standards for breakdown voltage, h_{FE}, etc. are not satisfied when $I_C \leqq I_{C(pulse)}MAX$. b) The time that I_C is kept at I_CMAX shall as rule be once for 5 minutes.
	2. The rating value shall be stipulated under either of the following conditions. i) In the current characteristics of h_{FE}, the current at which h_{FE} drops to 1/2 – 1/3 of its peak value. ii) A current at which normal operation is not impeded, due to dropping of the h_{FE}.	a) When the use is for switching, the current shall not be restricted to 1/2 – 1/3 of its peak value. b) The following values shall be used as rough indications for the lower limit of h_{FE}. $h_{FE} = 10$: for medium power. $h_{FE} = 3$: for high power. 
2. Pulse collector current	1. The pulse width and repetition frequency are designated according to the use, then under these conditions and the condition that T_j is less than $T_{jMAX.}$, breakdown or degradation of characteristics shall not occur when $I_C \leqq I_{C(pulse)}MAX$.	a) Characteristic degradation is the same as 1. (1) (a). b) The time that I_C is kept at $I_{C(pulse)}$ MAX shall be adequate for reading the value of the current. c) The pulse width and repetition frequency shall be designated.

3) Field Effect Transistors

- Drain current I_D:

  The current flowing through the drain. Usually, is limited by I_{DSS} in junction types (depletion mode), and by the power rating in insulated gate types. However, it shows the current at which breakdown will not occur, if current should flow due to static electricity or noise.

- Gate current I_G:

  The forward current flowing through the gate-channel junction. Usually, since reverse bias is applied I_G does not flow. However, this is the current at which breakdown will not occur, when forward biasing occurs due to static electricity or noise.

TEMPERATURE RATINGS

The temperatures of the junction region and channel region (T_j and T_{ch}) allowable under operating conditions and the temperature range (T_{stg}) allowable for storage are specified. These temperatures are mainly determined by the materials of the semiconductor and package and assure that the failure rate will be under a certain value (differs according to the manufacturer) when the devices are operated or stored at these temperatures.

POWER RATINGS

Due to the joule's heat generated in diodes or transistors, the temperature of the junction or channel region rises. The sum of this temperature rise and the ambient temperature signifies the power dissipation reached at the power rating.

1) Diodes

In the case of diodes, generally, the power rating is not specified. Since the major portion of the power dissipated in diodes is in a forward direction, the power rating will be inevitably determined by specifying the forward current.

2) Transistors

The collector power dissipation, P_C, at an ambient temperature of 25 °C (free air), or case temperature of 25 °C (with an infinitely large heat sink), or the total power dissipation, P_T, (sum of collector and emitter power dissipation), is specified.

$$P_C = \frac{Tj - Ta}{R_{th(j\text{-}a)}} \qquad \text{(free air)}$$

$$P_T = \frac{Tj - Ta}{R_{th(j\text{-}c)}} \qquad \text{(with an infinitely large heat sink)}$$

T_a: Ambient temperature, generally taken as 25 °C.
T_C: Case temperature, generally taken as 25 °C.
$R_{th(j\text{-}a)}$: Thermal resistance from junction to surroundings.
$R_{th(j\text{-}c)}$: Thermal resistance from junction to case.

Now, when temperature is considered analogous to electric potential, and thermal resistance analogous to electric resistance, the above relationship can be expressed as shown in Fig. 2.

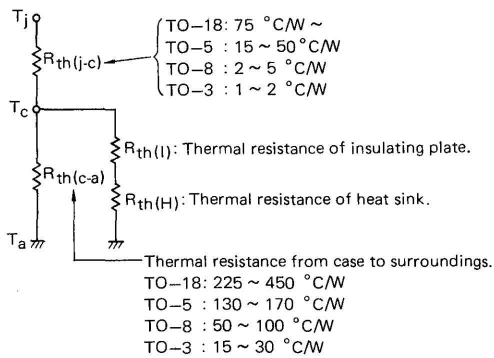


Fig. 2 (a) **Relationship of Thermal Resistances.**

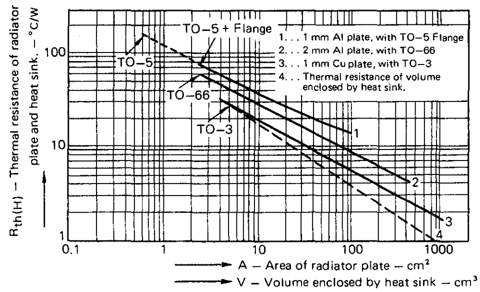


Fig. 2 (b) Relationship of Radiator Plate Area and Thermal Resistance.

3) Field Effect Transistors

The total power dissipation, P_T, is specified.

SAFE OPERATING AREA OF TRANSISTORS.

In the past, breakdown failures of power transistors occurred frequently when they were used in high power amplifiers having widely varying loads, or for the switching of inductive loads such as encountered when driving relays. Since it became known that the cause of these breakdowns was related to secondary breakdown phenomenon, it has become necessary to introduce the concept of the Safe Operating Area as the maximum rating of transistors in place of the classical idea that transistor could be safely operated in the range of $V_{CEMAX.}$, $I_{CMAX.}$, and $P_{TMAX.}$.

1) Secondary breakdown phenomenon.

As shown in Fig. 3, secondary breakdown is the phenomenon in which the voltage-current characteristics move, at a certain voltage and current, to a low impedance region with a speed of several μs or less, when the current is further increased after primary breakdown has occurred. Secondary breakdown differs in the following points from such primary breakdown phenomenon as electron avalanche breakdown.

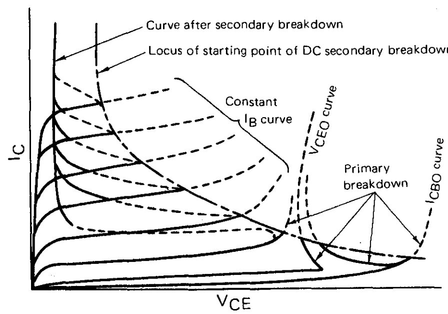
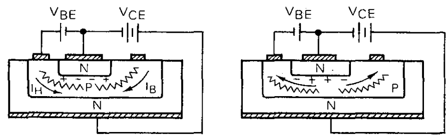


Fig. 3 **Primary Breakdown and Secondary Breakdown.**

(a) The secondary breakdown voltage shows an extremely low value, compared to BV_{CBO} and BV_{CEO}.

(b) The characteristic of the movement to secondary breakdown is a function of energy, and will change according to V, I, and t. But, as a primary approximation, BV_{CBO} and BV_{CEO} have no relationship with energy. The established theory is that secondary breakdown is caused by local thermal runaway brought about by concentrations of current, which are effected by pinch-in and fringing effects caused by a voltage drop in the transverse direction of the base region, or, defects of the base region, or, non-uniformity of the junction.



Current concentrated in the circumference of the emitter.
(a) Fringing effect (forward bias)

Current concentrated in the center of the emitter
(b) Pinch-in effect (reverse bias)

Fig. 4 Fringing and Pinch-in.

2) Testing method of safe operating area.

Testing methods for the safe operating area of transistors was included for the first time in the EIAJ standard "Transistor Testing Methods" (SD-71, 4th edition), published in November 25, 1969. The above standard contains such testing methods as the latching method, over-the-hill method, transient thermal resistance measuring method, etc. However, since in some testing methods there is a danger of the transistor breaking down, our company employs the transient thermal resistance measuring method. For power transistors, our company conducts 100 % inspection with a pulse width of 200 ms or 10 ms and the specified bias applied. Through this inspection thermally unbalanced transistors and those with faulty chip mounting are completely eliminated.

Next, the transient thermal resistance measuring method shall be described. This method, since secondary breakdown is caused by local thermal runaway brought about by concentration of current, utilizes the fact that when the junction temperature is kept under observation some change will appear when secondary breakdown occurs. The forward voltage of the emitter-base junction, V_{EB}, is observed as a measure of the junction temperature.

In the measuring circuit of Fig. 5, when power is applied by opening and closing SW at the specified pulse width, V_{EB} will become as shown in Fig. 6. V_{EB2} shows that the junction temperature rises due to the power applied, and V_{EB1} shows that the junction temperature drops when the power is removed. Since the temperature coefficient of V_{EB1} will vary according to the current, V_{EB1} is taken as the measure of the junction temperature.

(If the constant emitter current I_F is amply small, then the temperature coefficient of V_{EB}: $\Delta V_{EB}/T = 2$ mV/°C)

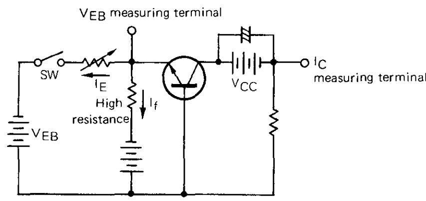


Fig. 5 Transient Thermal Resistance Measuring Circuit.

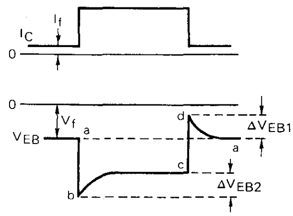


Fig. 6 I_C—V_{EB} Waveforms.

When V_{EB1} is measured, the change in junction temperature and the transient thermal resistance can be determined.

$$\Delta T_j = \frac{\Delta V_{EB1}}{\Delta V_{EB}/\Delta T} \approx \frac{\Delta V_{EB1}(\text{mV})}{2(\text{mV}/^\circ\text{C})} \quad (^\circ\text{C})$$

$$\Delta R_{th} = \frac{\Delta T_j}{\Delta P_C} \approx \frac{1}{\Delta P_C(\text{W})} \cdot \frac{\Delta V_{EB1}(\text{mV})}{2\ (\text{mV}/^\circ\text{C})} \quad (^\circ\text{C/W})$$

In this method, when the collector current I_C is kept constant and the collector voltage V_{CB} is increased, ΔV_{EB1}, depend on T_j, should rise linearly. However, at high voltages hot spots appear where the junction temperature rises rapidly, as shown in Fig. 8.

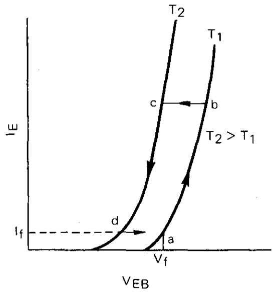


Fig. 7 Input Characteristics

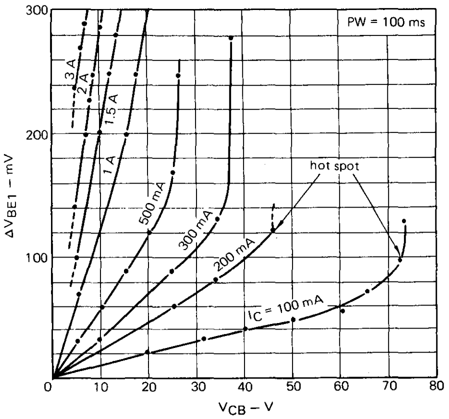


Fig. 8 Dependence of V_{EB1} on Bias.

Hot spots do not appear in low voltage regions, but since V_{EB1} = 300 mV (ΔT_j = 150 °C) corresponds to T_j = 175 °C the safe operating area can be obtained by plotting this point.

In this method, since measurement can be undertaken without making secondary breakdown to occur (hot spots appear as a forerunning phenomenon of secondary breakdown), the safe operating area can be measured without destroying the transistor. Therefore, the safe operating area obtained by this method is narrower than that obtained by the latching or over-the-hill methods.

3) Method of specifying the safe operating area.

Up to the present, our company has specified the safe operating area at the point where V_{EB1} = 300 mV (ΔT_j = 150 °C). This gave a safe operating area smaller than that given by other testing methods. Furthermore, we could not give an exact answer, when inquiries were received from customers as to how the safe operating area would be affected when the ambient temperature (case temperature) or repetition frequency was changed. Therefore, in the future our method of specifying the safe operating area shall be changed as follows.

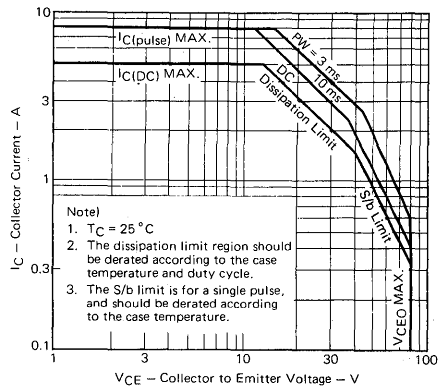


Fig. 9 Example of Safe Operating Area

The safe operating area is specified by 4 elements, as shown in Fig. 9.

* Region I

Current limit.

The region limited by the collector current rating.

* Region II

Dissipation limit.

The region limited by thermal resistance (total dissipation).

Limited by $R_{th(j-c)}$ in the case of DC, and by transient thermal resistance ΔR_{th} such as shown in Fig. 10 in the case of pulses.

Furthermore, when the pulse width is 100 ms, in the majority of packages,

$R_{th(j-c)} = \Delta R_{th}(100\ ms)$

Therefore, unless mentioned otherwise, DC means PW = 100 ms.

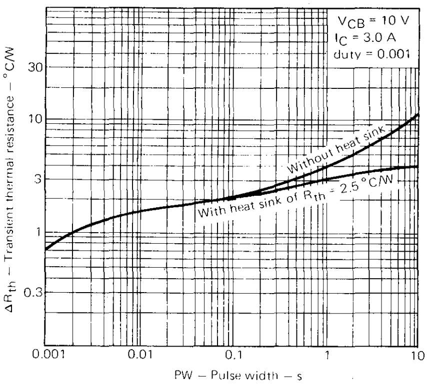


Fig. 10 Example of Transient Thermal Resistance Characteristics.

* Region III

S/b limit.

The region limited by secondary breakdown. The temperature of hot spots is said to be the temperature at which semiconductors become intrinsic (in the case of silicon: 600 °C). The breakdown of transistors is caused by the materials of the electrodes or mounting being melted by this temperature and diffusing into the semiconductor. Among these materials, the solder of the chip mounting has the lowest melting point. Therefore, the S/b limit is specified at the point where the junction reaches the melting point of the mounting solder. Specifically, these points are fixed as follows,

For devices where $T_{jMAX.}$ = 150 °C

––– the point at which V_{EB1} = 400 mV.

($\because$ $T_j = \Delta T_j + T_C$ = 225 °C)

For devices where $T_{jMAX.}$ = 175 °C

––– the point at which V_{EB1} = 500 mV.

($\because$ $T_j = \Delta T_j + T_C$ = 275 °C)

Furthermore, at the above temperatures the derating factor against case temperature is taken as zero, as shown in Fig. 11.

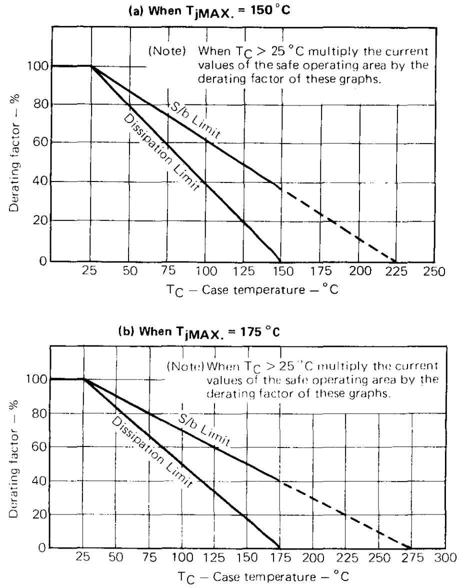


Fig. 11 Derating Curve for Safe Operating Area.

4) Method of utilizing the safe operating area.

Since the safe operating area is specified at a temperature of 25 °C, when the temperature is higher than this it is necessary to derate the safe operating area. In such case, the derating factor for the corresponding temperature is determined from Fig. 11 and the current values of the safe operating area are multiplied by this factor.

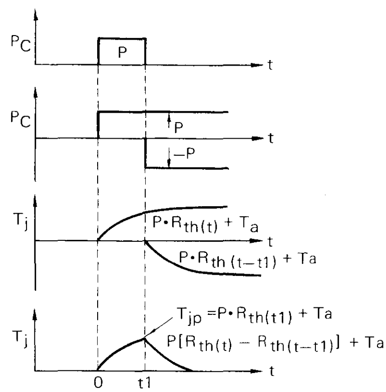
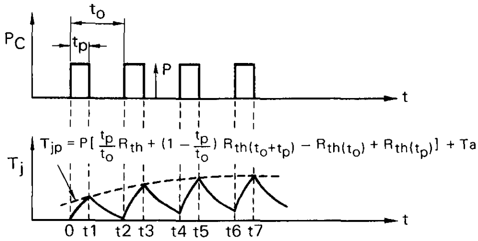


Fig. 12 Calculation of Junction Temperature When Pulse is Applied.

11



$T_{j(t1)} = P\ R_{th(t1)} + Ta$
$T_{j(t2)} = P\ [R_{th(t2)} - R_{th(t2-t1)}] + Ta$
$T_{j(t3)} = P\ [R_{th(t3)} - R_{th(t3-t1)} + R_{th(t3-t2)}] + Ta$

Fig. 13 Method of Determining Junction Temperature When Power is Repeatly Applied.

When the operating locus of the transistor is the dissipation limit region, surges may be repeatly applied. But, the frequency of application is determined as follows. When pulse power is applied the junction temperature will become as shown in Figs. 12 and 13, and if the peak value T_{jp} of junction temperature is less than the T_jMAX rating of the transistor, power may be repeatly applied.

In the above Figs., $R_{th}(t_1)$, $R_{th}(t_2)$ · · · · $R_{th}(t_o)$, and $R_{th}(t_p)$ are transient thermal resistances determined from charts like Fig. 10.

Furthermore, the S/b limit region is specified for single pulses only. Therefore, power may be applied again only after the heat generated by the applied surge has ample time to cool.

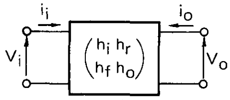
In practice, confirming experiments should be conducted with the actual circuit under the worst conditions. For this reason, adequate confirmation experiments are conducted during the development stages of the transistors, which are 100 % screened employing ΔV_{EB} tests and high voltage discharge tests pertaining to TV.

2. EQUIVALENT CIRCUITS AND 4 TERMINAL PARAMETERS

Equivalent circuits are useful for circuit design, since they closely correspond to the physical action of transistors and enable the characteristics to be grasped at a glance, however there are limitations to their application. In order to escape these limitations, the idea has been born to consider transistors as black boxes and express their characteristics as 4 terminal parameters.

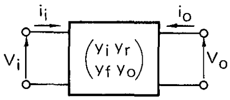
DEFINITION OF 4 TERMINAL PARAMETERS

h parameter



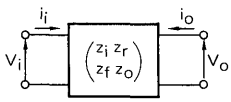
$$\begin{cases} V_i = h_i i_i + h_r V_r \\ i_o = h_f i_i + h_o V_o \end{cases}$$

y parameter



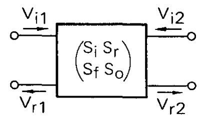
$$\begin{cases} i_i = y_i V_i + y_r V_o \\ i_o = y_f V_i + y_o V_o \end{cases}$$

z parameter



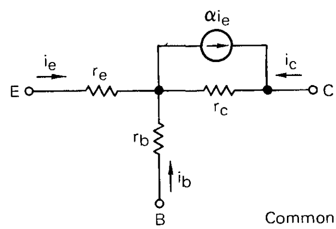
$$\begin{cases} V_i = z_i i_i + z_r i_o \\ V_o = z_f i_i + z_o i_o \end{cases}$$

s parameter

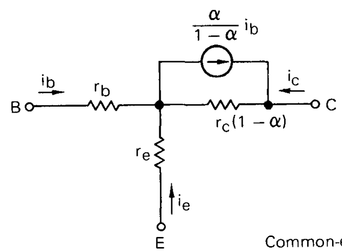


$$\begin{cases} V_{r1} = s_i V_{i1} + s_r V_{i2} \\ V_{r2} = s_f V_{i1} + s_o V_{i2} \end{cases}$$

T TYPE EQUIVALENT CIRCUITS



Common-base



Common-emitter

Fig. 14 T type Equivalent Circuits (low frequency)

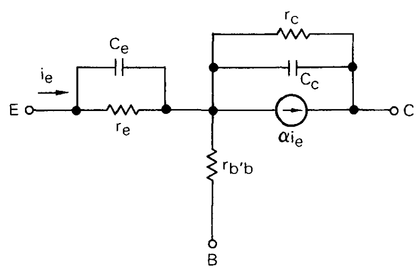
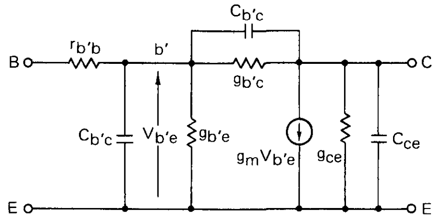


Fig. 15 T type Equivalent Circuit (high frequency)

HYBRID π TYPE EQUIVALENT CIRCUIT



$$g_m = \frac{qI_E}{kT},\ g_{b'e} = \frac{g_m}{B_0},$$

$$f_T = \frac{g_m}{2\pi(C_{b'c} + C_{b'e})},\ f_\alpha = \frac{g_{b'e}}{2\pi(C_{b'c} + C_{b'e})}$$

Fig. 16

EQUIVALENT CIRCUIT OF MICROWAVE TRANSISTORS

In transistors having a gain-bandwidth product exceeding 1 GHz, parastic elements of the container cannot be disregarded and it is necessary to considered a equivalent circuit such as shown in Fig. 17.

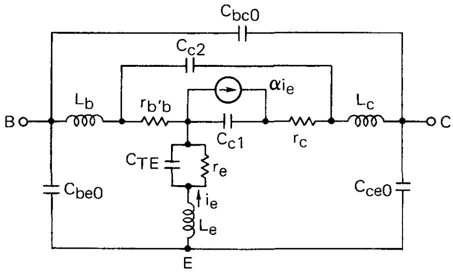
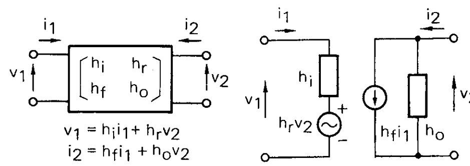


Fig. 17

h parameters



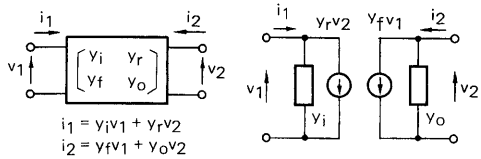
$v_1 = h_i i_1 + h_r v_2$
$i_2 = h_f i_1 + h_o v_2$

Fig. 18 Expression by h Parameters

Relationship between T type equivalent circuits. (low frequency) and h parameters.

$$\begin{cases} h_{ib} = r_e + (1-\alpha)r_b \\ h_{rb} = \dfrac{b}{r_c} \\ h_{fb} = -\alpha \\ h_{ob} = \dfrac{1}{r_c} \end{cases} \qquad \begin{cases} h_{ie} = r_b + \dfrac{r_e}{1-\alpha} \\ h_{re} = \dfrac{r_e}{(1-\alpha)r_c} \\ h_{fe} = \dfrac{\alpha}{1-\alpha} \\ h_{oe} = \dfrac{1}{(1-\alpha)r_c} \end{cases}$$

y parameters



$i_1 = y_i v_1 + y_r v_2$
$i_2 = y_f v_1 + y_o v_2$

Fig. 19 Expression by y Parameters.

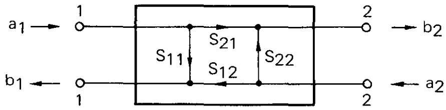
Relationship between T type equivalent circuits (high frequency) and y parameters.

$$\begin{cases} y_{ib} = \dfrac{1 + j\dfrac{f}{f_\alpha}}{r_e + jr_{b'b}\dfrac{f}{f_\alpha}} \\ y_{rb} = -2\pi f_\alpha C_c \dfrac{j\dfrac{f}{f_\alpha}\left(1 + j\dfrac{f}{f_\alpha}\right)}{\dfrac{r_e}{r_{b'b}} + j\dfrac{f}{f_\alpha}} \\ y_{fb} = -\dfrac{\alpha_0}{r_e + jr_{b'b}\dfrac{f}{f_\alpha}} \\ y_{ob} = 2\pi f_\alpha C_c \dfrac{j\dfrac{f}{f_\alpha}\left(1 + \dfrac{r_e}{r_{b'b}} + j\dfrac{f}{f_\alpha}\right)}{\dfrac{r_e}{r_{b'b}} + j\dfrac{f}{f_\alpha}} \end{cases}$$

$$\begin{cases} y_{ie} = \dfrac{(1-\alpha_0) + j\dfrac{f}{f_\alpha}}{r_e + jr_{b'b}\dfrac{f}{f_\alpha}} \\ y_{re} = -2\pi f_\alpha C_c \dfrac{r_e}{r_{b'b}} \cdot \dfrac{j\dfrac{f}{f_\alpha}}{\dfrac{r_e}{r_{b'b}} + j\dfrac{f}{f_\alpha}} \\ y_{fe} = \dfrac{\alpha_0}{r_e + jr_{b'b}\dfrac{f}{f_\alpha}} \\ y_{oe} = y_{ob} \end{cases}$$

S parameters

S parameters are mainly employed in microwave bands. These parameters have the advantages that measurement is easy because it is conducted with the input and output terminated with their characteristic impedance and, in addition, these parameters are convenient for the handling of the transfer and reflection of waves.



$b_1 = S_{11}a_1 + S_{12}a_2$

$b_2 = S_{21}a_1 + S_{22}a_2$

Fig. 20

$S_{11} = \frac{b_1}{a_1}/a_2 = 0$: Input reflection coefficient

$S_{21} = \frac{b_2}{a_1}/a_2 = 0$: Forward transfer coefficient

$S_{12} = \frac{b_1}{a_2}/a_1 = 0$: Backward transfer coefficient

$S_{22} = \frac{b_2}{a_2}/a_1 = 0$: Output reflection coefficient

Relationship between equivalent circuit of microwave transistors and S parameters.

$$S_{11e} = \frac{Z_{in} - Z_O}{Z_{in} + Z_O}$$

$$Z_{in} \risingdotseq (r_{b'b} + r_c + \omega'_T L_e) + j\omega\left\{(L_e + L_b) - \frac{\omega'_T r_e}{\omega^2}\right\}$$

$$\omega'_T = \frac{\omega_T}{1 + \omega_T C_c Z_o}$$

$$|S_{21e}| \risingdotseq \frac{2Z_o}{R + Z_o}\,\frac{\omega'_T}{\omega}$$

$$R = r_b + r_e + \omega'_T L_e$$

$$|S_{12e}| \risingdotseq \frac{2Z_o r_e\sqrt{1 + (\omega L_e/r_e)^2}}{(R_{out} + Z_o)(r_{b'b} + r_e + Z_o)}$$

$$R_{out} \risingdotseq \omega_T/(\omega_T^2 + \omega^2)\cdot C_c$$

$$S_{22e} = \frac{Z_{out} - Z_o}{Z_{out} + Z_o}$$

$$Z_{out} \risingdotseq \left\{\frac{\omega_T}{(\omega_T^2 + \omega^2)\,C_c} + \frac{L_e}{(r_{b'b} + Z_o)C_c} + r_c\right\} + j\omega\left\{L_e - \frac{1}{(\omega_T^2 + \omega^2)\,C_c}\right\}$$

Table 3 Mutual relationship between S, h, and y parameters.

	[S]	[h] $h_i' = h_i/Zo$, $h_o' = h_oZo$	[y] $y_i' = y_iZo$, $y_r' = y_rZo$, $y_f' = y_fZo$, $y_o' = y_oZo$
[S]	S_{11} S_{12} S_{21} S_{22}	$\frac{(h_i' - 1)(1 + h'_o) - h_r h_f}{(1 + h'_i)(1 + h'_o) - h_r h_f}$ $\frac{2h_r}{(1 + h'_i)(1 + h'_o) - h_i h_f}$ $\frac{-2h_f}{(1 + h'_i)(1 + h'_o) - h_r h_f}$ $\frac{(1 + h'_i)(1 - h'_o) + h_r h_f}{(1 + h'_i)(1 + h'_o) - h_r h_f}$	$\frac{(1 - y'_i)(1 + y'_o) + y'_r y'_f}{(1 + y'_i)(1 + y'_o) - y'_r y_f'}$ $\frac{-2y'_r}{(1 + y'_i)(1 + y'_o) - y'_r y'_f}$ $\frac{-2y_f'}{(1 + y'_i)(1 + y'_o) - y'_r y_f'}$ $\frac{(1 + y'_i)(1 - y'_o) + y'_r y_f'}{(1 + y'_i)(1 + y'_o) - y'_r y_f'}$
[h]	$\frac{(1 + S_{11})(1 + S_{22}) - S_{12}S_{21}}{(1 - S_{11})(1 + S_{22}) + S_{12}S_{21}}\cdot Z_o$ $\frac{2S_{12}}{(1 - S_{11})(1 + S_{22}) + S_{12}S_{21}}$ $\frac{-2S_{21}}{(1 - S_{11})(1 + S_{22}) + S_{12}S_{21}}$ $\frac{(1 - S_{22})(1 - S_{11}) - S_{12}S_{21}}{(1 - S_{11})(1 + S_{22}) + S_{12}S_{21}}/Z_o$	h_i h_r h_f h_o	$\frac{1}{y_i}$ $-\frac{y_r}{y_i}$ $\frac{y_f}{y_i}$ $\frac{y_i y_o - y_r y_f}{y_i}$
[y]	$\frac{(1 + S_{22})(1 - S_{11}) + S_{12}S_{21}}{(1 + S_{11})(1 + S_{22}) - S_{12}S_{21}}/Z_o$ $\frac{-2S_{12}}{(1 + S_{11})(1 + S_{22}) - S_{12}S_{21}}/Z_o$ $\frac{-2S_{21}}{(1 + S_{11})(1 + S_{22}) - S_{12}S_{21}}/Z_o$ $\frac{(1 + S_{11})(1 - S_{22}) + S_{12}S_{21}}{(1 + S_{11})(1 + S_{22}) - S_{12}S_{21}}/Z_o$	$\frac{1}{h_i}$ $-\frac{h_r}{h_i}$ $\frac{h_f}{h_i}$ $\frac{h_i h_o - h_r h_f}{h_i}$	y_i y_r y_f y_o

Table 4. Conversion of common-emitter and common-base 4 terminal parameters.

Common-base → common-emitter	Common-emitter → common-base
$h_{ie} = \frac{1}{A}(h_{ib})$	$h_{ib} = \frac{1}{B}(h_{ie})$
$h_{re} = \frac{1}{A}(\Delta h_b - h_{rb})$	$h_{rb} = \frac{1}{B}(\Delta h_e - h_{re})$
$h_{fe} = \frac{-1}{A}(h_{fb} + \Delta h_b)$	$h_{fb} = \frac{-1}{B}(h_{fe} + \Delta h_e)$
$h_{oe} = \frac{1}{A}(h_{ob})$	$h_{ob} = \frac{1}{B}(h_{oe})$
$y_{ie} = \Sigma y_b$	$y_{ib} = \Sigma y_e$
$y_{re} = -(y_{rb} + y_{ob})$	$y_{rb} = -(y_{re} + y_{oe})$
$y_{fe} = -(y_{fb} + y_{ob})$	$y_{fb} = -(y_{fe} + y_{oe})$
$y_{oe} = y_{ob}$	$y_{ob} = y_{oe}$
$A = 1 + h_{fb} - h_{rb} + \Delta h_b$	$B = 1 + h_{fe} - h_{re} + \Delta h_e$
$\Delta h_b = h_{ib}h_{ob} - h_{rb}h_{fb}$	$\Delta h_e = h_{ie}h_{oe} - h_{re}h_{fe}$
$\Sigma y_b = y_{ib} + y_{rb} + y_{fb} + y_{ob}$	$\Sigma y_e = y_{ie} + y_{re} + y_{fe} + y_{oe}$

3. SWITCHING CHARACTERISTICS

Generally, when a transistor is employed as a switching element, it assumes one of the states of ON or OFF. In order to be a ideal switch, a transistor should rapidly change the DC resistance between its collector and emitter output terminals from high resistance to low resistance, or vice versa, in response to a very small current injected into its control terminal.

Here, a simple explanation of the large amplitude operation of transistors as switches shall be given.

SWITCHING OF TRANSISTORS

When employing transistors for switching, the common-emitter connection which has large current gain is most widely used. An example of the static output characteristics of this connection is shown in Fig. 21. The operating region of a transistor can be divided into the saturation region, cutoff region and active region. Transistor switching circuits are of the saturated type which employ the two regions of saturation and cutoff, and due to their simple circuit construction and small power consumption are widely used.

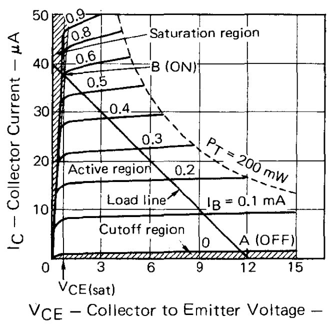


Fig. 21 Static Characteristics of Common-Emitter Output.

Fig. 22 is the basic form of a switching circuit of a common-emitter connected NPN transistor. The collector load line of this circuit is the line AB of Fig. 21. Following, based on Figs. 21 and 22 the operation of transistors in each region shall be described.

1) Cutoff Region (OFF state)

The cutoff region exists when both the emitter and collector junctions are reverse biased. In this state the operating point of the transistor rests at point A of the cutoff region in Fig. 21, the collector current takes a small value, and an extremely high

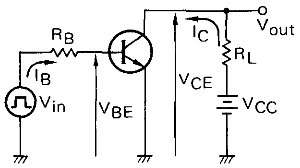


Fig. 22 Basic form of Switching Circuit

resistance is shown between the collector and emitter. That is to say, point A corresponds to a state of a transistor switch with its contacts open (OFF state). The collector current, that is the leakage current, in the OFF state poses a problem for transistor switches, however this current cannot be eliminated completely. According to Ebers' and Moll's analysis, the leakage currents flowing through the collector and emitter, when both junctions are reverse biased, can be expressed by the following formulae.

If $\alpha_I I_{CBO} = \alpha_N I_{EBO}$ is true, then

$$I_C = \frac{I_{CBO}(1 - \alpha_N)}{1 - \alpha_N \alpha_I}$$

$$I_E = \frac{I_{EBO}(1 - \alpha_N)}{1 - \alpha_I \alpha_N}$$

in the above equations,

α_N: Common-base forward current amplification factor

α_I: Common-base inverse current amplification factor

Also, the base current is shown as $I_B = I_C + I_E$

that is, $$I_B = \frac{I_{CBO}(1 - \alpha_I) + I_{EBO}(1 - \alpha_N)}{1 - \alpha_N \alpha_I}$$

2) Active Region

The active region, in a state where the emitter junction is forward biased and the collector junction reverse biased, is put to wide general use. In Fig. 22, when the potential of the base is made positive and a base current is made to flow, the operating point of the transistor will move along the load line from point A into the active region, and the speed of transition of the operating point across the active region is determined by the gain-bandwidth product f_T.

3) Saturation region (ON state)

In Fig. 22, when the base potential is made positive and an ample base current ($I_B < I_C/h_{FE}$) is made to flow, the transistor operating point will move along the load line from the active region and reach point B of the saturation region. Then an extremely low resistance will be shown between the collector and emitter, and this corresponds to the closed state (ON state) of the switch. The value of the collector current at point B will be approximately determined by the load resistance and the power supply voltage ($I_C = V_{CC}/R_L$), but the collector-emitter voltage will not drop to zero completely and a certain saturation voltage due to the internal resistance will remain. The collector-emitter saturation voltage is an important parameter of the saturation region, and when analyzed by Ebers' and Moll's model of a transistor, as shown in Fig. 23, becomes as follows.

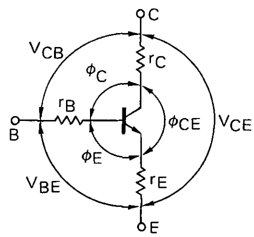


Fig. 23 Model of a Transistor.

$$V_{CE} = \phi_{CE} + r_E I_E + r_C I_C$$

$$\phi_{CE} = \frac{kT}{q} \ln\left(\frac{1}{\alpha_I}\right) \left\{\frac{1 + \beta_F(1 - \alpha_I)}{1 - \beta_F/h_{FE}}\right\}$$

here, kT/q: 26 mV at 27 °C

β_F: Circuit current amplification factor (I_C/I_B) of saturation region.

For reference, the above for the base-emitter junction are given below.

$$V_{BE} = \phi_E + r_B I_B + r_E I_E$$

$$\phi_E = \frac{kT}{q} \ln\left(1 + \frac{I_E - \alpha_I I_C}{I_{CBO}}\right)$$

As has been described, generally, transistor can be utilized as switches by controlling the base. However, as mention they differ from ideal switches in the following points.

* A certain amount of leakage current remains in the OFF state.

* A certain amount of saturation voltage remains in the ON state.
* There is a certain delay in action in respect to the input signal.

TRANSIENT RESPONSE TIME OF TRANSISTORS

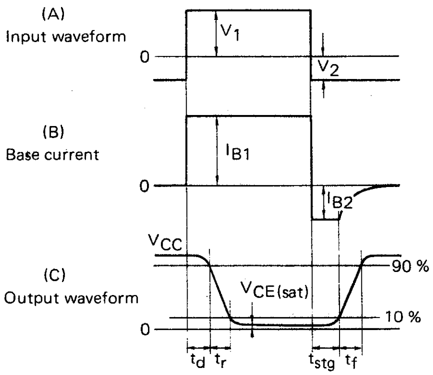
In the definition of the switching time of transistors the quantities shown in waveform (C) of Fig. 24, which appears in the output when an input waveform as shown in Fig. 24 (A) is applied to the circuit of Fig. 22, are employed. These quantities are defined as follows.

t_d : Delay time.
The time required, after the input pulse has been applied, for the output current waveform to reach 10 % of its maximum amplitude.

t_r : Rise time.
The time required for the output current waveform to increase from 10 % to 90 % of its maximum amplitude.

t_{stg} : Storage time.
The time required, after the input pulse has become zero, for the output current waveform to drop to 90 % of its maximum amplitude.

t_f : Fall time.
The time required for the output current waveform to drop from 90 % to 10 % of its maximum amplitude.



(Note) Since in the above chart the output is shown in voltage waveforms, the positions of 10 % and 90 % maximum amplitude are in inverse relationship to those mentioned in the definitions.

Fig. 24 Switching Waveforms.

Besides the above definitions, the 2 following expressions are frequently used.

t_{on}: turn-on time $t_{on} = t_d + t_r$

t_{off}: turn-off time $t_{off} = t_{stg} + t_f$

ANALYSIS OF SWITCHING TIME BY THE ELECTRON CHARGE CONTROL THEORY.

Here, the electron charge control method shall be described, in which the transistor is considered not as a current controlling element but as a electron charge controlling element and the transient response is expressed by the quantity of the electron charge contained in the base.

Simply stated, this method consists of, when a transistor changes from one state to another, finding the difference of the electron charge contained by the transistor in these two states and calculating the time required for charging this difference of charge ΔQ by current I as $t = \Delta Q/I$.

Methods for calculating the various switching times employing the electron charge control method shall be explained following.

1) Delay Time

The emitter-collector junction capacity and stray capacity of a transistor in an OFF state are charged so as to reverse bias both the collector and emitter junctions. The delay time is the time required to supply a charge to these junctions and make the emitter junction barely forward biased.

When the base current is of step form, this can be simply expressed as follows.

$$t_d = \frac{Q_{OB}}{I_{B1}}$$

here,

Q_{OB} : The electron charge stored in both the emitter and collector junctions.

I_{B1} : Turn-on base current.

$$Q_{OB} = \int_{V_{OB}}^{V_{TF}} C_{1d} dV_{BE} + \int_{V_1 + V_{OB}}^{V_1 - V_{TF}} C_{ob} dV_{CB}$$

here,

V_{OB} : Inverse voltage applied between base and emitter during OFF state.

V_{TF} : Threshold voltage between base and emitter.

V_1 : Voltage between collector and emitter during OFF state.

The voltage increment across the capacitor is ($V_{TF} - V_{OB}$). If this change is linear, the delay time can be expressed by the following formula.

$$t_d = \frac{(V_{TF} - V_{OB})(C_{ib} + C_{ob})}{I_{B1}}$$

2) Rise Time

In order to turn-on a transistor the following electron charges must be supplied: charge Q_1 for creating a carrier gradient within the base region in order to make the required collector current flow, Q_V for changing the voltage of the collector capacity from the OFF level, at which injection of the carrier starts, to the new level, and Q_R which is required for recombination.

Therefore, the equation for input current I_{B1} becomes,

$I_{B1} \cdot t_2 = Q_1 + Q_V + Q_R$

If, by amply over driving, I_C is considered to change linearly, then,

$$Q_R = \frac{t_r \cdot I_C}{2h_{FE}}$$

In addition, since Q_1 and Q_V can be expressed as follows and the rise time is defined at the 90 % point, when these are solved for t_r, t_r can be expressed as follows.

$$Q_I = \frac{I_C}{2\pi f_T}$$

$$Q_V = C_f \cdot \Delta V_{CB}, \quad \Delta V_{CB} = C_f \cdot I_C \cdot R_C$$

$$\therefore t_r = \frac{0.9 I_C \left(\frac{1}{2\pi f_T} + C_f \cdot R_C\right)}{I_{B1} - \frac{I_C}{2h_{FE}}}$$

here, C_f: Collector-base feedback capacity.
R_C: Thevenin's equivalent load resistance.

3) Storage Time

When a transistor is in the saturation region, due to the minority carrier in the base region, an excessive charge Q_X will be created. The quantity of this charge, with τ_X as the proportional constant, is proportional to the excessive base current I_{BX}. Furthermore, the charge which recombines is divided into two, one being charge Q_{RX} which is due to the recombination of the excessive carrier having a lifetime of τ_X. and the other being charge Q_{Ra} that has a lifetime τ_a and is due to the recombination of the activation carrier necessary to maintain the collector current. When the reverse base current I_{B2} is stepped, then,

$$-I_{B2} \cdot t_{stg} = -Q_X + Q_{RX} + Q_{Ra}$$

$$Q_{Ra} = \frac{t_s \cdot I_C}{h_{FE}}, \quad Q_{RX} = \frac{I_{BX} \cdot t_s}{2}$$

$$Q_X = I_{BX} \cdot \tau_X, \quad I_{BX} = I_{B1} - I_C/h_{FE}$$

$$t_{stg} = \tau_X \frac{I_{B1} - I_C/h_{FE}}{I_{B2} + \frac{I_{B1} + I_C/h_{FE}}{2}}$$

Furthermore, in recent transistors of the mesa or planar type, the minority carrier of the collector region rather than the base region becomes dominant and various modifications of the t_{stg} formula become necessary.

4) Fall Time

The fall time is calculated using the same reasoning as that followed for the rise time, and is expressed by the following formula.

$$t_f = \frac{0.9 I_C \left(\frac{1}{2\pi f_T} + R_C \cdot C_f\right)}{I_{B2} + I_C/h_{FE}}$$

4. NOISE CHARACTERISTICS

There have been spectacular improvements in the performance of low frequency low noise transistors being employed in audio equipment.

Here, the low noise bipolar transistors of alumina passivated structure and the mesh gate FETs of our company shall be explained. And, in addition, the equivalent input noise source method which is extremely effective in circuit design shall be described.

ALUMINA PASSIVATED STRUCTURE LOW NOISE TRANSISTORS.

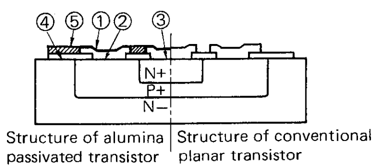
The features of the alumina passivated structure lie in the following points.

* Since the surface of the element, including the electrodes, is passivated by a stable alumina film the element will not be degraded by receiving contamination from the outside in the manufac-

turing processes coming after the electrodes have been formed.

* In NPN transistors, the low current characteristics of the h_{FE} are improved in particular and a low frequency low noise transistor of high PIV and high gain is obtained.
* The manufacture of more stable PNP transistors is possible.
* In plastic sealed type transistors, since the electrodes are passivated with a stable alumina film, the humidity resistance characteristics are improved greatly.

As described above, the adoption of the alumina passivated structure displays the features of both superior characteristics and reliability. The alumina passivated structure is as shown in Fig. 25.



① Non-porous alumina. ② Aluminum base electrode.
③ Aluminum emitter electrode. ④ SiO_2
⑤ Porous alumina.

Fig. 25 Structure of an Alumina Passivated Transistor

The technique for making this alumina film is a passivation technique that consists of the adoption of an improved aluminum evaporation process together with a combination of photoresist and anode oxidizing techniques, by which portions that were formerly removed by etching are selectively replaced by a stable alumina film chemically. This alumina film, together with the gettering action of the phosphor glass layer formed on the oxide film, stabilizes the surface to produce the superior features described above.

Actual examples of the improvement of characteristics are shown in Figs. 26 and 27.

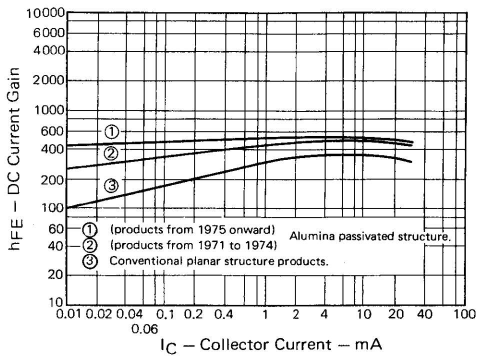


Fig. 26 h_{FE} Current Characteristics of a Bipolar Transistor (V_{CE} = 3 V)

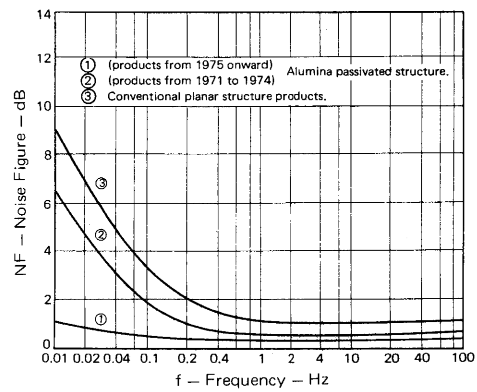


Fig. 27 Noise Figure vs. Frequency Characteristic of Bipolar Transistors. (V_{CE}=3 V, I_C=0.1 mA, R_G=10 kΩ, f=10 Hz, Δf=1 Hz)

As can be seen from the above Figs., alumina passivation technique together with the development from year to year of diffusion processes that create few crystal defects has resulted in great improvement of the h_{FE} low current and 1/f noise characteristics of transistors, compared to former products.

MESH GATE STRUCTURE, JUNCTION TYPE FIELD EFFECT TRANSISTORS.

The mesh gate structure consists of widening the channel width by shaping the gate in a mesh form, and its features lie in the following points.

* Since the degree of integration is improved, the g_m can be increased without increasing the chip area.
* The performance factor (g_m/C_{iss}) is improved.

* High g_m is easily attained, enabling low noise to be obtained.

The adoption of the mesh gate structure has enabled low cost, low noise field effect transistors to be manufactured, which has facilitated their employment in audio equipment.

EQUIVALENT INPUT NOISE SOURCE METHOD.

Generally, the noise figure is employed to show the noise characteristics of transistors.

Here, an explanation shall be given while comparing the NF and equivalent input noise source method, together with ways of thinking in the applying of the same to circuit design.

The case of bipolar transistors.

The common-emitter hybrid type equivalent circuit of a bipolar transistor can be shown as in Fig. 28 (a). As shown in Fig. 28 (b), this circuit can be drawn employing two independent noise sources, voltage noise source e_n and current noise source i_n, which can be expressed by the following formulae.

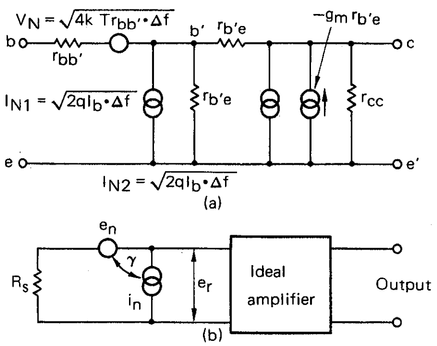


Fig. 28

When K : Boltzmann's constant.
T : Absolute temperature.
Δf : Frequency bandwidth.
g_m : Mutual conductance.
$r_{bb'}$: base resistance.
R_S : Signal source resistance.

then,

$$e_n = \sqrt{4kT(r_{bb'} + 1/2\, g_m)\cdot\Delta f}$$

$$i_n = \sqrt{\frac{4kT\cdot\Delta f}{2\beta/g_m}} = \sqrt{2qI_b\cdot\Delta f}$$

provided that,

k : Boltzmann's constant.
T : Absolute temperature.
Δf : Frequency bandwidth.
(Usually handled as Δf = 1 Hz).
g_m: Mutual conductance.

From the above equations, e_n and i_n can be equivalently related to the thermal noise in the resistors and can be expressed by the following equivalent resistances.

$$R_{Ne} = r_{bb'} + 1/2\, g_m$$
$$R_{Ni} = 2\beta/g_m$$

The case of field effect transistors.

In the case of field effect transistors, the concept is the same as that for bipolar transistors, but due to the difference in operating principle the formulae for e_n and i_n become as follows.

$$e_n = \sqrt{4KT\cdot\frac{1}{g_m}\cdot\Delta f}$$

$$i_n = \sqrt{2qI_G\cdot\Delta f}$$ I_G: Gate leakage current.

As shown in Fig. 34, the above gate leakage current I_G is that for ordinary bias and displays a voltage characteristic as shown in Fig. 29.

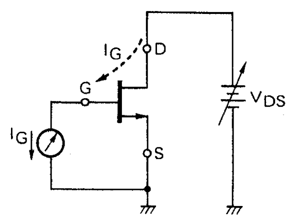


Fig. 29 Measuring Circuit for Gate Leakage Current.

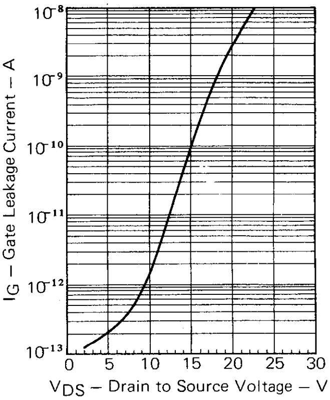


Fig. 30 Voltage Characteristic of Gate Leakage Current.

e_n, i_n and NF.

The total noise voltage at the input of the ideal amplifier of Fig. 28(b) can be expressed as the following formula.

$$e_T^2 = e_{RS}^2 + e_n^2 + i_n^2 \cdot R_s^2 + 2\gamma \cdot e_n i_n$$

provided that,

e_{RS} is the thermal noise of R_S as shown by $\sqrt{4kTR_S}$

γ: The correlation coefficient of e_n and i_n, and takes a value of $-1 < \gamma < 1$.

When the noise figure is shown employing the above equation, it becomes as follows.

$$NF = \frac{e_T^2}{e_{RS}^2} = 10\log_{10}\left[1 + \frac{1}{4kT}\left(\frac{e_n^2}{R_s} + i_n^2 \cdot R_s\right)\right] *$$

As shown above, if the NF is determined by measuring e_n and i_n which can be measure more precisely, rather than measuring the NF directly, the e_n and i_n components contained in the NF value shown can be determined at the same time.

Fig. 31 shows the relationship between the signal source resistance R_S, total noise voltage e_T and the NF, employing e_n and i_n as the parameters.

Furthermore, from the NF equation (*) it can be seen that a optimum signal source resistance $R_S = R_{SOPt}$, which makes NF minimum, exists.

When this value of NF is put as NF_{MIN}. the formula becomes as follows.

$$NF = 10\log\left[1 + \frac{e_n i_n}{2kT}\right]$$

$$= 10\log\left[1 + \sqrt{\frac{1}{\beta}\left(1 + \frac{2r_{bb'}I_C}{kT/q}\right)}\right]$$

$$R_{SOPt} = e_n / i_n$$

From the foregoing it can be seen that, in the case of bipolar transistors from a circuit standpoint it is desirable to set the bias point at a low current as possible and when R_S is large (over 10 kΩ) e_n may be disregarded and the noise will be dominated by the i_n characteristics. And, in the case of field effect transistors use at a low voltage is desirable, and when the voltage is high attention must be paid to i_n.

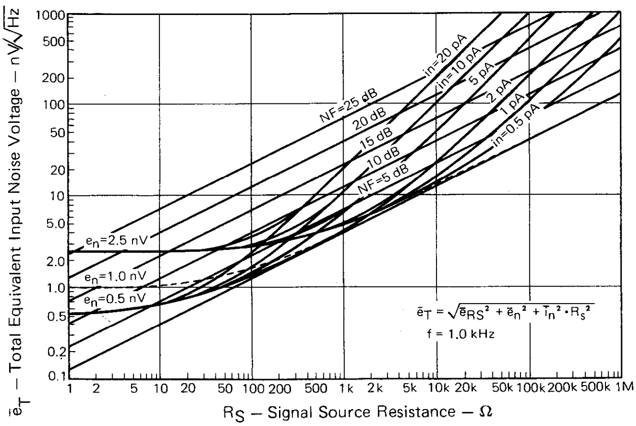


Fig. 31 Total Equivalent Input Noise Voltage vs. Signal Source Resistance R_S Characteristics.

By utilizing the equivalent input noise source method as described, a NF map can be drawn up from e_n and i_n, and from a circuit design standpoint the noise characteristics of transistors can be grasped in more diversified ways making it a very effective method.

In Fig. 32 the e_n and i_n current characteristics and the frequency characteristics of a low noise transistor are shown, and in Fig. 38 the e_n current characteristics of a low noise FET.

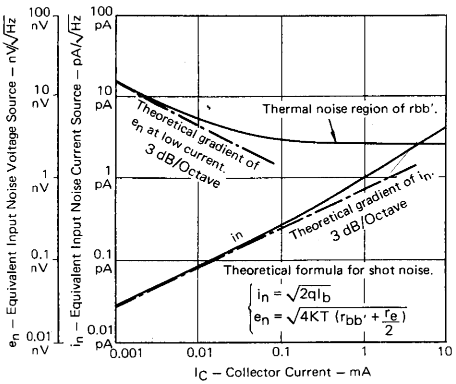


Fig. 32 e_n and i_n Current Characteristics of a Bipolar Transistor. (V_{CE} = 3 V, f = 100 Hz, Δf = 1 Hz)

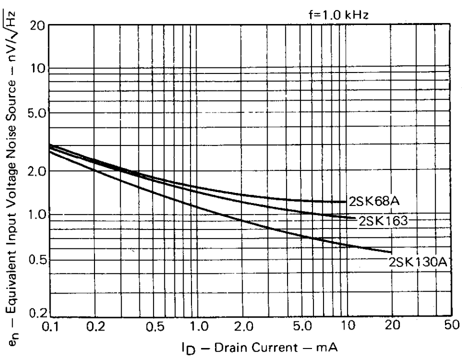


Fig. 33 Current Characteristics of Equivalent Input Voltaic Noise Source e_n of a FET.

THE SN RATIO OF AMPLIFIERS AND TRANSISTOR NOISE.

So far, the equivalent input noise source method has been explained, employing e_n, i_n and NF, in regards to the transistor alone. Here, the methods for utilizing these factors in the actual designing of circuits shall be explained.

The noise figure of an amplifier is shown by the following equation.

$$NF = \frac{N_o/S_o}{N_1/S_1}$$

Furthermore, when the power gain and noise figure of each stage are $G_1, G_2, \ldots$ and $F_1, F_2 \ldots$ respectively in a multistage amplifier, the total noise figure for an stage amplifier can be shown as follows.

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \ldots\ldots + \frac{F_n - 1}{G_1 G_2 \ldots\ldots G_{n-1}}$$

From this formula it can be seen that F_1 is determined from the noise figure of the first stage transistor and, making the gain of the first stage as large as possible will contribute towards to the improvement of the noise figure of multistage amplifiers.

Next, taking a stereo equalizing amplifier as an example of an actual circuit, the advantages of the equivalent input noise source method shall be described.

As have been described before, when low noise transistors are used, it is important to ascertain the circuit conditions and determine transistor operating conditions that will match the circuit conditions.

Fig. 34 shows a NF map. The method for determining optimum operating conditions from this map shall be explained.

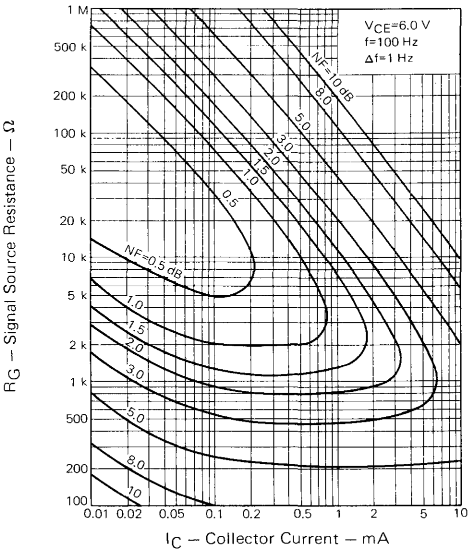


Fig. 34 NF Map.

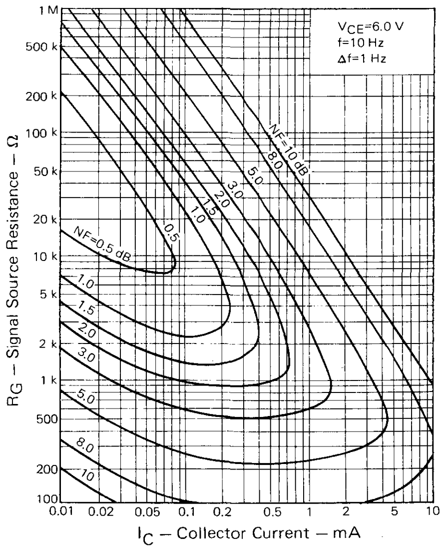


Fig. 35 NF Map.

When the signal sources of stereo equalizing amplifiers are considered to be magnetic cartridges or tape recorder heads, the majority of the signal source impedances will lie between 1 and 2 kΩ (f = 1 kHz). Also, when a frequency range of 100 Hz to 10 kHz is considered, these impedances will extend over the wide range of 500 Ω to 200 kΩ.

The I_C at which the NF will become as small as possible, within this signal source resistance range, is determined from the map. The frequency of the NF map shown in Fig. 34 is 100 Hz, however, when the frequency characteristics of a stereo equalizing amplifier is considered the gain becomes maximum at about 100 Hz, therefore this map was taken as an example. Furthermore, as reference a NF map for 10 Hz is shown in Fig. 35.

From Fig. 34 it can be judged that the collector current to be used should be selected from between several tens of μA and 100 μA.

Next, from the formula for the noise figure of multistage amplifiers it can be seen that in order to make the noise small the gain of the first stage should be made large. In order to achieve this, the collector current should be made as large as possible. Therefore, the final value of the collector current is determined through correlation of this point and the NF characteristics.

Depending on the coupling circuit with the 2nd stage, the actual gain of the first stage may be decreased. In other words, since the input resistance of the 2nd stage is the load of the first stage, the input resistance of the 2nd stage must be made large to a certain extent.

When designing low frequency low noise amplifiers as described, the NF map should be skillfully applied while giving ample consideration to the circuit conditions preceding and following each stage.

With the above, the basic way of thinking and the equivalent input noise source method and its application to NF map reading when designing low frequency low noise amplifiers have been described.

When undertaking actual designing, it is recommended that suitable use be made of specialist publications and technical journals.

5. DEPENDENCY OF PARAMETERS ON VARIOUS CONDITIONS

DC CHARACTERISTICS

Among the DC characteristics of transistors, h_{FE}, V_{BE} and $V_{CE(sat)}$ are representative. Between Ge transistors and Si transistors there is a difference in V_{BE} as shown in Fig. 36. Alloy type (step junction type) and diffusion type (graded junction type) transistors feature the difference shown in Fig. 37.

h Parameters

h parameters have a dependency on current and voltage as shown in Figs. 38 and 39 respectively. The relationship of h parameters with physical constants is as shown in the following equations.

$$h_{ib} \approx \frac{kT}{qI_E} + r_b(1-\alpha)$$

$$h_{rb} \approx -\frac{kT}{qW} \cdot \frac{\partial W}{\partial V_C} + r_b \cdot g_c$$

$$h_{oc} \approx \frac{-I_E}{W}\left[2(1-\beta^*) + 1 - \gamma\right]\frac{\partial W}{\partial V_C}$$

here, k : Boltzmann's constant = 8.63 x 10^{-5} (eV/K)

q : Charge of electron = 1.6 x 10^{-5} (C)

T : Absolute temperature 273 + t (K)

W : Effective base width

g_C : Collector conductance

$\alpha = \gamma\beta^*\alpha^*$ γ : Injection efficiency

β^* : Transportation efficiency

α^* : Intrinsic current amplification factor.

Conversion of common-base h parameters to common-emitter h parameters can be performed approximately by the following formulae.

$$h_{ie} = \frac{h_{ib}}{1+h_{fb}} \qquad h_{re} = \frac{h_{ib} \cdot h_{ob}}{1+h_{fb}} = h_{rb}$$

$$h_{fe} = \frac{-h_{fb}}{1+b_{fb}} \qquad h_{oe} = \frac{h_{ob}}{1+h_{fb}}$$

The dependency of $V_{CE(sat)}$ and $V_{BE(sat)}$ on current is as shown in Fig. 40.

JUNCTION CAPACITY

Junction capacity has a dependency on voltage as shown in Fig. 41. Generally, the capacity is approximately inversely proportional to the 1/2 power of the voltage in alloy type junctions, and approximately inversely proportional to the 1/3 power of the voltage in diffusion type junctions.

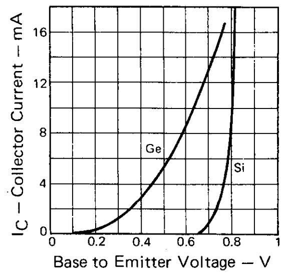


Fig. 36 Example of I_C–V_{BE} Characteristics.

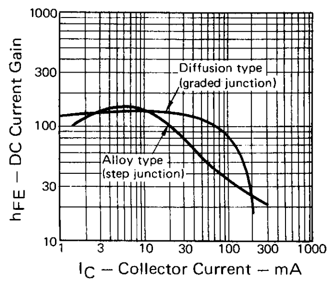


Fig. 37 Example of h_{FE}–I_C Characteristics.

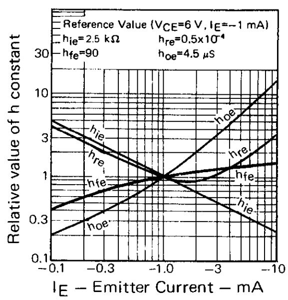


Fig. 38 Example of h Constant–I_E Chracteristics.

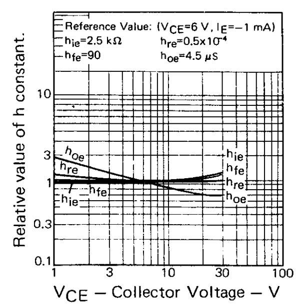


Fig. 39 Example of h Constant–V_{CE} Characteristics.

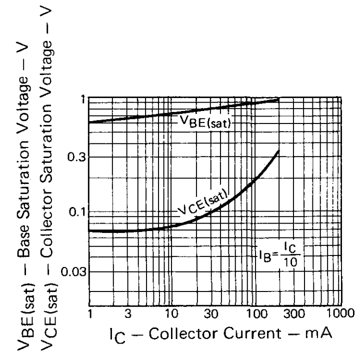


Fig. 40 Example of $V_{BE(sat)}$ and $V_{CE(sat)}$ vs. I_C Characteristics. Si Transistor

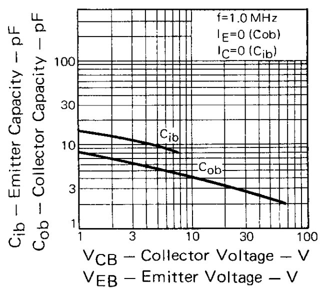


Fig. 41 Example of C_{ob}–V_{CB} and C_{ib}–V_{EB} Characteristics. Si Transistor

FREQUENCY CHARACTERISTICS

1) Frequency characteristics of current amplification factor.

The frequency characteristics of the current amplification factor are as shown in Fig. 42, and their relationship are expressed by the following formulae.

$$\alpha = \frac{\alpha_o}{1 + j\frac{f}{f_{\alpha b}}} \exp j\left(\frac{k-1}{k}\right)\left(\frac{f}{f_{\alpha b}}\right)$$

$$h_{fe} = \frac{\alpha_o}{1-\alpha_o} \cdot \frac{1}{1 + j\frac{1}{k(1-\alpha_o)} \cdot \frac{f}{f_{\alpha b}}} \quad \left(\frac{f}{f_{\alpha b}} < 0.1\right)$$

$$h_{fe} = \frac{h_{feo}}{1 + j\frac{f}{k(1-\alpha_o) f_{\alpha b}}} \exp\left(-j\frac{1-k}{\sqrt{k}}\frac{f}{f_{\alpha b}}\right)$$

$$(f < f_{\alpha b})$$

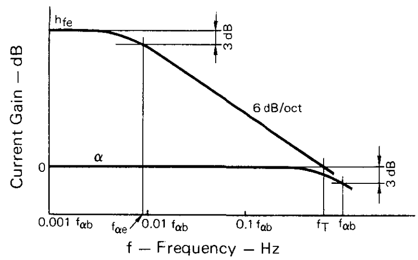


Fig. 42 Dependency of Current Amplification Factor on Frequency.

It is known that $f_{\alpha b}$, f_T and $f_{\alpha b}$ of the above formulae have the following relationship.

$$f_{\alpha e} = k(1-\alpha_o) f_{\alpha b}$$

$$f_T = \alpha_o k f_{\alpha b} \approx k f_{\alpha b}$$

In the above relationship, the constant k becomes 0.82 when the impurity density of the base is uniform like in alloy type junctions, and 0.5 to 0.7 when the impurity gradient is large like diffusion type junctions.

2) h parameter frequency characteristics.

The frequency characteristics of the h parameters are expressed by the following formulae.

$$h_{ie} = r_{bb'} + \frac{r_e}{1-\alpha} = r_{bb'} + \frac{r_e}{1-\alpha_o + j\omega C_e r_e}$$

$$\approx r_{bb'} + \frac{1}{j\omega C_c}$$

$$h_{re} = \frac{r_c}{r_c - (1-\alpha)} = \frac{j\omega C_e r_e}{1-\alpha_o + j\omega C_e r_e} \approx \frac{C_c}{C_e}$$

$$h_{fe} = \frac{\alpha}{1-\alpha_o + j\omega C_e r_e} \approx \frac{\alpha_o}{j\omega C_e r_e}$$

$$h_{oe} = \frac{1}{r_c(1-\alpha)} = \frac{j\omega C_c(1 + j\omega C_e r_e)}{1-\alpha_o + j\omega C_e r_e}$$

$$\approx \frac{j\omega C_c}{1-\alpha_o + j\omega C_e r_e} \approx \frac{C_c}{r_e C_e}$$

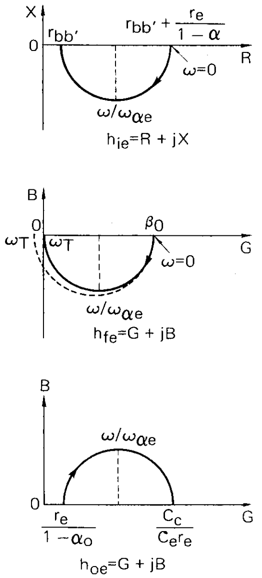


Fig. 43 Frequency Characteristics of h Parameters.

TEMPERATURE CHARACTERISTICS

Since transistors have such parameters as I_{CBO}, V_{BE} and h_{fe} which change sensitively against temperature, it is necessary to consider this point when designing circuits.

1) Temperature characteristic of I_{CBO}.

The temperature characteristic of I_{CBO} is shown by the following formula.

$$I_{CBO} = I_S \exp\left(-\frac{qE_G}{kT}\right)$$

$$\frac{\partial I_{CBO}}{\partial T} = \frac{qE_G}{kT^2} \cdot I_{CBO} \ldots\ldots \begin{cases} \text{Ge} \ldots\ \dfrac{\partial I_{CBO}}{\partial T} \approx 0.1\ I_{CBO} \\ \text{Si} \ldots\ \dfrac{\partial I_{CBO}}{\partial T} \approx 0.14\ I_{CBO} \end{cases}$$

Though the temperature coefficient of I_{CBO} is larger for Si transistors compared with Ge transistors, generally, since the absolute value of the I_{CBO} of Si transistors is amply small, in the majority of cases it may be disregarded without harm. However, in the case of Ge transistors, since the I_{CBO} is of several μA and is large, the temperature coefficient must be given consideration.

2) Temperature characteristic of V_{BE}.

The temperature characteristic of the V_{BE} is shown by the following formulae.

$$I_E = I_S\, e^{\frac{qV_{BE}}{kT}} = K e^{-\frac{qE_G}{kT}} \cdot e^{\frac{qV_{BE}}{kT}}$$

$$V_{BE} = \frac{kT}{q} \ln \frac{I_E}{K} + E_G$$

$$\frac{\partial V_{BE}}{\partial T} = \frac{k}{q} \ln \frac{I_E}{K} = \frac{1}{T}(E_G - V_{BE}) \approx -2\ (\text{mV}/^\circ\text{C})$$

That is to say, the temperature change of V_{BE} is about −2 mV/°C for both Ge and Si transistors. It is necessary to give ample consideration to this point, when designing circuits.

3) Temperature characteristic of h_{fe}.

The relation of h_{fe} to temperature is expressed by the following formula.

$$\frac{1}{h_{fe}} = \frac{\rho_e W}{\rho_b L_{ne}} + \frac{W^2}{2L_{pb}^2} + \frac{SA_S W}{AD_{pb}}$$

In the above formula, since the 1st term (emitter injection efficiency) and 2nd term (transportation efficiency) have a positive coefficient against temperature change and the 3rd term (surface recombination effect) has a negative coefficient it is difficult to quantitatively determine the temperature coefficient of h_{fe}. Experimentally, this coefficient has been determined to be about.

Alloy types, mesa types . . . . $\dfrac{\partial h_{fe}/\partial T}{h_{fe}} \approx 0.5\ \%/^\circ\text{C}$

Planar types . . . . $\dfrac{\partial h_{fe}/\partial T}{h_{fe}} \approx 1\ \%/^\circ\text{C}$

When designing circuits, consideration should be given to the decrease of h_{fe} at low temperatures.

4) Temperature characteristic of $V_{CE(sat)}$.

The temperature characteristic of $V_{CE(sat)}$ is expressed by the following formula.

$$V_{CE(sat)} = \frac{kT}{q} \ln \frac{\alpha_R \left(1 - \frac{I_C}{I_B} \cdot \frac{1-\alpha}{\alpha}\right)}{1 + \frac{I_C}{I_B}(1 - \alpha_R)} + I_E r_{SE} \cdot I_C r_{SE}$$

$V_{CE(sat)}$ has also been determined experimentally to be about.

$$\frac{\partial V_{CE(sat)}/\partial T}{V_{CE(sat)}} \approx 0.5\ \%/^\circ C$$

11

NEC
ELECTRON DEVICE

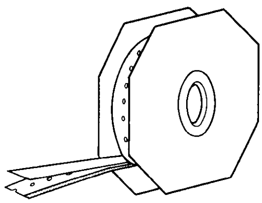
RADIAL TYPE LEAD TAPING OF TO-92 TRANSISTORS

DESCRIPTION

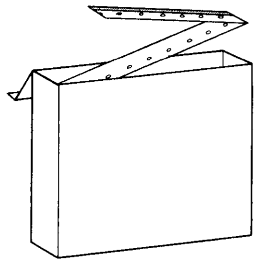
The RADIAL TYPE taped transistors are designed for use with automatic electronic component machines. Especially recommended for PANASERT and AVI-SERT.

FEATURES

- Type of packages . . . . REEL PACK and FOLD PACK



REEL PACK



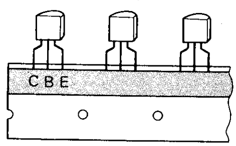
FOLD PACK

- Selection of the taping

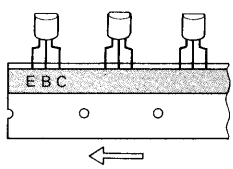
LEAD CONFIGURATION	FEEDING DIRECTION	
	STANDARD	REVERSE
EUROPEAN TYPE C B E	COLLECTOR forwarder	EMITTER forwarder
U.S.A. TYPE E B C	EMITTER forwarder	COLLECTOR forwarder
JAPANESE TYPE E C B	EMITTER forwarder	BASE forwarder

Ex. EUROPEAN TYPE

1) COLLECTOR forwarder (STANDARD)



2) EMITTER forwarder (REVERSE)



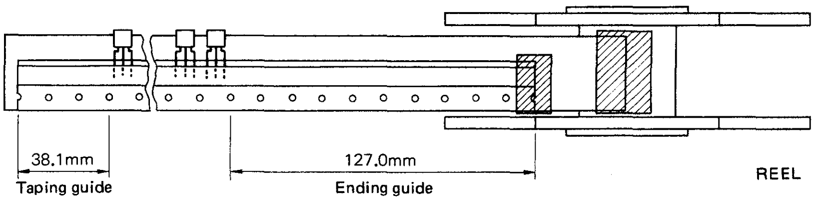
QUANTITY

PACKING	QUANTITY	Q'TY TOLERANCE	1 CARTON
REEL PACK	1500 pcs./REEL	± 2 pcs./REEL (PACK)	10 REELS (15000 pcs.)
FOLD PACK	2000 pcs./PACK		10 PACKS (20000 pcs.)

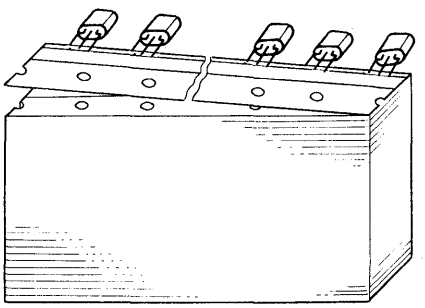
Fractional order is not acceptable.

EXCESSIVE TAPE LENGTH

1. REEL PACK
   Taping guide . . . . 3 pitches (38.1 mm)
   Ending guide . . . . 10 pitches (127.0 mm)



2. FOLD PACK
   The FOLD PACK has neither taping guide nor ending guide.



CODING FOR TAPED TRANSISTORS

EX. BC546 A –T

- T → FOLD PACK TAPING

BC327 16–TRC

- C → FEEDING DIRECTION
- TR → REEL PACK TAPING
- 16 → h_{FE} RANK
- BC327 → TYPE NO.

