Not just PCs, but also the technology to make them are for sale, p. 51

Course on MOS ICs, part 5
Printed circuit boards, make or buy?
Frequency synthesizing with phase locked loops
Speed/power chart for digital ICs
we're jacking up the current rating on eleven of the JQE power supplies

THE 0-25 VOLT, 0-36 AMPERE MODEL IS NOW GOOD FOR 0-25 VOLTS AT 0-40 AMPERES. THE 0-36 VOLT, 0-25 AMPERE MODEL IS NOW RATED FOR 0-30 AMPERES. OUR 0-55 VOLT MODEL USED TO BE 0-18 AMPERES. NOW IT'S 0-20 AMPERES!

- No Other Characteristics Have Changed -

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JQE models feature optional overvoltage protectors, operational control and, with their high-speed programming option, are the most powerful wide-band amplifiers offered. (60W to 1125W!!)

Kepco's brand new 1970 catalog lists all eleven increased-rating JQE models PLUS three NEW MODELS, 0-150 VOLTS at 0-1.5A, 0-3.5A and 0-7A. A total of 32 JQE models in all plus, of course, some 200 other power supplies, modules, high voltage, high speed, bipolar, digitally-controlled and current regulators.

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For Engineering Bulletins as noted above, write to:

THE BROAD-LINE PRODUCER OF ELECTRONIC PARTS

The Electronic Engineer • June 1970
Cinch-Graphik is the industry's largest independent producer of precision circuit boards, and we keep getting larger. Plant space increased 35% last year and we filled it with highly sophisticated equipment, including a computer for manufacturing programming, so we will continue to be the largest.

For information on Cinch-Graphik capabilities, contact your Cinch-Sales District Office or Cinch-Graphik, 200 South Turnbull Canyon Road, City of Industry, California 91744, Phone: (213) 333-1201.
Whether single- or double-sided, with plated-through holes or without, round or square, big or small, etched to remove copper or plated with it, plated circuits can be bought or made. But, more importantly, the technology to make them is also available for a fee. See page 51.

FEATURES

Three-pole active filter

Six, count them, six different responses are available to you from this circuit. Just change the capacitor values and you have a new filter.

By Russell Kincaid

Printed circuits—make or buy?

It's the old story! Price and your knowledge of the new processes of making printed circuits will help your choice for you.

By Jack Froelich

Speed/power chart for digital ICs

The specifying chart that compares bipolar digital ICs by their two most important parameters—propagation delay and power dissipation.

MOS integrated circuits . . . part five

Low power dissipation, regularity and packing density are some of the features that make RAMs and MOS technology a winning combination.

MOS random-access memories

Love may not be the only thing around the corner with MOS technology and random-access memories coming on strong.

By Warren Crews

Static or dynamic—two ways to remember

Can you afford to be less than dynamic when choosing a MOS random-access memory? Perhaps, if a static MOS memory suits your purpose, the better choice wouldn't be a dynamic RAM.

By Marcian E. Hoff, Jr.

Performance and cost trade-offs for MOS RAMs

Choosing the right MOS RAM for your application can be a lot simpler if you know the design compromises.

By Vernon G. McKenny

Frequency synthesizing with the phase locked loop

The versatility of the phase locked loop opens the door for this new digital frequency synthesizer design.

By Ed Renschler and Brent Welling

IC Ideas

- Clock rate limit circuit
- BCD to 9's complement converter
- Noise-insensitive monostable multivibrators
- Super-simple square wave generator
All Solid State
AC Power Source from ELGAR

A FAMILY OF INTERCHANGEABLE PLUG-IN MODULES will allow you to select any frequency from 45Hz to 10KHz — with accuracies from ±1% to ±.0001% to meet your requirements. The completely silicon solid state ELGAR Model 201 Power Source is unequalled for on-line instrument versatility and reliability. Newest in a growing array of precision power concepts from ELGAR, the Model 201 is ideal for gyro test applications, synchronous frequency instrument operation, for testing of equipment destined for overseas use, and for overseas operation of 60Hz equipment. Input power may be strapped to accept 115 VAC or 230 VAC; output range may be selected from 0-26 VAC, 0-130 VAC or 0.260 VAC by strapping. Special functions are available on request. Check the specs, then let us hear your specific requirements.

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Output Frequency Range: 45Hz to 10KHz
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Load Regulation: 1% — 45Hz to 5KHz; 2% — 5KHz to 10KHz
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PRECISION POWER BY ELGAR Complete isolation from high speed line transients is provided by the ELGAR series of A.C. Line Conditioners.

Send for complete specifications listing and free literature or see pages 1937-1943 of your 1969-1970 EEM catalog.

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The Electronic Engineer • June 1970
AN AMP FOR ALL REASONS

Whatever your reasons or critical parameters, Fairchild Controls has the amplifier to meet your needs. Fairchild Controls offers a wide selection of discrete, hybrid and monolithic amplifiers for industrial, military and commercial use.

And, Fairchild Controls has a computer programmed to help you select the amplifier best suited to your requirements. You can even rank your parameters in terms of priority and the Fairchild Controls computer will select, from over 70 amplifiers, the one that will give you optimum performance.

We'll be happy to send you our new “Selection Guide to Operational Amplifiers” to acquaint you with our full range of amps. But, our service does not stop there. Our field staff, in conjunction with our computer, stand ready to provide you with quick and reliable answers to any questions you have.

For more information, or a copy of the “Selection Guide,” write Sales Manager, Fairchild Controls, 423 National Avenue, Mountain View, Calif. 94040.

Circle 8 on Inquiry Card
end your signal pollution problems

Beldfoil® ISO-Shielded™ Cable

It's the cable with virtually perfect shielding. It's a Belden exclusive. Beldfoil ISO-Shield is like a continuous metal tube enclosing each pair of conductors in a cable. It locks out crosstalk or interference . . . whether from outside sources or between shielded elements in the cable.

Beldfoil is a layer of aluminum foil bonded to a tough polyester film (for insulation and added strength.) To form an ISO-Shield, we apply it in any one of several unique ways to meet the requirements of different applications. (See Figures 1 and 2, for example). Each gives more physical shield coverage than braided wire or spiral wrapped (served) shields. And greater shield effectiveness . . . even after repeated flexing.

Beldfoil ISO-Shielded Cables are small, lightweight. They terminate easily. They're modest in price. Your Belden Distributor stocks a wide variety of standard Beldfoil shielded cables as listed in the "Belden Electronic Wire and Cable Catalog" (ask him for the latest edition). And, should you have specifications no standard product can meet, ask him to quote on a specially engineered design. Or, if you choose, contact: Belden Corporation, P. O. Box 5070-A, Chicago, Ill. 60680. Phone (312) 378-1000.
Beldfoil Multiple Pair Individually Shielded Cable

The Figure 1 cross-section shows Belden's exclusive Z-folded Beldfoil ISO-Shield. Note the metal-to-metal contact between the two edges of the aluminum foil. In essence, you have a continuous aluminum tube. And the polyester layer on the outside of the fold assures the isolation between shields so necessary for best performance in the field.

Technical Data
Nominal values for multiple pair individually shielded cables containing 3 to 27 pairs (including 8769 and 8773 through 8778 Series cables)
Suggested working voltage: 300 volts rms max.
Working voltage between adjacent shields: 50 volts rms max.
Capacitance between conductors in a pair: 30 pf per ft. nom.
Capacitance between one conductor and other conductor connected to shield: 55 pf per ft. nom.
Capacitance between shields on adjacent pairs: 115 pf per ft. nom.
Insulation resistance between shields on adjacent pairs: 100 megohms per 1000 ft. nom.

Beldfoil Shielded Single Pair Cable

The Figure 2 cross-section shows the exclusive Belden Z-fold with the polyester insulating layer inward. This makes use of the high dielectric strength of the polyester film as bonus insulation between the conductors and the shield. (The cable jacket provides the primary insulation of the shield from outside objects or adjacent cables.)

Technical Data
Nominal values for 8451 Shielded Pair Cable
Suggested working voltage: 200 volts rms max.
Capacitance between conductors: 34 pf per ft. nom.
Capacitance between one conductor and other conductor connected to shield: 67 pf per ft. nom.

new ideas for moving electrical energy
The Phase Locked Loop has hit the market. It's better known as the monolithic phase locked signal conditioner and demodulator. And it's available from Signetics.

This small wonder has all kinds of applications for designers of communication and data equipment. Like 1) FSK and FM demodulation (without tuned circuits), 2) signal locking, reconstitution and conditioning, 3) tone and marker detection, 4) AM synchronous detection, 5) frequency multiplication and division, 6) signal searching and tracking.

In short, the phase locked loop, a complete system on a chip, eliminates tuned circuits altogether. And it reduces the cost and size of designs while improving their stability and reliability.

There are two versions—the 560 and the 561 (the latter adds an AM synchronous detector to the 560). And both operate from less than 1Hz up to 30MHz.

The device has so many possibilities. It will be the universal building block that the op amp has become.

So get in on it now. Write for a complete description of performance, applications and spec sheets.

And lock it up.
No, Virginia, you are too big for Santa Claus

The two electronic engineers sat late that night at the kitchen table, over a heap of papers that partially covered two coffee cups and a slide rule.

"This terminal will sell," said one of them, "and we can produce it for about $500. That's good. The least expensive one sells today for $4500—you know, the one that rents for $49.50 a month."

And on they went the rest of that night, and many other nights, until they had drafted a comprehensive financial and technical plan. Then, they talked to one of the best technicians in the computer company they worked for, and interested him in joining their budding venture. The technician quit his job and, supported by the two engineers, spent six months building a prototype in his garage.

In the meantime, they retained a lawyer who, in place of a fee, accepted a piece of ownership in the new company. When the prototype was ready, the engineers wanted to demonstrate the terminal to prospective customers to secure some preliminary orders. "Nonsense!" said the lawyer, "the first thing to do is to go public. By the time you fellows get the orders the shares will be on the market selling at a nice price and we'll be rich."

The two engineers spent another night over coffee and slide rules. They had hoped to get rich all right, but only after mass-producing the terminal. Right now, they only had a prototype that, even though it worked beautifully, had to be redesigned and debugged for production. In particular, they wanted to incorporate all the decoding, counting and memory circuits in a few MOS chips that they knew would take a year to design and produce. But—and the childhood image of a pot of gold that lies at the end of the rainbow glittered in their minds—after all, they were not financial experts, and maybe going public right now was the thing to do. Doesn't everyone?

"Sound convincing—no ifs or buts," they were told, and they did. The six prosperous-looking gentlemen from the underwriting firm listened attentively, one of them even seemed to understand what the engineers were saying. "Are you sure the MOS circuits will be ready in a year?" he asked. "We have a new MOS company in our portfolio, and they haven't delivered anything yet."

The engineers hesitated. Yes, they knew some companies had trouble delivering the type of MOS chips they would be looking for. Yes, to bring the price in to their range they would have to place large orders for those MOS ICs. No, they hadn't designed them yet.

Slowly, the rainbow seemed to fade, and the gold flashes at its end disappeared. They had to go back to work, and to the long stint of bootstrapping their company as they had planned before being dazed by the promise of instant riches.

"Before you go public," says Mr. Timothy Collins, president of Collins Securities Corp., "make sure you have made some sales. The public, who rushes to invest on technology it doesn't understand, is very unforgiving when it gets burned."

The two engineers may eventually get rich, but only after they prove their prototype, build a small production lot, and gear for mass production. One day, they will find themselves at the end of the rainbow, but by then they will feel they are not getting something for nothing—which is a principle that applies to things other than engineering.

Alberto Socolovsky
Editor
Fallout from NASA know-how on CAD . . . The now defunct Electronic Research Center of NASA in Cambridge, Mass., had accumulated quite a bit of talent and knowledge in computer-aided design, particularly microelectronics. To avoid wasting this, NASA organized a 5-day course on the subject which took place in April at the Jet Propulsion Lab in Pasadena, Calif. Although the course was open only to JPL personnel, NASA's intention is to polish it and make it available to universities and industry. Robert L. Trent of the ERC is managing the course, and the lecturers at the JPL included Dr. William C. Happ of NASA—long experienced in CAD—plus specialists from industry.

CAD time-sharing service . . . General Electric has come up with new applications of computer time-sharing for the electronics industry. For example, they now have a computer-aided design (CAD) package which includes programs in digital system simulation, circuit design and electronic analysis, and dynamic system simulation. Applications for the programs include design proposals and evaluations, design engineering, reliability and quality assurance, hardware performance checkout, and the study of parameter variations, design alternatives and component tolerance. A significant feature of GE's time-sharing service and one that's available to all subscribers is its library of 350 programs stored in their computer systems. A user may write and store programs for his specific applications in the system, and these would be unavailable to other subscribers.

Technology for society . . . Cal Tech's Jet Propulsion Laboratory has established a Civil Systems Projects Office headed by Howard H. Haglund, former manager of the Surveyor moon-exploration spacecraft project. The laboratory's space-age capabilities will be directed towards solving problems in medical engineering, public safety support, urban land use and transportation. Three activities already designated are space technology applications, transportation technology and biomedical application of computer technology.

Environmental specs for plastic ICs? . . . The military is taking another serious look at the reliability of plastic-packaged ICs. By definition, they are not hermetically sealed; there are no tests for hermeticity without a cavity in the package. The real question is whether or not the packages admit moisture. Silicone material is moisture-resistant, but is also a lubricant, so it tends to admit moisture along the leads. To prevent wetting, some companies use a protective silastic coating over the chip. National Semiconductor was the only one of eight companies at a recent Washington meeting to submit complete reliability test results. The Rome Air Development Center is expected to use this and other data to establish a new set of environmental tests for plastic ICs.

Computer graphic display system . . . Corning recently entered the information processing field with the introduction of a time-sharing interactive graphic computer terminal designated the 904. The system offers graphic and alphanumeric display, a built-in electrostatic hard copy device, and a method for superimposing slide data over computer generated data. A unique principle of the terminal is its use of photochromic glass as a storage medium. The 904 is priced at $19,650 and is complete with a software package consisting of 57 FORTRAN IV sub-routines. It is designed for linkage to a time-sharing system through voice grade telephones.

Monolithic alphanumeric readout . . . A monolithic, light-emitting diode alphanumeric readout is commercially available from Monsanto. Model MAN-3, a seven-segment display and totally monolithic semiconductor device, is the third in a series of solid state displays. The active light-emitting areas are planar, formed by zinc diffusion into n-type gallium arsenide phosphide wafers, and emit light from 6300 to 7000 angstroms. Suggested applications include digital displays in desk calculators, computers, and portable equipment.

Pay TV . . . New life may have been breathed into the pay TV issue with the Supreme Court's recent support of a lower court's decision. The lower court's decision was to permit the FCC to license pay TV. We say "may have been" because the opponents to pay TV are now seeking Congressional action to stop or at least severely limit the FCC's power in granting pay TV permits. The pay TV battle has been going on for at least a dozen years. If pay TV should ever come to pass, then a new sales area would open up for electronic products.

Lobbying unions . . . The second annual convention of the Council of Engineers and Scientists Organizations (CESO), an affiliation of engineering unions, was held in Washington, D. C. CESO, which has approximately 100,000 members in the United States and Canada, passed several resolutions including, in view of the "necessity of controlling the engineering population," an endorsement of a much broader educational base for engineers. This is in direct contradiction to the Engineers Joint Council (EJC) call for $500,000 from industry to encourage more young people to study engineering.
Sylvania introduces a new 40-lead, glass-ceramic, sandwich-type, unitized, hermetically sealable large scale integrated circuit package.

(whew.)

Simple, three-layer structure can do IC functions

Made with metal conductors, a layer of silicon dioxide and silicon base, this device can work for logic, memory and imaging applications.

Being developed at Bell Labs, a new class of devices offers imaging, logic, and memory functions at low cost. These new devices, called Charge Coupled Devices (CCD), can perform many functions of complex integrated circuits. Yet, they are simple, easily made, three-layer structures of silicon-silicon dioxide.

Because these devices are not restricted to materials in which it is possible to form a p-n junction, the technology can be applied to a wide range of semiconductor-insulator systems. In their designs, Bell Labs scientists used CCDs made of metal conductors, a layer of silicon dioxide and a base of silicon.

CCD devices create and store minority carriers, or their absence. This action occurs in a spatially defined depletion region, called a potential well, located on the surface of a semiconductor. (Minority carriers are holes at the semiconductor-insulator interface of an n-type semiconductor.)

Unless these wells (charges) can be moved and detected, we merely have a "capacitor." To produce and move the potential wells, an array of electrodes are formed on the insulator-semiconductor layers. These electrodes create and move the potential wells when a voltage is applied to them.

At Bell Labs, scientists apply a voltage to the metal electrodes. This voltage is negative with respect to n-type semiconductor. When the voltage is first applied, equally divided between the semiconductor and the insulator, there are no holes at the semiconductor-insulator interface. If holes are introduced into the depletion region—by avalanche multiplication, light, or other means—they will collect at the semiconductor interface, causing the interface potential to become more positive.

The minority carriers (in wells) may be then moved from under one electrode to a closely adjacent electrode on the same substrate by a more negative voltage applied to the adjacent electrode. The sequence is repeated to move the carriers in any desired direction. Because minority carriers may be stored and moved in precise patterns, in two dimensions, and can be detected and measured at some location, you could have a shift register. The basic shift register may be used as a recirculating memory or as a delay line.

CCDs could be an imaging device. Such a device would operate by shining a light image on the bottom of the semiconductor part of the device, creating electron-hole pairs. The holes would diffuse to the electrode side where they can be stored in the potential wells created by the negatively charged electrodes. Later, the image may be read out via shift register action.

The experimental 24-plate, 8-bit shift register uses Charge Coupled Device (CCD) technology. For experimental reasons, this version is larger than final manufactured models. The technology is applicable to a wide range of semiconductor-insulator materials systems.
Save money and get tighter specs.

Still using conventional components in your circuit design? Get out your pencil and start your next design with Ferroxcube ferrite pot cores. Now you can produce circuits that deliver better electrical performance at lower cost.

Here's how. Pot cores are completely self-shielding. They are rugged. They deliver high Q, high stability of inductance, plus small size. And they can meet exceptionally tight tolerances with utter reliability. They come pre-adjusted or adjustable. These characteristics can help you make cost-savings throughout all associated circuitry. Ferroxcube pot cores are ideal for automated production, too, including automatic PC board insertion.

Explore the pot core design approach with Ferroxcube.

It's the broadest line in the industry...97 types in 12 sizes and 5 materials. Plus prototype production quantities off-the-shelf from eight Stocking Centers nationwide. No one else makes pot cores so instantly available.

Send for our latest Linear Ferrite Catalog now. Once you've used pot cores you'll know why so many magnetic component designers are going to pot.

Ferroxcube
Saugerties, New York
A NORTH AMERICAN PHILIPS COMPANY
Optical Memory Systems of Santa Ana, California, has developed a unique optical read-only memory (ROM). Their OM-1000 Series ROMS contain an array of GaAs light-emitting diodes (LEDs) and an array of light-sensing PIN diodes separated by an optical mask.

When an individual light source is addressed, the bit pattern of the mask determines which sensors are exposed or blanked, thus creating a multi-bit word. Any LED can transmit as many bits as there are sensors. In effect, there is a different mask associated with each source, so any configuration of bits can be realized.

**Fewer components for more data**

The capacity of the memory is the product of the number of sources times the number of sensors, with the mask providing the bit values. The standard configuration of 1000 LEDs and 100 sensors provides 100,000 bits of ROM with only 1100 elements, compared to one or even two circuit elements per bit in other memory types. Units are available in several organizations.

High-speed amplifiers associated with each sensor provide pulsed outputs compatible with TTL, RTL, or ECL logic. Access time is less than 60 ns and cycle time less than 100 ns. Outputs can be multiplexed to give any word length desired.

**Large-scale changes are easy**

The mask is a glass photographic plate that can be interchanged in seconds without altering the electronics of the memory. It's as simple as changing a slide in a home slide projector. OMS can supply masks constructed so that untrained personnel may change bit locations in the field. If a manufacturer needs to change an ROM subroutine, he can generate completely tested masks in-house and ship any number to his customers, without expensive field maintenance, downtime, or rewiring, which add substantially to the cost of a memory.

OMS can make masks for its customers and is working on a standard package that will cover all of the basic code conversions and table look-up functions. The standard 100,000 bit ROM package will include at least 50 masks. It costs about $1,000 to set up and generate the first mask and less than $50 for any thereafter. In quantity, mask sets containing over 5 million bits can sell for around $2,500. Initial mask costs are 1¢ per bit compares favorably to an initial cost of about $1.00 per bit for an LSI mask.

Downstream planning calls for using stepper motors to change the ROM program in 100,000-bit increments by indexing a roll of film that stores several million bits.

Mask tolerances are typically 5 mils, and many customers already have enough mask-making equipment to generate their own. OMS will also be marketing a mask-making kit for about $10,000.

**Speed, capacity, and cost look good**

This type of optical ROM has the advantage of speed independent of capacity. An LSI ROM might have an access time of 60 ns for 500 to 1,000 bits; but the access time becomes much greater for 100,000 bits, which have to be mounted and logic-wired together.

The limit of single optical ROM capacity is not yet known. An array of 102,400-bit ROMS has been built and ¼ million bits/package seems within reach. The 100,000-bit production ROM is in a package 5½ in. in diameter and 12 in. long.

The 100,000-bit model costs about 4¢ a bit in quantities of 100 and 3¢ a bit in lots of 1,000. One cent a bit is predicted to be about two years away. In this type of memory, cost per bit continues to decrease with size. It does not level off as with other types of memories. Costs drop dramatically between 16,000 and 100,000 bits. Currently, 16,000-bit memories cost 10¢ a bit, but are expected to be lower within the near future. If you assume a 100,000-bit ROM costing $4,000 and add a 5-million-bit mask package at $2,500, the total cost per bit is only .13¢ with decoding and amplification. Initial deliveries have been slow, but Optical Memory Systems expects to provide 30-day delivery schedules by year end.

For further information, contact Optical Memory Systems, 1520 South Lyon St., Santa Ana, Calif. 92705. Circle 201 on Reader Service Card.
ALICE (Applicon’s Logic Simulator) can perform simulations ranging from a quick checkout to a detailed analysis of timing problems. With ALICE you can simulate circuits implemented in any form, from completely asynchronous designs to synchronous two and four phase MOS designs. Just describe your circuit to ALICE using manufacturers’ designations directly from your logic diagram. Then use the flexible simulation control commands to exercise your design and observe its behavior.

**ALICE** Network Description
- Convenient and flexible input
- Catalogs of standard logic families
- User defined building blocks
- Full editing capability
- Synchronous logic elements
- Independent rise and fall delays

**ALICE** Simulation Control Commands
- Periodic and nonperiodic input sequences
- Specify inputs and internal logic values at any time
- Flexible control over printing
- Observe any signals or functions of signals

**Additional Features**
- Three-valued simulation (0, 1 and undefined)
- Automatic spike and hazard detection
- Signal cross reference listings

**ALICE** is an interactive program that speaks your language. It’s as near as your Teletype. Write now for a brochure describing how ALICE can help you make the most of your design time.
Seven years ago we shook the relay world with the birth of the TO-5 (SPDT) relay. It was quite a breakthrough in the state of the art. Your demands for other configurations in the TO-5 transistor can lead to the introduction of magnetic latching and sensitive relays. In 1966, we performed another relay miracle by combining a transistor and a relay in the same TO-5 can. Would wonders never cease? We did it again in 1969 with what we fondly call our “Solid Citizen;” a series of solid state relays for industrial and military applications.

Our competition has increased, we know this, and further we welcome it; after all, isn’t imitation the sincerest form of flattery? We know that as long as there are unsolved switching problems we can’t afford to sit on our little cans and watch the world go by. We have other wonders up our sleeves and will let the world know when we’re ready.

No, sir, no easy chairs for us. We like it this way. We invite you to write or call and ask for any technical assistance regarding our growing family of little switching devices.
The EE Forefront is a graphical representation of the practical state of the art. You will find here the most advanced components and instruments in their class, classified by the parameter in which they excel.

**A word of caution**
Keep in mind the tradeoffs, since any parameter can be improved at the expense of others. If there is no figure-of-merit available, we either include other significant parameters of the same products, or we provide additional bar graphs for the same products.