C: COLLECTOR
B: BASE
E: EMITTER

OTHERS

1. Carton box dimensions (unit: mm)
   Exterior box for REEL PACK .... 340 x 340 x 460, t = 0.5
   Exterior box for FOLD PACK .... 340 x 270 x 490, t = 5.0
   Individual box for FOLD PACK .... 330 x 260 x 480, t = 4.5
2. In FOLD PACK, the tape is folded at every 25 pitchies (317.5mm).
3. In REEL PACK, craft paper (width: 38mm) is used as the spacer and the buffer.
4. Electrical characteristics of taped transistors are in accordance with SHIPMENT SPECIFICATION.
5. Total rejection rate of taping
   (mistaping, reverse taping, drop-out, mixture, etc.)
   MIL-STD-105D AQL=0.65% LEVEL II
6. Process flow chart of taping transistors
   See Fig. 1
7. Taping dimensions
   See Fig. 2
8. Taping reel dimensions
   See Fig. 3

Fig. 1 PROCESS FLOW CHART OF TAPED TRANSISTORS

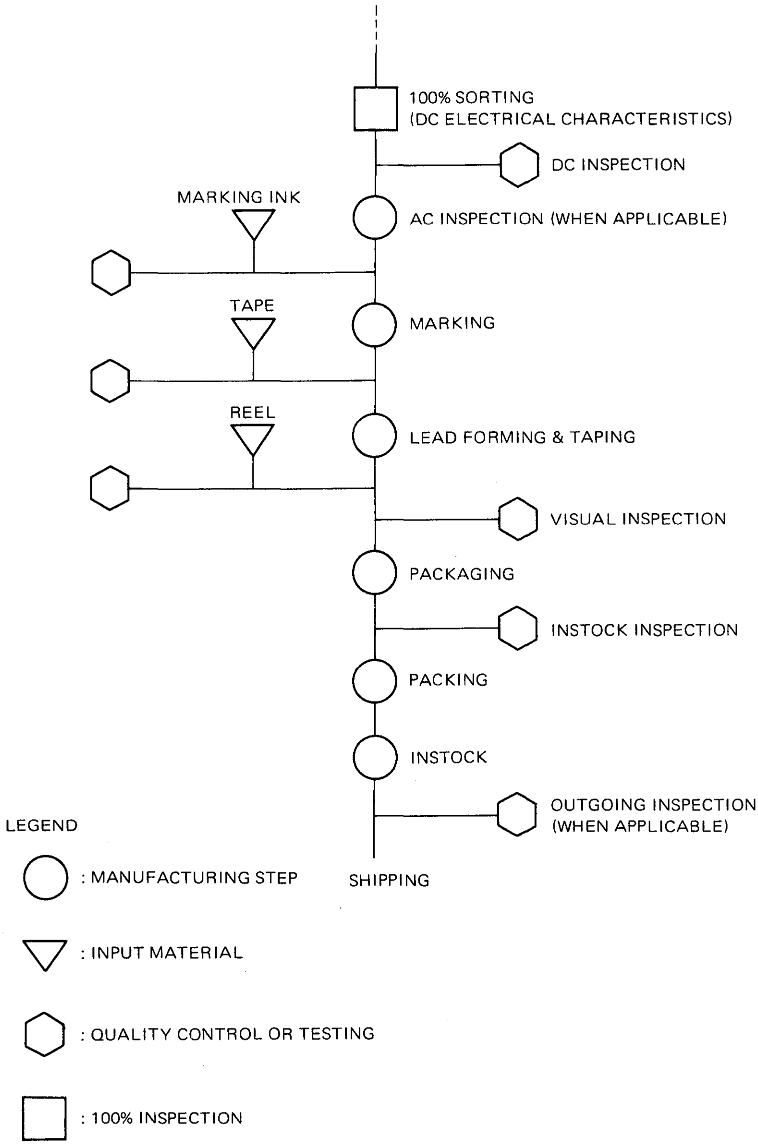
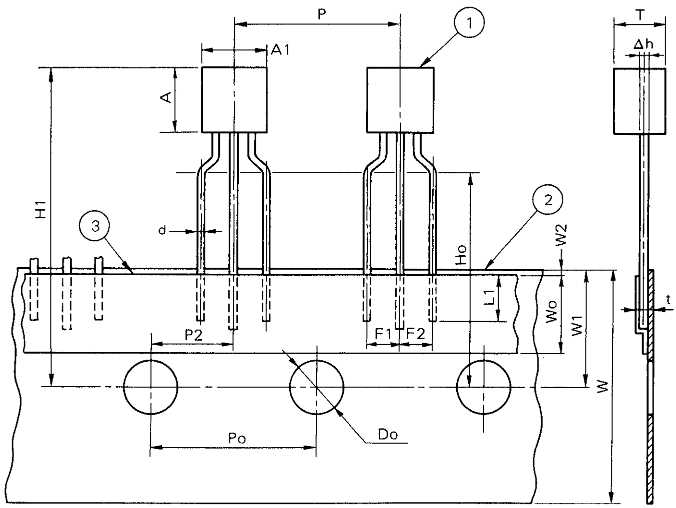


Fig. 2 TAPING DIMENSIONS

(UNIT: mm)

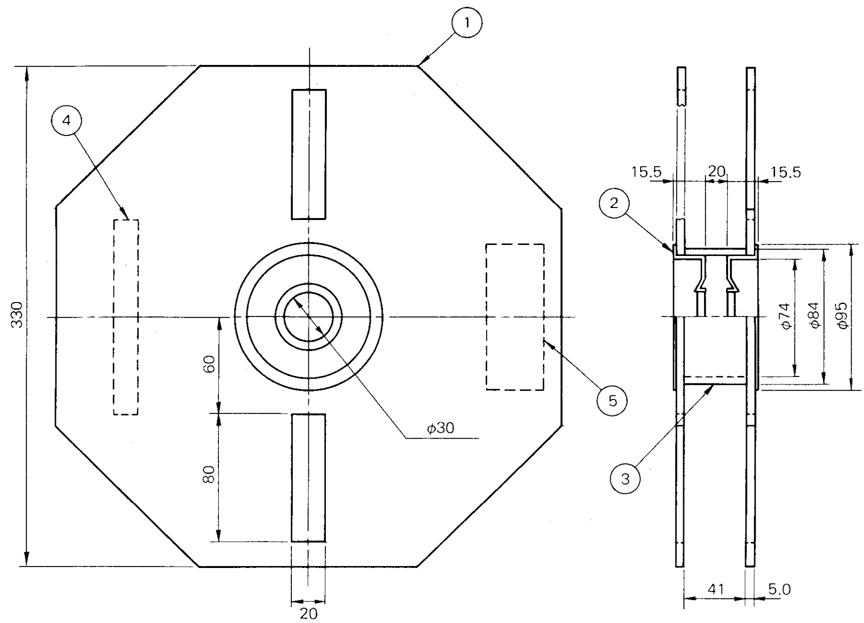


NO.	NAME	REMARK
①	TRANSISTOR	TO—92 TYPE
②	BASE TAPE	PASTEBOARD
③	ADHESIVE TAPE	

DESCRIPTION	SYMBOL	DIMENSION	REMARK
Transistor Width	A1	5.2 MAX.	
Transistor Height	A	5.5 MAX.	
Transistor Thickness	T	4.2 MAX.	
Transistor Lead Width	d	0.65 MAX.	
Transistor Taped Lead Length	L1	2.5 MIN.	
Taping Pitch	P	12.7±1.0	
Feed Hole Pitch	Po	12.7±0.3	Cumulative tolerance: ±1.0mm/20pit.
Feed Hole Position	P2	6.35±0.4	
Lead-to-lead Distance	F1, F2	$2.5^{+0.4}_{-0.1}$	
Transistor Bend	Δh	0.0±2.0	At Center of Transistor
Tape Width	W	$18.0^{+1.0}_{-0.5}$	Base Tape
Adhesive Tape Width	Wo	6.0±0.3	
Hole Position	W1	$9.0^{+0.75}_{-0.5}$	
Adhesive Tape Deviation	W2	0.5 MAX.	
Transistor Lead Clinch Height	Ho	16.0±0.5	
Upper Limit of Transistor	H1	32.25 MAX.	
Hole Diameter	Do	4.0±0.2	
Total Thickness of Tape	t	0.7±0.2	Base Tape Thickness: $0.55^{+0.15}_{-0.05}$

Fig. 3 TAPING REEL DIMENSIONS

(Unit: mm)



NO.	NAME	REMARK
①	FLANGE	Type: OCTAGON, Material: CARDBOARD t = 5.0
②	SHAFT	SPTE-C, 0.3t
③	SHAFT	φ84 x φ74 x 41W mm Material PASTEBOARD
④	MARKING	"NEC Electron Device"
⑤	MARKING	TYPE NO., Q'TY, LOT CODE, etc.

THE SAFE OPERATING AREAS OF TRANSISTORS UNDER SWITCHING OPERATIONS

1. INTRODUCTION

In recent years, the switching system which is of high efficiency and capable of miniaturization has become to be widely employed in the field of power supply units, in place of the series control system. And, occasions for the use of transistors as the switching elements in inductive load circuits, such as transformers, is on the increase.

In the switching operation of such inductive load circuits, large current and high voltage are applied simultaneously between the collector and emitter at the moment of turn-off. Since the definition and assurance of the safe operating area of transistors under such conditions had not been made clear in the past, destruction occurred frequently.

Here, taking NEC's high speed switching transistors, NTC1862 and NTC1871A, as examples, the concept of safe operating area under switching operations shall be described. Also, precautions to be observed when making practical applications of the transistors will be described, taking switching regulator circuits as the examples.

2. CONCEPT OF SAFE OPERATING AREA UNDER SWITCHING OPERATIONS

2-1 Problem of the conventional Safe Operating Area

Conventionally, NEC has indicated the safe operating area, as shown in Fig. 1, by the maximum allowable power applicable to the transistor when the pulse width is varied. This was measured according to the ΔV_{EB} method shown in Fig. 2, and since the base is always at a higher voltage (in NPN transistors) than the emitter, the emitter-base junction is forward biased. For this reason the conventional safe operating area is called the forward bias safe operating area. In other words, the forward bias safe operating area will serve as a yardstick for safe operation, only when the emitter-base junction is forward biased. And, this state of being forward biased corresponds to the moment of turn-on and the state of "on" in switching operations.

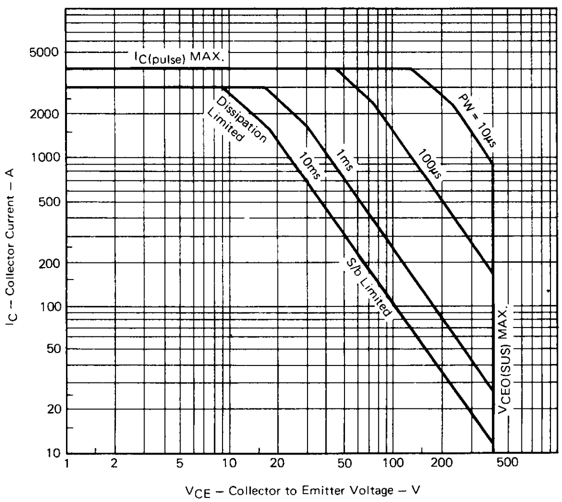


Fig. 1 Forward Bias Safe Operating Areas. (NTC1862)

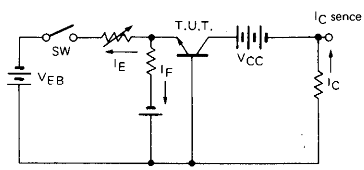


Fig. 2 Measurement Circuit for Forward Bias Safe Operating Areas. (NPN transistors)

2-2 Reverse Bias Safe Operating Area

When the transistor is turn-off during switching operation, a reverse bias, including no bias, will be applied to the emitter-base junction so that the collector is within the cutoff region.

Needless to say, the forward bias safe operating area described before cannot be applied to this state, and it is necessary to specify and assure, anew, a safe operating area for the condition when the base is reverse biased - - reverse bias safe operating area (refer to Fig. 3).

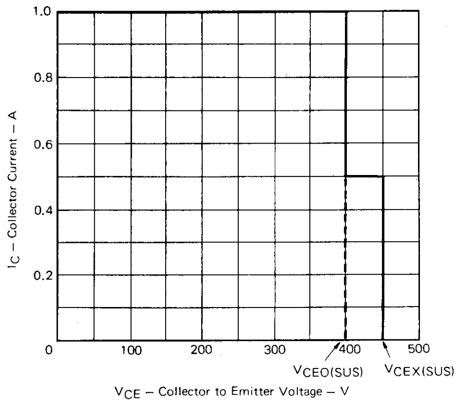


Fig. 3 Reverse Bias Safe Operating Area. (NTC1862)

3. METHOD OF APPLYING FORWARD AND REVERSE BIAS SAFE OPERATING AREAS TO ACTUAL CIRCUITS

3-1 Basic concept

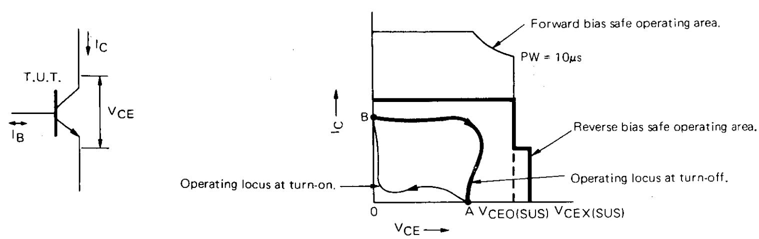


Fig. 4 Safe Operating Area of Switching Operation.

Generally, when a transistor is employed for switching of inductive loads the operating locus will move through the active area between the "cutoff" area [A] and "on" area [B], following the path [A] → [B] at turn-on, and the path [B] → [A] at turn-off, as shown in Fig. 4.

Here, the criterion of safe operation is that the operating loci of both turn-on and turn-off reside within the area defined by both the forward and reverse bias safe operating areas.

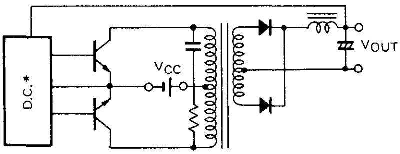
3-2 Application to actual Switching Regulator Circuits and Precautions.

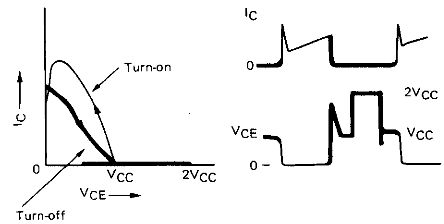
Table 1 shows the operating waveforms and loci of transistors employed in 4 typical types of circuits for switching regulators.

11

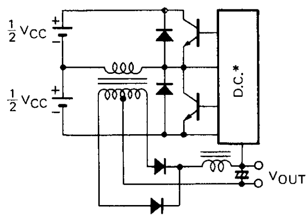
Table 1 Typical Switching Regulator Circuits and their Operating Waveforms.

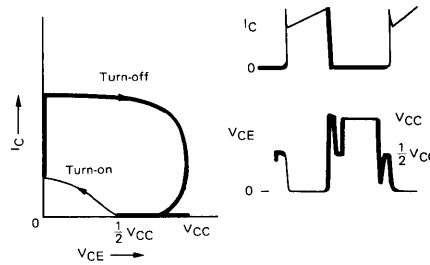
<table>
<tr><th>Circuit System</th><th>Typical Load Curves and Waveforms</th></tr>
<tr><td>1. Push-pull type.



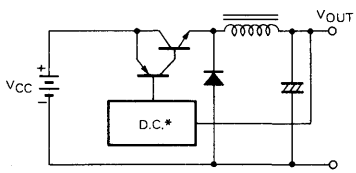
</td><td>


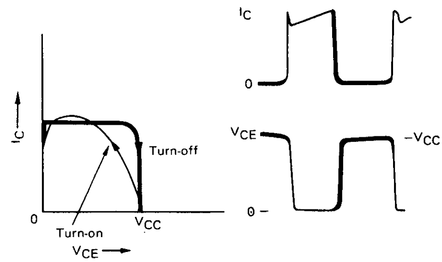
</td></tr>
<tr><td>2. Half-bridge type.



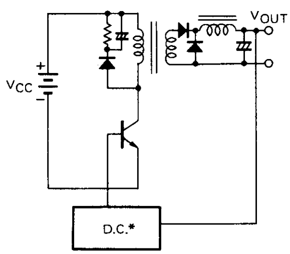
</td><td>


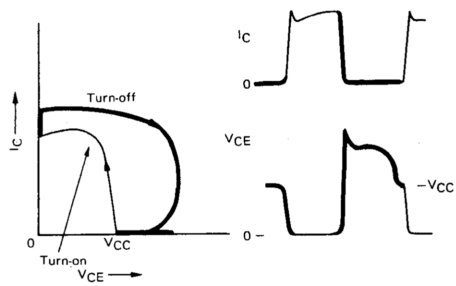
</td></tr>
<tr><td>3. Chopper type.



</td><td>


</td></tr>
<tr><td>4. Single-ended (ON-ON) type.



</td><td>


</td></tr>
</table>

D.C.* means Drive Circuit.

The method of ascertaining safe operation has been described in the preceding paragraph. However, when applying the forward and reverse bias safe operating areas to actual circuits the following precautions are necessary.

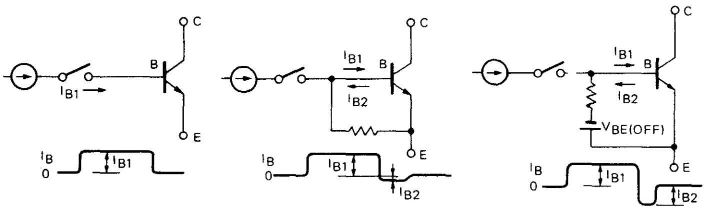
1) Forward bias safe operating area.

Since the turn-on time t_{on} is usually less than 10μs, the safe operating area when PW = 10μs will become the criterion for safe operation. Needless to say, when the turn-on time exceeds 10μs the safe operating area of the pulse width corresponding to the turn-on time will become the criterion of safe operation.

Furthermore, derating of the safe operating area to accord with the junction temperature should be performed by using the derating curve shown in the data sheets.

2) Reverse bias safe operating area.

It should be noted that the reverse bias safe operating area changes according to the driving conditions of the reverse bias applied to the emitter-base junction.



(1) No bias. (2) Resistance bias. (3) Forced reverse bias.

Fig. 5 Biasing methods for turning off the emitter-base junction.

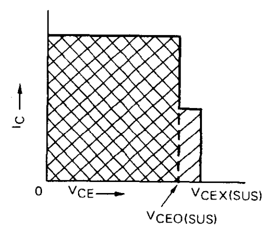


Fig. 6 Reverse bias safe operating area.

The sustaining voltage between collector and emitter of (1) to (3) of Fig. 5 are $V_{CEO(SUS)}$, $V_{CER(SUS)}$, and $V_{CEX(SUS)}$ respectively, and these form the reverse bias safe operating areas.

In Fig. 6 the portion marked \\\\\ is the safe operating area formed by $V_{CEO(SUS)}$, and this is the criterion for safe operation in the case of (1), No bias, in Fig. 5. Also, the portion marked ///// in Fig. 6 is the safe operating area formed by $V_{CEX(SUS)}$ which is the criterion for safe operation in the case of (3), Forced reversed bias, in Fig. 5. Generally, there is a relationship of $V_{CEO(SUS)} < V_{CER(SUS)} < V_{CEX(SUS)}$ between $V_{CEO(SUS)}$, $V_{CER(SUS)}$, and $V_{CEX(SUS)}$. However, since the value of $V_{CER(SUS)}$ may become $V_{CEO(SUS)} \leq V_{CER(SUS)}$ according to the values of the resistance and the collector current, in the case of (2), Resistance bias, in Fig. 5, similarly to the case of (1) No bias, the criterion of safe operation is the safe operating area formed by $V_{CEO(SUS)}$ that is shown by \\\\\ in Fig. 6.

Since it is necessary to shorten the storage time t_{stg} and fall time t_f in switching regulators, it is usual to apply forced reverse bias to the emitter-base junction, as shown in (3) of Fig. 5, so from this standpoint the safe operating area formed by $V_{CEX(SUS)}$ is the most important. In this case, the higher the reverse bias voltage the shortor will be the switching time, however, since the forward bias will tend to collect at the center of the emitter and the collector current will be concentrated at this point, breakdown will be liable to occur through the pinch-in effect shown in Fig. 7. Therefore, it is necessary that the condition of the reverse bias be below that of the measurement of $V_{CEX(SUS)}$ in the data sheets. (conditions: $V_{BE(OFF)} < -5V$, $I_{B2} < I_{B2}$ defined in spec.) Since the assurance of $V_{CEX(SUS)}$ is performed at the high temperature of $T_a = 125°C$, derating according to the junction temperature is not required for the reverse bias safe operating area.

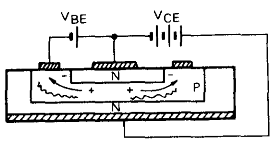


Fig. 7 Pinch-in Effect.

11

3) Other precautions.

In the use of these switching regulators, situations of which the ascertaining of safe operation is most required are: when power is switched on, and when the load changes suddenly or output terminals are shorted. Most destruction occur on such occasions.

Especially, when power is switched on a collector current of 2 to 4 times of normal current will flow, due to the flowing of the initial changing current of capacitors on the load, and spike voltages occurring at turn-off will rise. On the other hand, the reverse bias safe operating area of the transistor will decrease in inverse proportion to the increase of the collector current. Therefore, it is recommended that a soft start circuit be employed to limit the collector current.

Note) The operating waveforms and loci shown in Table 1 are only examples, and may change greatly under different load conditions.

4. THE NEC METHOD FOR ASSURANCE OF THE REVERSE BIAS SAFE OPERATING AREA.

(This paragraph is explained using the NTC1871A as an example)

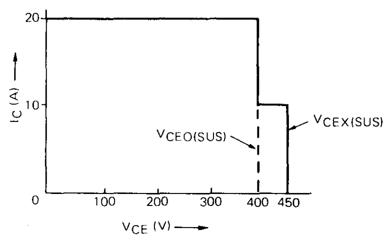


Fig. 8 Reverse Bias Safe Operating Area of NTC1871A.

The reverse bias safe operating area shown in Fig. 8 is composed by $V_{CEO(SUS)}$ and $V_{CEX(SUS)}$.

The definitions and assurance methods of $V_{CEO(SUS)}$ and $V_{CEX(SUS)}$ will be explained individually as follow:

4-1 $V_{CEO(SUS)}$

This is defined as the maximum value of the collector to emitter breakdown voltage when the emitter-base junction is in turn-off at no bias with inductive load. Assurance of $V_{CEO(SUS)}$ is given by noting that this value exceeds the $V_{CEO(SUS)}$ rating.

The measurement circuit for $V_{CEO(SUS)}$ and the waveforms of various parts of the circuit are shown in Figs. 9 and 10.

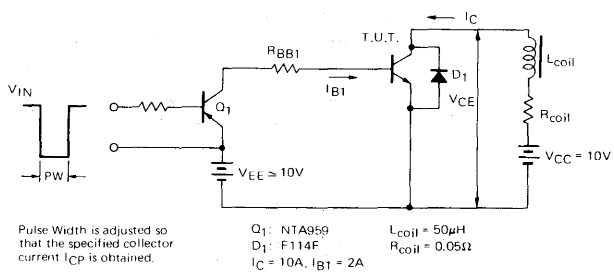


Fig. 9 Measurement Circuit for $V_{CEO(SUS)}$.

$V_{CEO(SUS)}$

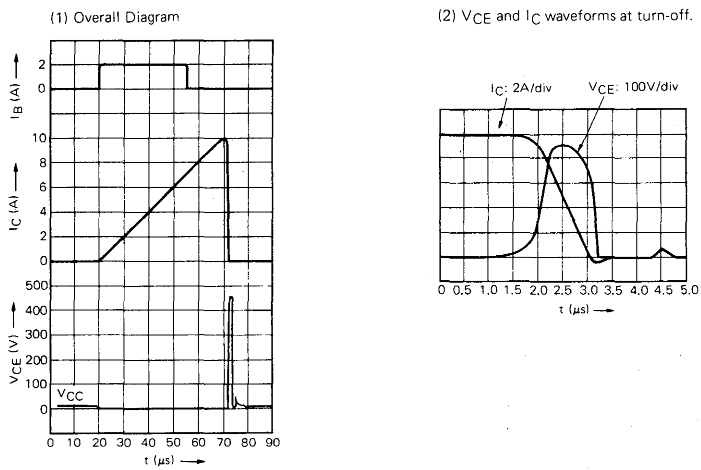
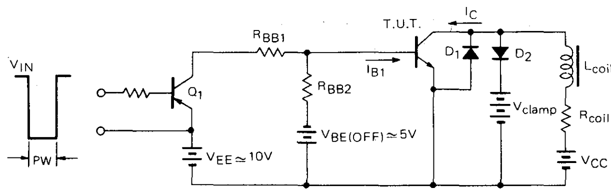


Fig. 10 Waveforms of various parts of the Circuit.

4-2 $V_{CEX(SUS)}$

This is defined as the applying between the collector and emitter of the energy stored in the inductance of the load, which is clamped at the $V_{CEX(SUS)}$ rating, while the emitter-base junction is in turn-off by the application of forced reverse bias. Assurance of $V_{CEX(SUS)}$ is given by the non-occurrence of destruction or degradation of characteristics during the above.

The measurement circuit for $V_{CEX(SUS)}$ and the waveforms of various parts of the circuit are shown in Figs. 11 and 12.



Pulse Width is adjusted so that the specified collector current I_{CP} is obtained.

Q_1: NTA959
D_1: F114F
D_2: 6FH4S

$L_{coil} = 180\mu H$
$R_{coil} = 0.05\Omega$

$I_C = 10A, I_{B1} = -I_{B2} = 2A$
$V_{clamp} = 450V$

Fig. 11 Measurement Circuit for $V_{CEX(SUS)}$.

11

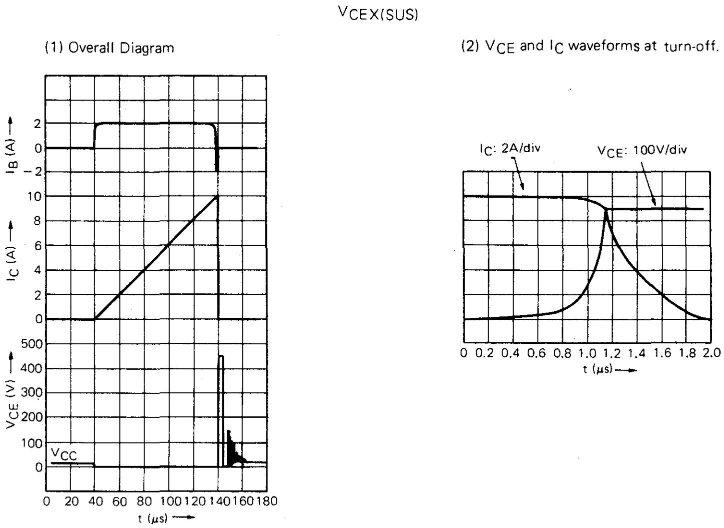


Fig. 12 Waveforms of various parts of the Circuit.

The above method assurance has the two following features.

1) Assurance is performed at the high temperature of $t_a = 125^\circ C$

2) Since the collector to emitter voltage is clamed at the $V_{CEX(SUS)}$ value, breakdown will not occur providing an assurance of high reliability.

5. CONCLUSION

The concept and method of assurance of the safe operating areas of transistors under switching operations have been described above. And, it has been shown that the reverse bias safe operating area is indispensable, when employing transistors lacking assurance of this item for switching.

CALCULATION METHOD FOR THE JUNCTION TEMPERATURE OF TRANSISTORS DURING PULSE POWER DISSIPATION

1. INTRODUCTION

Junction temperature is one of the important items for ascertaining the operating condition of transistors. Generally, the junction temperature is calculated from the following equation.

$$T_j = P_D \cdot R_{th\ (j\text{-}c)} + T_C$$

where,
- T_j : Junction temperature
- T_C : Case temperature
- P_D : Power dissipation
- $R_{th\ (j\text{-}c)}$: D.C. thermal resistance from junction to case.

However, when the power dissipation is in the form of pulses, accurate junction temperature cannot be determined unless transient thermal resistance is employed in the calculations. Here, a method for calculating the junction temperature during pulse power dissipation shall be described employing the high speed, high voltage switching transistor, NTC1871A, as an example, and including applications of the same to switching regulators.

2. TRANSIENT THERMAL RESISTANCE

Transient thermal resistance is defined as the reciprocal of the heat conductivity during the pulse power dissipation. The heat generated in the junction of the transistor by power dissipation is conducted away through the following path, and the resistance to this conduction is expressed as the thermal resistance. Junction → Pellet(silicon) → Mounting material → case → heatsink → Environment.

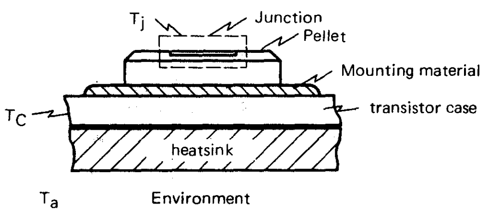


Fig. 1 Structure of a Transistor.

Generally, the time required for the heat between the junction and case, and the case and enviroment, to reach a steady state (thermal equilibrium) is 1 to 10 seconds for the former, and several minutes for the latter. Therefore, for power dissipation of short pulses, the temperature rise is limited to the proximity of the junction. And, for pulses of 100ms or less width, the temperature rise becomes almost irrelevant of the state of heat radiation of the transistor.

Note) When the pulse width of the power dissipation exceeds 100ms, the junction temperature cannot be calculated unless the transient thermal resistance of the whole system, including the heat sink, is known.

The Transient Thermal Resistance versus Pulse Width characteristics of the NTC1871A are shown in Fig. 2

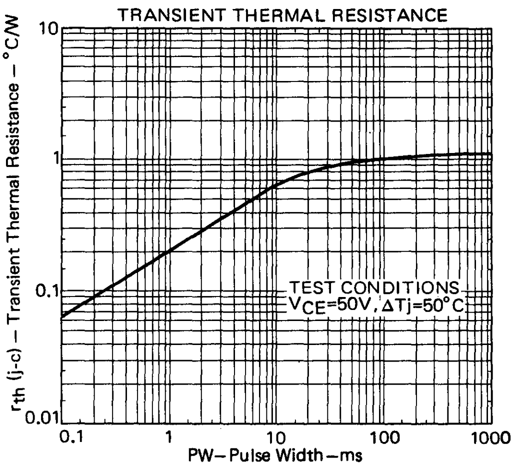


Fig. 2 Transient Thermal Resistance versus Pluse Width of the NTC1871A.

Generally, when the pulse width is short the transient thermal resistance is approximate to the following expression.

$r_{th\ (j\text{-}c)} \propto \sqrt{\tau}$ where, $r_{th\ (j\text{-}c)}$: Transient thermal resistance from junction to case.

τ : Width of pulse.

In the case of the NTC1871A, the transient thermal resistance corresponds to the above expression when the pulse width is less than 10ms.

3. APPLICATION RANGE OF TRANSIENT THERMAL RESISTANCE;

When determining the junction temperature rise caused by pulse power dissipation by employing transient thermal resistance, attention should be paid to the fact that the range over which transient thermal resistance may be applied is limited to cases where no local temperature rise (hot spot) has been created through concentration of current in the junction.

In other words, it is necessary that the pulse power dissipation is within the safe operating area and, at the same time, that no current concentration is created.

An example of a forward bias safe operating area is shown in Fig. 3. In this figure, "Dissipation Limited" indicates the region limited by transient thermal resistance, and "S/b Limited" indicates the region limited due to hot spots being formed through the concentration of current.

The dependency of ΔT_j (increment rise of junction temperature) on the V_{CB} bias is shown in Fig. 4, and region A corresponds to the "Dissipation Limited" mentioned before, and region B corresponds to "S/b Limited". Attention should be paid here to the fact that, even in the region B, when the collector current is derated enough, $I_C \times V_{CB} \propto \Delta T_j$ and the transient thermal resistance may be applied. In this case a derating of more than 40% of the I_C value is recommended.

If the assured range is not exceeded, the application of transient thermal resistance to reverse bias safe operating areas presents no problem. Refer to Semiconductor Technical Data "The Safe Operating Area of Transistors under Switching Operations".

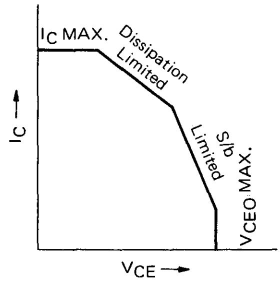


Fig. 3 Forward Bias Safe Operating Area.

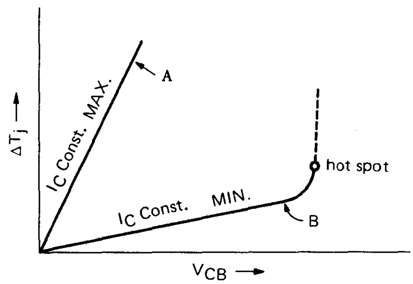


Fig. 4 The dependency of ΔT_j on the V_{CB} bias.

4. CALCULATION METHOD OF THE JUNCTION TEMPERATURE DURING PULSE POWER DISSIPATION

Basically, the junction temperature rise is calculated by approximating the power dissipation waveforms to square waves and employing the principle of superposition and the following equation.

$$\Delta T_j = r_{th(j\text{-}c)}(\tau) \times P_D$$

Where,
- ΔT_j : Temperature rise of junction from case temperature.
- $r_{th(j\text{-}c)}(\tau)$: Transient thermal resistance from junction to case, when pulse width is τ.
- P_D : Power dissipation.

4-1 Power Dissipation of irregularly repeating Square Waves.

The method of determining the junction temperature rise resulting from the power dissipation of irregular square waves is shown in Fig. 5.

It is assumed that an infinitely continuing step shaped power dissipation P_1 is applied from $t = t_0$, and after which an infinitely continuing negative step shaped power dissipation $-P_1$ is applied from $t = t_1$. The same assumptions are applied to P_2, P_3, and P_4, and then calculations are performed according to the principle of superposition.

Results of the calculations become as follows:

$$\Delta T_{j1} = P_1 \times r_{th(j\text{-}c)}(t_1 - t_0)$$

$$\Delta T_{j2} = P_1 \times [r_{th(j\text{-}c)}(t_3 - t_0) - r_{th(j\text{-}c)}(t_3 - t_1)] + P_2 \times r_{th(j\text{-}c)}(t_3 - t_2)$$

$$\Delta T_{j3} = P_1 \times [r_{th(j\text{-}c)}(t_5 - t_0) - r_{th(j\text{-}c)}(t_5 - t_1)] + P_2 \times [r_{th(j\text{-}c)}(t_5 - t_2) - r_{th(j\text{-}c)}(t_5 - t_3)] + P_3 \times r_{th(j\text{-}c)}(t_5 - t_4)$$

$$\Delta T_{j4} = P_1 \times [r_{th(j\text{-}c)}(t_7 - t_0) - r_{th(j\text{-}c)}(t_7 - t_1)] + P_2 \times [r_{th(j\text{-}c)}(t_7 - t_2) - r_{th(j\text{-}c)}(t_7 - t_3)] + P_3 \times [r_{th(j\text{-}c)}(t_7 - t_4) - r_{th(j\text{-}c)}(t_7 - t_5)] + P_4 \times r_{th(j\text{-}c)}(t_7 - t_6)$$

When expressed by a general equation the above become:

$$\Delta T_{jn} = \sum_{i=1}^{n} P_i [r_{th(j\text{-}c)}(t_{2n-1} - t_{2i-2}) - r_{th(j\text{-}c)}(t_{2n-1} - t_{2i-1})] \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

In the above:
- $P_1, P_2, P_3 \ldots\ldots P_n$: Power dissipation.
- $\Delta T_{j1}, \Delta T_{j2} \ldots\ldots \Delta T_{jn}$: Temperature rise of the junction from the case temperature at the end of $P_1, P_2, P_3 \ldots\ldots P_n$.
- $t_0, t_1, t_2, \ldots\ldots t_n$: Time at the start and end of power dissipation.
- $r_{th(j\text{-}c)}(t_X - t_Y)$: Transient thermal resistance from junction to case, when pulse width is $(t_X - t_Y)$

11

(a)
Power dissipation

(b)
Dissolution according to the principle of superposition.

(c)
Transformation to junction temperature rise.

(d)
Temperature rise of junction.

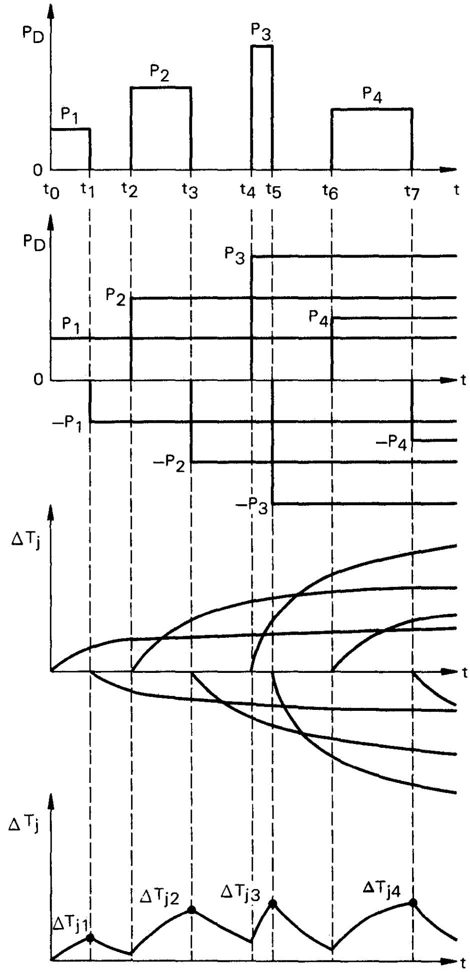


Fig. 5 Method of determining the Junction Temperature Rise from irregularly repeating Square Wave Power Dissipation.

4-2 Power Dissipation of regularly repeating Square Waves.

The method for determining the junction temperature rise resulting from regularly repeating square waves is shown in Fig. 6.

For power dissipation waveforms of this type. The 2 to 3 waves portions protruding from the average value of the total period are taken together for the calculation. This calculation method will be the most easy, accurate, and effective one.

In actual calculation, from the approximation of power dissipation waveforms (b), the increment of the junction temperature rise is determined by applying $\frac{\tau}{T}\cdot P_0$ for an infinite period, and further applying $(1-\frac{\tau}{T})P_0$ for $(\tau + T)$ period, $-P_0$ for T period, and P_0 for τ period. The result of the calculation is:

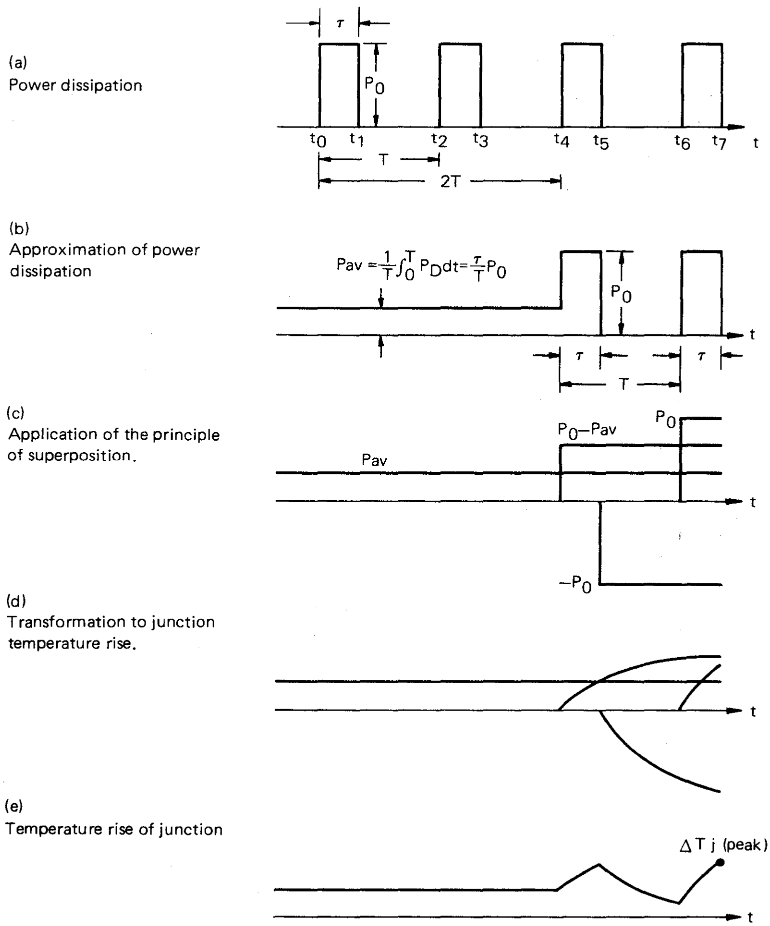


Fig. 6 Method for determining the Junction Temperature Rise for regularly repeating Square Wave Power Dissipation.

$$\Delta T_{j(peak)} = \frac{\tau}{T} \cdot P_O \cdot R_{th(j\text{-}c)} + (1 - \frac{\tau}{T}) \cdot P_O \cdot r_{th(j\text{-}c)}(T + \tau) - P_O \cdot r_{th(j\text{-}c)}(T) + P_O \cdot r_{th(j\text{-}c)}(\tau)$$

$$= P_O[\frac{\tau}{T} \cdot R_{th(j\text{-}c)} + (1 - \frac{\tau}{T}) \cdot r_{th(j\text{-}c)}(T + \tau) - r_{th(j\text{-}c)}(T) + r_{th(j\text{-}c)}(\tau)] \quad \ldots\ldots (2)$$

Where,

$\Delta T_{j(peak)}$	:	Maximum value of junction temperature rise from case temperature.
P_O	:	Power dissipation.
τ	:	Pulse width of power dissipation.
T	:	Period
$R_{th(j\text{-}c)}$	:	D.C. thermal resistance from junction to case.
$r_{th(j\text{-}c)}(t_X)$	:	Transient thermal resistance from junction to case for pulse width of t_X.

4-3 The Approximation to Square Waves of Non-Square Wave Power Dissipation.

Since the actual power dissipation waveforms are of complex form, the junction temperature is determined by the methods described in 4-1 and 4-2, after the waveforms have been approximated to square waves.

When the waveform is close to that of a square wave, as shown in (a) of Fig. 7, the peak values are made the same and the pulse width taken so that the areas are equal.

In the case of sinusoidal waves and triangle waves shown in (b), the peak value is made 0.7 x P_P and the pulse widths are taken as 0.91t and 0.71t respectively.

In the case of complex waveforms as shown in (c), the waveform is divided into several square waves totalling to the same area as the original waveform.

Care should be taken when approximating waveforms as described above, since, according to the method of approximation employed, great difference may result in the calculation of the same power dissipation.

Examples of power dissipation applied to a NTC1871A are shown in Fig. 8. For the same triangle wave power dissipation, there is a 25°C difference in the results calculated from approximation method (a) and (b).

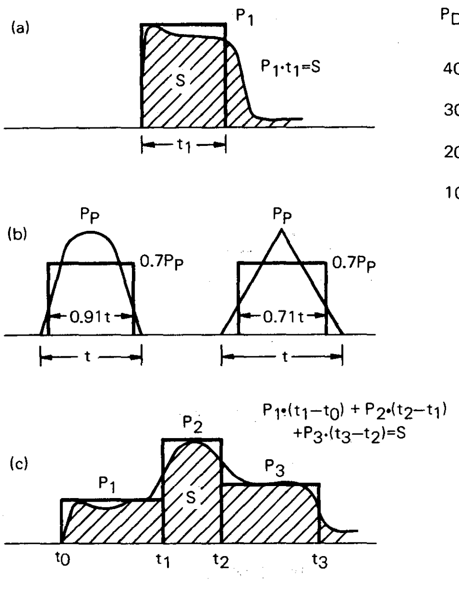


Fig. 7 Approximation to Square waves of Power Dissipation.

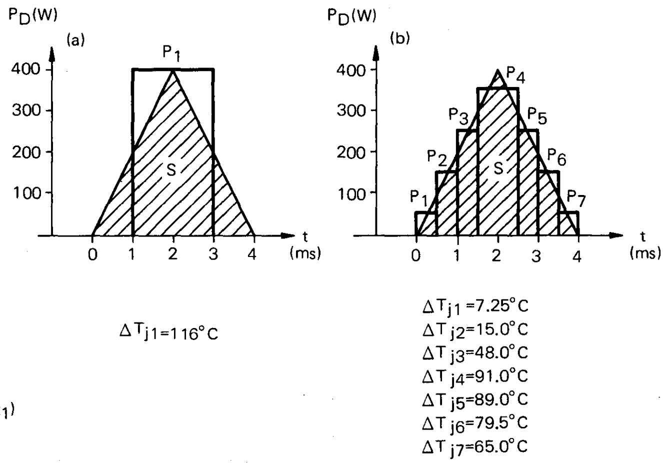


Fig. 8 Temperature Rise of Junction by Triangle Wave Power Dissipation.

This is because, for the same amount of energy, the junction temperature rise is more severe when the peak value is high and the pulse width short, than when the peak value is low and the pulse width long.
(This can also be explained from the fact that the transient thermal resistance is proportional to the 1/2 power of the pulse width, as described in 2. . . . . . $r_{th(j\text{-}c)} \propto \sqrt{\tau}$ . . . . .)

When (a) and (b) are compared, subdividing the waveform as shown in (b) gives a result approaching nearer to the actual temperature rise, and can be said to be a method preferable for economical design. Furthermore, it should be noted that the approximation of (b) of Fig. 6 gives a result of $\Delta T_j = 95°C$, which is approximately the same value as that given by (b) of Fig. 7.

5. APPLICATION TO ACTUAL USE.

Here, application to a switching regulator shall be described, using the NTC1871A as an example.

5-1 Junction temperature in a steady state.

Generally, in the switching mode power dissipation is composed of 3 portions, Namely:

P_1: Power dissipation at the moment of turn on.
P_2: Power dissipation during the on state. (Power dissipation due to saturation voltage.)
P_3: Power dissipation at the moment of turn off.

When the junction temperature rise is determined, employing the method described in 4-2, the result of calculation will be as follows:

$$\Delta T_{j(peak)} = P_4 \cdot R_{th(j\text{-}c)} + (P_5 - P_4) \cdot r_{th(j\text{-}c)}(T - \tau) - P_5 \cdot r_{th(j\text{-}c)}(T) + P_1 \cdot r_{th(j\text{-}c)}(\tau) - (P_1 - P_2) \cdot r_{th(j\text{-}c)}(t_2 + t_3) + P_3 \cdot r_{th(j\text{-}c)}(t_3) \quad (°C) \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where,

$\Delta T_{j(peak)}$	:	Maximum value of junction temperature rise from case temperature.
$P_1 - P_3$	:	See above.
P_4	:	Average power dissipation over total period.
P_5	:	Average power dissipation during period of τ.
$\tau = t_1 + t_2 + t_3$	:	Pulse width of power dissipation.
T	:	Period
t_1	:	Pulse width of turn on.
t_2	:	Pulse width of ON period.
t_3	:	Pulse width of turn off.
$R_{th(j\text{-}c)}$	:	Thermal resistance from junction to case.
$r_{th(j\text{-}c)}(t_X)$	:	Transient thermal resistance from junction to case, when pulse width is t_X.

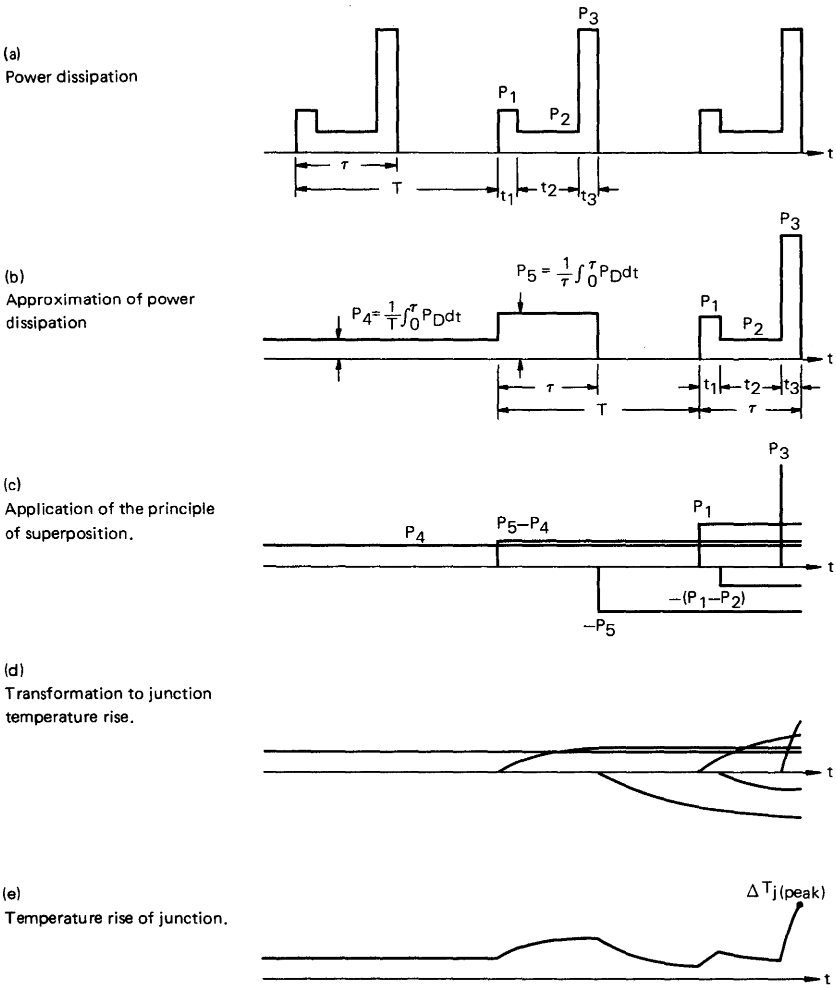


Fig. 9 Power Dissipation Waveforms in the Switching Mode, and Method of determining the Junction Temperature in the Steady State.

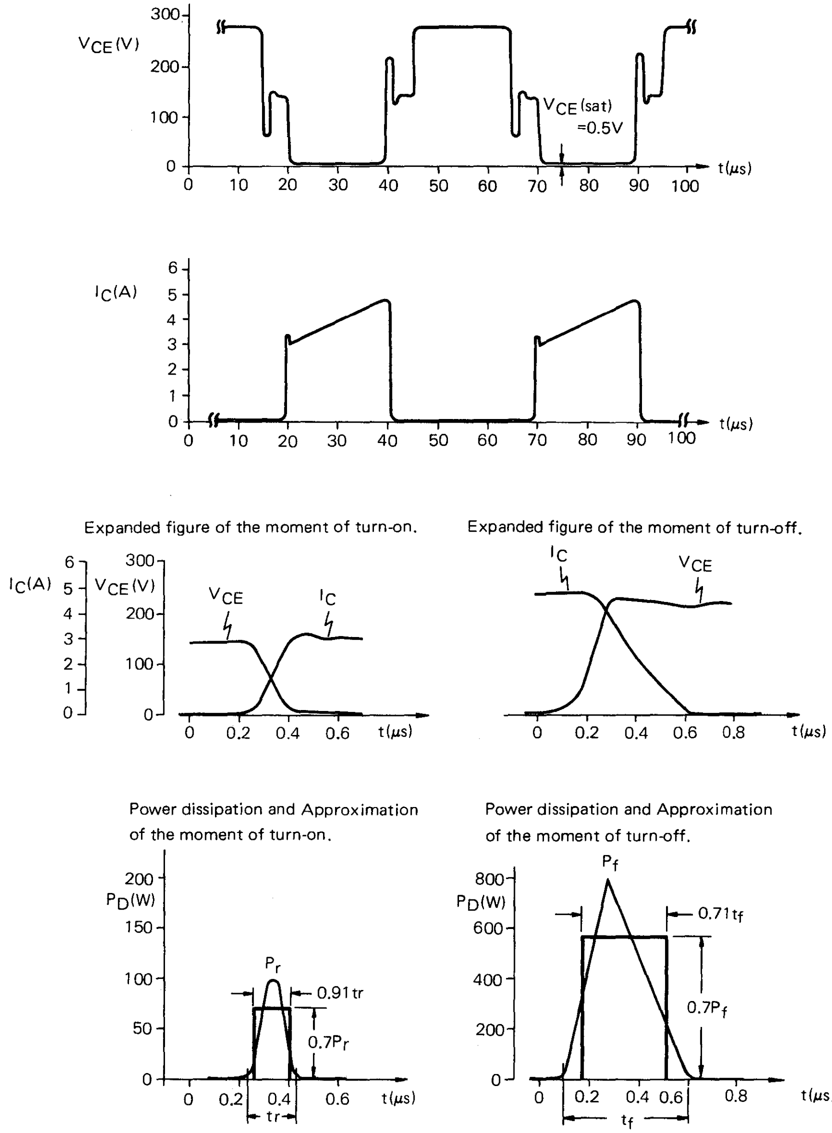


Fig. 10 Collector Current and Collector to Emitter Voltage Waveforms and Power Dissipation Approximation in Switching Regulators.

Typical waveforms of a switching regulator (V_{IN} : 140V_{DC}, Output : 300W, f = 20kHz) are shown in Fig. 10.

Now, the junction temperature is calculated by applying equation (3).

$P_1 = 70W, \quad t_1 = 0.18\mu s, \quad (P_r = 100W, t_r = 0.2\mu s)$

$P_2 = 2.0W, \quad t_2 = 19.5\mu s, \quad (V_{CE}(sat) = 0.5V, I_{C(av)} = 4.0A)$

$P_3 = 560W, \quad t_3 = 0.36\mu s, \quad (P_f = 800W, t_f = 0.5\mu s)$

$P_4 = \frac{1}{T}\int_0^T P_D dt = 5.06W$

$P_5 = \frac{\tau}{T}\int_0^\tau P_D dt = 12.7W$

$T = 50\mu s$

$\tau = 20\mu s$

The transient thermal resistance is read from Fig. 1.

$$\Delta T_{j(peak)} = 5.06 \times 1.25 + (12.7 - 5.06) \times 0.055 - 12.7 \times 0.046 + 70 \times 0.03 - (70 - 2.0) \times 0.03 + 560 \times 0.004$$
$$= 6.33 + 0.42 - 0.58 + 2.1 - 2.04 + 2.24$$
$$= 8.47\ (^\circ C)$$

Therefore, in the example of Fig. 10 the temperature rise of the junction from the case temperature will become 8.5°C.

In addition to the collector power dissipation described above, the power dissipation of transistors includes that of the base. However, since in a power unit as shown in the example this power dissipation is usually less than 0.5W, this has been neglected.

5-2 The junction temperature during transitory overloads.

In switching regulators, due to the response time of the control circuit, etc., a transitory overload of less than several milliseconds may be applied to the main switching transistor when power is thrown in or the load is short circuited.

Fig. 11 shows an example of such transitory overload, and the method described in 4-1 is employed to calculate the junction temperature rise. The result of calculation shows that the maximum value of the temperature rise of the junction is approximately 52°C from the case.

Caution should be observed, since if the load impedance of the transistor is markedly small compared to the steady state, or the pulse width is in an uncontrolled state, only the h_{FE} of the transistor is limiting the inrushing current.

Furthermore, since the transistor is operating in an unsaturated state, in this example the effect on the temperature rise of the junction from the power dissipation of pulse widths t_f and t_r is small, and is neglected.

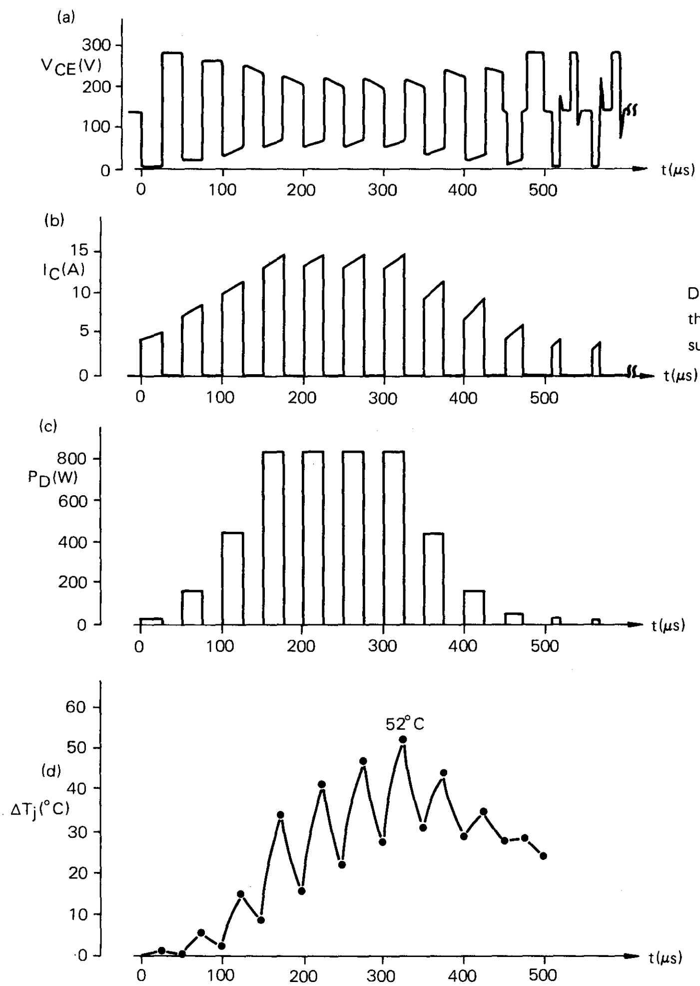


Fig. 11 Example of the application of a Transitory Overload.

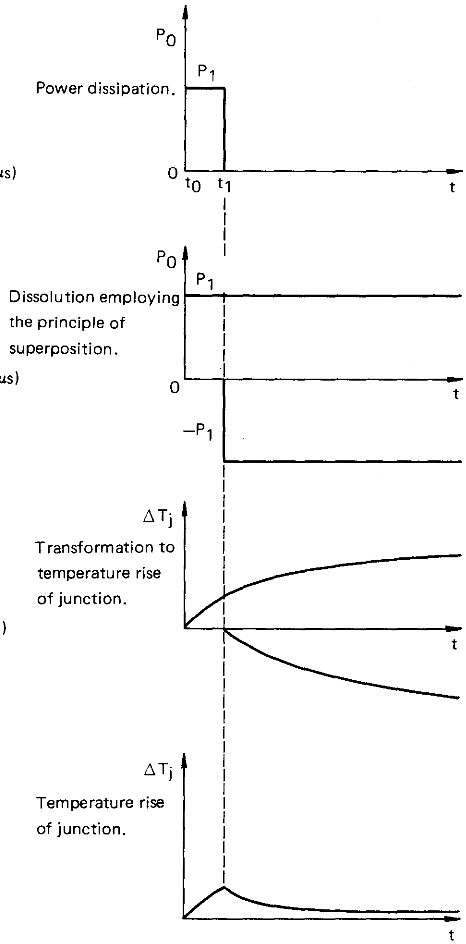


Fig. 12 Temperature rise of Junction from Mono-pulse Power Dissipation.

Now, when the overloaded state in the example of Fig. 11 continues for more than 1ms, the application of equation (1) becomes difficult.

That is, though the ΔT_j of mono-pulse power dissipation is given by equation (1) as:

$$\Delta T_j = P_1[r_{th(j\text{-}c)}(t) - r_{th(j\text{-}c)}(t - t_1)] \quad (t_1 < t)$$

when, for example, t_1 = 25µs and t = 1ms it becomes practically impossible to read the difference between $r_{th(j\text{-}c)}$ (1ms) and $r_{th(j\text{-}c)}$ (1ms – 25µs). See Fig. 12.

11

This is an important point, since the power dissipation of complex pulses are all determined from the combination of one-shot pulses (the principle of superposition).

In the above case, approximation is performed by using equation (2) of 4-1.

$$\Delta T_{j(peak)} = P_0[\frac{\tau}{T} \cdot R_{th(j\text{-}c)} + (1 - \frac{\tau}{T}) \cdot r_{th(j\text{-}c)}(T + \tau) - r_{th(j\text{-}c)}(T) + r_{th(j\text{-}c)}(\tau)] \quad \ldots \quad (2)$$

The maximum value of the junction temperature rise is calculated from the above equation by employing in place of the 1st term $R_{th(j\text{-}c)}$, that is the D.C. thermal resistance from junction to case, the transient thermal resistance of the period over which the transient state continues, and for P_0 the peak value in order to ensure safe design.

When the effect caused by the power dissipation of pulse widths t_r and t_f cannot be disregarded, equation (3) is employed.

6. PRECAUTIONS TO BE OBSERVED FOR SAFE DESIGN.

With the preceding paragraph, explanation of methods for calculating junction temperature has been finished. However, the junction temperature determined is one of the most important factors concerning the reliability of transistors, therefore in order to ensure safe design the following derating is recommended.

$T_j = (T_{jmax} - 25) \times 0.8 + 25$ (°C) . . . . [20% derating]

where, T_j : Junction temperature.

T_{jmax}: Maximum junction temperature at Absolute Maximum Rating.

7. CONCLUSION

In the above, methods of calculating the junction temperature rise of transistors resulting from pulse power dissipation and precautions to be observed for safe operation have been explained. These calculation methods may be applied to other semiconductor products such as thyristors and diodes, and the reader is persuaded to make application in these fields.

FEATURES AND APPLICATIONS OF HIGH SPEED POWER TRANSISTORS FOR USE IN SWITCHING REGULATORS

Beginning with computers and terminals, miniaturization of electronic equipment has advanced rapidly in recent years, owing developments in high-density construction resulting from the adoption of ICs and LSIs. Followed to this, the demand for miniaturized and highly efficient built-in power equipment has been very strong and switching regulators have become the object of public attention in place of series regulators which were widely used in the past.

To accomplish miniaturization of switching regulators, switching in high frequencies (higher than 20kHz or more) is required. To satisfy this need, development and improvement of electronic parts, such as, switching elements, low impedance electroltic capacitors, fast recovery diodes, etc., has been needed urgently.

NEC has recently placed a high frequency power transistor series on the market, which covers transistors for use in almost all kinds and capacities of switching regulator circuits.

Here, descriptions will be centered on the features and problems relating to the use of these power transistors, and will include some principles and application of switching regulators.

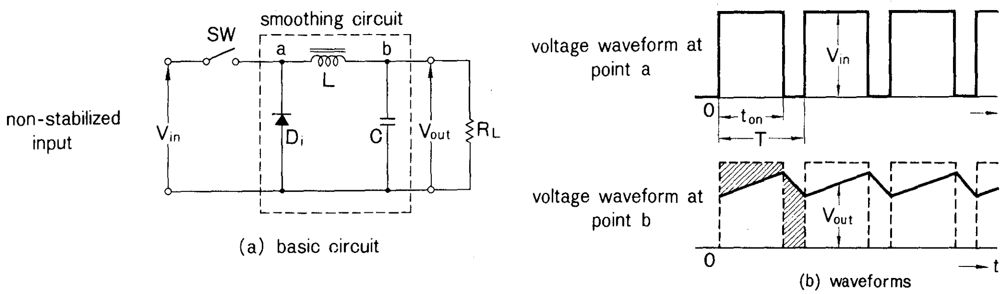


Fig. I Basic Circuit and Operational **Waveforms of Switching Regulator**

THEORY OF OPERATION OF SWITCHING REGULATORS

As shown in Fig. 1, the basic switching regulator circuit has switch SW, which turns on or off the non-stabilized input power, at its input and sends the switched ON-OFF pulses to the smoothing circuit. The output voltage of the smoothing circuit is proportional to the duty cycle of the ON-OFF pulses and this fact is utilized in switching regulators.

If switch SW is closing during a period of time T_{ON} in one repetition period T, output voltage V_{out} is given by the following equation.

$$V_{out} = \frac{t_{ON}}{T} \cdot V_{in}$$

The situation is shown in Fig. 1(b).

Since input voltage V_{in} of a switching regulator is derived from rectified and smoothed commercial AC power, it contains unavoidable voltage deviations resulting from an allowed variation of $\pm 10\%$ of commercial power and deviation of the smoothed output voltage in one period of commercial power related to load impedance. Accordingly, to derive a stabilized output from such non-stabilized power input, the duty cycle should be varied in accordance with input voltage variation.

If output voltage is stabilized by decreasing t_{ON} to $t_{ON}-\Delta t_{ON}$ with input voltage V_{in} increased to $V_{in}+\Delta V_{in}$, considering T is a constant, Δt_{ON} is given by the following equation.

$$\Delta t_{ON} = -\frac{\Delta V_{in}}{V_{in}+\Delta V_{in}} \cdot t_{ON}$$

$$\fallingdotseq -\frac{T_{ON}}{V_{in}} \cdot \Delta V_{in}$$

$$\text{where} \quad V_{in} \gg \Delta V_{in}$$

The equation shows that the pulse width should be changed by the amount which is approximately proportional to input voltage deviation ΔV_{in}.

In practice, however, deviations resulting from forward voltage V_F of flywheel diode Di and voltage drop caused by series resistance of choke coil L are included in the equation together with the input voltage deviation above. To smooth these deviations, a feedback system, which is controlled by an amplified difference voltage between reference voltage V_D and the divided portion of the stabilized output voltage, and sensibly responds to any small deviation in the output voltage, is generally adopted in practical regulators as shown in Fig. 2.

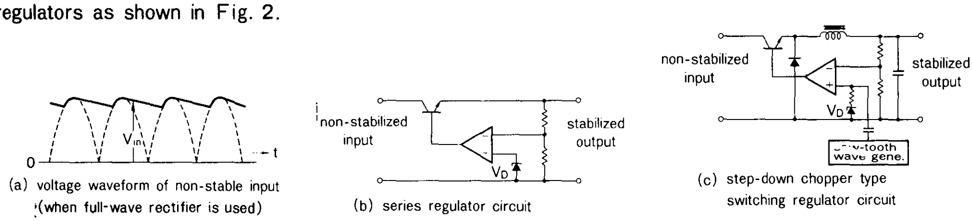


Fig. 2 Comparison of Series Regulator to Step-down Chopper Type Switching Regulator

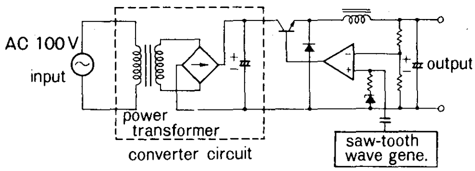
CONSTRUCTION OF SWITCHING CIRCUIT

For the switching circuit which derives non-stabilized DC input voltage from the commercial AC input and leads it to the switching element and then to the smoothing circuit, the step-down chopper circuit which can be constructed by using low voltage transistors (of $V_{CEO}=100V$), has been generally used so far. In recent years, however, as a result of the development of high-voltage high-speed transistors, controlled invertor type power equipment, which enables line operation, has been utilized. Now, an appropriate circuit system can be selected from among various systems in accordance with the desired input AC voltage (AC 100V or AC 200V) and specification of the power equipment (capacity and number of outputs, etc.). Various switching regulators are classified according to their circuit system in Table 1.

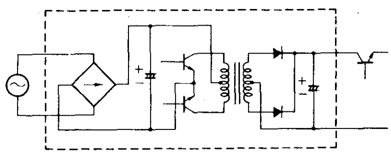
Table I Classification of Switching Regulators According to the kind of Circuit System

Switching Regulators	Controlled Inverter System (Control in primary side)	Single Drive Type	ON-ON Type
			ON-OFF Type
		Push-pull Type	
		Half-bridge Type	
		Full-bridge Type	
	Step-down Chopper System (Control in secondary side)	Step-down Chopper System (Transistor Switch)	
		Magnetic Amplifier System	

Among these, basic circuit construction of a step-down chopper type switching regulator which is particularly adaptable for a multi-output power source is shown in Fig. 3(a), and that of a push-pull switching regulator with its control device in its primary side, is shown in Fig. 4. Furthermore, to miniaturize the step-down rectifier circuit, switching regulators having their control devices in their secondary side will often be constructed by using a direct switching type high frequency invertor circuit which does not need any power transformer, as shown in Fig. 3(b).



(a) step-down chopper type switching regulator circuit



(b) AC to DC converter circuit

Fig. 3 Circuit Construction of Step-down Chopper Type Switching Regulator

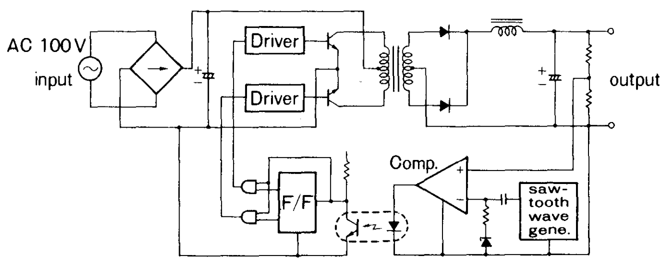


Fig. 4 Circuit Construction of Push-Pull Type Switching Regulator

POWER TRANSISTORS

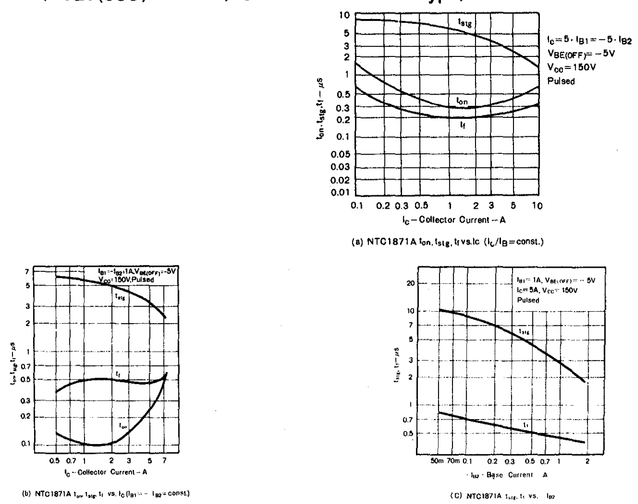
Existing switching power transistors having high breakdown voltage and low switching speed are not suitable for switching regulator applications, because they have various disadvantages, such as, switching loss, polarization of magnetic field in power transformer resulting from the difference of storage time t_{stg} of transistors in a push-pull circuit, etc.

Specifications and characteristics of the lately announced **NEC** high speed power transistor series are summarized in Table 2.

Table 2. NEC High Speed Power Transistor Series for Switching Regulator (New Product)

CODE NO.	PACKAGE	MAXIMUM RATINGS			CHARACTERISTICS				
		$V_{CEO(SUS)}$ (V)	$I_{C(DC)}$ (A)	P_T (T_C=25°C) (W)	h_{FE} V_{CE}(V)/I_C(A)	h_{FE} MIN.	SW. TIME TYP. I_C(A)/$I_{B1}=-I_{B2}$(A)	t_{stg} (μs)	t_f (μs)
NTC1860	TO-39	100	2.0	15.	5.0/2.0	20	2.0/0.2	0.45	0.06
NTC1861	TO-39	250	2.0	15	5.0/1.0	15	1.0/0.1	0.8	0.20
NTC1862	TO-39	400	2.0	15	5.0/0.5	10	0.5/0.1	1.9	0.30
NTC1863	TO-66	100	7.0	50	5.0/7.0	15	7.0/0.7	0.7	0.09
NTC1864	TO-66	250	7.0	50	5.0/5.0	15	5.0/0.5	1.3	0.20
NTC1865	TO-66	400	7.0	50	5.0/5.0	10	5.0/1.0	1.6	0.50
NTC1866	TO-3	100	7.0	100	5.0/7.0	15	7.0/0.7	0.7	0.09
NTC1867	TO-3	250	7.0	100	5.0/5.0	15	5.0/0.5	1.3	0.20
NTC1868	TO-3	400	7.0	100	5.0/5.0	10	5.0/1.0	1.6	0.50
NTC1869	TO-3	100	15	150	5.0/15	20	15/1.5	0.5	0.09
NTC1870	TO-3	250	15	150	5.0/10	15	10/1.0	0.75	0.25
NTC1871A	TO-3	400	15	150	5.0/10	10	10/2.0	1.6	0.35

The Table covers eleven models of transistors from NTC1860 ($V_{CEO(SUS)}$ = 100V, I_C = 2.0A and TO-39 type) to NTC1871A ($V_{CEO(SUS)}$ = 400V, I_C = 15A and TO-3 type).



(a) NTC1871A ton, tstg, tf vs. Ic (Ic/IB=const.)

(b) NTC1871A ton, tstg, tf vs. Ic (IB1 = − IB2 = const.)

(c) NTC1871A tstg, tf vs. IB2

Fig. 5 NTC1871A Switching Time Characteristics

The characteristics required in a transistor used in a switching regulator circuit are summarized in four items as follows.

(1) Quite a high switching speed.
(2) Small collector saturation voltage $V_{CE(sat)}$.
(3) High breakdown voltage.
(4) Wide safe operating area.

1. Breakdown Voltage

When a push-pull type switching regulator is operated by 100V AC, 280V DC the voltage value equivalent to two times of 140V which is the peak voltage of 100V AC is applied to the transistors. To comply with this requirement, the transistors should be of $V_{CEO}=400V$ or more. As for the transistor itself, however, higher breakdown voltage means smaller h_{FE} and disadvantageous switching characteristics, as shown in Table 2. So, it is practical to use a transistor of $V_{CEO}=100V$ or more in a step-down chopper circuit where high breakdown voltage transistor is not needed. Suitable transistors should be selected just to comply with the circuit requirement.

2. Switching Characteristics

Usually, a switching regulator adopts high speed switching as high as 20kHz in frequency, so that switching speed of the transistors in use should be sufficiently high.

(1) t_{on}, t_f

Since switching loss of a transistor is determined by t_{on} and t_f, these factors should be very short from the standpoint of efficiency and for the effective heat dissipation design.

(Refer to Table 2.)

(2) t_{stg}

Since storage time t_{stg} is equal to the delay time of the control circuit of the switching regulator, t_{stg} should be very short. Also, when two transistors operate symmetrically as in a push-pull circuit, the difference of storage time of the two transistors may cause polarization of magnetism in the power transformer. In this case storage time of the two transistors should have a small difference as well as very short duration.

(3) t_{stg} and t_f at light load

Switching characteristics of a transistor usually depend on collector current and are represented by curves such as shown in Fig. 5(a). When collector current of a transistor, operating by constant base driving current in a switching regulator circuit, decreases due to a sudden change of road, t_{stg} and t_f of the transistor usually tend to increase as shown in Fig. 5(b). Especially in case of a transistor having poor h_{FE} linearity, its t_{stg} and t_f may become exceedingly long. This fact may simultaneously turn on the two transistors in symmetrical operation causing damage of these transistors.

As explained above, switching speed of the transistor in use should be very high, while t_{stg} and t_f of a transistor varies with outgoing base current as shown in Fig. 5(c). In a circuit where I_{B2} is dependent on base-emitter resistance R_{BE}, both t_{stg} and t_f become very long. To avoid this phenomenon, the circuit should be designed to have a negative base bias whenever the transistor is turned to OFF. This negative bias voltage, around $V_{BE}=-5.0V$, is applied in general practice. If a negative

11

bias which exceeds its V_{EBO} is applied, deterioration such as decrease of h_{FE} might happen specially in case of a transistor having low V_{EBO}.

3. $V_{CE(sat)}$

Since $V_{CE(sat)}$ varies with drive ratio I_C/I_B, to decrease power loss resulted from $V_{CE(sat)}$, a transistor should be operated in a sufficiently saturated state with ample-driving current I_B. Especially, $V_{CEO}=400V$ class transistors, whose h_{FE} is not generally a high value, should preferably be operated with a drive ratio of about $I_C/I_B=5.0$.

4. Safe Operating Area

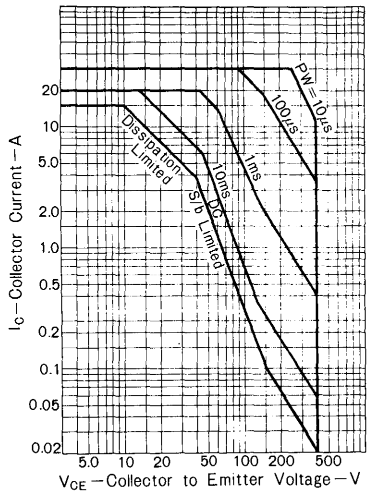


Fig. 6 NTC1871A Forward Bias Safe Operating Areas

Since a switching regulator is operated with its transistor in inductive load condition, it is difficult to eliminate a surge voltage induced when the transistor is turned to OFF. Accordingly, the transistor should have a breakdown voltage high enough to withstand such instantaneous voltage (less than 1.0 μs). Moreover, in preparing the power transformer, attention should be paid to the winding procedure to minimize the leakage flux.

Furthermore, since the transistor might be overloaded at the starting time of the switching regulator or during the delay time before the over-current protector circuit starts to operate, it should be confirmed beforehand that the transistor is operated in a safe operating area as shown in Fig. 6. Although the safe operating area in Fig. 6 is defined by forward current, another method of defining safe operating area by using $V_{CE(sus)}$ or $E_{s/b}$.[(1)] $V_{CE(sus)}$ is a value which represents durability of a transistor under primary breakdown conditions resulting from a surge voltage caused by an inductive load. These characteristics ($V_{CE(sus)}$ and $E_{s/b}$) are now being evaluated as a criterion for determined Safe Operating Area.

APPLICATION CIRCUIT OF SWITCHING REGULATOR

A schematic diagram of push-pull type switching regulator is shown in Fig. 8.