Do not use these charts to specify. Get complete specifications first, directly from the manufacturers.
SEMICONDUCTORS

Silicon power transistors (n-p-n)

- **Power dissipation** (Watts)
  - Westinghouse 1441: 200, 350, 400, 600, 625
  - Delco DTS-425: 700, 750, 1200, 1400
  - Solitron 2N4866: 70 (120V), 80 (100V), 100
  - Solitron SDT-141: 150 (V_CEO=120V), 250 (V_CEO=120V)
  - Westinghouse 1401: 100, 200, 350, 400, 600

- **V_CEO-Volts**
  - Delco DTS-402: 500, 600, 625
  - Motorola MJE8401: 500, 600, 625

- **Collector current** (Amps)
  - Westinghouse 1441: 100, 200, 350, 400, 600
  - Delco DTS-802: 100, 200, 350, 400, 600
  - Solitron SDT-141: 150 (V_CEO=120V), 250 (V_CEO=120V)

Dual bipolar transistors

- **Frequency** (MHz)
  - Union Carbide UCX 2910: 800 (V_CEO=15V)
  - Motorola 2N3424: 400 (V_CEO=15V)

Thyristors

- **Forward current** (Amps)
  - National NL-C150: 500 (AIR COOLED), 1000 (WATER COOLED)
  - International Rectifier 7IRA90DSBO: 1200, 1400

- **Voltage rise** (dv/dt - V/μs)
  - National NL-F150: 475 (200V), 740 (1500V), 850 (1500V)

Microwave semiconductors (low noise)

- **Frequency** (MHz)
  - KMC K5008: 60 MHz
  - KMC K5002: 1.4 dB, 450 MHz
  - KMC KD5001: 2.0 dB, SILICON, 1 GHz
  - Texas Inst. TIXM 105: 3.0 dB, SILICON, 2.25 GHz
  - Philco-Ford L8202-C: 4.5 dB, 9.375 GHz

Microwave semiconductors (power)

- **Frequency** (GHz)
  - TRW TRW-PT 6635: 1.0 GHz
  - TRW2N517 8 PT6821: (500 W-CW TRANSISTOR)

Microwave multiplier diodes

- **Frequency** (GHz)
  - Philco L8504: 10, 500 MHz (10 W)
  - Philco L8503: 4.5, 3 W (6 W)
  - Philco L8513: 10, 1 W (1.2 W)

The Electronic Engineer • June 1970
Motorola presents MOS at its economical best – the new MC1142G 200-Bit Dynamic Shift Register. Cost conscious designs will benefit by the MC1142G’s “under 3c/bit” price tag ($5.25 in 1K-up quantities) and even less for volume production requirements.

Constructed with P-channel enhancement mode devices in a single monolithic structure, the MC1142G contains a push-pull buffer for higher drive capability. The output is delayed 200 bit times from the input.

FEATURES
- 1.0 mW/Bit Power Dissipation @ 1.0 MHz
- 10 kHz to 1.0 MHz Operating Frequency Range
- Diode Protection on All Inputs
- Output Interfaces Directly With MDTL and MTTL

Shift A Bit For Less

The MC1142G is recommended for delay line memories and sequential digital applications, utilizing a two-phase clock for minimum power dissipation. Check your local distributor today for “off-the-shelf” evaluation devices which are supplied in a compact low-profile, 8-leaded metal can. You’ll find it costs less to shift a bit with Motorola’s MC1142G.

For details circle No. 150
New MC9300/8300 “Complements” Broaden DTL/TTL Capabilities

Four new MC9300/8300 series complex functions are ready to serve as basic building blocks for systems utilizing any TTL family or DTL. The new devices are completely TTL/DTL compatible and are direct replacements (electrically and functionally) for older 9300/8300 devices.

As system building blocks, the new devices are really versatile. The MC9300/8300 4-bit universal shift register, for example, provides the shift right, shift left, serial-to-parallel, parallel-to-parallel, serial-to-parallel, and parallel-to-serial functions. It also comes with a master reset input that sets all outputs to the logic “0” state (regardless of other input states), a parallel enable input, and J and K inputs providing full input logic capability for serial data entry.

Particularly useful for arithmetic operations (addition, subtraction, multiplication) as well as parity generation and checking, the MC9304/8304 dual full adder contains two independent, high-speed, binary full adders, and provides complementary SUM outputs. Adder one has a CARRY output while adder two has a CARRY output plus both active high and active low inputs. This input choice offers greater flexibility and helps minimize system package count.

The MC9309/8309 dual 4-channel data selector is particularly useful for data routing and sampling applications and may be used to convert 4 bits of parallel data to serial data. The device selects data present on one of four input lines, according to logic states of the control inputs, and routes that information to the output.

Another data routing natural is the MC9312/8312 8-channel data selector which is useful for routing data from one of eight sources, such as a bank of memories, when the memory address is presented to the select inputs.

The MC9300, 9304, 9309 and 9312 (full temperature range versions) are available in the ceramic dual in-line package (L suffix). The MC8300, 8304, 8309 and 8312 (0 to +75°C devices) are supplied in both ceramic dual in-line and plastic dual in-line (P suffix) packages. 100-up prices are: MC9300L - $13.00; MC8300L - $6.50; MC8300P - $5.05; MC9304L - $15.00; MC8304L - $7.50; MC8304P - $5.80; MC9309L - $10.60; MC8309L - $5.30; MC8309P - $4.10; MC8312L - $10.60; MC8312L - $5.30; MC8312P - $4.10.

These new DTL/TTL “complements” are immediately available from your nearby Motorola distributor.

Counter And Shift Register Join 54/74 TTL Functions

Two new versatile complex functions — the MC5492/7492 divide-by-twelve counter and the MC5495/7495 4-bit universal shift register — have been added to Motorola’s expanding 54/74 TTL line.

The MC5492/7492 is designed to provide a variety of counting moduli with no external gating. Comprised of a divide-by-two section and a divide-by-six section, the sections can be used independently, or can be connected to perform the divide-by-twelve function. The device is especially useful in any application requiring a division by 12, 6, or 3 such as time or measurement recorders.

The MC5495/7495 can be used in many part reducing, performance improving applications. The device performs as a right-shift/left-shift register, or as a parallel in/parallel out, parallel in/serial out, serial in/parallel out, serial in/serial out storage register, depending on the logic level present at the mode control input. Other applications include use as a divide-by-N counter, a programmable frequency divider, a programmable burst generator, and a 4-bit full adder and subtractor.

The devices are available in ceramic dual in-line packages (suffix L) for use over the full temperature range and both ceramic and plastic (suffix P) dual in-line packages for 0 to +75°C applications. Check your local distributor for “off-the-shelf” units. Prices (100-up): MC7492 — $4.15; MC7495P — $4.85.
MOS Dual Static Shift Registers Twice As Fast

Forced to build your low-power system's static registers with bipolar flip-flops because available MOS can't keep up with the system clock?

Two new MOS devices from Motorola might just be the answer — they run at 2.0 MHz, twice the usual speed of a MOS static shift register.

Both the MC1160G dual 100-bit and the MC1161G dual 50-bit registers share these outstanding features:

- Independent input/output lines for both devices in a package — plus the specs permit independent or cascade operation.
- Buffered outputs directly drive TTL.
- Common power supply and clock lines to both devices in a package.
- Diode protection on all inputs.

With features like these, the two registers are ideal used for delay lines or circulating data storage. And their de operation holds your data without needing constant refreshment.

The MC1160G and MC1161G both come in a 10-pin metal can off-the-shelf for $17.50 and $9.00, respectively — 100-up.

For details circle No. 153

MCMOS "Power Saver" Circuits Make Debut

When your circuit requirements call for minimum power dissipation, high noise immunity, and operation over a wide variation of power supply voltages, you have a ready solution in Motorola's Complementary MOS.

Two newly available MCMOS circuits, MC2597G and MC2598G, exhibit quiescent power dissipations of 100 nW, noise immunity of 4.5V @ VDD = 10 Vdc, and will operate over power supply ranges of 5.0 to 15 Vdc. The MC2597G is a dual 2-input NAND gate and the MC2598G is a type D flip-flop with Direct Set and Direct Reset inputs, plus complementary outputs. As such, the MC2598G can be used as a one-bit shift register element, or as a type T flip-flop for counter and toggle applications.

Both devices are packaged in a compact, low profile, 10-leaded metal can. Obtain evaluation samples from your distributor at low, low 100-up prices of $1.50 for the MC2597G and $2.50 for MC2598G devices.

More MCMOS coming!

Shortly you'll be able to apply these additional "power savers" — the MC2501L Quad 2-input NOR gate, MC2502L Dual 4-input NOR gate, and the MC2503L Dual Type D flip-flop. All three devices feature low power dissipation (100 nW type), will operate over input voltages from 4.5V to 20 Vdc, and offer high fanouts (>50). Check with your local Motorola representative for pricing and delivery.

For details circle No. 154

MTTL Complex Function Line Gains Nine New Members

Introducing nine new "cost cutting" complex functions for greater design flexibility. Leading off is the MC4002 dual data distributor, a very useful device for routing digital data from a single location to one of several registers or locations for further processing.

Where versatility is a prime consideration check the MC4023 4-bit universal counter. It's a natural for use in frequency synthesizers, digital displays and A/D converters! You can connect the MC4023 to divide by any number between 2 and 12 (except 7 and 11). Other counters are limited in counting — so consider the MC4023's counting capability of 2, 3, 4, 5, 6, 8, 9, 10, or 12, a definite advantage — especially at 30 MHz! For additional utility, reset inputs are provided on each of the four flip-flops in the counter to allow direct setting of the Q outputs to zero any time during the counting cycle.

The MC4026/27 full adders are designed for standard serial and ripple-carry parallel adder systems while the MC4028/29/30/31 are a family of fast adders for parallel look-ahead carry adder applications where high-speed addition is required. And it's simple to build 8-stage look-ahead carry subsystems when you combine the fast adders with Motorola's new MC4032 carry decoder.

For details circle No. 155
Dual OP AMP Doubles Savings In Both Space And Cost

Suppose you have a dual design challenge...one that incorporates both limited space and limited budget—in addition to the usual high performance specifications.

Sounds almost insurmountable, particularly when you also want to utilize the standard benefits of monolithic integrated circuits!

Not any more—thanks to the new MC1558G dual operational amplifier.

Here, essentially, are two industry-standard MC1741 op amps on one chip and in one hermetic package. Yet, the cost for this dual is very little more than the cost of one MC1741.

In addition to these space-saving, money-saving virtues, the MC1558 also offers all of the high-performance benefits of the MC1741:
- Internal frequency compensation.
- Short circuit protection.

For details circle No. 156

There's Only One Truly Flexible IC Regulator For Lab Power Supplies

If you need a laboratory power supply (and, who doesn't) think about this:

There's only ONE monolithic IC voltage regulator that offers a constant current source!

There's only ONE IC regulator where voltage is adjustable to zero (or, up to hundreds of volts)!

There's only ONE that provides automatic cross-over from voltage to current regulation! (See illustration).

For sheer versatility, the MC1566 is one of the most outstanding developments since the op amp. You can, for example, use the MC1566 in circuits for measuring a wide variety of circuit parameters, to perform remote sensing, or in a number of other applications.

As a power supply regulator, the MC1566 provides complete control over both voltage and current. With the MC1566 in charge, your power supply changes from constant voltage to constant current smoothly, automatically and almost instantly. And, the crossover point is pre-determined and programmable. In short using the MC1566, it's possible to regulate voltage from zero up to a value limited only by the breakdown voltage of the series-pass transistor at the power supply output.

As a result, you can use just one IC for all of your regulation jobs from millivolt levels to hundreds-of-volts!

Some of the outstanding specs of the MC1566 and its 0 to 75°C mate, MC1466 are:
- Excellent Line Voltage Regulation - 0.01% +1.0 mV
- Excellent Load Voltage Regulation - 0.01% +1.0 mV
- Excellent Current Regulation - 0.01% +1.0 mV
- Short Circuit Protection

Both types are available now in the 14-pin dual in-line ceramic package.

For details circle No. 157

Latest MECL II Quad Latch Eliminates Display Tube Flickering

The MC1070/1270 quad latch features both clocked inputs and gated outputs. Its applications include use as a buffer register for temporary storage of binary information between arithmetic processing units. A complete data sheet gives information outlining a storage technique using the quad latch to eliminate display tube flickering when working at input counting rates above the response time of the display device.

The MC1070 (0 to 75°C version) is packaged in both flat pack (F suffix) and 14-lead plastic dual in-line cases (P suffix). MC1270 is supplied in a 14-lead ceramic dual in-line package (suffix L). 100-up prices are: MC1070F - $9.50; MC1070P - $6.50; MC1270L - $7.70. Your local distributor has evaluation units "on the shelf."

For details circle No. 158
Control Full-Wave Power To 6000W With MAC35/36 Triacs

The new MAC35/36 triac team of "huskies" are straining in their traces, ready to pull a full, 25 amperes (rms) load in your demanding industrial/military control job. If it's economical, stepless 60 cycle power control in motors, heaters, welding gear or switching systems you need, these rugged types will easily handle 6,000 watts (240 V) in your circuits plus provide other advantages in ac designs, like symmetrical gating and holding.

The tough performers in this team were bred specially for their task. Just look at their pedigree: a low 1.5 V (max) on-state voltage at 35 A, uniform characteristics through all-diffused junctions, 225 A peak one-cycle surge current protection, and 4 mA (max) peak blocking current at VRM.

Turn-on time is a scant 1.0 μs, too, assuring efficient switching in all uses.

Even when cost is the prime consideration, the MAC35 series ensures optimum balance between price and continuous control performance - prices start as low as $1.70, 100-up!

Evaluation units of the ½" flangeless pressfit and 9/16" stud types are available from your distributor. Send for information on your triac "husky" today and we'll mail an Application Note, AN466, "Circuit Applications For the MAC35/36 Triacs" and a data sheet that gives both average and rms current derating curves.

Power Darlington transistors!

First of their kind available in the industry, the MJ900/1000 series promise to revolutionize conventional, silicon power circuits requiring separate, "one-for-one" driver and output transistors and associated emitter-base resistors.

Your power operational amplifiers, for example, such as relay or solenoid drivers, power supply regulators, servo amplifiers and series pass regulators can now be designed around one, discrete device containing driver, output and resistors - all on one chip in one TO-3 power package. You can drive the new Darlington power levels derived from integrated circuit logic gates and go from milliamperes to amperes directly, compatibly, easily.

You can cut your costs substantially by having only one device to install and heat sink. Reliability too is heightened, because of the lessening of component needs and variations.

And, with both NPN and PNP types available, you can build positive and negative-based systems. Or you can use them in complementary symmetry applications.

In addition to the new MJ900/1000 metal series, Thermopad plastic types will soon be introduced offering the designer even further economies. Introduce your circuits to today's world of silicon power Darlington systems...write for complete data!

New Plastic High Voltage Hot-Carrier Diodes Are Versatile, Rugged, And Inexpensive

MBD501 and MBD701, two new Motorola high-voltage silicon hot-carrier detector and switching diodes, offer designers outstanding qualifications as RF detectors in video and radar applications, and as ultra high-speed switches in digital logic applications.

All the typical cost advantages of Motorola's high volume plastic production capability are here, too. Low initial prices half those of competitive glass units for production run quantities, match manufacturing cost savings made possible by the package benefits. The TO-92 configuration is ideal for use in printed circuit board applications and lends ease to automatic insertion procedures.

The ruggedness of Motorola's void-free plastic package perfectly complements the reliable wire-bond construction of these devices to eliminate the fragility of "C" bend, "S" bend, and point contact diodes.

Key specs include low capacitance - 1.0 pF (max) @ VR = 20 V - and extremely low minority carrier lifetime of 100 ps (max) @ IR = 5.0 mA. VBR is 50 V for the MBD501 and 70 V for the MBD701.
HIGHER POWER, P-I-N SWITCHING DIODES
— Enhance Phased Array Radar Designs

The high peak and average power handling capability of two new Motorola high-voltage P-I-N diodes provides a potential boost in range for phased array radar systems. These MPN3208 and MPN3209 800/900 Volt P-I-N diodes are primarily intended for high-power phase-shifter applications at frequencies through S-band, but are readily adaptable to other RF power control jobs, too.

Because these devices utilize a silicon-dioxide passivated junction, they exhibit excellent stability and a very low reverse leakage of only 100 nA @ f = 500 V. Thermal resistance is also low at just 4.0°C/W (max).

Their low forward series resistance of 0.42 (max) @ f = 150 nA is a significant factor in securing minimal circuit losses. Both the MPN3208 and the MPN3209 are packaged in a stud-based ceramic pill case designed to mount readily in the standard 8/32 tapped hole.

These state-of-the-art P-I-N diodes are available off-the-shelf today.

For a data sheet circle 162

PLASTIC SILICON NPN CORE DRIVER
— Gives Dollars Switching Performance For Pennies Admission

Availability of Motorola's new 2N5845 NPN Silicon Annular transistor is news, good news, for designers with core driver or medium-current switching applications. Here is a device with just about everything. 40V (min) BVCEO @ 10 mA — high f2 — low saturation voltage — fast switching — rugged package — and a low, low cost indicated by the 1000-up price tag of only 44¢.

All this spells real value, and there's more. Even though the 2N2845 is supplied in the plastic TO-92 package, the chip is mounted on a copper lead frame that ups the total device dissipation to a full 500 mW@TA = 25°C. And, lead-forming to either the TO-18 or the TO-5 configuration is available, too.

When we say fast switching, we're talking about 40 ns ton and 60 ns toff at VCC = 40V and IC = 500 mA. VCEO = 0.6V (max) @ IC = 500 mA and the current-gain — bandwidth product is 200 MHz (min) @ 50 mA. The warehouse has been stocked with ample quantities to assure excellent delivery.

For a data sheet circle 162

THREE NEW MHIL "NOISE REJECTORS"
— Ease Design of Industrial Environment Circuity

Three new off-the-shelf members of Motorola's High Threshold Logic family, the MC679 dual lamp/relay driver, and the MC677 and MC678 hex inverters are ready to shrug off up to 6 V of electrical noise for designers of high-noise environment equipment.

The output transistors of the MC679 can operate 28 volt lamps or supply up to 150 mA. It's a natural for driving register clock lines, capacitive loads, or discrete components.

Strobe inputs allow one MC677 to replace 11/2 quad two-input NAND gate packages in many applications.

Its lack of output resistors permits the MC678 to drive low-current lamps, interface with discrete components or implement the "Implied AND" (wired-collector) function with minimum power dissipation.

In 1-k up quantities: MC677L/MC677P — $1.95/1.33; MC678L/MC678P — $1.87/1.27; MC679L/MC679P — $2.36/1.75.

For a data sheet circle 164

NEW PROGRAMMABLE UJT DEVICES
— Let You Tailor Their Specs For Your Circuits

Simply by varying the external resistors, you can "program" your own UJT specs into sensing, pulsing, timing, thyristor triggering and oscillator circuits with the new MPU131-133 series of plastic Unibloc UJT's.

Ras, eta, f2 and f3 device characteristics can be varied by changing resistor values making the part ideal for multi-socket, high volume applications.

The MPU131 series is also ideal for battery-powered and other low-voltage circuits. And, base 2 of the unijunctions may be used as a low-impedance output.

The MPU133 units are numbers 18, 19 and 20 in Motorola's complete UJT line and numbers 7, 8, and 9 offered in the ever-popular Unibloc plastic package. All are economical and all are available now.

For a data sheet circle 165

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**NEW PRODUCT BRIEFS**

**HIGH POWER, P-I-N SWITCHING DIODES**

— Enhance Phased Array Radar Designs

**PLASTIC SILICON NPN CORE DRIVER**

— Gives Dollars Switching Performance For Pennies Admission

**THREE NEW MHIL "NOISE REJECTORS"**

— Ease Design of Industrial Environment Circuity

**NEW PROGRAMMABLE UJT DEVICES**

— Let You Tailor Their Specs For Your Circuits
Supplements Ready For The Semiconductor And The Microelectronics Data Books

Supplement 2 to the 4th edition of the Semiconductor Data Book and the first supplement to the 2nd edition of the Microelectronics Data Book are fresh off the press and ready to bring your data book set completely up to date. If you’re a data book owner and have subscribed to the updating service of either book, you’ll automatically receive your supplement for that book, or books. If you are not a book owner and would like to obtain either or both of the data books use the handy coupon. You may also order an updating subscription for either or both books (you receive the first two supplements to the corresponding book) or one or more of the supplements.

Use special coupon in this issue to order

New Master Selection Guide And Price List Available

The June/July, 1970 edition of the Motorola Master Selection Guide and Price List is ready. Compiled to make it easy for you to keep your files up to date, the new publication conveniently combines in one publication all the selector guides and price lists for every product line offered by Motorola. The more than 100 pages in this edition cover all 17 major semiconductor categories and include a quick reference to new devices and price changes plus policies and ordering information – all in addition to the current prices of over 14,000 Motorola semiconductor devices.

For a copy circle No. 166
NEW LITERATURE BRIEFS

The Industry’s Fullest Line
Offered In Motorola’s New
1970 Catalog – Over 14,000 Items

Like a gracefully arching rainbow, the Motorola 1970 Condensed Catalog covers the solid-state world with a full, colorful spectrum of Motorola semiconductors. The new 104 page book bulges with the major electrical characteristics of nearly 14,500 items, altogether 20 pages and about 2,400 devices greater than the 1969 version. Representatives of nearly every kind of solid state device manufactured are offered.

To make it simpler to use, the new catalog is organized into three sections: Section I is an alpha-numerical index of device type numbers providing quick access to the appropriate table and page numbers in the catalog proper. Section II, the main listing, divides all components into natural categories and tabulates major electrical specifications so that easy component comparison or preselection can be made. Section III presents an alpha-numerical listing of military type semiconductors and also soon-to-be available devices. In addition to these sections, the outline dimensions for all packages in which any Motorola device is supplied are shown.

Highlights of additions to the new edition:
- New zener diode families, including low voltage avalanche zener regulator diodes and 500 mW Unibloc silicon-oxide passivated zener regulator diodes.
- Hot carrier power rectifier — 50 amperes.
- Silicon bidirectional triacs up to 25 amperes.
- Programmable unijunction transistor family.
- Silicon unidirectional and bidirectional switch family.
- New microwave devices including P-I-N switching diodes and hot-carrier diodes.
- Six new PNP silicon RF power transistors.
- New optoelectronic devices including a light-emitting diode.
- New family of dielectrically isolated MDTL integrated circuits.
- Nine additions to the MOS integrated circuit line including MCMOS devices.
- 31 new MTTL complex functions.
- 75 new linear integrated circuits featuring state-of-the-art introductions such as the MC1596, balanced modulator/demodulator, the MC1536 high voltage, internally compensated operational amplifier, the MC1566 laboratory specification voltage regulator, the MC1546 four-channel plated wire sense amplifier plus the industry’s only four quadrant multiplier, the MC1595. For a copy see your franchised Motorola distributor.

Motorola Semiconductor Products Inc., P. O. Box 20924, Phoenix, Arizona 85036

The circuitry shown external to Motorola products is for illustrative purposes only, and Motorola does not assume any responsibility for its use or warrant its performance or that it is free from patent infringement.

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NOTE: If Motorola’s Literature Request Coupon is missing, use magazine’s standard Reader Service Card.
There are seminars and seminars
While some engineers are improving their professional skills through developmental seminars, others are attending quite another type of program. The American Institute of Aeronautics and Astronautics (AIAA), in cooperation with several job-counseling groups, recently sponsored its first workshop for job-hunters in Los Angeles. (Others will be held throughout the country.) The first of three weekly meetings was attended by 150 pre-registered applicants; 200 had to be turned away at the door; and the AIAA backlog is now over 500.

The workshop does not function as an employment agency. Instead, it teaches effective job-hunting. The first session is devoted to orientation and guidance, the second to resumes and the third to interviewing techniques and salary negotiations.

Seven aerospace engineers were in the group to which I was assigned. Their situations found them out of work or within a few days of a layoff. They asked hard questions such as "What can I do right now—today?" and "How can you find me a job when there are no jobs?"

Space does not permit complete coverage of even one discussion, but some of the interesting tactics presented were:
• First, answer the question "What am I?" by listing your accomplishments.
• Specifically tailor those accomplishments for each company you approach.
• After an interview, show an interest. Write a thank you note; inquire about your status—you never know how close you are to being hired.

The AIAA workshops in Los Angeles are swamped with applicants, but the non-profit group they are patterned after, Thursday 13, can still handle prospective job seekers. Those outside Los Angeles can buy a package that contains their manual "Finding Your Place in Business." Kaye Kiddoo, Manpower Administrator for Lockheed Corp., thinks "...it's the best thing of its kind I have ever seen. It presents a real strategy for job-hunting." The package can be obtained for $5.00 from Thursday 13, 3435 Wilshire Blvd., Los Angeles, Calif.
Film-Mets? Wirewounds? Or Cermets?

What our extra choice means to you.

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It ends circuit design compromise.

Because now you can get the perfect match between design needs and trimmer performance.

Suppose you need infinite resolution, lowest noise characteristics and maximum contact setability. Then Film-Met™ would be your best choice.

But if it's infinite resolution and the widest resistance ranges you're after, then cermets would be best.

And of course, good old wirewounds still reign supreme in lowest temperature coefficient of resistance and lowest contact resistance variation.

Only Amphenol has all three types—and in all the popular military and commercial sizes.

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So send today for your free catalog. Or call your nearest Amphenol distributor. Amphenol Controls Division, Janesville, Wisconsin 53545.
The SSL Explosion!

Solid State Lamp technology is booming.
GE offers you the most complete data available today.

Everything about solid state lamps — technology, applications, product variety, prices — is changing almost day to day. How to keep up? Here's how, with the most complete up-to-the-minute information available on SSL's (previously known as light emitting diodes). Clip the coupon and start catching up today.

With each order placed now for either of the SSL Manuals, you also will get free all new SSL application bulletins issued during 1970.

1. GE's Complete Two-Part SSL Manual: Covers theory, characteristic and applications, with 108 pages of diagrams, graphs and circuit applications. The most complete source of new and revised SSL data available anywhere. (Price $2.00)

2. GE SSL Application Manual Only: 48 pages, 59 SSL circuit and application ideas, 22 of which have never been published before. (Price $1.00)

3. Infrared SSL Bulletins: Fully describes GE's 9 gallium arsenide emitters. Shows mechanical and electrical specifications, including characteristic curves. For card and tape readers, photoelectric systems, optoelectronics devices. (Free)

4. Visible SSL Bulletins: Has complete mechanical and electrical data on GE's duo of SSL indicators ... the SSL 3 green. And the plastic encapsulated SSL 22 red, the most visible red SSL available today. (Free)

5. Photon Coupler Bulletins: For electrical isolation and high speed switching. The new PC4-73 gallium arsenide SSL with a NPN planar silicon photo-darlington amplifier, the first of its kind, has the highest transfer ratio (125%) of any coupler on the market today. And the PC15-26, a gallium arsenide SSL coupler with a NPN planar silicon photo-transistor. Both isolate up to 2500 volts. (Free)

Check information you need and mail to: General Electric Company, Miniature Lamp Department, #382-EE, Nela Park, Cleveland, Ohio 44112.

Name ____________________________

Company ________________________

Address __________________________

City __________________ State ______ Zip ______

GENERAL ELECTRIC

Circle 17 on Inquiry Card

Bay Soundings

There’s been a lot of noise in the hybrid industry of late. And most of it has to do with the possibility of a big new market, that of hybrid circuits with beam-leaded components.

There are two good reasons for the great interest in hybrids with beam-leaded devices versus chip-and-wire types. Chips with beam leads are passivated and hermetically-sealed with a silicon-nitride coating. In addition, you can lay down all the leads of a beamed component at once, rather than sequentially. Also, there already exists automatic passivation equipment, and machines that can position beamed components to within 0.1 mil. Manufacturers argue that hybrids with beam-leaded chips are not yet widely enough available to take a chance on a new manufacturing operation. Furthermore, there is certain reticence among those hybrid manufacturers who already have large investments in chip-and-wire bonders, trained operators, and so forth, to change their lines.

Raytheon Semiconductor is laying it on the line and announcing that it is in the hybrid business for beam-leaded components. The Mountain View, California firm will build the circuits on a custom basis. It has taken aim at aerospace and medical applications, which have the hi-rel, compact, circuit requirements that are a natural challenge for these hybrids.

Raytheon Semiconductor's reasoning and hopes for success in the beam-leaded field are based on these facts:

• It is already known as a major supplier of beam-leaded semiconductor components, and can also build beam-leaded passive components to complete the circuit.

• The technology of laying down beams is relatively simple; much of the work has, in effect, been done by the bonder manufacturers.

• The Semiconductor Division has not previously committed capital to chip-and-wire products on a price basis.

• No other hybrid house is building hybrids with beam-lead devices in volume for the open market.

Based on its field inputs, Raytheon Semiconductor expects a million-dollar market this year mainly in low power, low voltage, highly stable linear circuits. And if Raytheon's entry into the hybrid field with beam-lead devices turns out to be the industry's long-awaited catalyst, next year's market size is anybody's guess.

Sheldon Feldman

Western Editor—San Francisco
Need high stability and low noise in trimming your circuitry?

The CTS Answer Man offers two new Cermet Rectilinear Trimmers

**CTS Series 190 and 195 trimmers** give you what you need: high stability and low noise. Settability is unusually easy—better than ±0.025%. Noise is very low—on the average, ±0.5%. Moreover, there's maximum stability in resistance after setting—no matter how severe the environment. Choice of 3 terminal configurations in each series. Price? Delivery? Highly satisfactory.

The CTS Answer Man is your man at CTS. He's more than a salesman—he'll quarterback your product requirement through the multi-resources of CTS. At his fingertips: broad production facilities, the latest technologies, plus 10 years of Cermet product experience. You can bet he'll come up with an answer every bit as good as our trimmers.

Trimmers. Potentiometers. Selector switches. Crystal products. Thick-film hybrid circuits. Cermet resistor modules. Loudspeakers. CTS makes them all in 10 U.S. and 8 foreign plants. And the CTS Answer Man stands ready to fit them to your application. To learn more, write:

**CTS Corporation**

Elkhart, Indiana
TI's quiet revolution in TTL
3ns at 20mW.

A new technology is born with TI's Schottky-clamped 54/74 TTL.

Until now, speeds below 5ns could only be achieved with current mode (unsaturated ECL-type) technology.

Now, TI has built integrated Schottky-barrier diode clamped transistors into its popular Series 54/74 integrated circuits. Our new 54S/74S family combines the high speed of unsaturated logic and the low power of saturated TTL logic. The best speed/power combination yet—and priced below competitive ECL logic families.

You gain these advantages, compared to conventional TTL integrated circuit technology:

- Typical gate propagation delay: 3ns.
- Power dissipation: 20mW per NAND gate at 50% duty cycle.
- 100 MHz typical flip-flop clock input frequencies.
- Smaller device geometries reduce internal capacitance—and increase speed.
- Schottky-barrier diode input clamps provide fast clamping protection.
- Active pulldown network squares transfer curves and raises logical 1' output level.

And you also gain these advantages, compared to current mode logic technology:

- Lower power dissipation.
- Better noise immunity. Typical d-c noise margins—more than 1V.
- Conventional PC boards may be used due to smaller line reflections with unterminated lines.
- Direct interface with all popular TTL and DTL families—same 5V power supplies (critical regulation not required), same logic functions, same packaging.

**Broad applications.** Series 54S/74S Schottky TTL circuits are ideal for applications in all high-speed digital systems:

- Computer central processor units.
- Peripheral controls.
- Digital test and measurement equipment.
- Digital communications systems.

Now available in plastic dual-inline packages are the SN74S00N—Quadruple 2-input positive NAND gates. The SN74S20N—Dual 4-input positive NAND gates. And the SN74S112N—Dual J-K negative edge triggered flip-flops (separate preset, clear and clock).

More are coming in 1970. TI is developing 13 circuits in the revolutionary 54S/74S series, including other standard TTL gates (NANDs, AND, HEX inverter, AND-OR-INVERT), dual J-K and D flip-flops, as well as MSI counters and shift registers. Ceramic DIPs and flat packs will be available soon.

For more information on the most significant TTL advance in four years, get our new Bulletin CB-118. Circle 175 on the Reader Service Card or write Texas Instruments Incorporated, P.O. Box 5012, MS 308, Dallas, Texas 75222. Or call your nearest authorized TI Distributor.

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*Texas Instruments has patented this technique in U.S. Patent number 3,463,975 titled "Unitary Semiconductor High Speed Switching Device Utilizing a Barrier Diode" issued August 26, 1969 (originally filed in 1964).*
Next time you spec a solenoid, odds are 61,034 to 1 that Guardian can provide the one that will do the job. Because we've got that many standards...solenoids in every imaginable shape and size to meet virtually any electro-mechanical requirement. AC or DC. Hefty 50 pound pull or a fraction of an ounce. Intermittent or continuous duty. Pull or push. Laminated, C-frame, box-frame or tubular. In 25 basic designs and 61 thousand variations. Not enough? Then we'll custom engineer a solenoid to fit your specialized application. (And you didn't know there was a Guardian Angel watching over engineers!)

NEW 44-PAGE GUARDIAN SOLENOID CATALOG is yours for the asking. Write for Bulletin G-3.

TALK TO YOUR GUARDIAN ANGEL AT THE WESCON SHOW

GUARDIAN® ELECTRIC MANUFACTURING COMPANY
1550 West Carroll Avenue, Chicago, Illinois 60607

Circle 19 on Inquiry Card

Your Guardian Angel stacks the odds in your favor (61,034 to 1)
SPEAK UP

Electrostatic charges in test chambers

Sir:
We have encountered a situation which might have significance throughout the military and aerospace electronics industry.

Potential overloading, permanent dielectric damage and/or false switching may be induced by build-up of large electrostatic field charges within environmental test chambers. These charge build-ups are generated by CO₂ gas discharge used for rapid cooling. MOS (and MOS-FETs) are most susceptible, due to the combined high impedance and relatively low dielectric strength at the “gate” of these devices.

We wonder if any of your readers have had similar experience and would appreciate letters relating background for and/or against the “damage” concept and also how they avoid the damage or meet the 5°C/min. rate of temperature decrease required by paragraph 5.3.1 of MIL-STD-781B (AGREE testing).

Norman W. VanDerstine
Reliability Engineering
General Dynamics
Electronics Division
1400 N. Goodman St.
Rochester, N.Y. 14601

EDITOR’S NOTE: Most manufacturers of MOSFETs protect against buildup of electrostatic charges by diffusing a zener diode across the gate, but this solution lowers the input impedance of the FET. Also, MOSFETs usually come packaged in conductive material, to avoid such buildup. In addition, they must be handled with great care to keep the leads shorted until the FET is connected in the circuit. If any readers can contribute some additional experience on the kind of environment Mr. VanDerstine describes, please write to him, or to The Electronic Engineer.

Engineering societies must work for engineers

Sir:
The report on the Cleveland IEEE meeting [Is anybody out there?, The Electronic Engineer, April 1970, pp. 42-45], conveyed the feeling of disappointment such sessions generally produce. There is no reason to expect useful action by the IEEE on subjects of interest to the working engineer, for the simple reason that it is controlled by and for the academic and research community. That this is true should be clear to anyone reading the Proceedings or the vast majority of the Transactions, or attempting to submit papers for publication.

This is not a criticism of the IEEE alone. The NSPE, ASME and most similar organizations are subject to the same malady. The academic community has tenure, prestige, time for professional societies, no restrictions on ability to publish—how can the working engineer compete?

I ask the IEEE to move towards representing the interests of the majority of its members. The first step should be to take over the “fringe benefit” functions of the private employer for its members. This should include life, medical and disability insurance, and pensions. The employer’s share of present plans, and the engineer’s payroll deductions should be paid to the Institute. Since such a large portion of present pension plans are forfeited by mobile engineers, there may be enough excess money, at present rates, to pay for the costs of administration. If not, I am sure that we would all be willing to pay more for a fringe package that would be portable, continuous between jobs, and adequate.

The next step could be a licensing function. The vast majority of engineers are not registered Professional Engineers, partly because their fields of competence did not exist at the time their State license exam was composed. While designation as “Engineer” by the IEEE may have no legal standing, it could become more important over a period of time.

Many other possible functions suggest themselves. However, what is needed now is a commitment. Is the IEEE to retreat from the problems of the working engineer and become a mere information service (mostly unintelligible), or will it start to face the real world?

Jerome V. White
IEEE Membership No. 125203
Program Manager
Systems Engineering Division
Sanders Associates, Inc.
Nashua, N.H. Hampshire

Don’t bring back the transistor radio

Sir:
I fully subscribe to the implications of the editorial in the December 1969 issue of The Electronic Engineer.

Leon W. Zelby
Director
School of Electrical Engineering
College of Engineering
The University of Oklahoma

The Electronic Engineer • June 1970
This column welcomes new companies or new divisions in the electronics industry.

Conversion modules for computers

The first snow of this past winter brought to New England not only ski enthusiasts, but a novice company as well. Datel Systems Corp., located at 943 Turnpike St., Canton, Mass., began plowing a trail for itself in the electronics industry in November, 1969. Formed to make ultraminiature A/D and D/A conversion modules, subsystems, and systems for the computer display area, data acquisition systems, and data transmission systems, its founders have future plans to produce A/D and D/A converter interface systems for minicomputers.

The four principals of the firm have been employed in the A/D and D/A converter field since the mid 1950's. Two of the founders, Nicholas Tagaris, president, and Arthur Pappas, treasurer, previously served as chief engineer and senior engineer, respectively, for Analog Devices, Inc. Datel has been financed by Private Venture Capital, an investment firm in Boston.

The company's products consist of three lines. One line, A/D converters, designated the ABC-E series, employs dual slope integration and resolutions of 8, 10 to 12 bits. They are available four weeks after ordering and range in price from $119 to $140. A second line is Datel's Successive Approximation Conversion Method which is subdivided into three families—ADC/L, ADC/M, and ADC/H, each one available at 8, 10 or 12 bits. The ADC/L employs a 25-kHz conversion rate, the ADC/M a 250-kHz conversion rate, and the ADC/H a 2.5-MHz conversion rate. Prices for the three types range from $225 to $990 and they are available two weeks after ordering.

Third, the new company offers a line of D/A converters consisting of four groups. The DAC-HB, priced from $69 to $119, employs a resolution of 8, 10 or 12 bits. The DAC-I series, employing the same resolution as the DAC-HB, features a fast settling time—150 ns, and is available for $115 to $165. The DAC-V, featuring an input storage register, sells for $129 to $189. The DAC-H series, priced at $149 to $169, offers a 25-ns settling time.

In addition to the above, Datel also manufactures a product that, to their knowledge, is the smallest dc isolated power supply available anywhere. Its dimensions are 1 x 2 x .4 in. producing 5 V at 1 A or ± 15 V at 150 mA. Prices range from $59 to $89.

When asked about unique features of his firm's products, a spokesman for Datel responded "All of our converters are in an encapsulated modular package which can be mounted on pc boards. The converters are .4 in. high, versus our competition's, which are at least .6 in. high. You might say the key features of Datel's products are packing density, price (ours is lower because our fabrication techniques are different from our competition), and performance (equal or better than our..."
We use a thick-film fabrication technique which means that we replace discrete resistors with thick-film ladder networks. This reduces assembly time and cost."

**Rf power**

In December of 1969 three men purchased one of the first lines in the rf power transistor business from ITT Semiconductor. ITT was on the verge of dropping the line, but these men caught it in time and the result was today’s Kertron Inc., located in Riviera Beach, Florida.

Bill Kearns, former general manager at Solitron, led the group into the venture. Those joining with him were George Reiland, former plant manager at Solitron, and Francis T. Ryan, local attorney and former part owner of the past Minneapolis Lakers (these men are versatile!). Most of the engineering staff came directly from ITT at the time the purchase was made.

Kertron specializes in high power devices. Their primary product line spans a frequency range of 2 MHz to 1 GHz with powers from 1 to 100 W. A secondary line opening up for the new company includes low frequency power devices of up to 300 V breakdown and with currents up to 100 A. High or low power, all are discrete devices.

When the line was about to be dropped by ITT, what did these men sense that would make its purchase worthwhile? "Product orientation," says Jim Benjamin, engineering manager for the new company. "With concentration on the technical market and on customer needs rather than a high volume market, there can be great accomplishments (and profits!) in the field. We are involved in the custom business in that we specify out of standard production runs the products best suited to our customers’ needs."

The company presently features several products that no other company can boast of. These include the 3TE610, a 100-W, 150-MHz device operating from a 40-V supply, and the 3TE611, a 75-W, 150-MHz device operating from a 28-V supply. The first device has been used in military and aircraft communications projects, and the second is said to be the highest power device operating from a 28-V power supply.

New products are on the way—ten to twenty are expected to be announced within the next four to six months. Many are in the high power area, further increasing the new company’s power frequency capabilities. But that’s not all that’s new to Kertron—they just opened a 20,000 sq. ft. facility at 7516 Central Industrial Drive where the growing company (now over 70 people) will have access to new manufacturing equipment.

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**These New standardized power modules were designed the hard way...**

The advanced engineering and unequalled reliability you’ll find in North’s new standard power modules didn’t just happen... these were developed through 37 years’ experience in custom power systems design. Yes, North went the hard way to bring you the exceptional quality and versatility of its new standard power line... but it was for good reason... to make your choice of standard power supplies easier.

Send for North’s new Standardized Power Catalog and start buying your custom power and standard power from one great source... NORTH.

Call 419/468-8244 (or TWX 419/464-4860) for immediate service. Attention Product Mgr., Standard Power Equipment.

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through 37 years of custom power engineering and problem solving.

A Subsidiary of UNITED UTILITIES, INCORPORATED

Circle 21 on Inquiry Card

Circle 499 on Inquiry Card

Circle 500 on Inquiry Card
To put a priority encoder on a single chip, Fairchild introduces the first MSI 8-input priority encoder ever put in a single package. In fact, it's the first encoder of any kind ever put in a single package.

The new 9318 accepts data from eight active low inputs, selects the most significant input signal, and provides a binary representation of it on the three outputs. Input and output enables permit encoders to be cascaded without using additional components. This allows priority encoding of any number of input signals. Also, a group signal output is provided to show when any input is active.

In the tradition of Fairchild’s MSI family, the 9318 is a highly versatile, highly reliable device. It can be used in code conversions, multi-channel D/A conversions, and decimal to BCD conversions. It will find application in priority interrupt systems, associative memories and keyboard encoders as well as a number of control applications.

The 9318 is TTL and DTL compatible and has a typical power dissipation of 200mW. It comes in DIP and Flatpak in both military and industrial temperature ranges.

To order the 9318, call your Fairchild distributor and ask for:

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<th>PART NUMBER</th>
<th>PACKAGE</th>
<th>TEMPERATURE RANGE</th>
<th>PRICE (1-24)</th>
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<td>U7B931859X</td>
<td>DIP</td>
<td>0°C to +75°C</td>
<td>$15.35</td>
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you have to get serious about MSI family planning.

We put together a family plan by taking systems apart. All kinds of digital systems. Thousands of them.

First we looked for functional categories. We found them. Time after time, in a clear and recurrent pattern, seven basic categories popped up: Registers. Decoders and demultiplexers. Counters. Multiplexers. Encoders. Operators. Latches.

Inside each of the seven categories, we sifted by application. We wanted to design the minimum number of devices that could do the maximum number of things. That’s why, for example, Fairchild MSI registers can be used in storage, in shifting, in counting and in conversion applications. And you’ll find this sort of versatility throughout our entire MSI line.

Finally, we studied ancillary logic requirements and packed, wherever possible, our MSI devices with input and output decoding, buffering and complementing functions. That’s why Fairchild MSI reduces—in many cases eliminates—the need for additional logic packages.

HOW ONE IC PRODUCER INCREASED YIELD 17% AND NOW SAVES OVER $50,000 IN YEARLY PRODUCTION COSTS

**PROBLEM:** A major producer of custom tapped resistor arrays found the yield of salable devices dropping drastically. Base diffusions had intolerably short lifetimes as well as low resistivity after furnace diffusion at 1000°C. The only visible clue was microscopic deposits on the vertical sides of base diffusion windows. The firm tried every correcting action in their book, but nothing worked. Then they turned to McCrone Associates.

**ANALYSIS:** Computerized electron microprobe analysis determined that the deposits were iron and tin—the ash from photoresist.

Solve your IC production problems. Phone McCrone Associates... the laboratory's laboratory... for increased IC yield through contamination identification and source location... contamination cure and prevention. Ask about our facilities monitoring program.

**CALENDAR**

**JUNE**

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**JULY**

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**'70 Conference Highlights**

WESCON — Western Electronic Show and Convention, Aug. 25-28; Los Angeles, Calif.


NEREM—Northeast Electronics Research Engineering Meeting, Nov. 4-6; Boston, Mass.

**Call for Papers**

Nov. 4-6: NEREM, Sheraton Boston Hotel and the War Memorial Auditorium, Boston, Mass. Submit three copies of a 35-40 word abstract and three copies of a 600-1000 word condensed version of the paper. (Mail to Program Chairmen, IEEE Nerem-70, 31 Channing St., Newton, Mass. 02158)

Optima 17
an elegant combination of chassis and case. Rackable.
Sometimes the purchasing of new electronic test and measurement equipment can be difficult. Selecting instruments that will meet both short- and long-term needs, getting authorization of funds, waiting out the manufacturer's delivery schedule. There are times when it just isn't worth it.

Let's say you have use for an ultra-high frequency, high-precision scope, but only for a month or two; or maybe you need half a dozen units to handle a peak development load; or maybe you were planning to buy a high-powered model complete with plug-ins but your controller is clamping down on capital expenditures. In situations like these, renting, instead of buying, can be the perfect solution.

R.E.I. can give you the fastest service, the widest selection and the lowest rates of any rental firm in the country. One of our inventory centers is located near you, wherever you are, for instant delivery. Let us tell you more about the many advantages of renting vs. buying. Send today for your free copy of the new R.E.I. Instrument Rental Handbook.

**COURSES**

**RCA Institutes:** Rather than just telling you what seminars and courses are available this month, we'd like to tell you a little bit about one that Steve Thompson, our Western Editor, recently attended. It was the week-long Digital Communications seminar sponsored by RCA Institute for Professional Development.

The subject matter was presented by breaking the communication channel into its constituent parts and working from the data source at one end and the data storage at the other inward towards the noise in the channel. Encoding and decoding modulation and demodulation, channel capacity and noise are other aspects of the subject covered. The course was comprehensive, more than enough information for a one-week course, and was presented by knowledgeable instructors.

If this one sounds interesting to you and you'd like more information on this or any of the other courses RCA sponsors, write to RCA Institute for Professional Development, Box 962, Clark, N.J. 07006.

**Technical Writers' Institute:** June 15-19, Troy, $225. The program has been designed to demonstrate how each person's job relates to the broader field of technical communications. Discussions and exercises in writing and editing begin the course, followed by techniques of technical reporting, proposal writing, etc. Rensselaer Polytechnic Institute, Troy, N.Y.. 12181.

**Computer Control:** June 29-30, Philadelphia, $250. This course will cover the application of the digital computer to the control of complex processes and interactions. Lectures will include basic control concepts and modern digital techniques. Computer architecture and control software will be reviewed and related to on-line system implementation. Instruments and Control Systems, 1 Decker Sq., Bala Cynwyd, Pa. 19004.

**Computer Control:** June 29-30, Philadelphia, $175. This course will detail the management, economic and technical aspects of digital computer control. A series of lectures and discussions will outline control philosophy, computer concepts and project implementation. Instruments and Control Systems, 1 Decker Sq., Bala Cynwyd, Pa. 19004.

**Data Communication:** July 6-18, Ames, $600. Digital computer fundamentals and data transmission concepts and applications will be covered. Topics such as information rate, system capacity, coding schemes, and bandwidth vs time relationship and noise will be included. Iowa State University, Ames, Iowa 50010.

**Computer-Aided Mathematical Modeling:** June 15-19, Syracuse, $250. Modern techniques of formulating realistic mathematical models and applying them to problems of engineering analysis, design and optimization will be examined. Use of analog and digital computers will be demonstrated, with emphasis on current developments in time-sharing systems and simulation programs. University College, 610 E. Fayette St., Syracuse, N.Y. 13202.

**Computer Graphics for Designers:** June 15-26, Ann Arbor, $450. This introduces design engineers to principles of graphic manipulation and application of computer graphics as aids in improved design methods. Univ. of Michigan, Engineering Summer Conferences, Chrysler Center, North Campus, Ann Arbor, Mich. 48105.