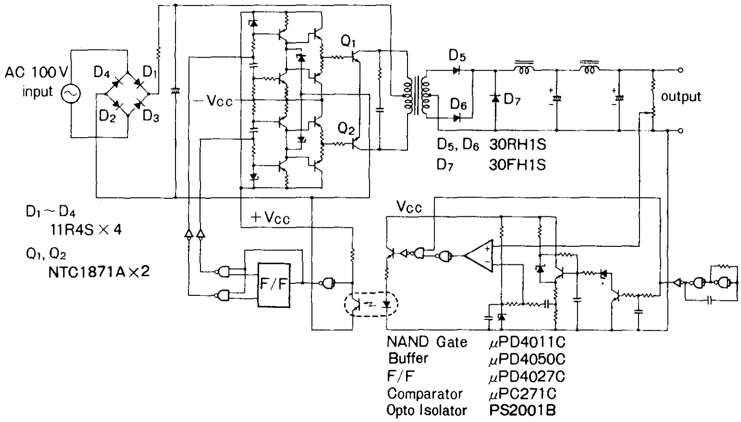
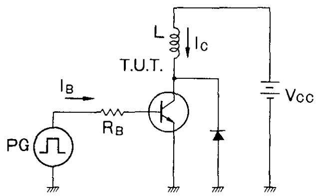
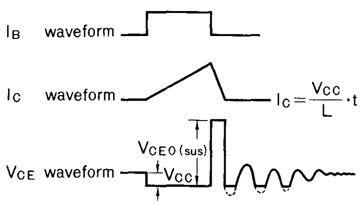


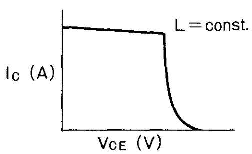
Fig. 8 An Example of Push-pull Type Switching Regulator Circuit



(a) measurement circuit



(b) waveforms



(c) $V_{CEO(sus)}$ vs. I_C

Fig. 7 $V_{CEO(sus)}$ Measurement Circuit and Waveforms

☆ ☆ ☆

At present, pulse-width control circuit of a switching regulator contains many devices such as oscillators, error amplifiers, comparators, flip-flops, gate, etc. and comprises component parts of thirty or more in number. Especially in miniaturized power equipment of 50W class, reduction in number of component parts and reduction of man power are considered to be urgently needed. Although circuit construction and parts in use of pulse-width control circuit are not yet standardized and each power equipment manufacturer has its own know-how and different designs, monolithic ICs with built-in protection circuits for the purpose will be developed in the future for the above mentioned reason.

11

(1) Notes on $V_{CE(sus)}$ and $E_{s/b}$

It is widely known that the $V_{CEO}-I_C$ characteristics of a transistor show a negative resistance. When a transistor with inductive load is switched ON and OFF, as shown in Fig. 7 a surge voltage is induced between both ends of inductor L at the instant when the transistor is turned to OFF. The transistor goes into (primary) breakdown consuming almost all of power $1/2LI_C^2$ in itself. The $V_{CE}-I_C$ characteristics in the course of this phenomenon are shown in Fig. 7(c), and it is recognized that V_{CE} decreases to a value 40 to 50V less than $V_{CEO(sus)}$ as measured current I_C increases. Then the value of I_C reaches a value where a secondary breakdown takes place to destroy the transistor. If the value of I_C just before the secondary breakdown is designated as $I_{C\,MAX.}$, the energy $E_{s/b}=\frac{1}{2}L\cdot(I_{C\,MAX.})^2$ shows a maximum bearable power of the transistor in its safe operating area.

THE SAFE OPERATING AREAS OF TRANSISTORS UNDER SWITCHING OPERATIONS

1. INTRODUCTION

In recent years, the switching system which is of high efficiency and capable of miniaturization has become to be widely employed in the field of power supply units, in place of the series control system. And, occasions for the use of transistors as the switching elements in inductive load circuits, such as transformers, is on the increase.

In the switching operation of such inductive load circuits, large current and high voltage are applied simultaneously between the collector and emitter at the moment of turn-off. Since the definition and assurance of the safe operating area of transistors under such conditions had not been made clear in the past, destruction occurred frequently.

Here, taking NEC's high speed switching transistors, NTC1862 and NTC1871A, as examples, the concept of safe operating area under switching operations shall be described. Also, precautions to be observed when making practical applications of the transistors will be described, taking switching regulator circuits as the examples.

2. CONCEPT OF SAFE OPERATING AREA UNDER SWITCHING OPERATIONS

2-1 Problem of the conventional Safe Operating Area

Conventionally, NEC has indicated the safe operating area, as shown in Fig. 1, by the maximum allowable power applicable to the transistor when the pulse width is varied. This was measured according to the ΔV_{EB} method shown in Fig. 2, and since the base is always at a higher voltage (in NPN transistors) than the emitter, the emitter-base junction is forward biased. For this reason the conventional safe operating area is called the forward bias safe operating area. In other words, the forward bias safe operating area will serve as a yardstick for safe operation, only when the emitter-base junction is forward biased. And, this state of being forward biased corresponds to the moment of turn-on and the state of "on" in switching operations.

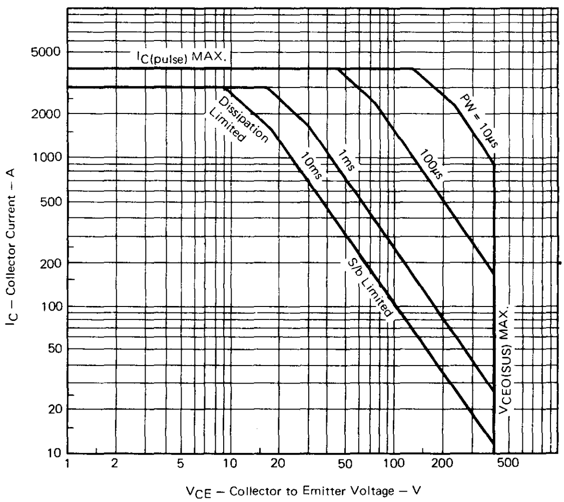


Fig. 1 Forward Bias Safe Operating Areas. (NTC1862)

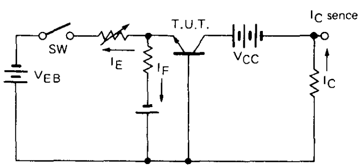


Fig. 2 Measurement Circuit for Forward Bias Safe Operating Areas. (NPN transistors)

2-2 Reverse Bias Safe Operating Area

When the transistor is turn-off during switching operation, a reverse bias, including no bias, will be applied to the emitter-base junction so that the collector is within the cutoff region.

Needless to say, the forward bias safe operating area described before cannot be applied to this state, and it is necessary to specify and assure, anew, a safe operating area for the condition when the base is reverse biased - - reverse bias safe operating area (refer to Fig. 3).

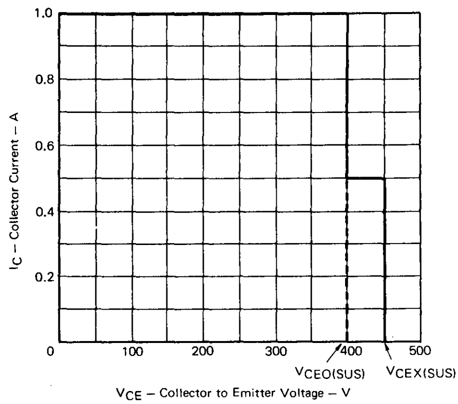


Fig. 3 Reverse Bias Safe Operating Area. (NTC1862)

3. METHOD OF APPLYING FORWARD AND REVERSE BIAS SAFE OPERATING AREAS TO ACTUAL CIRCUITS

3-1 Basic concept

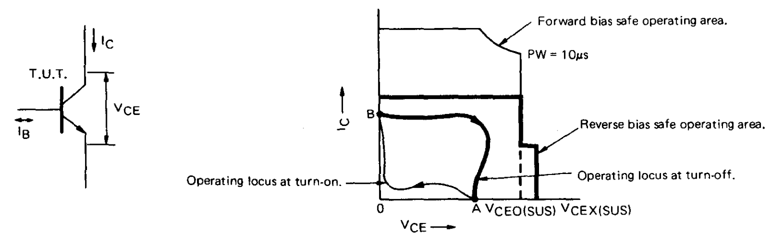


Fig. 4 Safe Operating Area of Switching Operation.

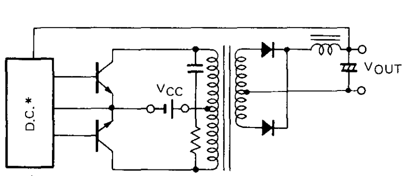
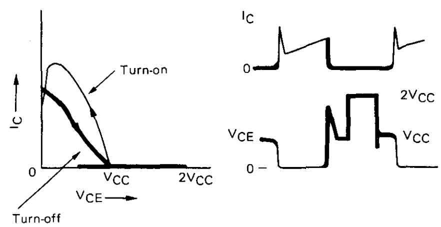
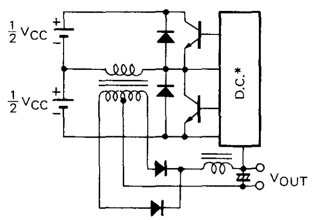
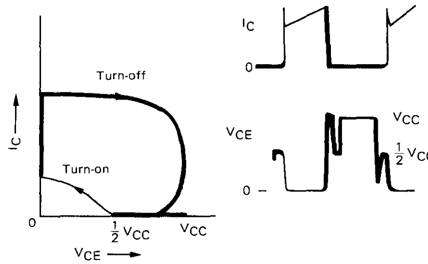
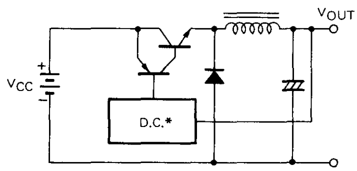
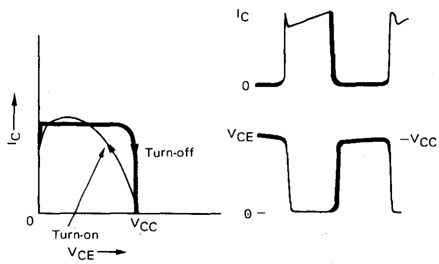
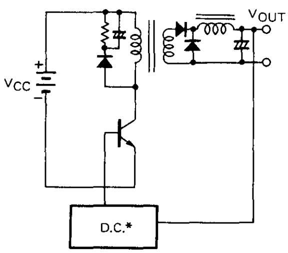
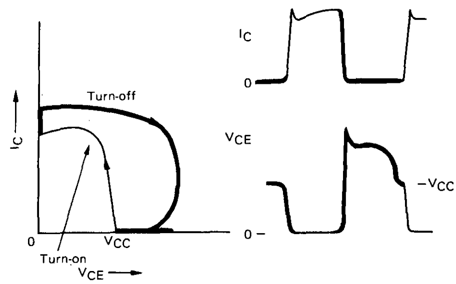
Generally, when a transistor is employed for switching of inductive loads the operating locus will move through the active area between the "cutoff" area [A] and "on" area [B], following the path [A] → [B] at turn-on, and the path [B] → [A] at turn-off, as shown in Fig. 4.

Here, the criterion of safe operation is that the operating loci of both turn-on and turn-off reside within the area defined by both the forward and reverse bias safe operating areas.

3-2 Application to actual Switching Regulator Circuits and Precautions.

Table 1 shows the operating waveforms and loci of transistors employed in 4 typical types of circuits for switching regulators.

Table 1 Typical Switching Regulator Circuits and their Operating Waveforms.

Circuit System	Typical Load Curves and Waveforms
1. Push-pull type. 	
2. Half-bridge type. 	
3. Chopper type. 	
4. Single-ended (ON-ON) type. 	

D.C.* means Drive Circuit.

The method of ascertaining safe operation has been described in the preceding paragraph. However, when applying the forward and reverse bias safe operating areas to actual circuits the following precautions are necessary.

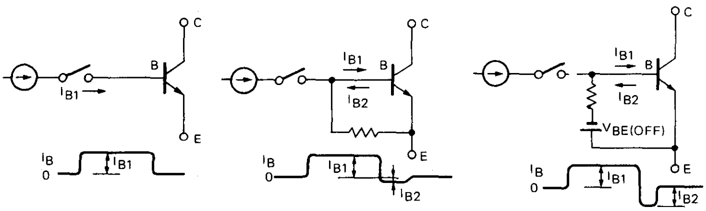
1) Forward bias safe operating area.

Since the turn-on time t_{on} is usually less than 10μs, the safe operating area when PW = 10μs will become the criterion for safe operation. Needless to say, when the turn-on time exceeds 10μs the safe operating area of the pulse width corresponding to the turn-on time will become the criterion of safe operation.

Furthermore, derating of the safe operating area to accord with the junction temperature should be performed by using the derating curve shown in the data sheets.

2) Reverse bias safe operating area.

It should be noted that the reverse bias safe operating area changes according to the driving conditions of the reverse bias applied to the emitter-base junction.



(1) No bias. (2) Resistance bias. (3) Forced reverse bias.

Fig. 5 Biasing methods for turning off the emitter-base junction.

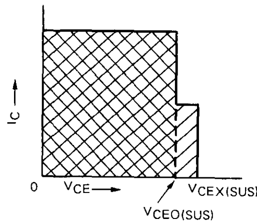


Fig. 6 Reverse bias safe operating area.

The sustaining voltage between collector and emitter of (1) to (3) of Fig. 5 are $V_{CEO(SUS)}$, $V_{CER(SUS)}$, and $V_{CEX(SUS)}$ respectively, and these form the reverse bias safe operating areas.

In Fig. 6 the portion marked \\\\\ is the safe operating area formed by $V_{CEO(SUS)}$, and this is the criterion for safe operation in the case of (1), No bias, in Fig. 5. Also, the portion marked ///// in Fig. 6 is the safe operating area formed by $V_{CEX(SUS)}$ which is the criterion for safe operation in the case of (3), Forced reversed bias, in Fig. 5. Generally, there is a relationship of $V_{CEO(SUS)} < V_{CER(SUS)} < V_{CEX(SUS)}$ between $V_{CEO(SUS)}$, $V_{CER(SUS)}$, and $V_{CEX(SUS)}$. However, since the value of $V_{CER(SUS)}$ may become $V_{CEO(SUS)} \leqq V_{CER(SUS)}$ according to the values of the resistance and the collector current, in the case of (2), Resistance bias, in Fig. 5, similarly to the case of (1) No bias, the criterion of safe operation is the safe operating area formed by $V_{CEO(SUS)}$ that is shown by \\\\\ in Fig. 6.

Since it is necessary to shorten the storage time t_{stg} and fall time t_f in switching regulators, it is usual to apply forced reverse bias to the emitter-base junction, as shown in (3) of Fig. 5, so from this standpoint the safe operating area formed by $V_{CEX(SUS)}$ is the most important. In this case, the higher the reverse bias voltage the shortor will be the switching time, however, since the forward bias will tend to collect at the center of the emitter and the collector current will be concentrated at this point, breakdown will be liable to occur through the pinch-in effect shown in Fig. 7. Therefore, it is necessary that the condition of the reverse bias be below that of the measurement of $V_{CEX(SUS)}$ in the data sheets. (conditions: $V_{BE(OFF)} < -5V$, $I_{B2} < I_{B2}$ defined in spec.) Since the assurance of $V_{CEX(SUS)}$ is performed at the high temperature of $T_a = 125°C$, derating according to the junction temperature is not required for the reverse bias safe operating area.

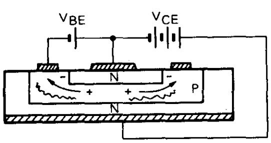


Fig. 7 Pinch-in Effect.

3) Other precautions.

In the use of these switching regulators, situations of which the ascertaining of safe operation is most required are: when power is switched on, and when the load changes suddenly or output terminals are shorted. Most destruction occur on such occasions.

Especially, when power is switched on a collector current of 2 to 4 times of normal current will flow, due to the flowing of the initial changing current of capacitors on the load, and spike voltages occurring at turn-off will rise. On the other hand, the reverse bias safe operating area of the transistor will decrease in inverse proportion to the increase of the collector current. Therefore, it is recommended that a soft start circuit be employed to limit the collector current.

Note) The operating waveforms and loci shown in Table 1 are only examples, and may change greatly under different load conditions.

4. THE NEC METHOD FOR ASSURANCE OF THE REVERSE BIAS SAFE OPERATING AREA.

(This paragraph is explained using the NTC1871A as an example)

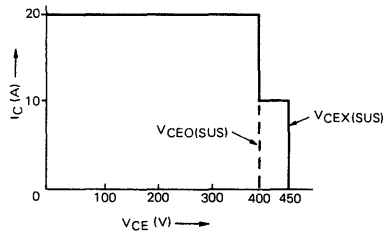


Fig. 8 Reverse Bias Safe Operating Area of NTC1871A.

The reverse bias safe operating area shown in Fig. 8 is composed by $V_{CEO(SUS)}$ and $V_{CEX(SUS)}$.

The definitions and assurance methods of $V_{CEO(SUS)}$ and $V_{CEX(SUS)}$ will be explained individually as follow:

4-1 $V_{CEO(SUS)}$

This is defined as the maximum value of the collector to emitter breakdown voltage when the emitter-base junction is in turn-off at no bias with inductive load. Assurance of $V_{CEO(SUS)}$ is given by noting that this value exceeds the $V_{CEO(SUS)}$ rating.

The measurement circuit for $V_{CEO(SUS)}$ and the waveforms of various parts of the circuit are shown in Figs. 9 and 10.

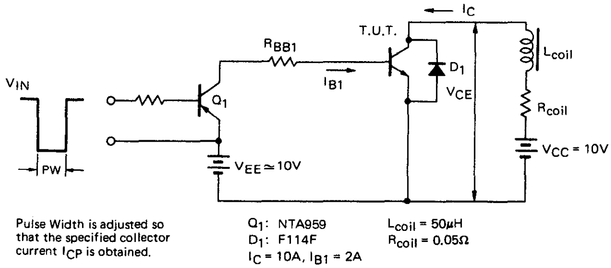


Fig. 9 Measurement Circuit for $V_{CEO(SUS)}$.

11

VCEO(SUS)

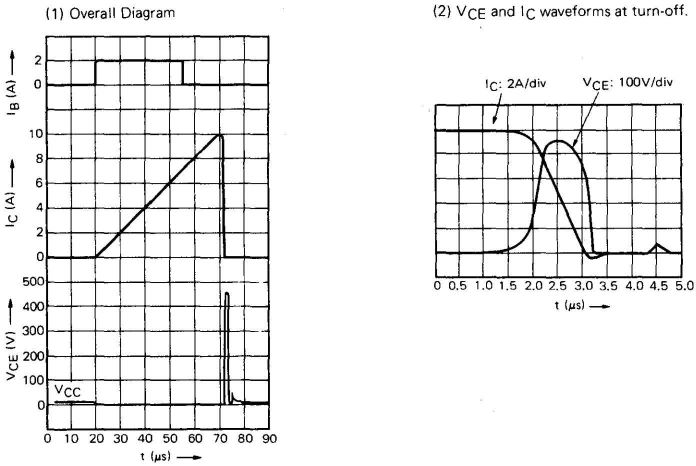


Fig. 10 Waveforms of various parts of the Circuit.

4-2 $V_{CEX(SUS)}$

This is defined as the applying between the collector and emitter of the energy stored in the inductance of the load, which is clamped at the $V_{CEX(SUS)}$ rating, while the emitter-base junction is in turn-off by the application of forced reverse bias. Assurance of $V_{CEX(SUS)}$ is given by the non-occurrence of destruction or degradation of characteristics during the above.

The measurement circuit for $V_{CEX(SUS)}$ and the waveforms of various parts of the circuit are shown in Figs. 11 and 12.

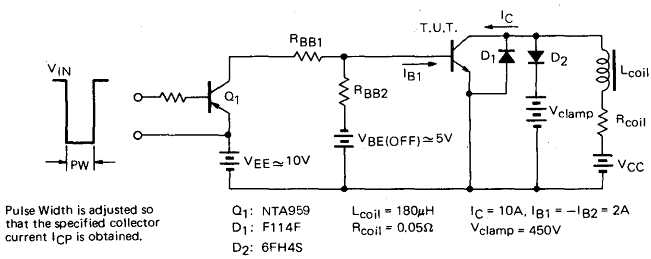


Fig. 11 Measurement Circuit for $V_{CEX(SUS)}$.

$V_{CEX(SUS)}$

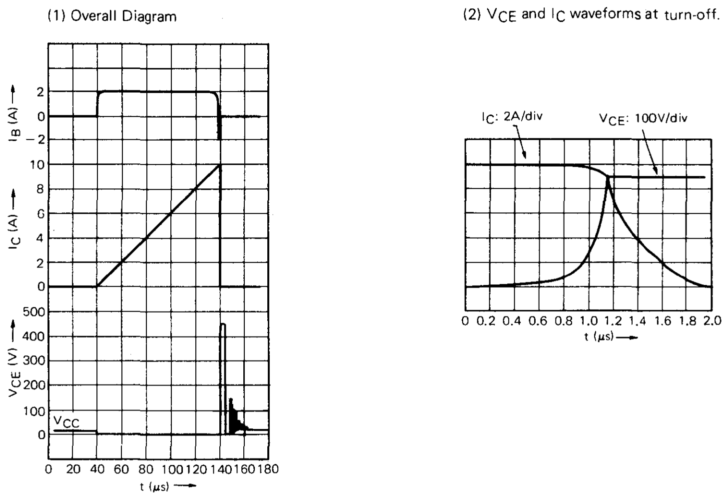


Fig. 12 Waveforms of various parts of the Circuit.

The above method assurance has the two following features.

1) Assurance is performed at the high temperature of $t_a = 125°C$.

2) Since the collector to emitter voltage is clamed at the $V_{CEX(SUS)}$ value, breakdown will not occur providing an assurance of high reliability.

5. CONCLUSION

The concept and method of assurance of the safe operating areas of transistors under switching operations have been described above. And, it has been shown that the reverse bias safe operating area is indispensable, when employing transistors lacking assurance of this item for switching.

CALCULATION METHOD FOR THE JUNCTION TEMPERATURE OF TRANSISTORS DURING PULSE POWER DISSIPATION

1. INTRODUCTION

Junction temperature is one of the important items for ascertaining the operating condition of transistors. Generally, the junction temperature is calculated from the following equation.

$$T_j = P_D \cdot R_{th\ (j\text{-}c)} + T_C$$

where,
- T_j : Junction temperature
- T_C : Case temperature
- P_D : Power dissipation
- $R_{th\ (j\text{-}c)}$: D.C. thermal resistance from junction to case.

However, when the power dissipation is in the form of pulses, accurate junction temperature cannot be determined unless transient thermal resistance is employed in the calculations. Here, a method for calculating the junction temperature during pulse power dissipation shall be described employing the high speed, high voltage switching transistor, NTC1871A, as an example, and including applications of the same to switching regulators.

2. TRANSIENT THERMAL RESISTANCE

Transient thermal resistance is defined as the reciprocal of the heat conductivity during the pulse power dissipation. The heat generated in the junction of the transistor by power dissipation is conducted away through the following path, and the resistance to this conduction is expressed as the thermal resistance. Junction → Pellet(silicon) → Mounting material → case → heatsink → Environment.

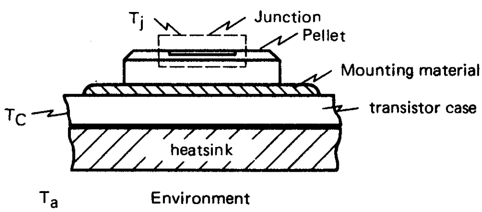


Fig. 1 Structure of a Transistor.

Generally, the time required for the heat between the junction and case, and the case and enviroment, to reach a steady state (thermal equilibrium) is 1 to 10 seconds for the former, and several minutes for the latter. Therefore, for power dissipation of short pulses, the temperature rise is limited to the proximity of the junction. And, for pulses of 100ms or less width, the temperature rise becomes almost irrelevant of the state of heat radiation of the transistor.

Note) When the pulse width of the power dissipation exceeds 100ms, the junction temperature cannot be calculated unless the transient thermal resistance of the whole system, including the heat sink, is known.

The Transient Thermal Resistance versus Pulse Width characteristics of the NTC1871A are shown in Fig. 2

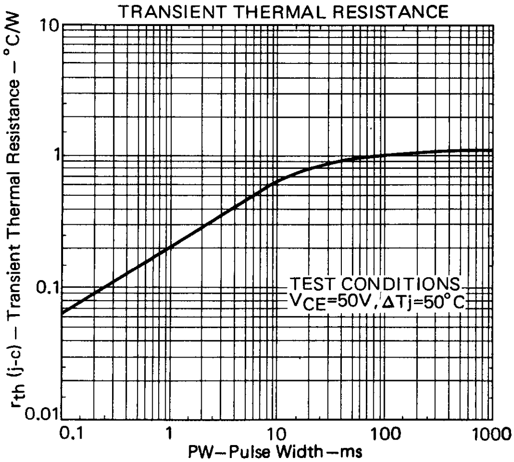


Fig. 2 Transient Thermal Resistance versus Pluse Width of the NTC1871A.

Generally, when the pulse width is short the transient thermal resistance is approximate to the following expression.

r_{th} (j-c) $\propto \sqrt{\tau}$ where, r_{th} (j-c) : Transient thermal resistance from junction to case.

τ : Width of pulse.

In the case of the NTC1871A, the transient thermal resistance corresponds to the above expression when the pulse width is less than 10ms.

3. APPLICATION RANGE OF TRANSIENT THERMAL RESISTANCE;

When determining the junction temperature rise caused by pulse power dissipation by employing transient thermal resistance, attention should be paid tó the fact that the range over which transient thermal resistance may be applied is limited to cases where no local temperature rise (hot spot) has been created through concentration of current in the junction.

In other words, it is necessary that the pulse power dissipation is within the safe operating area and, at the same time, that no current concentration is created.

An example of a forward bias safe operating area is shown in Fig. 3. In this figure, "Dissipation Limited" indicates the region limited by transient thermal resistance, and "S/b Limited" indicates the region limited due to hot spots being formed through the concentration of current.

The dependency of ΔT_j (increment rise of junction temperature) on the V_{CB} bias is shown in Fig. 4, and region A corresponds to the "Dissipation Limited" mentioned before, and region B corresponds to "S/b Limited". Attention should be paid here to the fact that, even in the region B, when the collector current is derated enough, $I_C \times V_{CB} \propto \Delta T_j$ and the transient thermal resistance may be applied. In this case a derating of more than 40% of the I_C value is recommended.

If the assured range is not exceeded, the application of transient thermal resistance to reverse bias safe operating areas presents no problem. Refer to Semiconductor Technical Data "The Safe Operating Area of Transistors under Switching Operations".

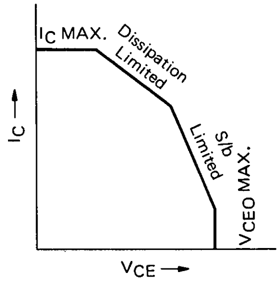


Fig. 3 Forward Bias Safe Operating Area.

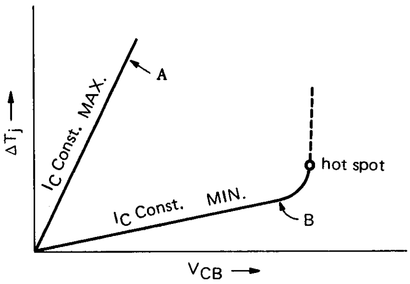


Fig. 4 The dependency of ΔT_j on the V_{CB} bias.

4. CALCULATION METHOD OF THE JUNCTION TEMPERATURE DURING PULSE POWER DISSIPATION

Basically, the junction temperature rise is calculated by approximating the power dissipation waveforms to square waves and employing the principle of superposition and the following equation.

$$\Delta T_j = r_{th(j\text{-}c)}(\tau) \times P_D$$

Where, ΔT_j : Temperature rise of junction from case temperature.

$r_{th(j\text{-}c)}(\tau)$: Transient thermal resistance from junction to case, when pulse width is τ.

P_D : Power dissipation.

4-1 Power Dissipation of irregularly repeating Square Waves.

The method of determining the junction temperature rise resulting from the power dissipation of irregular square waves is shown in Fig. 5.

It is assumed that an infinitely continuing step shaped power dissipation P_1 is applied from $t = t_0$, and after which an infinitely continuing negative step shaped power dissipation $-P_1$ is applied from $t = t_1$. The same assumptions are applied to P_2, P_3, and P_4, and then calculations are performed according to the principle of superposition.

Results of the calculations become as follows:

$$\Delta T_{j1} = P_1 \times r_{th(j\text{-}c)}(t_1 - t_0)$$

$$\Delta T_{j2} = P_1 \times [r_{th(j\text{-}c)}(t_3 - t_0) - r_{th(j\text{-}c)}(t_3 - t_1)] + P_2 \times r_{th(j\text{-}c)}(t_3 - t_2)$$

$$\Delta T_{j3} = P_1 \times [r_{th(j\text{-}c)}(t_5 - t_0) - r_{th(j\text{-}c)}(t_5 - t_1)] + P_2 \times [r_{th(j\text{-}c)}(t_5 - t_2) - r_{th(j\text{-}c)}(t_5 - t_3)] + P_3 \times r_{th(j\text{-}c)}(t_5 - t_4)$$

$$\Delta T_{j4} = P_1 \times [r_{th(j\text{-}c)}(t_7 - t_0) - r_{th(j\text{-}c)}(t_7 - t_1)] + P_2 \times [r_{th(j\text{-}c)}(t_7 - t_2) - r_{th(j\text{-}c)}(t_7 - t_3)] + P_3 \times [r_{th(j\text{-}c)}(t_7 - t_4) - r_{th(j\text{-}c)}(t_7 - t_5)] + P_4 \times r_{th(j\text{-}c)}(t_7 - t_6)$$

When expressed by a general equation the above become:

$$\Delta T_{jn} = \sum_{i=1}^{n} P_i [r_{th(j\text{-}c)}(t_{2n-1} - t_{2i-2}) - r_{th(j\text{-}c)}(t_{2n-1} - t_{2i-1})] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

In the above: $P_1, P_2, P_3 \ldots\ldots P_n$: Power dissipation.

$\Delta T_{j1}, \Delta T_{j2} \ldots\ldots \Delta T_{jn}$: Temperature rise of the junction from the case temperature at the end of $P_1, P_2, P_3 \ldots\ldots P_n$.

$t_0, t_1, t_2, \ldots\ldots t_n$: Time at the start and end of power dissipation.

$r_{th(j\text{-}c)}(t_X - t_Y)$: Transient thermal resistance from junction to case, when pulse width is $(t_X - t_Y)$

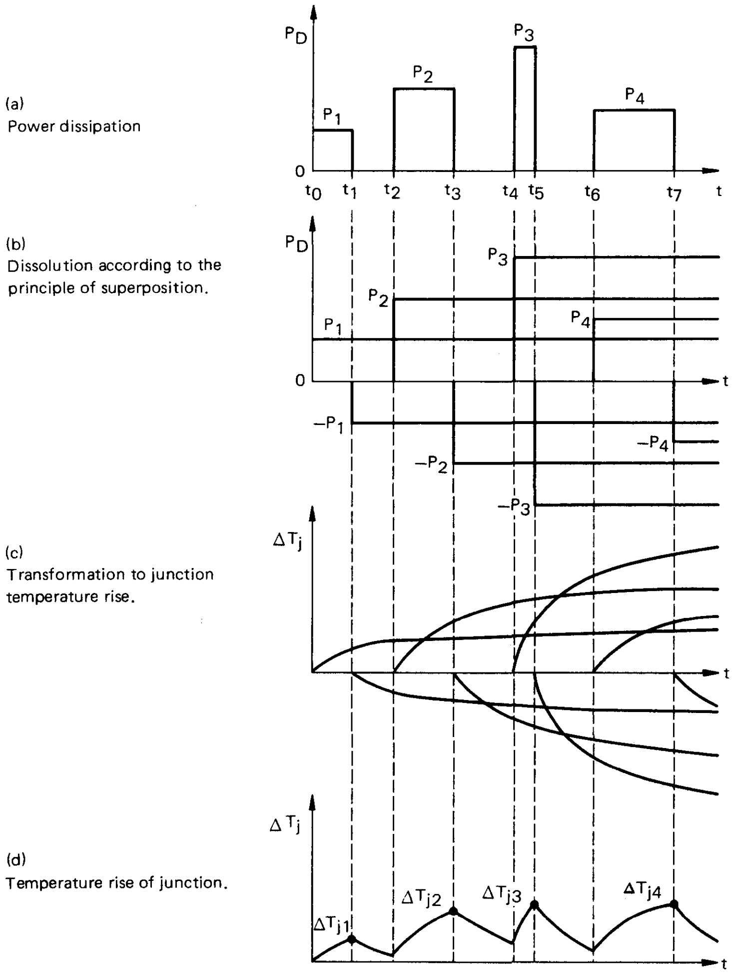


Fig. 5 Method of determining the Junction Temperature Rise from irregularly repeating Square Wave Power Dissipation.

11

4-2 Power Dissipation of regularly repeating Square Waves.

The method for determining the junction temperature rise resulting from regularly repeating square waves is shown in Fig. 6.

For power dissipation waveforms of this type. The 2 to 3 waves portions protruding from the average value of the total period are taken together for the calculation. This calculation method will be the most easy, accurate, and effective one.

In actual calculation, from the approximation of power dissipation waveforms (b), the increment of the junction temperature rise is determined by applying $\frac{\tau}{T} \cdot P_0$ for an infinite period, and further applying $(1 - \frac{\tau}{T}) P_0$ for $(\tau + T)$ period, $-P_0$ for T period, and P_0 for τ period. The result of the calculation is:

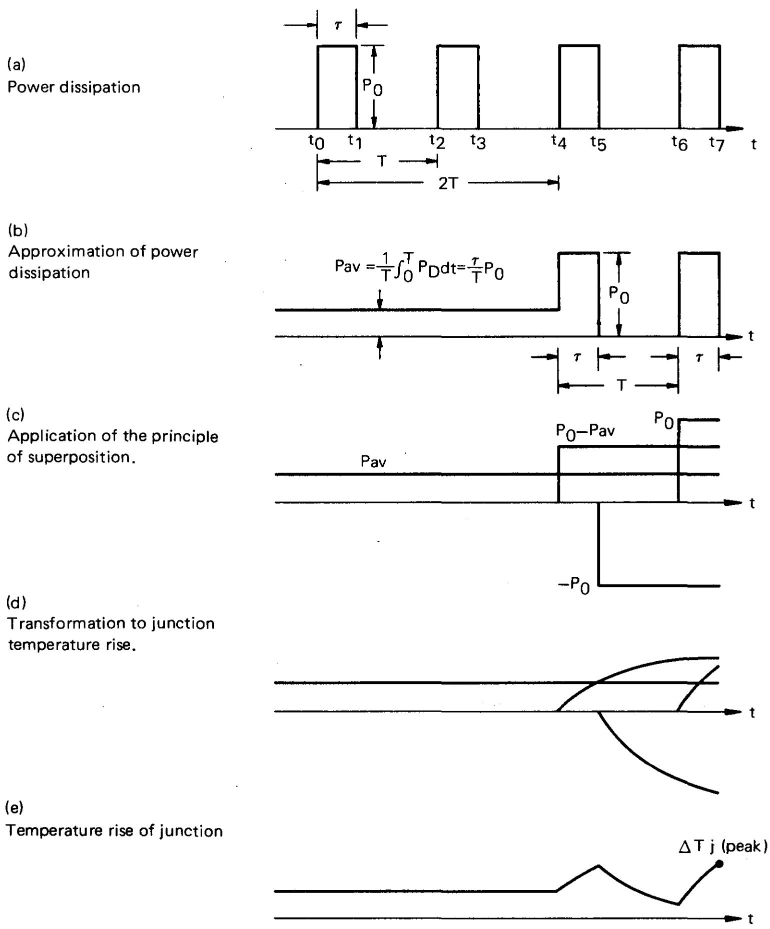


Fig. 6 **Method for determining the Junction Temperature Rise for regularly repeating Square Wave Power Dissipation.**

$$\Delta T_{j(peak)} = \frac{\tau}{T} \cdot P_O \cdot R_{th(j\text{-}c)} + \left(1 - \frac{\tau}{T}\right) \cdot P_O \cdot r_{th(j\text{-}c)}(T + \tau) - P_O \cdot r_{th(j\text{-}c)}(T) + P_O \cdot r_{th(j\text{-}c)}(\tau)$$

$$= P_O\left[\frac{\tau}{T} \cdot R_{th(j\text{-}c)} + \left(1 - \frac{\tau}{T}\right) \cdot r_{th(j\text{-}c)}(T + \tau) - r_{th(j\text{-}c)}(T) + r_{th(j\text{-}c)}(\tau)\right] \quad \ldots\ldots (2)$$

Where,

$\Delta T_{j(peak)}$	:	Maximum value of junction temperature rise from case temperature.
P_O	:	Power dissipation.
τ	:	Pulse width of power dissipation.
T	:	Period
$R_{th(j\text{-}c)}$	:	D.C. thermal resistance from junction to case.
$r_{th(j\text{-}c)}(t_X)$	:	Transient thermal resistance from junction to case for pulse width of t_X.

4-3 The Approximation to Square Waves of Non-Square Wave Power Dissipation.

Since the actual power dissipation waveforms are of complex form, the junction temperature is determined by the methods described in 4-1 and 4-2, after the waveforms have been approximated to square waves.

When the waveform is close to that of a square wave, as shown in (a) of Fig. 7, the peak values are made the same and the pulse width taken so that the areas are equal.

In the case of sinusoidal waves and triangle waves shown in (b), the peak value is made 0.7 x Pp and the pulse widths are taken as 0.91t and 0.71t respectively.

In the case of complex waveforms as shown in (c), the waveform is divided into several square waves totalling to the same area as the original waveform.

Care should be taken when approximating waveforms as described above, since, according to the method of approximation employed, great difference may result in the calculation of the same power dissipation.

Examples of power dissipation applied to a NTC1871A are shown in Fig. 8. For the same triangle wave power dissipation, there is a 25°C difference in the results calculated from approximation method (a) and (b).

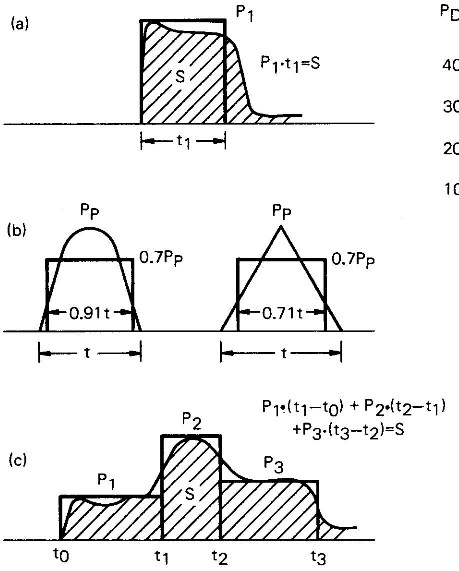


Fig. 7 Approximation to Square waves of Power Dissipation.

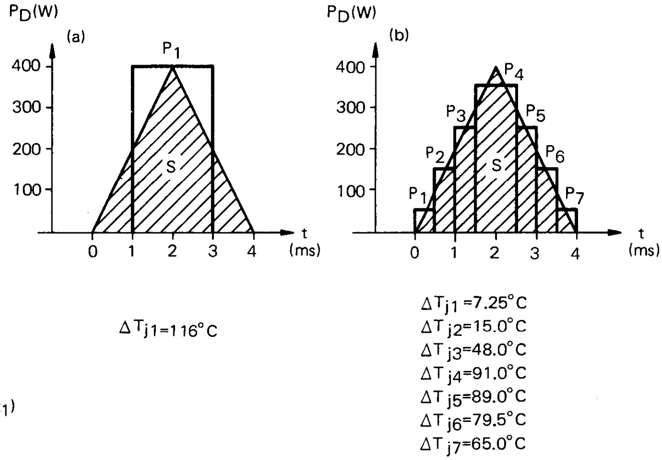


Fig. 8 Temperature Rise of Junction by Triangle Wave Power Dissipation.

This is because, for the same amount of energy, the junction temperature rise is more severe when the peak value is high and the pulse width short, than when the peak value is low and the pulse width long.
(This can also be explained from the fact that the transient thermal resistance is proportional to the 1/2 power of the pulse width, as described in 2. . . . . . $r_{th(j\text{-}c)} \propto \sqrt{\tau}$ . . . . .)

When (a) and (b) are compared, subdividing the waveform as shown in (b) gives a result approaching nearer to the actual temperature rise, and can be said to be a method preferable for economical design. Furthermore, it should be noted that the approximation of (b) of Fig. 6 gives a result of $\Delta T_j = 95°C$, which is approximately the same value as that given by (b) of Fig. 7.

5. APPLICATION TO ACTUAL USE.

Here, application to a switching regulator shall be described, using the NTC1871A as an example.

5-1 Junction temperature in a steady state.

Generally, in the switching mode power dissipation is composed of 3 portions, Namely:

P_1: Power dissipation at the moment of turn on.

P_2: Power dissipation during the on state. (Power dissipation due to saturation voltage.)

P_3: Power dissipation at the moment of turn off.

When the junction temperature rise is determined, employing the method described in 4-2, the result of calculation will be as follows:

$$\Delta T_{j(peak)} = P_4 \cdot R_{th(j\text{-}c)} + (P_5 - P_4) \cdot r_{th(j\text{-}c)}(T - \tau) - P_5 \cdot r_{th(j\text{-}c)}(T) + P_1 \cdot r_{th(j\text{-}c)}(\tau)$$
$$- (P_1 - P_2) \cdot r_{th(j\text{-}c)}(t_2 + t_3) + P_3 \cdot r_{th(j\text{-}c)}(t_3) \quad (°C) \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (3)$$

Where,

$\Delta T_{j(peak)}$	:	Maximum value of junction temperature rise from case temperature.
$P_1 - P_3$	:	See above.
P_4	:	Average power dissipation over total period.
P_5	:	Average power dissipation during period of τ.
$\tau = t_1 + t_2 + t_3$	:	Pulse width of power dissipation.
T	:	Period
t_1	:	Pulse width of turn on.
t_2	:	Pulse width of ON period.
t_3	:	Pulse width of turn off.
$R_{th(j\text{-}c)}$	:	Thermal resistance from junction to case.
$r_{th(j\text{-}c)}(t_X)$	:	Transient thermal resistance from junction to case, when pulse width is t_X.

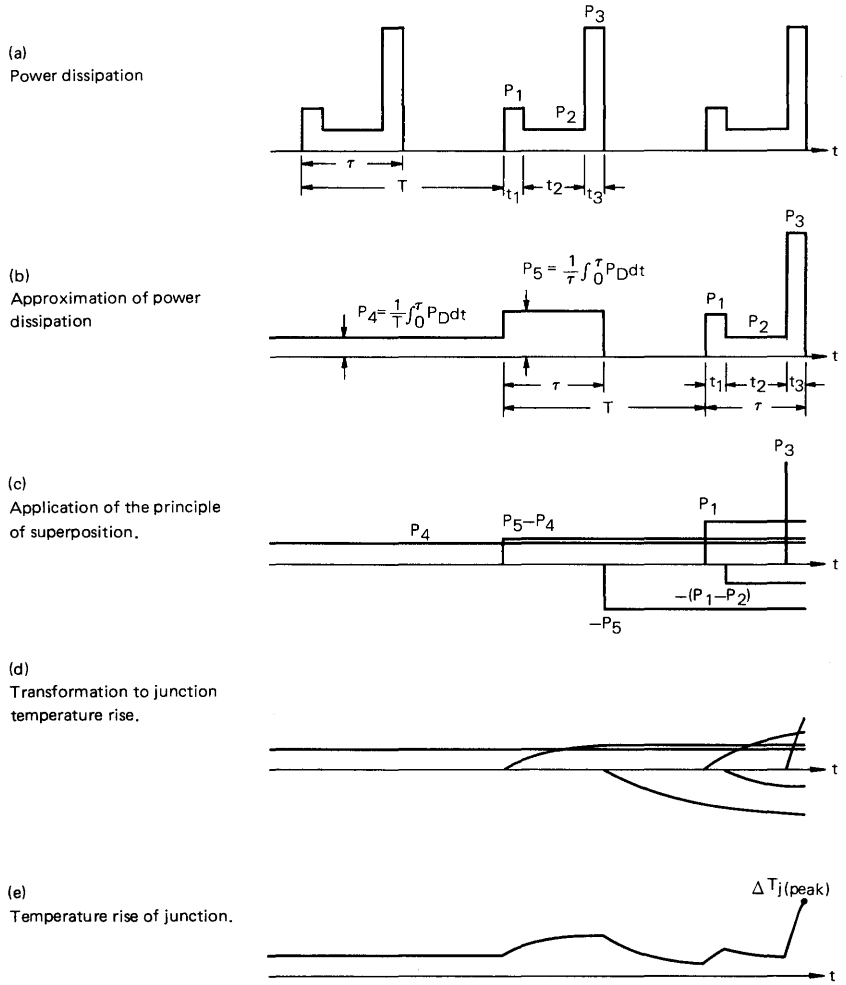


Fig. 9 Power Dissipation Waveforms in the Switching Mode, and Method of determining the Junction Temperature in the Steady State.

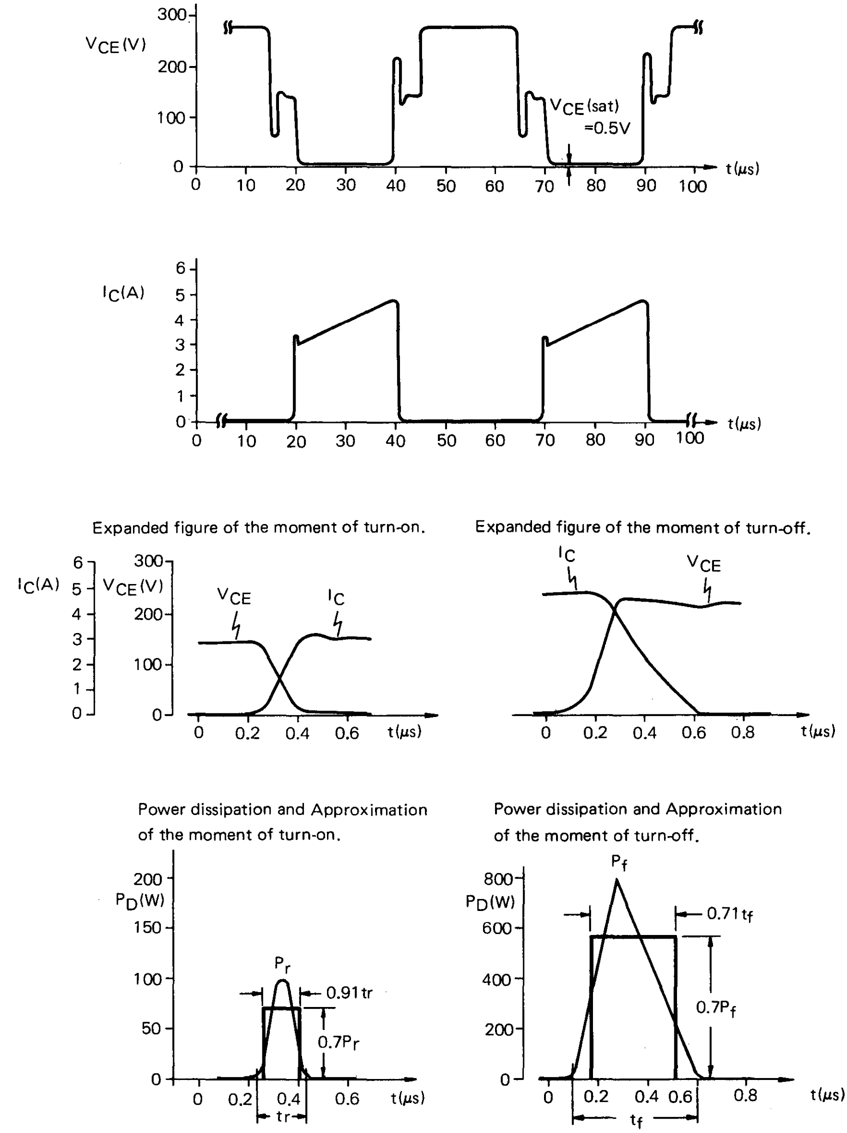


Fig. 10 Collector Current and Collector to Emitter Voltage Waveforms and Power Dissipation Approximation in Switching Regulators.

Typical waveforms of a switching regulator (V_{IN} : 140V_{DC}, Output : 300W, f = 20kHz) are shown in Fig. 10.

Now, the junction temperature is calculated by applying equation (3).

$P_1 = 70W, \quad t_1 = 0.18\mu s, \quad (P_r = 100W, t_r = 0.2\mu s)$

$P_2 = 2.0W, \quad t_2 = 19.5\mu s, \quad (V_{CE}(sat) = 0.5V, I_{C(av)} = 4.0A)$

$P_3 = 560W, \quad t_3 = 0.36\mu s, \quad (P_f = 800W, t_f = 0.5\mu s)$

$P_4 = \frac{1}{T}\int_0^T P_D dt = 5.06W$

$P_5 = \frac{\tau}{T}\int_0^\tau P_D dt = 12.7W$

$T = 50\mu s$

$= 20\mu s$

The transient thermal resistance is read from Fig. 1.

$$\begin{aligned}\Delta T_{j(peak)} &= 5.06 \times 1.25 + (12.7 - 5.06) \times 0.055 - 12.7 \times 0.046 + 70 \times 0.03 - (70 - 2.0) \\ &\quad \times 0.03 + 560 \times 0.004 \\ &= 6.33 + 0.42 - 0.58 + 2.1 - 2.04 + 2.24 \\ &= 8.47\ (^\circ C)\end{aligned}$$

Therefore, in the example of Fig. 10 the temperature rise of the junction from the case temperature will become 8.5°C.

In addition to the collector power dissipation described above, the power dissipation of transistors includes that of the base. However, since in a power unit as shown in the example this power dissipation is usually less than 0.5W, this has been neglected.

5-2 The junction temperature during transitory overloads.

In switching regulators, due to the response time of the control circuit, etc., a transitory overload of less than several milliseconds may be applied to the main switching transistor when power is thrown in or the load is short circuited.

Fig. 11 shows an example of such transitory overload, and the method described in 4-1 is employed to calculate the junction temperature rise. The result of calculation shows that the maximum value of the temperature rise of the junction is approximately 52°C from the case.

Caution should be observed, since if the load impedance of the transistor is markedly small compared to the steady state, or the pulse width is in an uncontrolled state, only the h_{FE} of the transistor is limiting the inrushing current.

Furthermore, since the transistor is operating in an unsaturated state, in this example the effect on the temperature rise of the junction from the power dissipation of pulse widths t_f and t_r is small, and is neglected.

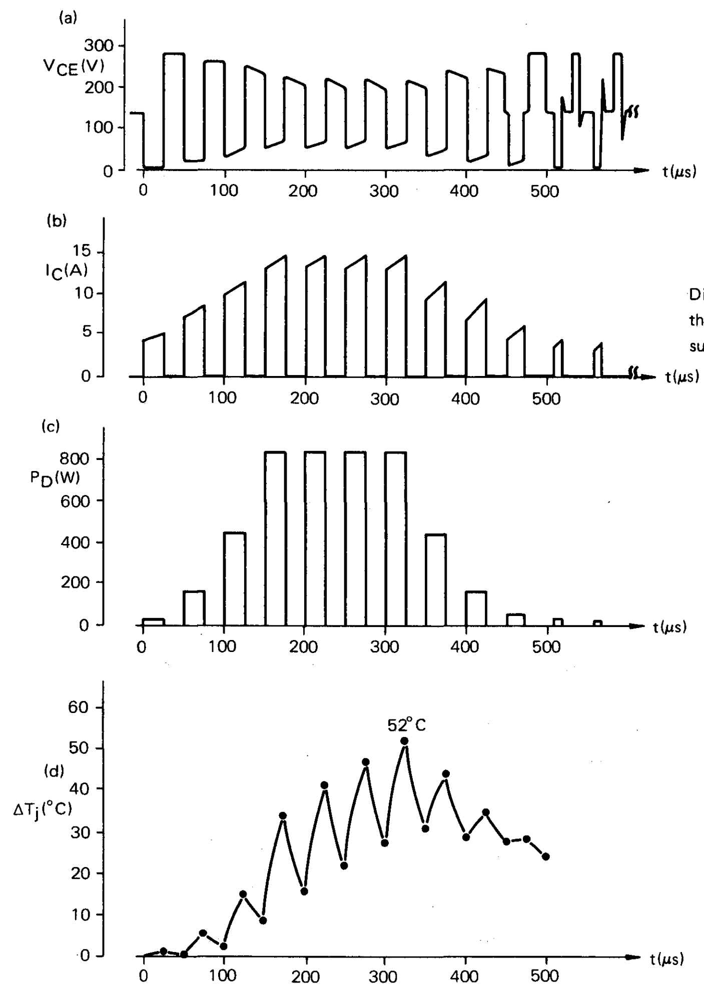


Fig. 11 Example of the application of a Transitory Overload.

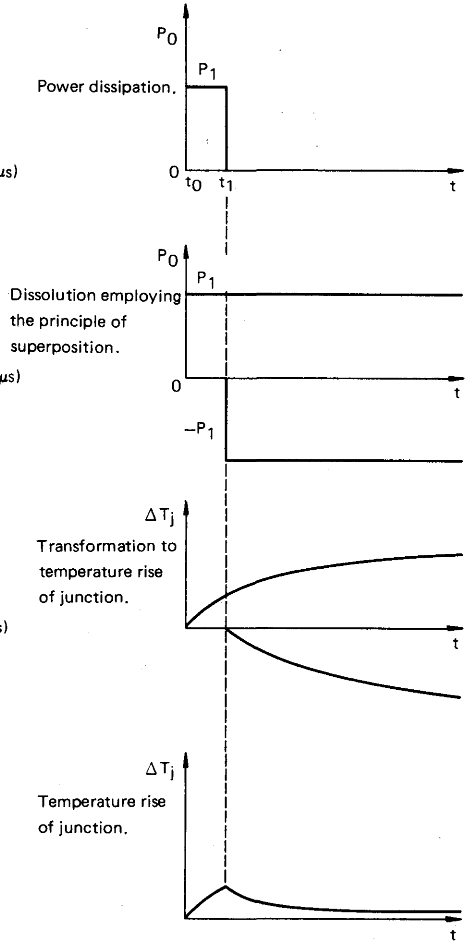


Fig. 12 Temperature rise of Junction from Mono-pulse Power Dissipation.

Now, when the overloaded state in the example of Fig. 11 continues for more than 1ms, the application of equation (1) becomes difficult.

That is, though the ΔT_j of mono-pulse power dissipation is given by equation (1) as:

$$\Delta T_j = P_1 [r_{th(j\text{-}c)}(t) - r_{th(j\text{-}c)}(t - t_1)] \quad (t_1 < t)$$

when, for example, t_1 = 25μs and t = 1ms it becomes practically impossible to read the difference between $r_{th(j\text{-}c)}$ (1ms) and $r_{th(j\text{-}c)}$ (1ms – 25μs). See Fig. 12.

This is an important point, since the power dissipation of complex pulses are all determined from the combination of one-shot pulses (the principle of superposition).

In the above case, approximation is performed by using equation (2) of 4-1.

$$\Delta T_{j(peak)} = P_O[\frac{\tau}{T} \cdot R_{th(j\text{-}c)} + (1 - \frac{\tau}{T}) \cdot r_{th(j\text{-}c)} (T + \tau) - r_{th(j\text{-}c)} (T) + r_{th(j\text{-}c)} (\tau)] \quad \ldots \quad (2)$$

The maximum value of the junction temperature rise is calculated from the above equation by employing in place of the 1st term $R_{th(j\text{-}c)}$, that is the D.C. thermal resistance from junction to case, the transient thermal resistance of the period over which the transient state continues, and for P_O the peak value in order to ensure safe design.

When the effect caused by the power dissipation of pulse widths t_r and t_f cannot be disregarded, equation (3) is employed.

6. PRECAUTIONS TO BE OBSERVED FOR SAFE DESIGN.

With the preceding paragraph, explanation of methods for calculating junction temperature has been finished. However, the junction temperature determined is one of the most important factors concerning the reliability of transistors, therefore in order to ensure safe design the following derating is recommended.

$$T_j = (T_{jmax} - 25) \times 0.8 + 25\ (^\circ C) \quad \ldots\ldots\ldots\ldots\ldots \quad [20\%\ \text{derating}]$$

where, T_j : Junction temperature.

T_{jmax}: Maximum junction temperature at Absolute Maximum Rating.

7. CONCLUSION

In the above, methods of calculating the junction temperature rise of transistors resulting from pulse power dissipation and precautions to be observed for safe operation have been explained. These calculation methods may be applied to other semiconductor products such as thyristors and diodes, and the reader is persuaded to make application in these fields.

NEC

APPLICATION NOTE

DESIGN OF PUSH-PULL TYPE SWITCHING REGULATORS (BASIC)

1. Introduction

Regulator IC's such as the μPC305C have allowed simplification of circuitry and improvement in performance of series regulators. Little progress has been made in reducing the size and weight of these systems, however, due to large and heavy power transformers, smoothing capacitors and heat sinks.

In recent years highly efficient pulse width controlled power supplies (switching regulators), which are smaller and lighter, have been developed and are being used commercially, mainly for computers and terminal equipments. These switching regulators are gradually dominating applications in power supply systems.

Here we present a brief description of switching regulator designs from the standpoint of high voltage, high speed switching power transistors NTC1863–NTC1871A.

2. Principle of Switching Regulators.

2-1 Explanation of Switching Regulators.

A choke input type smoothing circuit is shown in Fig. 1.

Fig. 1 (a) Choke Input Type Smoothing Circuit

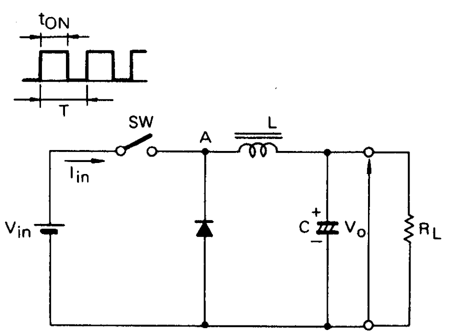
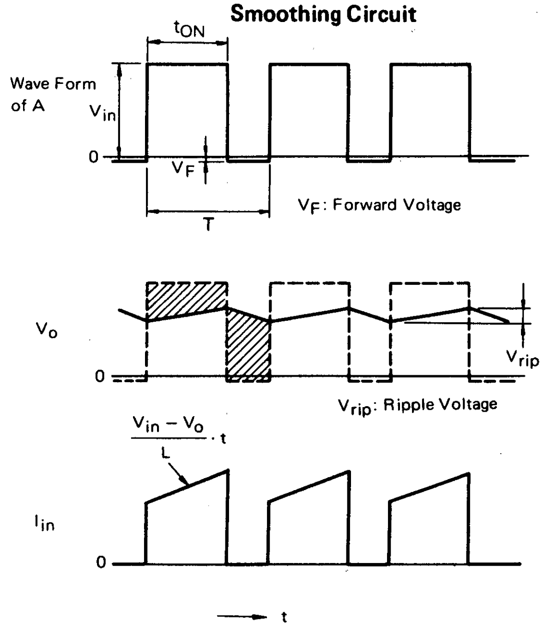


Fig. 1 (b) Operating Waveforms of Choke Input Type Smoothing Circuit



In Fig. 1 (a), when switch SW is switched on-off with a period of T and an on-time of t_{ON}, the output voltage V_O will be approximately equal to the product of the duty cycle D = t_{ON}/T of the on-time and the input voltage V_{in}.

That is:

$$V_O \fallingdotseq \frac{t_{ON}}{T} \cdot V_{in} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Provided that: $T \ll 2\pi\sqrt{LC}$

$$R_L \leqq \frac{2L}{T - t_{ON}}$$

(conditions for current flowing through choke coil to be continuous)

From the above it can be seen that in order to obtain a constant output voltage V_O, regardless of the variations of the unregulated input voltage V_{in}, it is necessary that the duty cycle be changed according to variations of the input voltage.

Now, if the goal is to stabilize the output by reducing the pulse width t_{ON} to $t_{ON} - \Delta t_{ON}$, when the input voltage V_{in} increase to $V_{in} + \Delta V_{in}$, then,

$$-\Delta t_{ON} = -\frac{\Delta V_{in}}{V_{in} + \Delta V_{in}} \cdot t_{ON} \fallingdotseq -\frac{\Delta V_{in}}{V_{in}} \cdot t_{ON} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

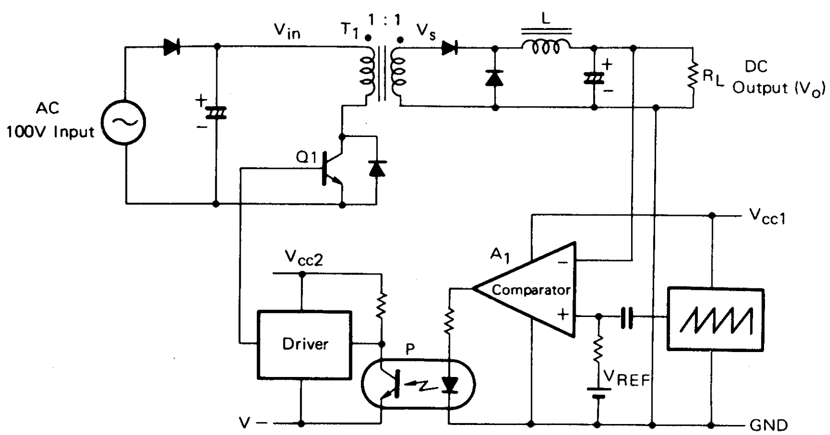
Provided that: $\Delta V_{in} \ll V_{in}$

Therefore, it can be seen that it is sufficient if the pulse width is varied an amount approximately proportional to the variation of the input voltage ΔV_{in}.

2-2 Operating Principle of Switching Regulators.

A simple switching regulator circuit is shown in Fig. 2.

Fig. 2 Single-Ended Operation Type Regulator Circuit



11

Generally, since power supply units are generally used in a floating operation, the input and output are isolated by a high frequency transformer T_1.

Due to the switching of transistor Q_1, the primary winding of T_1 is excited and, since the secondary winding has the same number of turns as the primary winding, a voltage $V_s = V_{in}$ is generated in the secondary winding. The output circuit is the same type of choke input smoothing circuit as shown in Fig. 1, therefore, the output voltage V_o is given by the equation (1). In order to stabilize the output voltage, the variation of output voltage is sensed and fed back to control the driving pulse width. A_1 is a comparator having the output voltage consisting of a sawtooth wave superposed upon the reference voltage applied to the non-inverting input terminal V_N. Therefore, since the slice level of the sawtooth wave at the output of the comparator will change according to the slightest variation of the output voltage V_o, the output of A_1 will become a pulse width modulated signal having the same period as that of the sawtooth wave. When V_o increases this signal acts to decrease the width of the pulse, and enters the driver through photo-coupler P to drive transistor Q_1. As described above, the on-time of the transistor is controlled according to the variations of the output voltage, and a stable output is always obtained.

3. Kinds of Switching Regulator Circuits and Optimum Switching Power Transistors.

NEC's optimum switching power transistors for switching regulators are shown in Table 1.

Table 1. Product Series of High Speed Switching Power Transistor

V_{CEO} \ Outline, $I_{C(DC)}$, P_T*	Type No.		
	TO-66 7A 40W	TO-3 7A 80W	TO-3 10A 100W
100V	NTC1863	NTC1866	NTC1869
250V	NTC1864	NTC1867	NTC1870
400V	NTC1865	NTC1868	NTC1871A

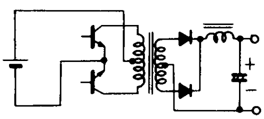
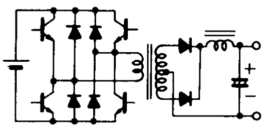
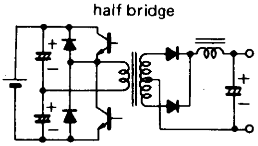
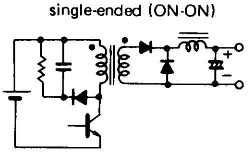
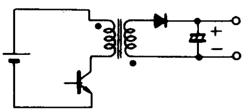
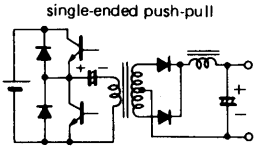
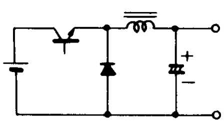
* $T_c = 25°C$

The above table shows a series of high voltage, high speed switching power transistors newly developed for use in switching regulators, in which, compared to usual power transistors, an extremely high switching speed of t_{ON}, $t_f < 1\mu s$ and $t_{stg} < 2\mu s$ has been realized.

Various circuits of switching regulators, and the optimum switching power transistors are shown in Table 2.

In addition to the single-ended operation type described previously, there are various switching regulator circuits of such as the push-pull type, bridge type, etc. And, since the voltage range and current capacity required to the switching element will vary according to the input voltage and output capacity of the regulator, it is necessary to select the optimum transistor from Table 1. Among the various circuits, the push-pull type switching regulator as compared with the single-ended operation type has a high utilization factor of the high frequency transformer and secondary side smoothing circuit; and compared with the bridge type requires only half the number of switching elements, thus simplifying the driver circuit. For these reasons, the push-pull type is most frequently used as a switching regulator.

Table 2. Circuits of Switching Regulators and Optimum Switching Power Transistors

Circuits		Optimum Power Transistor — Input Voltage: AC 100V or DC 130V	AC 220V	DC 12V or 24V	DC 48V	Output Capacity (W)
Types of Inverter	push-pull 	NTC1865	V_{CEO}=900V class Po. Tr.	NTC1863 or NTC1866	NTC1864	100
		NTC1868	"	NTC1869	NTC1867	200
		NTC1871A	"	–	NTC1870	~500
	full bridge 	NTC1864	NTC1865	NTC1863 or NTC1866	NTC1863	150
		NTC1867	NTC1868	NTC1869	NTC1866	250
		NTC1870	NTC1871A	–	NTC1869	500
	half bridge 	NTC1864	NTC1865	–	NTC1863 or NTC1866	75
		NTC1867	NTC1868	–	NTC1869	150
		NTC1870	NTC1871A	–	–	300
	single-ended (ON-ON) 	NTC1865	V_{CEO}=900V class Po. Tr.	NTC1863 or NTC1866	NTC1864	50
		NTC1868	"	NTC1869	NTC1867 or NTC1870	100
		NTC1871A	"	–	–	200
	single-ended (ON-OFF) 	NTC1865	"	NTC1863 or NTC1866	NTC1864	50
		NTC1868	"	NTC1869	NTC1867 or NTC1870	100
		NTC1871A	"	–	–	200
	single-ended push-pull 	NTC1864	NTC1865	NTC1863 or NTC1866	NTC1863 or NTC1866	75
		NTC1867	NTC1868	NTC1869	NTC1869	150
		NTC1870	NTC1871A	–	–	300
chopper type 		(NTC1864)	(NTC1865)	NTC1863	NTC1863	50
		(NTC1867)	(NTC1868)	NTC1866	NTC1866	75
		(NTC1870)	(NTC1871A)	NTC1869	NTC1869	150

4. Design of Push-Pull Type Switching Regulators.

We will now describe a typical method of designing push-pull type switching regulators.

4-1 Composition.

The block diagram of push-pull type switching regulator is shown in Fig. 3, and the timing chart of the circuit is shown if Fig. 4. The circuit of Fig. 3 differs from the single-ended switching regulator in the point that a separately excited high frequency push-pull inverter is used for voltage conversion. Since in the circuit of Fig. 2 the output voltage is directly compared with the sawtooth wave, the loop gain should be low and allowing large variations of the output, so an error amplifier of about 50dB gain is necessary as shown in Fig. 3. In addition, in order to provide the output signal into 2 phases is required in an after the isolator; and also an over-current flowing in the switching elements during overloads. Also, auxiliary power source is required to supply power to these control circuits. This power source consists of a line operated DC—DC converter, in order to permit AC/DC operation and reduction of size.

Fig. 3 Block Diagram of Push-pull Type Switching Regulator.

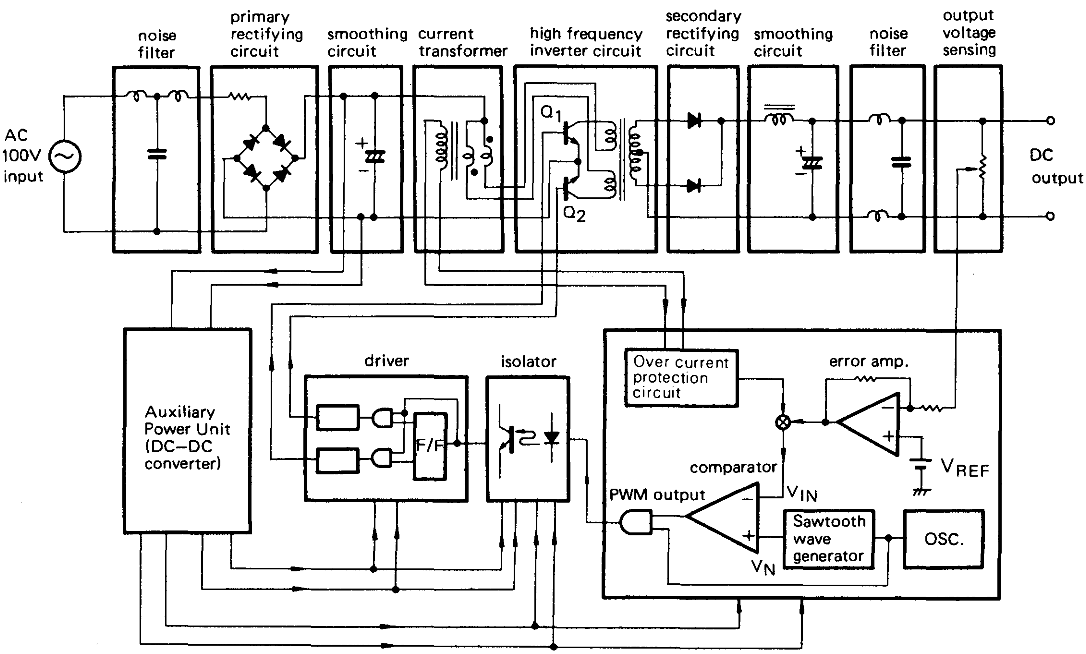
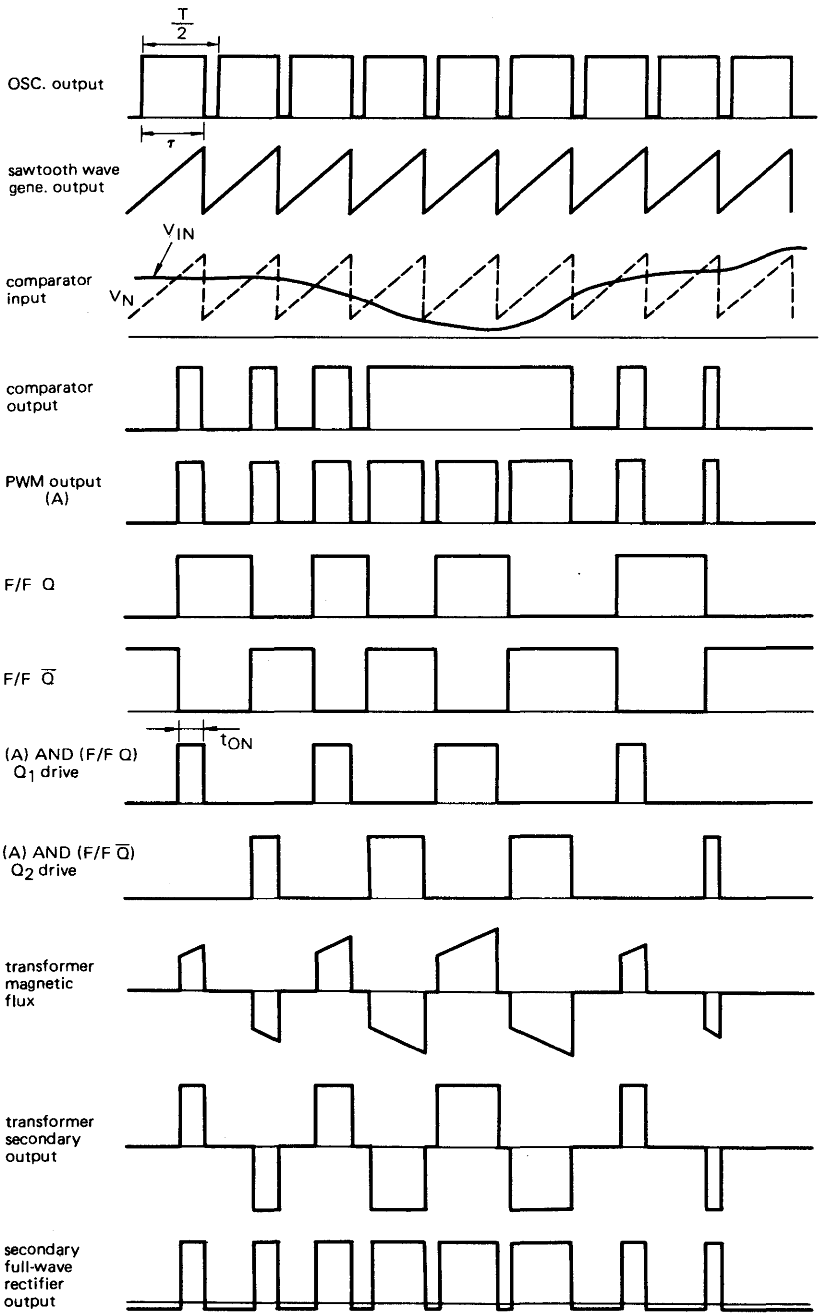


Fig. 4 Timing Chart of Push-Pull Type Switching Regulator Circuit



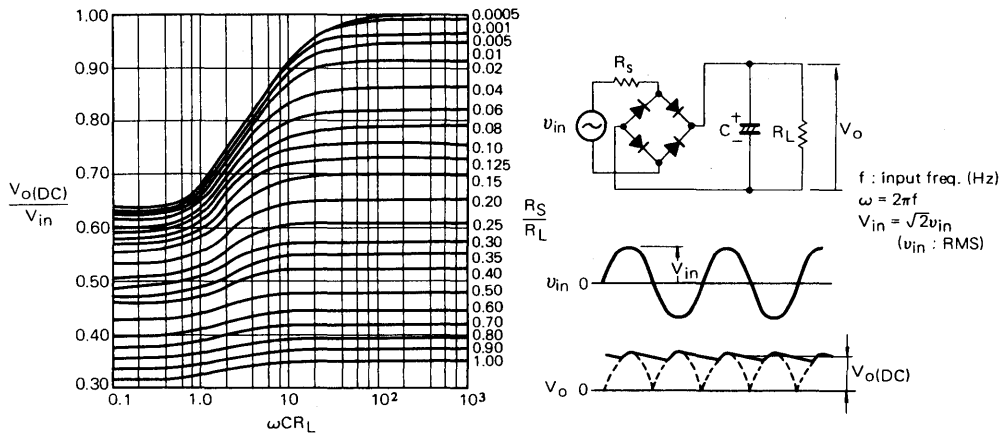
4-2 Design Method of the Various Blocks.

(1) Primary Rectifying and Smoothing Circuit.

A line operated full-wave rectifying and smoothing circuit is composed of a bridge rectifier and a smoothing capacitor, and the rush current flowing into the rectifier and capacitor when power is turned on is limited by a low resistor in series with the AC line. Also, in the case of large capacity power supplied, slow starting circuits using SCRs or relays may be employed.

The capacity of the smoothing circuit is determined by the input capacity of the power unit and the required ripple level, and for this purpose there is an extremely convenient curve (chart) by O. H.Schade, as shown in Fig. 5.

Fig. 5 0. H. Schade's Curve (for determining Circuits Constants of Full-Wave Rectifying Circuits.)



(2) Design of Transformers.

In order to reduce size and avoide audible noise, high frequency is used in switching regulators. However, considering the high frequency characteristics of diodes, transistors, capacitors, etc. a frequency of about 20kHz is generally used in push-pull type regulators.

i) Material and Shape of Cores.

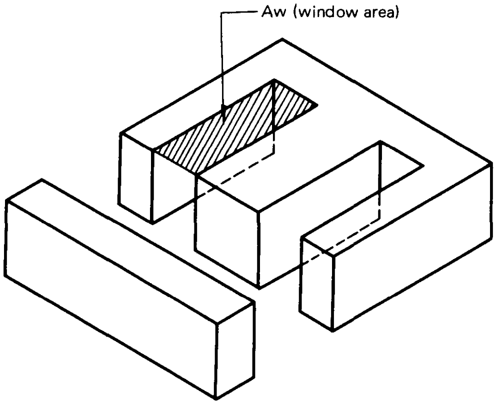
From the point of saturation (magnetic) flux density, permeability, and iron loss Tohoku Kinzoku's 3100B or TDK's H_{5A} is used as the core materials of transformers and choke coils.

EI shaped cores are easy to handle. The volume of the core is determined from such factors as follows: the input voltage, the number of turns of the primary winding which is determined from the frequency used, the cross section area of the primary winding which is determined from the output capacity, the primary winding inductance, and the superposed DC current.

When a square wave voltage of frequency f (Hz) and peak value V_{in} (V) is applied to a transformer which has N_p turns as the primary winding around a core of A_e (m^2) cross section, the relationship between the flux density B (wb/m^2) created in the core and V_{in} can be shown by the following expression.

$$V_{in} = 4 \cdot B \cdot A_e \cdot f \cdot N_p \ (V) \quad \ldots\ldots (3)$$

Fig. 6 Shape of Core



On the other hand, if in Fig. 6 δ (A/m^2) is the allowable current density of the winding, and w.f. (window factor) the proportion (space factor) of the total cross sectional area of the primary and secondary windings (A/m^2) to the total window area $A_W(m^2)$ of the core, then,

$$A_c = (w.f.) \cdot Aw = \frac{2N_p \cdot I_p}{\delta} \quad \ldots\ldots (4)$$

Therefore, from equations (3) and (4) the maximum input P(VA) which can be applied to the transformer is:

$$P = V_{in}.I_p = 2B.f.A_e.(w.f.).\ A_W.\ \delta\ (VA) \quad \ldots\ldots (5)$$

Now, when in equation (5) the following values are substitued for the items below, equation (6) is obtained.

$B = 1500$ (Gauss) $= 1.5 \times 10^{-1}$ (wb/m^2)

(Generally, taking in consideration the balance of the decrease of saturation (magnetic) flux density with rise in temperature and iron loss, a magnetic flux density of 1500 Gauss is used.)

$\delta = 2(A/mm^2) = 2 \times 10^6$ (A/m^2)

(From the temperature rise caused by the specific resistance of the copper wire, generally, $2A/mm^2$ is used as the allowable current density of the copper wire employed in transformer windings.)

w.f. = 0.7

(From the thickness of the insulating material of the windings and the space taken up by the shield, 0.7 is generally used for the w.f.)

f = 20 (kHz)

then,

$$P = 8.4 \times A_e \times A_W \times 10^9\ (VA) \quad \ldots\ldots (6)$$

When the maximum input capacity P(VA) of Tohoku Kinzoku's EI shaped cores are determined using equation (6) the results are as shown in Table 3. Actually, when employing these cores in switching regulators, due to the necessity of taking into consideration a margin of the (magnetic) flux density to

11

cope with variations of the input and also the DC superposed characteristics, it is common for the design to have a considerable allowance in regards to the P(VA) values of Table 3.

Table 3. Kinds & Maximum Input Capacity of EI Cores.

B = 1500 Gauss, f = 20kHz, δ = 2A/mm², w.f. = 0.7 * Core material: 3100B

Kind of core	Total window area of core A_W (cm²)	Effective cross section area of core A_e (cm²)	Maximum input capacity P (VA)	Practical example of output capacity P_O (W)
FEI 30	1.44	1.09	132	25
FEI 40	3.10	1.46	380	50
FEI 50	4.78	2.30	923	100 – 150
FEI 60	7.84	2.45	1,600	Undetermined

ii) Windings.

(a) Number of turns of primary winding: N_p

N_p is determined, employing equation (3), so that the design (magnetic) flux density B shall be obtained at maximum input voltage $V_{in(max)}$.

$$N_p = \frac{V_{in(max.)}}{4 \cdot B \cdot A_e \cdot f} \quad \cdots\cdots (7)$$

(b) Diameter D_p of primary winding wire.

If an average current through into the primary winding is $I_{c(av)}$.

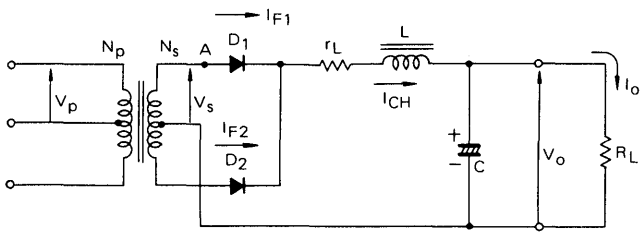
$$\frac{I_{c(av)}}{\pi \cdot (\frac{D_p}{2})^2} \leqq \delta$$

$$D_p \geqq \sqrt{\frac{4 I_{c(av)}}{\pi\, \delta}} \quad (m) \quad \cdots\cdots (8)$$

(c) Number of turns of secondary winding: N_s

N_s is designed so that the specified output voltage will be obtained under the worst conditions (minimum input voltage, maximum load, and minimum ambient temperature).

Fig. 7 Secondary Smoothing Circuit



V_p: primary input voltage (V)
V_s: secondary output voltage (V)
V_o: smoothed output voltage (V)
V_F: forward voltage (V) of diodes D_1 and D_2
L: inductance (H) of choke coil
r_L: internal resistance (Ω) of choke coil
C: capacity (F) of smoothing capacitor
R_L: load resistance (Ω)
I_o: output current

In the secondary smoothing circuit shown in Fig. 7, the relationship between the input and output voltages and number of turns of the primary and secondary windings of the transformer is shown by the following equation.

$$V_S = \frac{N_S}{N_P} \cdot V_P \quad (V) \qquad \cdots\cdots (9)$$

And, when an output voltage of period T(sec), maximum pulse width τ (sec), and peak value V_S (V) is induced in the secondary side of the transformer, the output voltage V_O(V) obtained when a load current I_O(A) is taken out is shown by the following equation.

$$V_O = V_S \cdot \frac{\tau}{\frac{T}{2}} - V_F - I_O \cdot r_L \quad (V) \qquad \cdots\cdots (10)$$

Therefore, from equations (9) and (10) the number of turns of the secondary winding can be determined from the following equation.

$$N_S \geq \frac{(V_O + V_F + I_O \cdot r_L) \cdot N_P \cdot T}{2\,\tau \cdot V_P} \quad \text{(turns)} \qquad \cdots\cdots (11)$$

(d) Cross section of secondary winding.

When round copper wire is used for the secondary winding, the same as for the primary winding, the diameter D_S(m) of the secondary winding can be determined from the following equation, similarly to equation (8).

$$D_S = \sqrt{\frac{4\, I_{O(max.)}}{\pi\,\delta}} \quad (m) \qquad \cdots\cdots (12)$$

Provided that, I_O(max): Maximum output current (A)

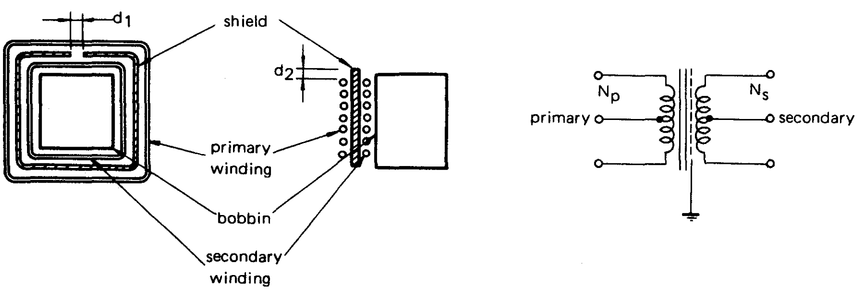
However, in the case of low output voltage, large current capacity power such as are used in terminal equipment, foil may be used for the winding to reduce skin effect. In this case the cross sectional area S_S(m^2) of the winding is determined from the following equation.

$$S_S = \frac{I_{O(max.)}}{\delta} \quad (m^2) \qquad \cdots\cdots (13)$$

iii) Static shield.

To prevent the influence of noise to be easily passed through the static coupling due to the stray capacity between the primary and secondary windings of the transformer, it is necessary to provide static shield by inserting metallic foil between the primary and secondary windings, or by other means.

Fig. 8 Static Shield of Transformer



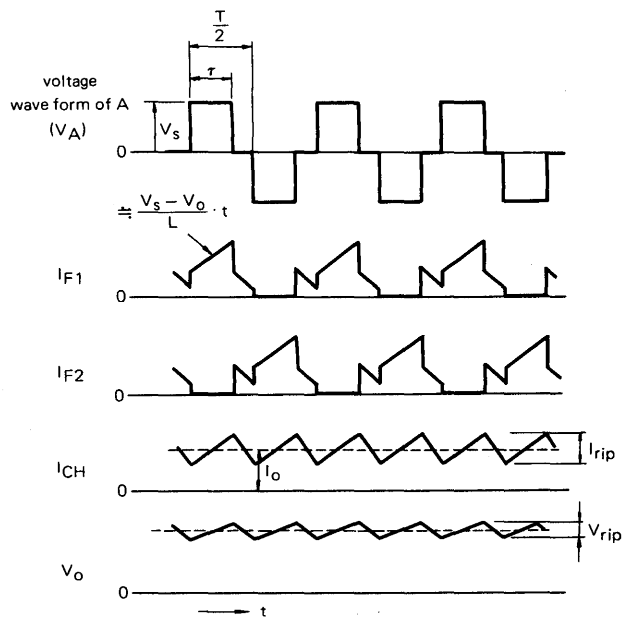
(a) (b) (c)

Shielding of the transformer is conducted as shown in Fig. 8, but care should be taken since when d_1 of the shielding foil joint in Fig. (a) is too large the shielding effect will decrease and, when the joint overlaps, loss will increase. Also, unless the shield foil extends beyond the edges of the winding the static coupling at the edges of the windings cannot be decreased, therefore it is necessary to provide distance d_2 as shown in Fig. (b).

(3) Secondary Rectifying and Smoothing Circuit.

Fig. 9 shows the waveform during operation of the various point of the secondary smoothing circuit shown in Fig. 7 previously.

Fig. 9 Waveforms of the various parts of Secondary Smoothing Circuit



I_{rip} : ripple current (A)
V_{rip} : output ripple voltage (V)

During interval τ (sec) of period T (sec) a voltage V_s (V) will be induced in the secondary of the transformer, and during this interval the smoothing circuit will be supplied with power from the primary. During this interval a current having a gradient of $(V_s - V_o) \cdot t/L$ will flow in the rectifier elements D_1 and D_2 connected to the terminals of the secondary, and this current will flow through the choke coil in a superposed manner. On the other hand, during the quiescent time $T/2 - \tau$ (sec) the choke coil will function to continue the current, thus rectifier elements D_1 and D_2 will act as flywheel diodes. As a result, the current flowing in the choke coil taked the form, as shown in Fig. 9, of a ripple current I_{rip} (A) superposed on a current equal to the output current I_o (A). This ripple current flows into the smoothing capacitor connected in parallel with the output terminals.

i) Selection of Rectifying Elements.

Since the currents I_{F1} and I_{F2} flowing in the rectifying elements D_1 and D_2 take the form shown in Fig. 9, it is necessary to select elements for D_1 and D_2 having a current capacity appropriate for I_{F1} and I_{F2}. Also, since in normal state a maximum voltage of $2V_s$ (V) is applied to these elements, it is necessary to select elements capable of withstanding this voltage. In addition, as the secondary rectifying circuit operates at a frequency of about 20kHz, the use of fast recovery diodes having a short recovery time is required. Specifically, in the case of power units of low voltage (≃5V), large current output the use of Schottky barrier diodes, which have an extremely fast recovery time, is appropriate.

ii) Smoothing Capacitors.

As described earlier, the secondary smoothing circuit is of the choke input type, and the smoothing factor ($\alpha = V_{rip}/V_s$) of such a circuit is generally shown by the following equation.

$$\alpha = \frac{V_{rip.}}{V_s} = \frac{1}{\omega^2 LC} \quad \cdots\cdots (14)$$

$$\omega = 2\pi f$$

However, since electrolytic capacitors, which do not have very good frequency characteristics, are employed for smoothing, the impedance Z_C of the capacitors cannot be expressed as $Z_C = 1/\omega C$ at a frequency around 20kHz. The smoothing factor is usually determined from the following expression.

$$\alpha = \frac{Z_C}{\omega L} \quad \cdots\cdots (15)$$

Z_C: Impedance of capacitor at frequency used.

iii) Choke Coils.

As described before, a ripple current I_{rip} inversely proportional to the inductance L of the choke coil will flow in the choke coil. But, when the load is light and the output current I_O becomes less than $2\,I_{rip}$, the current flowing in the choke coil will become discontinuous and the filtering effect will be lost. This value is called the critical current I_{CHO} (A), and expressed as follows.

$$I_{CHO} = \frac{V_S - V_O}{2L} \cdot t_{ON} \ (A) \quad \cdots\cdots (16)$$

The critical current is related to the size of the dummy resistor used to prevent an abnormal rise of the output voltage, and is usually taken at 1/7 to 1/10 of the rated output current $I_{O(max)}$ (A).

that is,

$$I_{CHO} \leqq \left(\frac{1}{7} \sim \frac{1}{10}\right) \cdot I_{omax.} \ (A) \quad \cdots\cdots (17)$$

Therefore, from equations (1), (16) and (17) the inductance required by the choke coil will become:

$$L \geqq \frac{(3.5 \sim 5) \cdot (V_S - V_O)}{I_{omax.}} \cdot \frac{V_O}{V_S} \cdot T \ (H) \quad \cdots\cdots (18)$$

EI shaped Ferrite cores, similar to the for choke coils. But since direct current is superposed upon the choke coils, gapped cores are necessary to prevent (magnetic) flux saturation.

The number of turns and core volume required for a choke coil having the inductance and rated output current $I_{O(max)}$ (A) shown in equations.

The number of turns N_1 are shown by the well known in equation (20).

$$L = AL \times N^2 \times 10^{-9} \ (H) \quad \cdots\cdots (19)$$

11

AL: AL – value (nH/T^2) of core at gap t.

$$N_1 = \sqrt{\frac{L}{AL} \times 10^9} \quad \text{(turns)} \quad \dots\dots \quad (20)$$

Core volume is determined by selecting a core in which the product of the DC superposed current under actual load and the number of turns does not exceed the DC superposed characteristic NI (ampere-turns) of the core at the gap t (mm).

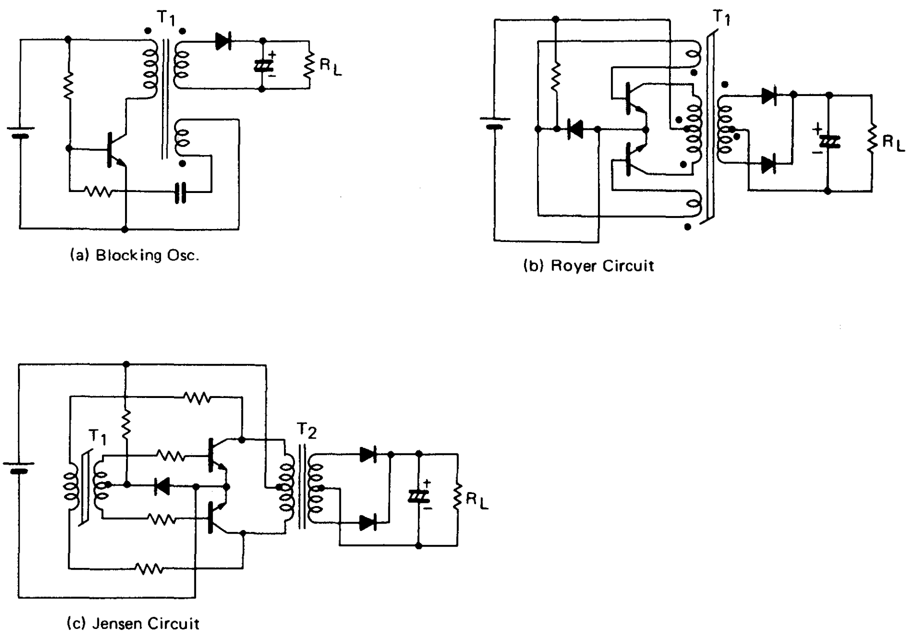
That is,

$$NI > N_1 \times I_{omax.} \quad \text{(Ampere Turns)} \quad \dots\dots \quad (21)$$

(4) Auxiliary Power Supply Circuits.

As shown in Fig. 10, all of the DC–DC converters used as auxiliary power supplies operate on the principle of having a base feedback winding on the transformer to sustain self-excited oscillation.

Fig. 10 Examples of DC–DC Converter Circuits for Auxiliary Power Supplies.



(a) Blocking Osc.

(b) Royer Circuit

(c) Jensen Circuit

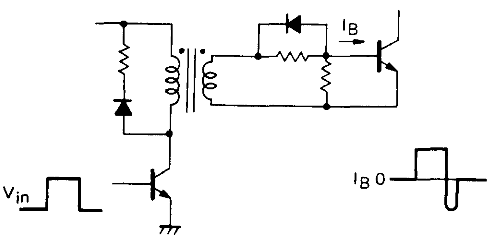
Among the circuits shown, when the output is small the Blocking Oscillator type shown in Fig. 10 (a) is suitable from the standpoint of needing a few parts. Design of transformers for converters is conducted in the same way as described in Item (2). But particularly, since the transformers T_1 of circuits (b) and (c) of Fig. 10 are used at saturated magnetic flux, TDK's H_{5C2}, which has a square hysteresis characteristic, is suitable as core material. Since converters are operated from the AC 100V – 117V line, transistors of the V_{CEO} = 400V are required for use in converters. When it is necessary to stabilize the output of converters, as in control circuits which are operated from the output of the auxiliary power supply, monolithic voltage regulators of the μPC143xxH or μPC78L are used..

(5) Base Driving Circuits.

The base driving circuit of the main switching transistor is important from the standpoint of reducing the switching time and thus the switching loss of the transistor. Particularly, since the high voltage, high speed switching transistor which is the main switching element has a low h_{FE} of about 10, the base current becomes considerably larger. Therefore, a pulse transformer is generally used to provide current amplification. (Sometime it also performs the function of isolation.)

A pulse transformer of 2 : 1 to 5 : 1 turns ratio is employed in the circuit of Fig. 11, and extraction of the carrier accumulated in the base of the final stage transistor is performed through diode D_1 by the backswing voltage generated in the pulse transformer during OFF time. (Since in this method the backswing voltage becomes low when the width of the input becomes narrow, some ingenuity is required in arranging the circuit.)

Fig. 11 Base Driving Circuit



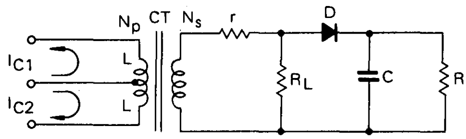
(6) Overcurrent Sensing Circuit.

Current sensing methods for protecting the main switching transistor and primary and secondary rectifying diodes from overcurrent are: the method of utilizing the voltage drop of a low resistance resistor placed in series in the GND line of secondary circuit; and the method of directly sensing the collector current of the transistor employing a current transformer.

However, from the points of ease of control and low power loss in the sensing section the latter method is superior. A circuit using this method is shown in Fig. 12. The peak value of the collector current is detected by the diode D and capacitor C in the secondary of the current transformer (CT).

11

Fig. 12 Overcurrent Sensing Circuit



L : Inductance of primary winding wire.
CT: TDK's H_{5C2} T shaped core used.
$N_p = 3T$, $N_s = 150T$

i) Core Material and Shape.

In order to improve detecting sensitivity and to reduce sagging of the output waveform as much as possible, TDK's H_{5C2} toroidal cores which have high permeability and good coupling coefficients are used.

ii) Windings.

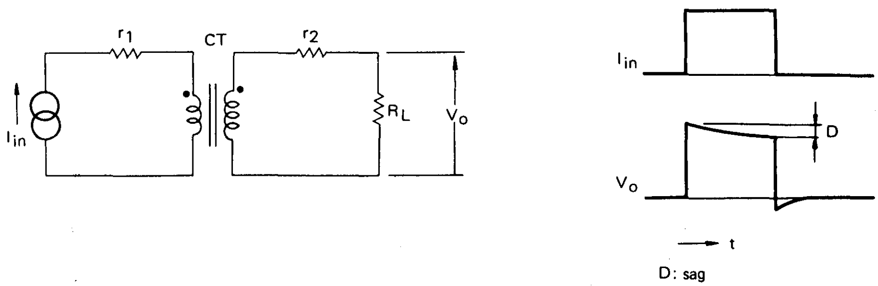
The number of turns of the primary and secondary also greatly effect the detection sensitivity, and a turn ratio of about 1 : 50 is usually employed. The sag D, shown in the output wave form of Fig. 13, is determined by the internal resistance r of the winding and the terminal resistor R_L. The sag D is expressed by the following equation.

$$D = \frac{r \cdot R_L}{R_L + r} \cdot \frac{\tau}{L} \quad \cdots\cdots (22)$$

τ : Width of input pulse
L: Primary inductance of CT

Therefore, in order to reduce the sag, it is necessary to use a wire having larger diameter for the secondary winding to reduce the internal resistance.

Fig. 13 Operating Waveforms of Current Transformer



5. Ending

Design methods for switching regulators centering around the selection of the elements and design of the transformers have been briefly described above. Design of control circuits and actual examples of the design of switching regulators are described in the "Applications" edition, to which we refer you.

DESIGN OF PUSH-PULL TYPE SWITCHING REGULATOR (APPLICATIONS)

1. INTRODUCTION

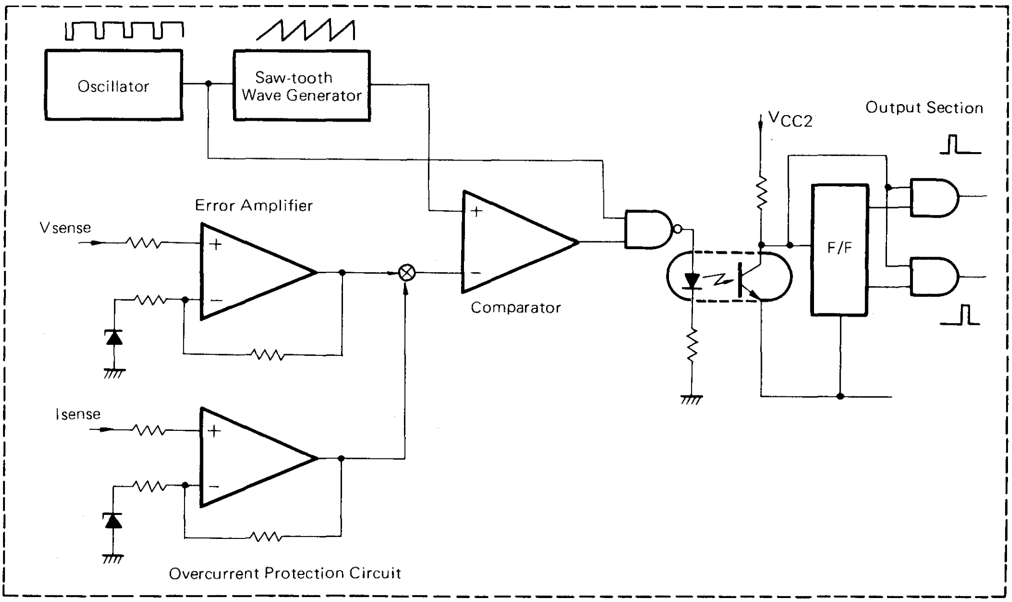
Switching regulators can be made smaller in dimension plus more efficient than conventional series regulators. Thus, they are dominating in design applications of power supply systems.

In this material, we present the design of pulse width modulation type control circuits, giving an example of actual design for a push-pull switching regulator as the succeeding item to Technical Data Sheet "Design Of Push-Pull Type Switching Regulator (Basics)."

2. DESIGN OF CONTROL CIRCUIT

Figure 1 represents the block diagram of the control circuit of a push-pull switching regulator.

Figure 1. Block Diagram of Control Circuit



In this material, the switching regulator is composed of four circuits; a circuit which performs pulse width modulation in response to the fluctuation of input power or load for the stabilization of output power voltage, an isolator which transmits an isolated pulse width-modulated signal, a frequency divider circuit which operates two switching elements alternately and an additional circuit (overcurrent protection circuit).

The saw-tooth wave generator output signal which is synchronized to the oscillator frequency is applied to the (+) input terminal of the comparator where it is compared with the amplified error signal from the power source and converted into a signal which is pulse width-modulated in response to the output voltage fluctuation of the power source. Because this output signal is often at a low level according to the status of error amplifier, it is AND'ed with the oscillator output signal with the specified quiescent time and further applied to the isolator.

In addition, the output signal of the overcurrent protection circuit is applied to the (−) input of comparator to prevent the collector current from increasing due to the short-circuiting of load, etc. The isolator uses the high speed photocoupler to transmit the signal which is pulse-modulated by approximately 40-kHz frequency. The light receiving side of the photocoupler divides the input signal into two, with a phase difference of 180°. by the two-phase clock circuit composed of a flip-flop and gates.

As explained above, the control circuit requires a logic IC in addition to linear IC. To minimize varieties of power source voltages, in this circuit design, CMOS is employed as a logic IC because of wide input voltage range and also because it can be used on a common line with the linear IC.

2-1 Oscillator

The oscillator determines the oscillation frequency of a switching regulator, as well as the maximum duty required for the elimination of ON-ON operation of the switching devices.

Figure 2 represents an astable multivibrator circuit composed of CMOS NAND gates and Figure 3, output waveform of the astable multivibrator.

Figure 2. Block Diagram of Oscillator circuit Composed of NAND Gates

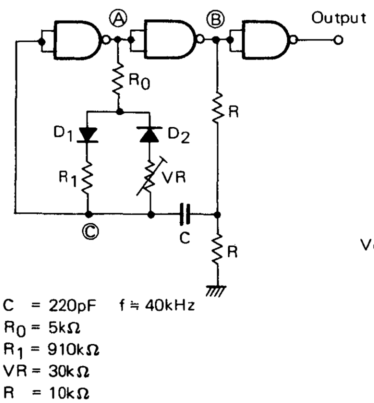
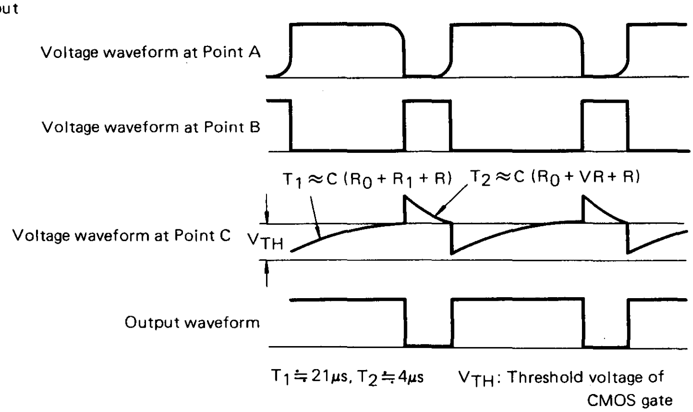


Figure 3. Waveform of Oscillator



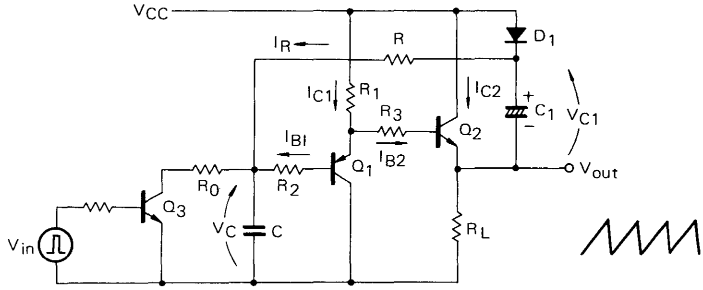
Since the charging and discharging paths of timing capacitor C are changed by diodes D_1 and D_2 in response to the direction of the current, the resultant voltage at point C is a combination of two waveforms of different time constants as shown in Figure 3.

2-2 Saw-tooth Wave Generator

Since a saw-tooth wave generator has great influence over the linearity of input voltage and pulse width of the succeeding comparator circuit, the output waveform of the saw-tooth wave generator should be of excellent linearity.

For such a circuit as explained above, a bootstrap circuit composed of discrete components is shown in Figure 4.

Figure 4. Saw-Tooth Wave Generator with Bootstrap Circuit



C = 560pF	R_0 = 47Ω	V_{BE1}: Base to emitter voltage of Transistor Q_1
C_1 = 1.5μF	R_1 = 15kΩ	V_{BE2}: Base to emitter voltage of Transistor Q_2
D_1: 1S953	R_2 = 100Ω	V_C : Voltage across Capacitor C
Q_1: 2SA603	R_3 = 47Ω	V_{C1} : Voltage across Capacitor C_1
Q_2, Q_3: 2SC943	R_L = 2kΩ	
	R = 56kΩ	

In Figure 4, suppose that the voltage across capacitor C is 0 V at the time t (=0). In this case, since the capacitor C is connected to the power source through diode D_1 and resistor R_L, voltage V_{C1} across capacitor C is, in equilibrium,

$$V_{C1} = V_{CC} - V_F \ \text{(V)} \qquad \text{(1)}$$

where

V_{CC}: Power source voltage of the circuit (V)

V_F : Forward voltage of diode D_1 (V)

Also, in this circuit, current I_R through feed back resistor R is

$$I_R = \frac{V_{C1} + V_{out} - V_C}{R} \ \text{(A)} \qquad \text{(2)}$$

as

$$V_{out} + V_{C1} - I_R \cdot R - V_C = 0 \ \text{(V)}$$

From

$$V_{out} = V_{E1} - R_3 \cdot I_{B2} - V_{BE2} \ \text{(V)}$$
$$V_{E1} = V_C + R_2 \cdot I_{B1} + V_{BE1} \ \text{(V)}$$
$$V_{out} = V_C + V_{BE1} - V_{BE2} + R_2 \cdot I_{B1} - R_3 \cdot I_{B2} \fallingdotseq V_C \ \text{(V)} \qquad \text{(3)}$$

as

$$V_{BE1} \fallingdotseq V_{BE2} \ \text{(V)}$$
$$R_2 \cdot I_{B1} \fallingdotseq R_3 \cdot I_{B2} \ll V_C \ \text{(V)}$$

Therefore, from equation (1), (2) and (3)

$$I_R \fallingdotseq \frac{V_{CC} - V_F}{R} \ \text{(A)} \qquad \text{(4)}$$

Thus, the current is constant regardless of output voltage V_{OUT}. And, therefore, the current through capacitor C is almost equal to I_R, if the base current of transistor Q_1 is disregarded.

$$V_c = \frac{1}{C}\int I_R \cdot dt = \frac{1}{C} I_R \cdot t \fallingdotseq \frac{(V_{CC} - V_F)}{CR} \cdot t \qquad \text{(5)}$$

Thus, output voltage V_{OUT} has the value in proportion to time t. On the other hand, charging voltage V_c of capacitor C is discharged through the resistor R_O when the transistor Q_3 turns on by the short pulse signal syncronized to the aforementioned oscillator signal.

Thus, saw-tooth waveforms can be obtained.

2-3 Pulse Width Modulator

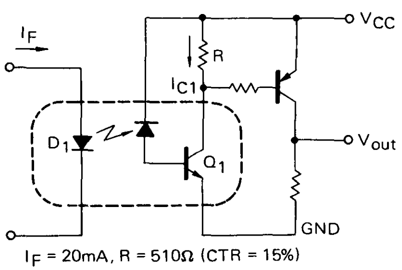
The pulse width modulator requires a high speed comparator to perform the pulse width modulation with approximately 40-kHz. frequency.

In addition, to avoid the occurrence of erroneous operation caused by noise in input signal, a Schmitt trigger circuit having hysteresis to the input circuit is employed.

2-4 Isolator

As an isolator to transmit a pulse width-modulated signal to isolating the input circuit from the signal transmission path, a pulse transformer can be used in addition to its proper application to the base driving circuit. But the photocoupler is preferable to pulse transformer in insulation resistance and CMR. For actual application, however, a high speed photocoupler is necessary because conventional photocouplers are not satisfactory due to the insufficient response speed. Figure 5 represents the isolator circuit with high speed photocoupler.

Figure 5. Isolator Circuit using High Speed Photocoupler



I_F : Input current at the light emitting side (forward current of light emitting diode D_1)

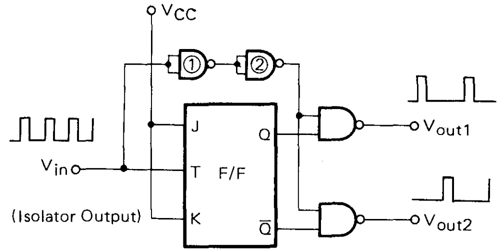
I_{C1}: Collector current of transistor Q_1 of light receiving side. (I_{C1} = CTR x I_F, CTR: Current transfer ratio)

At the light receiving side of photocoupler, a low-resistance resistor is required at the collector of transistor Q_1 for its operation in the active region to avoid the degradation in response speed which is dependent on the storage time of transistor Q_1. In addition, due to the presence of coupling capacitance between input and output circuits erroneous operation may be caused by the outside noise. And such countermeasure as inserting a capacitor of small capacitance between the base and emitter of transistor Q_1; is required to eliminate them.

2-5 Two-Phase Clock Circuit

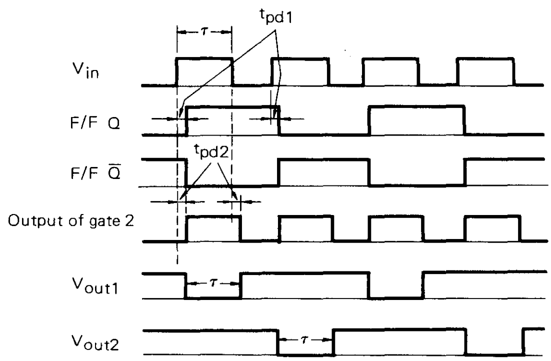
The two-phase clock circuit divides the signal which is pulse width-modulated by approximately 40 kHz frequency into two with difference in phase of 180° in order to make main switching devices operate alternately. Figure 6 represents the block diagram of two-phase clock circuit. In Figure 6, gates 1 and 2 are delay circuits to prevent the output signal from generating spikes by propagation delay time t_{pd} of flip-flop circuit. The delay time of approximately 75 ns can be obtained when the power source voltage V_{DD} is 10V.

Figure 6. Two-Phase Clock Circuit



The clock terminal of J-K flip-flop is used to make the circuit as T flip-flop. Figure 7 represents the operating waveform of this circuit.

Figure 7. Operating Waveform of Two-Phase Clock Circuit



t_{pd1}: Propagation delay time of flip-flop
t_{pd2}: Propagation delay time by two NAND gates

3. EXAMPLE OF 5V, 20A OUTPUT SWITCHING REGULATOR

3-1 Specifications of Power Supply and Test result

Table 1 shows specifications of trial-manufactured power supply with the test results in the right column.

Table 1. Specifications of Switching Regulator and Test Results of Trial-manufactured Unit

Characteristic	Symbol	Specifications	Test Results
Input Voltage	v_{in}	100V ±10% (AC 50Hz)	100V ±10%
Output Voltage	V_O	5V ± 10%	5V ±10%
Output Current	I_O	20A	20A
Ripple Voltage	V_{rip}	Within 20mV	14mV
Line Regulation		≦ ±0.25%	±0.22%
Load Regulation		≦ ±1%	+0.9%
Efficiency	η	> 70%	76%
Dimensions		–	130(H) x 125(W) x 197(D)mm^3

3-2 Schematic Diagram

Figure 8 represents the complete schematic diagram of 5V, 20A output switching regulator (push-pull type)

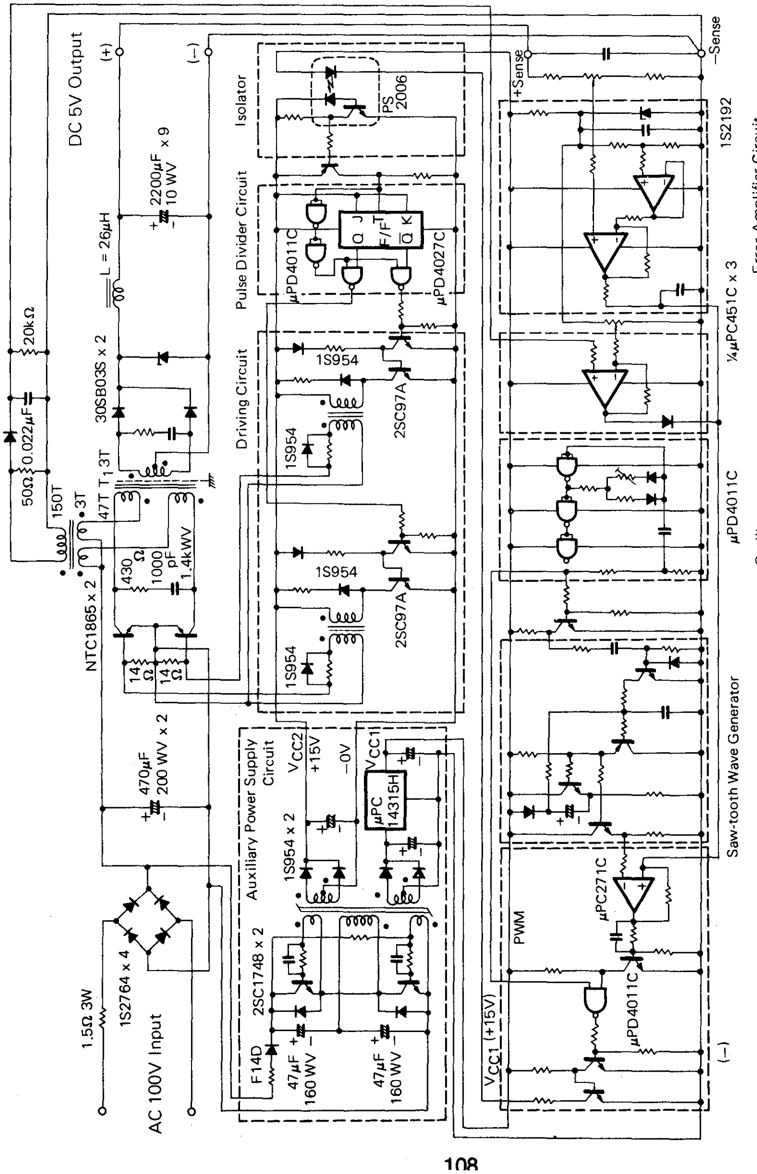
3-3 Design of Whole Blocks

(1) Rectifying and Smoothing Circuit of Primary Side

i) Rectifier

The input power P_{in} at rated output (P_O = 100W) is approximately 140 VA if the efficiency η is assumed 70%.

Figure 8. Schematic Diagram of 5V, 20A Output Switching Regulator (Push-Pull Type)



(Note) Diode out of specification: 1S953
NPN Transistor out of specification: 2SC943
PNP Transistor out of specification: 2SA603

In this case, an average current of approximately 1.4 A runs every half cycle in the rectifier. However, the conducting angle becomes narrower and surge current becomes larger, as the smoothing capacitance increases to decrease ripple components of input voltage. In addition, since a maximum of $2\sqrt{2}$ times AC input voltage V_{in} is applied to the bridge rectifier, it should have reverse breakdown voltage of approximately 400V when AC input is 100V.

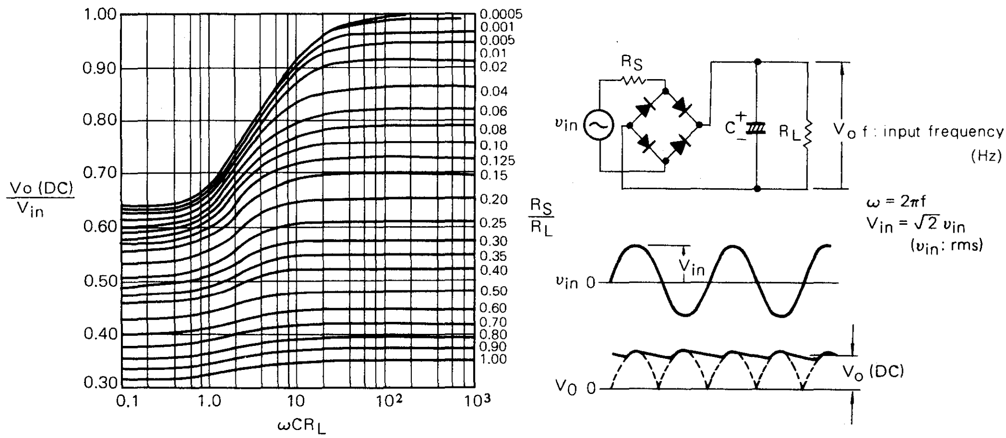
To comply with this requirement, NEC's 1S2764 is employed in this circuit, (V_{RRM} = 400V, V_F = 1.0V at I_F = 3.0A)

Resistance R_S for preventing the rush current differs with the rectifier and capacitance of smoothing capacitor and shown in the characteristic curve of the rectifier. It is approximately 1.4Ω for 1S2764 at C = 500μF.

ii) Smoothing Capacitor

Capacitance C of the smoothing capacitor is dependent on the load and the ripple reducing rate. It can be simply obtained from the chart prepared by 0. H. Schade. (Figure 9)

Figure 9. Chart for Circuit Constant of Full-Wave Rectifier Circuit



With input voltage V_{in} minimum and the load P_O maximum, and the smoothing output voltage V_O is set to 100V (minimum value), from

$$v_{in(min.)} = 90V, \quad P_{in(max.)} = \frac{P_{O(max.)}}{\eta} = \frac{5.5 \times 20}{0.70} \fallingdotseq 157 \text{ (W)}$$

(Supposing efficiency is 70%)

the peak value of output voltage is

$$V_{in(min.)} = \sqrt{2}\, v_{in(min.)} \fallingdotseq 127 \text{ (V)}$$

Therefore, the average output voltage is

$$V_{O(DC)} \geqq \frac{127 + 100}{2} \fallingdotseq 114 \text{ (V)}$$

11

Substituting the above results in the chart,

$$\frac{V_O(DC)}{V_{in(min.)}} \fallingdotseq 0.90 \qquad \frac{R_S}{R_L} \fallingdotseq \frac{1.4}{63.7} \fallingdotseq 0.022$$

as, $$R_{L(min.)} = \frac{(V_{O(min.)})^2}{P_{in(max.)}} \fallingdotseq 63.7 \ (\Omega)$$

thus,

$$\omega C R_L \geqq 20$$

therefore

$$C \geqq \frac{20}{\omega R_L} = \frac{20}{2\pi f R_L} \fallingdotseq \frac{20}{2\pi \times 50 \times 63.7} \fallingdotseq 9.99 \times 10^{-4} \ (F)$$

Therefore, two capacitors of 200V, 470μF are arranged in parallel (940μF) in this circuit.

(2) Design of Transformer

i) Core

Use Tohoku Kinzoku's EI type ferrite core FE140-3100B. The performances of this core are given in Table 2 below.

Table 2. Performances of Core FE140-3100B (from Ferrite Core Manual "Cat. No. FR-17" of Tohoku Kinzoku)

Item	Symbol	Specifications
Cross Section	A_e	1.46 cm^2
Magnetic Path Length	l_e	7.59 cm
Induction Coefficient	AL	1210nH at t = 0.13mm / 6040nH at t = 0*
DC Overlapping Characteristic	NI	≒ 20 AT at t = 0.13mm / 1.5 AT at t = 0
Effective Saturated Magnetic Flux Density	Bms	5200 Gauss

* t: Core Gap

ii) Winding

a) Number of Turns of Primary Winding N_p

from

$$N_p = \frac{V_{in}}{4 \cdot B \cdot A_e \cdot f}$$

Where: V_{in} = 130V, B = 2400 Gauss (= 0.24 wb/m^2), f = 20kHz, A_e = 1.46cm^2 (= 1.46X 10^{-4} m^2)

$N_p \fallingdotseq 46.4 \fallingdotseq 47$ (turns)

b) Diameter of the wire of Primary Winding D_p

from

$$D_P = \sqrt{\frac{4I_{in(av)}}{\delta\,\pi}} \qquad 2I_{in(av)} = \frac{P_{in}}{V_{o(DC)}} = \frac{157}{114} \fallingdotseq 1.38\ (A),\ \delta = 2A/mm^2$$

$$D_P \fallingdotseq \sqrt{\frac{4 \times \frac{1.38}{2}}{2 \times 10^6 \times 3.14}} \fallingdotseq 0.66\ \ (mm)$$

c) Number of Turns of Secondary Winding N_S

from

$$N_S = \frac{(V_O + V_F + I_O \cdot r_L) \cdot N_P \cdot T}{2\tau \cdot V_P}$$

where

$V_O = 5.5V$, $V_F = 0.5V$ ($I_F = 20A$), $r_L = 0$, $T = 50\mu s$, $\tau = 23\mu s$,
$N_P = 47$, $V_P = V_{in(DC)} = 100V_{min.}$

$N_S \fallingdotseq 3.06 \fallingdotseq 3$ (turns)

d) Shape of Secondary Winding

From the standpoint of skin effect, use wheel winding with a copper plate of 15mm width and 0.3mm thickness considering the bobbin shape of core.

e) Electrostatic Shield

Use alminum foil. Ground the foil to the case.

f) Core Gap and Inductance of Primary Side

Due to the difference in storage time of switching devices DC superimposed current flows through the circuit of primary side, so the core should have DC superimposed characteristics.

When designing, DC superimposed characteristic NI is set to 20 AT considering the margin for NI, from

$t = 0.13mm$, $AL = 1210nH$

inductance L_P of primary side is

$L_P = AL \cdot N_P^2 \cdot 10^{-9} = 1210 \times 47^2 \times 10^{-9} \fallingdotseq 2.67$ (mH)

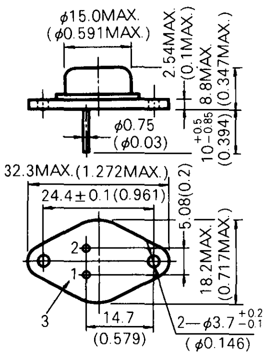
(3) Selection of Switching Devices

Prepare two transistors NTC1865 for switching devices to effectuate the push-pull operation at AC 100V line, remembering that V_{CE} is 280V and I_C is 2A.

Table 3 represents a summary of the characteristics of transistor NTC1865.

Table 3. Characteristics of NTC1865

PACKAGE DIMENSIONS
in millimeters (inches)



1. Base
2. Emitter
3. Collector(Case)

EIAJ :TC-16, TB-23
JEDEC:TO-66
IEC :C13

FEATURES
- High speed switching.
- Low collector saturation voltage.

ABSOLUTE MAXIMUM RATINGS
Maximum Voltages and Currents (Ta = 25°C)

Collector to Emitter Sustaining Voltage	$V_{CEO(sus)}$	400	V
Collector to Emitter Sustaining Voltage	$V_{CE(sus)}$	450	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Continuous Collector Current	$I_{C(DC)}$	7.0	A
Peak Collector Current	$I_{C(Pulse)}$*	15	A
Continuous Base Current	$I_{B(DC)}$	4.0	A
Maximum Power Dissipation (T_C = 25°C)			
Total Power Dissipation	P_T	50	W
Maximum Temperature			
Junction Temperature	T_j	200	°C
Storage Temperature	T_{stg}	−65 to +200	°C

*Pulse PW ≦ 300 μs, duty cycle ≦ 10%

ELECTRICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CEX}			100	μA	V_{CE} = 500V, $V_{BE(OFF)}$ = −1.5V
Emitter Cutoff Current	I_{EBO}			100	μA	V_{EB} = 5.0V, I_C = 0
DC Current Gain	h_{FE1}	15		100		V_{CE} = 5.0V, I_C = 3.0A*
	h_{FE2}	10				V_{CE} = 5.0V, I_C = 5.0A*
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	I_C = 5.0A *
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	I_B = 1.0A
Turn On Time	t_{on}			1.0	μs	I_C = 5.0A, I_{B1} = $-I_{B2}$ = 1.0A
Storage Time	t_{stg}			2.0	μs	R_L = 30Ω, V_{CC} ≃ 150V
Fall Time	t_f			0.7	μs	

*Pulsed PW ≦ 350μs, duty cycle ≦ 2%

(4) Rectifying and Smoothing Circuit of Secondary Side

i) Selection of Rectifier Elements

Use 30A schottky barrier diode 30SBO3S. Table 4 gives characteristics of this diode.

Table 4. Characteristics of 30SB03S

	Item	Symbol	Conditions	Standard
Maximum Rating	Repetitive Peak Reverse Voltage	V_{RRM}	———	30V
	Forward Current	$I_{F(AV)}$	$T_C = 64°C$, duty cycle $\leqq 50\%$	33A
		$I_{F(RMS)}$	———	47A
	Junction Temperature	T_j	———	100°C
Charac-teristics	Repetitive Peak Reverse Current	I_{RRM}	$T_j = -40$ to $+100°C$, $V_{RM}=V_{RRM}$	150mA
	Forward Voltage	V_{FM}	$I_{FM} = 100A$	0.8V
	Thermal Resistance	$R_{th(j-c)}$	between Junction and Case, DC	1.4°C/W

ii) Choke Coil

a) Inductance of Choke Coil

from

$$L \geqq \frac{(3.5 \sim 5) \cdot (V_S - V_O) \cdot V_O \cdot T}{I_{omax.} \cdot V_S}$$

where

$$V_S = \frac{N_S}{N_P} \cdot V_{in(DC)} = \frac{3}{47} \cdot 130 \fallingdotseq 8.3V, \qquad I_{omax.} = 20A,\ T = 50\mu s$$

$$L \geqq \frac{3.5 \times (8.3 - 4.5) \times 4.5 \times 50 \times 10^{-6}}{20 \times 8.3} \fallingdotseq 18\ (\mu H)$$

b) Core and Number of Turns

Considering the applicable current and the required inductance, use core FEI40-3100B of Tohoku Kinzoku giving a gap of t = 1.8mm under DC superimposed characteristic NI = 300 AT. (AL = 181 nH)

For winding, use a copper plate (t = 0.3mm, W = 15mm). In this case, the number of turns is N = 12 (turns).

Therefore

$$L = AL \cdot N^2 \cdot 10^{-9} = 181 \times 12^2 \times 10^{-9} \fallingdotseq 26\ (\mu H)$$

c) Smoothing Capacitor

In normal cases, an electrolytic capacitor is used as a smoothing capacitor. However, a capacitor of low impedance which has excellent impedance Z_C for frequencies over 10 kHz is especially desirable.

For this reason, Nippon Tsusin Kogyo's "Rawimpac" is applicable.

The impedance Z_C required by the capacitor can be obtained as follows:

from

$$Z_C = \frac{V_{rip.}}{V_S} \cdot \omega \cdot L \qquad Z_C \leqq 7.9 \times 10^{-3}\ (\Omega)$$

11

where

$V_S \fallingdotseq 8.3V$, $V_{rip.} \leqq 20mV$, $\omega = 2\pi f$, $f = 20kHz$, $L = 26\mu H$

To satisfy the above impedance requirement, use aluminum electrolytic capacitors (10 WV, 2200 μF X 9 (19800μF)).

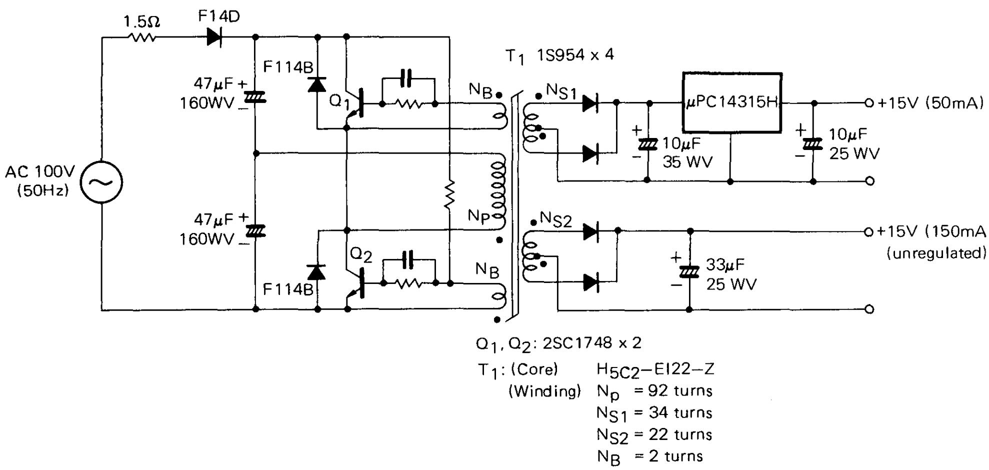
(5) Auxiliary Power Supply Circuit

Use self-running half-bridge type DC—DC converter shown in Figure 10. With such DC—DC converter, the voltage applied to the transistor can be smaller than push-pull type power source voltage.

i) Specifications

Input Voltage (V_{in}) : 100 ~ 150V
Output Voltage (V_{O1}): 15V (for stabilized output)
Output Voltage (V_{O2}): 15V (for unstabilized output)
Output Current (I_{O1}) : 50mA (for control circuit)
Output Current (I_{O2}) : 150mA (for driver)
Frequency : 10 kHz

Figure 10. Schematic Diagram of Half-Bridge Type DC—DC Converter



ii) Applicable Transistor

As can be seen from the characteristics given above, the auxiliary power supply circuit requires power of approximately 3W. As a result, a current of approximately 50 mA runs across the transistor. Therefore, use transistor 2SC1748. Table 5 presents characteristics of transistor 2SC1748.

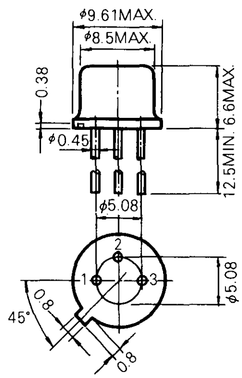
Table 5. Characteristics of 2SC1748

Absolute Maximum Ratings (Ta = 25°C)

Item	Symbol	Rating	Unit
Collector to Base Voltage	V_{CBO}	300	V
Collector to Emitter Voltage	V_{CEO}	300	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Collector Current (DC)	$I_{C(DC)}$	100	mA
Collector Current (pulse)	$I_{C(pulse)}$*	150	mA
Base Current (DC)	$I_{B(DC)}$	50	mA
Total Power Dissipation (Ta = 25°C)	P_T	800	mW
Junction Temperature	T_j	150	°C
Storage Temperature	T_{stg}	−65 to +150	°C

* PW ≦ 10 ms, duty cycle ≦ 50%

Package Dimensions (Unit:mm)



1. Emitter
2. Base
3. Collector (Case)

EIAJ : TC-5, TB-5B
JEDEC: TO-205MD (TO-39)
IEC : C4, B4B

Electrical Characteristics (Ta = 25°C)

Characteristic	Symbol	Test Conditions	MIN.	TYP.	MAX.	Unit
Collector Cut-off Current	I_{CBO}	V_{CB} = 300V, I_E = 0			1.0	μA
Emitter Cut-off Current	I_{EBO}	V_{EB} = 5.0V, I_C = 0			100	nA
DC Current Gain	h_{FE}	V_{CE} = 2.0V, I_C = 50mA *	30	60	150	
Collector Saturation Voltage	$V_{CE(sat)}$	I_C = 50mA, I_B = 5.0mA *		0.12	1.0	V
Base Saturation Voltage	$V_{BE(sat)}$	I_C = 50mA, I_B = 5.0mA *		0.75	1.5	V
Gain-bandwidth Product	f_T	V_{CE} = 30V, I_E = −10mA		50		MHz
Collector Capacitance	C_{ob}	V_{CB} = 30V, I_E = 0, f = 1.0MHz		4.2		pF
Turn-on Time	t_{on}	I_C = 50mA, I_{B1} = $-I_{B2}$ = 5.0mA		0.3		μs
Storage Time	t_{stg}			3.5		μs
Turn-off Time	t_{off}			4.0		μs

Pulsed PW ≦ 350μs, duty cycle ≦ 2%

iii) Design of Transformer for Converter

a) Type of Core

Use core H_5C_2−EI_{22}−Z of TDK for its rectangular hysterisis loop characteristic.

Effective area (A_e): 0.41 cm^2

Effective Saturation

Magnetic Flux Density (B_{ms}): 4300 Gauss (T_a = 25°C)

Induction Factor (AL): 10000 nH (at t = 0)

DC Superimposed Characteristics (NI): 0.9 AT (at t = 0)

b) Number of Turns and Diameter of Winding

Number of turns (N_p) of the primary winding is as follows:

from

$$N_P = \frac{V_{in}}{4 \cdot B_{ms} \cdot A_e \cdot f}$$

$$N_P = \frac{65}{4 \times 4300 \times 10^{-4} \times 0.41 \times 10^{-4} \times 10 \times 10^3} \fallingdotseq 92 \text{ turns}$$

Diameter of winding for the primary winding is as follows:
from

$$D_P \geqq \sqrt{\frac{4 I_{c(av)}}{\pi\, \delta}}, \quad I_{c(av)} = \frac{\frac{P_o}{7}}{V_{in}}$$

$$I_{c(av)} = \frac{\frac{3}{0.70}}{50} \fallingdotseq 86\text{mA} \quad (\text{supposing } \eta = 70\%)$$

therefore

$$D_P \geqq \sqrt{\frac{4 \times 86 \times 10^{-3}}{\pi \times 2 \times 10^6}} \fallingdotseq 0.23\text{mm}\phi$$

Numbers of turns (N_{S1} and N_{S2}) of the secondary winding are as follows:
from

$$N_{S1} = \frac{V_{S1}}{V_{in}} \cdot N_P, \quad V_S = V_{o1} + 2.5 + 0.7$$

$$N_{S1} = \frac{15 + 2.5 + 0.7}{50} \times 92 \fallingdotseq 34 \text{ turns}$$

and from

$$N_{S2} = \frac{V_{S2}}{V_{in}} \cdot N_P$$

$$N_{S2} = \frac{15}{65} \times 92 \fallingdotseq 22 \text{ turns}$$

Wire diameters (D_{S1} and D_{S2}) of the secondary winding are as follows:
from

$$D_{S1} \geqq \sqrt{\frac{4 I_{S1(av)}}{\pi\, \delta}}, \quad I_{S1(av)} = I_{o1} = 50\text{mA}$$

$$D_{S1} = \sqrt{\frac{4 \times 50 \times 10^{-3}}{\pi \times 2 \times 10^6}} \fallingdotseq 0.18\text{mm}\phi$$

and from

$$D_{S2} = \sqrt{\frac{4 I_{S2(av)}}{\pi\, \delta}}, \quad I_{S2(av)} = I_{o2} = 150\text{mA}$$

$$D_{S2} = \sqrt{\frac{4 \times 150 \times 10^{-3}}{\pi \times 2 \times 10^6}} \fallingdotseq 0.30\text{mm}\phi$$

c) Core Gap and Inductance

The core for a converter is used with saturated magnetic flux.

When fixing the EI core, the gap should be kept as small as possible to reduce the exciting current by striking the contacting surfaces to each other.

Inductance L_P of the primary winding is,

from

$$L_P = AL \cdot Np^2 \cdot 10^{-9}$$

$$L_P = 10000 \times 92^2 \times 10^{-9} \fallingdotseq 85 \text{ (mH)}$$

Therefore, exciting current I_{PK} is

from

$$I_{PK} = \frac{V_{in}}{L_P} \cdot \tau$$

$$I_{PK} = \frac{65}{85 \times 10^{-3}} \times 50 \times 10^{-6} \fallingdotseq 38\text{mA}$$

(6) Base Driving Circuit

As shown in Figure 11, pulse transformer is used in base driving circuit for the current amplification.

i) Design of Transformer

a) Core

Use core H_{5A}–EI22–Z of TDK.

Effective Area (A_e): 0.41 cm^2

Magnetic Path Length (1_e): 4.42 cm

DC Superimposed Characteristics ($NI/1_e$): Approx. 2.5 AT/cm

AL-Value (AL): 600 nH (at t = 60 μm, $\mu_{rev.}$ = 500)

b) Base Current I_B

Base current I_B can be obtained in relation to the drive ratio ($I_{cmax.}/I_B \fallingdotseq 5 \sim 10$) with the maximum collector current.

from $$\frac{P_O}{\eta} = \frac{\tau}{T} \cdot I_{Cmax.(av)} \cdot V_{in}$$

$$I_{Cmax.(av)} = \frac{P_O}{\eta} \cdot \frac{T}{\tau} \cdot \frac{1}{V_{in}} = \frac{110}{0.75} \cdot \frac{50}{44} \cdot \frac{1}{100} \fallingdotseq 1.67 \text{ (A)}$$

where

$P_O = V_O \times I_O = 5.5 \times 20 = 110$ (W),

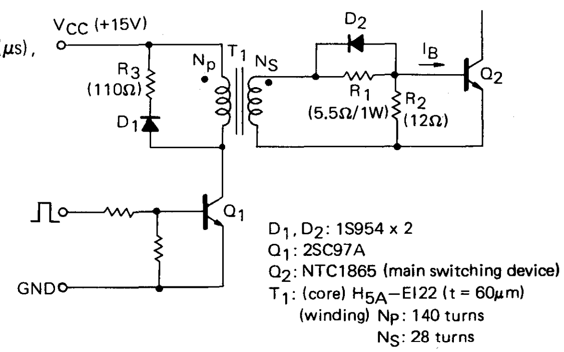
$\eta = 75\%$, $T = 50\mu s$, $\tau = 22 \times 2 = 44$ (μs),

$V_{in} = 100V$ (min.)

Therefore

$$I_B = \frac{I_{Cmax.}}{5} \fallingdotseq \frac{1.67}{5} \fallingdotseq 350 \text{ (mA)}$$

Figure 11. Base Driving Circuit



c) Number of Turns and Diameter of Winding

The primary winding requires the maximum number of turns to make the loss caused by exciting current small. Therefore, it is represented as following.

$N_P = 140$ (turns)

The number of turns for the secondary winding is,

from

$$N_S = \frac{V_S}{V_{CC}} \cdot N_P, \quad N_S = 28 \text{ (turns)}$$

where

$V_S = 3$ V, and $V_{CC} = 15$ V

Diameters of Windings are as follows:

Diameter (D_p) of Primary Winding : 0.2 mm

Diameter (D_s) of Secondary Winding: 0.4 mm

(7) Overcurrent Sensing Circuit

According to the test result, details of the current transformer for the overcurrent detector circuit are as follows:

i) Applicable Core

H_{5C2} T14.5–20–7.5 of TDK

ii) Number of Turns and Diameter of Winding

N_p: 3 (turns)

N_s : 150 (turns)

D_p: 0.8 mm

D_s : 0.4 mm

iii) Sensing Sensitivity

With the component parts given above, the test results are as follows:

Detection Sensitivity: 1.64 V/A

Sag (Droop: D) : 2.4% (where $I_{in} = \sim 5$A and $\tau = 20\ \mu s$)

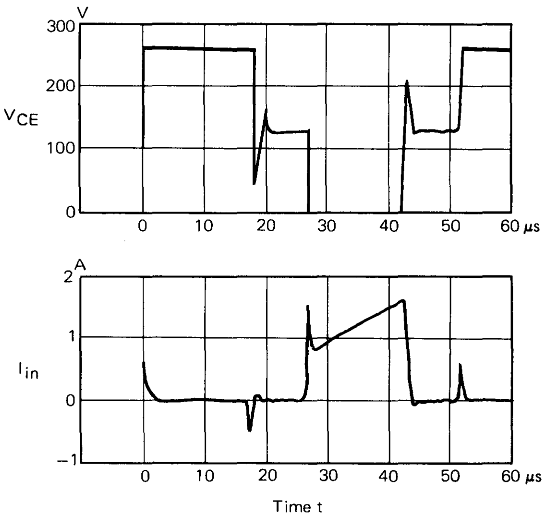
3-4 Operating Waveform

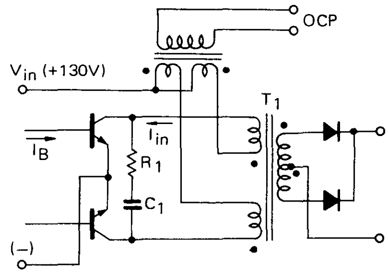
Figure 12 shows the operating waveform of the trial-manufactured switching regulator with actual loading.

The surge voltage applied to a transistor is due to the leakage inductance of transformer T_1. Thus, the surge absorbing circuit (C and R) is required to prevent the surge voltage from exceeding the breakdown voltage of the transistor.

In this circuit design, inductance L_p of the primary side of transformer T_1 is set to 2.67 mH. If a margin is left for the DC superimposed characteristics, gap t of transformer T_1 can be set to 40 μm (L_p = 5mH).

Figure 12. Operating Waveforms of Switching Regulator





R_1, C_1 : Surge Absorption Circuit

R_1 = 430Ω, 2W

C_1 = 1000pF, 1.4kWV

Conditions

Input Voltage : 100V (AC 50Hz)

Output Voltage: 5V

Output Current: 20A (full load)

4. CONCLUSION

We have given general descriptions on examples of the switching regulator design. We are not able to touch on the design of the heat sink for lack of space.

For the trial-manufactured circuits in this technical data sheet, we have not finished the examinations of transient response and temperature characteristics. In addition, the circuit constants are not suited for mass-production of the circuit, due to the lack of consideration of the deviation and temperature characteristic of the component parts.

It is noted that we cannot take the responsibility for any claim or suit on the patent right regarding the circuit illustrated in this technical data sheet.

SWITCHING REGULATOR CONTROL IC μPC1042C APPLICATION CIRCUIT

1. INTRODUCTION

The switching regulator has been noticeably improved about weight, dimensions, and efficiency as compared with the conventional series regulator. On the other hand, however, its control circuit being very complicated, requires many knowhows. μPC1042C contains such a complicated control circuit in one chip by making the best use of features of monolithic IC, and it permits reducing the number of component and mounting and adjusting manhours to a large extent as compared with a circuit using discrete devices. It is also provided with various protection circuits to cover many technical problems which may arise when designing a switching regulator. It is, thus, the best suited as a control circuit for line operate type switching regulator.

2. FEATURES AND OUTLINED SPECIFICATIONS OF μPC1042C

μPC1042C is a control IC adopting the most popular pulse width modulation (PWM) system and the push-pull output composition to apply to push-pull or bridge type regulator. It features as listed below.

* Symmetrical triangular oscillation output
* Dead time is adjustable over 0 to 100%
* Three external phase compensating terminals are provided
* The common mode input voltage of over-current protection error amplifier ranges up to GND level (0 to 3V).
* No double pulsing of same output during load transient conditions
* Malfunction prevention circuit is built in for low level inputs.

Fig. 1 indicates the block diagram of this IC. One chip of this IC accommodates operational amplifiers, timer, reference, gate, flip-flop, and other circuits corresponding to 5 to 6 ICs required in conventional discrete circuit composition, and it is the best suited for a line operate type push-pull type (or bridge type) switching regulator control circuit. In case of a push-pull type with an AC 100V input, the final-stage transistor can directly be driven via a pulse transformer by the built-in buffer transistor, and no external transistor is needed when the output capacity of the power supply is 25W max.

Fig. 2, Table 1 and Table 2 indicate the terminal connections and outlined specifications of μPC1042C.

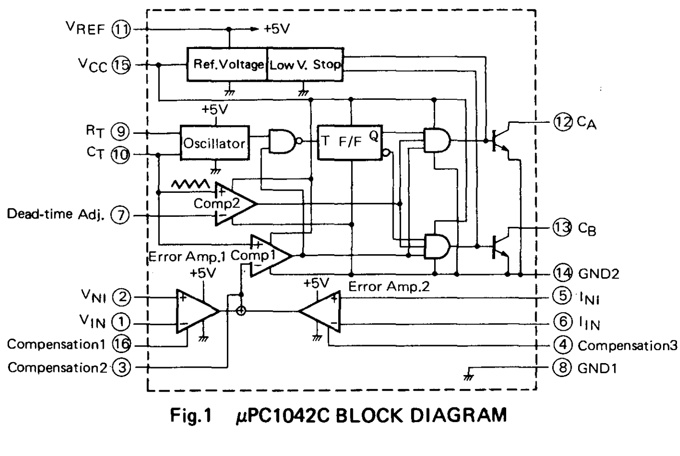


Fig.1 μPC1042C BLOCK DIAGRAM

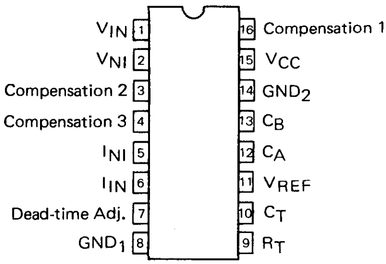


Fig. 2 CONNECTION DIAGRAM
(Top View)

TABLE 1 ABSOLUTE MAXIMUM RATINGS (Ta=25°C)

ITEM	SYMBOL	RATING	UNIT
Supply Voltage	V_{CC}	30	V
Output Voltage	V_{CER}	40	V
Output Current (each output)	I_C	100	mA
Reference Output Current	I_{REF}	40	mA
Total Power Dissipation (Ta=25°C)	P_T	800	mW
Operating Temperature Range	Topt	–20 to +85	°C
Storage Temperature Range	T_{stg}	–40 to +125	°C

TABLE 2 ELECTRICAL CHARACTERISTICS (V_{CC}=12V, Ta=25°C unless otherwise noted)

BLOCK	CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Reference Section	Output Voltage	V_{REF}	4.6	5.0	5.4	V	I_{REF}=0
	Temperature Coefficient	$\Delta V_{REF}/\Delta T$		200	750	μV/°C	–20°C≦T_{opt}≦+85°C
Low Voltage Stop Sec.	Start-up Voltage	V_{CC}(L to H)		7.5		V	0≦V_{CC}≦12V
	Hysteresis Voltage	V_H		0.5		V	0≦V_{CC}≦12V
Oscillator Section	Maximum Oscillation Frequency	fmax	100			kHz	
	Initial Accuracy			±5	±10	%	R_T,C_T constant
	Temperature Stability			–6	–10	%	–20°C≦T_{opt}≦+85°C
Error Amp. 1 Section	Input Offset Voltage	$V_{IO(1)}$		±2	±10	mA	
	Large Signal Voltage Gain	A_{V1}	72	87		dB	
	Common Mode Voltage		1.2		4.0	V	
	Small Signal Bandwidth	f_{01}		2		MHz	A_{V1}=0dB,C_1=560pF,C_2=150pF
Error Amp. 2 Section	Input Offset Voltage	$V_{IO(2)}$		±3	±10	mV	
	$V_{IO(2)}$ Temperature Coefficient	$\Delta V_{IO(2)}/\Delta T$		±3	±10	μV/°C	–20°C≦T_{opt}≦+85°C
	Large Signal Voltage Gain	A_{V2}	72	100		dB	
	Common Mode Voltage		0		3	V	
	Small Signal Bandwidth	f_{02}		1.2		MHz	A_{V2}=0dB,C_3=220pF,C_4=470pF
	Maximum Output Current	$I_{O(AMP)}$			1.0	mA	
Output Section	Collector to Emitter Voltage	V_{CER}	40			V	I_C=1mA
	Collector Emitter Cutoff Current	I_{CER}			10	μA	V_{CE}=40V
	Collector Saturation Voltage	$V_{CE(sat)}$		0.55	0.7	V	I_O=20mA
	Rise Time	t_r		80		ns	I_C=20mA
	Fall Time	t_f		70		ns	V_{CC}=12V,R_L≒560Ω
Total Standby Current		I_{CC}		12	15	mA	V_{CC}=20V, I_{REF}=0

11

3. COMPOSITION AND OPERATION OF EACH BLOCK

(1) Outlined operation of each block

The operation of the block diagram shown in Fig. 1 will be outlined below.

i) Reference voltage block

An internal series regulator produces a +5V reference voltage from the power supply voltage given via Vcc terminals. It gives the reference voltage to external circuits through No. 11 terminal. It also serves as the power supply for analog circuits (error amplifier, oscillator, etc.) built-into the IC.

ii) Oscillator block

This circuit produces symmetrical triangular wave oscillation outputs by externally connecting a timing resistor and a capacitor, and gives this output to external circuit with a 2~4V swing through No. 10 terminal. This waveform is input to (+) input terminals of comparators 1, 2 in the IC via one-stage emitter-follower. The oscillator block produces a square wave oscillation output being synchronized with the above triangular wave output, and this output is employed as an input signal to the flip-flop (F/F) described later.

iii) Comparators

The comparators (1 and 2) are voltage-pulse width converters for modulating the pulse width according to input voltages. Comparator 2 is used for adjusting the dead time to avoid simultaneous turn-on (usually called cross current conduction) of two transistors which may cause a problem when the switching regulator transformer is push-pull operated. In order to adjust the duty over a range of 0 to 100% from outside, (—) input terminal is provided via No. 7 terminal.

Comparator 1 is a PWM for stabilizing the power output. The added signals are given to this (—) input terminal from error amplifier I for controlling output voltage, and error amplifier 2 for controlling the output current to stabilize the power output voltage and to get a constant output current drooping characteristic for protecting the power supply from overload.

Comparator 1 output signal is input as a clock signal of the following T-type flip-flop via NAND gate together with the square wave output produced by the preceding oscillator, and then, it is frequency-divided by this flip-flop for the purpose of obtaining the 2-phase output composition.

Since the clock signal is not input to the T-type flip-flop when comparator 1 output signal is in zero duty, no inversion action occurs. Thus, so-called double pulse phenomenon can be avoided.

iv) Error amplifiers

Error amplifiers 1, 2 are used for detecting the output voltage and output current of the power supply, respectively.

After addition by the emitter-follower, these error amplifier outputs are input to the (—) input terminal of comparator 1. This adding point is taken out externally via No.3 terminal, and the loop gain can optionally be set by externally connecting a feedback resistor between each (—) input terminal and this terminal. The common mode input voltage range of error amplifier 1 is 1.2 to 4V, and the V_{REF} output is given to the other input terminal by resistance division as a reference input voltage.

Error amplifier 2 adopts a PNP composition in its first stage, and therefore, its common mode input voltage ranges from 0 to 3V. Thus, it is applicable to the method of detecting and controlling a voltage drop of a very small resistance inserted into ordinary GND line, when obtaining the constant current drooping characteristic, of the power supply.

These error amplifiers contain 3 pins including No. 3 terminal as phase compensating terminals, so that the frequency response of the gain is variable by two external capacitors, respectively.

v) Output block

The output block adopts the two output composition (push-pull composition) system, in such a manner that emitter grounded open collector output transistors are alternately operated at max. 50% duty at active low.

Accordingly, when the 100% max. duty is required for a chopper circuit, etc., it can be realized by wired-OR of two outputs.