**Parametric Design of Digital Filters:** June 16-19, Washington, D.C., $275. Methods for the design and realization of digital filters using z-transformations applied to continuous filter transfer functions will be covered in this course. Emphasis will be on the application of Laplace transform and Fourier Series methods to achieve recursive and non-recursive designs. Technology Service Corp., 225 Santa Monica Blvd., Santa Monica, Calif. 90401.

**Digital Process Control:** June 22-26, Philadelphia, $250. This course will cover the application of the digital computer to the control of complex processes and interactions. Lectures will include basic control concepts and modern digital techniques. Computer architecture and control software will be reviewed and related to on-line system implementation. Instruments and Control Systems, 1 Decker Sq., Bala Cynwyd, Pa. 19004.

**Inter-System Electromagnetic Compatibility:** Aug. 18-27, Syracuse, $375. The purpose of this course is to review electromagnetic compatibility as a problem-oriented specialty interfacing with the technical specialties of components, circuit design, systems design and evaluation, antenna development and signal processing. Continuing Engineering Studies Program, Technical Resources Center, 610 E. Fayette St., Syracuse, N.Y. 13202.
Last month, we told you why we didn’t make the “Super” Op Amp. We said that ideal op amps exist only in textbooks and real applications in the real world need a family of op amps to meet a family of requirements. Which got us into a discussion of our family of fifteen different op amps.

This month, we’ve got another op amp story. This one has a Moral:

EDITORIAL

You Can’t Afford to Wait Until the Price Goes Down

Once upon a time (5 years ago to be exact), Fairchild designed an Op Amp. It was called the µA709. It cost $64.00 and people bought them as fast as we knew how to make them. (Maybe even faster.) Some people didn’t buy the µA709. They said the price was too high. And so, they built their systems the old way.

Then, as time passed, the popularity of the new µA709 grew and grew. And the price went down and down. So fast, in fact, that the companies who first used them were surprised. And happy. Their systems performed better and were more profitable than those of their more cautious fellows. Today, these companies are reaping the benefits of their foresighted decisions of those pioneer days.

Today, the µA709 sells for $1.90. MORAL? When you see a new LIC such as the µA725, µA741 or µA796, think of the lesson of the µA709. You can’t afford to wait until the price goes down.
Here's a list of the most popular consumer industry LlCs from the only major supplier in the world that spends all of its time making circuits and none of its time making television sets. (We don't make radios either.)

**µA703 RF-IF Amplifier**
Symmetrical Limiting
Internally Biased
Forward Transadmittance - 35mmhos
Best selling IF amp in the business
Reader Service Number 180

**µA732 — FM Stereo Multiplex Decoder**
Stereo Switching, Audio Muting, Stereo Lamp Driving Capability
45dB Channel Separation with Minimum Component Count
(Replaces MC1304)
Reader Service Number 181

**µA739 — Dual Low Noise High Gain Operational Amplifier**
Great for Stereo Phono Inputs
1V RMS Noise Voltage (Audio Band)
High Gain
High Output
Very Low Distortion
Reader Service Number 182

**µA742 — “TRIGAC” Zero-Crossing A.C. Trigger**
Economical Solid State Power Control
for Consumer and Industrial Applications
Minimum External Component Count
2 amp Peak Output
Reader Service Number 183

**µA746 — Color TV Chroma Demodulator**
The Industry's Best Seller!
Low Output Drift
10V P-P Output Swing
Doubly Balanced Demodulators
Internal NTSC Matrix
Reader Service Number 184

**µA749D — Dual Operational Amplifier**
Perfect Stereo Tape Recorder Input Amplifier
Very Economical
Compact TO-5 Package
Reader Service Number 185

**µA754 — TV/FM Sound Channel System**
Gain, Limiting, Detection and Audio Preamplifier
100µV Sensitivity
Can drive output device to 4 watts
High Performance
Low Price!
Reader Service Number 186

**µA757 — Gain Controlled I.F. Amplifier**
70dB Gain
70dB AGC Range
30mV Signal Handling Capability
Stable Characteristics Despite Supply and Temperature Changes
Reader Service Number 187

**µA796 — Modulator — Demodulator**
Double-Balanced Modulator
Demodulator on a Chip
Use in AM, FM, SSB, Phase Lock Loop, Disc and Tape Systems
(Replaces the MC1596)
Reader Service Number 188

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You can take it with you. We've just published an all-new Fairchild Linear Condensed Catalog. It's pocket sized so that you can lug it around with you.

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**We're About to Announce the First Winner**

By now you ought to be down to the final strokes of preparing your entry in our recently announced Linear Applications Contest. Here are the rules, remember?

1. Get all the facts on a Fairchild Linear IC.
2. Design the world's greatest application for it.
3. Send to: Fairchild Linear Contest, P.O. Box 880 A, Mountain View, California 94040.

All entries will be judged by the editors of IEEE Magazine. They will select the most imaginative application and give us the designer's name. We'll publish the winning design and give the winner $100 upon publication. Ready. Set. Design!
**The New µA796:**

*We Knew It Was Going To Be Versatile, But We Didn’t Know How Versatile.*

The new low-cost µA796 Doubly Balanced Modulator/Demodulator is finding its way into an amazing variety of systems. Communications-gear engineers are taking advantage of its great versatility and high carrier suppression in modulators and demodulators for single sideband, suppressed carrier and phase shift key transceivers. It’s also being used as a synchronous AM demodulator, a quadrature FM demodulator, and as a phase comparator for phase locked loop receivers.

Digital tape/disc memory designers are utilizing the µA796’s unique properties in fast differentiators and phase correcting circuits for NRZ or phase encoding systems, while remote D.C. R-G-B gain controls, color shade and keystone corrections are practical for color TV broadcast equipment use. Other possibilities lie in signal chopping, frequency changing, linear mixing and more.

**Here Are The Specs:**
- Carrier Suppression: 65dB
- Transadmittance Bandwidth:
  - Carrier Port: 300MHz
  - Signal Port: 80MHz
- Signal Gain: 3.5V/V
- Input Impedance (signal port): 200KΩ
- Input Offset Current: 6.7µA
- Differential Output Swing: 8.0 volts p-p

---

**Good Old µA723:**

*Everybody’s Favorite Voltage Regulator.*

Fairchild’s µA723 is the only voltage regulator on the market that can handle just about any power supply application. It works from both positive and negative sources in series, shunt, or as a switching regulator.

If 2 to 37 volt output range isn’t enough, it can also be used in a floating mode.

On one chip, you get a temperature-compensated ±3% absolute accuracy zener diode reference, an error amplifier, a 150mA series pass element, short circuit protection and a zener level shifter.

The µA723 was the first monolithic linear circuit to employ a J-FET as a current source for voltage reference. An external series pass element can be added if larger output currents are needed. An internal feature — remote shut-down — may be used to conserve system power when a section of logic is not being used.

The µA723 also features .01% line regulation, .03% load regulation, .003%/°C temperature coefficient and ripple rejection of 74dB.

The most popular applications for the µA723 include laboratory power supplies, isolation regulators for low-level data amplifiers, airborne power supplies and local on-board card regulators.

**The µA723 and Foldback Current Limiting**

The µA723 includes adjustable current limiting. As an alternative to the standard current limiting techniques, foldback current limiting may be used to advantage in any power supply situation in which the output device power dissipation under short circuit conditions becomes intolerable due to device and/or heat sink limitations. This technique utilizes positive feedback to accomplish the foldback action of reducing both the output voltage and current during overload conditions.

**Here Are The Prices:**
- USF7796312
  - -55°C to +125°C $4.95 @ 100 pcs.
- USF7796393
  - 0°C to +70°C $2.25 @ 100 pcs.
Three-pole active filter

Changing capacitor values gives six different responses from this circuit.

By Russell Kincaid
Sanders Assoc. Inc., Nashua, N. H.

This three-pole active filter has 0-dB insertion loss. You can get a Tchebycheff or Butterworth response with a cutoff frequency by using the tabulated capacitance values and the 1-kΩ resistances shown. To change the cutoff frequency by a factor K, divide the resistance or capacitance values by K. As another option, you can change the impedance levels by multiplying the resistance and dividing the capacitance values by a constant factor.

The amplifier in the circuit should have unity gain, a high input impedance and low output impedance over the frequency range of interest. The amplifier can be a single transistor emitter-follower if the performance is not critical.

The graph shows the theoretical response of six configurations possible from the circuit. The actual responses will typically be within 1 dB if you use 1% components. By the way, the 3-dB ripple filter is more critical of component tolerances than the lower ripple types.

<table>
<thead>
<tr>
<th>dB Ripple</th>
<th>C₁ (µF)</th>
<th>C₂ (µF)</th>
<th>C₃ (µF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>0.2217</td>
<td>0.5645</td>
<td>0.03222</td>
</tr>
<tr>
<td>0.1</td>
<td>0.2092</td>
<td>0.7627</td>
<td>0.01542</td>
</tr>
<tr>
<td>0.5</td>
<td>0.3049</td>
<td>1.523</td>
<td>0.01213</td>
</tr>
<tr>
<td>1</td>
<td>0.3731</td>
<td>2.353</td>
<td>0.009346</td>
</tr>
<tr>
<td>2</td>
<td>0.4797</td>
<td>4.287</td>
<td>0.0005997</td>
</tr>
<tr>
<td>3</td>
<td>0.5775</td>
<td>6.910</td>
<td>0.004031</td>
</tr>
</tbody>
</table>

*Butterworth
The Tung-Sol® development that created a whole new set of digital display standards

The new HP 3480 A/B Digital Voltmeter is more than a digital voltmeter. It's an advance in the state-of-the-art. It's the omniscient triskelameter that sees all the values you are measuring. It's really a measuring instrument that is ideally suited for bench and systems applications.

The HP 3480 A/B is the first DVM capable of making 1000 correct dc or ohms readings per second. It takes the 3480 less than 1 ms to respond to a full scale input and digitize the input signal.

The HP 3480 A/B is the first 4-digit multifunction DVM having an ac converter that is true rms responding to eliminate large errors caused by harmonic distortion or noise and extends your measurement capability to include the rms value of non-sinusoidal wave forms. The 3480 A/B has a 100 mV range and covers from 1 Hz to 1 MHz and will measure ac plus dc.

**The HP 3480 A/B DVM is ideal as a bench instrument.** No other instrument — single purpose or multiple function — equals the 3480 A/B. Top performance in measuring dc, three-terminal dc ratio, true rms ac, ac-plus-dc in one measurement, and ohms is assured by the accuracy designed into the instrument.

You get four-digit readout plus 50% overranging which results in greater resolution and less range change. The high dc input resistance (>10^16Ω on the lower three ranges) reduces the possibility of loading errors.

True rms ac conversion makes the 3480 A/B immune to large errors caused by small amounts of harmonic distortion and expands the range of precision ac measurements to non-sinusoidal wave forms.

The wide bandwidth (1 Hz to 1 MHz) and the capability of making ac-plus-dc measurements gives the 3480 A/B a broader range of applications not available before. And, the high ac and dc sensitivity (100.00 mV full scale) reduces the need for preamplification.

*HEWLETT PACKARD*
The HP 3480 A/B DVM is ideal as a systems instrument. Up to this time, DVM's have been the slowest part of a measurement system. Now, the system doesn't have to wait for the DVM. The HP 3480 A/B DVM can make up to 1000 dc and ohms readings per second. You can save automatic test time and increase production—or you can appreciably reduce computer idle time.

The 3480 A/B is fully guarded to improve common-mode rejection. There is a switchable 3-position input filter to give you the optimum trade-off between noise rejection and speed. The 3480 A/B is fully programmable including range, function and filter position.

With the optional isolated BCD and isolated remote control you can reduce errors created by ground loops, improve your common-mode rejection even more, and make floating measurements into a guarded system.

Modest prices, too! All the capability packed into the 3480 A/B is not expensive. Prices range from $1150 for one range of dc to $3375 for multi-function ac, dc, ohms capabilities with isolated BCD and isolated remote control.

For the best in bench and systems DVM's, get the omniscient triskelameter—the new HP 3480 A/B DVM. Ask your local HP field engineer for full particulars, or write to Hewlett-Packard, Palo Alto, California 94304. Europe: 1217 Meyrin—Geneva, Switzerland.
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Elco rack-and-panel connectors give you a better head start.
And a choice of tails.

The head start is the connecting end of an Elco connector: the patented Varicon™ contact that fully meets the requirements of MIL-E-5400. The four mating surfaces of this unique contact are coined to an exceptional hardness and wipe clean with each make. Once the contacts are joined, the inherent springiness of the gold/nickel-plated phosphor bronze and the fork-like design make a superior, gas-tight fit.

Because the contacts are free floating, they align perfectly. A few contacts or 100 or more, all fit precisely together every time, over a long service life. There's no contact chatter.

Nobody else gives you a contact head quite like the Varicon.

And nobody else gives you the choice of tails you get with Varicon. You can wire-wrap, crimp, clip, stake, or solder them. Whatever terminating technique or combination of techniques your assembly lines are set up for, we'll furnish the appropriate tail. If staking or crimping is your style, we can supply the equipment too. Manual or automatic. Purchase or lease.

Elco rack-and-panel connectors come in standard rectangular models, or as miniature connectors, or in modular units. You can have them with 2 Varicon contacts, or up to 140, or anything in between.

In short, our line of Varicon rack-and-panel connectors has a lot going for it. Except price. Though it's a precision component, the Varicon contact is easily produced in high speed progressive dies. There's no expensive machining, no waste. When you can turn out millions of Varicons a week, you don't have to charge a fortune for them.

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Elco Corporation, Willow Grove, Pa. 19090.
(215) 659-7000.
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0.078" Taper Tab
Solder/.098" Taper Tab
Wire Wrap Tail .024" x .050" x .567"
Wire Wrap Tail .024" x .050" x .760"
Crimp (Loose contact)
Printed circuits—make or buy?

The costs involved, and your familiarity with the new processes, will decide which route you should take.

By Jack Froelich, Contributing Editor

A printed circuit can be made by using a sunlamp, a couple of basins and a bench-drill. On the other hand, you can spend from $250,000 to $2½ million to set up a plant to manufacture reliable printed circuit boards. The boards can cost from less than 1¢ each to $2500.

The interdisciplinary boards

The design and fabrication cycle of a printed circuit board exposes you to all the physical sciences—electrical and mechanical engineering disciplines are only a beginning. Before you are through, physics, chemistry, photography, metallurgy, computer technology and the graphic arts may all have been called into play.

The printed circuit board, one of the basic elements in any electronic equipment, interconnects the functional components of a circuit and, in general, replaces handwiring. The manufacture requires conductive paths to be photographically and chemically reproduced on the surface of an insulated substrate, and terminal areas to be provided to mount the electronic components. Soldering, in all its varieties—hand, dip, flow, and reflow—is the most common method used to connect the components. Or, you can weld them, or even make pressure-fitted gas-tight joints.

What it costs to buy

At present the market for all types of printed circuit boards is running around $500 million a year, and may increase to $950 million by 1975. About two-thirds of all the printed circuits manufactured are produced “in-house” with IBM and Western Electric leading the field. Computer manufacturers, the entertainment industries, and communication people also tend to make their own boards. The remaining one-third of the printed circuits are manufactured by independent companies, ranging from the large—such as Cinch-Graphic, Lockheed and Photocircuits and Sylvania—to medium size (50 to 250 employees), to small houses geared for small quantities and quick delivery. The larger independent manufacturers make anything their customers demand, from high-volume simple single-sided boards to the complex multi-layer printed circuits. They even set up special lines inside their own plant for high-volume orders.

The types of boards manufactured are broken down as follows:

<table>
<thead>
<tr>
<th>Type of PC</th>
<th>% of market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-sided</td>
<td>20</td>
</tr>
<tr>
<td>Double-sided</td>
<td>55</td>
</tr>
<tr>
<td>Multi-layer</td>
<td>22</td>
</tr>
<tr>
<td>Flexible-circuit</td>
<td>3</td>
</tr>
</tbody>
</table>

About one-third of the entire market is federal. Table I lists the type of boards used for the major applications, and Table II provides some typical figures for boards that vendors make today in volume.

Moment of truth

Before deciding whether to make circuit boards in-house or buy them, you should know the answers to these questions:

What is the product? What quantity? Is it a high volume commercial application requiring elaborate tooling and automation? Is it a relatively sophisticated board with yearly requirements in hundreds or thousands? How many do I need this year, next year, in five years?

What equipment will I need? How much will it cost? Making reliable printed circuit boards is a complicated multi-step operation and will require some or all of

(text continues on page 56)
Printed wiring was invented by Paul Eisler in England during World War II. Its first major application was for artillery proximity fuzes, thanks to printed wirings' advantages of compactness, ruggedness and reliability.

The type of circuit board first manufactured—and still the most widely used—is the single-sided printed-circuit board. A conductive conductor pattern provides wiring on one side of a rigid insulating substrate, the components being mounted on the other side. Single-sided boards are generally used with discrete components, relatively simple circuitry, and a low component density per square inch of board. This type of board continues to be used by the millions in the radio and television industry.

Miniaturized components, the transistor, integrated circuits, higher switching speed—all required greater wiring density, more connections, and more holes per square inch, as well as more conductors and smaller spacing between conductors. Advancing printed wiring technology met the challenge by providing conductors on both sides of the substrate, plus electrical connections between both sides of the board.

The hole problem

The vital connection between the conductors on either side of the boards was first a simple jumper wire, placed through a hole, clinched and soldered to the pad on both sides of the board. Simple but slow! Eyelets—inserted by machine to improve uniformity and decrease cost—were also widely used.

The most popular method today is chemical, consisting of plating the walls of a hole. The conventional plated-through-hole process starts with an insulating laminate clad with copper-foil on both sides, through which holes are drilled in appropriate locations. Copper is deposited first chemically (electroless copper), then electrochemically over the entire board surface, and through the holes.

Print-and-etch process for a single-sided board starts with a copper-clad insulated substrate. Photo-resist (positive or negative), photo printed or screened onto the copper, masks the areas that will become conductors on the board. The unmasked copper is etched away. After removing the resist, the operator drills the holes for the components' leads. The main advantage of this method is simplicity. Its main reliability problem is that the etchant not only removes the unmasked copper, but also undercuts the edge of the copper lands. When the board is dip-soldered later, solder slivers will hang from the undercut copper, forming bridges and producing shorts.
Now a 'resist' negative pattern is applied to both sides of the board, covering all areas of the foil where copper conductors are not required. The next step is to electro-deposit a thin layer of etch-resistant plating—usually solder or gold—which adheres to the exposed copper. After removing the resist, the conductor-paths are obtained by etching away the exposed, unplated copper. This explanation, although simplified, illustrates the multi-step technology inherent in the manufacture of printed-wiring—a reliable process evidenced by the millions of plated-through holes produced every day.

For even greater wiring densities—such as in computer back-planes—the multi-layer printed-circuit was developed. It consists of a series of layers of circuit boards, bonded together to produce a monolithic assembly with internal and external connections to each layer of the circuitry. Multi-layer boards often have one or more copper planes devoted to grounding, to supply busses, and to transmission lines. The number of layers, which can be as high as thirty, is generally between five and eight layers.

The processes for fabricating multi-layer boards are basically similar to those used for manufacturing single- and double-sided boards, plus the lamination. Again, there is a tremendous diversity of processes to manufacture multi-layers and to obtain the interlayer connections. Multi-layers, which are the most expensive printed circuit boards, are normally produced in smaller quantities than the single- and double-sided boards. The cost of a multi-layer board is higher than that of a double-sided board by 10-15% per layer.

Mechanical interconnections for doubled sided boards. Although largely superseded by plated-through holes, these methods are still used for prototype boards and in some military applications.
TABLE I

<table>
<thead>
<tr>
<th>Applications</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entertainment (radio, TV)</td>
<td>S and D (more single-side boards)</td>
</tr>
<tr>
<td>Appliances</td>
<td>S and D (more single-side boards)</td>
</tr>
<tr>
<td>Industrial</td>
<td>S and D (double-sided increasing)</td>
</tr>
<tr>
<td>Computers — central processor</td>
<td>S, D, M</td>
</tr>
<tr>
<td>Computer — peripheral</td>
<td>S, D, M</td>
</tr>
<tr>
<td>Federal — military, airborne, aerospace</td>
<td>S, D, M</td>
</tr>
</tbody>
</table>

Applications for printed circuit boards, listed in increasing order of complexity and cost. (S: single-sided; D: double-sided; M: multilayer)

TABLE II

<table>
<thead>
<tr>
<th>Type of Printed Circuit Board</th>
<th>Single-sided</th>
<th>Double-sided, with plated-through holes</th>
<th>Multilayer (6-8 layers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity</td>
<td>5000</td>
<td>1000-5000</td>
<td>50-100</td>
</tr>
<tr>
<td>Width of conductors (mils)</td>
<td>20</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Hole density (holes/sq. in.)</td>
<td>3 to 5</td>
<td>10 to 15</td>
<td>40 to 50</td>
</tr>
<tr>
<td>Tolerance in location of holes</td>
<td>±5 mils</td>
<td>±4 mils</td>
<td>±4 mils</td>
</tr>
<tr>
<td>Cost ($/sq. in.)</td>
<td>0.8</td>
<td>10 to 15</td>
<td>1.00/sq. in.</td>
</tr>
<tr>
<td>Delivery (weeks)</td>
<td>4 to 6</td>
<td>4 to 6</td>
<td>12 to 16</td>
</tr>
</tbody>
</table>

TABLE III

1. Equipment:
   - Cameras $30,000.00
   - Automatic perforating equipment $50,000.00
   - Plating $100,000.00
   - Cleaning and finishing $20,000.00
   - Ovens, screens, jigs, routers, saws, shears, degreasers $50,000.00
   - Total $250,000.00

2. Engineering and installation:
   - Waste treatment, water filtration, acid-proof floor, special electrical installation, ventilation, dust filtration, air conditioning, steam, air-pressure, etc. $120,000.00

3. Quality assurance:
   - Material test equipment, ovens, microscopes $20,000.00

4. Start-up and training:
   - 10% of first year's requirements $100,000.00
   - Raw material inventory $30,000.00

5. Work in process inventory: (one month) $80,000.00

6. Expendable supplies $20,000.00

Total $620,000.00

Capital investment required to make $1,000,000 worth of printed circuit boards per year. (Source: Photocircuits Corp.)

NT-1 process was designed by Photocircuits to produce densely patterned printed wiring. It uses a special insulating substrate—a copper-clad laminate with a catalytic base that provides a foundation for the electroless copper of step 4. The major steps of the process are: (1) The conductor pattern is formed by photo-printing and etching copper on both sides. (2) A permanent epoxy coat on each side forms a solder mask which prevents bridging during dip-soldering, and acts as a conformal coat. (3) Holes are drilled through the epoxy, copper pads and catalyzed laminate. (4) The board is immersed in a plating solution of electroless copper which deposits copper in the holes, thus interconnecting both sides of the board. The copper buildup projects slightly over the epoxy, forming a bead that greatly assists solderability. Finally, a coat of lacquer is applied to protect the exposed copper of the hole.
The prime movers

"Photocircuits has been responsible for most of the innovations in printed circuits," says Stanley J. Feldman, manager of Manufacturing Engineering at Redcor Corp. And, as atypical as this sounds in electronics, where progress usually takes place across a broad front of companies, Photocircuits has an impressive record of original developments in manufacturing technology for printed circuits. A few of their best known ones are

- the copper-clad epoxy-glass laminate, developed in 1952, which replaced the phenolic-base laminates in many military and most industrial applications;
- a method to deposit ductile "electroless" copper on a catalyzed laminate. This development allows copper to be added to an insulating base, as opposed to etching the copper of a laminate. It has made a new and economic process for "plated-through" holes possible in printed circuits, and is incorporated in other manufacturing processes developed by Photocircuits such as NT-1 and "Catelec."

Their latest process, still under development, is called "Multiwire." Directed at numerically-controlled point-to-point wiring of very high density (25-mil grid), it bonds fine insulated wire to an insulating board, which is then drilled and the holes metallized to receive the components.

Photocircuits sells their processes worldwide through a patent-licensing program, which allows the licensee to use not only the patented development, but also the improvements that any other licensee may make to the process.