Fig. 3 indicates the timing chart for operating waveform of each block

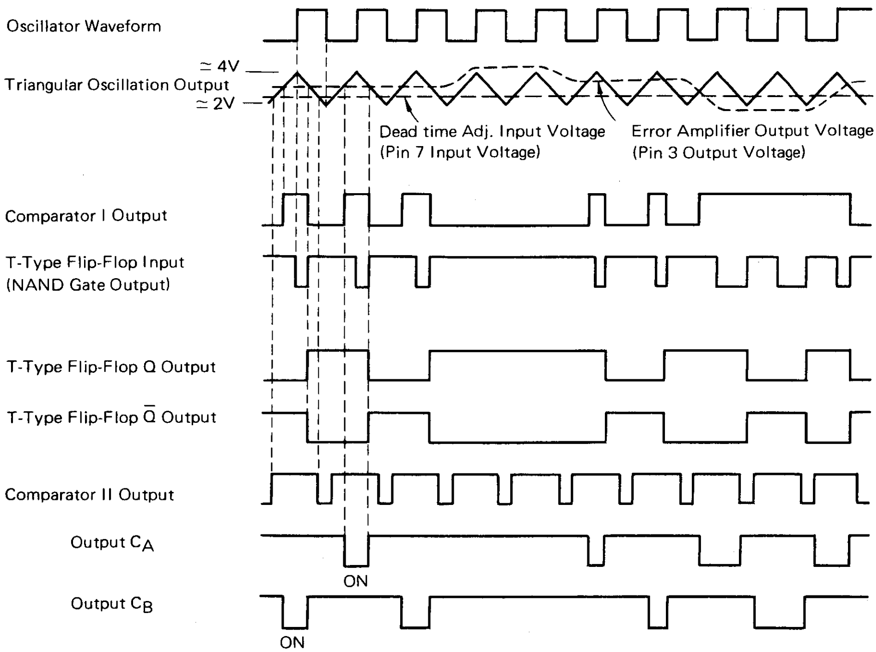


Fig.3 INTERNAL WAVEFORMS (TIMING CHART)

(2) Circuit compositions and operation

i) Reference voltage block

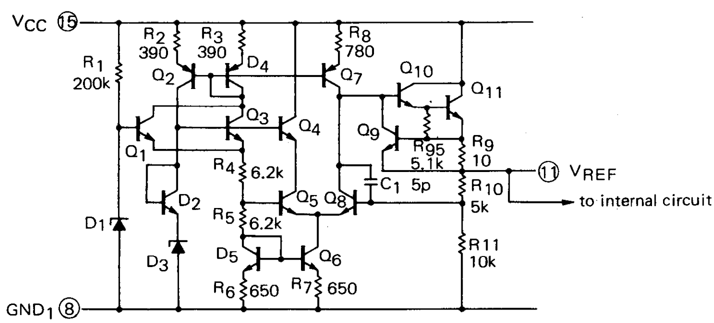


Fig.4 REFERENCE VOLTAGE CIRCUIT COMPOSITION

11

When Q_1 is turned on by the start-up circuit consisting of R_1 and D_1, D_4 is biased via Q_1 collector, and also Q_2 and Q_7 operate to start the reference voltage block. Q_2, D_4 and Q_7 compose a constant current bias circuit, so that a constant current proportional to the D_4 collector current flows according to the resistance ratio of R_2, R_3, and R_8 under steady-state condition, respectively.

The reference voltage circuit consisting of D_2 and D_3 outputs a reference voltage of about 6.4V by means of the constant bias current flowing from Q_2 collector. Under this condition, the Q_1 emitter potential becomes about 5.7V, and the base-emitter circuit is reverse biased and cut off.

The output is stabilized by the Q_5, Q_8 current mirror circuit. The reference voltage output is obtained by the following equation at this time.

$$V_{REF}=\left\{(V_{ZD3}+V_{BED2}-V_{BEQ3}-V_{BED5})\cdot\frac{R_5+R_6}{R_4+R_5+R_6}+V_{BED5}\right\}\cdot\frac{R_{10}+R_{11}}{R_{11}}\fallingdotseq 5V$$

R_9 serves as a short-circuit protection resistor, and if output current I_{REF} exceeds the specified value, Q_9 turns on to lower the Q_{10} base potential.

ii) Malfunction prevention circuit at low level input

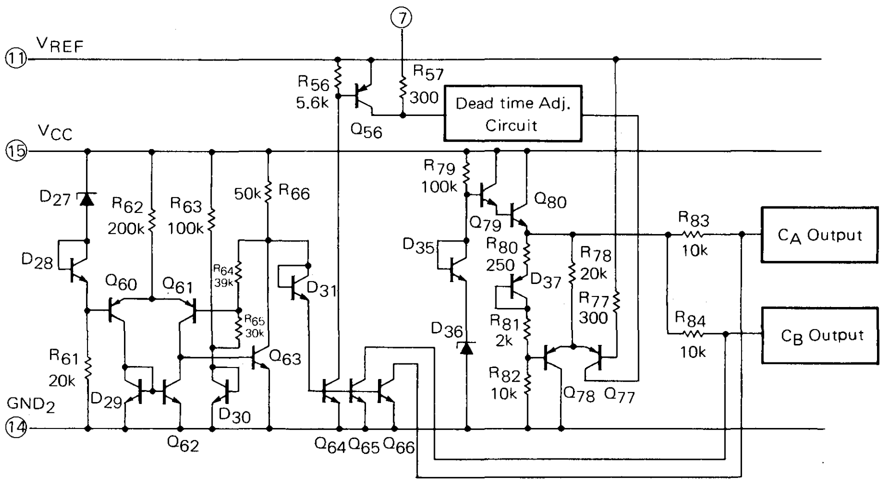


Fig.5 COMPOSITION OF MALFUNCTION PREVENTION CIRCUIT AT LOW INPUT

This circuit cuts the output circuit bias to prevent a malfunction due to unstable operation of the oscillator, etc. when the power supply voltage input to μPC1042C is lower than specified. Its detector part consists of the following two circuits.

One is the differential amplifier consisting of Q_{60} and Q_{61}, which detects power voltage Vcc. If Vcc exceeds about 7.5V, the differential amplifier is reversed by the voltage which biases R_{61} via D_{27}, D_{28}, causing Q_{63} to turn on. Thus, Q_{64}~Q_{66} are cut off to release the output part. Since Q_{56} remains turned on during hold time, unnecessary charging of the soft start capacitor externally connected to No. 7 terminal, can be avoided.

In addition, two bias points are given to Q_{61} by ON-OFF operation of Q_{63} so as to obtain a hysteresis width of about 0.5V as shown by the following equation. Thus, a chattering phenomenon due to a ripple component of Vcc can be avoided.

Hysteresis width $$V_H=\frac{R_{65}}{R_{64}+R_{65}}\cdot(V_{BEQ60}+V_{BEQ61})\fallingdotseq 0.56\ (V)$$

The other is the V_{REF} detector circuit to prevent a malfunction against slow rising (an effect by the output limiter circuit in the reference voltage block) caused by addition of a large-capacity capacitor to the V_{REF} output terminal.

The output of the differential amplifier consisting of Q_{77} and Q_{78} stops the dead time adjusting circuit to hold the output block.

Fig. 6 shows the operating waveforms of this malfunction prevention circuit.

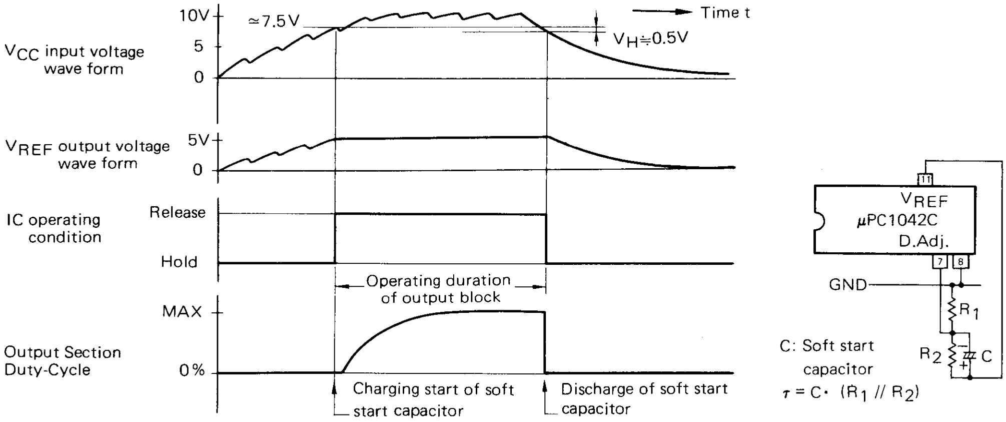


Fig.6 OPERATING WAVE FORMS OF MALFUNCTION PREVENTION CIRCUIT AT LOW LEVEL INPUT

iii) Oscillator block

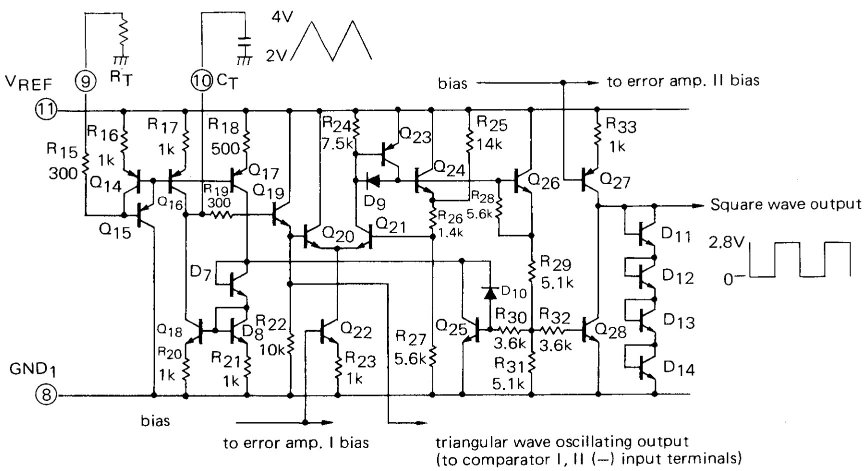


Fig.7 OSCILLATOR CIRCUIT DIAGRAM

The oscillator block is composed of a constant current source and a level detector amplifier. It is self-oscillated by externally connecting a timing resistor and a capacitor to No. 9 and 10 terminals, causing two oscillating waveforms (tirangular and square waveforms) to be output.

The triangular wave oscillating output is obtained by the charge and discharge of the external capacitor by means of positive/negative constant current sources.

As shown in Fig. 8 "principle diagram", the constant current source is composed of a positive constant current source A_1 and a negative constant current source which is on-off controlled by a level detector amplifier A_3 having a hysteresis.

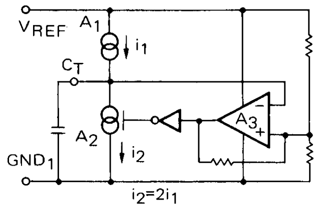


Fig.8 PRINCIPLE DIAGRAM OF A TRIANGULAR WAVE OSCILLATOR

Oscillation frequency f determined by the external capacitor and resistor can be obtained approximately by the following equation.

$$\frac{10^3}{f} = 1.05 \cdot C_T \cdot (R_T + 1.3) + 1.5$$

f : [kHz]
C_T : [nF]   Applicable range $C_T \geqq 200\text{pF}$
R_T : [kΩ] $10\text{k}\Omega \leqq R_T \leqq 100\text{k}\Omega$

iv) Error amplifier I

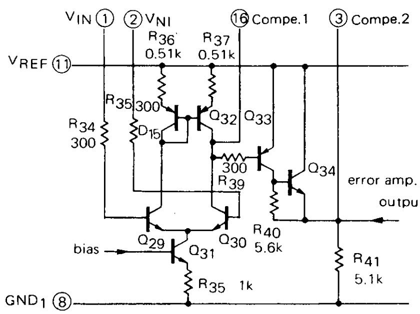


Fig.9 ERROR AMPLIFIER I CIRCUIT DIAGRAM

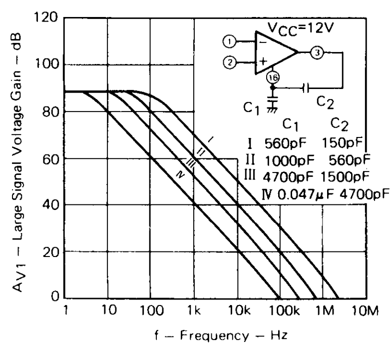


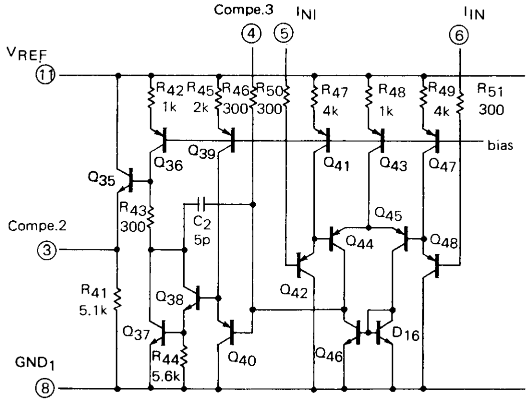
Fig.10 ERROR AMP. I GAIN vs. FREQUENCY

The error amplifier employs a regulated reference voltage output of +5V as the power supply voltage to obtain SVR in the same manner as in the oscillator block. It is composed of 2-stage direct-coupled amplifiers with a differential input, and open loop voltage gain A_{V1} is as high as about 85dB.

This multistage amplifier composition contains plural poles, and no internal phase compensation is done. Thus, the phase angle exceeds 180° at about 2MHz or higher. It is, therefore, necessary to conduct external phase compensation to prevent oscillation as shown in Fig. 10.

C_1 is required for preventing leakage noise the oscillator block.

v) Error amplifier II



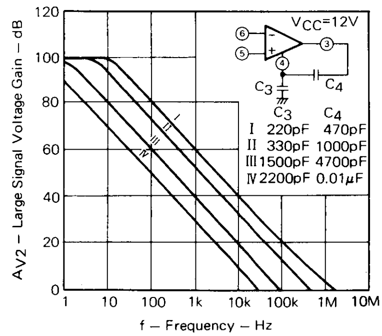


Fig.11 ERROR AMPLIFIER II CIRCUIT DIAGRAM

Fig.12 ERROR AMP. II GAIN vs. FREQUENCY

Error amplifier II is used as an overcurrent protection circuit of the power supply. It amplifies the output current signal obtained via a low resistor connected in series with the load, in general. Accordingly, it requires a high gain (about 60dB at ordinary working level), and also the common mode input voltage range is required up to the GND level of this IC being operated by a single power supply. This circuit is composed of the initial-stage PNP differential amplifier as shown in Fig. 11.

The open loop voltage gain is about 100dB, which is higher than that of error amplifier I by about 15dB. However, the external phase compensation is required as shown in Fig. 12. The zero cross frequency is about 1.2MHz when the minimum phase compensating constant is externally connected.

vi) Dead time adjusting circuit

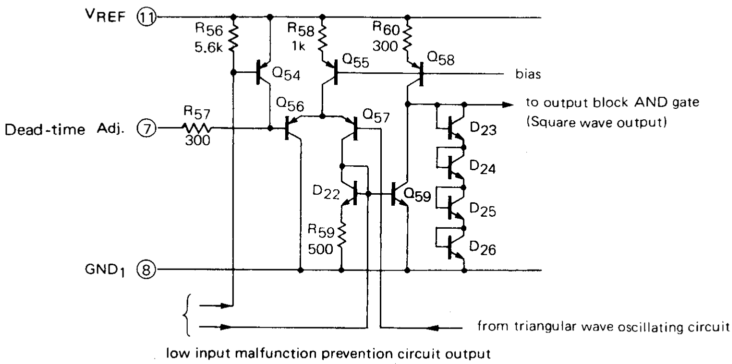


Fig.13 DEAD TIME ADJUSTMENT CIRCUIT

The dead time adjusting circuit adjusts the dead time by changing the DC input voltage given to No. 7 terminal so as to change the slice level of the triangular wave through comparison with the triangular wave oscillating output by means of the differential amplifier consisting of Q_{56} and Q_{57}.

11

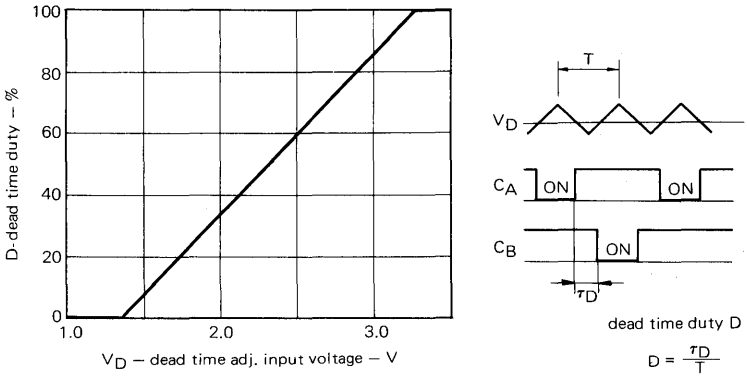


Fig.14 RELATION BETWEEN DEAD-TIME ADJUSTMENT INPUT VOLTAGE AND DEAD TIME DUTY

vii) Output block

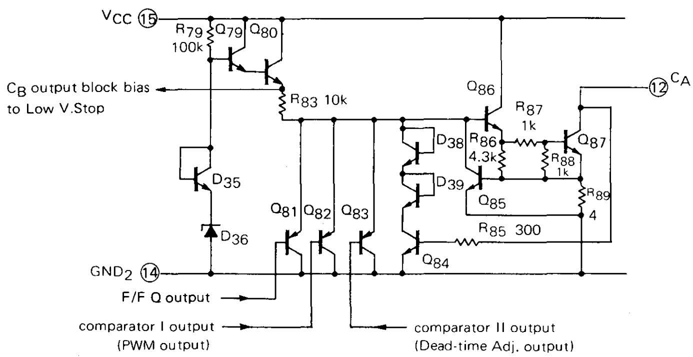


Fig.15 C_A OUTPUT BLOCK (This is also applicable to C_B OUTPUT BLOCK)

The output block is composed of the 3-input AND gate consisting of Tr s Q_{81}~Q_{83}, buffer open collector output Tr, for buffer Q_{87}, and its driving Tr, Q_{86}. Also, R_{89} is attached as a short-circuit prevention circuit, and Q_{84} is attached to prevent the saturation of Q_{85} or Q_{87}.

(3) Equivalent circuit

Fig. 15 indicates the equivalent circuit of μPC1042C. Since this IC contains many functional blocks, the number of the elements amounts to about 230, featuring a large scale in this class..

Fig. 17 shows the entire circuit diagram of a switching regulator to be tentatively manufactured according to the above specifications, and Table 3 shows the parts employed for the circuit.

4. APPLICATION EXAMPLE TO 5V, 10A OUTPUT PUSH-PULL TYPE SWITCHING REGULATOR

As an application example of μPC1042C, the design method, parts employed, and circuit constants will be determined for AC 100V line operate type 5V 10A output switching regulator as a typical example, and the details of manufacturing procedure and performance are described below.

(1) Specifications

Input voltage	AC 100V (50 or 60Hz) ±10%
Output voltage and current:	DC 5V ±5%, 10A max.
Operating frequency:	f=20kHz

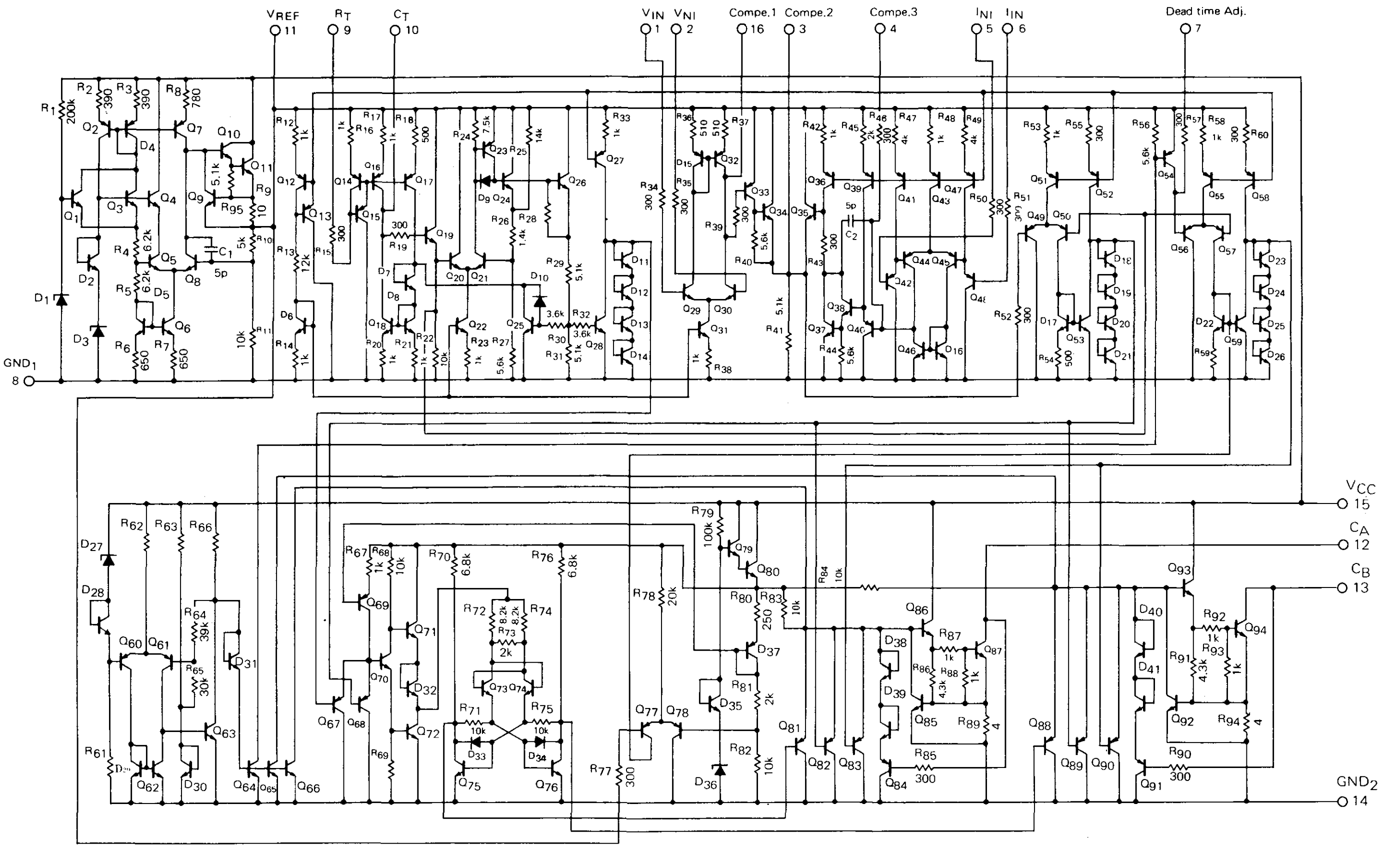


Fig.16 EQUIVALENT CIRCUIT DIAGRAM OF μPC1042C

(2) Design of each block

Fig. 17 shows the entire circuit diagram of the switching regulator according to the above specifications. Table 3 is the parts list.

As shown in the broken line in this circuit diagram, the switching regulator is composed of 7 blocks including the control part employing μPC1042C. Its major blocks will be described below. This circuit requires an external auxiliary power supply input of 12V 80mA as a power source for the control block. In practice, a converter circuit using a blocking oscillator and a small-sized power transformer etc are employed together with an AC 100V line input.

i) primary rectifying and, line input smoothing block

This block full-wave rectifies AC 100V from the input terminals via a line filter, by means of a diode-bridge, and turns it to a DC (with ripple) voltage of about 130V through a capacitor input type smoothing circuit. Since a voltage corresponding to twice the peak value (about 141V) of AC input voltage is applied to the rectifiers D_1~D_4, rectifiers with 400V repetitive reverse voltage are required.

And the average current amounts to about 0.7A, so four F14D or 2B8M (stack) are recommended. R_1 serves as a rush current limiting resistor and the value is about 1.5Ω/2W.

Since R_1 is not enough to prevent a rush current in case of a large capacity, use of an SCR in parallel with R_1 is recommended.

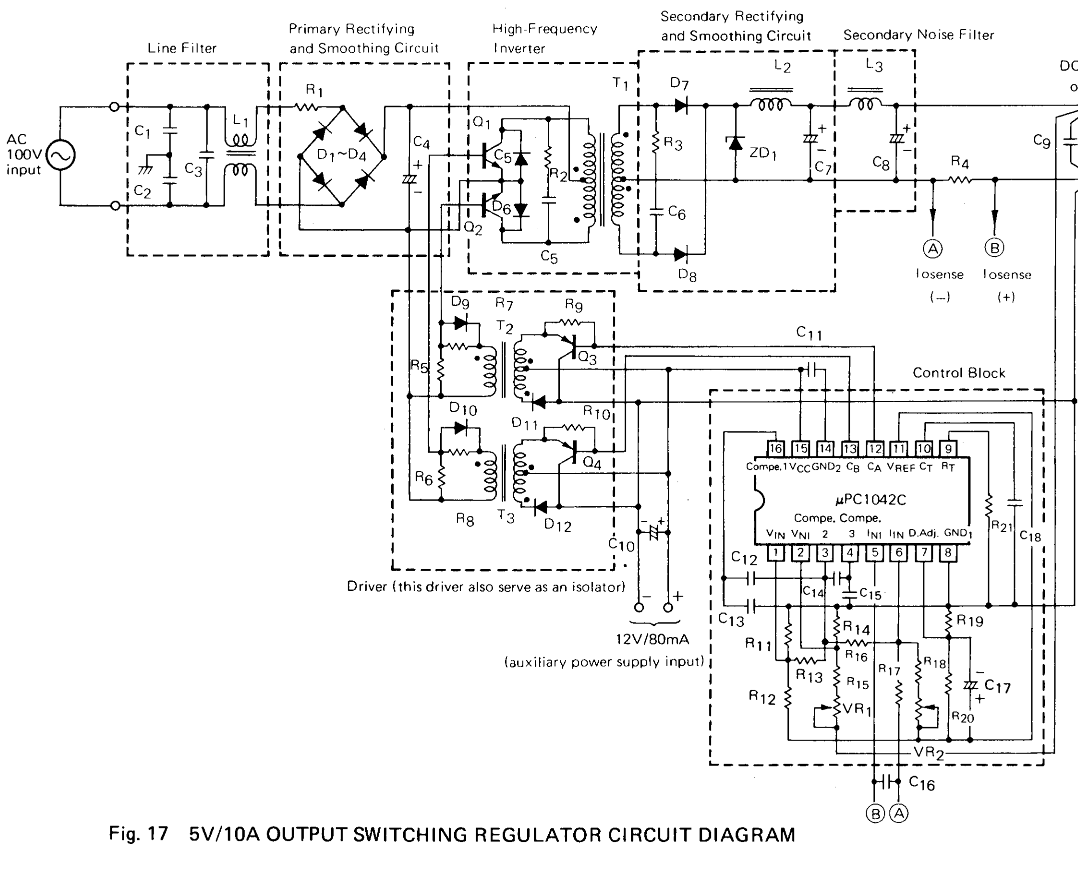


Fig. 17 5V/10A OUTPUT SWITCHING REGULATOR CIRCUIT DIAGRAM

TABLE 3 PARTS LIST OF SWITCHING REGULATOR

Symbol	Ratings	Symbol	Ratings	Symbol	Ratings
$C_{1,2}$	1000pF,3kV ceramic capacitor	$Q_{1,2}$	2SC2335x2	R_{14}	5kΩ metal film resis.
$C_{3,5}$	2200pF, 3kV cera. capa.	$Q_{3,4}$	2SA883x2	R_{15}	4.3kΩ metal film resis.
C_4	470μF, 200V Al electrolytic capa.	L_1	filter choke coil using TM	R_{16}	470kΩ carbon film resis.
C_6	2200pF, mylar film capa.		dust core T12-60	R_{17}	470Ω carbon film resis.
C_7	2200μF, 10Vx5 Al electro capa.		N=29T x 2, D=0.7mmφ	R_{18}	91kΩ carbon film resis.
$C_{8,17}$	3.3μF, 16V tantalum electro. capa.		L=75μH	R_{19}	3.6kΩ carbon film resis.
C_9	0.47μF mylar film capa.	L_2	Smoothing choke coil using T14-60	R_{20}	6.8kΩ carbon film resis.
C_{10}	10μF, 25V Al electro. capa.		N=24T, D=0.7mmφx8 parallel	R_{21}	20kΩ metal film resis.
C_{11}	0.015μF mylar film capa.		L=35μH	T_1	main transformer
C_{12}	470pF ceramic capa.	L_3	Filter choke coil using T12-60		core employed FX3730 (made by PHILIPS)
C_{13}	680pF "		N=3Tx2, D=0.7mmφx8 parallel		N_p=80Tx2, D_p=0.6mmφ
C_{14}	0.068μF mylar film capa.		L=1.2μH		N_s=6.5Tx2, core gap t=50μm
C_{15}	4700pF "	R_1	1.5Ω, 2W Solid resistor		
C_{16}	0.015μF "	R_2	1kΩ, 1W Solid resistor	T_2	pulse transformer
C_{17}	3.3μF tantalum electro. capa.	R_3	75Ω carbon film resis.		core employed $H5C_2$ EE12
C_{18}	1000pF mylar film capa.	R_4	2mΩ manganin wire resis.		(made by TDK)
$D_{1 \text{ to } 4}$	F14D x 4 (1A, 400V diode)	$R_{5,6}$	51Ω carbon film resis.		N_p=70T x 2, D_{p1}=0.2mmφ, D_{p2}=0.1mmφ
$D_{5,6}$	F114D x 2 (first recovery Di.)	$R_{7,8}$	12Ω, ½W carbon film resis.		N_s=18T, D_s=0.25mmφ
$D_{7,8}$	15SB03S x 2 (shottky barricr Di.)	$R_{9,10}$	100Ω carbon film resis.		core gap t=10μm
$D_{9 \text{ to } 12}$	1S954 x 4	$R_{11,12}$	5kΩ metal film resis.	VR_1	2kΩ B type variable resistor
IC	μPC1042C	R_{13}	510kΩ carbon film resis.	VR_2	50kΩ B type variable resis.
				ZD_1	RD24EB

The capacitance value of aluminum electrolytic smoothing capacitor C_4 can be obtained from O.H.Shade diagram (See technical data "Design of push-pull system switching regulator (Basic)"). In case of full-wave rectification, an about 500μF capacitor may be used without trouble per 50W of power output.

ii) High-frequency inverter block

The high-frequency inverter block has conventionally been the most complicated in designing a switching regulator. This is because a high-speed power transistor for the line operate type were not available, and the knowledge about high-frequency inverter transformer design has not been fully enriched. However, many kinds of high-speed high-voltage switching power transistors are available now and we can generally obtain such devices that are required for a power supply with an output capacity of about 10W to 1kW in recent years. On the other hand, exclusive transformer cores have recently been developed, in addition to conventional EI type core for telecommunication equipment.

(a) Selection of transistor

In this design, industrial use plastic Tr 2SC2335 is employed because it can easily be mounted and the circuit does not require especially high reliability.

Structure: NPN triple diffused silicon transistor

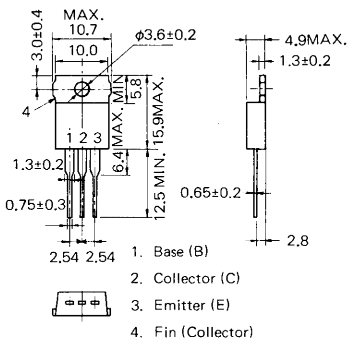
TABLE 4 OUTLINED SPECIFICATIONS OF 2SC2335

ABSOLUTE MAXIMUM RATINGS ($Ta=25°C$)

ITEMS	SYMBOL	RATINGS	UNIT
Collector to Base Voltage	V_{CBO}	450	V
Collector to Emitter Voltage	V_{CEO}	400	V
Emitter to Base Voltage	V_{EBO}	7.0	V
Collector Current (DC)	$I_{C(DC)}$	7.0	A
Collector Current (Pulse)	$I_{C(pulse)}$*	15	A
Base Current (DC)	$I_{B(DC)}$	3.5	A
Total Power Dissipation	$P_T(Tc=25°C)$	40	W
Total Power Dissipation	$P_T(Ta=25°C)$	1.5	W
Junction Temperature	Tj	150	°C
Storage Temperature	T_{stg}	−55 to +150	°C

* PW≦300μs, duty cycle ≦10%

PACKAGE DIMENSIONS (Unit : mm)



ELECTRICAL CHARACTERISTICS ($Ta=25°C$)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
Collector Cutoff Current	I_{CBO}			10	μA	$V_{CB}=400V, I_E=0$
Emitter Cutoff Current	I_{EBO}			10	μA	$V_{EB}=5.0V, I_C=0$
DC Current Gain	h_{FE1}	20				$V_{CE}=5.0V, I_C=0.1A$ *
	h_{FE2}	10				$V_{CE}=5.0V, I_C=3.0A$ *
Collector Saturation Voltage	$V_{CE(sat)}$			1.0	V	$I_C=3.0A$ *
Base Saturation Voltage	$V_{BE(sat)}$			1.5	V	$I_B=0.6A$ *
Turn on Time	t_{on}			1.0	μs	$I_C=3.0A$
Storage Time	t_{stg}			2.5	μs	$I_{B1}=-I_{B2}=0.6A$
Fall Time	t_f			1.0	μs	$V_{CC}≒150V, V_{BE(OFF)}=-5V$

* Pulsed PW≦350μs, duty cycle ≦2%

b) Design of transformer

The transformer is designed based on the following two equations. Equation (1) gives the allowable maximum input P(VA) which is determined according to the core size and shape, and the number of turns of the primary winding can be obtained by equation (2).

$P=2(w.f.)\cdot B\cdot f\cdot Ae\cdot Aw\cdot\delta$ (1)

$V=4\cdot B\cdot Ae\cdot f\cdot N$ (2)

where, P :Allowable maximum input of transformer (VA)

w.f :Occupation ratio (Ratio of total sectional area of winding to total window area Aw(m^2) of the core)

Ae :Effective sectional area of the core (m^2)

δ :Allowable current density of the winding (A/m^2)

V :Applied voltage to the winding (V)

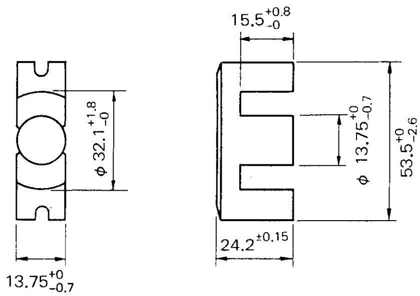
B :Magnetic flux density (Wb/m^2)

f :Operating working frequency (Hz)

N :No. of turns of the winding

Determination of the core

FX3730 made by PHILIPS is employed as a core, since its cylindrical center pole facilitates winding (See Fig. 18).



Saturated flux density	B_{ms}=3900G_{auss} (T_a=25°C)
Initial permeability	μi=3500
Effective sectional area	Ae=121mm²
Effective magnetic path length	Le=89.3mm

Fig. 18 OUTLINE DIMENSIONS AND CORE CONSTANT OF FX3730

Determination of windings

The number of turns of primary winding N_P can be obtained by transforming equation (3) and giving the following constants to the equation.

V_{in} = 130V, B=1700 G_{auss} ($\simeq \frac{1}{2} B_{ms}$)

Ae = 121 mm² f = 20kHz

$$N_P = \frac{V_{in}}{4 \cdot B \cdot Ae \cdot f} = \frac{130}{4 \cdot 1700 \cdot 10^{-4} \cdot 121 \cdot 10^{-6} \cdot 20 \cdot 10^{3}} \fallingdotseq 80 \text{ (turns)} \quad (3)$$

The wire diameter is determined while taking the limit due to allowable current density and core size into consideration. The primary winding wire diameter of Dp=0.6mmφ is suitable for this design.

The number of turns required for the secondary winding can be obtained from the output voltage, forward voltage of secondary rectifier, maximum duty of inverter, allowable AC input voltage range, etc.
This can be expressed by the following equation.

$$N_S = \frac{V_S}{V_{in}} \cdot N_P = \frac{(V_{out} + V_F + \alpha)}{V_{in} \cdot D_{max}} \cdot N_P$$

where, Ns: No. of turns of secondary winding

Vs : Terminal voltage of secondary winding (V)

Vout : Output voltage of power supply (V)

V_F : Forward voltage of secondary rectifier (V)

α : Voltage drop due to choke coil, wiring, etc. (V)

Dmax: Maximum duty of inverter D=τ/T (T: Cycle τ: ON time)

The number of windings is obtained by applying the following constants into the above equation.

into the above equation.

$V_{out} = 5.5V$, $V_F = 0.6V$, $\alpha = 0.2V$, $T = 25\mu s$, $\tau_{max} = 20\mu s$

$V_{in} = 100V$ (min), $N_P = 80$

$$N_S = \frac{5.5 + 0.6 + 0.2}{100 \cdot \frac{20}{25}} \cdot 80 = 6.3 \fallingdotseq 6.5 \text{ (turns)}$$

iii) Secondary recitifier smoothing block.

a) Rectifier

Since the power loss due to a forward voltage of the secondary rectifier largely affects the efficiency in a low voltage, large current power supply having an output voltage of 5V, Schottky barrier diode (SBD) is employed in most cases. Table 5 shows the outlined specifications of 15SB03S used in this design.

SBD features a low forward voltage, but its breakdown voltage is as low as 30V, and also it is not strongly resistible against a surge voltage.

Thus, C_6, R_8, and Zener diode ZD_1 are used for surge absorption to protect the SBD, as shown in Fig. 17.

TABLE 5 15SB03S RATINGS

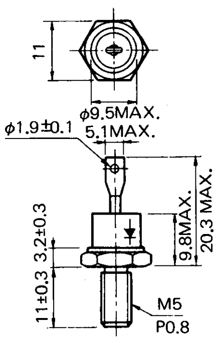
MAXIMUM RATINGS

ITEM	SYMBOL	15SB03S	15SB04S	UNIT
Repetitive Peak Reverse Voltage	V_{RRM}	30	40	V
Non-repetitive Peak Reverse Voltage	V_{RSM}	36	48	V
Average Forward Current	$I_{F(AV)}$	15(T_C=98°C Rectangular wave, Duty cycle 50%)		A
Surge Forward Current	I_{FSM}	250		A
Junction Temperature	T_j	125		°C
Storage Temperature	T_{stg}	–40 to +150		°C
Stud Torque		13 to 18		kg–cm

CHARACTERISTICS

ITEM	SYMBOL	TEST CONDITIONS	RATING	UNIT
Repetitive Peak Reverse Current	I_{RRM}	T_j=–40 to +125°C $V_{RM}=V_{RRM}$	100	mA
Forward Voltage	V_{FM}	T_j=25°C, I_{FM}=15A	0.6	V
Termal Resistance	$R_{th(j-c)}$	Junction to case, DC	2.0	°C / W

PACKAGE DIMENSIONS (Unit : mm)



b) Choke coil

The choke coil absorbs a discontinuous current flowing from the secondary winding of the transformer via the rectifier, reducing the ripple current to be flown into the smoothing capacitor.

Accordingly, the core material and the number of turns of winding are selected according to a DC superimposing current (or, output current) and the inductance which is determined by the allowable ripple current when designing the choke coil.

Since the ripple current affects the ripple voltage of the power supply and it causes the choke coil current to be discontinuous at a light load, resulting the output voltage in stability and inferior transient response.

Thus, the inductance value is an important parameter to determine the performance of the power supply.

Note:

When the choke coil current becomes discontinuous, this current is called a critical current. In addition, the proportional relation between the duty and the output voltage no longer holds true when the choke coil current is lower than the critical value.

However, the core material becomes too big when complete suppression of ripple current is required, the critical current is generally designed to be 1/7~1/10 of the rated output current, in practice.

This can be expressed by the following;

$$L \geq \frac{(3.5 \sim 5) \cdot (V_S - V_{out})}{I_{out}} \cdot \frac{V_{out}}{V_S} \cdot T$$

where, V_S : Voltage applied to the choke coil (V)

V_{out} : Load output voltage of the choke coil (V) (Output voltage of the power supply)

I_{out} : Rated output current (A)

This value can be obtained by inserting the constants in this design, as follows;

$$L \geq \frac{(3.5 \sim 5) \cdot (12 - 5)}{10} \cdot \frac{5}{12} \cdot 25 \cdot 10^{-6} \fallingdotseq 26 \sim 36 \ (\mu H) \quad (5)$$

$$\text{Since} \quad V_S = \frac{N_S}{N_P} \cdot V_{in}, \ V_{in} = 150V \ (max), \quad V_S = \frac{6.5}{80} \times 150 \fallingdotseq 12 \ (V)$$

Determination of core material and windings

An EI core or cut core may sometimes be employed as a core material.

However, TM dust core T14-60 (made by TOHOKU METAL CO) is employed here, since this troidal core features an excellent DC superimposing characteristic. For details, refer to data on TM dust core.

The number of turns can be obtained by substituing a required inductance value (L=35μH) into the following equation, taking into consideration that the permeability of core is reduced by about 30% when a DC superimposing current flows.

$$N = \sqrt{\frac{L_n}{L_{1000}} \cdot 10^6} = \sqrt{\frac{\frac{35}{0.7} \cdot 10^{-6}}{75 \cdot 10^{-3}} \cdot 10^6} \fallingdotseq 26 \ (\text{turns})$$

where, L_n : Inductance value after n-turns (H)

L_{1000} : Inductance value peculiar to the core per 1,000 turns (H)

L_{1000}=75mH in case of T14-60

Since it is very difficult to wind a single conductor of about 2mmϕ, eight 0.7mmϕ copper wires are bundled as a winding conductor.

iv) Driver

The driver circuit amplifies the current signals coming from the control block by a PNP transistor and drives the pulse transformer which also serves as an insulator so as to feed the base current of the final-stage transistor.

In order to accelerate t_f of the final-stage transistor, $-I_{B2}$ is obtained by utilizing the flyback caused by the exciting current of the pulse transformer.

Fig. 19 shows this driver circuit extracted from Fig. 17.

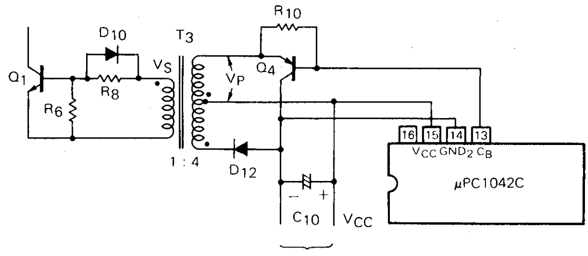


Fig.19 DRIVE CIRCUIT

In this figure, Q_1 is the final-stage transistor, and a collector current of about 1A (peak) flows at the rated load.

Accordingly, I_B=140mA, if the drive ratio (I_C/I_B) is assumed to be 7 while taking a due allowance from h_{FE} of Q_1 at 1A. It is also recommended to maximize the winding ratio of the pulse transformer employed from the viewpoints of current amplification for improving efficiency.

However, since about 2~3V is required as a drive voltage, a suitable ratio may be about 1:4.

Tne valve of the resistance R_8 to determine I_B from the above conditions can be obtained as follows;

$$R_8 = \frac{V_S - V_{BEQ1}}{I_B + I_{R6}} \ (\Omega), \ V_S = \frac{1}{4} \cdot V_P \ (V), \ V_P = V_{CC} - V_{BEQ4} - V_{CE(SAT)} \ (V)$$

where, V_{BEQX} :Saturation voltage between base and emitter of Q_X (V)

I_B :Base current to be fed to Q_1 (A)

I_{R6} :Consumption current of R_6 (A) $\quad I_{R6} = \frac{V_{BEQ1}}{R_6} = \frac{0.8}{51} \fallingdotseq 16mA$

$V_{CE(sat)}$:Saturation voltage of IC's output transistor

Thus, $V_P = 12-0.7-0.6 \fallingdotseq 10.7$ (V), $V_S \fallingdotseq \frac{10.7}{4} \fallingdotseq 2.7$ (V), $V_{BEQ1} \fallingdotseq 0.8V$, $R_8 = \frac{2.7-0.8}{140 \cdot 10^{-3} + 16 \cdot 10^{-3}} \fallingdotseq 12\ (\Omega)$

I_B=140 (mA), I_{R6}=16mA

Resistor R_6 is required for assuring the breakdown voltage (V_{CER}) when Q_1 is turned off and also cancelling the exciting current of the pulse transformer. No particular problem will arise when this resistor is 20~100Ω. (In this design, this value is 51Ω). Diode D_{10} is also required for obtaining $-I_{B2}$.

Design of the pulse transformer

When the pulse transformer also serves as an insulator between the primary and the secondary, the insulation between the windings must be taken care of. It is not necessary to use a large core material, but H_{5A}EE12 (made by TDK) or the like is suitable.

However, since the flyback energy is positively employed during OFF time, a core gap must be provided.

Observe the following procedures when obtaining the number of turns of the winding.

The following three requirements must be satisfied, but this value is practically obtained by cut and try method.

(a) Obtain a necessary inductance value from the exciting current allowable to the primary winding.

(b) Decide the number of turns of winding and the gap size required for obtaining the inductance calculated from (a). Check the core for saturation under the above conditions.

(c) Check allowable current density.

In the present design, $L_P \geqq \frac{V_P}{I_{PK}} \cdot \tau = \frac{10.7}{50 \cdot 10^{-3}} \cdot 20 \cdot 10^{-6} \fallingdotseq 4.3$ (mH)

where, I_{PK} : Exciting current by primary inductance (A)

τ : ON time of pulse transformer

I_{PK}=50mA, τ=20μs, and V_P=10.7V

Obtain N_P gap t to realize $L_P \geqq$4.3mH,

N_P =70 turns, t=10μm N_S=¼-N_P=18 turns

Transistor employed:

Since an about 100mA current including the exciting current flows to the primary of the pulse transformer, 2SA883 is employed in this design.

v) Control block

Fig. 20 indicates the control block circuit

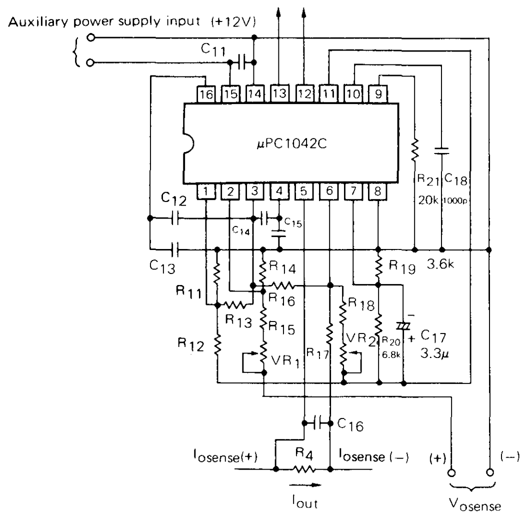


Fig.20 CONTROL CIRCUIT DIAGRAM

The control block can easily be composed by externally connecting the resistor and capacitor for determining the oscillator timing as well as those required in the vicinity of the error amplifiers and dead-time adjusting circuit, by using μPC1042C as shown in the right figure.

The method of obtaining the value of external components required for each block of IC will be described.

(a) Timing constant

The triangular wave frequency must be twice (40kHz) the operating frequency of the switching regulator (20kHz).

Accordingly, the capacitor and resistor externally connected for obtaining the timing constant can be obtained from the f_{OSC}—R_T, C_T characteristic in Fig. 21.

R_T=20kΩ (R_{21})

C_T=1000pF (C_{18})

(b) Error amplifier

The following three items must be carefully noted for determining the external components of the error amplifiers.

* Problem of common mode input voltage range due to a single power supply operation
* Setting of the loop gain according to the output voltage and current of the power supply
* Values of phase compensating capacitors (frequency response adjustment)

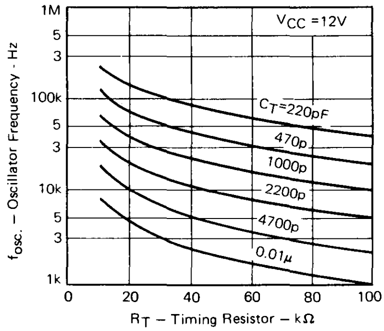


Fig.21 $f_{osc.}$ – R_T, C_T CHARACTERISTIC

In this design, the loop gain of the error amplifier I is set to $G_1 = \frac{R_{13}}{R_{11}//R_{12}} = 200$ times. On the other hand, the loop gain of the error amplifier II is set to $G_2 = \frac{R_{16}}{R_{17}//(R_{18}+VR_2)} \fallingdotseq 1000$ times, since current detecting resistor R_4 is as low as 2mΩ and a high gain is required for assuring a constant current drooping characteristic. Four phase compensating capacitors C_{12}~C_{15} are required so as to adjust the frequency response of these error amplifiers and keep the power supply stable. The constants are determined in the adjusting stage of the equipment. However, they may be unavoidably determined by the cut and try method to a certain extent.

(3) Operating waveforms

Fig. 22 shows the operating waveforms at each part at the rated conditions of the switching regulator manufactured on trial this time. As is understood from the collector current and voltage waveforms, the leakage inductance of the transformer is considerably high, so that the reverse voltage is applied between C-E during a certain period at full load. Thus, D_5 and D_6 are inserted for protection. The voltage applied between C and E is about 280V with AC 100V and the rated load. So the transistors have enough margin even when taking an input fluctuation of ±10% into consideration.

(4) Various characteristics

Table 6 and Fig. 23 show output voltage regulation, ripple voltage, efficiency and other characteristics.

TABLE 6 PERFORMANCE OF SWITCHING REGULATOR MANUFACTURED ON TRIAL

Items	Conditions	Measured values
Line regulation $\Delta V_{out}(\Delta V_{out}/V_{out})$	V_{in}=90~110V ($\Delta V_{in}/V_{in} \doteq \pm 10\%$) V_{out}=5V I_{out}=10A	4.3mV(0.086%)
Load regulation $\Delta V_{out}(\Delta V_{out}/V_{out})$	I_{out}=2.5~10A (¼⇄full load) V_{in}=100V V_{out}=5V	6.0mV (0.12%)
Output ripple voltage V_{ripple}	V_{in}=100V V_{out}=5V I_{out}=10A	20mV_{p-p}
Efficiency η	V_{in}=100V V_{out}=5V I_{out}=10A	78.5%
Outline dimension	———	80(W) X 205(D) x135(H) mm^3

Fig. 24 shows the drooping characteristic of the output when the operating point setting control registor variable VR_2 of the overcurrent protection circuit is adjusted to 110% of the rated value.

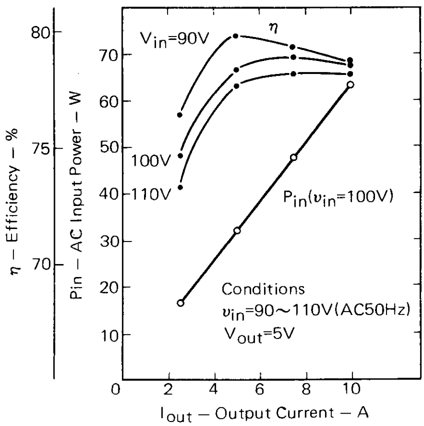


Fig. 23 EFFICIENCY-OUTPUT CURRENT CHARACTERISTIC

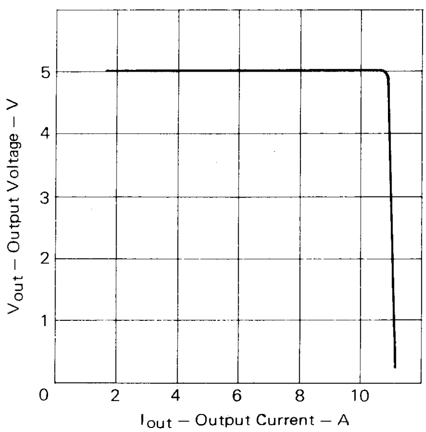


Fig. 24 OUTPUT VOLTAGE, CURRENT CHARACTERISTIC

11

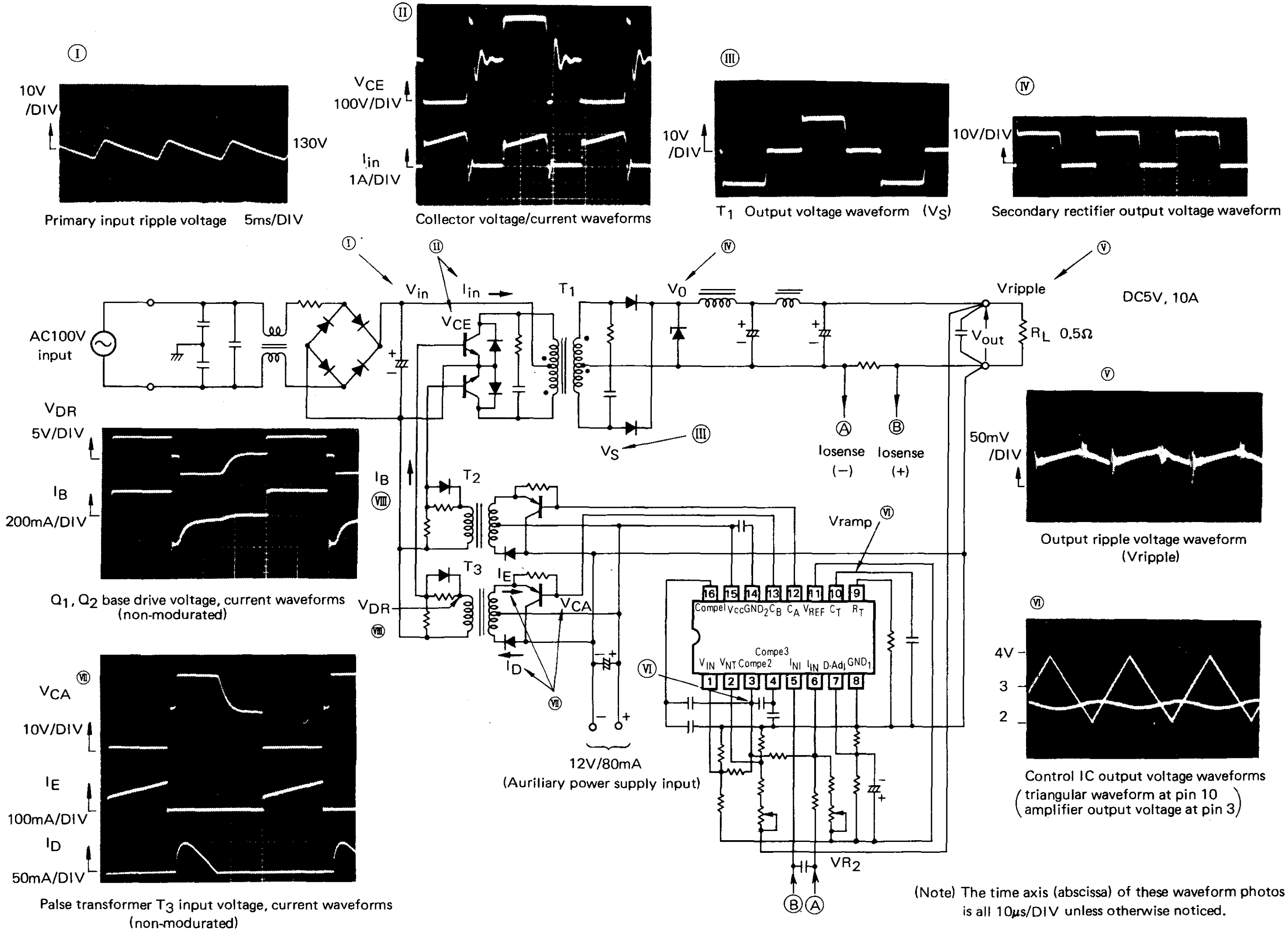


Fig. 22 OPERATING WAVEFORMS AT EACH PART OF THE SWITCHING REGULATOR MANUFACTURED ON TRIAL

5. COUNTERMEASURES AGAINST FAULTS OF SWITCHING REGULATOR

When a switching regulator was newly designed, manufactured, and adjusted according to the circuit diagram, frequent abnormal symptoms caused the breakage of switching transistor in most cases. In such a case, it is presumed that very high stress is added to the switching transistor as compared with the steady-state condition, and it may unfavorably affect the reliability of the switching transistor, even if the switching transistor has not been broken. Accordingly, it is necessary not to apply an overload to the transistor under any operating condition, and during a transient time, in particular, from the system points of view. However, this problem often depends upon the design of the control circuit. Now, examples of troubles and their countermeasures will be described below.

(1) Polarized magnetic phenomenon in push-pull system and its countermeasure

If transistors Q_1 and Q_2 composing the high-frequency inverter are unbalanced, the collector current becomes unbalanced as shown in Fig. 25. In this case, if the unbalance is not so noticeable, only a difference of DC superimposing current is detected as shown in Fig. (a). However, if the unbalance becomes noticeable, the collector current waveform is largely deformed due to the saturation of the transformer as shown in Fig. (b).

When considering this phenomenon from the viewpoints of the transformer, the saturation phenomenon of the core may be produced on one side of the hysteresis loop because the polarized magnetic current due to the unbalance exceeds the DC current superimposing characteristic of the transformer as shown in Fig. 26.

If the switching regulator continues to operate under this condition, the flyback energy applied to the transistor increases at the moment the collector current is turned off, causing the transistor to be broken due to over $V_{CEX(SUS)}$, or causing the thermal runaway produced by the deflection of the switching loss. This polarized magnetic phenomenon may basically be caused by the following three factors.

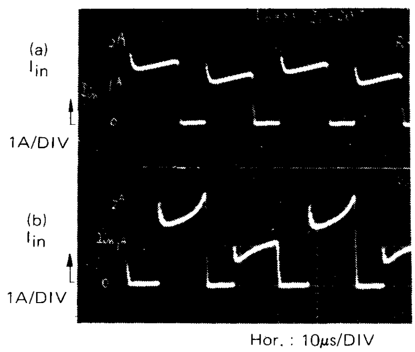


Fig.25 COLLECTOR CURRENT WAVEFORM WHEN UNBALANCED

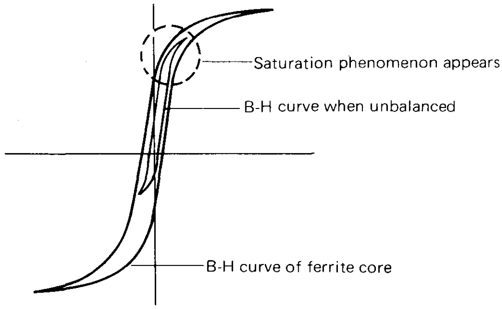


Fig.26 HYSTERESIS LOOPS OF CORE WHEN UNBALANCED

(a) Cause due to transformer design

The number of turns of the transformer windings is wrong, the core gap is small, or the DC superimposing characteristic is to 0 small.

(b) Cause due to a difference of the ON-time of the transistors driving the transformer

The storage time t_{stg} of the transistor is largely different with each other, or the pulse widths of the output signals of the alternately operating control circuits differ from each other due to a circuit lag, etc. under the steady-state condition.

(c) Cause due to the frequency response of the error amplifiers employed in the control circuit

This is caused by an inappropriate values of the phase compensating capacitors which are externally connected to the error amplifiers for the purpose of detecting the output voltage or current and amplifying the fluctuation component to modulate the pulse width control circuit.

Since the frequency response of the error amplifier gain is flat up to higher frequency, and the closed loop gain of the power supply is positive at a frequency which is half the triangular oscillating output frequency, this frequency component is superimposed onto the error amplifier output. Accordingly, the gain at higher frequency must be lowered by increasing the values of the phase compensating capacitors for the purpose of avoiding the above phenomenon. (See Fig. 27)

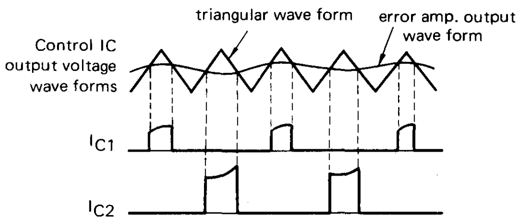


Fig.27 POLARISED MAGNETIC PHENOHENON DUE TO INSUFFICIENT PHASE COMPENSATION

(2) Intermittent operation of transistor when the overcurrent protection circuit is in operation

This phenomenon is caused by the constant current drooping characteristic provided for protecting the transistors against an overload. Since the output current detecting resistor has a very low resistance value (2mΩ in the present design) as shown in the circuit diagram in Fig. 17, the error amplifier II is operated with a high gain. Accordingly, the intermittent operation may be produced as shown in Fig. 28, unless a phase compensating capacitors having a considerably large value is connected. In this case, the peak collector current of more than two times may flow due to the intermittent operation duty.

Particularly to assure the drooping characteristic, the transistor is operated at a very low duty as shown in Fig. 29, so that the transistor operation is apt to be affected by an AC component superimposed into the error amplifier output. It is, therefore, necessary to considerably reduce the gain of error amplifier II at higher frequency, as compared with error amplifier I.

However, if a phase compensating capacitor having a large value is employed for reducing the high frequency gain, the slew rate is lowered, and no protection is activated momentarily against an abrupt load short-circuit such as dead shortage of output terminals, etc. Accordingly, this problem must be considered while taking SOA of the transistor into due consideration, concurrently.

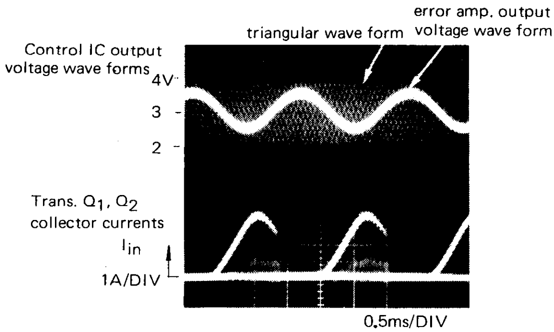


Fig.28 INTERMITTENT OPERATION OF TRANSISTOR

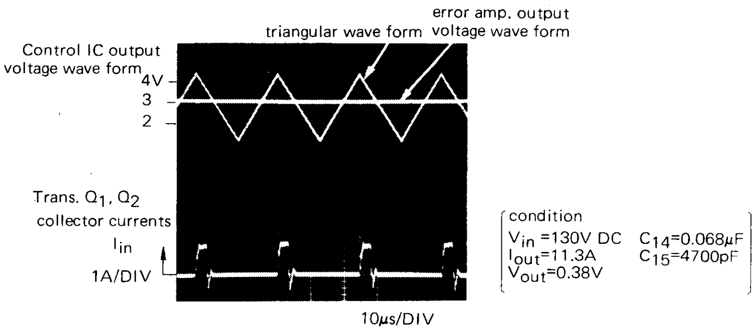
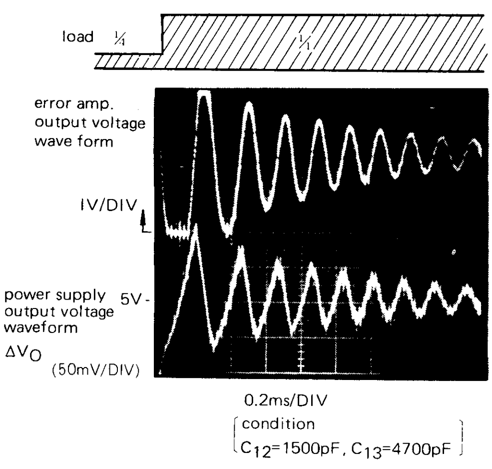


Fig. 29 COLLECTOR CURRENT WAVEFORM IN CONSTANT CURRENT DROOPING
(Normal condition)

(3) Damped oscillation of output voltage in step variation of load

One of the measures of preventing the polarized magnetic phenomenon of the transformer, the capacitors externally connected to error amplifiers must have higher values. However, if these values are too high, the output voltage oscillates when the load fluctuates. Fig. 30 indicates the transient response of the output voltage when the load of the switching regulator manufactured on trial was switched stepwise from 1/4 to 1/1 of the rated value.

a) OSCILLATING OUTPUT



b) NON-OSCILLATING OUTPUT

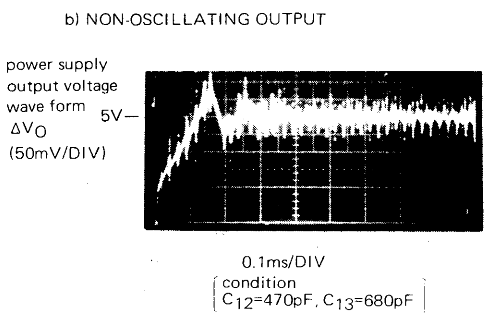


Fig.30 RESPONSE OF OUTPUT VOLTAGE AGAINST STEP VARIATION OF LOAD

11

Figure (a) indicates the transient response when the value of the external capacitor of error amplifier I was increased. It shows the damping oscillation of the output response at a time constant of about 1.5ms.

On the other hand, figure (b) indicates the output response waveform in case of non-oscillation for a comparison purpose.

In this case, the response time of the output voltage is about 200μs, and the response is made 8 cycles after the control signal appears. The transient response characteristic becomes oscillating, if the values of the phase compensating capacitors are too high, or the high frequency gain of error amplifier I is low. In addition, the transient response characteristic is affected by the DC gain concurrently.

The oscillation can be reduced by decreasing the DC gain in such a case. These oscillations may be caused by such a fact that the filter has a resonant frequency at fo point (fo = in case of this proto-type design). Accordingly, the phase compensating method has recently been designed to reduce the gain at only fo and the neighborhood.

6 CONCLUSION

When designing switching regulator using μPC1042C, many new knowhows are required. This technical data sheet covers the details of IC itself and the details of applications in push-pull circuit, as an example. A bridge, single-transistor or, chopper circuit has respective particular problems. However, they can be basically designed based on this data sheet. μPC1042C is also applicable to multiple inverter, PWM amplifier and other different application, and not limited to a switching regulator. The selection of parts described in these proto type circuits is not intended for mass production design by taking deviations and temperature characteristic into consideration.

NEC cannot assume any responsibility for any circuits shown or represent that they are free from patent infringement.

NEC reserves the right to make changes at any time without notice in order to improve design and supply the best product possible.

COMPARISON OF GaP RED LED TO GaAsP RED LED

As the compactness of sets and low energy consumption are promoted, demands for LED's of higher brightness in lower current are increasing. In this document, the characteristics of new red LED made recently by NEC using GaP crystal is described,as contrasted to our conventional red LED made of GaAsP crystal. (the data here after referred to are based on NEC's products only.)

1. CRYSTAL STRUCTURE

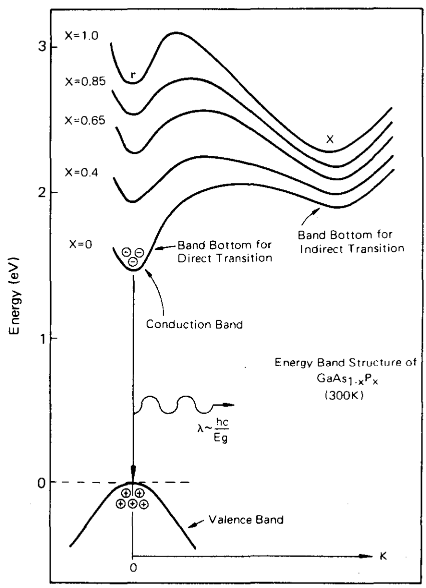
1-1 Difference in Light Emission Mechanism

The light emission mechanism in GaP LED is different from that of GaAsP LED.

Fig. 1 shows the energy band structures of $GaAs_{1-x}P_x$. Ordinary GaAsP LED is made of crystal with x, composition ratio, at about o.4, where the bottom of the conduction band is located at the same wave number as the top of the valence band and direct transitions will take place. Namely, the electrons in the conduction band and holes in the valence band are directly recombined to emit light.

On the other hand, in GaP LED having an energy band structure with composition ratio of unity, the positions of the bottom of the conduction band and the top of the valence band are not at all the same. That is, transitions must be indirect and the electrons in the conduction band cannot be directly recombined with the holes in the valence band. In order to make GaP red LED light-emitting, zinc (Zn) and exygen (O) are doped to form Zn-O complexes in the crystal as the light emitting centers.

Since light is emitted via light emitting centers, the energy of light emitted from GaP LED is smaller than the band gap and the light can go out without being absorbed by the crystal, whereas the energy of light from GaAsP LED is almost the same as the band gap and it is difficult for the light to go out because of absorption in the crystal.



Momentum (Wave Number)

Fig. 1

11

2. STRUCTURES AND FEATURES OF CHIPS

Fig. 2 shows the chip structures of GaAsP LED and GaP LED. Their features are summarized in Table 1.

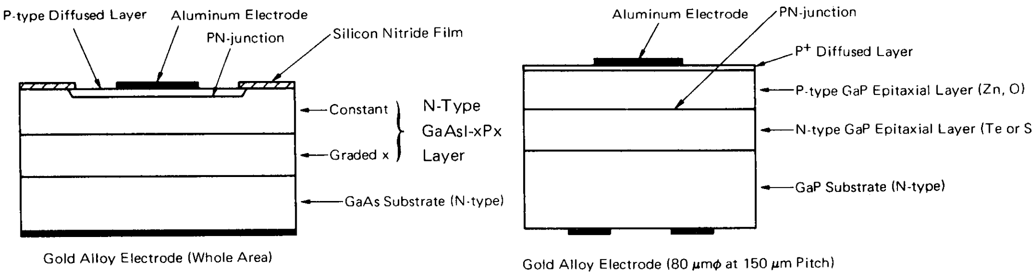
2-1. Crystal and PN Junction

GaAsP crystal is formed on N-type (100) GaAs substrate by means of epitaxial growth. The epitaxial layer is made up of a graded composition region grown with gradually increasing composition ratio x of $GaAs_{1-x}P_x$ and a uniform composition region with x at about 0.4. Tellurium (Te) is doped in the epitaxial layer to make it N-type.

Next, zinc is diffused to form PN junctions with silicon nitride (Si_3N_4) film as the mask.

On the other hand, to prepare GaP red LED,an N-type epitaxial layer doped with tellurium (Te)or sulphur (S) is grown on N-type (111) GaP substrate by means of liquid phase growth and a P-type epitaxial layer doped with zinc (Zn) and oxygen (O) is grown in a similar way. That is, the PN-junction is formed by liquid phase growth.

GaAsP LED has its PN-junction as shallow as 2 to 5 μm deep from the surface because, as described before with energy band diagram, the light absorption in the crystal is much. However, the PN-junction of GaP LED is formed under the P-type epitaxial layer 20 to 40 μm thick. Furthermore, while the PN-junction of GaAsP LED is planar because it is formed by diffusion with a mask made of silicon nitride, the PN-junction of GaP LED is exposed on the side face of chip and it serves for an effective light emission.



(a) GaAsP Chip Structure (b) GaP Chip Structure

Fig. 2

	GaAsP LED	GaP LED
Substrate Material	GaAs	GaP
Crystal Surface Orientation	(100)	(111)
PN-junction Fabrication Process	Diffusion	Liquid Phase Epitaxial
PN-junction Structure	Planar	Whole Area
Depth of PN-junction	3~5 μm	20~40 μm
Top Side Electrode Material	Aℓ	Aℓ
Bottom Side Electrode Material	Gold Alloy	Gold Alloy
Bottom Side Electrode Configuration	Whole Area	80 μmφ at 150 μm Pitch
Band Gap	~1.9 eV	2.2 eV
Type of Band Structure	Direct Transition	Indirect Transition
Peak Emission Wavelength	660 nm	700 nm
Spectral Line Half Width	25 nm	100 nm
External Quantum Efficiency of Light Emission	~ 0.2 %	~2 %

Table 1

2-2. Electrodes

Top side electrode, on which wire bonding is done, is made of aluminum, for both of GaAsP and GaP LED's.

Bottom side electrode for GaAsP LED is made of gold alloy and it covers whole bottom area. However, for GaP LED, the gold alloy is applied in circular dot electrodes with 80 μm diameter at 150 μm pitch. This configuration serves to take out light emission effectively whichis otherwise reflected by the bottom surface because of low absorption inside the crystal.

2-3. Pellet Shape

The wafers for GaAsP LED, oriented to (100) direction, can be cut into chips by scribing with a diamond point in the direction of cleavage-Plane. The chip is as thin as about 150 μm for the ease of scribing.

However wafers for GaP LED, oriented to (111) direction, cannot be cut into rectangles because the direction of cleavage-plane makes angle of 60°. For this reason GaP chips are fabricated by dicing with a thin diamond wheel. Since internal absorption of light is less in GaP and the dicing does not require thinness of chips, the chips are 200 μm or more in thickness.

3. DIFFERENCES IN CHARACTERISTICS

3-1. Electrical Characteristics

GaAsP LED and GaP LED are different from each other in built in voltage of the forward voltage due to the difference in energy band gaps. Electrical characteristics of the both LED's are not described here since they are referred to later.

3-2. Light Emission Characteristics

For GaAsP LED, the luminosity of light emission increases nearly proportionally to the increase of forward current. However, for GaP LED, the luminosity begins to saturate at a fairly low forward current (about 5 A/cm^2). This is caused by the low concentration (10^{16}cm^{-3}) of Zn-O complex as light emission center and, hence, by the saturation of electrons captured by the center in spite of increase of the current.

Wave length spectral distribution of light emitted by GaAsP LED shows the peak value at about 660 nm with a half width of bout 35 nm, almost monochromatic. The distribution of light emitted by GaPLED has its peak at about 700 nm and it has a half width as broad as 100 nm. If corrected to human eye's response, hue of the LED is seen soft at about 630 nm.

4. ABSOLUTE MAXIMUM RATINGS

ITEM	SYMBOL	RATING				UNIT
		SR503D, C, W	SR103D, C, W	SR505D, C, W	SR105D, C, W	
Power dissipation	P	60	100	60	80	mW
Forward Current	I_F	30	50	30	40	mA
Reverse Voltage	V_R	5	3	5	3	V
Junction Temperature	T_j	100	80	100	80	°C
Storage Temperature	T_{stg}	−40~+100	−30~+80	−40~+100	−30~+80	°C

11

5. ELECTRICAL CHARACTERISTICS

(1) SR503D, C, W

ITEM	SYMBOL	MIN.	TYP.	MAX.	UNIT	CONDITION
Forward Current	V_F		2.0	2.5	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Terminal Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		695		nm	I_F = 10 mA
Spectral Line Half Width	$\Delta\lambda$		100		nm	I_F = 10 mA
Luminous Intensity	I_V	1.5	5		mcd	I_F = 10 mA (SR503D, 503W)
Luminous Intensity	I_V	4	10		mcd	I_F = 10 mA (SR503C)

(2) SR103D, C, W

ITEM	SYMBOL	MIN.	TYP.	MAX.	UNIT	CONDITION
Forward Current	V_F		1.65	1.95	V	I_F = 30 mA
Reverse Current	I_R		0.01	50	μA	V_R = 3.0 V
Terminal Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		660		nm	I_F = 30 mA
Spectral Line Half Width	$\Delta\lambda$		35		nm	I_F = 30 mA
*Luminous Intensity	I_{V1}/I_{V2}	0.5	3/8		mcd	I_F = 30 mA

*I_{V1} denotes luminous intensity of SR103D and SR103W, and I_{V2} does luminous intensity of SR103C.

(3) SR505D, C, W

ITEM	SYMBOL	MIN.	TYP.	MAX.	UNIT	CONDITION
Forward Current	V_F		2	2.5	V	I_F = 10 mA
Reverse Current	I_R		0.01	10	μA	V_R = 4.5 V
Terminal Capacitance	C_t		100		pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		695		nm	I_F = 10 mA
Spectral Line Half Width	$\Delta\lambda$		100		nm	I_F = 10 mA
Luminous Intensity	I_V	1.5	5		mcd	I_F = 10 mA (SR505D, 505W)
Luminous Intensity	I_V	4	10		mcd	I_F = 10 mA (SR505C)

(4) SR105D, C, W

ITEM	SYMBOL	MIN.	TYP.	MAX.	UNIT	CONDITION
Forward Current	V_F		1.6	1.95	V	I_F = 20 mA
Reverse Current	I_R		0.01	50	μA	V_R = 3.0 V
Terminal Capacitance	C_t			50	pF	V = 0, f = 1.0 MHz
Peak Emission Wavelength	λ_{peak}		660		nm	I_F = 20 mA
Spectral Line Half Width	$\Delta\lambda$		35		nm	I_F = 20 mA
Luminous Intensity	I_V	0.8	4		mcd	I_F = 20 mA

6. V_F DATA

(1) Fig. 3 shows V_F data for randomly chosen samples of SR503D, SR103D, SR503C and SR103C. (The samples are called here after Samples A, B, C and D, respectively.)

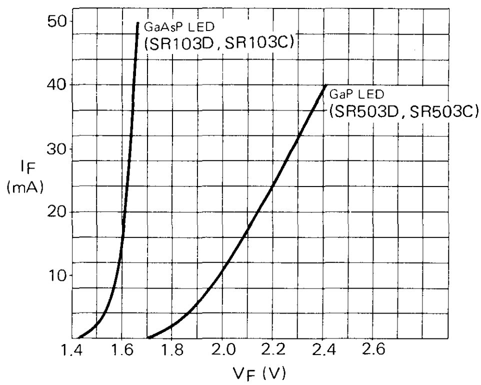


Fig. 3 I_F — V_F Characteristic

(2) When GaP red LED's such as SR503D and SR503C are substituted to a circuit which has been using GaAsP red LED's like SR103D and SR103C, the correspondence of I_F due to difference of V_F as shown in Fig. 3 will be expressed by the curves in Fig. 4.

These curves have been obtained from the measurements with a circuit shown in Fig. 5. Samples A, B, C, and D have been used for every combination of power supply voltage (V_{CC}) and protection resistance (R) as shown in Table 2.

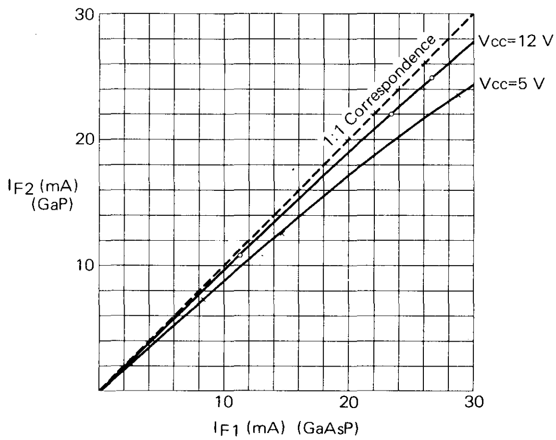


Fig. 4 Comparison of I_F Between GaP and GaAsP LED's

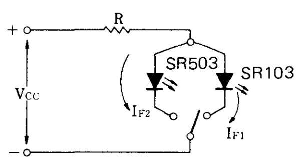


Fig. 5 Circuit for Measurement

V_{CC}(V)	R(Ω)
5	110, 220, 390, 910
12	390, 430, 910

Table 2

11

The results tell that, when a GaP LED is loaded to a lighting circuit with the same circuit constants as that for a GaAsP LED, I_F is reduced by $I_{F1}-I_{F2}/I_{F1} \doteqdot 7$ %.

NOTE: SR503D, C, or W is different from SR505D, C, or W respectively in package dimensions but the both are made of the same type of chip. The same thing is applied to SR103D, C, or W and SR105D, C, or W. Therefore, the samples of measurement has been carried out typically with SR503D and C, and, SR103D and C. The comparison of SR505 series and SR105 series leads to results that can be approximated by the above data.

7. LUMINOUS INTENSITY (I_V)

Fig. 6 and 7 show I_V-I_F characteristics of Samples A, B, C, and D.

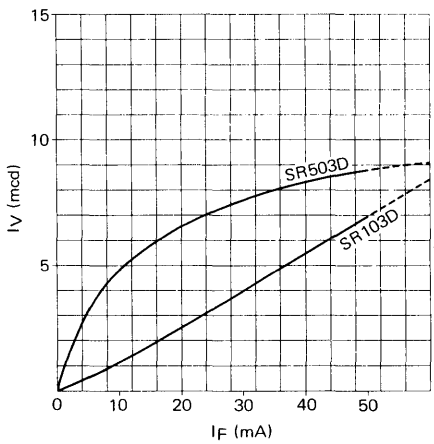


Fig. 6 $I_V - I_F$ Characteristics

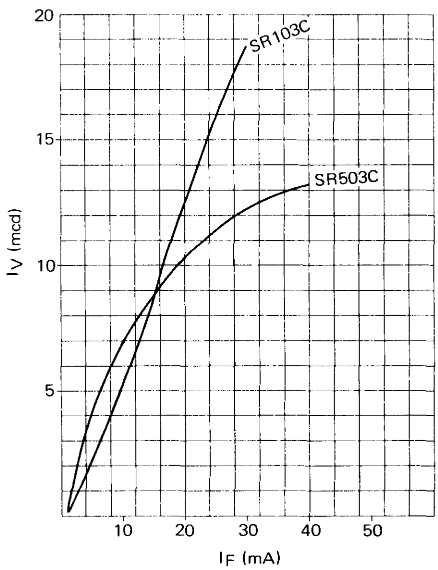


Fig. 7 $I_V - I_F$ Characteristics

As shown by the experimental data, the relationship $I_V \propto I_F$ approximately holds for GaAsP LED. While for GaP LED, I_V rises steeply in low current region (I_F=3-10 mA) and begins to saturate in high current region ($I_F >$ 10 mA). This is a major property of GaP LED, for which it is called low-current-emitting LED. This feature is critically empolyed to determine which driving circuit system should be used, static system (d.c. lighting) or dynamic system (pulse lighting). Fig. 8 shows the Luminous Intensity characteristics of GaP LED's. The curves are drawn for GaP LED loaded in place of GaAsP LED and suffering from I_F reduction due to the difference in V_F.

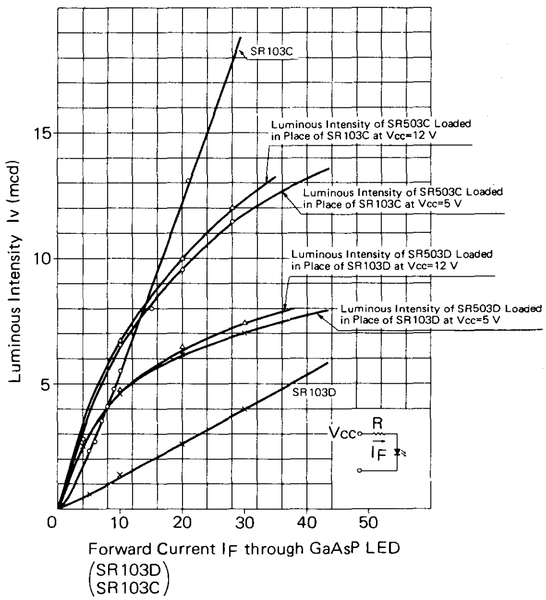


Fig. 8 Luminous Intensity of GaP LED loaded in Place of GaAsP LED

8. SPACIAL DISTRIBUTION

Figs. 9, 10, 11, and 12 show the spacial distributions of light emission of SR503D, C, W, SR103D, C, W, SR505D, C, W, and SR105D, C, W, respectively.

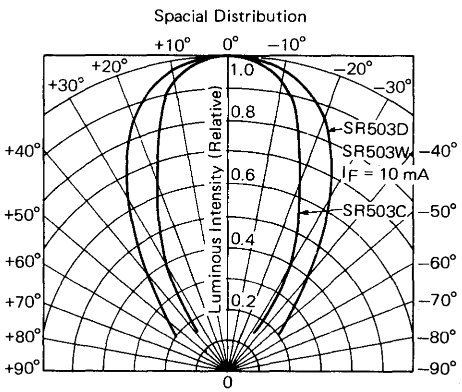


Fig. 9 Spacial Distribution Characteristics of SR503D, C, and W

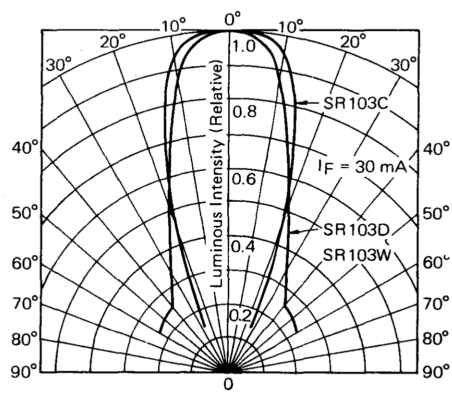


Fig. 10 Spacial Distribution Characteristics of SR103D, C, and W

11

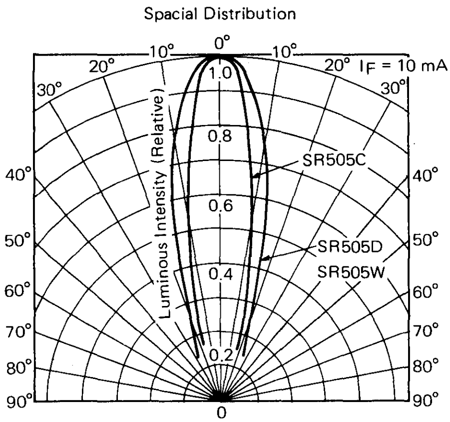


Fig. 11 Spacial Distribution Characteristics of SR505D, C and W

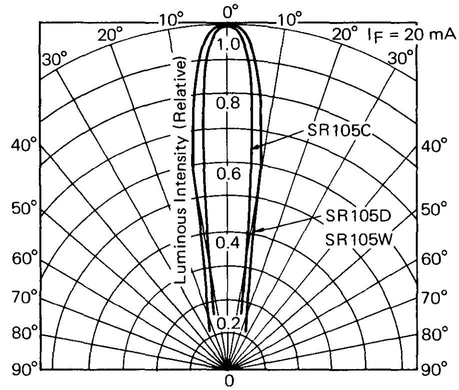


Fig. 12 Spacial Distribution Characteristics of SR105D, C and W

The difference in spacial distributions of GaP and GaAsP are brought about by the difference in light emission distributions in crystal and also by the changes in configuration. They are:

(1) Light emission distribution in crystal
  (a) GaAsP: light emission on front face.
  (b) GaP: light emission on all surfaces.
(2) Configuration changes
  (a) Structure change of lead frame
  (b) Chip height in resin mold.

9. RELIABILITY

The major difference in product reliabilities of GaAsP LED and GaP LED resides in their operating lifetimes that depend on their respective crystal structures. Anti-environmental characteristics of the both are the same.

Fig. 13 shows the estimated operating lifetime curves of SR103D GaAsP LED and SR503D GaP LED. When the both are compared at the same current, the lifetime of GaAsP LED is better. However, when they are compared at current values for the same luminous intensity GaP LED is better in lifetime (SR103D at I_F=30 mA offers nearly the same luminous intensity as SR503D at I_F = 10 mA).

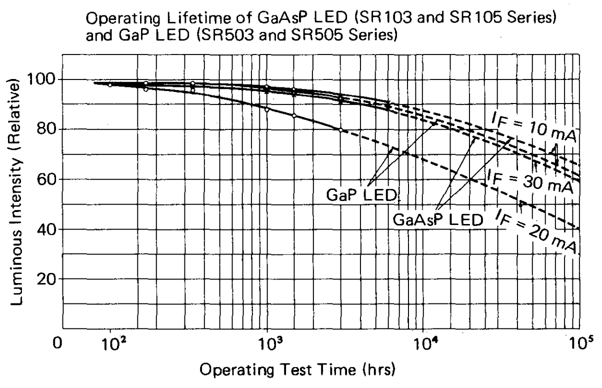
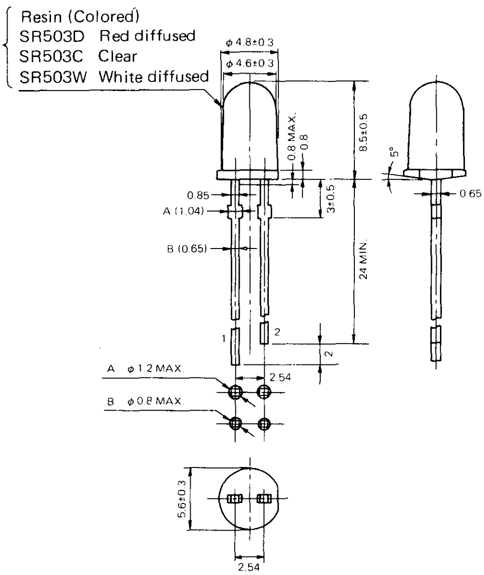


Fig. 13

10. PACKAGE DIMENSIONS

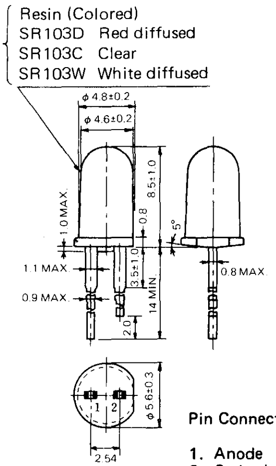
SR503D, C and W

Package Dimensions (in mm)



SR103D, C and W

Package Dimensions (in mm)



Pin Connection (Bottom View)

1. Anode
2. Cathode

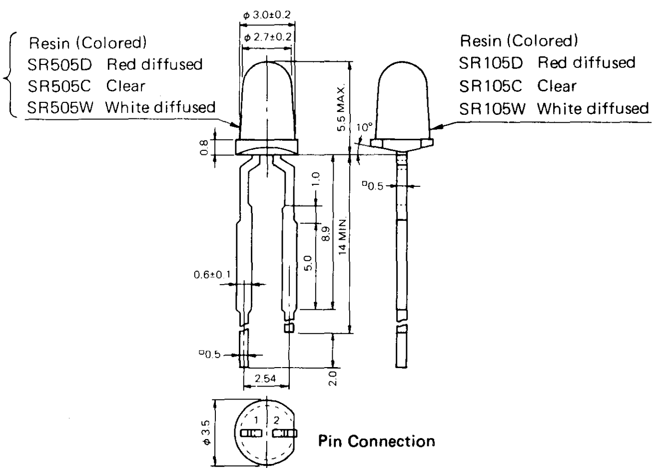
Dimensions show standard values unless specified otherwise.

Pin Connection (Bottom View)

1. Anode
2. Cathode

SR505C, D, W, SR105D, C, and W

Package Dimensions (in mm)



Pin Connection

1. Anode
2. Cathode

11

11. OVERALL COMPARISON TABLE OF GaP and GaAsP

	Item	GaP (SR503D, C, W / SR505D, C, W)	GaAsP (SR103D, C, W / SR105D, C, W)	Remarks
Absolute Maximum Rating	Power dissipation	60 mW	100/80 mW	GaP is supposed to be used at low current.
	Forward Current	30 mA	50/40 mA	GaP is supposed to be used at low current.
	Reverse Voltage	5 V	3 V	Ratings of GaP have been improved.
	Junction Temperature	100 °C	80 °C	Ratings of GaP have been improved.
	Storage Temperature	−40~+100 °C	−30~+80 °C	Ratings of GaP have been improved.
Electrical Characteristic	Forward Voltage	2 V TYP.	1.5 V TYP.	at I_F = 10 mA. Energy gap of GaP is wide.
	Reverse Current	10 μA MAX.	50 μA MAX.	
	Terminal Capacitance	100 pF TYP.	100 pF TYP.	Ratings of GaP have been improved.
	Peak Emission Wavelength	695 nm TYP.	660 nm TYP.	
	Spectral Line Half Width	100 nm TYP.	35 nm TYP.	Spectral distribution of GaP light emission is broader.
	Luminous Intensity	3~5 mcd TYP.	1~3 mcd TYP.	External quantum efficiency of GaP is higher.
	Half Value Angle	±35~±25/±10~±8° TYP.	±20/±10~±8° TYP.	Because of improvements in lead frame and mold.
Package Dimension and Finishing	Lead Dimension	24 MIN./14mm MIN.	14 mm MIN.	
	Lead Circumscribing Diameter	φ 0.8/φ 0.8 mm	φ 1/φ 0.8 mm	
	Mold Resin Color	Light Red	Deep Red	
	Parting Line	Detouring Head Center/ Located at Center	Located at Center	
Reliability	Operating Lifetime	About 210 Thousand Hours (at I_F = 10 mA)	About 280 Thousand Hours (at I_F = 10 mA)	
	Anti-environmental Property	Same as GaAsP LED	—	

APPLICATION OF SE303A AND PH302 TO REMOTE CONTROL SYSTEMS

1. INTRODUCTION

Remote control systems by light emitting diode have become common control mechanisms of TV receivers. Power ON/OFF, channel selection, volume control, etc. are performed by the remote control system employing a combination of infrared LED and PIN photodiode. Remote-controlling of air-conditioners, audio equipment and electric fans has recently been started to be examined and some manufacturers have succeeded in its practical application.

This is due to many advantages it has, such as easy miniaturization of transmitting and receiving equipment allowed by this type of system as compared with the conventional wire type remote control system and ultrasonic remote control system, fast response speed (high speed pulse modulation is possible), limited mis-operation due to Doppler effect, limited effect on external equipment, easy operation, being free from giving trouble to animals, etc.

This application manual describes important characteristics to be considered when you design a remote control circuit using infrared LED SE303A and PIN photodiode PH302, which have been produced by NEC to be applied mainly to the remote control systems of this type, and simple remote control circuits using these characteristics are shown.

2. CHARACTERISTICS OF SE303A AND PH302

2.1 SE303A is an infrared LED of GaAs crystal material made by the liquid phase epitaxial growth, developed as mainly a TV remote control light emitting source and is characterized by the peak emission wave length $\lambda_p \fallingdotseq 940$ nm and a little degradation output. This SE303A features high output and wide directional angle required for the light source of TV remote control system. Table 1 shows absolute maximum ratings and electro-optical characteristics of SE303A. Fig. 1 shows the directional pattern of SE303A. The directional angle pattern shows how the light output power would become when it deviates from the optical axis to a certain degree if the light output power on the optical axis is assumed to be 1.0 Half-power angle, which is the angle at which the relative value of the light output becomes 0.5, is used for representing the extent of directional angle and the half-power angle of the SE303A is set at approx. 25 °C to 26 °C.

ABSOLUTE MAXIMUM RATINGS (T_a = 25°C)

ITEM	SYMBOL	RATING	UNIT
Power Dissipation	P	150	mW
Forward Current	I_F	100	mA
Pulse Forward Current	I_{FP}*	1.0	A
Reverse Voltage	V_R	5	V
Junction Temperature	T_j	80	°C
Storage Temperature	Tstg	−30 to +80	°C

11

ELECTRO-OPTICAL CHARACTERISTICS (Ta = 25°C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	CONDITIONS
Forward Voltage	V_F		1.27	1.45	V	I_F=50mA
Pulse Forward Voltage	V_{FP}*		2.45	3.0	V	I_{FP}=1.0 A
Terminal Capacitance	Ct		40		pF	V=0, f=1.0 MHz
Peak Emission Wave-length	λ_{peak}		940		nm	I_F=50 mA
Spectral Half-power Value	$\Delta\lambda$		60		nm	I_F= 50 mA
Light Output Power	Po	3.0	6		mW	I_F= 50 mA
Response Time	ton, toff		1		μs	

* f=1 kHz, duty cycle = 1%

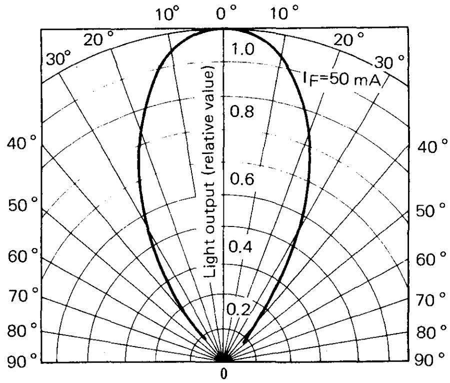


Fig. 1 Light Output Power Distribution

In the remote control system of TV etc., a handy-type output control unit is generally used, and the power supply uses dry cells, giving supply voltage of approx. 4.5 to 9 V and 2 or 3 LEDs are used. In this case, if the forward voltage V_F of infrared LED is high, required current cannot be flown. In the case of SE303A, when pulse forward current I_{FP} = 1 A (PW = 350 μs), V_F≒ 2.45 V TYP. thus giving ideal relationship with the supply voltage.

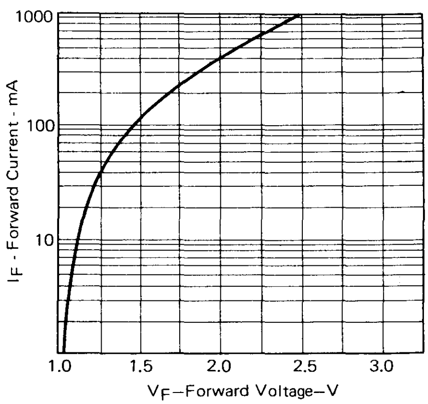


Fig. 2 Forward Current vs. Forward Voltage

Referring to the above figure, if a single infrared LED is used and pulse forward current $I_{FP} \fallingdotseq 300$ mA is flown, 3 V power supply would suffice to drive the infrared LED. While, if three infrared LEDs are connected in series and pulse forward current $I_{FP} \fallingdotseq 300$ mA is flown, pulse forward voltage would become 5.4 V (1.8 V x 3 = 5.4 V) and required power supply would become 6 to 7.5 V when the voltage drop due to protective resistance is taken into account.

2.2 PH302 is a silicon PIN photodiode developed primarily as a light sensor for TV remote control systems. This product has a convenient vertical contour to achieve optimum mounting, and has realized high quality and low price by all resin molded package.

It features high-speed response and high sensitivity. The PIN construction is used to get high-speed response. While, wide area chip is used to get high sensitivity. In addition, owing to the adoption of resin mold having the filter characteristic that selectively transmits infrared light above 700 nm the peak value of the light sensitivity comes at 940 nm, and it is almost free from disturbance light such as fluorescent lamps and shows excellent noise-free characteristics. Accordingly, there is no need for providing an infrared filter to the light sensor. Table 2 shows PH302 absolute maximum ratings and electrical characteristics. Fig. 3 shows the light sensitivity characteristics.

ABSOLUTE MAXIMUM RATINGS (T_a=25 °C)

ITEM	SYMBOL	RATING	UNIT
Reverse Voltage	V_R	32	V
Power Dissipation	P_D	150	mW
Junction Temperature	T_j	80	°C
Storage Temperature	Tstg	−40 to +80	°C

ELECTRICAL CHARACTERISTICS (Ta=25 °C)

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT	CONDITIONS
Dark Current	I_R			30	nA	V_R=10 V
MAX. Sensitivity Wave-length	λ_{max}		940		nm	
Quantum Efficiency	η		0.88			λ=940 nm
Sensitivity	S	35	50		nA/lx*	V_R=5 V
Energetic Sensitivity	S		0.6		A/W	λ=940 nm
Open Voltage	V_L		285		mV	*Ev=100 lx
Open Voltage	V_L		365		mV	*Ev=1 000 lx
Rise Time	t_r, t_f		125		ns	R_L=1 kΩ, V_R=0, λ=940 nm
Fall Time	t_r, t_f		50		ns	R_L=1 kΩ, V_R=5 V, λ=940 nm
Terminal Capacitance	C_t		14		pF	V_R=5 V, f=1 MHz
Light Sensitive Area	A		9		mm²	
Noise Equivalent Power Limit	NEP		4.2×10^{-14}		$W/\sqrt{Hz}$	V_R=10 V
Detection limit	D		6.6×10^{-12}		$cm\sqrt{Hz}/W$	

* Light source color temperature 2 854 K

11

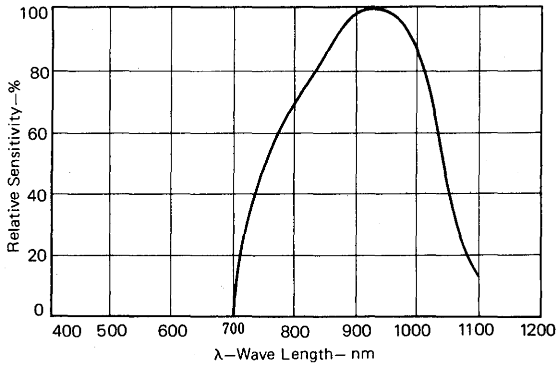


Fig. 3 Spectral Sensitivity Characteristic

3. SE303A-PH302 COMBINATION CHARACTERISTICS

It is very difficult to estimate overall characteristics by making a system design based on individual characteristics when SE303A and PH302 are applied to remote control systems. Therefore, several important characteristics are given below to facilitate SE303A-PH302 combined designing.

3.1 Relative Value of Light Output Power — Pulse Forward Current Characteristics

Fig. 4 shows relative value of light output power — pulse forward current (I_{FP}) characteristic when pulse width PW = 300 μs and duty cycle = 1/16. In the figure, light output power is represented by relative value of the light output when the light output Power at I_F = 50 mA is taken as 1.0.

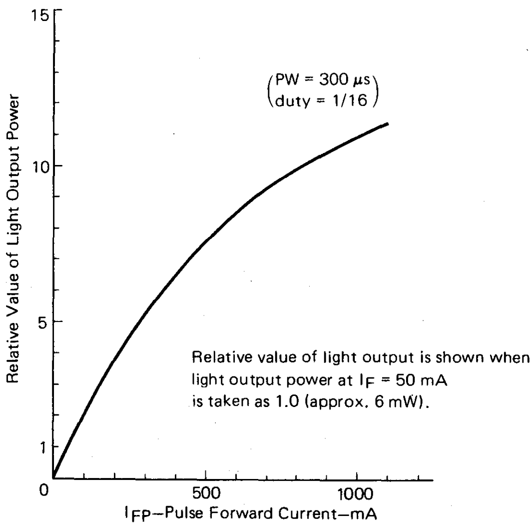


Fig. 4 SE303A Relative Value of Light Output — Pulse Forward Current

3.2 Photo Current – Pulse Forward Current Characteristic

Fig. 5 shows I_L–I_{FP} characteristic, where photocurrent I_L is a current generated in PH302 when SE303A pulse forward current I_{FP} is flown, in case SE303A is spaced 30 cm from PH302. Pulse conditions are PW = 300 μs and duty ratio = 1/16. PH302 used here has a light sensitivity of 50 nA/lx which is almost typical of PH302. As seen from the characteristic indicated by a broken line in Fig. 5, when the minimum light output power of SE303A Po = 3 mW (I_F = 50 mA) and SE303A is combined with PH302 having a typical light sensitivity, light current I_L becomes approx. 6 nA MIN.

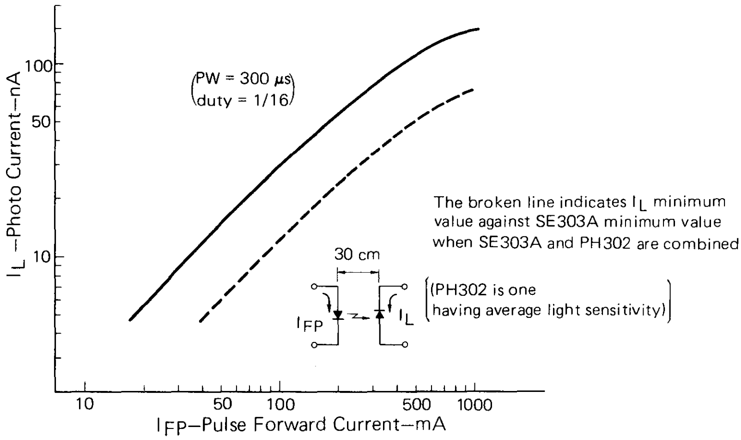


Fig. 5 SE303A-PH302 I_L–I_{FP} Characteristic

3.3 Photo Current – Distance Characteristic

Radiation intensity of infrared-ray radiated from SE303A decreases in inverse proportion to the square of the distance between the elements of SE303A and PH302. Accordingly, if photo current generated at PH302 when SE303A and PH302 are combined is I_L, and distance between SE303A and PH302 is γ,

$$I_L \propto \frac{1}{\gamma^2},$$

therefore

$$\log I_L \propto -2 \log \gamma$$

Fig. 6 shows an example of I_L-γ characteristic when SE303A and PH302 are combined and I_{FP} is taken as a parameter.

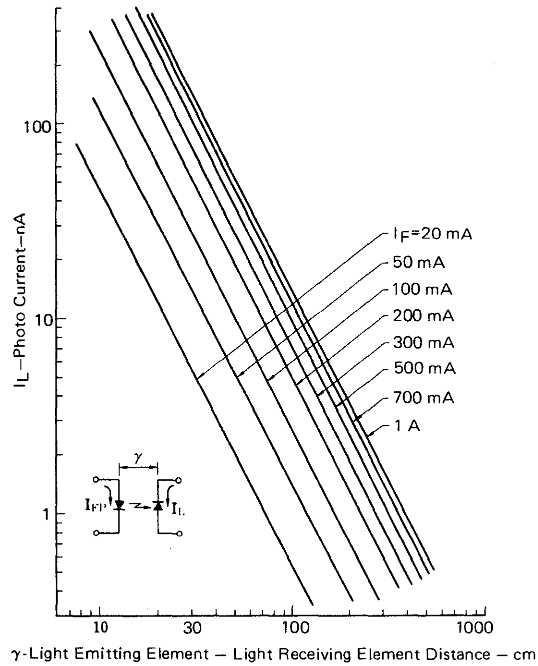


Fig. 6 SE303A-PH302 I_L–γ Characteristic

4. DESIGNING A REMOTE CONTROL SYSTEM

For designing a remote control system, how much photo current I_L can be generated in PH302 is examined based on the target distance between the light emitting element and light receiving element taking advantage of SE303A-PH302 combined characteristics given in Section 3 and the drive condition (pulse forward current value) of light emitting element of SE303A, and from the result gain of the amplifier for amplifying photo current I_L is determined. It is noteworthy that a circuit having a high gain in the first stage should be avoided since noise due to external light, etc. is also amplified.

A block diagram is shown below.

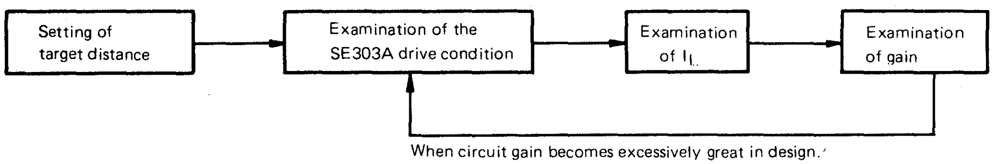


Fig. 7 Block Diagram

5. CIRCUIT EXAMPLES

5.1 Examples of general remote control circuit

Fig. 8 and 9 show the pulse driving circuit of the SE303A and the pulse receiving circuit of the PH302, respectively, as circuit examples of remote control system using the SE303A and the PH302.

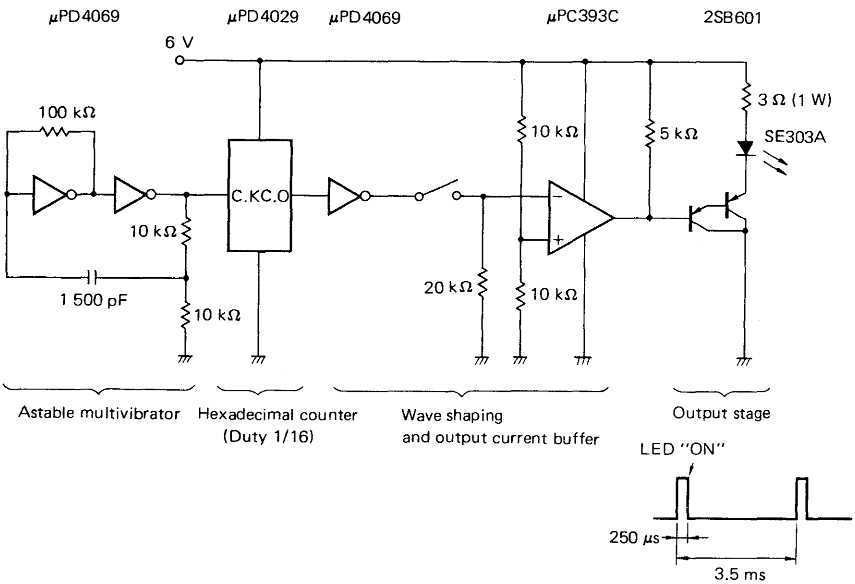


Fig. 8 SE303A Pulse Driving Circuit

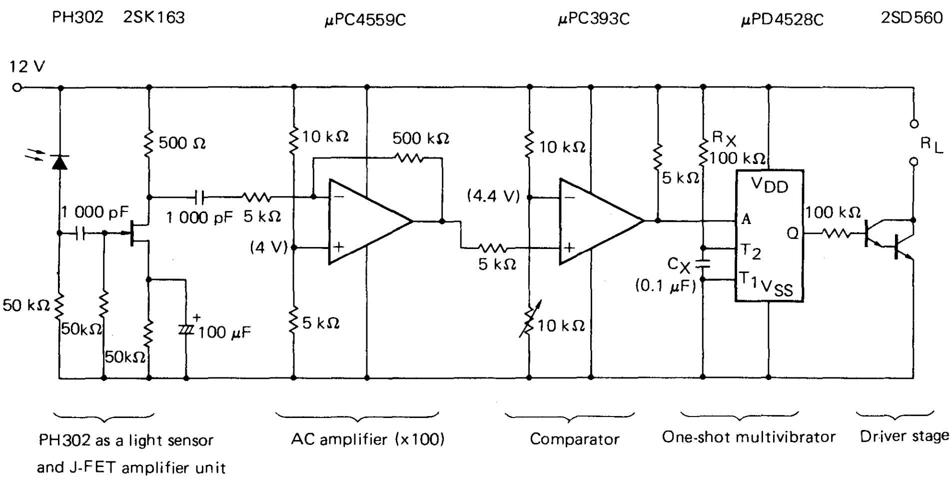


Fig. 9 PH302 Pulse Receiving Circuit

In Fig. 8, the astable multivibrator is composed of μPD4049C, the duty cycle of the SE303A is made 1/16 by the hexadecimal counter, and μPC393C as the wave shaping and output current buffer drives 2SB601. Since saturation voltage between the collector and emitter of 2SB601 is approx. 1 V and forward voltage V_F of SE303A is approx. 2.5 V, I_{FP} of approx. 800 to 900 mA flows.

Referring to Fig. 9, light received at PH302 is converted to electric current, which is amplified to approx. 10 times the original at 2SK163 and the current is further amplified by μPC4559C. Then, the One-shot multivibrator is driven through the comparator μPC393C. Subsequently, the last stage 2SD560 drives the load. The drive condition of the load in the last stage can be changed by narrowing the pulse interval of SE303A or changing the time constant of one-shot multivibrator.

In this circuit a 1 000 pF capacitor is inserted between 2SK163 and μPC4559C to eliminate the influence of external light of around 50 Hz or 60 Hz.

5.2 Examples of application to TV remote control system

Application to TV remote control system is currently most common. In the case of TV remote control, pulse modulation is performed for the channel selection, power ON/OFF, volume control, etc. Pulse modulation systems differ widely in manufacturers making the control unit.

This application manual presents circuit examples employing NEC remote control transmitting/receiving IC, μPD1986C and μPD1987C in Fig. 10 and 11. For details, refer to catalogs of μPD1986C and μPD1987C.

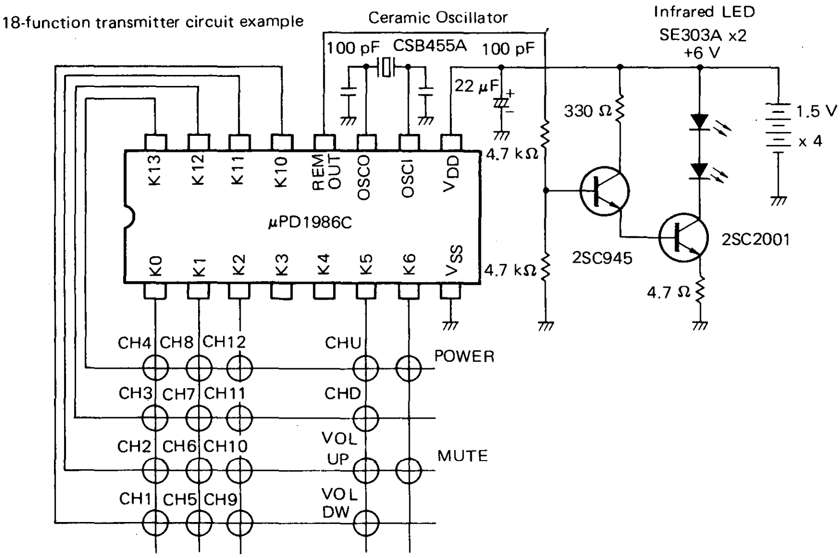


Fig. 10 Example of Application of SE303A to TV Remote Control System

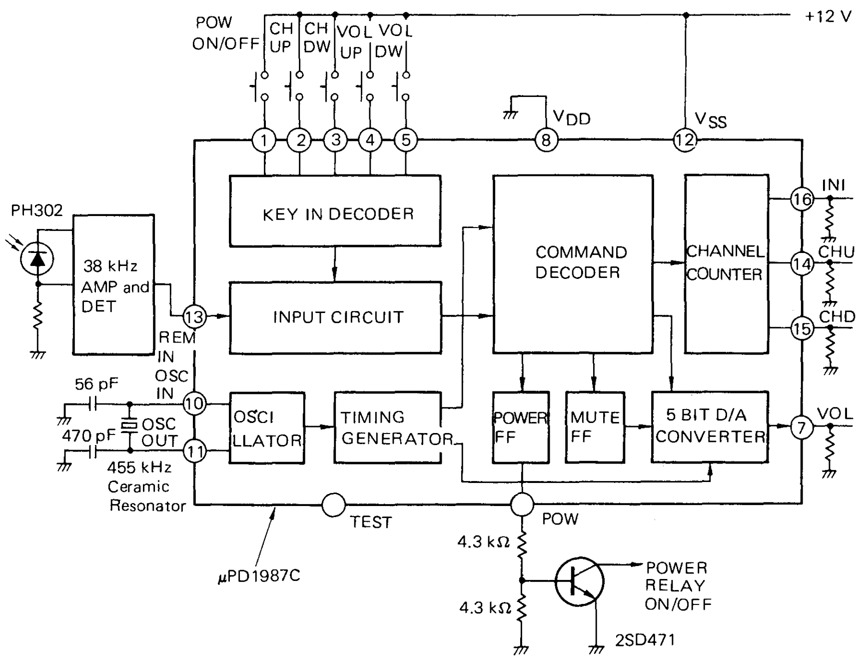


Fig. 11 Example of Application of PH302 to TV Remote Control System

6. CONCLUSION

As previously mentioned, remote control systems employing light are in use mainly for TV, air-conditioner, audio equipment, etc. It is expected that the field of application will extend to opening/closing of a garage door from a car, remote control of vehicle including obstruction detection at the time of mobile backing, opening/closing of door, remote control of toys, etc. In addition, applications to telephone set and coin detection in vending machine, VTR tape detection, etc., which have so far been impracticable due to limited distance available between the light emitting element and light receiving element, may be possible as a photointerrupter in combination of SE303A and PH302. It is desired that better remote control systems will be developed based on the information contained herein.

MANUAL FOR THE MOUNTING OF LEDS AND PHOTOTRANSISTORS

1. INTRODUCTION

Differing from conventional tungsten lamps, LED lamps have the advantages of low power consumption, low heat generation, and long life. However, they require precautions in handling which are particular to semiconductor products, and their handling differs from that of tungsten lamps.

Furthermore, since importance is placed on the optical properties of LED lamps and phototransistors, they require the use of plastics which transmit light to the outside with good efficiency. Therefore, the handling of LED lamps and phototransistors differs from that of conventional transistors and diodes. The plastic employed in optosemiconductor devices, such as completely plastic moulded or metal stem plus plastic potting types, differs from the black moulding material used for ordinary plastic moulded transistor or ICs, and nearly pure transparent epoxy plastic is used alone or with the addition of a minute quantity of colouring or scattering material. For this reason, when compared with ordinary semiconductor devices, optosemiconductor devices are slightly inferior in resistance to heat and chemicals, and in strength against mechanical shock and wear. Therefore, special precautions should be taken when handling and mounting these devices.

Adept mounting methods and general precautions for the handling of LED lamps are described below. It is desired that by referring to the description the occurrence of trouble can be prevented when mounting or working with LED lamps.

2. ADEPT METHODS OF MOUNTING LED LAMPS.

2.1 Fitting with the use of Panel Mounters.

When mounting LEDs on various apparatus or equipment, panel mounters may be employed due to problems of decoration or space, or to improve contrast.

NEC is producing 2 types of panel mounters to be supplied according to demands of customers. These 2 types are namely: one for use with TO-18 stem plus plastic potting type LEDs (Examples: SR101C, SR104D, SG204D, etc.), and one for use with completely plastic moulded type, large size, LEDs (Examples: SR503C, D.W. SG203DA, TA . . . , etc.)

(1) Method of mounting SR101C type LED with a panel mounter.
(Can be used commonly with SR101C, SR104D, SG204D, SY404D, and SY404T types)

The external view of the panel mounter is shown in Fig. 1 (a), and a diagram of a SR101C type LED completely mounted with a panel mounter is shown in Fig. 1 (b). A flow chart for the order of fitting is shown in Fig. 1 (c), the procedure of which shall be explained following. When mounting a SR101C lamp employing a panel mounter, first insert the LED into the ring tube ①. When doing this, make sure that the tab (projection of flange) of the LED enters the slit of ring tube ①. Next, in order to secure the LED, the internal ring ② is inserted from the bottom. The internal ring ② should be pushed in until its projecting part enters the inside groove of the ring tube ①. The whole construction is then inserted into the panel hole, and the panel mounter is secured to the panel with the external ring ③. For mounting, a panel hole diameter of 8.0 mmϕ is recommended, and a panel thickness of from 1.0 mm to 3.5 mm is suitable.

* Precautions to take when mounting.

- Care should be taken, since if the panel hole is too large there will be excess room between the panel and the mounter, and the mounter may move.
- The outer ring should be pushed in securely, since if the tightening of the outer ring is insufficient the whole mounter will be loose against the panel.
- When it is desired to use an adhesive to secure the outer ring, a cyano acrylate or synthetic rubber type adhesive should be used. In the above case the use of excessive amount of adhesive should be avoided, since appearance will be spoiled if adhesive sticks to the panel surface or visible parts of the LED.

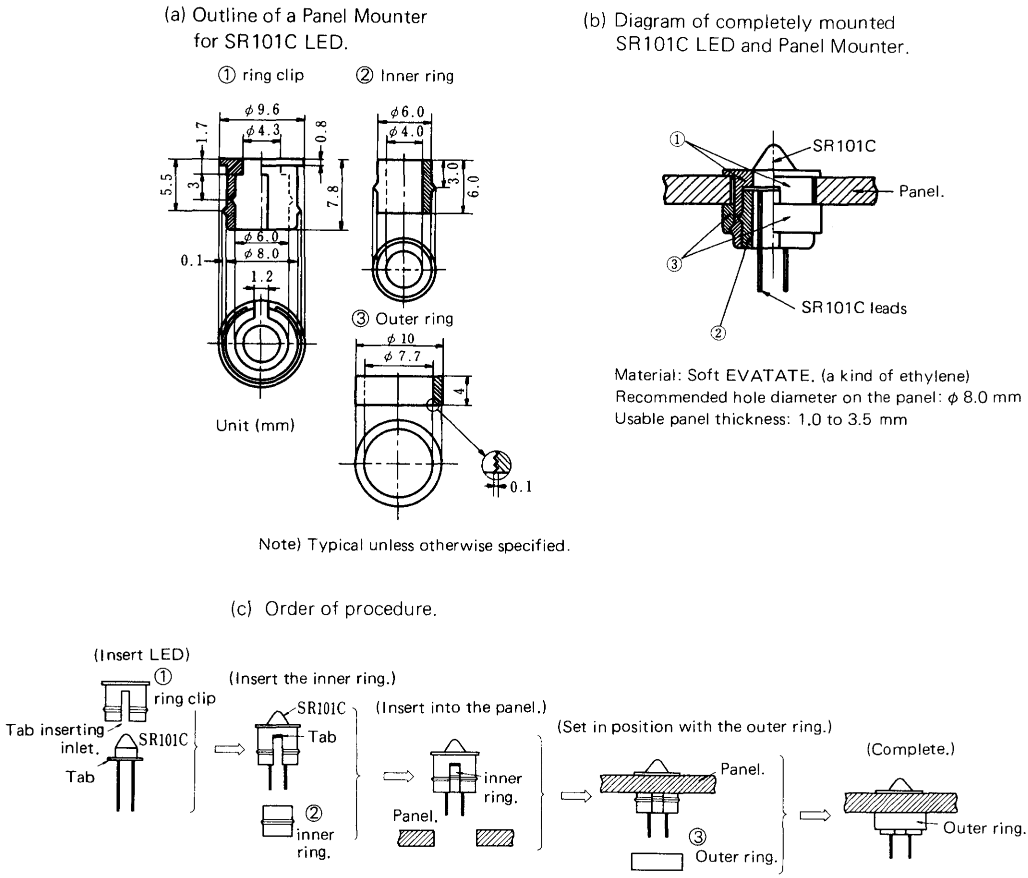


Fig. 1 Method of fitting SR101C type Panel Mounter.

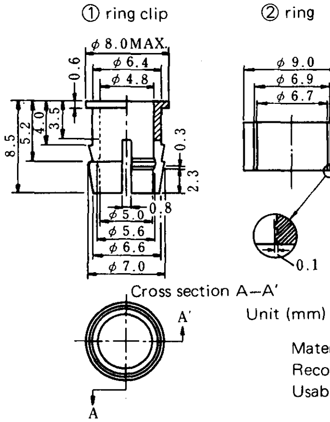
(2) Method of mounting SR503D type LED with a Panel Mounter.
(Can be used commonly with SR503D, C, W, SG203DA, TA and SY403DA, TA types.)

The external view of the panel mounter is shown in Fig. 2 (a), a diagram of SR503D type LED completely mounted with a panel mounter is shown in Fig. 2 (b), and the order of the procedure for mounting is shown in Fig. 2 (c). Compared with the SR101C type panel mounter, the SR503D type is made of harder material and the inserting of the outer ring has a tighter fit. Furthermore, since the maximum diameter (7.0φ) of the ring tube ① is larger than the dimension (6.4φ) of the part contacting the panel, attention should be paid to the panel hole diameter and to the observance of the exact procedure.

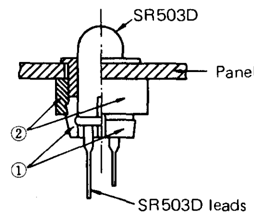
To fit this mounter, first it is necessary to insert the ring clip ① into the panel hole as shown in Fig. 2 (c). For this, the recommended hole diameter on the panel is 6.7 mmφ, and a panel thickness of 0.6 to 3.0 mm is suitable. Since the diameter of the panel hole inevitably becomes large and the excess room between the panel and mounter increases in Method-2, which consists of inserting the ring clip into the panel hole while it contains the LED, it is recommended that Method-1 be employed whenever possible. After the ring clip has been inserted into the panel, the LED is inserted into the ring clip until it is fixed securely against the groove inside the ring clip. Finally, the ring clip and panel are secured together with the ring ②. When doing this, the ring clip should be secured by hand or with a jig while the ring is pushed in.

* Precautions to take when mounting.
○ The fit between the ring tube and ring is extremely tight, therefore, attention should be paid to the position and direction of the panel, the direction of the LED, etc. before final mounting.

(a) Outline drawing of a Panel Mounter for SR503D type LED.



(b) Diagram of a completely mounted SR503D LED and a Panel Mounter.



Material: Polypropylene plastic.
Recommended hole diameter on the panel: φ 6.7 mm
Usable panel thickness: 0.6 to 3.0 mm.

Note) Typical unless otherwise specified.

(c) Order of procedure.

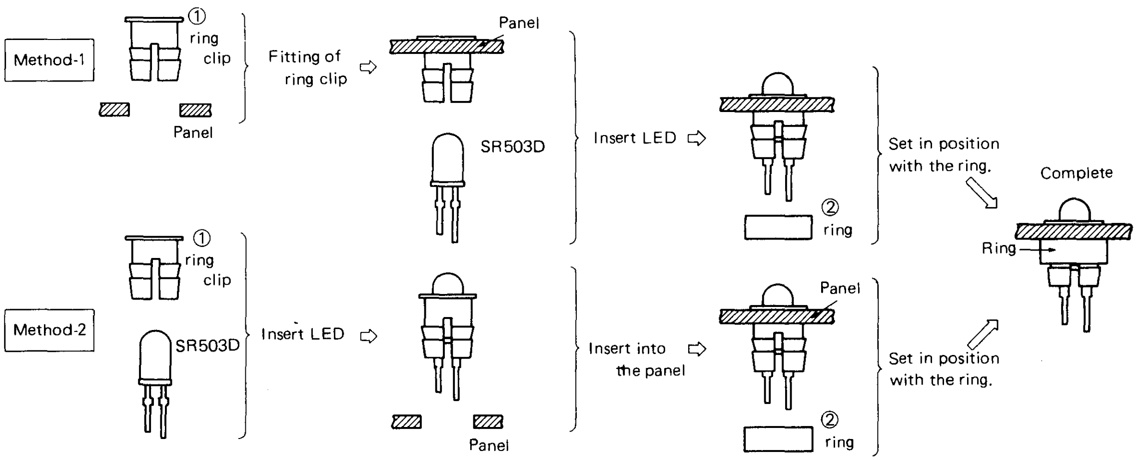


Fig. 2 Method of fitting SR103D type Panel Mounter.

2.2 Method of mounting on Printed Wiring Board (PWB).

This method of mounting the LED directly on the PWB is the most popular mounting method. Here, recommended methods of mounting and precautions to be taken when mounting are described, in accordance with the shape of the LEDs.

(1) Conditions of soldering work.

Recommended conditions for soldering work, according to the shape of the LED, are shown in Table 1.

Table 1. Recommended conditions for Soldering Work according to shape of LEDs.

Shape	Conditions for soldering work			Recommended PWB conditions	
	Solder temperature	Working time	Place of soldering	Hole spacing	Hole diameter (mm)
TO-18 type	260 °C	5 s or less	1.5 mm or more distance from moulding base.	2.54 mm	0.6 ϕ
(SR101C type)	300 °C	3 s or less			
4.8 ϕ type	260 °C	5 s or less	5 mm or more distance from moulding base.	2.54 mm	1.0 ϕ: Can be inserted at distance up to 3.5 mm from base.
(SR503D type)	300 °C	3 s or less			
3 ϕ type	260 °C	5 s or less	Ditto	2.54 mm	0.8 ϕ
(SR105D type)	300 °C	3 s or less			
Double ended type	260 °C	5 s or less	3 mm or more distance from moulding base.	(3.5 mm)	0.8 ϕ
(SR106D type)	300 °C	3 s or less			

Generally, no problems in mounting should occur when the work is performed according to the conditions of Table 1. And, the occurrence of such failures as drastic reduction of brightness, open and short circuits, and damage to the moulding can be prevented. However, due to restrictions of space or proximation of other components it may not be possible to always observe the recommended conditions. In such cases, the PWB should be designed so as to avoid applying stress to the lead wires and working procedures which prevent temperature rise of the LEDs should be employed.

When soldering or lead wire bending conditions are faulty, or when mechanical stress remains between the lead wires and a thermal stress is applied, the possibility of danger will be high for the occurrence of such failures as reduction of brightness, open and short circuits, and damage to the moulding.

(2) Recommended mounting methods according to the shape.

① The case of TO-18 type LEDs.

As shown in Fig. 3, in the case of TO-18 type LEDs, there are two methods of mounting, one in which the LED is mounted directly onto the PWB, and one in which stopper consisting of a bushing is used.

When it is specially desired to raise the height of the moulded part, bushings for power transistors (for example: NEC's B-17 and B-18 bushings) can be used.

Name of bushing.	Dimension of part A.
B – 17	2.1 mm
B – 18	2.5 mm

(a) Recommended method. (b) Method using bushing.

Fig. 3 Methods of mounting TO-18 type LEDs.

② The case of 4.8 ϕ type completely moulded LEDs.

The lead wires of the 4.8 ϕ type LEDs have steps in diameter at a distance of 3.5 mm from the moulding base, therefore, when the lead wires are inserted into 1.0 mmϕ holes these steps act as stoppers, and soldering can be easily performed.

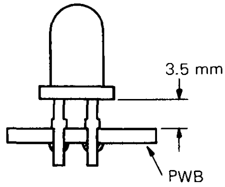
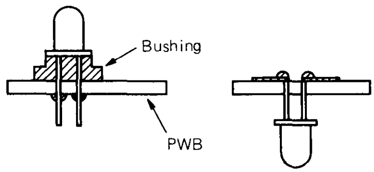


Fig. 4 Methods of mounting 4.8 ϕ type LEDs.

③ The case of 3 ϕ type completely moulded LEDs.

Since the lead wires of 3 ϕ type LEDs have no step in diameter like the 4.8 ϕ type LEDs, an object to act as a stopper will be required to be inserted between the PWB and LED. One method is to employ bushings used for power transistors (For example, the B-18 bushing introduced before.). However, there is a simpler method in which the lead wires are bent, the PWB turned over, and the LED positioned in an upside down position and then soldered in place.



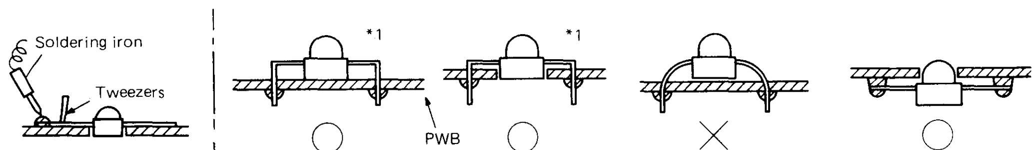
(a) Bushing employed. (b) Bent lead wires employed.

Fig. 5 Methods of mounting 3 ϕ type LEDs.

④ The case of Double ended type LEDs and Phototransistors.

Differing from self-supporting LEDs, in the case of double ended type LEDs there are two methods of mounting, one in which the lead wires are bent and inserted from the front of the PWB as shown in (a) and (b) of Fig. 6, and one in which the LED is mounted on the reverse side of the PWB.

In the former method, the shifting of the optical axis should be kept as small as possible through positioning the LED by providing a hole in the PWB for inserting the plastic base of the LED. A precaution common to both methods (a) and (b) is that, inserting the LED forcibly into the hole or soldering while mechanical stress is applied should be absolutely avoided. Furthermore, since these type of devices are of ultrasmall size, the amount of plastic is small and the temperature of the plastic will rise rapidly when soldering. Therefore, it is recommended that, as far as possible when soldering, the lead wires be gripped with pliers or tweezers in order to dissipate heat as shown in the Fig. below.



(a) Method of mounting by bending lead wires and inserting from the front surface.

(b) Method of mounting from reverse side of PWB.

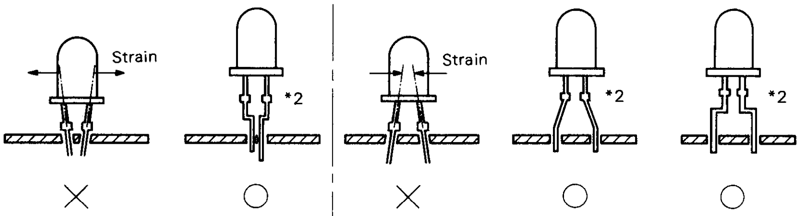
Fig. 6 Methods of mounting Double-ended LEDs and Phototransistors.

*1: Lead wires are inserted into PWB after forming.
For forming a refer to (3) — ②

(3) Precautions for Mounting.

① When mounting LEDs on a PWB having a different hole pitch.

Great care should be exercised, since, when LEDs are forcibly inserted into PWBs having different hole pitches open circuits or reduction of brightness due to gaps forming between the pellets and plastics may occur. In such cases the method shown in Fig. 7 should be followed.



(a) When the hole pitch is less than 2.54 mm

(b) When the hole pitch is more than 2.54 mm.

Fig. 7 Method of mounting when the hole pitch of the PWB is different.

*2: Lead wires are inserted into the panel board after forming. For forming, refer to ②.

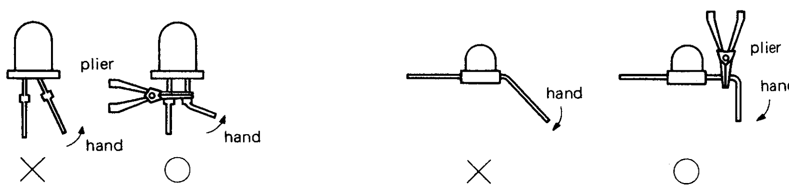
② When bending the lead wires.

When lead wires are to be formed according to Fig. 6 *1 or Fig. 7 *2, follow the method shown in Fig. 8. Recommended method of bending Lead Wires.

a) In the case of a self-supporting LED, the lead near the base should be held with tweezers or pliers, in order to prevent any stress remaining in the plastic part.

b) In the case of double-ended type LEDs, bend the lead wires at a distance 1.5 mm or more from the lead wire constriction or moulding base.

c) In the case of phototransistors, bend the lead wires at a distance 1.5 mm or more from the moulding base, while gripping the lead near the base with tweezers or pliers, in order to prevent any stress remaining in the moulded part.



(a) The case of self-supporting LEDs.

(b) The case of Double-ended type LEDs and Phototransistors.

Fig. 8 Methods of bending LED Lead Wires.

③ When alignment is performed after soldering.

When a number of LEDs are mounted onto a single PWB, after soldering it may be necessary to correct the shifting in position of the heads of the LEDs. Before performing alignment of the heads of the LEDs, always leave the LEDs 5 to 10 minutes to cool after soldering, so that the LEDs can return to normal temperature. When correcting the position of the LEDs, since pushing the heads of the LED lamps with the fingers or pushing the LEDs forcibly into the panel holes may cause internal open circuits, correction of the LED positions should be accomplished by grasping together with pliers the anode and cathode lead wires at the same time and bending the lead wires at the joint with the PWB.

2.3 Direct adhesion to the panel.

When LEDs are to be fitted into such small equipment as pager receivers or hand microphones, due to restrictions of space it may not be posssible to mount the LEDs on the PWB. In such cases, it is recommended that panel mounters be used whenever possible and, as a rule, direct adhesion to the panel be avoided. When direct adhesion cannot be avoided, this should be performed while paying special attention to the following points.

Methods of Mounting.

Direct adhesion of 4.8 ϕ type LEDs and 3 ϕ type LEDs to the panel.

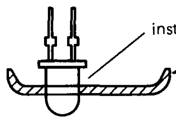


Fig. 9 Method of direct adhesion to the panel.

An adhesive suitable for the panel material should be selected, and be coated on the LED neatly. As an example; an instant adhesive has been used to mount a SR503D LED on a SSB plastic case.

Precautions.

- o Pushing the moulded part forcibly into the panel hole should be avoided, since this may cause open circuits or degradation of brightness.
- o Use of excessive amounts of adhesive should be avoided, since it will make the surface of the plastic dirty, and also cause it to be deformed.

3. PRECAUTIONS FOR HANDLING.

In the aforementioned paragraph "2. Adept methods for the mounting of LED lamps.", several precautions for the mounting of LED lamps were noted. General precautions for the handling of LEDs and phototransistors shall be given here.

(1) Resistance to chemicals.

If such solvents as trichloroethylene or acetone come into contact with the surface of LEDs, the state of the surface may change, therefore, as a rule cleaning with solvents should be avoided. When cleaning with solvents has to be performed, solvents of comparatively weak reactive strength such as alcohol of freon should be used.

(2) Resistance to wear.

In order to maintain transparency, comparatively soft plastics are used for moulded products. Therefore, intentional rubbing with metal or the finger nails or the use of sand blasting should be avoided. No trouble will be caused by ordinary handling of LEDs with the fingers.

(3) Resistance to heat.

Care should be taken to avoid heating the plastic part reaching to the temperature of more than 100 °C, since this will cause discolouration of the plastic.

(4) Mechanical stress between lead wires.

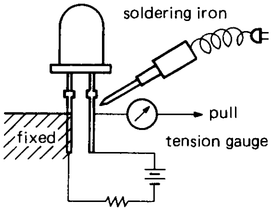
It has been mentioned before that soldering while stress is applied between the lead wires, or the applying of such strains as tension, torsion, or compression between the lead wires while they are still hot from soldering, will be the cause of such breakdowns as open or short circuits inside the element. For reference, the results of tensile strength tests of lead wires under soldering conditions will be given in Table 2.

[Reference Data]

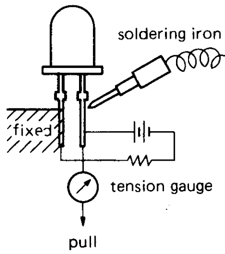
Tensile strength tests of lead wires.

Testing method.

o The case of 4.8 ϕ type and 3 ϕ type LEDs.



(a) Tension in horizontal direction.



(b) Tension in vertical direction.

Fig. 10 Measurement diagram of tensile strength tests of self-supporting LEDs.

① Pulling in horizontal direction, at normal temperature.
Position of the lead wire pulled : 5 mm from base.
Tension gauge: 2 kg fullscale

② Pulling in horizontal direction with soldering iron applied.
Soldering iron temperature: 260 °C
Position of heat application: about 5 mm from base.
Duration of the tension application: Pulling starts 5 seconds after soldering iron is applied. Solder-iron continues to apply.

③ Pulling in vertical direction, at normal temperature. (Same conditions as ①)

④ Pulling in vertical direction after soldering iron is applied. (Same conditions as ②)

○ The case of Double-ended LEDs.

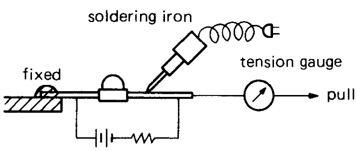


Fig. 11 Measurement diagram of tensile strength tests of Double-ended type LEDs.

① Pulling in horizontal direction, at normal temperature.
Tension gauge: 2 kg fullscale.

② Pulling in horizontal direction with soldering iron applied.
Soldering iron temperature: 260 °C
Position of heat application: About 3 mm from the base.
Duration of the tension application: Pulling starts 5 seconds after soldering iron is applied. Soldering iron continues to apply.

Table 2 Results of Tensile Strength Test of Lead Wires.

Testing method / Type	Horizontal direction (g)		Vertical direction (g)	
	(1) Normal temperature	(2) Heating with soldering iron	(1) Normal temperature	(2) Heating with soldering iron
SR503D (4.8 ϕ type)	n = 10 100 % OK up to 2 kg	n = 10 $\bar{x}$ = 320 g (MAX. = 370 g MIN. = 270 g)	n = 10 100 % OK up to 2 kg	n = 10 $\bar{x}$ = 410 g (MAX. = 500 g MIN. = 310 g)
SR105D (3 ϕ type)	n = 10 100 % OK up to 2 kg	n = 10 $\bar{x}$ = 150 g (MAX. = 230 g MIN. = 100 g)	n = 10 100 % OK up to 2 kg	n = 10 $\bar{x}$ = 310 g (MAX. = 390 g MIN. = 220 g)
SR106D (Double-ended type)	n = 10 $\bar{x}$ = 1.8 kg (MAX. = 2 kg MIN. = 1.5 kg)	n = 10 $\bar{x}$ = 210 g (MAX. = 400 g MIN. = 60 g)		

Note

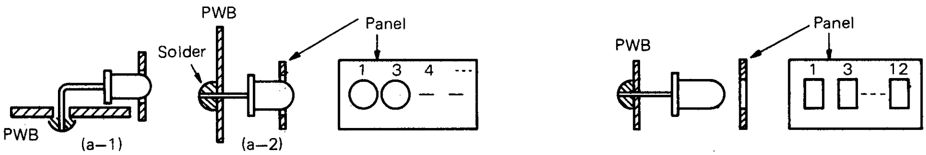
1. Due to the fullscale of the tension gauge being 2 kg, the normal temperature tensile tests ① and ③ of 4.8 ϕ type and 3 ϕ type LEDs, were conducted at a maximum load of 2 kg.
2. In the tests ② and ④, in which the soldering iron was applied, loosing of lead wires due to cracking and softening of the plastic was observed just before open circuits occurred. For some examples, pulling out of lead wires occurred when the load was further increased.

4. EXAMPLES OF THE APPLICATION. (Use of plural LEDs)

Recently, in addition to the use of a single LED as an indicating lamp, the cases have become more prevalent where plural LEDs are employed for such uses as the indication of automatic channel selection in television receivers, peak level meters and channel indications in tape decks and radio tuners, etc. LEDs in plurality are further used in a wide range of applications, including matrix and embossed indication of characters, and photo-interrupters which are combinations of light emitting and receiving. Here, examples of practical application and fields of future application of these uses shall be described.

(1) Indication of electronic channel selection in television receivers.

At present, 7 or 8 red LEDs of the SR503D type are used in the automatic channel selector of television receivers employing ICs. There are 2 ways of mounting these LEDs, one in which the heads of the LEDs protrude directly from the panel surface, and one in which indications are made through filters. In the former case, care is necessary when aligning the LEDs to the panel. When filters are employed, special filters having diamond cuts can be used in addition to purple filters (For example: Mitsubishi's Purple 373). Practical examples of these methods are shown in Fig. 12.



(a) Method where LED heads are directly exposed on the panel surface. (b) Method employing filters.

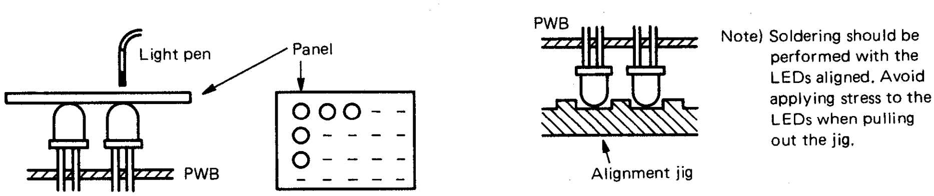
Fig. 12 Examples of automatic channel indication in television receivers.

(2) Peak level and channel indication in tape recorders and decks, and stereo receivers.

The above indications are accomplished in the same way as automatic channel indication, and several LEDs are arranged in a single row. In these types of indication, in nearly all cases the LED heads are made to protrude directly from the panel surface. Depending on the size of the equipment, either SR503D or SR105D type LEDs may be used.

(3) Matrix indication.

There are cases where about 500 high brightness LEDs are employed as the item panel of the light pen equipment of computers. The item panel is in the form of a matrix of about 20 x 25 LEDs, and employs a system in which one LED is normally designated and lit, and scanning is performed until the next LED is designated. The light pen has an optical fiber at the end of which a photo detector is mounted. Clear type LEDs of the SR102 or SR503C type are used in them.



(a) Practical example (b) Method of mounting

Fig. 13 Practical example of light pen equipment.

(4) Embossed indication of characters.

In function indicating methods employing lamps, the state of the function is generally indicated by ON-OFF of the LED. However, in order to make the state of the function more clear, there is a method in which indication is made with lighted characters. Examples of this method are often seen in large equipment and control panels, with tungsten lamps being replaced by several LEDs or design lamps. When several LEDs are employed, particularly, the size of the characters, the distance between the LEDs and the character panels, the use of reflector panels, and the use of filters will present problems. Among NEC's LEDs, the large size SR503D, or SR503C, or SR104D and SR101C of the TO-18 type should prove suitable. NEC is presently developing a flat surface type LED.

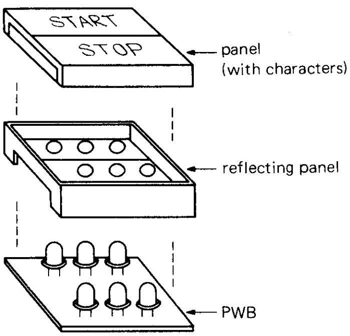


Fig. 14 Practical example of lighted character displays and precautions for it.

Precautions:

In order to adjust the brightness of characters and make the brightness of each character uniform, pay attention to the following points.

(1) The size of the characters and the number of LEDs.

(2) The distance between the character panels and the LEDs.

(3) The use, of a reflector panel.

(5) Push-button indication of telephones.

Cases are rapidly increasing where incandescent lamps are being replaced by LEDs for the channel indications of telephone set. Depending on the types of telephone set, 3, 4, or even 8 LEDs may be used. In order for these LEDs to function as flat surface lamps they are generally employed with multi-directional reflective filters (For example: Transparent filters with diamond cuts, or filters having uneven reflective surfaces, etc.). Bright LEDs of broad directivity are desirable, and among NEC products red SR104D, SR104DA, and SR503D LEDs are being used.

In the future, in order to distinguish the kind of the line being used, green or amber LEDs will be considered.

(6) Photo-interrupters.

At present, photoelectric switches, consisting of pairs of LEDs and photo detectors, for use as the speed control of motors, printers, and rotating disc in various equipments can be seen everywhere. In Fig. 15, the structure of a typical photo-interrupter is shown.

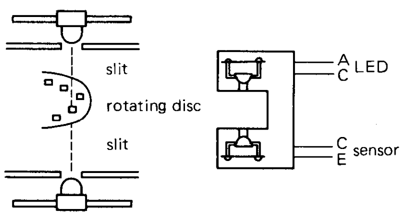


Fig. 15 Structure of Photo-interrupter.

When designing a photo-interrupter, if a slit as shown in Fig. 15 is used, it is necessary to pay attention to the shifting of the optical axis, and adjust the size and distance of the slit appropriately. In the case of NEC products, pairs of SR106C or SE302A and PH101 or PH102, photo detectors, have gained an excellent reputation on the market.

11

APPLICATIONS OF PHOTOCOUPLERS PS2003B & PS2009B (Part 1)

1. INTRODUCTION

As electronic devices have rapidly come into wide use and become versatile, the utilization of photocouplers as isolators has been paid attention in recent years. Photocouplers are generally known for their practicality as interfaces in circuits with different potentials as a method of noise suppression of transmission lines, and as interfaces between DC- and AC-lines, etc. In addition, by virtue of their technological innovation which has brought about improvement in characteristics and uniform quality, together with their cost reductions, photocouplers as a matter of course have been in great demand not only in industrial applications but also in light industrial applications and consumer ones. In particular, with the popularization of micro computers, the applications of photocouplers have widely spread from home appliances such as airconditioners and microwave ovens, to vending machines, copying machines, and especially to TV sets and audio sets.

Based on the electrical characteristics of the PS2003B, this data sheet provides a description of the application examples of photocouplers in consumer equipment, and the operating notices. We hope this will be of much help for your to comprehend the electrical characteristics of photocouplers, and starting wtih this data sheet, you would further consider many other electronic equipment.

2. CHARACTERISTICS OF PHOTOCOUPLERS

A photocoupler consists of a light emitter and a light sensor. With light as its medium, a photocoupler as an isolator is an optical coupler transmitting electrical signals, having the following function.

Table 1. Comparison of Photocoupler, Lead Relay and Pulse Transformer.

Item	Photocoupler	Read Relay	Pulse Transformer
Space merit	O	Δ	X
Light weight & Ruggedness	O	X	X
Service life	O	X (having contacts)	O
Vibration & Shock	O	X	O
Chattering	O	X	O
Welding	O	X	O
Switching speed	O (10 μs)	Δ (1 ms)	–
Frequency response	Δ (DC~several 100 kHz)	O (DC~30 MHz)	–
On-resistance	X ($V_{CE(sat)}$)	O	–
Electrostatic Capacitance	X	O	X
Interface with IC	O	X	X
Explosionproof Structure	O	X	O
Magnetic effect	O	X	X
Installation flexibility	O	O	X
Overall reliability	O	X	Δ

1. Transmitting electrical signals in only one direction.
2. Isolating input and output, and eliminating common-phase noise.

The functions can be compared to those of read relays and pulse transformers, as shown in Table 1, with all their advantages and disadvantages going hand in hand, presently photocouplers and the other two are coexistent. Nevertheless, in the light of their merits, the applications of photocouplers are expected to expand further.

The usage of photocouplers roughly falls under two catergories: the digital switching function, and the linear transmission of signals. Due to problems of non-linearity as well as long term variation of the current Transfer Ratio (CTR), the usage of photocouplers is overwhelmingly centered on the former. For the digital switching function, photocouplers are used for interfacing logic circuit and power circuit, used in photo chopper circuits, and substitutes for pulse transformers, etc. On the other hand, for the linear function, it is used for eliminating noise upon transmitting sound signal or other sensed signals, for interchanging ground points, etc.

3. ELECTRICAL CHARACTERISTICS

The PS2003B and the PS2009B are optically coupled isolator containing a GaAs infrared LED and a Si-phototransistor. The PS2003B has a base terminal. The use of this base terminal makes possible the improvements in the switching speed, the transistor leakage current, and noise elimination for input signals, etc. (For handling the base terminal, referring to the Technical Note for Opto Electronic Applications LEP-501 "PHOTOCOUPLER PS2001 CIRCUIT DESIGNING MANUAL") As for the PS2009B, because its base terminal is not exposed, it has no antenna effect to external noise, and therefore it is effectively strong against external noise. Following is a description of the characteristics of the PS2003B (same as the PS2009B), particularly the most essential ones among the electrical characteristics, namely the CTR (Current Transfer Ratio $I_C/I_F \times 100$ %), the noise-immunity, the switching speed, and the frequency response.

3-1 CTR Characteristics.

The CTR, a constant corresponding to the Current Amplification Factor (h_{FE}) of transistor, is varied by input current I_F, base resistance R_B, and ambient temperature Ta. Attention should be paid to the CTR characteristic upon designing, and in case of switching operation make sure that I_F is set in such a manner that the operation is always in over-drive state.

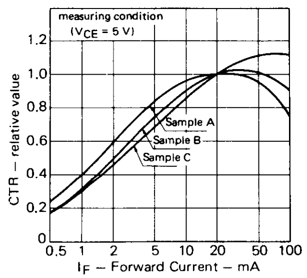


Fig. 1 An example of CTR–I_F characteristic.

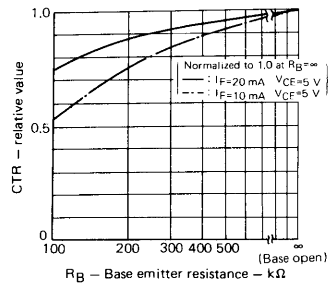


Fig. 2 An example of CTR–R_B characteristic.

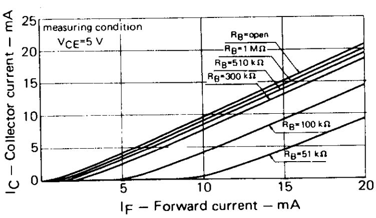


Fig. 3 An example of I_C–I_F characteristic with varied R_B.

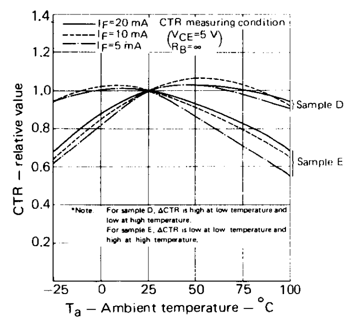


Fig. 4 An example of CTR–Ta characteristic.

Figure 1 shows CTR-I_F characteristic. Figure 2 shows CTR-base resistance R_B characteristic. Figure 3 shows I_C—I_F characteristic when varying R_B, And Figure 4 shows CTR-Ta characteristic.

Figure 1 shows the dependence of CTR on I_F, CTR decreases when the current is low, and reaches maximum value when I_F is approx. 20 to 50 mA. Listed in the catalog is the value of CTR when I_F is set at 20 mA, therefore note that when the forward current I_F on the LED side is set at 10 to 5 mA, the absolute value of CTR becomes small. (CTR varies accordingly with forward current.) For example, assuming CTR is 1 at I_F=20 mA, CTR is approx. 0.9 and 0.8 at I_F=10 mA, 5 mA, respectively. As shown in Figure 2 CTR also decreases when base resistance R_B is inserted between emitter and base of transistor. The smaller is R_B, the smaller is CTR, assuming that CTR_1 be the value of CTR at this time, and CTR_0 that of CTR in the open state, then CTR $\doteqdot$ CTR_0 $(1-V_{BE}/I_{CBL} \cdot R_B)$, where $h_{FE0} \doteqdot h_{FE1}$. In the open state, a part of the light sensor current I_{CBL}—which flows between collector and base as an effect of light—will not become base current as a result of inserting of R_B, but will instead flow into R_B and become bias between emitter and base of the transistor. Thus the base current of the transistor is reduced exactly by that amount.

Figure 3 shows an example of I_C—I_F characteristic with varied R_B inserted. It is evident that in order to obtain the same value of CTR, the smaller is R_B, the higher the current I_F of LED is needed. That is when both R_B and I_F are small, the collector current I_C will not flow, and CTR will remain almost at zero. In Figure 3, for example, at R_B = 100 kΩ, I_F = 5 mA, note that CTR is almost zero. Figure 4 shows the data of the dependence of CTR on temperature. It is an example of the variation of CTRs of two samples (samples D and E) whose ΔCTRs are high against temperature variation for a given lot, with I_F as a parameter.

3-2 I_{CEO}, I_{CER} Characteristics.

The collector current is rated at 200 nA MAX. in the catalog, however, at 25 °C, V_{CE} = 10 V, its typical value are normally below 5 nA. Figure 5 shows I_{CEO} and I_{CER} characteristics versus ambient temperature Ta.