Another important development, this one on photo-resists, was introduced by DuPont in 1968. Called Riston®, it consists of a solid photo-resist that the user laminates under heat and pressure to the printed-circuit board instead of impregnating the board with the popular liquid resists.

Riston®, a solid photoresistive film, comes sandwiched between two 1-mil films, one of Mylar polyester, and the other of polyethylene. (1) The photoresist is laminated under heat to the copper-clad board after peeling the polyethylene film. Since the Mylar film that remains is transparent, the mask can be applied in direct contact with it, as in (2). After exposure to ultraviolet light through the polyester film, this film is peeled back (3) to permit washing the unexposed resist away. Since the photoresist is solid, it has uniform thickness and neat sidewalls, and it covers the board's holes without penetrating in them. After etching the copper away (4), Riston is stripped with the same solutions used for liquid resists.
Automation in the manufacture of PC boards has advanced to the point where not only the artwork, but even the tooling, can be determined and controlled by the computer. Here a layout is digitized to feed the inputs to the computer (Photo courtesy of Photocircuits Corp.).

(continued from page 51)

the following plant and equipment during the fabrication cycle.

(a) Plant space

(b) Photo-lab—Camera and darkroom; equipment to apply and develop photo-resists. Also, a thermal press for laminated photo-resists (such as Du Pont's Riston®).

(c) Drilling machines—they range from a single-spindle manual-operated type to tape-programmed numerically controlled machines.

(d) Panel and hole cleaning machines—to prepare the substrate for screening and plating operations. Can range from hand scrubbers to semi-automatic cleaners.

(e) Plating and etching facility—the heart of the printed-circuit process. You may need to plate copper, nickel, gold, rhodium, with equipment ranging from simple tanks to automated lines.

(f) Fabrication equipment—Some or all of the following: screens, jigs, ovens, routers, shears, punches.

(g) Quality assurance: Control of plating thickness and quality can occupy the corner of a desk or a complete lab. Both destructive and non-destructive tests may be required.

(h) Installation: A plating line requires heavy duty electrical fixtures, acid-proof floors, air-conditioned and dust-free areas. Waste treatment for the neutralization and disposal of dangerous chemicals is important. The list is formidable. But whether the electronic equipment you are designing contains thirty boards with different circuit functions, or even one large double-sided board with plated-through holes, their fabrication may require every item mentioned above.

The total investment for such equipment starts at $50,000 and goes up from there. A study made by Photocircuits for a small facility in California (shown in Table III), gives an entire capital outlay of $620,000 for a $1,000,000 worth of printed circuit boards/year.

What it costs to make

The facility will have to be staffed. Photolab technicians, experienced platers, a chemist and metallurgist are key personnel. Step-by-step inspection is necessary to avoid costly rejections at the end of the line. Mario Lombardi of Circuitron gives a ratio of one inspector to every six operators.

It takes some time to develop the know-how to produce consistently reliable printed-circuit boards. The start-up and learning period is a seemingly never-ending procession of all the maladies that the printed wiring process is susceptible to: improper registration, defective cleaning, spotting, halos, over-etch and under-etch, delamination, and warp.

The return on investment is relatively slow—a minimum of three to four years of printed circuit production. The danger of technical obsolescence is very real in this expanding and technologically effervescent industry. Some processes being used today—such as Photocircuits NT-1 or Du Pont's Riston®—did not exist five years ago. Techniques in the laboratory may some day obsolete present technology.

A premature investment in a small PC facility can lead to restricting the designs to those that can be produced by the facility (very frustrating to design engineers!). All the foregoing ifs, ands, or buts do not mean that in-house production of printed circuits is a stubborn conspiracy to deprive the heroic independent fabricators of their rightful R.F.Qs. But a successful in-house facility is no easy operation to set up. You must know your product and its volume. A rigorous cost-accounting can then determine whether you should do it yourself!

References:


Dimensional tolerances for printed circuit boards, booklet IPC-D-200. Cost: $1.00. Order from the Institute of Printed Circuits, 3525 W. Patterson Avenue, Chicago, Ill. 60645.

INFORMATION RETRIEVAL
Packaging, Materials

56
The HP 4815A RF Vector Impedance Meter will conveniently measure complex impedance over the entire impedance domain. You get instant, direct readout of impedance magnitude from 1 ohm to 100K ohms and phase angle from 0 to 360°, over a frequency range of 500 kHz to 108 MHz. Now you can easily measure impedances with negative real parts, often present in feedback amplifiers with small phase margin.

To measure impedance at multiple frequencies, simply set the frequency, probe, and read. No nulling and balancing, as with conventional bridge measurements.

A convenient probe lets you measure directly in active circuits to determine driving point impedance under actual operating conditions, with minimum residual effects. For example, amplifier input or output impedance can be continuously monitored while bias, feedback, load, and frequency are varied. In-circuit measurements for determining loop gain and phase margin can also be made.

The 4815A is also ideal for evaluating passive devices, such as components and networks. Use it to characterize transformers, resonant circuits, transmission lines, filters, and crystals. You can measure at actual operating frequencies and make network adjustments while impedance parameters are monitored. For example, antenna/transmission line matching networks can be quickly adjusted. Price: $2650.

To learn more about how easy it is to use impedance for evaluating circuits and components, request Application Note 86 and a special impedance issue of the HP Journal. If you would like to discuss a particular application, call your local HP field engineer or write: Hewlett-Packard, 100 Locust Ave., Berkeley Heights, N.J. 07922. In Europe: 1217 Meyrin-Geneva, Switzerland.
Speed/power chart for digital ICs

This specifying chart should be an old friend by now. The chart, which first appeared in The Electronic Engineer in 1967, is the fourth updating.

The chart shows typical propagation delay in nanoseconds plotted against the average power dissipation (usually for a 50% duty cycle) in milliwatts per gate. All of the over 125 commercial ICs listed are bipolar monolithic devices. The chart does not include MOS and hybrid devices.

Each circuit configuration is indicated on the chart by a color dot. The larger dots indicate those popular circuits, made by several manufacturers, that have the same or nearly the same speed/power parameters.

The most apparent difference between last year's chart and this new edition is in the number of listings for each logic type. Four of the five categories include more entries (either new circuits or new second sources) than last year. The biggest gain, as you might expect, was by TTL which lists 62 entries this year as compared to 50 in 1969. The one circuit type which shows no additions to the 1969 listing is RTL.

The following list represents the individual ICs shown on the chart. The number next to the manufacturer corresponds to the number of a circuit configuration shown on the chart. Also shown below is a list of names of circuit classifications and their acronyms, including most of the better known types.

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**DTL**

1. Amperex FCI 111, 211
2. Fairchild 121, 131, 191, 211
3. Amperex FCI 221
4. Amelco NHU 300
5. Continental Device HNIL DTL 330BG, CG
6. Fairchild DTL 930
7. Hughes HSM 930 J
8. RCA CD2300
9. Fairchild DTL 10 MHz PL 9930
10. Motorola MOJL MTL930/7400
11. Motorola MTTL MC505/4000
12. Fairchild DTL 10 MHz PL 930 (radio hardened)
13. Radiation hardened circuits Raytheon 930
14. Siliconix 9380, 930
15. Stewart-Warner SW930
16. Texas Instruments 15300, 15830
17. Radiation hardened circuits Raytheon 200 series
18. Signetics SP600A
19. National DTL DM300
20. Siliconix CA1, A41
21. Radiation 200, 300, 500
22. Fairchild 9950
23. Philips-Shell 9950
24. SGS Varadine 9950
25. Siliconix SC 126/426

**RTL's**

1. Texas Instruments 17.900L, 17.800L
2. Fairchild LPR/1, 9010
3. Fairchild MWT 1.8 MHz PL9908
4. Motorola mW MRTL MC908
5. Motorola mW MRTL MC800/708
6. Motorola mW MRTL MC800/700P
7. Amelco 100G
8. Philips-Shell 10.5 MHz PL9900
9. Fairchild R14, R4100
10. Motorola MRTL MC390/800
11. Motorola MRTL MC300/800
12. Philips-Shell MW11-15 MHz PL995
13. Philips-Shell RDT 35 MHz PL6900

**TTL's**

1. Amelco 500-509
2. Amelco 530-548
3. Fairchild 9400 (low power TTL)
4. Philips-Shell MWT 5 MHz PL9900
5. National S4L
6. Texas Instruments S4L/74L
7. Amperex FH 231, 251

**ECL's**

1. Motorola MECL II MC1200/1000
2. Stewart-Warner SW1000, and 350 Series ECL I
3. Motorola MECL II MC1200/1000
4. RCA CD2500
5. Fairchild 9500 Series temperature compensated intermediate speed
6. Texas Instruments 2500
7. Motorola MECL III, MC1660
8. Fairchild 9500 temperature compensated high speed

**SPECIALS**

1. Texas Instruments RCTL 51 and 51R (130 ns at 5 V)
2. Motorola MHTL M660
3. Signetics UJ300K, SU300G/K
4. Signetics LV and SP900A
5. Fairchild C71
6. Fairchild C71
7. Philips-Shell SPD-199A
8. Philips-Shell PLB 980 (radiation hardened)
9. United Aircraft 820

**Types of Logic Circuits and Their Acronyms**

- CCSL: Compatible Current-Sinking Logic
- CRL: Counting Logic
- CML: Current-Mode Logic
- CTL: Complimentary Transistor Logic
- DCTL: Direct-Coupled Transistor Logic
- DTL: Diode-Transistor Logic
- DTLM: Diode-Transistor Micrologic
- ECSLL (EC'SCL):Emitter-Coupled Transistor Logic
- ECL: Emitter-Coupled Logic
- ECL (ECC): Emitter-Coupled Logic
- HLTTL (HL'TTL): High-Level-Transistor-Logic
- HMIL: High Noise Immunity Logic
- LPDTL: Low-Power Diode-Transistor Logic
- LPRTL: Low-Power Resistor-Transistor Logic
- LPRTL: Low-Power Resistor-Transistor Micrologic
- MCML: Motorola Current Mode Logic
- MECL: Motorola Diode-Transistor Logic
- MECL: Motorola Emitter-Coupled Logic
- MEL: Micro Energy Logic
- MHTL: Motorola High-Threshold Logic
- MRSL: Motorola Resistor-Transistor Logic
- MTTL: Motorola Transistor-Transistor Logic
- MWTL: Motorola Variable-Threshold Logic
- mW/L: Millivolt Micrologic
- mwMRTIL: Microwatt Motorola-Resistor Logic
- OMIC: Optimized Microcircuits
- RCT: Resistor-Capacitor-Transistor Logic
- RTL: Resistor-Transistor Logic
- RTP: Resistor-Transistor Micrologic
- STHL: Silicon Universal High-Level Logic
- TLT (TL): Transistor-Transistor Logic
- VHL: Variable-Threshhold Logic
- UHlogic: Utility Logic (with features of DTL, RTL, TIL)

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This month, our course on MOS integrated circuits is devoted to random access memories (RAMs). RAMs are the structures in which a computer stores the information that is currently being used. This information, by the way, is not just the data being operated on, but also includes the program that directs the computer's operations.

Many ways to remember

There are a number of techniques used to store the information used by a computer. Among the more familiar storage media are magnetic tape, paper tape, punched cards and magnetic discs and drums; all of which are basically mass sequential storage forms. The information they store is organized into fairly large blocks with the information within a block stored sequential—the computer uses storage location #1 first, location #2 second and so on through the block.

However, in the course of all those computations and manipulations that a computer does so quickly, the most efficient organization for data is not necessarily in sequential blocks. A more practical approach with a block of data is to let the computer write-into or read-out-of any storage location at random. Not so surprisingly, this brings us back to our topic at hand—random access memories.

What’s in a RAM

Before we talk about RAMs, let’s look at the organization of a memory. All the information in a computer is

<table>
<thead>
<tr>
<th>Characteristics of Main Memory Systems</th>
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<td>(2.5 x 10^5 bits)</td>
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<td>Cell spacing</td>
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<td>Sense signal</td>
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<td>Word drive current</td>
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<td>Word drive voltage</td>
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<td>System cycle time (¾ million bit system)</td>
<td>600 ns</td>
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<td>System access time</td>
<td>320 ns</td>
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<td>System power</td>
<td>300 W</td>
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Here's how a computer manufacturer compares MOS and magnetics in mainframe applications. (Contributed by Mr. W. F. Jordan, Honeywell Computer Control Div., Framingham, Mass.)
This bipolar IC memory is used as a buffer memory in the IBM 360/85 and 360/195. The memory chips store 64 bits each and have a read time of 7 ns and a write time of 12 ns. The complete memory stores 2048 words of 72 bits each—a total of 147,456 bits—and has an access time of 40 ns. (Courtesy of IBM Corp., Essex Junction, Vt.)

stored as binary 1's and 0's. In a computer, these bits are organized into words, where a word is just a string of bits treated as an entity. Random access memories store each bit individually, but the smallest amount of data that can be written into or read out of the memory is one word.

Because the RAM stores the information that is currently being used by the computer, its most important parameter is speed. How fast you can get the information into and out of the memory significantly affects how fast the computer will operate.

Following speed as a parameter of interest, is a combination of physical size and power dissipation. Computers are becoming faster and smaller. The need is to cram more information into the same or less space than is now used. Besides the physical size of the storage device, power dissipation limits the packing density.

Mostly magnetics

By far, the greatest portion of the random access memories in today’s computers use the magnetic cores, with a fairly small portion using plated wire. Magnetic core technology has probably played as large a part in the advancement of the computer industry as has the transistor. Magnetic cores have performed more than adequately up to now in the areas of speed, packing density and power dissipation. But there is a new challenger on the scene and this challenger is the integrated semiconductor memory.

Except in specialized applications, bipolar semiconductor memories have not displaced cores to any large extent. Now, however, semiconductor manufacturers are cranking out IC memories that are either all MOS or that combine MOS and bipolar to take advantage of the strong points of each. Read the three articles that comprise this installment of our course. You’ll see that the authors are not addressing themselves to the question, “will IC memories replace cores?” Rather they are debating the question, “which configuration will be the one to replace cores?”

One plane of a 3-D organized random access core memory. Each core in this plane stores the same bit for each word in the memory. This plane is repeated for each bit in a word so that the number of planes equals the word length.

To write a 1 in a particular core, currents of $I/2$ are passed down the appropriate X-select and Y-select lines. The $I/2$ current is not large enough to reverse the state of a core. However, the core that is located at the intersection of the particular X-select and Y-select lines sees an effective current of $2(I/2)$ or $I$. This current $I$ is large enough to change the state of the core and a 1 is written.

To write a 0, the direction of the current flow is reversed. The selected core then sees an effective current of $-I$ and a 0 is written.

This same procedure is used to read the memory. The $-I/2$ currents cause the core to change states if it contains a 1. When the core changes state, it produces a current pulse on the sense line. Therefore, when reading, a current pulse on the sense line means that particular bit is a 1. If there is no current pulse, the bit is a 0.

Since the read process converts all 1’s to 0’s, it is necessary to write the 1’s back into the memory. To accomplish this, $+I/2$ currents are passed through all the X-select and Y-select lines for the word being addressed. If a particular bit was a 1, the 1 is written back. If the particular bit was a 0, a current of $-I/2$ is passed through the inhibit line for that particular plane. This inhibited line results in the core seeing an effective current of only $I/2$ and it remains a 0.
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The wait is not over yet, but MOS technology may someday make cores just a memory.

What's a RAM?

Basically, a random access memory requires that any location within it can be reached or accessed without regard to any other location. At the selected location, data may be written (stored) in the memory or read (retrieved) from it. Between the time data is written and read, it must be reliably stored.

The basic capacity of the random access memory to store data and retrieve it at will makes the random access memory or RAM a popular system design tool. Categories such as scratch pads, buffers, main memories, and mass storage are all applications for RAMs.

A scratch-pad memory is a small, fast memory normally associated with the central processor of a computer. The scratch pad, which is used for temporary storage of interim calculation results, must operate at speeds comparable to those of the central processor. This speed requirement means that except for all-MOS computers, scratch-pad operation is not an MOS strong point.

Buffer memories may be employed between sections of a computer, between a computer main-frame and peripheral equipment, or in any digital system where temporary storage is required between operating units. The speed of the buffer must be at least equal to that of the input-output rate of the faster of the operating units and its information storage capability is related to the data rates of the units. MOS random access memories are a logical choice for many buffer memory applications, especially in computer peripherals.

Fig. 1. The basic MOS storage cell. The two p-channel transistors, identified as $R_1$ and $R_2$, are biased on by $V_{SS}$ and act as resistors. The cross-coupled combination of $Q_1$ and $Q_2$ forms the actual storage element and $Q_3$ and $Q_4$ act as switches to connect or isolate the individual cell and the sense-digit lines.
The main memory, or main-frame memory, is the primary operational storage block of a general-purpose computer. In today's computers, this role is filled by magnetic cores almost exclusively. The next generation of computers, however, is expected to use semiconductor main-frame memories. The fastest core memories generally available today operate in the 400- and 500-ns cycle time region. Their semiconductor replacements will operate in the 100- and 500-ns region. Along with this speed requirement, however, is the demand for an enormous number of bits. Main-frame applications start with storage capabilities of about 64,000 bits and many applications demand storage capacities in excess of one million bits.

Mass storage or auxiliary memory is today primarily the province of the magnetic disc. These partially random access and partially sequential magnetic devices store millions of bits at extremely low cost. In order to compete successfully in this market, extremely large LSI arrays must be fabricated at very low cost.

The features that make MOS circuitry so attractive for memory use are very high circuit density, low cost, and low power dissipation. The nature of memories—large regular arrays of identical units—is serving as a spur for LSI development, since memories represent one of the few types of large arrays that can be used in volume by a number of equipment manufacturers.

**The MOS RAM**

The typical MOS storage cell is a remarkably simple, effective, and low-cost design. The cell consists of only six p-channel, enhancement mode devices. Two of these (R1 and R2 in Fig. 1) act as resistors and are biased on by the VDD supply. The two cross-coupled transistors, Q1 and Q2, act as a storage element, and Q3 and Q4 are switches that selectively connect or isolate the individual storage cell from the sense-digit lines. Two sense-digit lines are used, providing dual rail—signal and complement—drive to the cell. The word-select line drives the gates of Q3 and Q4 and operates as a single rail—signal only—input.

With the p-channel devices used, the VSS power supply is the most positive voltage and VPP is negative by 10 V or more. Depending on the particular processing technology used in the construction of the cell and the cell operating constraints, VGG is better equal to, or more negative than, VPP. Since p-channel enhancement mode devices are turned on when the gate is sufficiently negative (relative to the substrate), the substrate is connected to the most positive system voltage, i.e., VSS.

In the storage mode, the cell maintains one of its two stable states. The word select line is in the high logic state (close to VSS) so that transistors Q3 and Q4 are off. As a result, the storage cell is isolated from the sense-digit line. One of the possible stable states exists when the gate of Q1 is low. This means that Q2 is conducting so that its drain (node B) is at a high potential (close to VDD). The difference in potential between VPP and the drain of Q2 is dissipated across resistor R2. The high potential on node B is coupled to the gate of Q1. With this high potential on the gate, Q1 is turned off. As a result, node A is at approximately VPP since there is essentially no current flow through R1. The drain of Q1 (node A), which is connected to the gate of Q2, provides the low or VDD potential that we defined as being stable state 1.

**Writing data in**

To change the information stored in the basic cell, the sense-digit lines are appropriately biased and the word-selection line placed in the active or low state. Assume the sense-digit line condition shown in Fig. 2. Sense-digit line A is at a high potential. The complementary signal is present on sense-digit line B which is connected to a low potential. When the word select line goes to...
Fig. 3. Reading out of the basic storage cell. The portion of the circuit in color is the simple MOS inverter used as the sense circuit.

a low potential, transistors \( Q_3 \) and \( Q_4 \) turn on, connecting the sense-digit lines to the cross-coupled transistors \( Q_1 \) and \( Q_2 \). In the example shown in Fig. 2, \( Q_3 \) connects node \( A \) to the high level on sense-digit line \( A \). This high potential is coupled to the gate of \( Q_2 \) and tends to turn \( Q_2 \) off. At the same time, because \( Q_4 \) is conducting, node \( B \) is coupled to the low supply. This low voltage is applied to the gate of \( Q_1 \) and tends to turn \( Q_1 \) on. This provides an additional path from \( V_{SS} \) to node \( A \), further increasing the potential on the gate \( Q_2 \). Therefore, the indicated sense-digit line potentials in Fig. 2 result in transistor \( Q_1 \) turning on and transistor \( Q_2 \) turning off. This is the alternate stable-state of the storage element. Completing the write operation, raising the word-select line potential, turns off \( Q_3 \) and \( Q_4 \) and isolates the storage cell from the sense-digit lines.

Connecting sense-digit line \( B \) to \( V_{SS} \), sense-digit line \( A \) to \( V_{DD} \), and activating the word-select line will reverse the state of the flip-flop, turning \( Q_2 \) on and \( Q_1 \) off.

Organizations

Applying complementary \( V_{SS} \) and \( V_{DD} \) signals to the sense-digit lines while the word-select line is activated permits writing into the storage cell. For reading, the word-select line is again activated, but this time both sense-digit lines are terminated with MOS resistors. The read scheme is shown in Fig. 3.

Fig. 4. Partial schematic of 64-bit MOS random-access memory (Motorola's MC1170).
The resistive terminations on the sense-digit lines do not change the state of the storage cell when \( Q_3 \) and \( Q_4 \) conduct the sense-digit lines to the storage cell. For the node that is in the high state, the sense-digit line resistor appears in parallel with the internal resistance (\( R_1 \) or \( R_2 \)). For the drain node of the off storage transistor, the sense-digit line terminating resistance appears as an additional source of \( V_{DD} \) potential and through the cross-coupling of \( Q_1 \) and \( Q_2 \) tends to keep the conducting transistor turned on.

In addition to terminating resistors, at least one of the sense-digit lines must contain sensing circuitry to determine the state of the storage cell. At its simplest, this sense circuitry can be an MOS inverter as shown in Fig. 3.

The cell sensing function is shown as a single rail, or signal only, operation. In an actual memory, sensing may be either single or dual rail. The decision is largely determined by the operating voltages and the processing of the MOS structures. As a generalization, low-voltage applications require double rail operation for reliability, while at the higher voltages single rail operation is satisfactory.

**Reading out**

We have spent a considerable amount of space discussing the basic characteristics and the operation of an MOS storage cell. If this design were limited to a single application, the effort might be unwarranted. This is not the case, however, and the simple storage cell is the basis for a wide variety of MOS random access memories.

Where relatively few bits of memory are required, a number of storage cells can be combined with read, write, address, decode, and driving circuitry to form a self-contained memory on a single chip of silicon. For example, Fig. 4 shows a partial schematic of Motorola's MC1170L, a 64-bit random access MOS memory. Organized into 16 words of four bits each, a single unit may be used as a buffer in MOS systems or a number of MC1170s can be combined with additional decoding circuitry to build a main memory of substantial size.

Figure 5 is a close-up of the read and write circuitry of the MC1170 that displays an elaboration of the basic concepts shown in Figs. 2 and 3.

Small MOS memories such as the MC1170 are highly useful. The modest amount of information stored in a single 64-bit memory with the 500-ns cycle time, however, is a far cry from the requirements of a practical replacement for magnetic cores in computer main-frame memory applications.

A much more suitable main-frame building block is the random access storage module shown in Fig. 6. This module stores 8192 bits, and has a cycle time of < 150 ns. For all its sophistication, however, the 8-k memory module employs the same basic storage cells as the 64-bit memory considered previously.

The 8-k memory is not contained on a single monolithic chip, but is a hybrid assembly consisting of 42 separate LSI chips. Thirty-two of these chips are MOS storage arrays, each of which contains 256 basic storage cells (Fig. 7). The principal difference in technology,
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Fig. 8. The storage cell used in the 8-k memory module.

however, is that the relatively slow MOS decoding, driving, and sensing techniques have been replaced by bipolar technology in the 8-k memory module. Figure 8 shows the basic storage cell adapted to the 8-k memory. The four transistors, labelled $Q_{EN}$ and $Q_{FF}$, connect or isolate the chip bit (sense-digit) lines on each storage chip and the memory sub-system bit lines.

The high functional densities, low cost, and low power dissipation of the MOS storage arrays are retained in this concept. The relatively slow operation of MOS circuits does not seriously reduce the operating speed of the module since very few MOS components are involved in any single operation. The complex logic operations, such as decoding and driving, are performed by very high-speed ECL circuits. The interface circuits between the conventional narrow logic swing ECL and the wide logic swing MOS circuits are special bipolar types that provide good driving capability.

For a wide variety of system applications, random access memories and MOS technology are made for each other.

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MOS Course—Part 5

Static or dynamic—two ways to remember

Should the data go round and round or should it just stand still? Here's a look at the two approaches

By Marcian E. Hoff, Jr.
Intel Corp., Mountain View, Calif.

Random access memory devices made with MOS technology use two different techniques to store information. Depending on the type of basic memory cell, MOS RAMs can be categorized as being either static or dynamic. Static MOS memories that usually show poorer performance and higher costs are easier to drive than the dynamic which generally require clock signals in addition to power supplies.

Dynamic MOS circuits make use of the very low leakage associated with the gate circuits and junctions of well made MOS devices. These leakage currents are small enough to permit the circuit's parasitic capacitances to exhibit time constants between milliseconds and seconds. These long time constants may be used to provide temporary storage, which may be made permanent by appropriate cycling or "refreshing" operations.

The static RAM

In the static RAM stage of Fig. 1a, two static inverters are wired together to make a flip-flop. Devices $Q_5$ and $Q_6$ are used as (two-way) transmission gates. When reading, the conducting side of the flip-flop pulls the data line toward ground via these gates. Writing is accomplished by forcing the data lines to the value desired in the cell, thereby overriding the contents of the cell. Because of the small current capability of devices $Q_5$ and $Q_6$, it is important that neither of the data lines be near ground when the transmission gates are turned on. With grounded data lines, the charge associated with the capacitance of the data lines may flip the cell.

As a vehicle for comparison, let's consider a 256-bit static RAM made with p-channel, silicon gate MOS technology. The memory is organized as one 256-bit plane, with full address decoding, and except for additional power supplies, is fully compatible with TTL logic levels. Typical access time is approximately 1 $\mu$s.

The memory chip is easily connected in an array to provide greater memory capacity. Figure 2 shows how the individual packages are connected to realize a 1024-byte memory. Address inputs, write gates (read/write controls), and power leads are common to all packages in the array. Each row in the array corresponds to one plane of a ferrite-core memory, i.e., one row provides storage for one bit of each data word. All data inputs in a given row are connected together. All of the data outputs in a given row are similarly connected. Each memory package realizes one bit from each of 256 bytes. Each column of packages in Fig. 2 corresponds to 256 bytes of memory.

Because it uses silicon gate technology, this static memory provides easy interface to TTL logic levels. The portion of the circuit between the vertical dotted lines in Fig. 3 represents the MOS circuitry on the IC chip interfacing with TTL/DTL levels.

On the output side, a push-pull output stage with input signals $D$ and $\bar{D}$ drives the input to a TTL gate. The output devices are made large enough to draw 2 to 4 mA in the negative direction, sufficient to drive one or two TTL inputs negative. (The TTL should have input diodes so that the TTL input cannot go strongly negative with respect to ground.) Because, in general, it is easier to produce more current in the positive output direction than in the negative, an external resistor $R$ may be used. This resistor draws current from the TTL input, aiding the current drive capacity for the low output. When the MOS output is positive, the upper MOS output device delivers current to the resistor.

The outputs of MOS devices with push-pull outputs of this type may be or-tied if an enable signal $E$ is used. When $E$ is positive, both $D$ and $\bar{D}$ can drive the output. However, when $E$ is negative, the two devices driven by $E$ conduct and cut off both output devices. The output then appears to float. When no resistor $R$ is used, the TTL gate input resistor will pull the MOS output positive. However, if a suitable value of $R$ is used when $E$ is negative, the output will go negative.
This type of connection is used in the output of the 256-bit memory shown interconnected in Fig. 2. Each package has a chip select signal (cs) that is equivalent to the signal E. When cs is positive, the outputs float. In this way, the OR-tied output connection may be used.

The dynamic RAM

The dynamic memory cell of Fig. 1 may also be used as the basis of an MOS random access memory. Unlike the memories constructed with the static cell, the data of these dynamic memories must be periodically refreshed to maintain its validity. Because of the small size of the cell, many more bits of memory may be produced on a chip of given size than can be made with static cells.

The dynamic cell is used as the basis for random access memory chips of up to 1024-bits. One possible organization of a 1024 bit chip is shown in Fig. 4. With this organization, reading and writing occur for all cells of one row simultaneously. Because only one bit at a time is available for writing, an (internal) read operation must be performed prior to writing. This operation insures that the refresh amplifiers contain data corresponding to the contents of the row into which writing will take place.

There are three clock-like signals associated with the dynamic RAM: X-enable, Y-enable, and precharge. The X and Y enable both act as a chip select for both reading and writing. Several chips may have the input-output lead OR-tied to realize larger than 1024-bit planes.

Using silicon-gate MOS technology, the clock signals and addresses are nominally 20 V peak-to-peak. These high voltages are necessary to get high speed performance. The use of TTL compatible levels would add significantly to the memory cycle and access times. Memory cycle times with the high levels are from 300 to 600 ns, depending upon chip organization (several versions are being developed), and drive signal rise and fall times.

To illustrate how the dynamic random-access memory chip of Fig. 4 may be used in a memory, consider the design of 4096 word, 12-bit/word memory. Figure 5 shows how the devices are connected in an array. Each block labeled L is a level shifter to convert from logic levels to approximately 20-V levels. The blocks, labeled W/S, are word driver/sense amplifiers which sense the memory output currents when reading and perform level shifting when writing.

In the memory of Fig. 5, the inputs to the X-enable, Y-enable, and precharge leads of the devices are individually decoded to provide chip selection. Decoding X-enable is sufficient for this function; however, the use of the extra decoders reduces the power dissipation of the memory. A major portion of the memory power dissipation comes from energy associated with charging the device capacitances. The additional decoding reduces the amount of capacitance charged and discharged in each memory cycle (see below, under Volatility).

Optimum configuration

The memory shown in Fig. 5 realizes a 4096-word-by-12-bit memory with 22 level shifters. However, given a particular clock driver (level shifter), some other configuration may require fewer peripheral com-
ponents. The input capacitances of a single device are typically as listed here:

<table>
<thead>
<tr>
<th>Component</th>
<th>Capacitance (pF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1024 bit dynamic MOS RAM capacitances</td>
<td></td>
</tr>
<tr>
<td>Address (X or Y)</td>
<td>5 pF</td>
</tr>
<tr>
<td>X-enable</td>
<td>10 pF</td>
</tr>
<tr>
<td>Y-enable</td>
<td>30 pF</td>
</tr>
<tr>
<td>precharge</td>
<td>30 pF</td>
</tr>
</tbody>
</table>

In the worst case, each input line must make one 20-V transition in each direction during a memory cycle. If rise and fall times must not exceed 20 ns, each package corresponds to a total current drive requirement of 120 mA. With clock drivers of 1-A capability, at least one clock driver must be used for every eight memory packages. The configuration of Fig. 5 required 22 drivers for 48 memory packages—a much poorer ratio.

In general, the lowest cost configuration of this type of memory will be a relatively large array so that all clock drivers can be fully loaded. In this respect, the dynamic MOS RAM differs from many other types of semiconductor memory, in that there is a significant degree of configuration sensitivity. The effect of this configuration sensitivity is to make larger arrays more economical.

**Volatility considerations**

All semiconductor memory devices now available (with the exception of ROMS) are volatile storage devices. To retain stored data, power must be applied to the memory. Static MOS and some bipolar memories may have provision for reduced power operation in which no read or write operations may take place, but data is not lost. In general, power levels to retain data are in the order of several hundred mW/bit. However, dynamic MOS memories offer much lower data-retention power requirements.

As outlined above, each 1024-bit package of dynamic MOS RAM has a total capacitance (sum of all input capacitances) of approximately 120 pF. At most, one 20-V transition in each direction must be made per input per memory cycle. To retain the data, 32 memory cycles must be executed in each 2-ms period. To charge the 120-pF capacitance to 20 V, 2400 picocoulombs must be delivered by the power supply. As only one transition draws power from the supply, the approximately 16,000 memory cycles/s draw a total charge of about 38.4 µC from the supply each second. The total power to execute these drive signals averages under 800 µW, or 0.8 mW/bit. The dc power used by the cells is a fraction of the clock power, and an allowance must be made for the clock driver bias currents. Nevertheless, using suitably efficient clock drivers, total power requirements to retain data should be in the range of 1 to 2 W/million bits. At these power levels, even a small battery pack may be sufficient for retention of data for several hours or more.

These two types of random access MOS memories are examples of components that are being developed by integrated circuit manufacturers. Static 256-bit MOS memories are already available off-the-shelf and larger dynamic memories should be available soon. Initial experience already shows the static memories should cost less than any of the core memories now available, and yet offer significantly higher operating speeds.
2240-BIT MOS CHARACTER GENERATOR.

Off the shelf.

Most static ROM's are custom made for special applications. The Philco® pMS2240C static ROM is different. It's mass-produced and preprogrammed to generate 64 alphanumerics display symbols when addressed by the standard ASCII code.

Another big difference...it’s available right now to fill your digital display circuit requirements.

Bits are organized in 64 groups, in 5 x 7 patterns...enough to create all the alphanumerics characters on a conventional teletypewriter.

Access time for first-row bits is 1 μs, and .7 μs for successive bits.

Output buffers drive either MOS or bipolar circuits. A chip-select lead is provided so that the five parallel output bits can be OR-tied. And because the pMS2240C is a static ROM, the output data will remain valid as long as an address is present.

Prices on request, or order from Philco-Ford Corporation, Microelectronics Division, MOS Marketing, Blue Bell, Pa. 19422; (215) 646-9100.

The better idea people in MOS.
MOS course—Part 5

Performance and cost trade-offs for MOS RAMS

Selecting the right MOS RAM for your application means knowing the design compromises involved.

By Vernon G. McKenny
Mostek Corp., Dallas, Tex.

A number of MOS Random Access Memories (RAMs) are presently on the market. Each has a different combination of speed, power, package, and timing characteristics, and new RAMs, both bigger and faster, will be soon introduced. Some of these new memories will be very easy to use and completely compatible with +5-V bipolar logic. Others will require large input voltage swings, complex timing, refresh cycles, and high-speed sense amps on the outputs. The MOS RAM user can better evaluate all these possibilities if he first gives some thought to the reasons for the different approaches and the trade-offs involved. These trade-offs can be illustrated by examining some of the possibilities for MOS RAMs.

At one extreme, the high-speed RAM aims for high speed and low power resulting in high peripheral complexity. The high-speed RAM with decoding is a compromise between speed and peripheral complexity. On the other end of the spectrum is the RAM with full decoding, output buffering, and read-write control logic. This RAM is by far the simplest to interface with, but speed and power characteristics suffer.

Large dynamic RAMs, although they are subject to the same trade-off considerations as the smaller static memories, are aimed primarily at the low cost market.

The high-speed RAM

The high-speed RAM has its access time specified at 50 ns or less. This so-called access time, however, covers only the delays from the input to the output of the MOS RAM. Since there is no decoding, other than an X-Y matrix, and no output buffering, the memory system must perform these functions in the peripheral circuitry surrounding the MOS memory plane. Decoding, address line buffering, and output sense amps are required. If TTL circuitry performs these functions, a systems speed of 150 to 200 ns is easily attained. The exact speed is dependent on the size of the system. With ECL circuitry, one can expect read or write cycle times in the order of 80 to 100 ns, depending again on both the size of the system and the capability of the address line drivers.

A high-speed RAM can be easily wire-or'ed with the addressing accomplishing the chip enable function; that is, only the selected chip would have both an X-line and...
a Y-line negative. All other outputs would then look like open circuits (except for some transients introduced when switching the x and y address lines).

This approach can keep the power quite low because $V_{DD}$ can usually be pulsed asynchronously to obtain power duty cycles in the order of 1%. However, $V_{DD}$ can even be continuously held negative without dissipating excessive power.

We can consider a 256-word-by-1-bit, high-speed RAM to be a low complexity chip since it contains only the basic memory cell (a simple cross-coupled flip-flop). The chip size is fairly large because of the large device geometries necessary to deliver the required output current. The package is a large 40-lead DIP because of the large number of address lines which must be brought directly off the chip.

Testing this RAM is difficult. A large and sophisticated tester is required to both drive the inputs over a 16 to 20 V swing while sensing output data in the order of 20 to 100 mV across a termination resistor. It is difficult to measure the 50-ns propagation delay through the chip on an automatic basis.

**A high-speed RAM with partial decode**

In this case, a RAM with "partial decode," the address lines are actually fully decoded, but each address input requires high amplitude true and complement signals. Thus, for a 256 by 1 RAM, a total of 16 input pins (8 true and 8 false) would be required rather than the 32 input pins on the high-speed RAM without any decoding. Using the same current-sense type outputs as the high-speed unit, access times of about 200 ns through the chip can be obtained with system read or write cycle times in the order of 300 ns.

Since the decoder requires no dc current, the power consumption remains essentially the same as on the high-speed RAM.

The complexity would be considered medium and the chip could go in a 24-lead DIP. The chip size would be somewhat larger than that of the high-speed RAM, although if the load devices inside the cell were left out, a considerably smaller chip could be obtained. However, a refresh pulse would be required periodically.

The testing problems are similar to that of the high-speed RAM, except that it now becomes easier to measure speed automatically.

The cost is about the same as the high-speed RAM without decode because the chip is larger but the package is smaller.

**RAM with full decode**

The RAM with full decode has complete address decoding and buffering, data and control input buffering, and output buffering. In addition, it can accept TTL input signals and drive TTL outputs without any external resistors or other components. A static memory system would require no components other than the memory chips themselves. This simplicity of use, unfortunately, is not free. The price to be paid is speed and power.

The speed has been reduced to about a 1.0-µs cycle time and 400 to 500 mW of power dissipation for the low-threshold version.

![Chip interface for a memory with full decode and low threshold voltage.](image1)

With $V_{ss}$ equal to +5 V, a high threshold MOS RAM chip can drive TTL directly. However, the input does require level shifters.

![Microphotograph of a high-speed RAM.](image2)
The speed can be improved to about 0.5 µs by combining a high-threshold process and correspondingly large supply voltages at the cost of increased power (about 600 mW), and using external rather than internal interface components. There are at least two ways to handle the interface problem. First, if the substrate voltage, \( V_{SS} \), is connected to +5 V, then the outputs can drive TTL with no external components. The inputs, however, will require level shifters that can swing between +5 and all least −5 V. A second approach connects \( V_{SS} \) to +12 or +15 V so that open-collector TTL can drive the inputs. Each MOS output must now have a 6.8-KΩ resistor in series with the output pin with one or two diodes to protect the TTL from overdrive. The best approach depends on the power supplies available and the total number of inputs vs outputs in a given system.

This high complexity chip is only slightly larger than the high-speed RAM because of the smaller cell; it does not have to drive the outside world directly. The organization, 64 words by 4 bits, compromises between package (which is a 24-lead DIP), layout, and speed. A 256 by 1 organization, while offering a smaller package, requires a small MOSFET within the cell to discharge a capacitance almost four times that in the 64 by 4. A 128 by 2 organization is no more attractive as it will not fit into a smaller package. A 32 by 8 organization requires a larger package, probably a 40-lead DIP, with no significant improvement in speed but a significant increase in power due to the number of input and output buffers required. A complex, though less sophisticated, tester than that required for the high-speed RAM would be used that could accomplish 100% testing (including speed), on a completely automatic basis.

Even though this RAM has the same chip size and package size as the high-speed RAM with decode, it costs somewhat less because the thin-oxide area is significantly less.

Large dynamic RAMs

A dynamic RAM would have its input address lines fully decoded, either with or without input buffering depending on the speed desired. Likewise, the outputs could be completely buffered and capable of driving TTL directly. Current sense outputs can provide higher speed, although the output current would probably not come directly from the cell as in the high-speed RAM.

A high-speed version—no input buffering and current sense outputs—would probably have an access time in the order of 0.5 µs and power consumption of <100 mW. A low speed version—full input and output buffering—would probably no slower than 2.0 µs but would have power consumption in the range of 500 to 600 mW.

The dynamic cell, usually three small MOSFETS, forms half of what amounts to a cross-coupled flip-flop, or half of a clocked, 1-bit shift register recirculating upon itself. In a 1024-bit, dynamic RAM, 32 cells in a column would share the “refresh” circuit at the top of the column. This refresh circuit forms the other half of the 1-bit shift register. Only the cell in the selected row can be connected to the refresh and read-write circuitry, and only the cell in the selected column is connected to the read-write circuit. The result is that all cells in a selected row are refreshed even though only the cell in the selected column can be read from or written into. Although this means that the RAM can be refreshed in 32 refresh

(Continued on page 81)
MOS GOES BIPOLAR

MOS shift registers and read only memories in the National Semiconductor product line have been bipolar compatible since we began manufacturing MOS. Some devices are more compatible than others. It is all a matter of degree. In this brief, we show what voltage levels are required on each pin of the device and what must be done to interface with bipolar circuits.

There have been many questions about applying negative voltages to the input and high voltages (+10 or +12 volts) to the output of a TTL or DTL device. It is true that the bipolar data sheets do not guarantee this operation. Part of the reason being that the situation had not occurred previously. When a negative potential is applied to the input of the TTL/DTL device, it is clamped to one diode drop below ground. The current is limited by the output transistor in the MOS device to about 5 mA or by the external pull-down resistor to 1.6 mA. Since the input clamp diode can handle at least 10 mA, this will cause no trouble in the system.

When a high positive potential (+10V to +12V) is applied to the output of a TTL device, two precautions should be taken: either use a series 54/74 device that has a reverse biased diode in the active pull-up, or use an uncommitted collector output. If the maximum breakdown voltage of the device is exceeded (it probably will not be on our TTL devices), the output will go into a non-destructive breakdown mode. The output will assume the LVCEO voltage level of the output transistor as long as the current is limited. For those customers that are still concerned about these operating characteristics, we have two TTL devices guaranteed to have 14 volt breakdown voltage output. They are the DM8810 Quad 2 Input Gate and the DM8812 Hex Inverter Gate.

The voltage required on each pin of our standard product line is shown in this brief. Also included are logic diagrams showing the recommended methods of combining MOS and bipolar circuits in a system. New products will be added as they become available.
MOS/TTL interface connection diagrams

**FIGURE 1**

**FIGURE 2**

**FIGURE 3**

**FIGURE 4**

**FIGURE 5**

**FIGURE 6**

**FIGURE 7**

**FIGURE 8**

**FIGURE 9**

**FIGURE 10**

*Resistor optional.

National Semiconductor Corporation
2900 Semiconductor Drive, Santa Clara, California 95051
(408) 732-5000 / TWX (910) 339-9240
### Comparison of Characteristics

<table>
<thead>
<tr>
<th>RAM Type</th>
<th>Organization</th>
<th>Speed</th>
<th>Power</th>
<th>Complexity</th>
<th>Package (DIP)</th>
<th>Cost per bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>H.S. RAM</td>
<td>256 x 1</td>
<td>50 - 200 ns</td>
<td>500 mw/5mw</td>
<td>Low</td>
<td>40</td>
<td>10 - 12¢</td>
</tr>
<tr>
<td>H.S. RAM with partial decode</td>
<td>256 x 1</td>
<td>200 - 300 ns</td>
<td>500 mw/5mw</td>
<td>Medium</td>
<td>24</td>
<td>10 - 12¢</td>
</tr>
<tr>
<td>RAM with full decode</td>
<td>64 x 4</td>
<td>0.5 µS - 1.0 µS</td>
<td>600 - 400mw</td>
<td>High</td>
<td>24</td>
<td>7 - 10¢</td>
</tr>
<tr>
<td>Dynamic RAM</td>
<td>1024 x 1</td>
<td>0.5 µS</td>
<td>100 mw</td>
<td>Medium</td>
<td>16</td>
<td>3¢</td>
</tr>
<tr>
<td></td>
<td>256 x 4</td>
<td>2.0 µS</td>
<td>500 mw</td>
<td>High</td>
<td>24</td>
<td>5¢</td>
</tr>
</tbody>
</table>

cycles (which may also be read and write cycles), it also means that entire memory cannot be refreshed at once. It is possible to have a refresh cycle going on inside the chip which would function during memory standby time.

The simple cell reduces the high-speed version of the dynamic RAM to a medium complexity chip. The fully buffered, lower speed version, with its automatic refresh feature, would be a high complexity chip. The low-speed version would offer the advantage of a 16-lead DIP if the same pin could be used for both input and output data flow. Even the high-speed version, with its simplified inputs and outputs, would be a large chip. The fully buffered version would probably push the upper limits of practical chip size.

Testing would be difficult. Not only would the input timing and data patterns be complex, but the testing of the automatic refresh feature would involve a large amount of test time for each chip.

A dynamic RAM of 1024 bits would cost more per chip than any of the smaller RAMs. The cost per bit, however, would be significantly less.

### Memory Organization

The basic organization of most memories usually conforms to binary word and bit lengths. The most convenient, from the users' standpoint, is probably X words by 1 bit for an X-bit RAM. This is also the optimum organization for keeping the pin count to a minimum if the chip is fully decoded. However, circuit layout and performance limitations often dictate other organizations, such as X/2 by 2 or X/4 by 4.

Organizations of X/8 by 8 and beyond usually become impractical due to power (more input and output buffers) and pin count considerations. A change from X by 1 to X/2 by 2 can usually be accomplished without sacrificing too much in terms of pin count (one additional pin). This can mean a significant increase in speed because the small, high resistance devices inside the cell now have about half the capacitance to discharge.

The change from X/2 by 2 to X/4 by 4 will not gain the circuit designer quite as much speed as does the change from X by 1 to X/2 by 2 due to the other propagation delays within address decoder and output buffers. The X/4 by 4 may be necessary to gain the required speed but it will most certainly need a larger (and more expensive) package as a result.

**Summary**

Of the four RAMs outlined here, the most popular are the "RAM with full decode" and the "large dynamic RAM." The reasons are the simplicity of application and the lower cost per bit, respectively. The "high-speed RAM" is, by far, the fastest and offers the lowest power dissipation, but at the cost of increased complexity of the peripheral circuitry. The "high-speed RAM with partial decode" is a compromise between lower complexity in the surrounding circuitry and speed (although the speed is not much slower than the "high-speed RAM" when TTL decoding and sensing is used).

Many combinations of the illustrated trade-offs are possible. In fact the large MOS RAM user can have a RAM chip tailored to fit his system requirements, provided that he is aware of the limitations and advantages of each approach.
Had enough talk about LSI memories?

Incomparable 256-bit MOS RAMs

In volume production since August 1969, Intel's Model 1101 is a fully-decoded silicon-gate MOS device with 1.5 μsec maximum cycle time. Drives DTL and TTL logic directly. Has OR-Tie capability. Dissipates only 50 μW per bit on standby and 2 mW per bit during access. Packaged in 16-lead DIPs. Intel can begin immediate delivery to you in production volume at a price of about 6¢ per bit.

Fast 64-bit bipolar RAMs

Intel's Model 3101 has been in volume production since September 1969. It's a fully-decoded Schottky-process bipolar RAM with fast 60 ns maximum access. Compatible with DTL and TTL logic. Has OR-Tie capability. Dissipates 6 mW per bit. Packaged in 16-lead DIPs. Immediate delivery in production volume at a price of about 25¢ per bit.
Here's the real thing in volume!

Big 1024-bit bipolar ROMs

Intel's Model 3301 has been in volume production since December 1969. It's a Schottky-process bipolar ROM with 60 ns maximum access. Supplied in 16-lead DIPs that combine to form memories storing 1024 words of any length. Intel can deliver custom 3301's to match your truth table in 4 to 6 weeks at a price of about 2¢ per bit in production quantities.

Ultra-fast 1024-bit shift registers

In production and in stock right now. They're silicon gate MOS devices with five times the speed (5 MHz) and twice the bit capacity of any others. A single TO-5 holds one long 1024-bit register (Model 1404) or two 512-bit registers (Model 1403). And there's a 16-lead DIP that holds four 256-bit registers on one chip (Model 1402). Clock capacitance is a low 140 pF. Power dissipation is only 500 mW at 5 MHz, dropping to 200 mW at 1 MHz. Input and outputs are DTL and TTL compatible. These registers (plus a dual 100-bit register with similar characteristics) are available immediately in volume for about 1½¢ per bit.