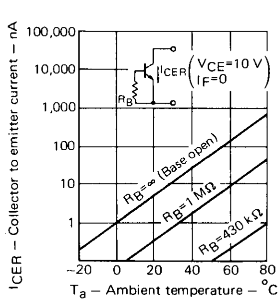
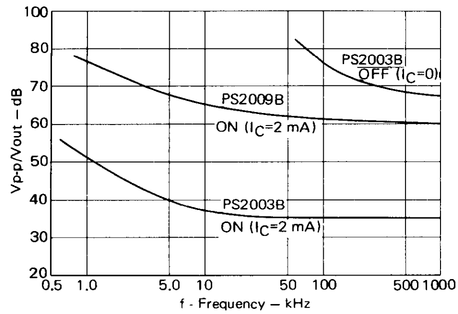


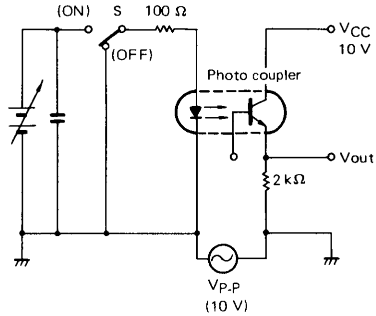
Fig. 5 An example of I_{CEO}, I_{CER} characteristics.

3-3 Noise-Immunity Characteristic

As an isolator, a photocoupler is used for insulating and eliminating common-phase noise between input and output. In case of DIP type plastic package such as the PS2003B, the input-output capacitance is approx. 0.8 pF. In general, this capacitance is almost of a negligible value, but at locations where high-frequency noise exists malfunction may occur. This is the result of the noise which is picked up by the base terminal functioning as an antenna. Therefore, it is recommended that the PS2009B, which has no base terminal, be used at noisy environments. Figure 6(1) shows the common-phase noise characteristics of PS2003B and PS2009B; and Figure 6(2) shows the measuring circuit.



(1) In-phase noise characteristic.



(2) Measuring circuit.

Fig. 6 An example of common-phase noise characteristic.

3-4 Switching Characteristics.

When performing switching operation in digital mode, this characteristic becomes important. If the load resistance R_L is increased, the switching times t_{on}, t_{off} generally become longer, and as the base resistance R_B is decreased ton and toff become shorter. Figures 8, 9 respectively show these characteristics. When $R_L >$ 300 Ω, $R_B <$ 300 kΩ, ton and td decrease because the measured sample, under the measuring condition, is put into the saturation region.

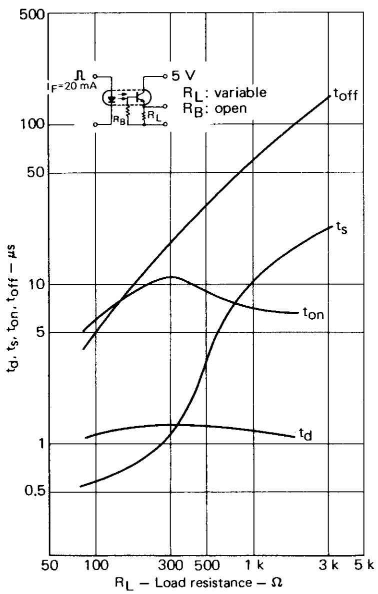


Fig. 7 An example of switching time—R_L characteristic.

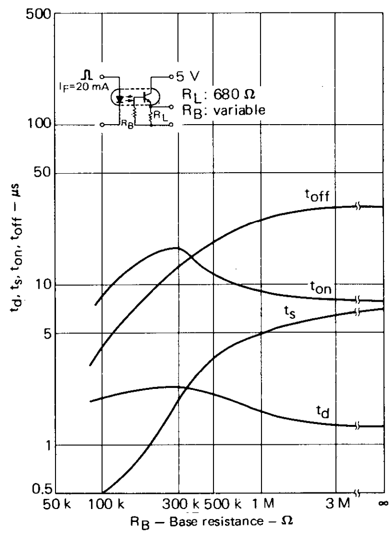


Fig. 8 An example of switching time—R_B characteristic.

3-5 Frequency Response

When a photocoupler is used in analog mode, the frequency response becomes important. As CTR varies with a change in the input current I_F, and it becomes important that under what conditions good frequency response is required. Figure 9 shows the frequency response when the general collector current I_C is chosen as reference. Figure 10 shows the frequency response when the forward currents I_F, $I_{F(p\text{-}p)}$ on the LED side are chosen as references.

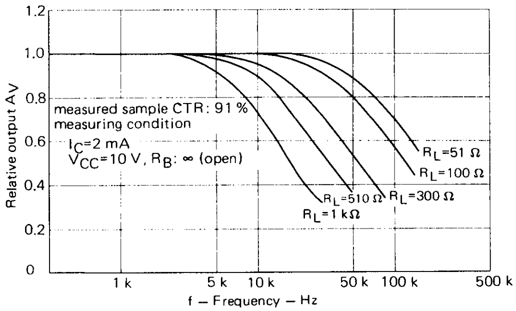


Fig. 9 A sample of frequency response, with collector current as a reference.

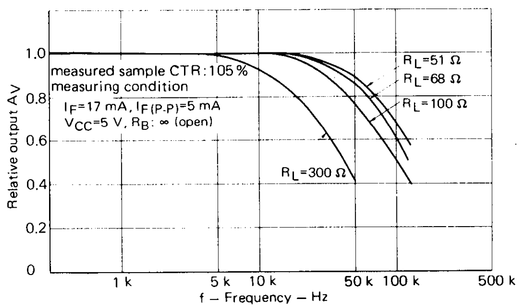


Fig. 10 A sample of frequency response, with forward current as a reference.

TERMINOLOGY AND CHARACTERISTICS OF HIGH SPEED PHOTO COUPLERS

1. Introduction

Since photocouplers convert the input electrical signal to light before taking out the output electrical signal, they posses the features of having hardly any electrical coupling and high insulation resistance between the input and output, and one way signal transfer characteristics. For this reason they are employed as:

(1) Interfaces between high and low voltage circuits.
(2) Noise eliminators.
(3) Replacements for relays and pulse transformers.

Up to the present, photocouplers with phototransistor or photodarlington outputs have been used most frequently. However, since the response time of such photocouplers is from about 5μs to several hundredμs, their applicable fields are limited when it comes to data transmission systems or the interfaces of computer and terminal equipment where high speed response is required.

In high speed photocouplers the response time has been reduced by 1 or 2 orders, compared to conventional photocouplers with phototransistor output.

NEC's high speed photocouplers are available in the P-N photodiode + amplifying transistor output types, PS2006 and PS2006(1), and the P-N photodiode + linear amplifier + Schottky transistor output type, PS2007. The outputs of the PS2006 and PS2006(1) are analog and digital, and that of the PS2007 is digital, and they are available for the following uses:

(1) Feedback circuits of switching regulators.
(2) Interfaces between computers and terminal equipment.
(3) Line receivers.
(4) Interfaces between data transmission systems.

Now, since the high speed photocoupler is a new device and it's terminology is not well known, the characteristics, terminology, and methods for measurement of PS2006, PS2006(1), and PS2007 high speed photocouplers are written below.

2. Absolute Maximum Ratings and Electrical Characteristics.

The absolute maximum ratings and electrical characteristics of the PS2006 and PS2006(1) are shown in Table 1.

Absolute Maximum Ratings. (Ta = 25°C)

	Symbol	Ratings	Unit
Input			
Forward current	I_F	25	mA
Reverse voltage	V_R	5	V
Power dissipation	P_D	45	mW
Output			
Supply voltage	V_{CC}	−0.5 to +15	V
Output terminal voltage	V_O	−0.5 to +15	V
Output current	I_O	8	mA
Emitter-base voltage	V_{EBO}	5	V
Power dissipation	P_C	100	mW
Insulation breakdown voltage	BV	3000	V_{DC}
Operating temperature	T_{opt}	−55 to +100	°C
Storage temperature	T_{stg}	−55 to +125	°C

Electrical Characteristics. (Ta = 25°C)

	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input Characteristics						
Forward voltage	V_F	I_F=16mA		1.43	1.7	V
Reverse current	I_R	V_R=5V		0.01	10	μA
Forward voltage temperature coefficient	$\Delta V_F/\Delta T$	I_F=16mA		–1.51		mV/°C
Terminal capacitance	C_t	V=0, f=1MHz		60		pF
Output Characteristics						
High level output current	$I_{OH(1)}$	I_F=0mA, V_{CC}=V_O=5.5V		3	500	nA
High level output current	$I_{OH(2)}$	I_F=0mA, V_{CC}=V_O=15V			100	μA
DC amplification factor	h_{FE}	V_O=5V, I_O=3mA		120		
Transfer Characteristics						
Current transfer ratio	CTR	I_F=16mA, V_{CC}=4.5V, V_O=0.4V	15/7	22		%
Low level output voltage	V_{OL}	I_F=16mA, V_{CC}=4.5V, I_O=2.4mA/1.1mA		0.1	0.4	V
Low level supply current	I_{CCL}	I_F=16mA, V_O=open, V_{CC}=15V		50		μA
High level supply current	I_{CCH}	I_F=0mA, V_O=open, V_{CC}=15V		0.01	1	μA
Insulation resistance	R_{1-2}	$V_{in\text{-}out}$=1kV		10^{12}		Ω
Input-output capacitance	C_{1-2}	V=0, f=1MHz		0.7		pF
Propagation delay time (H → L)	t_{PHL}	I_F=16mA, V_{CC}=5V R_L=1.9kΩ/4.1kΩ		0.3/0.5	0.8/1.5	μs
Propagation delay time (L → H)	t_{PHL}	I_F=16mA, V_{CC}=5V R_L=1.9kΩ/4.1kΩ		0.3/0.8	0.8/1.5	μs

Values shown by / in Table 1 indicate the values for PS2006/PS2006(1).

Table 1.

The absolute maximum ratings and electrical characteristics of PS2007 are shown in Table 2. Since the light receiving chip of the PS2007 is a temperature compensated IC, the principal electrical characteristics are established for a temperature range Ta = 0 – 70°C.

Absolute Maximum Ratings. (Ta=25°C)

	Symbol	Ratings	Unit
Input			
Forward current	I_F	10	mA
Reverse voltage	V_R	5	V
Output			
Supply voltage	V_{CC}	7	V
Output terminal voltage	V_O	7	V
Output current	I_O	50	mA
Enable voltage	V_E	5.5	V
Power dissipation	P_C	85	mW
Insulation votlage	BV	3000	V_{DC}
Operating temperature	T_{opt}	0 to 70	°C
Storage temperature	T_{stg}	–55 to +125	°C

Electrical Characteristics. (Ta = 0 to 70°C)

	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Input characteristics						
Forward voltage	V_F	I_F = 10mA, Ta = 25°C			1.7	V
Reverse current	I_R	V_R = 5V, Ta = 25°C		0.01	10	μA
Terminal Capacitance	C_t	V = 0, f = 1MHz		60		pF
Output characteristics						
High level enable current	I_{EH}	V_{CC} = 5.5V, V_{EH} = 2.0V		–0.8		mA
Low level enable current	I_{EL}	V_{CC} = 5.5V, V_{EL} = 0.5V		–1.2	–2.0	mA
Transfer characteristics						
High level output current	I_{OH}	V_{CC} = V_O = 5.5V, I_F = 250μA V_E = 2.0V		30	250	μA
Low level output voltage	V_{OL}	V_{CC} = 5.5V, V_E = 2.0V I_F = 5mA, I_O = 13mA		0,4	0.6	V
Low level supply current	I_{CCL}	V_{CC}=5.5V, V_E= 2V, I_F=10mA		10	18	mA
High level supply current	I_{CCH}	V_{CC}=5.5V, V_E=0.5V, I_F=0mA		7	15	mA

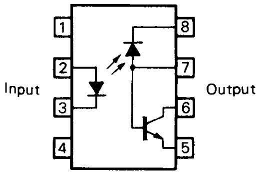
Electrical Characteristics. (Ta = 25°C)

	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Transfer characteristics						
Current transfer ratio	CTR	I_F = 5mA, V_{CC} = 5V, R_L = 100Ω		600		%
Insulation resistance	R_{1-2}	$V_{in\text{-}out}$ = 1kV		10^{12}		Ω
Input-output Capacitance	C_{1-2}	V = 0, f = 1MHz		0.7		pF
Propagation delay time (H→L)	t_{PHL}	I_F = 7.5mA, V_{CC} = 5V		50	75	ns
Propagation delay time (L→H)	t_{PLH}	R_L = 350Ω, C_L = 15pF		50	75	ns
Enable Propagation delay time	t_{EHL}	I_F = 7.5mA, V_{CC} = 5V R_L = 350Ω, V_{EH} = 3V		15		ns
Enable Propagation delay time	t_{ELH}	C_L = 15pF		30		ns

Table 2

3. Functions.

3 – 1 Functions of PS2006 and PS2006(1).



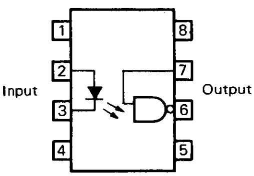
	Pin No.	Function
Input	1	NC
	2	Anode
	3	Cathode
	4	NC
Output	5	GND
	6	V_O
	7	V_B
	8	V_{CC}

Fig. 1 Functions of PS2006 & PS2006(1)

The functional diagram of the PS2006 and PS2006(1) is shown in Fig. 1. The light emitting diode (LED) operates in the current mode, and should be driven by a current or voltage source so that the specified current flows through it.

The light of the LED is received by a P-N photodiode, and the photocurrent generated here becomes the base current of the amplifying transistor. The output is an open collector circuit, and usually a load resistance R_L is connected between V_{CC} and V_O. The No. 7 pin, V_B terminal, is employed only for special uses such as the injecting of an external electrical signal or the inserting of resistances or capacitances, and is not required for ordinary uses.

3 – 2 Function of PS2007.



	Pin No.	Function
Input	1	NC
	2	Anode
	3	Cathode
	4	NC
Output	5	GND
	6	V_O
	7	V_E
	8	V_{CC}

Fig. 2 Function of PS2007.

The functional diagram of the PS2007 is shown in Fig. 2. The light of LED driven by the current is received by the P-N photodiode of the light receiving IC. The generated photocurrent is amplified by the internal linear amplifier to drive the Schottky transistor of the final stage. Since the Schottky transistor of the final stage has an open collector output, a load resistance R_L should be connected between terminals V_{CC} and V_O. The V_E terminal and the light of the LED functionally compose a NAND gate and, the V_E terminal is biased internally to a high level and so if terminal V_E is left open or kept at a high level (V_E = 2V) normal operation will be obtained. When the V_E terminal is made low level ($V_E \leqq 0.5V$), the output will always be at high level. The PS2007 is usually used with the V_E terminal open. The truth value table of the PS2007 is shown in Table 3. In this table, H of input I_F indicates that $I_F \geqq 5mA$, and L indicates that $I_F \leqq 250\mu A$. And, H of the enable voltage V_E indicates that $V_E \geqq 2V$, and L indicates that $V_E \leqq 0.5V$.

Input I_F	Enable V_E	Output V_O
H	H	L
H	L	H
L	H	H
L	L	H

Table 3 Truth value table of PS2007.

4. Terminology, Characteristics, and Measurement Methods.

Since the terminology, characteristics, and methods of measurement of high speed photocouplers differ somewhat from that of conventional photocouplers with phototransistor or photodarlington transistor output the main items of terminology, characteristics, and measuremental methods concerning high speed photocouplers are written below.

4 – 1 Insulation Breakdown Voltage, BV

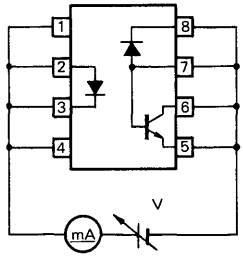
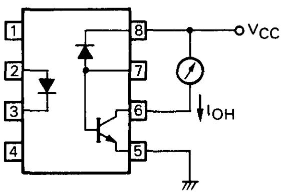


Fig. 3 Measurement Method of Insulation Breakdown Voltage.

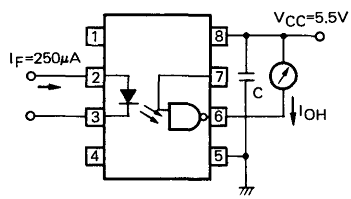
As shown in Fig. 3, under the environmental conditions of Ta = 25°C and RH (relative humidity) = 60%, a specified DC voltage is applied for 1 minute between the input and output, with all input and output terminals connected in parallel respectively.

Failed photocouplers will show such phenomena as a current of more than 0.5mA flowing between the input and output, failed characteristics after the insulation breakdown voltage test, or the destruction of the plastic mold.

4 – 2 High Level Output Current, I_{OH}.



(a) PS2006, PS2006 (1)



(b) PS2007

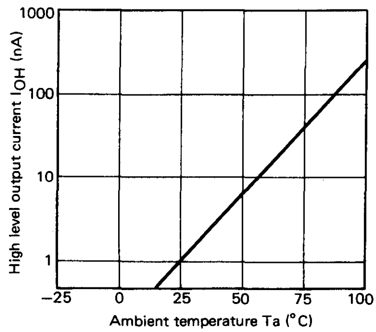
Fig. 4 Measurement of I_{OH}

The method of measuring I_{OH} is shown in Fig. 4.

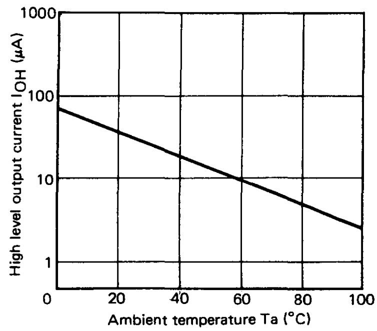
The high level output current I_{OH} is the leakage current which flows in the final stage of output, when I_F = 0mA in the case of the PS2006 and PS2006 (I) types, and when I_F = 250μA in the case of the PS2007. I_{OH} corresponds to the I_{CEO} of phototransistor output or photodarlington transistor output type photocouplers.

In the case of the PS2006 and PS2006(1), when designing circuits it is necessary to give consideration to the temperature characteristics of the photocouplers within the operating temperature range. In the case of the PS2007, the standard for I_{OH} is determined for the temperature range of 0°C to 70°C, therefore, circuit design should follow this standard.

The temperature characteristics of I_{OH} for the PS2006 and PS2006(1) are shown in (a) of Fig. 5, and that of the PS2007 in (b).



(a) PS2006, PS2006(1)



(b) PS2007

Fig. 5 I_{OH} Temperature Characteristics.

4 – 3 Current Transfer Ratio, CTR.

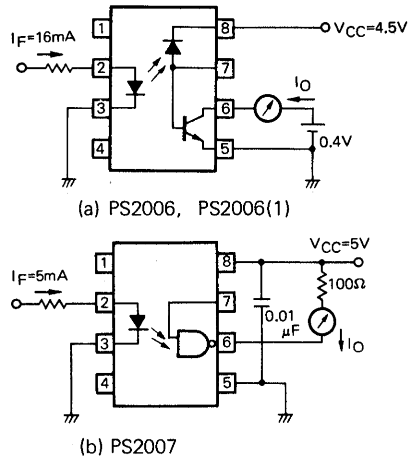


Fig. 6 Measurement of CTR.

The current transfer ratio shows the proportion of output current I_O which flows against an input current I_F and is defined as:

$$CTR(\%) = \frac{I_O}{I_F} \times 100(\%)$$

In the case of the PS2006 and PS2006(1), the CTR is a fundamental parameter of design, and careful consideration should be given to the CTR when designing circuits.

The method of measuring the CTR of the PS2006 and PS2006(1) is shown in (a) of Fig. 6, and that of the PS2007 in (b). When using the PS2007, the CTR is not a fundamental parameter in design.

4 – 4 Low Level Output Voltage, V_{OL}.

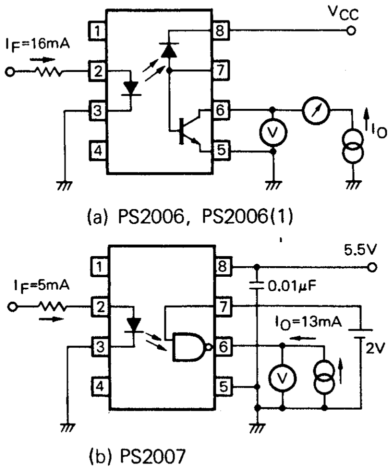
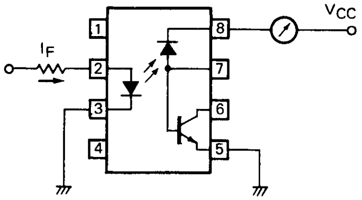


Fig. 7 Measurement of Low Level Output Voltage.

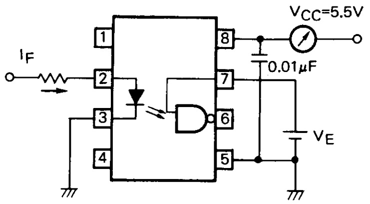
The output current I_O is specified as I_O = 2.4mA and 1.1mA respectively for the PS2006 and PS2006(1), therefore, in the case of the PS2006(1) standard TTLs cannot be driven since this value is smaller than the $-I_{IL}$ = 1.6mA of standard TTLs. However, since the $-I_{IL}$ of LS TTLs is 0.4mA, these may be fully driven.

The method of measuring the low level output voltage of the PS2006 and PS2006(1) is shown in (a) of Fig. 7, and that of the PS2007 in (b).

4 – 5 Low Level and High Level Supply Currents, I_{CCL} and I_{CCH}.



(a) PS2006, PS2006(1)



(b) PS2007

Fig. 8 Measurement of I_{CCL} and I_{CCH}.

The low level supply current I_{CCL} is the current dissipated within the light receiving element, when the logic output is in low level. In the case of the PS2006 and PS2006(1) this is equal to the photocurrent generated by the P-N photodiode. In the case of the PS2007 it is the sum of the photocurrent and the current dissipated in biasing the internal amplifier.

The high level supply current I_{CCH} is the current dissipated the light receiving element, when the logic output is in high level.

The method of measuring the I_{CCL} and I_{CCH} of the PS2006 and PS2006(1) is shown in (a) of Fig. 8, and that of the PS2007 in (b).

4 – 6 High Level Enable and Low Level Enable Currents, I_{EH} and I_{EL}.

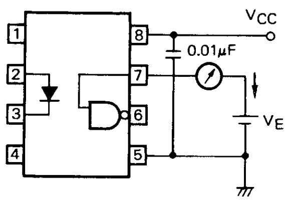


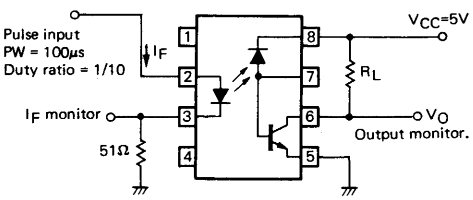
Fig. 9 Measurement of I_{EH} and I_{EL}.

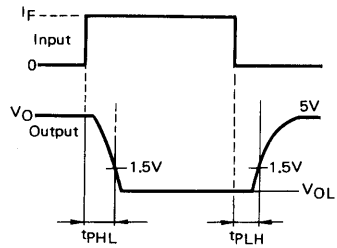
The high level enable current I_{EH} is the current which flows out of the enable terminal V_E when the enable terminal is brought to high level (V_E = 2.0V). And the low level enable current I_{EL} is the current which flows out of the enable terminal V_E when the enable terminal is brought to low level (V_E = 0.5V).

The mothod of measuring I_{EH} and I_{EL} is shown in Fig. 9.

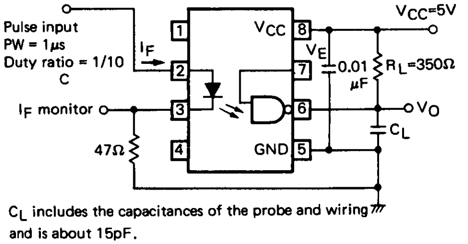
4 – 7 Propagation Delay Time, t_{PHL} and t_{PLH}.

Propagation delay time t_{PHL} is the time required for the output to change from high level to low level, and in the PS2006 and PS2006(1) is the time from the zero point of a pulse input, which has a rise time that can be disregarded, to the point where the output drops to 1.5V. In the PS2007, the t_{PHL} is the time from the 50% rise point of a pulse input, which has a rise time of 5ns, to the point where the output drops to 1.5V. t_{PLH} is the time required for the output in a low level to reach 1.5V, after the pulse input has disappeared. Methods for measuring the t_{PHL} and t_{PLH} of the PS2006 and PS2006(1) are shown in (a) of Fig. 10, and those of the PS2007 in (b).





(a) PS2006, PS2006(1)



(b) PS2007

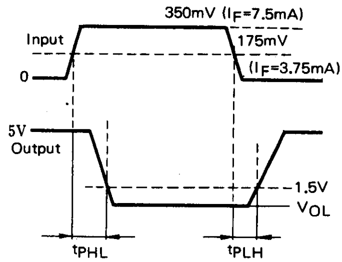
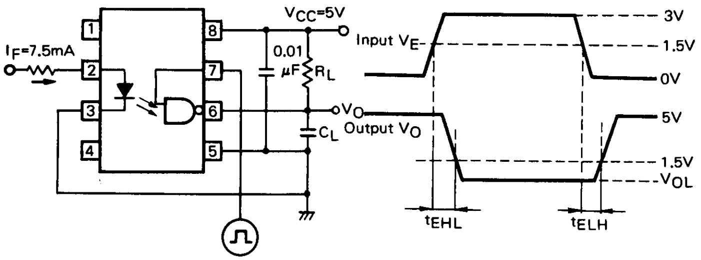


Fig. 10 Measurement of t_{PHL} and t_{PLH}.

4 – 8 Enable Propagation Delay Time, t_{EHL} and t_{ELH}.



Enable Propagation delay time is the propagation delay time when a pulse input of V_{EH}=3V is applied to the V_E terminal. The method of measuring t_{EHL} and t_{ELH} is shown in Fig. 11.

Fig. 11 Measurement of t_{EHL} and t_{ELH}

5. Application Methods.

5 – 1 Application of the PS2006 and PS2006(1).

Application shall be described, employing the PS2006 as an example. When the input LED is driven by a TTL, as shown in Fig. 12, a standard TTL capable of flowing an I_F current of over 16mA through the input LED should be used.

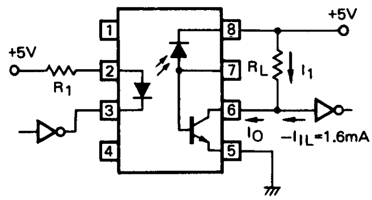


Fig. 12 Application of the PS2006.

R_1 is a current limiting resistance, and since,

$$R_1 = \frac{V_{CC} - V_{OL} - V_F}{I_F} = \frac{5V - 0.4V - 1.43V}{16mA} = 198\Omega$$

180Ω is taken as the value of R_1.

Since the lower limit of the CTR of the PS2006 is 15%, an output current of I_O = 16mA x 0.15 = 2.4mA will flow. Since this output current I_O must be larger than the sum of the current I_1 flowing in the load resistance R_L and the sink current, $-I_{IL}$ = 1.6mA, of the standard TTL,

$$I_O \geqq I_1 + (-I_{IL}) = \frac{V_{CC} - V_{IL}}{R_L} + (-I_{IL})$$

from this,

$$R_L \geqq \frac{V_{CC} - V_{IL}}{I_O - (-I_{IL})} = \frac{5V - 0.8V}{2.4 - 1.6} = 5.25k\Omega$$

thus 5.6kΩ is taken for the value of R_L. The above calculations are for the case when Ta = 25°C, but when actually designing circuits the changes due to the aging degradation and the temperature characteristics of the CTR should be taken into consideration.

For example, if it is assumed that the CTR will drop by X% compared to its value at Ta = 25°C due to temperature within the operating temperature range and, in addition, that the CTR will drop by Y% due to aging compared with its initial value, the output current I_O will become:

$$I_O = [\, I_F \times \frac{CTR\,(\%)}{100\,(\%)}] \cdot [\frac{100 - X}{100}] \cdot [\frac{100 - Y}{100}]$$

and design should be performed taking this current value as the worst case.

5 — 2 Application of the PS2007.

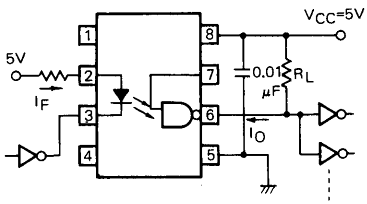


Fig. 13 Application of the PS2007.

An example of an application of the PS2007 is shown in Fig. 13. The method of driving the input of the PS2007 is similar to that of the PS2006. Since an output current of I_O = 13mA can be obtained when I_F = 5mA, if standard TTLs are considered to be the load and it is assumed that the fan-out is N, then,

$$1.6mA \times N \leqq 13mA$$

from this it can be seen that a load of up to N = 8 standard TTLs can be driven. This load of 8 standard TTLs is equivalent to a load resistance of about 350Ω.

The load resistance is determined as follows: When the number of the TTLs of the load is N, then,

$$I_O \geqq N \cdot (-I_{IL}) + \frac{V_{CC} - V_{IL}}{R_L}$$

thus,

$$R_L \geqq \frac{V_{CC} - V_{IL}}{I_O - N \cdot (-I_{IL})}$$

The switching action will be more reliable, the larger R_L is taken within the range that no misoperation occurs due to I_{OH}.

6. Precautions on the Use of Photocouplers.

6 — 1

Since the PS2007 incorporates a high gain linear amplifier, its operation may become unstable due to variations in the power supply of the light receiving side. Therefore, a capacitance of over 0.01μF should be inserted between the V_{CC} and GND terminals. This capacitance should be placed near the PS2007, and a capacitance for high frequency use will be the most effective.

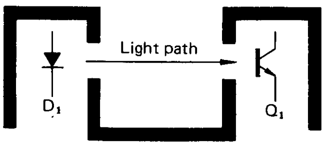
6 — 2

If the operation of the PS2006 becomes unstable, employ the same method as that for the PS2007.

APPLICATION HINTS FOR PHOTOINTERRUPTER

1. Abstract

This report describes the application hints for photointerrupters.
A rough sketch of a photointerrupter is shown in Fig. 1. Infrared light beam from a light emitting Diode (D_1) travels on light path and arrives at a phototransistor (Q_1). Then, Q_1 gets current energy which is useful for signal transfer. If the light path is interrupted it is impossible to transfer the light signal to Q_1 from D_1. Q_1 can not get current energy any more. So, we can use this characteristic for photointerrupter as a non-contact switch.

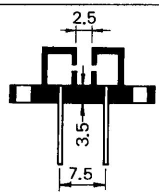
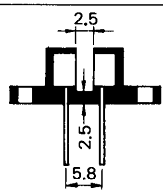
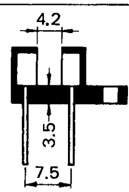


(Light emitting diode) (Phototransistor)

Fig. 1 A rough sketch of a photointerrupter

2. Photointerrupters

PS4001, PS4003, PS4005 are mass produced now. These devices are not the same in the external shapes, but their electrical characteristics are very similar. The cross sections of these devices are shown in Fig. 2.

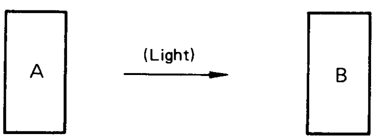
Part numbers	PS4001	PS4003	PS4005
External shapes (cross section)			

* Each of these devices uses an infrared LED and a darlington phototransistor.

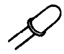
Fig. 2 NEC Photointerrupter Family

3. The application as a photointerrupter of a combination of LED and a photo-detector.

When the space does not permit to use an assembled photointerrupter an equivalent one can be obtained by combining discrete devices (LED and a photo-detecter).



(Light emitting) (Light receiving)

	External shape	 (φ 2~φ 3.8)	 (φ 4.8)	 (□5)
A	Visible red light	SR106C	SR503C SR603C	SR110
(Light emitting)	Infrared light	SE302A	*SE303	SE304
B	Single phototransistor	PH102	*PH105	PH104
(Light receiving)	Darlington phototransistor	PH101	—	PH103

* Under development (For detailed specifications, please refer to catalog).

Table 1. Application of Single Elements to Photointerrupters

4. Application hints for designing photointerrupter circuits

This section describes application hints for designing photointerrupter.

4-1 Current transfer ratio

When I_F is the current through the LED (D_1), and I_C is the current through the phototransistor (Q_1), we can get CTR (note 1) as follows;

$$CTR = \frac{I_C}{I_F} \times 100 \ (\%) \ .... \ (1)$$

(note 1) CTR is an abbreviation of current transfer ratio.

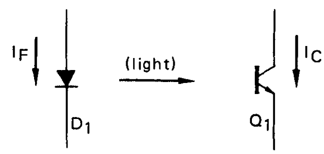


Fig. 3 Current transfer ratio

We have now two materials for D_1, one is a red LED and the other is an infrared LED. At the same current, the light emitting efficiency of the infrared LED is 3 to 5 times higher than that of the red LED.
As for the wavelength sensitivity of Si phototransistors, the sensitivity in infrared region is 2 to 3 times better than that in red region. So, an infrared emitter is the most suitable one for a photointerrupter.

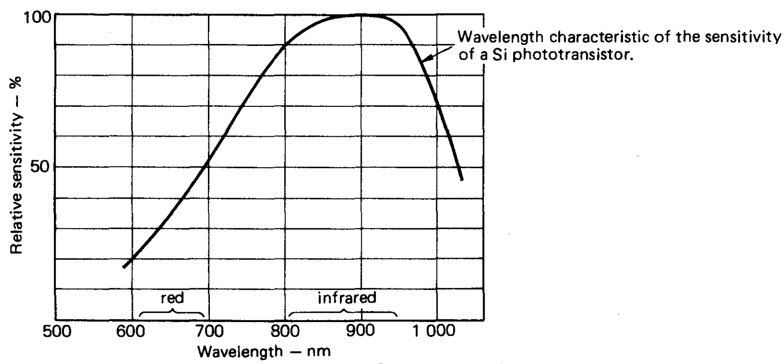


Fig. 4 Relative Sensitivity Characteristic of a phototransistor

11

4-2 Output Level

We can calculate the output voltage in reference to Fig. 4. At first, I_F passing through the LED is shown as follows.

$$I_F = \frac{V_1 - V_F}{R_1} \quad \text{.......... (2)}$$

V_F is the forward voltage drop of the LED. At infrared LED,
$V_F = 1.1$ V (at $I_F \doteqdot 20$ mA), at red LED (GaAsP) $V_F \doteqdot 1.6$ V (at $I_F = 20$ mA).

Assuming CTR is η(%), the output level of the phototransistor which is ON state is as follows;

$$I_C = I_F \times \eta \quad \text{.......... (3)}$$

$$\therefore V_{out} = R_L \times I_C$$

$$= R_L \times I_F \times \eta$$

$$= \frac{R_L}{R_1} \times (V_1 - V_F) \times \eta \quad \text{.......... (4)}$$

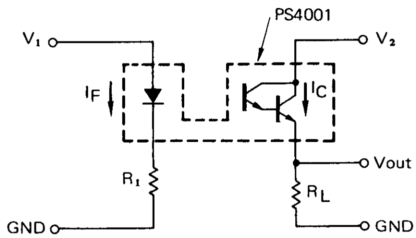


Fig. 5 Example of Photointerrupter circuit

If R_1 and R_2 are selected so that the output level Vout $\gg V_2$, it is in a saturated condition. And if R_1 and R_2 are selected so that the output level $V_2 >$ Vout $>$ GND, it is in a nonsaturated condition. In case of using the latter condition, the periodical check of the system is required due to the variation of CTR. In general, we can not recommend to use a photointerrupter in nonsaturated linear condition. If the use of a photointerrupter in linear condition is required, please contact us beforehand.

4-3 Temperature dependence of CTR

At a constant current output power of a LED decreases as the temperature increases, while at a constant bias voltage the sensitivity of a phototransistor increases as the temperature decreases.
Fig. 6 shows examples of temperature characteristics of CTR comparing when a single photo-transistor or a darlington photo-transistor is used as a receiving element.

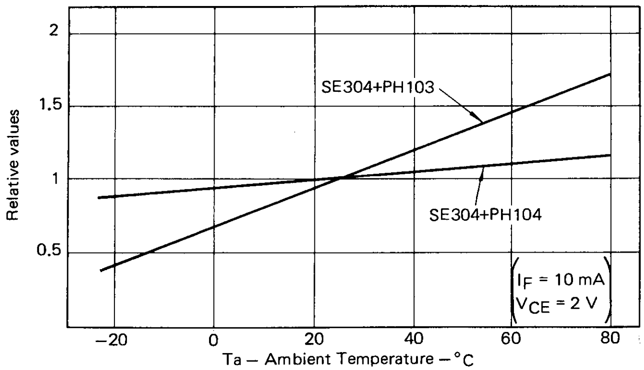


Fig. 6 Temperature Characteristics of CTR

4-4 CTR versus the distance between the LED and the phototransistor

Since brightness is inversely proportional to the distance, the brightness will become $1/n^2$ when the distance from a point light source increase by n times. Now, when a LED is approximated to a point light souse and the distance to the phototransistor is d, then

$$CTR \propto \frac{1}{d^2} \quad \cdots\cdots (5)$$

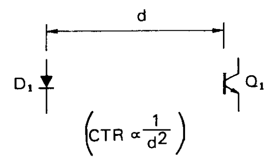


Fig. 7 CTR vs. distance

The typical characteristic of CTR vs. distance is shown in Fig. 8. This data is made of SE304 and PH103.

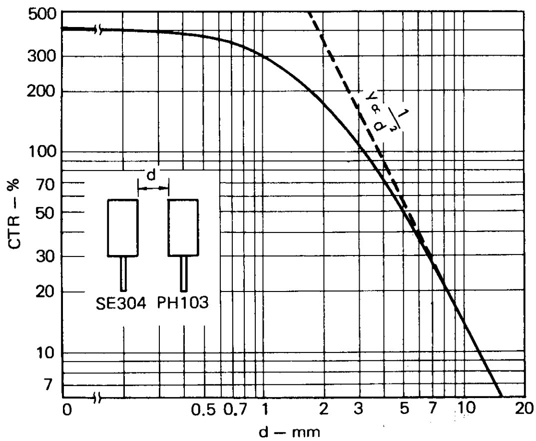


Fig. 8 CTR vs. distance characteristic

4-5 Life test characteristic

Excellent circuits cannot be designed, unless, at the time of designing, the change in characteristics due to aging of the components are fully understood. As shown in Fig. 9 to Fig. 12, in the case of photointerrupters, except the change in the CTR, the change of other characteristic due to aging do not present any particular problems.

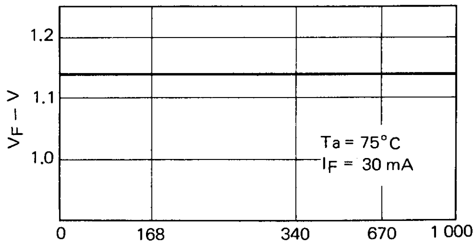


Fig. 9 V_F Life Test Data

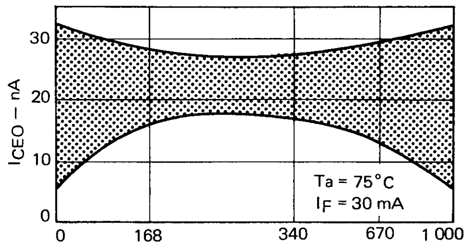


Fig. 10 I_{CEO} Life Test Data

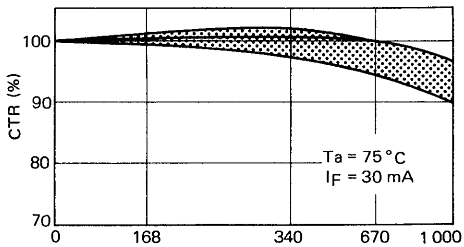


Fig. 11 CTR Life Test Data

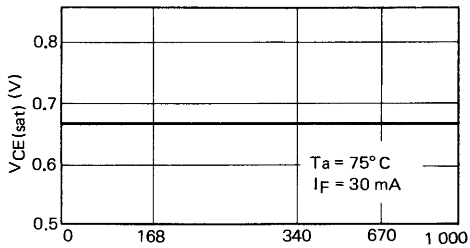


Fig. 12 $V_{CE(sat)}$ Life Test Data

4-6 Switching Speed

When a shielding object cuts the light path ON and OFF at high speed, unless the switching speed of the phototransistor fully responds to this speed. We cannot get the output signal that the object cuts the light path. PH102 and PH104 which are single phototransistors have high switching speeds, t_r and $t_f \fallingdotseq 5\ \mu s$ (at R_L = 100 Ω). PH101 and PH103 which are darlington phototransistors have a switching speeds, t_r and $t_f \fallingdotseq 200$ to 500 μs (at R_L = 100 Ω).

4-7 Switching Speed vs. Load Resistance

PS4001 has a switching speed characteristics shown in Fig. 13. Fig. 14 and Fig. 15 show the characteristics of switching speed of a single phototransistor PH104 and a darlington phototransistor PH103 under sinusoidal wave light.

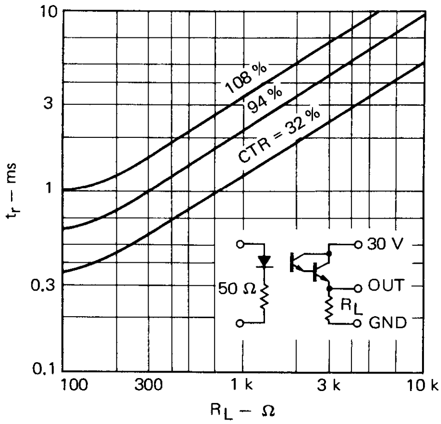


Fig. 13 tr vs. R_L characteristic of the PS4001

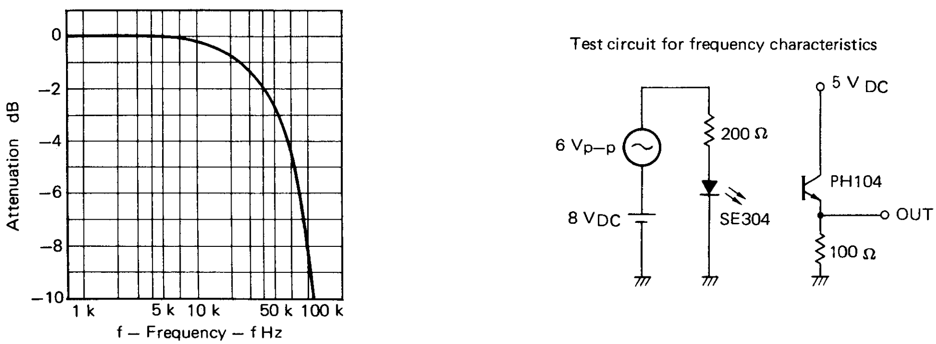


Fig. 14 Frequency characteristics of a single phototransistor

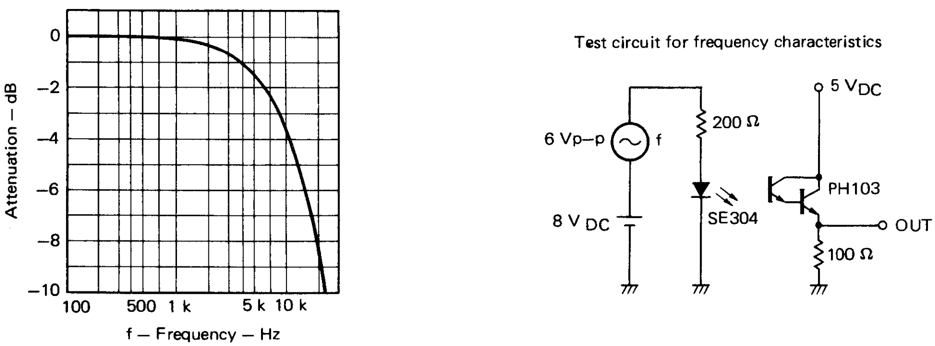


Fig. 15 Frequency characteristics of a darington phototransistor

11

4-8 Shielding Characteristic

The relationship between the moving distance of the shielding object and the output voltage, when the interrupter moves across the light path, is also an important point to observe when designing photointerrupter circuits.

When the object moves 0.5 mm to 0.6 mm, the output level of PS4001 turns from "H" to "L", as shown in Fig. 16.

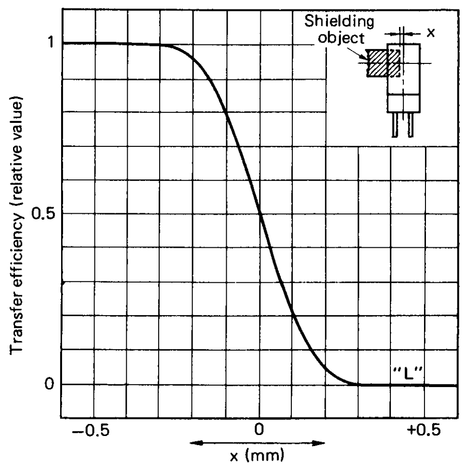


Fig. 16 Shielding characteristics of PS4001

The shielding characteristics are considerably different between the flat surface phototransistor and the lens effect surface one as shown in Fig. 17.

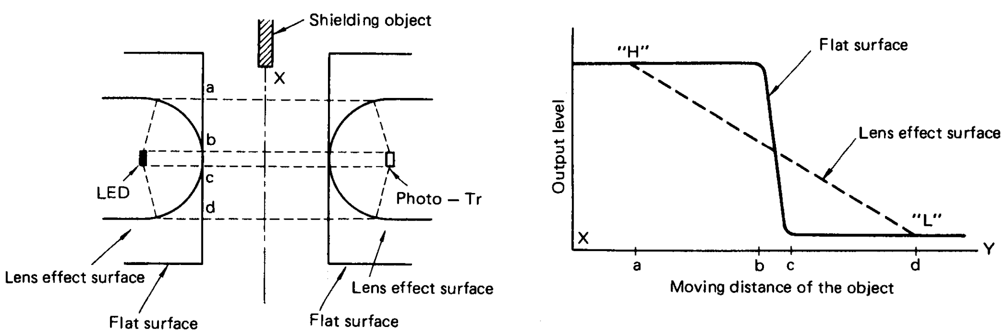


Fig. 17 Shielding characteristics due to surface states

In the case of plane surfaces, the output level can be reversed by moving the object only from b to c. But, in the case of lens effect surfaces, it has to be moved from a to d in order to reverse the output level. That is to say, though the CTR will become larger when a lens effect is given to the surfaces, the movement of the shielding object in order to cut off the light path will become longer.

4-9 Reduction of Power Consumption

In standard photointerrupter circuits, a continuous DC current flows through the LEDs. However, recently, with the popularization of microcomputers, the control of equipment has begun to be performed by logic signals. Under such circumstances, a method can be considered in which a pulsive current timed by the CPU (note 2) is passed through the LEDs and judgment of the output signal is performed by the CPU. When the equipment becomes large, this can be considered to be an effective method.
(note 2: CPU is an abbreviation for central processor unit)

5. Ultrahigh Speed Photointerrupters

The switching speed of single photo transistors is about 5 μs with a load resistance of 100 Ω. In order to compose a photointerrupter having a higher speed, it is necessary to employ an avalanche or PIN photodiode as the light receiving element. Diodes of these type usually have a switching speed of a few to several tens of nanoseconds, thus they can be used for most applications. The only problem that needs attention when designing is that, due to the low photosensitivity, high gain amplification is required for the minute current (or voltage) generated.

6. Ultrahigh Breakdown Voltage Photocouplers

In photo interrupters, the signal is transmitted by the shielding object moving across the light path, but in photocouplers the signal is transmitted by turning ON and OFF the current flowing through the LED. At present, the breakdown voltage between the input and output circuits of photocouplers available in the market is about up to 4 kV. When a higher breakdown voltage is required, by inserting a transparent insulating material between the LED of the light emitting side and the phototransistor of the light receiving side a photocoupler of higher breakdown voltage is obtained.

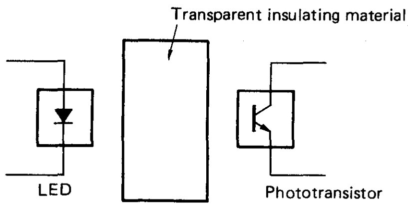
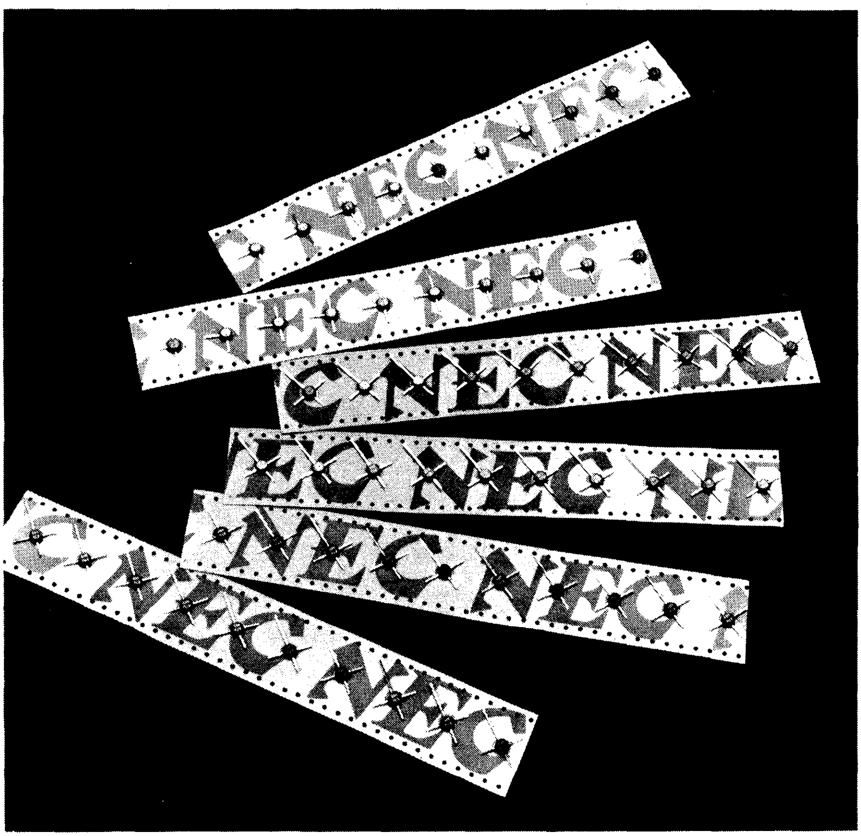


Fig. 18 Application to ultrahigh breakdown voltage photocoupler

11

NEW HIGH-FREQUENCY TRANSISTOR PACKAGE "DISKMOLD"

— Its Construction and Applications —



CONTENTS

Introduction

INTRODUCTION

Diskmold transistors are small disk type active elements designed for use in TV tuners and CATV sets. A typical example of small disk type active elements we have so far is microdisk transistors (housed in ceramic packages), which have been used in large volume in the fields of applications to VHF - UHF TV-tuners and high-density mounting of hybrid integrated circuits, etc., because of their special features that is the availability of varieties of types for entertainment applications ranging from low frequency to UHF frequency, distinguished HF characteristics and compactness. Meanwhile, plastic mold transistors (such as TO-92) featuring much lower cost, higher stability, and higher reliability have been also employed widely for entertainment use. Although microdisk transistors are still used widely, mainly in TV tuners, as compact, flat package devices with excellent high-frequency characteristics, market requirements for price and quality are becoming more exacting. Under these circumstances, we have just succeeded in developing diskmold transistors replaceable with microdisk transistors used so far.

1. FEATURES OF DISKMOLD TRANSISTORS

Diskmold transistors developed provide the following features.

(1) With a compact, flat package and T-shaped leads, the diskmold transistors have excellent RF characteristics because of their low RF losses, small stray capacitances and lead inductances as microdisk transistors.

(2) Being housed in compact packages, diskmold transistors have small space factors and are most suitable for high-density mounting.

(3) Microdisk transistors use low-melting point glass for sealing and may somehow be subject to thermal stress and mechanical shocks and vibration depending on the usage. Diskmold transistors employ resin encapsulation and have improved strength against thermal and mechanical stresses ensuring ease of handling.

(4) In spite of their compact packages diskmold transistors employ such resin as has a strong adhesiveness between the resin and metal (leads), achieving as high reliability as that of conventional plastic molded transistors such as (TO-92).

(5) The specification of diskmold transistors specifies them to be easily replaceable with conventional microdisk transistors.

2. CONSTRUCTION AND MANUFACTURING METHOD

2-1 Package Construction

Figs. 1 and 2 show the package construction of diskmold transistors. Their packages are formed with disk-shaped resin of 1.8 mm in thickness and 3.8 mm in diameter as typical values. Diskmold transistors are available in two types, one having three leads (Fig. 1) and the other having four leads (Fig. 2) as in the case of microdisk transistors.

PACKAGE DIMENSIONS (Unit: mm)

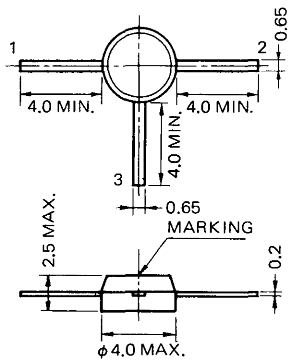


Fig. 1 DISKMOLD Transistor with 3 Leads

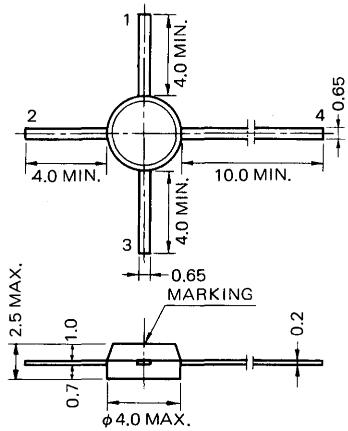


Fig. 2 DISKMOLD Transistor with 4 Leads

Connectors

DISKMOLD Transistor (Fig. 1)	DISKMOLD Transistor (Fig. 2)	Field Effect Transistor (Fig. 2)
1. Base	1. Base (or Emitter)	1. Gate 2
2. Emitter	2. Emitter (or Base)	2. Gate 1
3. Collector	3. Base (or Emitter)	3. Source
	4. Collector	4. Drain

2-2 Construction and Manufacturing Method

(1) Construction

Figs. 3 and 4 show the interior construction (models) of 3-lead and 4-lead diskmold transistors, respectively.

The active element (chip) of Fig. 3 is mounted on the lead ribbon of lead 3 and is connected through the electrodes of the chip to leads 1 and 2 by inner wires (gold wires). Fig. 4 shows the construction of such a type that has an improved RF characteristics by providing lead 1 between leads 2 and 4 (where leads 1 and 3 are shorted to each other).

The package is molded with an uninflammable epoxy resin. Leads are made of steel dipped by solder with a lead-tin solder.

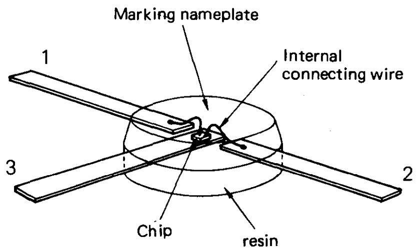


Fig. 3 Interior Construction of 3-Lead DISKMOLD Transistor

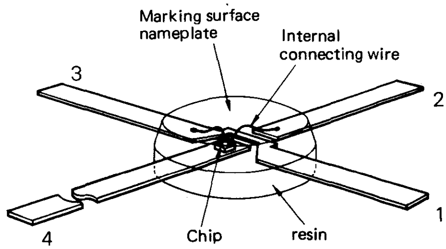


Fig. 4 Interior Construction of 4-Lead DISKMOLD Transistor

11

(2) Manufacturing method

The method of manufacturing diskmold transistors is based on the manufacturing method of conventional microdisk transistors and small-signal mold transistors. To produce diskmold transistors, first prepare the lead frame (ribbon), then insert the lead frame into an automated element manufacturing equipment for chip mounting by a special solder and interconnection of the electrodes of the chip and external leads (ribbons) with Internal Connecting wires, and resin shielding is made semi-automatically by batch processing, as shown in the flow diagram of Fig. 5.

Then, after effecting stabilization of high-temperature aging, etc., the leads are cut and DC items (and AC items when required) are all selected by an automatic selector. After this, rejection of defective products and classification of products by performance characteristic are performed and marked. This completes all process of manufacturing diskmold transistors.

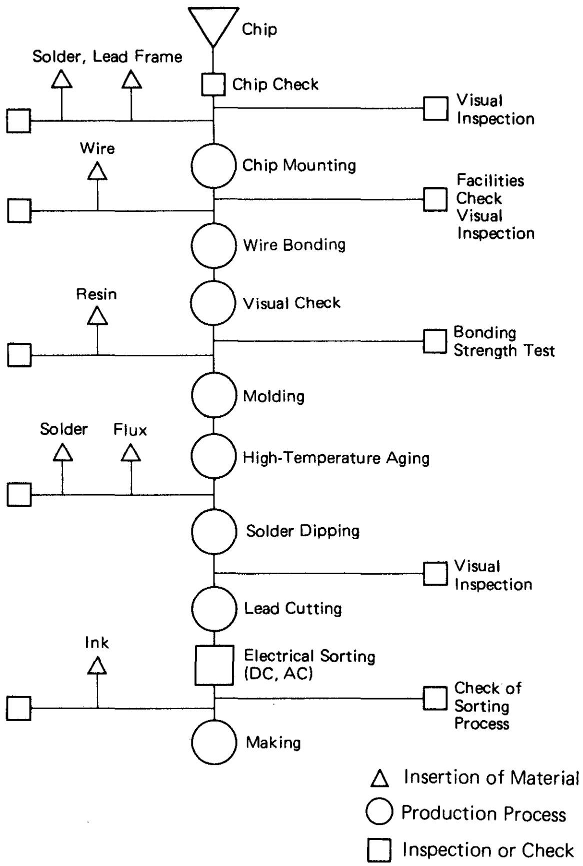


Fig. 5 Manufacturing Process

3. APPLICATIONS AND TYPES OF DISKMOLD TRANSISTORS

For discrimination from the existing microdisk transistors and equivalent, diskmold transistors have product nomenclature with (B) as shown below, except for new products.

Example

2SC1070 . . . . .Microdisk transistor
2SC1070 (B) . . . . Diskmold transistor

TABLE 1

Type No.	Structure	Application	Absolute Maximum Rating (Ta=25°C) V_{CBO} (V)	V_{CEO} (V)	V_{EBO} (V)	Ic (mA)	P_T (mW)	T_j (°C)	Electrical Characteristics Rank vs. Marking	I_{DSS}, h_{FE} or I_{AGC}	Con-dition	Cob (pF) TYP.	f_T (MHz) TYP.	Gp (dB) TYP.
3SK74	Si N-ch Dual Gate MOS FET	VHF band RF amplifier	(BV_{DSX}) 20	(V_{G1S}) ±10	(V_{G2S}) ±10	(I_D) 20	200	(Tch) 125	K L M	17 ~ 25mA 9 ~ 19mA 7 ~ 11mA	I_{DSS} V_{DS}=6V V_{G1S}=0 V_{G2S}=3V	(Crss) 0.03	(Y_{fs}) 20m℧	22
3SK87	Si N-ch Dual Gate MOS FET λ/2-Tuner	UHF band RF amplifier	(BV_{DSX}) 20	(V_{G1S}) ±10	(V_{G2S}) ±10	(I_D) 25	200	(Tch) 125	K	0~10mA	I_{DSS} V_{DS}=10V V_{G1S}=0 V_{G2S}=4V	(Ciss) 2.3	(Y_{fs}) 22m℧	18
3SK88	Si N-ch Dual Gate MOS FET λ/4-Tuner	UHF band RF amplifier	(BV_{DSX}) 20	(V_{G1S}) ±10	(V_{G2S}) ±10	(I_D) 25	200	(Tch) 125	K	0 ~ 10mA	I_{DSS} V_{DS}=10V V_{G1S}=0 V_{G2S}=4V	(Ciss) 2.0	(Y_{fs}) 17m℧	16
2SC287A(B)*	NPN Si Ep	VHF band Oscillator	35	15	4.0	20	200	125	E F	100 ~ 200 60 ~ 120	h_{FE} V_{CE}=10V I_C=5mA	0.8	1100	–
2SC288A (1•B)*	NPN Si Ep	UHF Oscillator	35	15	4.0	20	200	125	E F	100 ~ 200 60 ~ 120	h_{FE} V_{CE}=10V I_C=5mA	1.05	1100	–
2SC288A (5•B)*	NPN Si Ep	UHF Oscillator	35	15	4.0	20	200	125	E F	100 ~ 200 60 ~ 120	h_{FE} V_{CE}=10V I_C=5mA	0.8	1300	–
2SC605(B)*	NPN Si Ep	VHF band Mixer	30	30	4.0	20	200	125	K L	100 ~ 200 60 ~ 120	h_{FE} V_{CE}=10V I_C=3mA	0.6	500	–
2SC606 (B)*	NPN Si Ep	VHF band RF amplifier	30	30	4.0	20	200	125	V T	–8 ~ –10mA –9 ~ –11mA	I_{AGC} I_E at PG–30dB	0.6	550	23
2SA983	PNP Si Ep	UHF band RF amplifier (with forward AGC)	–30	–35	–4.0	–20	200	125	K L M	8.5 ~ 9.8mA 8.0 ~ 9.0mA 7.2 ~ 8.5mA	I_{AGC} I_E at PG–30dB	0.5	1000	16
2SC1070(B)*	NPN Si	UHF band RF amplifier (with forward AGC)	30	25	4.0	20	200	125	K L	–9 ~ 11mA –8 ~ 10mA	I_{AGC} I_E at PG–30dB	0.6	900	16
2SC2353	NPN Si Ep	UHF band Mixer and Oscillator	30	14	3.0	50	200	125	K L	100 ~ 200 60 ~ 120	h_{FE} V_{CE}=10V I_C=10mA	0.85	2300	(Gcb) 12.5
2SC2368	NPN Si Ep	UHF/VHF CATV Low-noise amplifier	30	14	3.0	50	250	150	K	40 ~ 200	h_{FE} V_{CE}=10V I_C=10mA	0.7	3000	(MAG) 17
2SC2369	NPN Si Ep	UHF (Microwave) band low-noise	30	12	3.0	70	250	125	K	40 ~ 200	h_{FE} V_{CE}=10V I_C=20mA	0.75	4500	(MAG) 17

* Replaceable with conventional microdisk transistor

4. ELECTRICAL CHARACTERISTICS

The method of determining the absolute maximum rating and electrical characteristics of diskmold transistors is the same as the method for determining those of microdisk transistors. Diskmold transistors differ from microdisk transistors in that plastic packages used to increase allowable power loss and thus provide more margin in circuit design.

Tables 2 and 3 give general performance characteristics of diskmold transistor and other existing similar transistors for comparison. Fig. 6 shows parasitic elements of a diskmold transistor.

TABLE 2 General Performance Characteristics of DISKMOLD Transistor and Other Similar Transistors

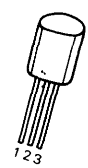
Type of Transistor	Operating Frequency	Power Dissipation	Junction Temperature	Storage Temperature	Size	Package
DISKMOLD Transistor	~2GHz	~ 200mW	~ 125°C	–55 ~ +125°C	ϕ3.8x1.8 mm	Plastic
Microdisk Transistor	~ 1GHz ~	~ 150mW	~ 150°C	–65 ~ +150°C	ϕ3.5x1.5 mm	Ceramic
Signal Mold Transistor (TO-92)	~ 1GHz ~	250 ~ 600mW	~ 125°C	–55 ~ +125°C	5x5x4.0mm	Plastic

TABLE 3 Stray Capacitances between Terminals of Transistors for Comparison

		Cc (1-2)	Cc (1-3)	Cc (1-4)	Cc (2-3)	Cc (2-4)
3-Lead Transistors	DISKMOLD Transistor	0.02pF	0.13pF	—	0.13pF	—
	Microdisk Transistor	0.02pF	0.13pF	0.13pF	0.14pF	—
4-Lead Transistors	DISKMOLD FET	0.14pF	0.13pF	0.14pF	0.13pF	0.02pF
	DISKMOLD Transistor	0.14pF	Internal Short	0.14pF	0.14pF	0.02pF
	Microdisk Transistor	0.13pF	Internal Short	0.13pF	0.14pF	0.02pF
Signal Mold Transistor		0.33pF	0.19pF	—	0.33pF	—

Note 1: Cc (1-2) denotes stray capacitance between leads 1 and 2. Figures in ( ) correspond to those given in Figs. 1 and 2.

Note 2: Terminal No. of signal mold transistor are: Terminal 1 (emitter), Terminal 2 (collector), and Terminal 3 (base).



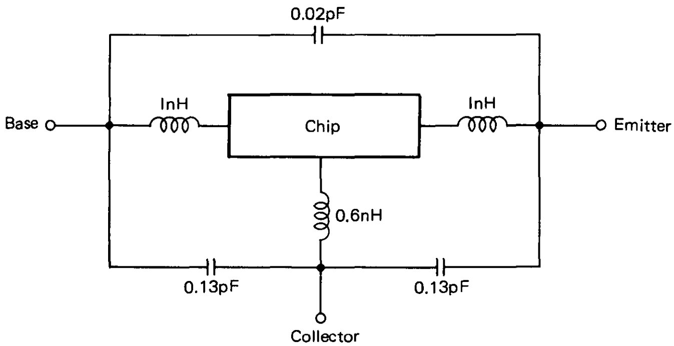


Fig. 6 Parasitic Elements of DISKMOLD Transistor

Allowable power dissipation and thermal resistance

In general, allowable loss P_T is given by:

$$P_T = \frac{T_{jMAX.} - Ta}{R_{th}}$$

where $T_{jMAX.}$ is the maximum junction temperature, Ta the ambient temperature, and R_{th} the thermal resistance of the device.
The thermal resistance of a diskmold transistor in free air is 0.5°C/mW.
Fig. 7 shows data of allowable power dissipation of a diskmold transistor.

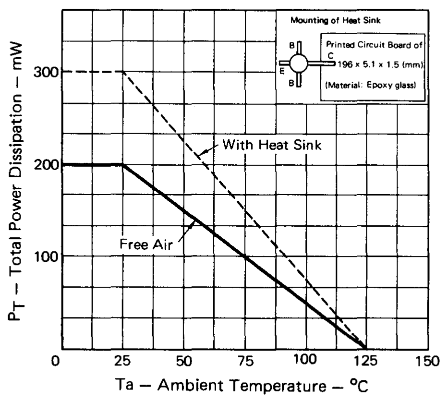


Fig. 7 P_T vs. T_a

5. RELIABILITY

The reliability of diskmold transistors has been confirmed by a similar evaluation method as used in evaluating plastic mold transistors.
In general, plastic mold type transistors differ from hermetic sealed transistors (metal canned, microdisk transistors) in modes of failure.

That is, plastic mold type transistors differ from hermetic sealed transistors in the following three properties.

(1) Moistureproof property
(2) Thermal stress
(3) Mechanical strength

5-1 Moistureproof Property

The damproof property of plastic mold products depends greatly on the properties of the resin in use. Moisture absorption of resin increases leakage current and when moisture reaches the chip, characteristic degradation or wire breakdown due to melting of electrodes may be caused.
Diskmold transistors use such a resin that provides an excellent adhesiveness between the resin and metal (between leads), achieving nearly equal moistureproof property as that of conventional signal mold transistors despite of their compactness.

5-2 Thermal Stress

Thermal stress causes expansion or contraction of resin, giving stress to internal wirings.
Gold wires are used as internal wirings of diskmold transistors. Gold wires are sufficiently strong to withstand expansion and contraction of the resin in use. A new bonding method is introduced in addition to the improvement in strength against thermal stress which is a demerit of microdisk transistors.

5-3 Mechanical Strength

Mechanical strength depends on the adhesiveness between the resin and metal (between leads).
Diskmold transistors use a resin of higher adhesiveness and improved lead frames to achieve much higher mechanical strength than conventional microdisk transistors and thus can be used without anxiety.

5-4 Reliability Control Procedure of DISKMOLD Transistors

Reliability control of diskmold transistors is effected by the procedure shown in Fig. 8. All control data are properly feed back to respective processes to establish systematization for maintaining high-stability performance.

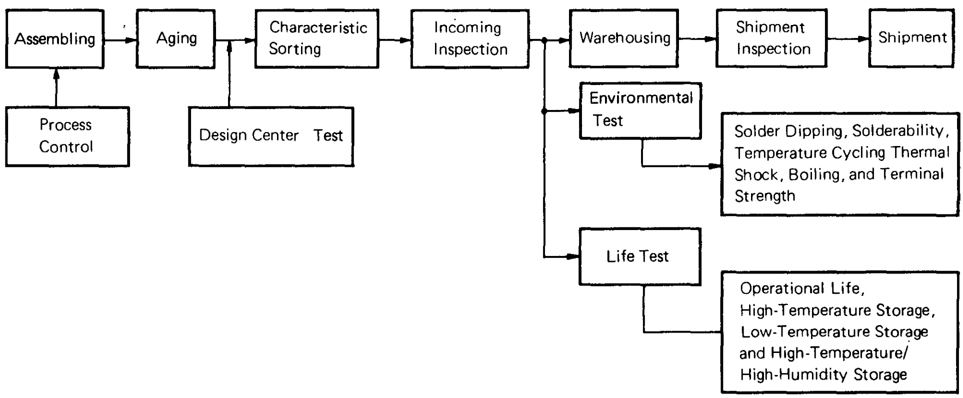


Fig. 8 Reliability Control Procedure

5-5 Reliability Test Data

Reliability tests of diskmold transistors are performed every month regularly. These tests are mostly acceleration tests and some test items are evaluated by their limits. Relationship with actual operating condition can be assured by field data, and we are willing to file test data for submission to customers on request.

TABLE 4 DISKMOLD Transistor Reliability Test

	Test Item	Test Condition	Test Duration	Criterion Items
1	Physical dimensions	Physical dimensions shall meet spec.		Out of spec
2	Strength of Marking	After dipping in chrolothene for 5 min. and drying for 10 sec. by natural drying, lightly rub 5 times.		Marking disappears or not.
3	Solderability	Dipping in melt solder at 230°C (eutectic solder) for 5 sec. using flux.		Solderability
4	Solder dipping	Dipping in melt solder at 260°C (eutectic solder) every 10 sec. using flux.		Characteristic degradation
5	Temperature cycling	High temp.: 125°C, 30 min. Low temp.: –55°C, 30 min.	30 cycles	Characteristic degradation
6	Thermal shock	High temp.: 100°C, 5 min. Low temp.: 0°C, 5 min.	10 cycles	ditto
7	Terminal strength	Force application to lead: 225g, 90° bending	3 times	Breakdown of lead
8	Salty water spraying	Temp.: 35°C, Salt concentration: 0.6%	24 hours	Rust on lead
9	Boiling	Temp.: 100°C with city water	24 hours	Characteristic degradation
10	Operating life	Continued application of power with allowable loss	1000 hours	ditto
11	High-temperature storage life	Temp.: 125°C	1000 hours	ditto
12	Low-temperature storage life	Temp.: –55°C	1000 hours	ditto
13	High-temperature/ High humidity storage life	Temp.: 60°C, Humidity: 90%	1000 hours	Rust on lead Characteristic degradation

Test Data (2SC1070 (B) HHT)

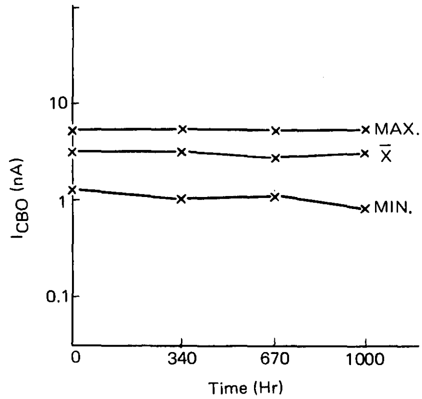


Fig. 9 Aging of I_{CBO}

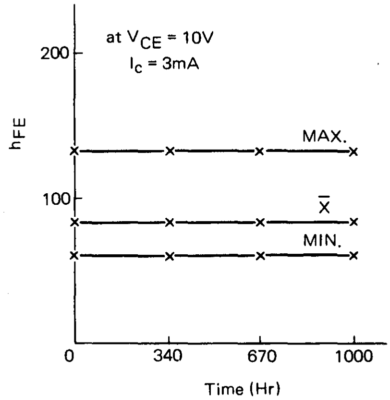


Fig. 10 Aging of h_{FE}

Mechanical Strength Test Data

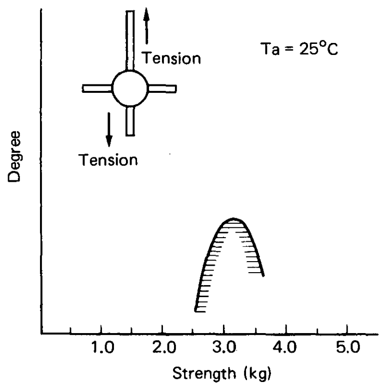


Fig. 11 Tension Strength

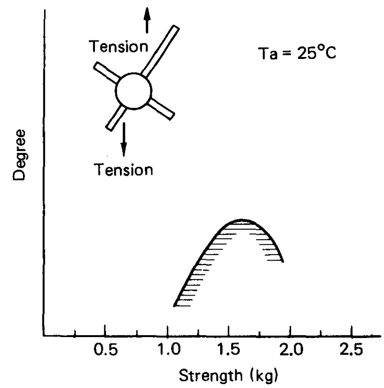


Fig. 12 Tension Strength

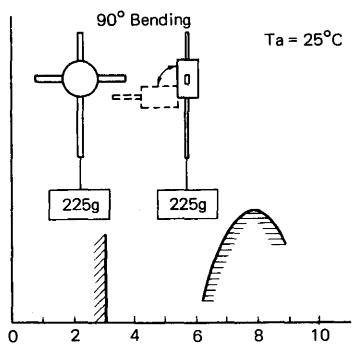


Fig. 13 Bending Strength

6. MOUNTING METHODS OF DISKMOLD

Although diskmold transistors can, of course, be mounted as conventional transistors, they allow introduction of many other new mounting methods. Some examples of mounting diskmold transistors mainly on a printed circuit board are given hereunder. Variations of these examples of mounting may be considered.

6-1 Mounting of Transistors in Conventional Method

(1) Mounting on front side of printed circuit board

Diskmold transistors can be mounted as easily as in the case of other conventional transistors, as shown in Fig. 14. In this mounting method, however, it is sometimes reported that because leads are in ribbon form short and project to three (four) different directions, they will not readily be inserted into the printed circuit board. Meanwhile, NEC has mounting jigs which allow a transistor to be easily mounted into a printed circuit board for microdisk transistor use. The special features of these jigs are in tweezers with a bent tip, a lead shaping jig, and a roller for bending leads. Examples of mounting methods are shown in pages 14 ~ 17 for reference's sake.

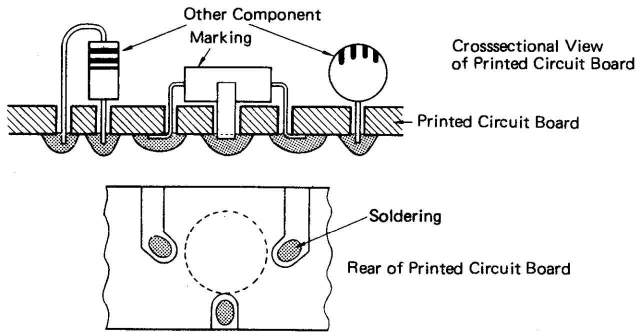
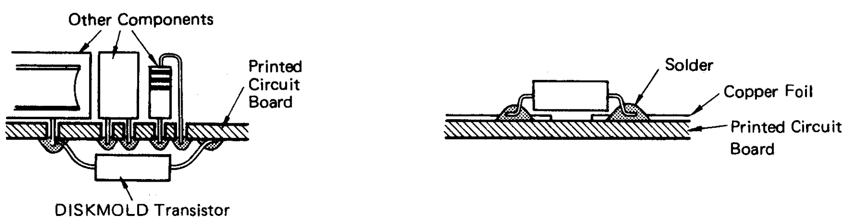


Fig. 14 Mounting on Front Side of Printed Circuit Board

(2) Mounting on Rear of Printed Circuit Board

This method of mounting allows the best use of the outside shape of the diskmold transistor while still using the conventional printed circuit board. By this mounting method, space on the surface of the printed circuit board can be saved completely. It required a considerable time to solder the three (four) leads with a soldering iron. If it is possible to fix these leads in advance to the printed circuit board by adhesive or a like, the solder dipping method may be employed. It has been confirmed that the transistor proper may be dipped in melt solder.