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Intel's advanced high-yield technologies (like the Schottky process for bipolar and the silicon gate for MOS devices) produce custom MSI's fast and dependably. You can get delivery of parts within 4 to 6 months after you place the order. Intel can meet or beat anyone's specs, and prototype development is free.

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DESIGN FEATURES

Frequency synthesizing with the Phase Locked Loop

The advancement of IC technology has made phase locked loop circuits feasible. Here the phase locked loop is the basis for a new, somewhat unconventional digital frequency synthesizer design.

By Ed Renschler and Brent Welling,

Once it is understood, the principle of the phase-locked loop has many applications. An ideal application is a multichannel frequency synthesizer, because many precise frequencies can be generated with only one reference frequency.

With more and more versatility being offered by ICS, we decided to take a fresh look at normal digital frequency synthesizer designs. We chose a portion of an aircraft communications band synthesizer system as a test vehicle for this study. This system, which uses monolithic ICS wherever possible, has the following specifications:
- freq. range, 116.000-136.000 MHz;
- channel spacing, 50 kHz (400 channels);
- ref. freq. sideband level, -66 dB;
- ref. freq. harmonic sideband level, -70 dB;
- spurious sideband level, -60 dB;
- power output (min.), 2mW.

System considerations

The frequency going into the variable counter (Fig. 1) must be N times the frequency at the reference input of the phase detector. To achieve the design goals, the variable counter must be externally programmable over 400 different counting states. We must now consider two things:
- The variable counter must function at a worst case rate of 136.0 MHz.
- Stability of the frequency reference (and phase) at the input of the phase detector is the key to the system's frequency stability.

The first is the real problem area. Making a 9 to 12 bit counter, (depending upon counting method used) operate at a clock rate of 136 MHz is a big problem. To solve it we decided that the vco's output frequency (116-136 MHz) should be counted down by a high speed decade counter to yield 11.6-13.6 MHz, a less restrictive frequency range.

Stability of the reference is easily solved by using a crystal controlled reference oscillator (Electronic Research Co., Model 800 TS3 703-B-4), which provides a 10 MHz reference frequency with a long term stability of 4 parts in 10^8.

To further reduce clocking requirements of the programmable counter, we mixed the reference frequency with the 1.6-13.6 MHz frequency and used the difference (1.6-3.6 MHz), for the counter clock.

To obtain 400 channels in a frequency spectrum of 1.6-3.6 MHz, the channel spacing must be 5 kHz at the counter, or 50 kHz at the vco—as desired. It follows that a 5 kHz highly stable frequency reference is needed at the input of the phase detector. This can be obtained by dividing the 10 MHz frequency by 2000.

Another problem with the simplified diagram is that when a new channel is dialed into the counter, the vco will sweep until it reaches phase lock once again. This could cause considerable interference to be transmitted during sweeping time. Thus when an out-of-lock condition exists, the output rf amplifier is gated off, and remains off until phase-lock is once again established.

One last point of interest is the vco tuning voltage

![Fig. 1: Linearized phase-locked loop model.](image-url)
Basic analysis of a phase-locked loop system*

In a basic system, the phase detector will generate a voltage proportional to the phase difference between output and reference frequencies. The detector's output voltage is filtered to remove all time variant components before it is applied to the voltage controlled oscillator (vco). Since the vco generates a frequency proportional to its input voltage, any ripple appearing on the control voltage will frequency modulate the vco.

This system may be analyzed like any feedback control system with the understanding that the phase (θ) is the variable of interest. As was just discussed, the phase detector will generate a control voltage proportional to the phase difference as

\[ V_c = K_p (\theta_{REF} - \theta_{VCO}) \text{ volts,} \]

where \( K_p \) is the proportionality constant in volts/radian, and \( (\theta_{REF} - \theta_{VCO}) \) is the phase difference in radians.

When \( f_{VCO} \) and \( f_{REF} \) are not the same, the control voltage produced by the phase detector will cause the vco to sweep in frequency. While the vco is sweeping, there will be an instant when

\[ f_{VCO} = f_{REF}. \]

When this condition exists, phase lock is established.

The basic system will generate a single (reference) frequency. This is an example of a phase-locked loop used as a very selective, low noise filter. If you want the system to generate more than one stable output frequency without using multiple reference crystals, you can insert a variable counter in the feedback loop.

The operation of this modified system is identical to that of the basic system except that the vco control voltage now is

\[ V_c = K_p (\theta_{REF} - \frac{\theta_{VCO}}{N}), \]

where \( N \) is the number programmed into the variable counter. From this last equation the range of allowable numbers in \( N \) determines the number of finite control voltages, which in turn specify the number of controlled output frequencies obtainable. Also, each of these frequencies, once phase-locked, will be phase coherent with the reference crystal and thus have the same stability as the reference.

From the diagram, for phase lock to occur, we must have:

\[ f_{REF} = \frac{f_{VCO}}{N}. \]

That is, the vco frequency must be the divide ratio \( (N) \) times the reference frequency:

\[ f_{VCO} = Nf_{REF}. \]

From this it would appear that we could obtain any output frequency and any desired channel spacing, but practical considerations limit the use of this basic diagram.

The vco's output frequency is proportional to the control voltage. However, in terms of phase, the vco functions as an integrator. To illustrate this, consider the case when the phase detector's output \( [\theta_{REF} (t) - \theta_{VCO} (t)] \) is a step function of voltage. This voltage drives the vco, and causes a step change in the vco's output frequency. Since frequency is the time rate of change of phase, the phase angle of the vco output with respect to the reference phase will start to increase linearly at time zero and continue indefinitely like a ramp function. This ramp function-step function relationship illustrates the integrating operation of the vco on phase changes in the system.

The vco gain constant, \( K_p \), is the sensitivity of the vco to a change in the control voltage, \( V_c \).

We can show that a phase-locked loop is nonlinear. However, if each subsystem is properly defined in a linear range, reasonably valid results can be predicted from the linearized model.

*For a comprehensive analysis of a phase-locked loop see Motorola Application Note AN463.
Fig. 2: Improved digital frequency synthesizer system. Circuitry for boxes A, B, C, D and E can be found in Fig. 4: Sampling timing diagram.

Fig. 3: boxes F and G in Fig. 6; box I in Fig. 7; box J in Fig. 8 and box K in Fig. 9.

Fig. 5: Loop filter response.
range. The phase detector's output must generate a voltage that will cause the vco to sweep its entire 20 MHz band. This causes the vco sensitivity ($K_v$) to be very high, making the filter requirements much more severe and the loop stability marginal. In addition, the vco will be susceptible to noise on its control line. To reduce this sensitivity, a D/A converter pretunes the vco to within ±1 MHz of the correct frequency. (The converter obtains its input from the programmable counter control logic.) In this way, the full output of the phase detector is used only to fine-tune and establish phase lock, reducing the sensitivity by a factor of 10.

**System design details**

A more detailed diagram of the system is shown in Fig. 2. Each block is identified by a letter.

(A) The reference frequency is obtained from a 10 MHz crystal oscillator that is enclosed in a temperature controlled environment.

(B) It is necessary to have a 5 kHz reference frequency, with crystal accuracy, available for the phase detector and frequency discriminator. To obtain this 5 kHz reference, a divide-by-M ($M = 2000$) counter is needed. Since the frequency of the reference is within the frequency of operation of medium-speed saturated logic, it is convenient to use MC838P packaged decade counters. The divide-by-2000 function is achieved using a MECL level translator to obtain saturated logic levels compatible with standard MDTL. The output from the divide-by-M counter is compatible with the phase detector and the frequency discriminator. Thus, further level translation is not needed.

(C) The phase detector is a sample-hold-delay-sample-hold configuration. One input comes from the op amp (MC1520G) integrator whose input is the 5 kHz reference frequency and whose output is a 5 kHz ramp. The phase detector consists of two MOS transistors (2N4351), which perform the sampling function, two holding capacitors, a high dc input impedance (JFET) amplifier (2N4221), and three IC one-shots (MC851P) which perform the sample-delay-sample function. The sampled input is the 5 kHz reference ramp and the sampling frequency is the output frequency of the variable divider. Each of the one-shots has been adjusted by means of the 160 pF capacitor to give a period of 1 µs.

The phase detector operates as follows: The input waveform to be sampled is shown in Fig. 4. Assume that the variable divider's output is out of phase with the reference frequency by a phase difference $\theta_D$. Output of the divide-by-N counter triggers the first one-shot. This one-shot samples the reference frequency ramp for 1 µs placing voltage $V_{s1}$ on the first capacitor. At the end of this sample time, the first MOS transistor turns off and holds $V_{s1}$ on the first capacitor. Also, when the one-shot turns off, it triggers the second one-shot to produce a 1 µs delay. At the end of the delay, the third one-shot fires, turning on the second MOS transistor which transfers part of the charge of the first capacitor to the second capacitor. Since the capacitors are equal, the voltage on the second capacitor at the

---

**Fig. 6: High-speed divide-by-ten function.** Four ceramic flat-pacs were used, with care taken in the layout.

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Thus, for this particular system, we measured the emitter follower provides an impedance transformation of the reference ripple passing through this sample and hold phase detector along with the dc voltage and found it to be 10 µV. This method of phase comparison greatly relaxes the requirements of the low pass filter.

(D) The low-pass filter should provide two functions: (1) a dc gain of 15 (23.5 dB) to increase the vco tuning voltage range from 0.9 to about 13 V, and (2) to further supress the 5 kHz reference ripple which can frequency modulate the vco. The active filter shown in Fig. 3 was chosen. Its response is shown in Fig. 5.

The vco fine tuning voltage has now been increased to a dynamic range of 0 V to 13 V while the 5 kHz ripple has been attenuated 30 dB.

To further improve the system's performance and reduce the sideband levels, we could use a multiple notch filter. An active filter with notches at 5 kHz, 10 kHz, 15 kHz, and 20 kHz would reduce the sideband levels considerably.

(E) The system's vco is a basic Clapp type using collector-to-emitter feedback in the common base configuration. With this configuration the frequency selective, high Q tank network can be in the collector circuit. An hf 2N3959 transistor is biased to a collector current of 0.7 mA giving a minimum fT of 400 MHz. Voltage tuning is accomplished with three Epicap diodes in the tank circuit. One set of diodes acts as a course tuning control with the input voltage (VTC) generated by the D/A converter operating from the counter logic switches. The third Epicap diode is in series with a small trimming capacitor and is used as the fine tuning control in the phase loop with its input voltage (VTF) coming from the loop filter.

If we assume a linearized system, the vco must have a constant sensitivity, Kp, (the plot of frequency vs. tuning voltage should be linear). The network-using diode D1 (the silicon diode connected to the +5.2 V supply) was used to achieve a good linearity (5%). Diodes D2 and D3, were inserted into the low side of the tank circuit to provide temperature compensation to the oscillator.

Operation of this temperature compensation is as follows: as the temperature increases, the capacitance of the Epicap diodes increases and the frequency of oscillation decreases. However, as the temperature increases, the voltage drop across D2 and D3 in series decreases. Since the tuning voltage remains constant, the total voltage across the tuning diodes goes up, causing the capacitance to go down, ideally causing a zero net change in frequency. When measured over a range from 0°C to 85°C, the maximum deviation with temperature was ±200 kHz.

(F) It is desirable to reduce the high-speed clock requirements of the programmable counter. To achieve this, we divided the vco output (116-136 MHz) by ten (K = 10) and mixed the resulting frequency (11.6-13.6 MHz) with the crystal reference frequency (10 MHz). The difference frequency out of the digital mixer (1.6-3.6 MHz) is then used to clock the variable counter.

The first step in reduction of the vco frequency requires a high-speed decade counter compatible with the vco output. Two things point to use of an emitter-coupled current-mode counter:

- It is reasonably compatible with the vco output signal.
- It must clock at about 140 MHz worst case.

We decided that the optimum arrangement would be to have one high-speed current-mode flip-flop (MC1034F) operating in the toggle mode which will divide the 116-136 MHz down to 58-68 MHz, followed by a divide-by-five circuit, again using the MECL emitter coupled ics. In this way, the clocking requirement of the divide-by-five counter is only 70 MHz instead of 140 MHz.

(G) The digital mixer circuit takes the output from the high speed decade counter \( F_{\text{vco}} \) and mixes it with the crystal reference \( F_R = 10 \text{ MHz} \) to obtain a difference frequency \( F_D \) as

\[
F_D = \frac{F_{\text{vco}} - F_R}{10}
\]

\[
F_D = (11.6 - 13.6 \text{ MHz}) - 10 \text{ MHz}
\]

\[
F_D = 1.6 - 3.6 \text{ MHz}
\]

which is suitable for clocking the variable counter. There are several ways to perform this mixing action. One which seems to be satisfactory is the use of an exclusive-or gate. When this function is analyzed it is found that the sum, difference, and a spectrum of harmonics are available at the output for two different frequency inputs. Hence, the difference frequency can be extracted by inserting a bandpass filter. The exclusive-or digital mixer is simple, accepts digital inputs, and provides a digital output suitable to drive the variable counter.

(H) The difference frequency out of the digital mixer is the input frequency for the programmable counter. For Eq. 3, we have \( F_{\text{in}} = F_D = 1.6-3.6 \text{ MHz} \). The variable counter will divide this input by a number \( N \) such that the output is 5 kHz, which is used as the sampling frequency input to the phase detector. Hence,

\[
N = \frac{F_D}{5 \text{ kHz}} = \frac{1.6 - 3.6 \text{ MHz}}{5 \text{ kHz}} = 320 - 720
\]

This illustrates that \( N \) varies in increments of 1 over a range of 400, which accounts for the 400 possible chan-
Fig. 7: D/A converter is a weighted resistor configuration. The input is obtained from the selector switches that program the variable counter.

Fig. 8: Frequency discriminator. The criterion for determining out-of-frequency-lock is when the output of the variable-counter waveform crosses a reference point, going negative, more than once since the reference waveform has crossed a similar point going negative. Since only negative going transitions are of interest, the input MC851 one-shots are used which generate a 100 ns pulse to indicate each negative transition. When an out-of-frequency exists, a pulse is generated in the second MC851 which produces a 100 μs pulse. This pulse is filtered and applied to the input of a differential output op amp (MC1520). Output of the op amp drives a dual voltage comparator (MC1711) operating as a window detector. As long as the output from the op amp is zero plus or minus a small amount, it lies within the input window of the detector and the detector output will be a logical “0”. However, if the output of the op amp deviates from this window, as it will in an out-of-frequency condition, the detector output will be a logical “1”. The logic output from the window detector is used to drive the inhibit gate of the output rf amplifier.

Fig. 9: Gated amplifier. This stage serves as a buffer between the output of the synthesizer and the system into which it feeds. It also lowers the output of the synthesizer at least 40 dB when the synthesizer is out of frequency lock. This is done by applying the logical output from the window detector to the 2N3904 transistor, as shown. When this transistor is turned on, it removes the dc bias from the amplifier, which causes the 40 dB reduction in output.

Fig. 10: Actual measured closed loop response. The measured damping coefficient of 0.55 indicates that very little overshoot is present, giving rise to a stable system with excellent transient response. Lock-up time is about 2 ms.
nels. For 5 kHz steps in $F_D$ ($K = 10$ in the high speed counter), the steps in the vco output are 50 kHz, which is the desired channel spacing. This explains the use of a 5 kHz reference frequency in the phase detector.

Examining the counter requirements, we find that we need a three decade counter that can be programmed externally to count over the proper counting range at the clock frequency specified. The worst case clock frequency for this design is 3.6 MHz. The logic setup available with the company's MECL II 50 MHz divide-by N counter easily meets these counting needs.

With this counter, a BCD equivalent of the decimal number $N$ is initially preset into a three stage counter. Each clock pulse that arrives reduces the count by one. When a count of one is reached, a reset cycle is initiated, and at the zero count the number $N$ is reloaded into the counter stages so that when the next clock pulse arrives, the counting sequence can begin again.

The counter, as designed, required two clock periods to achieve reloading, therefore, its counting capabilities are $2 \leq N \leq 999$ which well satisfies this system's need. The counter can also be programmed directly from a computer. It can allow its divide number input, $N$, to be changed while counting is in process, without miscounting, as long as the input number is not being changed during a reload period.

The counter has been operated in a worst case count of $N = 2$ at a clock rate of over 50 MHz.

(I) The D/A converter coarse tunes the vco to within $\pm 1$ MHz of the final frequency. This requires a fine tune voltage—the output of the low filter—to be able to capture and lock-up within a 2 MHz range. This approach yields an order of magnitude improvement in vco sensitivity over a system that requires the phase detector voltage to be the sole tuning voltage.

(J) The frequency discriminator and logic gate inhibit the rf amplifier until the vco is at the proper frequency. This prevents unwanted frequencies from being passed through the rf amplifier into a modulating section and jamming a number of communication channels as the vco searches to achieve lock-up.

(K) The circuit used for the rf amplifier (with inhibit) uses a monolithic rf-if amplifier, the MC1550.

Acknowledgement

We wish to express our appreciation to Loren Kinsey and Al Collum for their assistance in building and evaluating the synthesizer system.

Bibliography

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915  Clock rate limit circuit

Stephen Faris
Honeywell Co., Waltham, Mass.

When working with pulse circuitry, it is often desirable to limit the maximum clock rate that can be applied to a system.

One simple way of accomplishing this clock rate limiting is with a dual one-shot such as the Amelco 342CJ, in the circuit shown here.

The output from the first one-shot blanks its own input by means of the diode expander gate on the 342. You should choose \( T_1 \) and \( T_2 \) slightly less than \( T / 2 \). In this way, any repetition rate higher than \( 1/T \) will not pass because of the diode expander which forms a \textit{NAND} gate.

Since each one-shot has a recovery time, you cannot use just one. With a single circuit, excess pulses could sneak through during the recovery interval. With the connection shown, the only problem would occur when control is transferred from the first to the second one-shot. You can prevent this by slowing down the rise of the first one-shot output with capacitor \( C_1 \).

916  BCD to 9's complement converter

Ken Erickson
Interstate Electronics Corp., Anaheim, Calif.

The 9's complement of binary coded decimal numbers is often used in programming \textit{bcd} frequency dividers or in performing decimal subtraction. This circuit easily accomplishes the transformation from \textit{BCD} to 9's complement.

The circuit uses a 4-bit binary adder and four inverters. Conversion is accomplished because of the fact that the 9's complement of a \textit{BCD} number is formed by first deriving the 1's complement and then adding \( 10 \) (binary 1010) to it. The inverters in the circuit form the 1's complement which is then fed to the binary adder where 10 is added. The carry output \( C_4 \) is not used.

The circuit shown would be repeated for each decimal digit. If the inverted \textit{BCD} inputs are already available, as is often the case, then of course the inverters are not needed.

Carry input \( C_0 \) can be grounded as shown if only the 9's compliment is desired. You may, however, use the input to add an end-around carry in subtraction applications. Also, the 10's compliment of the input can be formed by applying logic 1 to \( C_0 \).
917 Noise-insensitive monostable multivibrators

E. G. Faris
Sparton Electronics, Jackson, Mich.

Common monostable multivibrators are extremely sensitive to $B^+$, ground, and input trigger noise. The greatest source of nonsignal triggering in a common monostable multivibrator is $B^+$ noise which couples through $R_1$, $C_1$, $D_1$, and the base of $Q_2$ and thus turns off $Q_2$. Another problem is that at power turn-on, there is no assurance that the circuit will start in its stable state (i.e., $Q_2$ is cut off).

You can eliminate the inadvertent triggering problem with this circuit. It combines a modified unijunction transistor oscillator with a flip-flop and two inverters. The combination of $R_1$ and $C_1$, effectively filters $B^+$ noise to ground. Furthermore, the flip-flop is very stable because it will only trigger on a large $B^+$ noise.

When power is turned on, the voltage at $C_5$ rises exponentially to $+5$ V. This causes the voltage at $A$ to go high and remain high until an input signal reverses the state of the flip-flop (high = logic 1 = $+5$ V; low = logic 0 = 0.2 V). Since $V_A$ is high, the unijunction oscillator is shut off and $V_E$ is high; that is, the output $V_E$ is a logic 1.

When the flip-flop changes state, $V_B$ goes high, $V_A$ and $V_E$ go low. With $V_A$ low, $Q_4$ is shut off allowing $C_1$ to charge through $R_1$ to $\eta$ $B^+$ with a time constant of

$$T \approx R_1 C_1 \ln \frac{1}{1 - \eta}.$$

When $Q_4$ fires, $V_B$ goes low and resets the flip-flop. This turns on $Q_1$ and shuts off the oscillator causing $V_E$ to become high again. Thus, the output pulse width is determined by $T$ and is free of the effects of erroneous trigger noise.

Note that if at power turn-on the input signal is low, both inputs of the flip-flop are high. Therefore, to prevent an erroneous output signal, the output is derived from point $A$.

Resistor $R_4$ must be of sufficient value that the output pulse of $Q_2$ exceeds the maximum threshold voltage needed to turn on the inverter. Resistor $R_3$ must be of sufficient value that it does not prevent the regenerative action of the flip-flop.
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This simple circuit generates excellent square waves over a wide frequency range with a minimum number of components and with a convenient 12-V supply. With the component values shown, the circuit produces 42 Hz to 13 kHz square waves with only one tuning control.

The circuit consists of a unijunction transistor pulse generator operating from about 84 Hz to 26 kHz, followed by a new high-voltage RTL frequency divider.

The UJT circuit is a conventional relaxation oscillator. The capacitance of $C_1$ can be increased for a lower frequency range, or decreased for higher frequencies. A Mylar, mica or other stable capacitor should be used since many disc ceramics are very temperature sensitive. The circuit easily oscillates to 1 MHz with an Annular UJT; the plastic 2N4871 at 68 cents is recommended. The combination of $R_1$ and $R_2$, along with $C_1$, determines pulse rate:

$$f = \frac{1}{2C_1(R_1 + R_2)}$$

The maximum tuning ratio is equivalent to $(R_{1 \text{MAX}} + R_2)/R_2$. In this case it is about 5 MΩ/15kΩ or 333. Resistor $R_1$, which determines the maximum frequency, must be at least 15 kΩ to ensure oscillation, while 5 MΩ is about the maximum useful value for $R_2$. A log taper potentiometer used for $R_1$ minimizes scale crowding. You may have to trim $R_1$ to provide reliable triggering of the following stage at the extremes of the frequency range, especially if $C_1$ is changed.

The MFC4040 is a low-cost, divide by two IC. It is basically a high-voltage RTL flip-flop with only four terminals (input, output, positive supply and ground). The output is through an internal buffer stage. The circuit operates reliably from 4 to 16 V and draws about 12 mA at 12 V, instead of the 45 mA at 3.6 V required by conventional RTL. It seems to trigger reliably to at least 5 MHz.

Output of the circuit is a peak-to-peak voltage slightly less than the supply voltage (about 11 V with a 12 V supply). The output level can be adjusted with potentiometer $R_5$. 
Two simple facts make this diode the best current-controlled resistor you can buy.

**Performance.** HP’s PIN diode offers better cross-modulation and second order distortion performance than FETs or other conventional techniques. Our current-controlled resistors have an effective minority carrier lifetime of 1.3 $\mu$s with extremely low distortion over the 1 MHz to 1 GHz range. They also have tight resistance tracking between units, and the RF resistance limits are fully specified.

**Price.** You get all this for 99¢ each in 10,000 lots, the lowest priced PIN diode anywhere! Even lower costs in larger quantities. Which now moves true high performance within the price range of low-frequency designers.

Before you design your next equipment with current-controlled attenuators, constant-impedance AGC, levelling and switching circuits, talk to us about specs and prices and immediate delivery on the 5082-3080 PIN diodes.

**HEWLETT PACKARD**

**SOLID STATE DEVICES**

Circle 50 on Inquiry Card

114 The Electronic Engineer • June 1970
New keyboard simplifies electronics

Many of the keyboards presently on the market use reed switches because of their proven reliability. However, contact bounce can be a problem. The problem has been solved in a variety of ways, but each of these approaches has added to unit cost and complexity and has decreased reliability.

Now Cherry Electrical Products Corp. has developed a new concept in keyboard design that simplifies the electronics. It works by continuously scanning all possible codes every 256 µs. When you depress a key the scanning process is stopped at the selected code.