(a) Soldered on Rear of Other Components (b) General Use of Rear Side

Fig. 15 Mounting on Rear of Printed Circuit Board

11

6-2 Mounting of DISKMOLD Transistor by Partially Processing Conventional Printed Circuit Board for Transistors

(1) In this mounting method, a diskmold transistor is mounted embedded in a hole, as shown in Fig. 16. Since the diameter of the transistor is 4.0mm maximum, the diameter of the hole should be approx. 4.3mm. It is also allowed to arrange the transistor upside down.

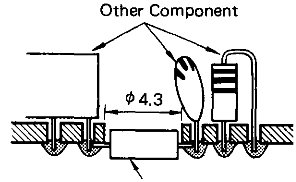


Fig. 16 Mounting by Embedded in Printed Circuit Board

(2) Other Methods
Mounting by seating diskmold transistor in a shallow hole made on printed circuit board as shown in Fig. 17 or mounting as shown in Figs. 18 and 19 are allowed. These mounting methods contribute to efficient use of space on the front or rear surfaces of the printed circuit board. Use of adhesive for fixing the transistor may facilitate soldering work.

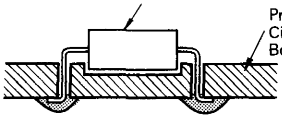


Fig. 17 Mounting by Seating Transistor on Shallow Hole on Printed Circuit Board

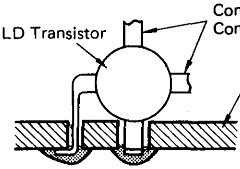


Fig. 18 Mounting by Erecting Transistor

7. CAUTIONS IN HANDLING

In general, various restrictions impose in handling transistors. Misoperation may cause breakdown or quality or reliability degradation. So ratings given in the specification must be met.
Environmental requirements and cautions to be taken upon handling diskmold transistors are given hereunder.

7-1 Mechanical Strength

For maintaining the performance and reliability of diskmold transistors, avoid as much as possible twisting leads. For shaping a lead, fix it at the foot and shape it to avoid the stress at the sealing.

7-2 Soldering Temperature and Flux

The semiconductor device solder thermal resistance requirements set out in JIS C 7021 are: 10 seconds at 260°C and 3 seconds at 350°C. These limits should not be exceeded in soldering.
Among various soldering fluxes, rosin flux is most recommendable. Use of inorganic flux (such as zinc chloride) would require cleaning after solder dipping to avoid the degradation of reliability of the device applied.

7-3 Cleaning

After completion of soldering, flux should be washed away by using such a solvent as alcohol, chlorothene and Freon but dipping for a long time would result in vanishing of the marking and should thus be avoided. When other components are not influenced, ultrasonic cleaning may be employed as rigidness is achieved by using resin encapsulation but in this case the cleaning condition should be set as moderate as practicable.

7-4 Fixation by Resin, etc.

When fixation by resin or a like is employed after mounting the transistor to the printed circuit board in the case of thin-film IC, heat or gas generated upon hardening may give undesirable influences. Resin protection may be accomplished by using epoxy and silicone.

AN EXAMPLE OF MOUNTING OF DISKMOLD TRANSISTOR

Described hereunder is an example of mounting a diskmold (microdisk) transistor developed by NEC. Use of this mounting method will greatly reduce time required for mounting when compared with the mounting method of a single-ended transistor and thus save labor for assembly.

PHOTO 1

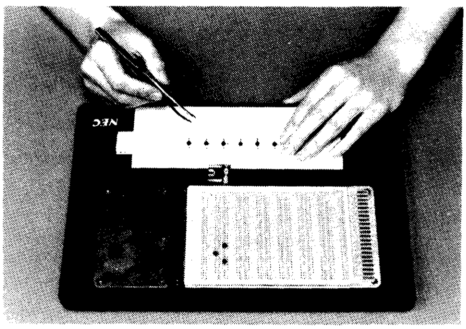


Photo 1

In this mounting method, lead shaping can readily be made and after mounting the diskmold transistor on the printed circuit board, the leads can be fixed bent at a time on the rear rise by means of a roller. The mounting jigs comprise:

(1) Tweezers (of which the tip is so processed that facilitates taking up a diskmold transistor)
(2) Lead former
(3) Roller for bending leads on the rear side.

11

PHOTO 2

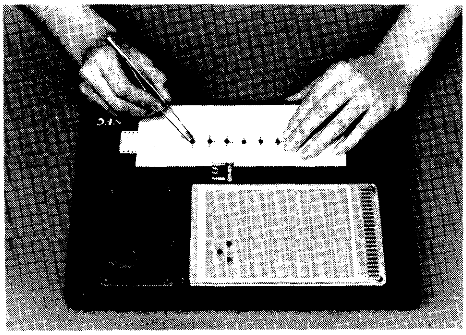


PHOTO 4

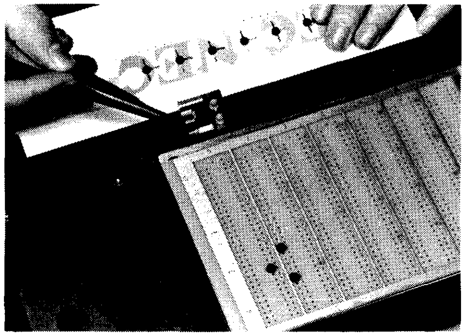


PHOTO 3

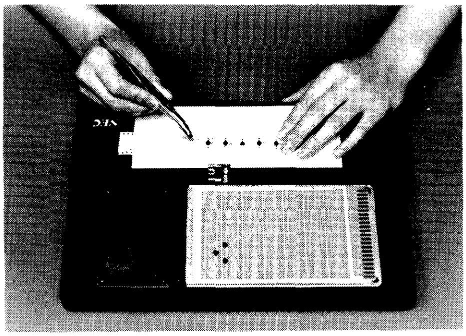
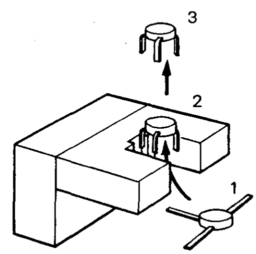


Fig. 19



Acrylic lead bending jig

Photos 2 and 3

Taped diskmold transistor is removed from tape by tweezers and wrapped. Tweezers be such that are processed so as to facilitate picking up diskmold transistor.

Photo 4 and Fig. 19

Diskmold transistor picked up by tweezers is passed through lead shaper (by pulling up transistor).

PHOTO 5

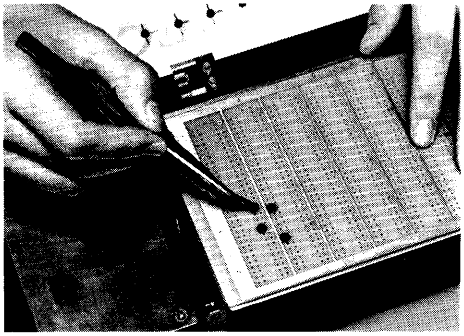
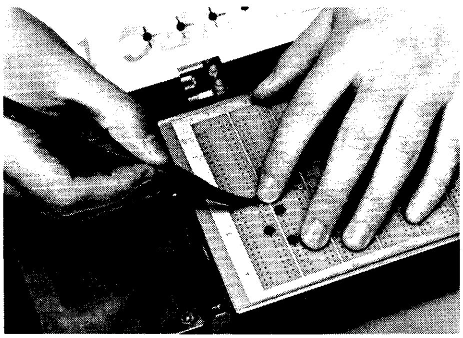


PHOTO 6



Photos 5 and 6

Leads of diskmold transistor are inserted into holes on printed circuit board.

PHOTO 7

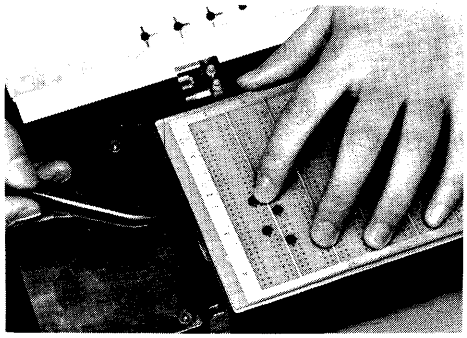
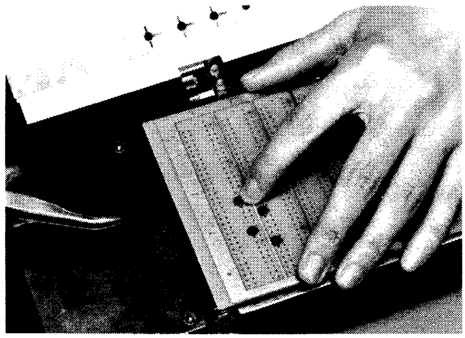


PHOTO 8



Photos 7 and 8

Diskmold transistor with leads inserted into holes on the printed circuit board is depressed by a finger.

PHOTO 9

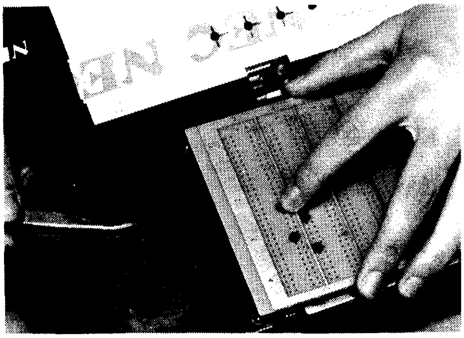
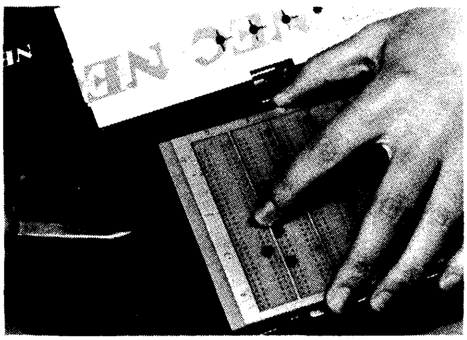


PHOTO 10



Photos 9 and 10

Printed circuit board is slided on the roller while securing the diskmold transistor with a finger.

PHOTO 11

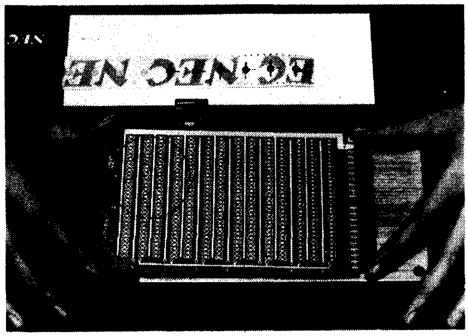


Photo 11

On the rear of printed circuit board the leads are bent and diskmold transistor is fixed.

FEATURES AND APPLICATIONS OF 1SV77 (PIN DIODE)

The 1SV77 is a low-cost PIN diode that operates as a high-frequency variable resistor with a good linearity when its dc biasing current is changed. It is suitable for applications in high-frequency signal attenuator and high-frequency switching circuit of consumer use.

This application note describes the features of PIN diodes and the application examples of 1SV77.

1. PIN DIODES AND THEIR FEATURES

PIN diode is a diode having a high resistive region called I-layer (intrinsic semiconductor layer) between P and N regions of a PN junction. The behavior of the I-layer provides the PIN diode with the following remarkable features of high-frequency resistor element.

1) When forward current flows through a PIN diode, the high-frequency impedance of the diode has little reactance component and the diode acts as a pure resistor with very small distortion.
2) This high-frequency resistance can be adjusted largely and continuously from several kiloohms to several ohms by changing the diode forward dc current from several microamperes to several milliamperes.
3) When the diode is reversely biased, the terminal capacitance is very small due to the existence of I-layer and, hence, a good isolation is obtained even in a very high frequency region.

2. STRUCTURE, PACKAGE DIMENSIONS AND PRECAUTIONS FOR USE OF 1SV77

Since formed in a lateral type PIN arrangement as shown in Fig. 2 which is different from conventional vertical type PIN structure (see Fig. 1), 1SV77 has a good productivity. The plastic molding shown in Fig. 3 has largely reduced the cost.

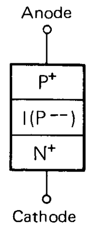


Fig. 1 Vertical Type PIN Diodes

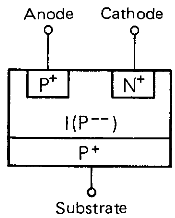
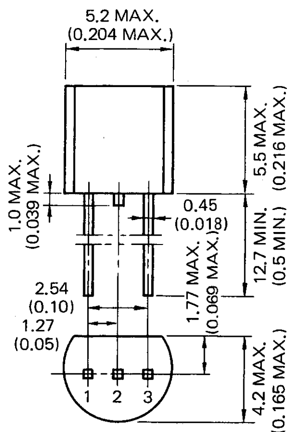


Fig. 2 Lateral Type PIN Diodes



1. Anode EIAJ : SC-43
2. Substrate JEDEC : TO-92
3. Cathode IEC : PA33

Fig. 3 Package Dimensions in millimeters (inches)

3. CHARACTERISTICS OF 1SV77

Figs. 4, 5 and 6 show the impedance characteristics, the frequency characteristics, and the capacitance characteristics of 1SV77, respectively. Fig. 7 compares IMD (Intermodulation) of this PIN diode with that of a PN-junction diode (1S953). With this PIN diode, the third order intermodulation (IM_3) is improved by 40-50 dB.

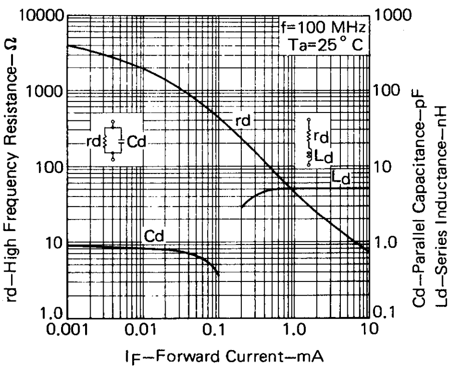


Fig. 4 Impedance Characteristics

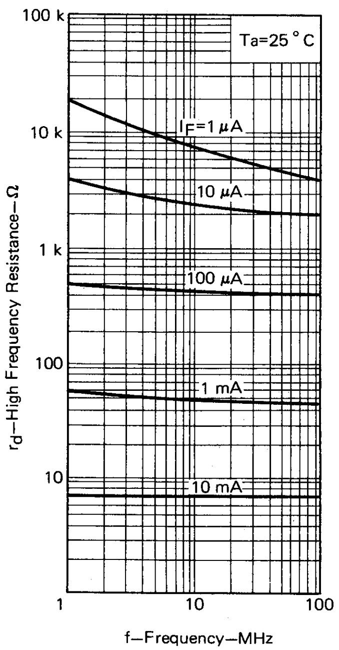


Fig. 5 Frequency Characteristics

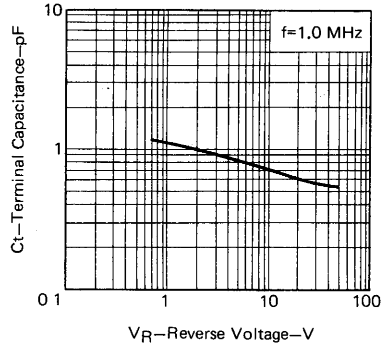


Fig. 6 Capacitance Characteristics

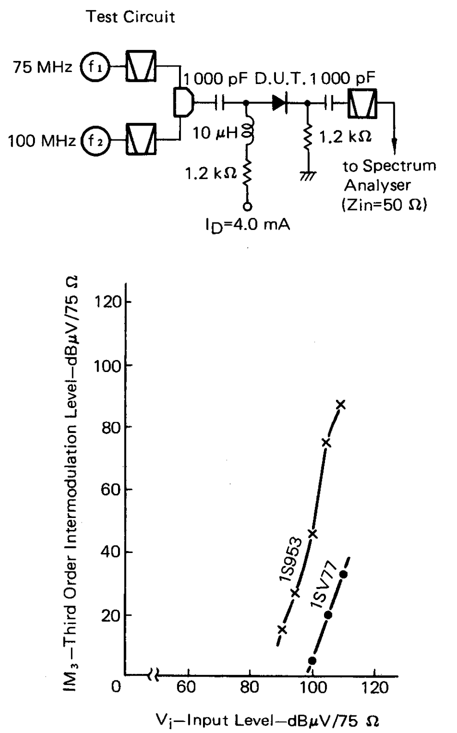


Fig. 7 Intermodulation Comparision of 1SV77 with 1S953 (PN Junction Type Diode) and Test Circuit

4. TYPICAL APPLICATIONS

As examples of using 1SV77 for consumers' applications, circuits such as high-frequency signal attenuators for car radio receiver and signal switching circuit for VTR are described on this paragraph.

4-1 Attenuator for Car Radio Receiver or the Like As a Countermeasure Against Too Strong Input.

In recent front-ends, the IMD, produced by broadcasting stations whose carrier frequencies are arranged in integer multiples to each other, is considered to be of importance. The electronic tuning system, in particular, tends to suffer from distortions due to strong input because the tuner circuit employs variable capacitance diodes which are nonlinear elements, and hence, a deterioration of the set performance characteristics results. In order to avoid this distortion, an attenuator to be switched on the front panel is provided before the antenna tuning circuit. This arrangement has a difficulty of long signal line drawn inside the set to cause an interference to other parts of circuit. However, when PIN diodes are employed instead, the following merits are produced.

1) The attenuator circuit can be localized to antenna input stage only.
2) The attenuator can be controlled by dc current.
3) Automatic attenuation can be realized by providing a controlling circuit.

Fig. 8 shows an example of a π-type attenuator with input/output matched to 75 Ω by using three PIN diodes. The attenuation can be varied from 1 dB to 27 dB. (The designed attenuation: ATT=1~30 dB)

Fig. 9 shows the intermodulation characteristics of the set with this attenuator.

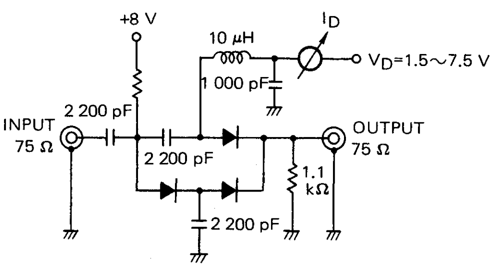
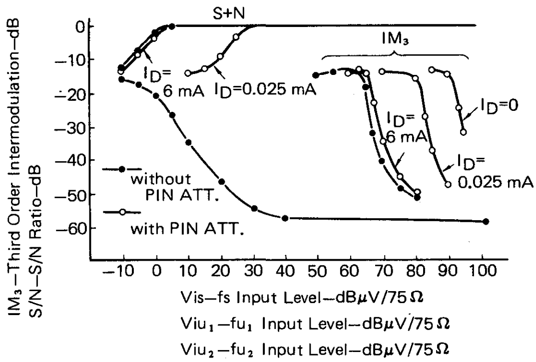
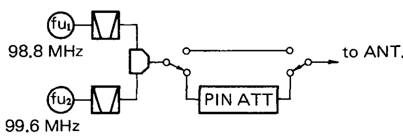


Fig. 8 π-Type Attenuator



Block Diagram



Test Condition
fs=98 MHz, fmod=400 Hz, fdev=22.5 kHz
fu_1=98.8 MHz
fu_2=99.6 MHz
by IHF method

Fig. 9 S/N Ratio, IMD Characteristics and Test Method

Fig. 10 shows an example of unmatched attenuator using only one PIN diode. Fig. 11 shows its characteristics.

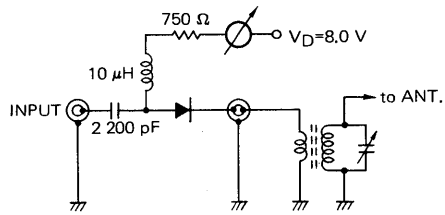


Fig. 10 Attenuator Used with One PIN Diode

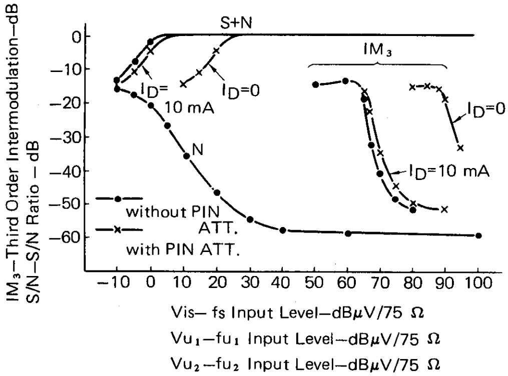


Fig. 11 S/N Ratio and IMD Characteristics Due to Fig. 10's Circuit

4-2 Signal Switching Circuit for VTR or the Like

Home-use VTR's switches video/TV by means of mechanical high-frequency switch on the VTR's set. The switch can be replaced with a PIN diode switch such as shown in Fig. 12(a) or (b), resulting in the following improvements.

1) The switch can be localized in the antenna circuit.
2) The control can be done by only switching dc bias.

Fig. 13 shows the respective attenuation characteristics.

These switches can be applied to various VHF-band switching circuit such as antenna switch of TV game as well as to VTR.

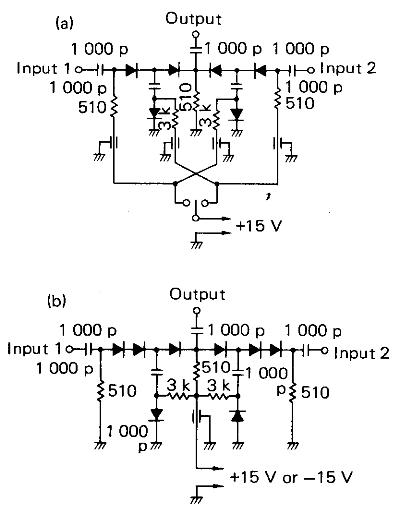


Fig. 12 Switching Circuit Use with PIN Diodes

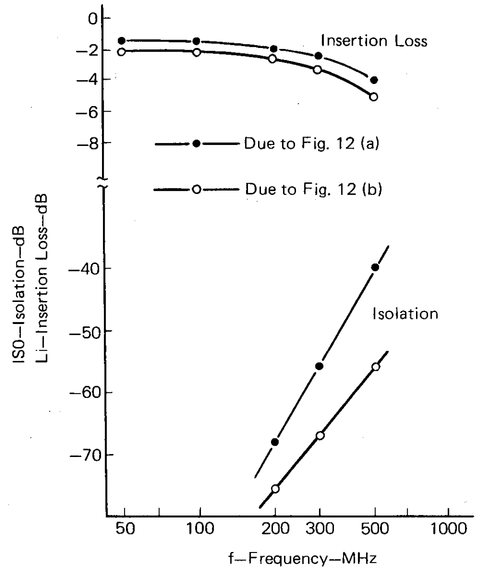


Fig. 13 Attenuation Characteristics Due to Fig. 12's Circuit

4-3 Combination with a Transistor Reverse AGC

In order to reduce PIN diode resistance to several ohms, usually a current of several milliamperes is fed to the diode. But, in portable sets where no ample margin of power is expected, a countermeasure against strong input is taken by flowing RF amplifier current through the PIN diode and by applying AGC to the transistor base. The following merits are obtained in this arrangement.

1) Current for PIN diode can be omitted.
2) Power for AGC can be reduced.

Fig. 14 shows a circuit combined with 2SC1674. Fig. 15 shows the intermodulation characteristics of this circuit.

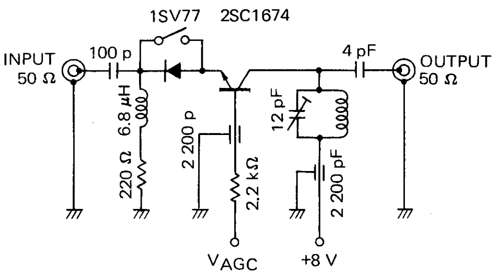


Fig. 14 Circuit of Combination with a Transistor Reverse AGC

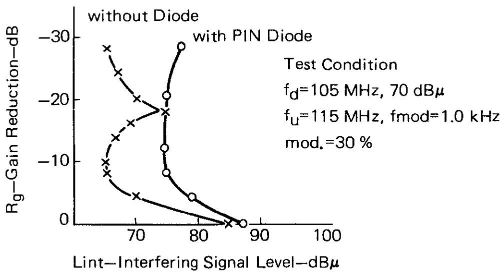


Fig. 15 Intermodulation Characteristics Due to Fig. 14's Circuit

11

TYPICAL APPLICATION OF 2SA983 TO RF AMPLIFIER OF UHF TV TUNER

1. GENERALS

2SA983 is a PNP epitaxial silicon transistor developed principally for RF amplifier of UHF TV tuner.

Features of this transistor include the applicability of AGC in the same direction as in VHF MOS FET.

Its f_T high and it exhibits a good frequency characteristic. Because of small input/output feedback capacitance, its performance is very stable.

The following description will explain the characteristics of 2SA983 used for RF amplifier of UHF TV tuner.

2. TYPICAL RF AMPLIFIER USING 2SA983

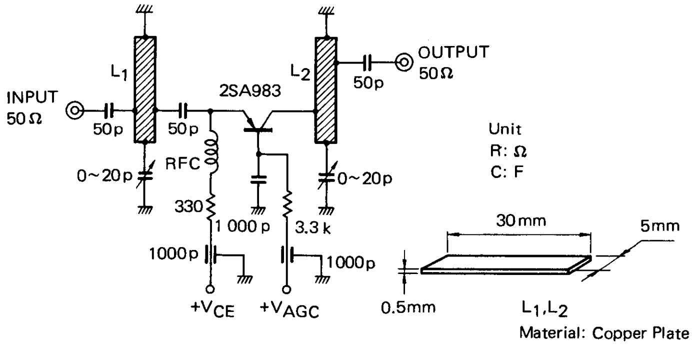


Fig. 1 Application Circuit

3. CHARACTERISTICS OF RF AMPLIFIER USING 2SA983

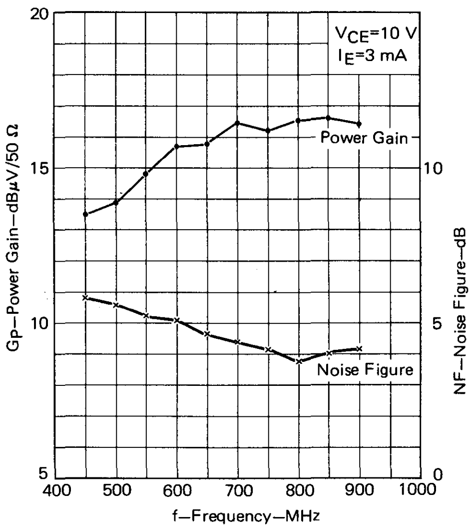


Fig. 2 Power Gain and Noise Figure vs. Frequency

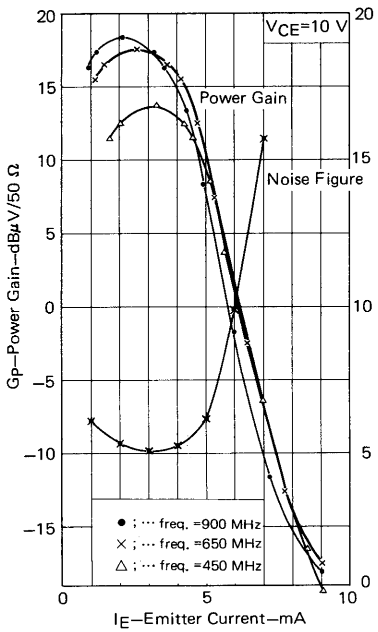


Fig. 3 Power Gain and Noise Figure vs. Emitter Current

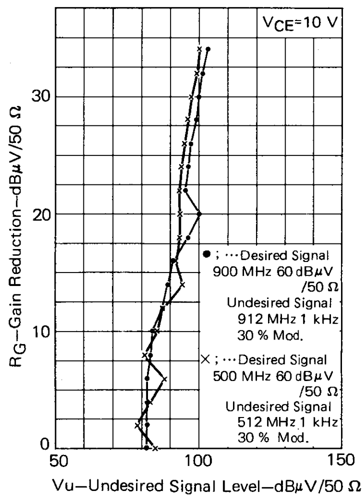


Fig. 4 1 % Cross Modulation Characteristics

4. RELATIONSHIP OF h_{FE} OF TRANSISTOR WITH AGC AND AGC CHARACTERISTICS

Fig. 6 – 8 shows the AGC characteristics of 2SA983.

Power gain is controlled by I_E which is in turn controlled by the voltage applied to the base (V_{AGC}).

For a certain value of I_E, V_{AGC} is dependent on the base resistance (R_B) and the emitter resistance (R_E) of the circuit shown in Fig. 5 as well as on h_{FE} of the transistor. It is expressed by the following formula.

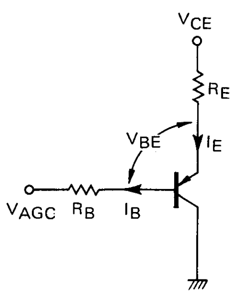


Fig. 5 Calculation of AGC Voltage

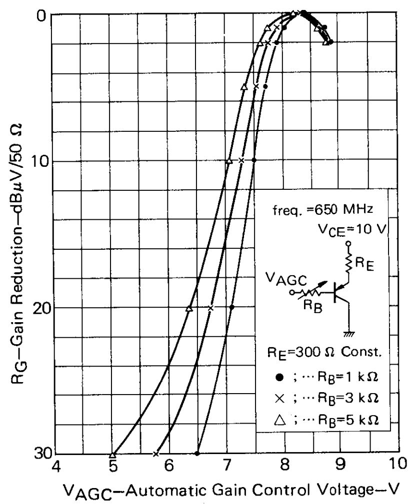


Fig. 6 AGC Characteristics for Various Base Resistances

11

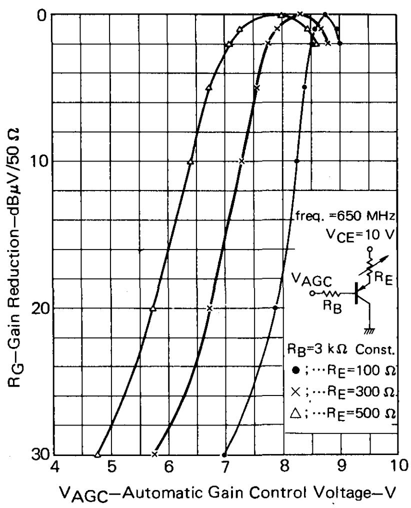


Fig. 7 AGC Characteristics for Various Emitter Resistances

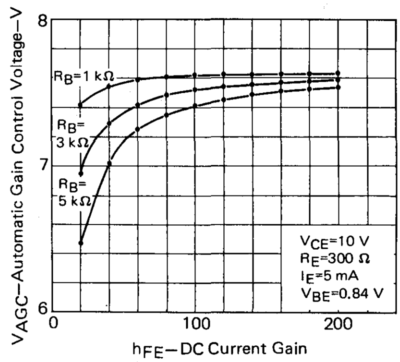


Fig. 8 Influence of h_{FE} on AGC Voltage for Various R_B Values

$$V_{CE} - V_{AGC} = I_E R_E + V_{BE} + I_B R_B,$$

where $I_B = I_E/(1 + h_{FE})$. Therefore,

$$V_{AGC} = V_{CE} - V_{BE} - I_E \left(R_E + \frac{R_B}{1 + h_{FE}}\right).$$

The formula tells that, for the same V_{AGC} applied, I_E varies with h_{FE}. Hence, with transistors having the same I_{AGC} (I_E at power gain of −20 dB) but having different h_{FE}'s, the values of V_{AGC} are different.

The effect of h_{FE} on AGC characteristics is the more enhanced for the larger R_B and for the smaller R_E. When h_{FE} is considerably large, the effect is not marked any longer.

Therefore, in order to protect the AGC characteristics from the effect of h_{FE} variations, it is recommended to select small R_B (about 1 kΩ) and large R_E. Concerning transistor characteristics, it is better to select one with a large h_{FE}.

NEC sets the standard value of h_{FE} to 60 or larger for reducing the influence of h_{FE} variation as far as possible.

TYPICAL APPLICATION OF 2SC2353 FOR UHF TV TUNER MIXER

1. GENERALS

2SC2353 is an NPN epitaxial silicon transistor developed principally for mixers of UHF TV tuner. Provided with features such as high gain bandwidth product f_T and wide current characteristics, it is the most suitable for mixers.

The following descriptions will explain the characteristics of 2SC2353 used in a mixer of a UHF TV tuner.

2. TRANSISTOR MIXERS

A transistor mixer performs frequency conversion on the principle that the signal voltage v_s is applied to the emitter junction of the transistor in series to the oscillator voltage v_o and the input conductance of the transistor is periodically varied by v_o.

The IF voltage generated on the input side is amplified by the transistor and only the IF component is selected by the output side IF tuning circuit and delivered to the next stage.

The merit of transistor UHF TV tuner mixer lies in its higher power gain by 20 dB than that of diode mixer, provided that a conversion gain (G_{cb}) of the transistor mixer is assumed to be 10 dB and a conversion loss of the diode mixer to be 10 dB.

In addition, noise figure (NF) of the transistor mixer is reduced concurrently.

The power gains and NF for a diode mixer and for a transistor mixer can be estimated as Fig. 1 and Fig. 2.

since

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 \cdot G_2} + \frac{F_4 - 1}{G_1 \cdot G_2 \cdot G_3}$$

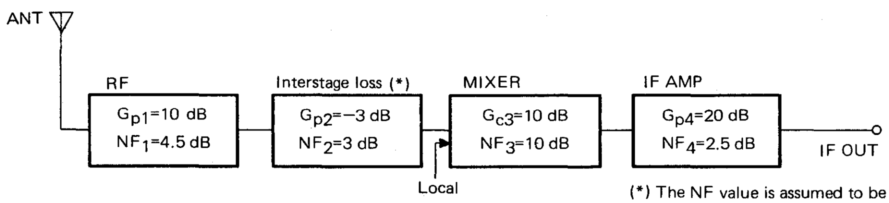
NF of transistor mixer tuner is calculated as

$$F = 2.82(4.5\text{ dB}) + \frac{2(3\text{ dB}) - 1}{10(10\text{ dB})}$$

$$+ \frac{10\ (10\text{ dB}) - 1}{10(10\text{ dB}) \times 0.5\ (-3\text{ dB})}$$

$$+ \frac{1.78(2.5\text{ dB}) - 1}{10(10\text{ dB}) \times 0.5\ (-3\text{ dB}) \times 10(10\text{ dB})}$$

$$= 4.74,$$



(*) The NF value is assumed to be equal to the interstage loss which is estimated as 3 dB.

Fig. 1 Gp and NF Distribution of Transistor Mixer

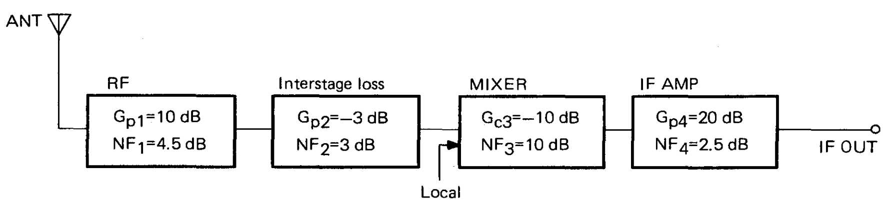


Fig. 2 Gp and NF Distribution of Diode Mixer

and NF = 10 log 4.74=6.75 dB. While, for diode mixer tuner,

$$F = 2.82 + \frac{2-1}{10} + \frac{10-1}{10x0.5} + \frac{1.78-1}{10x0.5x0.1} = 6.28$$

NF = 10 log 6.28 = 7.98 dB.

The power gains of tuner are 37 dB and 17 dB for transistor mixer and for diode mixer, respectively.

The results clearly demonstrate the superiority of transistor mixer tuner to diode mixer tuner.

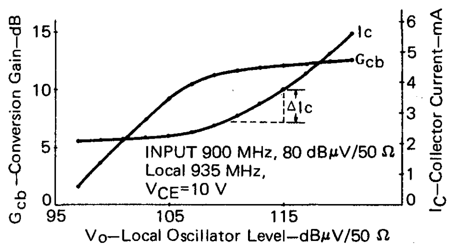


Fig. 5 Conversion Gain and Collector Current vs. Local Oscillator Level

3. CHARACTERISTICS OF UHF TV TUNER MIXER USING 2SC2353

The characteristics of a UHF TV tuner mixer using 2SC2353 will be described below. The circuitry is as illustrated in Fig. 3. It is a base-grounded, emitter-input and emitter injection type and its IF is 35 MHz. The actual circuit constants have been shown in Fig. 4.

Fig. 5 shows the local level vs. Gcb and Ic relationship. note 1)

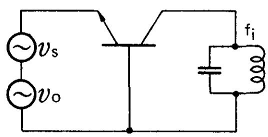


Fig. 3 Emitter Input and Injection Type Mixer for Base Ground

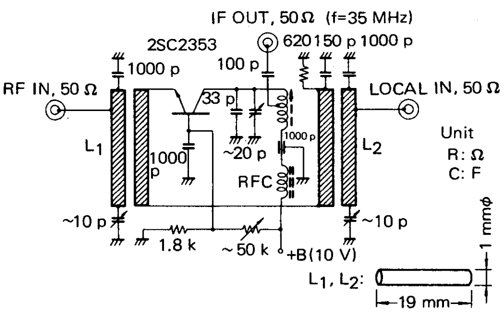


Fig. 4 Application Circuit

note 1)

local level .... The output power of the local oscillator. In the experiment, the local oscillator is substituted by an SG (signal generator), and the SG output is used as the local level.

ΔIc .... The bias current (Ic) variation due to local signal injection.

When the local level is 105 dBμV or more, Gcb is saturated. Gcb cannot be increased any more by raising the local level. Fig. 5, 6 and 7 show the Gcb, NF relationshop to current and frequency response. Fig. 6 tells that Gcb reaches the maximum at Ic of about 10 mA and NF is good for Ic of 3–8 mA. When 2SC2353 is used as an RF amplifier, its NF is about 4.5 dB for Ic of 3–8 mA. This means that the NF reduction by about 5 dB is experienced when the transistor is used as a mixer.

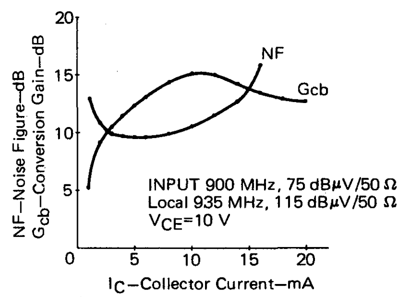


Fig. 6 Conversion Gain and Noise Figure vs. Collector Current

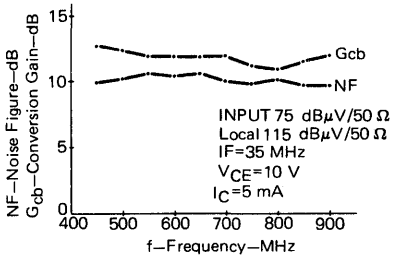


Fig. 7 Conversion Gain and Noise Figure vs. Frequency

The intermodulation (IM) note 2) shown in Fig. 8 is as good as 53 dB for a small current (I_C=1 mA).

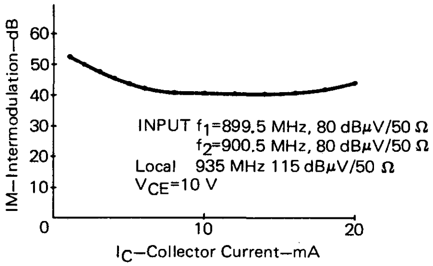


Fig. 8 Intermodulation vs. Collector Current

note 2)
When f_1 (899.5 MHz) and f_2 (900.5 MHz) are input to RFIN of the mixer, third order distortions $2f_1-f_2$ (898.5 MHz) and $2f_2-f_1$ (901.5 MHz) are produced. fosc (935 MHz) is input to those signals to convert then into IF signals. The level difference (X dB) between the converted outputs and the third order distortions is called intermodulation (IM).

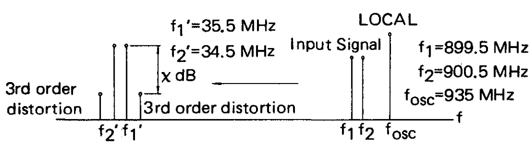


Fig. 9 Definition of Intermodulation

But this condition is not favorable because Gcb is small there. Hence the optimum current range for G_{cb}, NF, and IM is limited to 3–8 mA. Furthermore, if a local level, which is so small that G_{cb} is not saturated as shown in Fig. 5, could be selected as the optimum, it would be favorable. But, the constancy of the local level cannot be maintained in UHF band having a very wide bandwidth.

Therefore the local level should be set to a point where G_{cb} is hardly affected by the local level variation. This means a local level setting in a region where no G_{cb} increase takes place in spite of possible local level rising, namely in the region of G_{cb} saturation. On the other hand, too high local level is meaningless because of increase in radiation from the antenna. Therefore, the recommended local level setting in conditions shown in Fig. 5 would be 110–115 dBμV, where the bias current increment (ΔIc) is 1–2 mA (for R_E=620Ω).

Fig. 10 shows the characteristics of the intermodulation and the collector current versus local oscillation level. Fig. 11 shows the input to output characteristic of the mixer along with the IM characteristic.

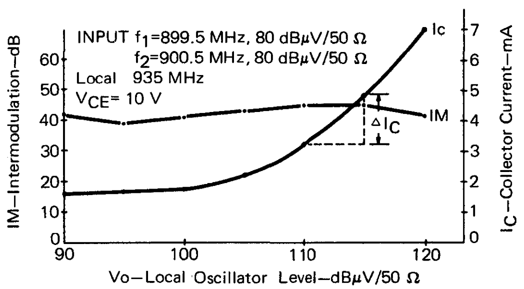


Fig. 10 Intermodulation and Collector Current vs. Local Oscillator Level

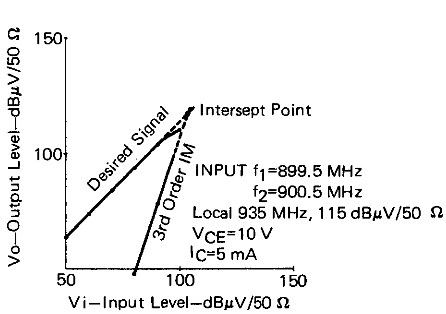


Fig. 11 Output Level vs. Input Level

As the input level is increased, the output level and IM are also increased. Typically, 10 dB increase of the input brings about (10 dB increase of the output and) 20 dB deterioration of IM. Further increase of the input would finally equate the IM level to the output level. (Actually, the transistor must be saturated and it is impossible that the IM level becomes equal to the output level). This point is called intercept point; IP (refer to Fig. 11). When this IP is known, the IM value for any input or output level can be obtained through the following formula.

|Third order intermodulation (IM)| = 2(IP-Pi), where Pi is the input power. The input level at the intercept point of 2SC2353 is read as 103 dB. So, for an input level of 80 dBμV, IM=2(103−80)=46 dB.

From the above reasoning, a typical condition regarded as optimum is Vcc=10 V(15 V is also usable) for bias and I_C=5 mA. Then Ic includes an additional current increment (ΔIc) of 2 mA due to the local signal injection. Therefore the biasing circuit should be set to have Ic of about 3 mA before hand.

The final circuit arrangement for the experiment is shown in Fig. 12.

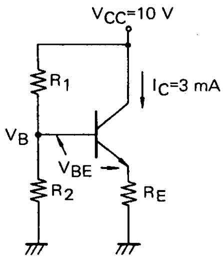


Fig. 12 Biasing Circuit

- R_E = 620 Ω (since ΔIc has been measured at R_E of 620 Ω).
- $V_B - V_{BE} = 620 \times 3 \times 10^{-3} = 1.86$ V, and for V_{BE} of 0.78 V, $V_B = 1.86 + 0.78 = 2.64$ V
- Using a relationship $V_B = \frac{R_2}{R_1+R_2}$ Vcc, R_1=5 kΩ for R_2 of 1.8 kΩ.

The characteristics of the mixer are; at input level of 80 dBμV and local level of 115 dBμV(ΔIc of 2 mA),

Conversion Gain : G_{cb} .... 12 dB
Noise Figure : NF .... 9.6 dB
Intermodulation : IM .... 46 dB,

Fig. 13 and 14 show UHF RF amplifier circuit use with 2SC2353 and G_{pb}, NF characteristics due to Fig. 13's circuit.

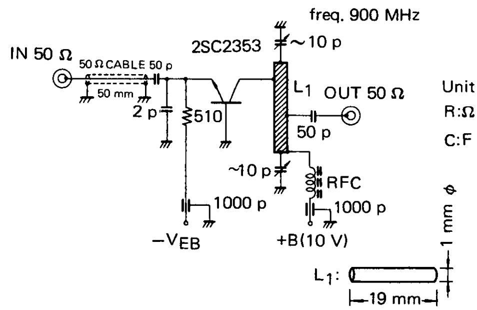


Fig. 13 Application Circuit for UHF/RF Amplifier

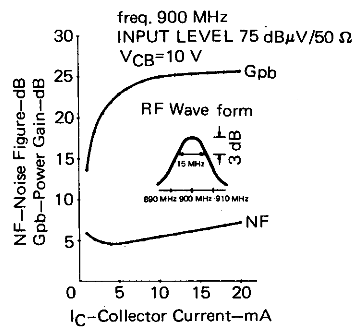


Fig. 14 Power Gain and Noise Figure vs. Collector Current

TYPICAL APPLICATION OF 3SK74 TO VHF TUNER RF AMPLIFIER

1. GENERALS

3SK74 is an N-channel MOS field effect transistor developed principally for RF amplifier and mixer of VHF tuner.

The transistor has the following features. Because of the dual gate structure, its feedback capacitance is very small (0.03 pF typical), and, due to its low input impedance (1.6 kΩ typical at 200 MHz) and its large gm (20 mS typical), y_{fs}/y_{rs} is large. So the transistor works very stably and a high power gain is obtained. Its noise figure is very small, too.

Furthermore, it has an excellent low voltage operating and can be used safely in a low power supply voltage circuit.

The following descriptions will explain the characteristics of 3SK74 applied to RF amplifier of VHF tuner.

2. APPLICATION TO RF AMPLIFIER

The characteristics to be considered generally in RF amplifier include stable gain, noise, AGC characteristic, and cross modulation.

2-1 Stable Gain

The maximum available gain (MAG) of an element is defined as the gain obtainable when the unidirectional use and the input/output matching of the element are perfectly achieved. In actual circuit, any design can hardly attain MAG practically. The concept of stable gain is therefore introduced here. It is a power gain obtained in a circuit containing feedback component by considering the performance stability. The stability index s of element itself is defined through the following formula.

$$s = \frac{2}{1+\cos(\phi_r+\phi_f)} \cdot \frac{g_i \cdot g_o}{|y_r| \cdot |y_f|}$$

where ϕ is the phase angle of y parameter.

When the stability index s of element itself is such that $s \leqq 1$, the stable gain is equal to the product of MAG and s. (When $s > 1$, the circuit works stably regardless of input/output matching conditions.)

The stable gain will be calculated below by using the actualy parameter of 3SK74.

unit: mS

	y_{is}	y_{rs}	y_{fs}	y_{os}
g+jb	0.62+j5.67	0.01−j0.02	20.4−j9.3	0.31+j2.73
$\lvert y \rvert \angle \phi$	5.705∠83.8	0.019∠−62.0	22.418∠−24.5	2.744∠83.5

@ V_{DS} = 10 V
V_{G2S} = 5 V
I_D = 10 mA
f = 200 MHz

(Data are measured with products whose y_{fs} values are typical.)

$$S = \frac{2}{1+\cos(\phi_r+\phi_f)} \cdot \frac{g_i \cdot g_o}{|y_r| \cdot |y_f|}$$

$$= \frac{2}{1+\cos(-62-24.5)} \cdot \frac{0.62 \cdot 0.31}{0.019 \cdot 22.4} = 0.85,$$

$$MAG = \frac{|y_f|^2}{4 g_i \cdot g_o} = \frac{22.4^2}{4 \times 0.62 \times 0.31} = 653 \text{ (=28.15 dB)},$$

and

stable gain = MAG x s,

(Gp)s = 653 x 0.85 = 555 (= 27.4 dB).

The result tells that a stable power gain of 27.4 dB would be obtained.

However, in an actual circuit, the Q's of the loads to the input/output tuning circuits are adjusted in order to get the bandwidth required to the circuit. This adjustment adds an insertion loss in the tuning circuits, and, hence, the measured value of gain is usually lower than the calculated stable gain.

Fig. 1 and Fig. 2 show the measured values of power gain of RF amplifier using 3SK74. The figure gives Gps of 22 dB at about 200 MHz. The stability index of the circuit is calculated as

$$\frac{Gp}{Gp(max)} = \frac{158.5\ (=22\ dB)}{653(=28.15\ dB)} = 0.24$$

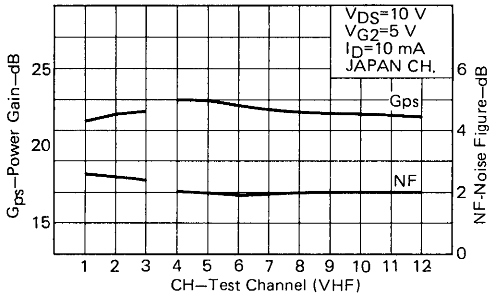


Fig. 1 Power Gain and Noise Figure vs. VHF Channel

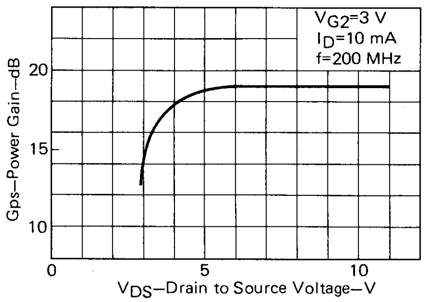


Fig. 2 Power Gain vs. Drain to Source Voltage

Fig. 3 shows about value

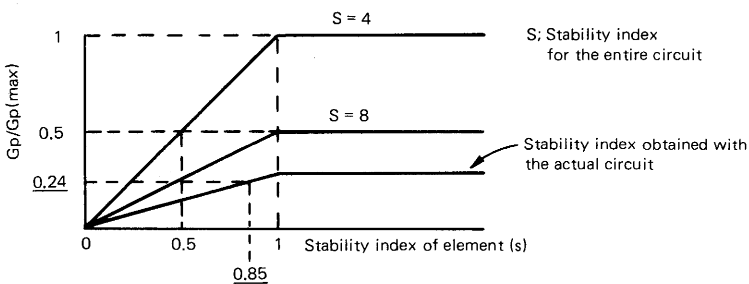


Fig. 3 Stability Index

Thus, it is shown that a very stable and high power gain is obtained.

When 3SK74 is used in an RF amplifier of electronic tuning type tuner, the unloaded Q of the tuning circuit is depressed and the insertion loss is increased as compared with a capacitance type tuner because a variable capacitance diode is used in the electronic tuning circuit.

The insertion loss in the tuning circuit using a variable capacitance diode will be obtained in the following manner. Assume the tuned capacitance as 10 pF and r_s = 0.5 Ω at 200 MHz. Q_o of the variable capacitance diode is

$$Q_o = \frac{1}{\omega C_{rs}} = \frac{1}{2 \times \pi \times 200 \times 10^6 \times 10 \times 10^{-12} \times 0.5} = 159.$$

When Q_o of L used in the tuning circuit is assumed 140 (which is a value obtained with an R-X meter at 200 MHz), the Q_o of the tuning circuit takes a value $\frac{159 \times 140}{159+140}$ = 74.4. When Q_L of the circuit is 13.3 (for 3 dB bandwidth of 15 MHz and at 200 MHz), the insertion loss of the tuning circuit using a variable capacitance diode is calculated as

$$20 \log \left(1 - \frac{Q_L}{Q_o}\right) = 20 \log \left(1 - \frac{13.3}{74.4}\right) = -1.71\ dB.$$

On the other hand, for a tuning circuit using a capacitor with Q_O of 1000, the similar calculation leads to Q_O of the tuning circuit which is

$$\frac{1000 \times 140}{1000 + 140} = 122.8,$$

and the insertion loss which is

$$20 \log \left(1 - \frac{13.3}{122.8}\right) = -1.0 \text{ dB}.$$

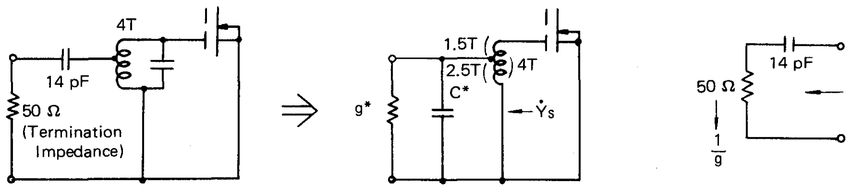
The difference of the insertion losses of the both types of tuning circuits is 1.71 − 1.0 = 0.71 dB which means that a larger loss is expected in the tuning circuit having a variable capacitance diode.

2-2 Noise Characteristics

Fig. 1 shows the noise figure (NF) of 3SK74. NF at about 200 MHz is 2 dB.

Generally the condition for the minimum NF is $g_s > g_i$ (input conductance of element). This condition does not coincide with that of power gain matching. (The power gain is 22 dB when NF is 2 dB.)

Fig. 4 represents the input circuit at 200 MHz and for NF of 2 dB.



(g* and ωc* are equivalent admittance of 50 Ω and 14 pF series-parallel converted, respectively.)

Fig. 4 Equivalent Source Admittance and Impedance

The signal source admittance in this configuration is calculated below.

$$\dot{Z}s = \frac{1}{g} + \frac{1}{j\omega C}$$

$$\dot{Y}s = \frac{1}{\frac{1}{g} + \frac{1}{j\omega c}} = \frac{(\omega c)^2}{g^2 + (\omega c)^2} g + j \frac{g^2}{g^2 + (\omega c)^2} \omega c$$

$$\dot{Y}s = \frac{(2 \times \pi \times 200 \times 10^6 \times 14 \times 10^{-12})^2 \times 20 \times 10^{-3}}{(20 \times 10^{-3})^2 + (2 \times \pi \times 200 \times 10^6 \times 14 \times 10^{-12})^2}$$

$$+ j \frac{(20 \times 10^{-3})^2 \times 2 \times \pi \times 200 \times 10^6 \times 14 \times 10^{12}}{(20 \times 10^{-3})^2 + (2 \times \pi \times 200 \times 10^6 \times 14 \times 10^{-12})^2}$$

$$= 8.73 \times 10^{-3} + j\, 9.9 \times 10^{-3} = 8.73 \text{ mS} + j\, 9.9 \text{ mS}$$

This value is stepped up by L to the signal source admittance seen from FET of

$$(8.73 \times 10^{-3} + j\, 9.9 \times 10^{-3}) \times \left(\frac{2.5}{4}\right)^2 = 3.41 \times 10^{-3} + j\, 3.86 \times 10^{-3}$$

$$= (3.41 \text{ mS} + j\, 3.86 \text{ mS})$$

$$\downarrow g_s \qquad \downarrow b_s$$

The real part of the result leads to the signal source impedance of $\frac{1}{3.41 \times 10^{-3}} = 293\ \Omega$.

2-3 AGC Characteristics

Among AGC characteristics, AGC range and AGC sensitivity are important. AGC range is expressed by the difference of power gains for the maximum sensitivity and for the maximum attenuation. The gain attenuation capability of an active element reaches its limit at the point of equivalence of forward transfer gain and reverse transfer gain.

Fig. 5 shows the AGC characteristics of 3SK74. The figure demonstrates that the AGC range is 48 dB. This large range is obtained in virtue of a very small feedback capacitance due to the dual gate structure of the FET.

AGC sensitivity is defined by the amount of control voltage required for obtaining a certain amount of attenuation.

Since AGC of 3SK74 is a reverse one, the AGC sensitivity is almost determined by the pinch off voltage of Gate 2. The insertion of a source resistance can raise the AGC sensitivity at a reasonable V_{G2} (V_{AGC}) value.

Fig. 5 shows the AGC characteristics with and without the source resistance: Rs.

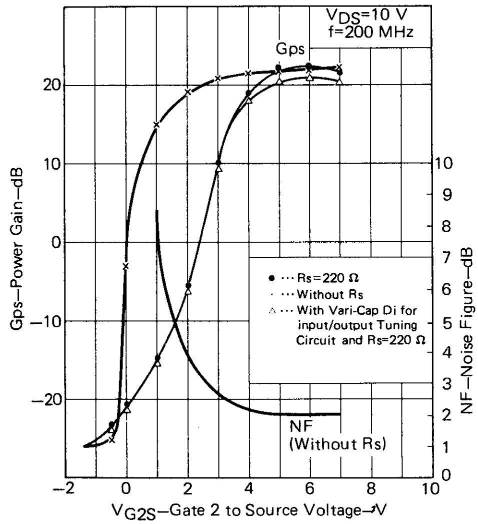


Fig. 5 AGC Characteristics

2-4 Cross Modulation Characteristics

Fig. 6 shows the cross modulation characteristics of 3SK74.

Because of a quasi-square transfer characteristics which are inferent to FET, the cross modulation at a small AGC voltage is for superior to that of bipolar transistor. Also, the remote cutoff transfer characteristics resulted by the dual gate configuration permit no deterioration of cross modulation even for a large AGC voltage.

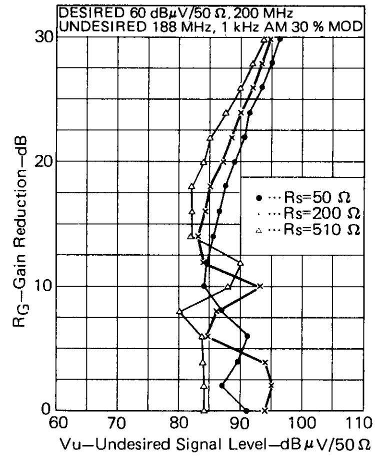


Fig. 6 1 % Cross Modulation

Fig. 7 to 9 provide data with which the dependence of the cross modulation to the biasing condition of the FET are estimated. Fig. 7 shows the relationship of I_D to V_{G1S} with V_{G2S} as a parameter. Load lines coresponding to the source resistances of 50, 200, and 510 Ω at V_{G1}=2V are drawn in the figure. By using the load lines, V_{G1S} for any V_{G2S} is obtained. Then g_m is obtained from Fig. 8 (g_m vs. V_{G1S}). Fig. 9 shows the g_m to V_{G2S} characteristics when the FET is operated of the load lines for source resistances of 50, 200 and 510 Ω at V_{G1}=2V. The cross modulation variations for these operation conditions are demonstrated in Fig. 6.

As the result, it can be said, in general, that the cross modulation will depend on the source resistance as schematically shown in Fig. 10.

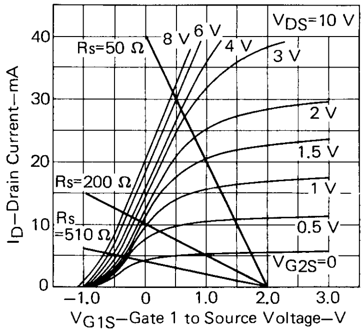


Fig. 7 Drain Current vs. Gate 1 to Source Voltage

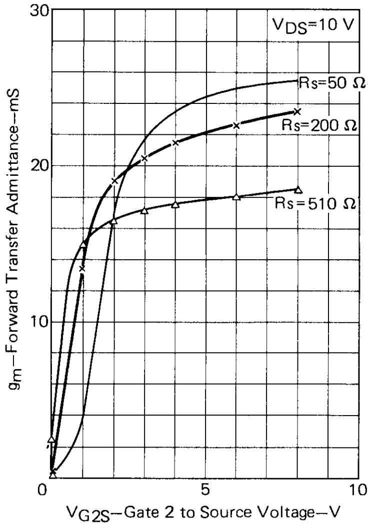


Fig. 9 Forward Transfer Admittance vs. Gate 2 to Source Voltage

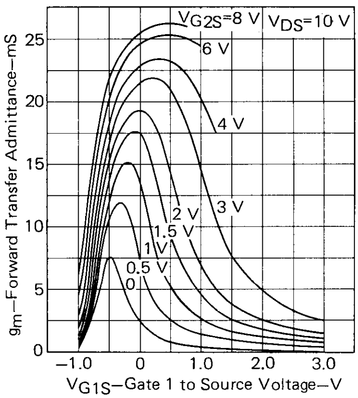


Fig. 8 Forward Transfer Admittance vs. Gate 1 to Source Voltage

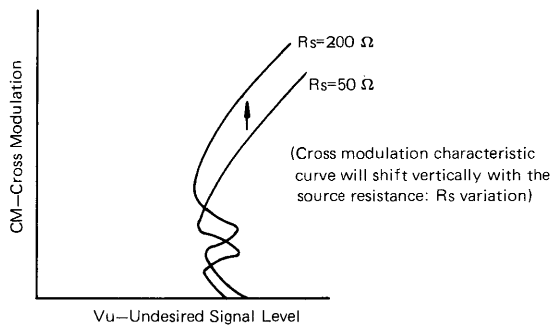


Fig. 10 Cross Modulation Characteristics

Therefore, in order to improve the cross modulation characteristics at a large AGC voltage, a larger source resistance and a smaller I_D are desirable when the distortion produced by FET tends to be deteriorated at a larger AGC voltage, and, a smaller source resistance and a larger I_D are desirable when the distortion produced by FET tends to be ameliorated at a larger AGC voltage, on the contrary.

3SK74 belongs to the latter. But, too small source resistance should be avoided because, at a small source resistance (about 50 Ω), AGC sensitivity is inferior and much more power is consumed.

Concurrently, the appropriate biasing condition for 3SK74 is assumed to be V_{G1}=2 V and source resistance of 220 Ω at V_{DS}=10 V. The cross modulation characteristic will then be;

at full gain, undesired signal level of 94 dBμV/50 Ω,
at 30 dB attenuation, undesired signal level of 95 dBμV/50 Ω,

at the desired frequency of 200 MHz and the undesired frequency of 188 MHz.

2-5 Characteristics of RF Amplifier Using 3SK74

The characteristics of 3SK74 used in the circuit shown in Fig. 11 are summarized, with regard to items up to 2–4.

- o Power Gain (Gps) .... 22 dB
  (stability index of circuit ...... 14.2)
  at 200 MHz.
- o Noise Figure (NF) .... 2 dB at 200 MHz.
- o AGC Range .... 48 dB
  (AGC voltage .... 5 to −1 V)
  at 200 MHz.
- o Cross Modulation
  at full gain 94 dBμV/50 Ω
  at 30 dB attenuation 95 dBμV/50Ω

for $f_{des.}$ = 200 MHz.
$f_{undes.}$ = 188 MHz, 1 kHz
AM 30 % modulation.

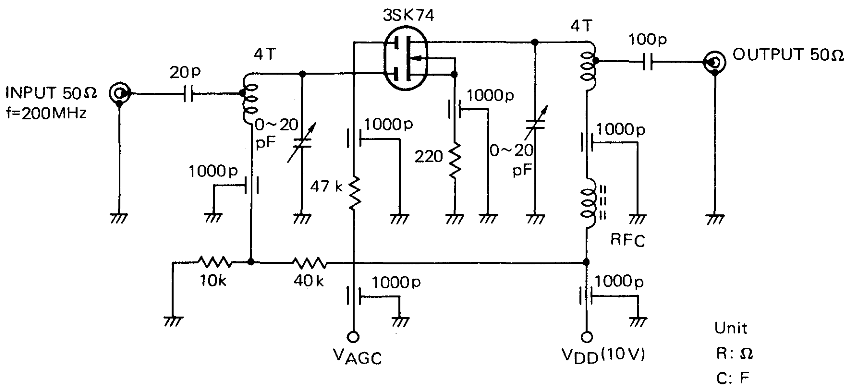


Fig. 11 Application Circuit

TYPICAL APPLICATION OF 3SK74 TO VHF TUNER MIXER

1. GENERALS

3SK74 is an N-channel MOS field effect transistor developed principally for RF amplifier and mixer of VHF tuner.

The transistor has the features that, because of dual gate structure, its feedback capacitance is very small (0.03 pF, typically), and, due to its low input impedance (1.6 kΩ typically at 200 MHz) and its large g_m (20 mS typically), its y_{rs}/y_{rs} is large and very stable. Hence a large power gain and a very small noise figure are obtained. In spite of a demerit that, when FET is used for a mixer, a large local oscillation signal injection level is needed for obtaining a satisfactory conversion gain since its g_m is smaller than that of bipolar transistor, the merit of large improvement in intermodulation characteristics is expected as a substantial one.

The following description will explain the characteristics of 3SK74 used for mixer of VHF tuner.

2. APPLICATION TO MIXER

In an application of a FET to a mixer (MIX), it is expected that the intermodulation and the spurious signal are largely reduced because its transfer characteristic is quasi-square as contrasted to the characteristic of a bipolar transistor. However, it is necessary to boost the local oscillation signal level because the g_m of FET is small. Usually, a dual gate FET is used in either of two ways: Gate 1 input – Gate 1 injection, and, Gate 1 input – Gate 2 injection. Fig. 1 shows G_{cs} vs. local injection level characteristics (conversion power gain). In Gate 1 input – Gate 1 injection type, the smaller is the injection capacitance, the larger is G_{cs}. On the other hand, in Gate 1 input – Gate 2 injection type, the larger is the injection capacitance, the larger is G_{cs}.

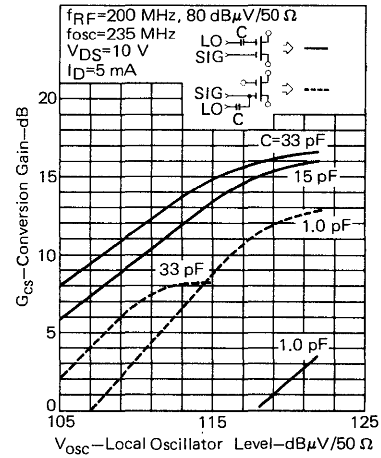
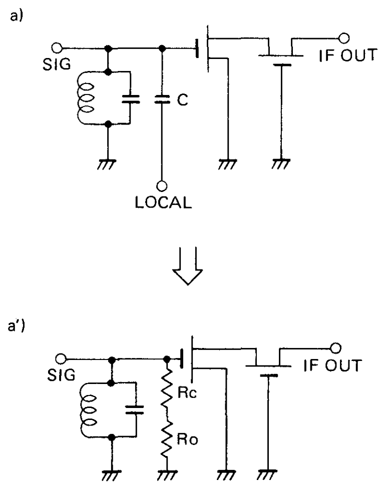


Fig. 1 Conversion Gain vs. Local Oscillator Level

These situations can be illustrated below (Fig. 2) by interpreting the dual gate FET as the equivalent cascode connection of single gate FET's.



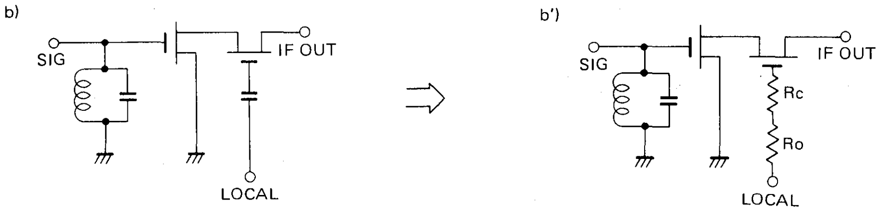


Fig. 2 Interpreting the Dual Gate FET as the Equivalent Cascode Connection of Single Gate FET's

a) represents a Gate 1 input – Gate 1 injection type which is equivalently grounded through the injection capacitance and the output impedance of the local oscillator. (In the experiment, an SG has been used for the local and, hence, the termination impedance of the SG was 50 Ω. In an actual circuit, the impedance will be the output impedance of local oscillator transistor.) This is equivalent to the Q-dumping of the input tuning circuit with R_C (impedance of the capacitance) and R_O (output impedance of local oscillator) as shown in a'). Therefore these R's should be so increased that they can be ignored. This requires the smallness of the injection capacitance C. (Refer to Fig. 3.)

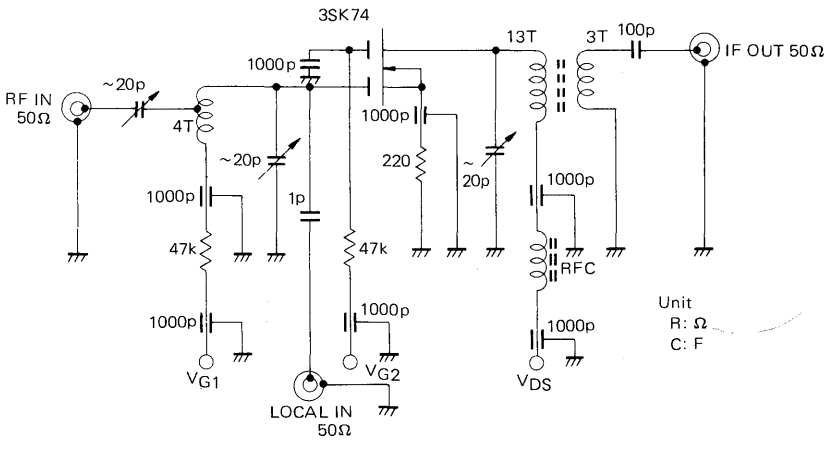


Fig. 3 Gate 1 Input – Gate 1 Injection Type Mixer Circuit

b) represents a Gate 1 input — Gate 2 injection type. Gate 2 must not be perfectly RF-grounded because Gate 2 should receive local signal. In this configuration Gate 2 is equivalently grounded via the injection capacitance and the output impedance of the local oscillator, and these grounding impedances affects the feedback capacitance and, hence, G_{cs}. In order to have a large G_{CS}, it is necessary to use as large a capacitance as possible so that the impedance can be ignored. (Refer to Fig. 4.)

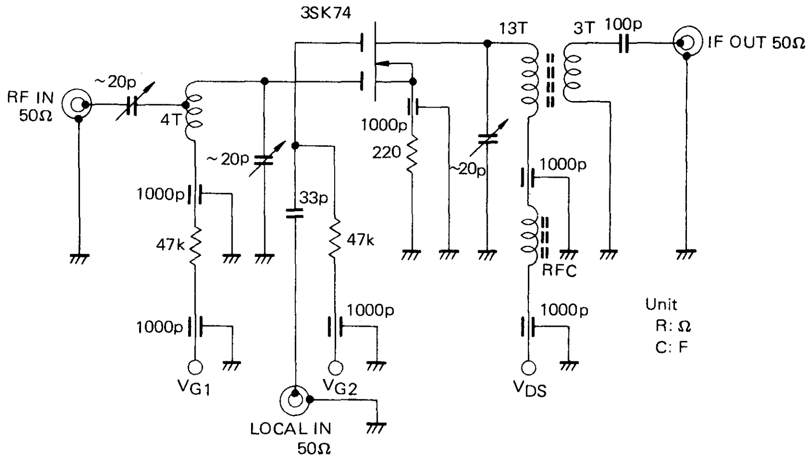


Fig. 4 Gate 1 Input — Gate 2 Injection Type Mixer Circuit

Another measure can be conceived that, for grounding Gate 2 with regard to IF, an IF trap is inserted. But experiment has shown that the measure was not so effective.

Fig. 5 shows the G_{CS} vs. V_{G2} and I_D characteristics.

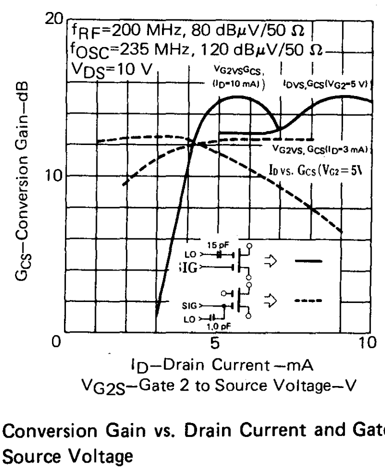


Fig. 5 Conversion Gain vs. Drain Current and Gate 2 to Source Voltage

In Gate 1 input — Gate 1 injection type, G_{CS} is not so affected by V_{G2} when V_{G1} is kept constant. Also, if V_{G2} is fixed and V_{G1} is varied to vary I_D, the G_{CS} change is rather slight. In Gate 1 input — Gate 2 injection type, G_{cs} experiences a rather large effect of V_{G2}, with V_{G1} kept constant. However, G_{cs} does not largely depend on I_D variation caused by V_{G1} shift. Summaries of the above described results are shown in Table 1, which lists the characteristics, merits and demerits of both Gate 1 input — Gate 1 injection and Gate 1 input — Gate.

Table 1 Comparing with Gate 1 Injection and Gate 2 Injection Type

CIRCUIT TYPE	MERIT	DEMERIT	CHARACTERISTICS	TEST CONDITIONS
GATE 1: INPUT GATE 1: INJECTION	① Relatively small dependence on biasing (V_{G2} and I_D). ② The smaller the local injection capacitance, the better (the load for the local oscillator transistor is the lighter).	Gcs is smaller compared with that of Gate 2 injection type	Gcs=12.4 dB Intermodulation = 63 dB (Refer to Fig. 6)	V_{DS}=10 V, V_{G2}=3.0 V I_D=5.0 mA f_{RF}=200 MHz fosc=235 MHz,120 dBμV/50 Ω Cinj=1.0 pF f_{RF1}=199.5 MHz, f_{RF2}=200.5 MHz } 80 dBμV/50 Ω fosc=235 MHz,120 dBμV/50 Ω
GATE 1: INPUT GATE 2: INJECTION	Gcs is larger compared with that of Gate 1 injection type.	① Relatively large dependence on biasing (V_{G2} and I_D). ② The larger the local injection capacitance, the better (the load the local oscillator transistor is the heavier).	Gcs=16.4 dB Intermodulation = 60 dB (Refer to Fig. 6).	Same Conditions as above except that injection capacitor: C_{inj}=33 pF

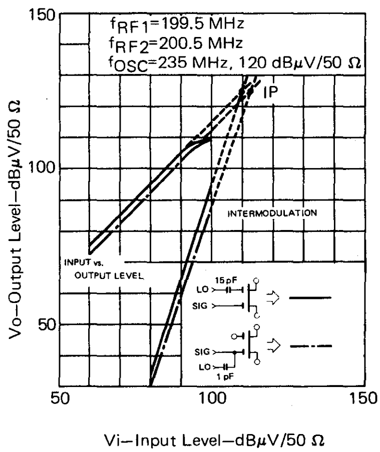


Fig. 6 Intersept Point

Based on the data on Table 1, Gate 1 input – Gate 1 injection type circuit system is recommended for the practical MIX tunner. (Refer to Fig. 7.)

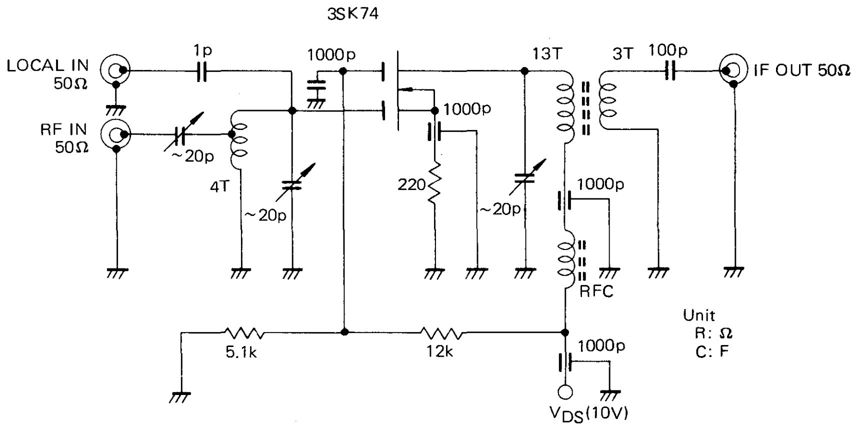


Fig. 7 Useful Mixer Circuit
(Gate 1 Input – Gate 1 Injection Type)

11

NEC
NEC Electron
A Division of NEC Electronics U.S.A. Inc.
252 Humboldt Court
Sunnyvale, California 94086
Telephone: (408) 745-6520