The new keyboard uses a single PC board, a magnet actuated hermetically sealed dry reed switch in each key module and off-the-shelf components. Contact bounce isn't a factor since the code doesn't come from the key.

The new keyboard does not rely on analog or current sensing devices to detect two key rollover. It uses a new approach that eliminates the need for steering diodes, diode encoding, delayed strobe, two key rollover detection circuitry, second level PC board and having to interconnect two PC boards. The entire encoding and keyboard in the new system is limited to a single PCB in most applications, thereby contributing to increased reliability.

A "flying magnet motion" mechanism provides more reliable reed switch operation and improved sensory and audible feedback to the operator. The new module and mechanism is shown in the accompanying illustration.

The key module consists of a molded key button, a plunger with keeper plate that holds the magnet, upper and lower springs, hermetically sealed dry reed switch (Form A) and nylon housing.

As the key is depressed to the operating position, the upper spring stores energy until it has enough to overcome the magnet-to-keeper plate seal force of 70 grams. The magnet is suddenly released from its captive position against the keeper plate and flies down the tube to the region of the reed switch contacts, coming to rest against the lower spring. The reed switch contacts close with a sharp.

(Continued on page 116)
**NEW PRODUCTS**

positive action. The magnet presses downward against the lower spring until the energy stored in it overcomes the upper spring force and returns the magnet to the captive keeper plate position. Reed switch contact closure is the result of the dynamic action of the magnet which contributes to more reliable reed switch operation.

Another feature of the keyboard is its inherent ability to store data bits once the key has been depressed. With this feature the bits are not lost or inhibited when two keys are pressed at the same time. The bits remain online until the first key is released, at which time the code of the second key will appear.

Still another feature is the ability to provide "n" key rollover by addition of electronics at modest (about $20.00) cost.

The keyboards are available with standard encoding formats including ASCII, BCD, and EBCDIC. Special codes are also available. The number of bits in a code is not limited to eight as with most conventional keyboards. Up to 16 bits in a code can be provided with little difficulty.

Keyboard performance meets or exceeds Mil. Std. 188C. Operating environment for commercial applications is 0°C to 70°C, and -55°C to +125°C at 90% relative humidity for military applications. Prices for a standard 52 key ASCII coded keyboard (not including metal housing) range from $250 for one to $140 for 1000. The keys (not including buttons) range from $2.60 for one to $1.40 for 1,000 to $0.87 for 50,000. Cherry Electrical Products Corp., 1650 Old Deerfield Rd., Highland Park, Ill. 60035. (312) 831-2100.

**Automated network analyzer**

Here's an example of how to tie your lab instruments to a computer for automatic data reduction. The system is packaged and sold by Wiltron, and called the Model 312 vector network analyzer.

The heart of the 312 is a device made not by Wiltron, but by Pacific Radionics: the Model LP-1000 coupler.

Couplers such as this convert the digitized, parallel-line outputs of the various instruments into serial-coded, teletype-compatible ASCII data. And the teletype is the "open sesame" to automatic processing by computer.

Wiltron combined their Model 310 phase, level, and impedance indicator with their Model 311 rf resolver to make a network analyzer. To this they added their 610B sweeper as a signal source, and a Tektronix 503 oscilloscope for a Smith-chart display.

Pacific Radionics' LP-1000 ties the system together because it acts as the input/output adapter between the measuring instruments and a standard ASCII teletype (included).

The 312 system controls the test equipment, records data, and reduces it to a usable form. And because it operates through a timeshare terminal, you can use the large computer central to control as many of these automated analysis stations as you may need.

Wiltron's system measures and displays transmission phase-shift and insertion-loss or gain, and reflected signal amplitude and phase. It operates in the range of 1 to 20 GHz, depending on the units you select.

Significant characteristics of the 312 include standards lab accuracy in both coax and waveguide, and automatic adjustment to the calibration curves of the reference standards; automatic error correction on both the teletype print-out and the Smith-chart display; and instant data analyses and computations via automatic reference to built-up, test data files.

The system comes with all software routines for calibration, operation, and print-out in engineering units (dB gain or loss, and phase). And note that once you're plugged in, you have access to all the routines provided by your timeshare service.

The Model 312 is expandable and easily adaptable to pulsed-signal analysis. For more information, contact Wiltron Company, 930 E. Meadow Dr., Palo Alto, Calif. 94303.

Circle 294 on Inquiry Card
Want longer delay times?
Shorter rise times? Higher or lower impedances in dual inline packaging?

IT'S DAVEN...ACROSS THE BOARD

Good news for circuit designers! Daven's new lumped constant Delay Lines have the broadest range of parameters available in a DIP configuration. Their 14-lead package will fit any DIP-IC board.

How's that for versatility?

Built with Daven expertise, they're ideally compatible with the latest generation of computers. Standard packages mean you pay less, get delivery faster.

Write for Bulletin DL70.
Or call 603-669-0940.

DAVEN
Manchester, N.H. 03101  TWX 710-220-1747
The complete line of BUSS fuseholders and fuseblocks is available with quick-connect terminals to save assembly time and cut costs.

Bussmann Mfg. Division, McGraw-Edison Co., St. Louis, Mo. 63107

Available in sizes from 1/2 to 1000 amps for voltages up to 1500, TRON Rectifier Fuses are ideal for protecting variable speed drives, inverters, battery chargers, plating power supplies, power controls, and any other application where fast opening and great current limitation are required.

Bussmann Mfg. Division, McGraw-Edison Co., St. Louis, Mo. 63107

New concept simplifies logic design

The standard back-plane approach to logic-card system design requires complex interconnections if you want to use function cards such as digital comparators or shift registers. And, complex interconnections mean extensive run lists and many hours of engineering design time.

Now, however, with the "Wrap-X" logic card system recently announced by Datascans, Inc., you can select the complex function card you need and then do the simple logic yourself. You merely plug standard ICs into a Wrap-X printed circuit board and interconnect them (with Wrap-X most of the interconnect is plated). Then you make the connections to function cards.

The new Wrap-X board contains 16 solderless-wrap sockets for either 14-pin ICs and/or 16-pin MSI chips. It is mechanically compatible with over 100 DTL, HTL and TTL standard off-the-shelf “function” logic cards such as comparators, decimals converters and shift registers.

Competing with the large scale back-plane approach, Wrap-X has an economic advantage in small systems and prototype quantities of large systems because complex function cards can't be economically duplicated with the back-plane approach. With the back-plane, complex solderless-wrap interconnections are needed to replace the function cards. Thus, the extensive run list. Also, in the back-plane, you must house discrete components and semiconductors on plug-in platforms, and each of these requires a physical design before you can generate the run list. This also means that you will spend many hours of design and drafting time that are not necessary with the Wrap-X and standard card approach, where function cards have already been designed, and laid out.

Another important plus is that both the Wrap-X and standard card approach include the company's Dynamic Decoupling circuit which greatly reduces a system's susceptibility to noise on the power supply lines.

Wiring for the large back-plane is much more extensive than for the Wrap-X system because all of the plated interconnect on the function cards must be hard wired. Thus, there is a greater chance of noise problems because summing junctions and other low level signal points must be run over some distance, and may be mixed with digital wiring.


Bussmann Mfg. Division, McGraw-Edison Co., St. Louis, Mo. 63107

Bussmann Mfg. Division, McGraw-Edison Co., St. Louis, Mo. 63107

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NEW PRODUCTS

Controller/coupler interfaces with computer

This new instrument gives you a programmable, bidirectional link among up to eight digital equipments (DVMs, counters, power supplies, and so forth). With it, you can coordinate and control these equipments to build a stand-alone test and measurement system, or one that is controllable by a computer.

Hewlett-Packard's 2570A consists of a mainframe assembly that holds a power supply, and control and clocking circuits. Input/output slots hold up to eight interface cards corresponding to the eight digital equipments that you choose to control.

Among the interface cards available, one lets you interface the 2570A to a computer. This means that you can use the unit to automatically transfer data from a group of instruments to a central computer for on-line data analysis. (You can also record data on punched tape for off-line analysis.)

Now, remember that the 2570A can communicate in two directions.

So, with the computer interface card installed, you can use the computer program not only to control the process under study, but also to reduce the data, print a report, and plot the results. Furthermore, a number of instrumentation terminals, each with its own 2570A, can simultaneously access the central computer.

The operational concept of the controller/coupler is straightforward. The input/output interface cards provide a standard language for the controller/coupler: the cards convert BCD inputs from various digital instruments to ASCII code. The input cards gather and insert measured data onto a data bus. The output cards, in effect, gather the data from the bus, and output it. Both input and output cards are interconnected through, and under the command of, a mainframe control card.

You can control the 2570A by diode pin positions on a control-card matrix. Or, you can program the control card to shift control to any ASCII-generating unit such as a teletype or punched-tape reader.

The Model 2570A controller/coupler costs $1625. This price doesn't include interface cards, but does include the standard controller panel, control card, and so forth. The various interface cards cost from $450 to $700 each, depending on function and options selected. Interface cards include a 16-bit relay register, an 8-bit duplex register, a TTY interface, and, of course, 10-digit-BCD to ASCII (and vice versa) conversion cards. Inquiries Mgr. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94303.

Circle 290 on Inquiry Card

Fuseholders of Unquestioned High Quality

FUSES
for protection of Electronic Devices

There is a complete line of BUSS Quality fuses in 1/4 x 1 inch, 1/4 x 1 1/4 inch, and miniature sizes, with standard and pigtail types available in quick-acting or dual-element slow blowing varieties.

Bussmann Mfg. Division, McGraw-Edison Co., St. Louis, Mo. 63107
Circle 53 on Inquiry Card

Subminiature Fuses and Fuseholders

BUSS has the fuses and fuseholders for space-tight applications, in a wide range of ampere ratings from 1/100 to 15. Allow visual inspection of element. Tiny but tough, they're built to withstand severe environments.

Bussmann Mfg. Division, McGraw-Edison Co., St. Louis, Mo. 63107
Circle 53 on Inquiry Card
Microwave transistors: new supplier enters lists

There's a new source to be reckoned with in the rf and microwave power transistor field, Raytheon Semiconductor—not previously known for power devices—has jumped into the swim in a big way with an announcement of 11 overlay transistor types. And that's just for starters.

To create an image as a supplier of state of the art microwave power packages, Raytheon launched a development program some time back to make use of those advantages which discrete devices have over monolithics: power, voltage, frequency, and current. The first results of the program are shown below.

<table>
<thead>
<tr>
<th>Device</th>
<th>Freq./Pwr./Min. Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS4976 (*)</td>
<td>2GHz/1W/5dB</td>
</tr>
<tr>
<td>LS5110 (*)</td>
<td>1GHz/10W/5dB</td>
</tr>
<tr>
<td>LS5108A (*)</td>
<td>1GHz/1W/7dB</td>
</tr>
<tr>
<td>2N5108A</td>
<td>1GHz/1W/5dB</td>
</tr>
<tr>
<td>LS7101 (*)</td>
<td>1GHz/1W/7dB</td>
</tr>
<tr>
<td>2N5108</td>
<td>1GHz/1W/5dB</td>
</tr>
<tr>
<td>2N5109</td>
<td>1GHz/0.5W/3dB</td>
</tr>
<tr>
<td>LS4429 (*)</td>
<td>1GHz/1W/5dB</td>
</tr>
<tr>
<td>LS4428 (*)</td>
<td>500MHz/0.75W/10dB</td>
</tr>
<tr>
<td>2N3886</td>
<td>400MHz/1W/10dB</td>
</tr>
<tr>
<td>2N3553</td>
<td>175MHz/2.5W/10dB</td>
</tr>
</tbody>
</table>

The devices marked with an asterisk are in stripline, stud mounted packages, while the others are in TO-39 cans. You may recognize the 2N5108 as an earlier Raytheon product; the company used it as an introductory vehicle.

All the 2N-numbered devices are second-source items except for the 2N5108A, which is a premium version of the 2N5108. It has a leakage current two orders of magnitude less than that of the original, unlettered version, plus higher reliability and efficiency. Raytheon sole-sources the stripline items.

Although this semiconductor house has never been known as a price leader, the new line offers value at industry-competitive prices. For one thing, the stripline devices are in hermetically-sealed packages, not, as is common, in epoxy cases. For another, Raytheon is aiming at the high-reliability market (airborne radars, and so forth), and so you can expect a quality product. In fact, their 2N3886 and 2N3553 will soon appear on the JAN-qualified lists.

And finally the company plans to beam-lead as much of their product line as is possible (this should occur later in the year). Beam-leading, you know, generally gives a more reliable device and is a popular technique among microwave people. Interestingly, the beam-lead units will be housed in plastic packages, because the chip itself will be hermetically sealed.

Raytheon expects to expand its base in the Fall, with a much broader line of 2-GHz transistors. Beam-led chips, too, will be available for microwave hybrids. And by the end of the year, Raytheon expects to have a 3-GHz, coaxially packaged transistor on the market.

The company is already offering its new line in custom packages to meet the varied needs of users, and you can have any of the devices in either a common-base package (for oscillator circuits), or a common-emitter package (for amplifier circuits). Limited production lots—100 to 500 pcs.—will be available next month. For more information, contact Raytheon Corp., Semiconductor Div., 350 Ellis St., Mountain View, Calif. 94040. (415) 968-9211.

Circle 291 on Inquiry Card

Word generator operates to 100 MHz

Here's an example of a test instrument manufactured by a firm that is normally a user of instruments.

Advanced Memory Systems, Inc., needed a word generator to test their high-speed ic memories. The company felt that the right combination of word patterning, clock rate, and rise/fall times it needed were not available from any instrument on the market, so they designed their own unit. And because logic card and mss/1st memory users have test requirements similar to those of AMS, the company decided to offer the generator as a standard product.

[For a discussion of such instruments see The Electronic Engineer, Vol. 29, No. 1, January 1970, pp. 42-45, "All word generators are not women," by Jerry Heyer. And for a survey of instruments on the market see the same issue, pp. 47-48, "Commercially available word generators," by Stephen A. Thompson.]

Some key features of the Model PPG-1 are:

• Manual/remote programming — you can use the word generator as a stand-alone instrument in the lab (manual operation), or you can incorporate it into an automated test system in which a computer or other digital equipment (remotely) controls address selection and data pattern generation.

• Precise data positioning—there are eight data-channel outputs with 64 bits/channel. This means that there are 64 time slots—one for each address in the generator's storage—in each channel. At the maximum clock rate of 100 MHz, each of these time slots is only 10 ns long. In other words, when you operate the PPG-1 at its highest rate, you can vary each channel's pulse widths from 10 to 640 ns, in 10-ns intervals. And the time relationships among the pulses on the eight channels are similarly variable in 10-ns increments.

• High-rate clocking—you can vary the frequency of the PPG-1's internal clock from 100 MHz down to 1MHz, while an external clock (minimum pulse width, 3 ns) will take you down to dc. Address changes occur on the positive-going edges of the clock pulses. Typical delay from clock signal to data output is 20 ns, and all changes in the output data take place within ±1 ns of this delay. Cycle length is 1 to 64 words external, and 8, 16, 32, or 64 words internal.

• Fast rise/fall times—the output data signal is in the NRZ (non-return to-zero) format, and rise/fall times are < 1.5 ns into a 50-Ω load. These specs are for the ECL version, which has a minimum output signal swing of −0.85 to −1.55 V.

The standard version of the PPG-1 has ECL-compatible programming inputs and data outputs, costs $5995, and has a 90-day delivery time. Option 02 gives you DTL/TTL-compatible outputs, and costs an extra $500. There is no charge either for Option 01, which gives you DTL/TTL-compatible inputs, or for Option 03, which matches the PPG-1 input levels to your particular needs. Advanced Memory Systems, Inc., 1276 Hammerwood Lane, Sunnyvale, Calif. 94086. (408) 734-4330.

Circle 292 on Inquiry Card
Circle 29 on Inquiry Card
Circle 54 on Inquiry Card
The $2500 Necessity.

If you use an oscilloscope at your lab or production facility, then you need our EC-22 Byte Generator™. This compact, versatile electronic marvel is designed for simulation and testing of all digital equipment.

It features 32 or 64 eight-bit bytes; serial or parallel output; variable program length; automatic ASCII code formatting; expandable pattern in length and width by stacking units; and up to 8MHz bit or byte rate.

The EC-22 is perfect for – Testing of peripherals, data terminals, CRT displays, IC's, LSI's, and PC's – Simulation of computer output, Telemetry, and Teletype – Generation of analog functions.

Considering what the EC-22 does for only $2,500, it's a steal. Get in touch with us today, and we'll tell you how the EC-22 can help make your job a whole lot easier. It's nice to be needed. Call Bill Noren, collect.

NEW MICROWORLD PRODUCTS

I/O CIRCUITS
In 14-lead TO-116 DIPS.

The CM1150 dual transmitter and CM4160 dual receiver meet EIA RS232B/C and Mil-STD-188B specifications. The ±1.25 V noise margin at the inputs of the CM1160 receiver is the highest currently available. Price for both devices is $8.45 ea. in 100 pc. quantities. Cermetek, Inc., 660 National Ave., Mountain View, Calif. 94040. (415) 969-9433.

Circle 235 on Inquiry Card

ACTIVE FILTERS
With low freq. response to 1 mHz.

Key features of the Series 700 filters include 0.001 Hz to 20 kHz cutoff frequency, 2% f, tolerance and 50 µV noise level. Extensive use of CAD allows standard units to be adjusted to specific f, with standard component values. Prices start at $22 ea. in 100 lots quan. Analog Devices, Inc., 221 Fifth St., Cambridge, Mass. 02142. (617) 492-6000.

Circle 236 on Inquiry Card

MONOLITHIC BREADBOARD
For custom IC fabrication.

The SG3801 QuikChip contains over 50 separate components. A wire bonding machine lets you construct prototypes as needed. They come in chip form or mounted on TO-100, 10-pin headers with pressed-on caps. Prices: (100 pieces) $5.30 ($4.50 in chip form). Silicon General, Inc., 7382 Bolsa Ave., Westminster, Calif. 92683. (714) 839-6200.

Circle 237 on Inquiry Card

MOS LOGIC CIRCUITS
For off-the-shelf design.

This family consists of the EA 1800 universal logic array, EA 1801 control array, EA 1802 register array and EA 1803 carry array. Features include power dissipations ranging from 180 to 200 mW/package and typical propagation delays of 150 to 500 ns. Electronic Arrays, Inc., 501 Ellis St., Mountain View, Calif. 94040. (415) 964-4321.

Circle 238 on Inquiry Card

DUAL SHIFT REGISTERS
Both 50- and 64-bit lengths.

These static registers give you the choice of interfacing directly with TTL/DTL or MOS. Both the 50-bit (SL-6-2050) and the 64-bit (SL-6-2064) come in 8-lead, TO-77 packages and have Zener clamp protection. Prices in quantities of 100 are: SL-6-2050, $13 ea.; SL-6-2064, $16.75. General Instrument Corp., 600 W. John St., Hicksville, N.Y. 11802.

Circle 239 on Inquiry Card

POWER OP AMP
Gives you 500 mA at ±10 V.

These op amps, Series 210, feature an input impedance of 10^12Ω, and voltage drifts from 2 µV/°C. They are especially useful in instrumentation where the recording device (galvanometer) requires dc stability and a high current drive or in applications as a power buffer. Polytron Devices, Inc., 844 E. 25th St., Paterson, N.J. 07513. (201) 523-5000.

Circle 240 on Inquiry Card

TV SOUND SYSTEM
Needs fewer external components.

The CA3065 offers high sensitivity and high-level output for direct drive of an n-p-n audio transistor or a high transconductance tube. An electronic attenuator eliminates shielding of volume control leads and allows simplified remote control design. $1.40 ea. in 1000 pc. lots. Commercial Engineering, RCA/Electronic Components, Harrison, N.J. 07029.

Circle 241 on Inquiry Card

VOLTAGE REGULATOR
Hybrid unit is in a 10-lead TO-5.

The DVR100 provides an output voltage of 12 V ±5% (or ±1%) and load currents up to 100 mA with internal over-current protection. By adding external components, you can get voltages of 12 to 40 V and load currents up to 3 A. Prices range $23 to $28 (100-999 quan.). Dickson Electronics Corp., Box 1390, Scottsdale, Ariz. 85252. (602) 947-2231.

Circle 242 on Inquiry Card

DC CURRENT REGULATORS
Both plus and minus models.

Models 868 and 878 feature an adjustable current range from 1 to 400 mA, ±0.5% output current setting tolerance and stability and ±0.01% output current to. The two units are completely complementary in circuit design, internal layout and terminal designation. Helipot Div., Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, Calif. 92634.

Circle 243 on Inquiry Card

Circle 55 on Inquiry Card
Look who has the popular new size at a popular price.

Cermet or wirewound.

Now it's no longer necessary to settle for less than the best.
These popular new Weston ¾" rectangular series 530-533 combine the famous features of our Squaretrim® potentiometer line—high quality, wide temperature range, precision tolerance, low noise, 15 turn adjustability with slip clutch protection—in a case size that's rapidly becoming industry's number one choice. In addition to standard models, sealed equivalents are available for protection against water, cleaning solvents, flux and encapsulating compounds. Units are priced as low as $1.30*.
Cermet series 532 and 533 come in standard resistance values to one megohm. Those who prefer wirewounds may order series 530 and 531 in standard values from 10 ohms to 35K. Both cermet and wirewound models are available with tab mounting centers of either .10" or .20".
However you choose, you're clearly a winner with Weston's 530-533 rectangular trimmers. Write or phone today for sample units and complete data.

WESTON COMPONENTS DIVISION, Archbald, Pennsylvania 18403, Weston Instruments, Inc. a Schlumberger Company

*100 quantity unit price for standard models.
100 quantity unit price for sealed models is $1.63.
Features:

1. Fast—guaranteed maximum access times: 850 nsec to 1.5 µsec.
2. Low Power—90 mW typical.
3. Complete decoding within each ROM.
4. Wire-OR capability.
5. May be biased to be bipolar compatible.
7. 24-pin dual-in-line packages.

Standard Patterns available today at EA distributors

1. EA 3001—Starburst character generator and Selectric bail to ASCII code converter.
2. EA 3101—ASCII to Selectric Line Code and Selectric Line Code to ASCII code converter.
3. EA 3307—ASCII to EBCDIC and EBCDIC to ASCII code converter.
4. EA 3501—Row Scan Dot Code Matrix Character Generator.
5. EA 3701—Column Scan Dot Code Matrix Character Generator.

Custom Patterns

Any EA ROM can be programmed to your specialized bit patterns. Allow 6 to 8 week delivery.

For data sheets and forms for submitting your specialized bit patterns, contact your local representative or write Electronic Arrays, Inc., 501 Ellis Street, Mountain View, California 94040, (415) 964-4321.
NEW MICROWORLD PRODUCTS

J-FET INPUT OP AMP
Draws 200 pA max. input current.

This monolithic circuit, the µA740, differs in design from the super beta or "punch-through" operational amplifiers. While punch-through devices provide current gains of 1000, this device features equivalent betas of more than 15,000. Other key parameters include a unity gain slew rate of 6 V/μs, a 120 dB voltage gain, a typical, 20 pA input offset current, and an input offset voltage of 20 mV maximum (all at 25°C). Because of the FET input, you get an input impedance of 10^12 Ω. The package is a TO-99 can and unit prices are $73.50 (military) and $37.50 (industrial). Fairchild Semiconductor, 464 Ellis St., Mountain View, Calif. 94040. (415) 962-3563.

Circle 231 on Inquiry Card

LINE DRIVER/RECEIVER CIRCUITS
For digital transmission in high noise environments.

The SS334 series consists of a quad, logic-level driver for digital transmission and two types of receivers. One receiver is a quad single-ended device and the other is a dual differential receiver. These units perform interface functions between standard TTL or DTL and interconnecting lines. As an example of noise protection offered, the series show common mode noise rejection of ±5 V with worst case power supplies of ±5%. The circuits are packaged in a TO-85 ceramic, 14-lead flat pack with a metal lid. In quantities of 100 and over, the cost of these circuits ranges from $5.90 ea. for industrial grade to $12.45 ea. for military grade. Semiconductor Div., Sylvania Electric Products Inc., Woburn Mass. 01801.

Circle 232 on inquiry Card

TTL CIRCUIT
Can be wire-OR'ed

The DM7551/8551 is a quad n flip-flop for use with common data lines in small computers. To get the wire-OR capability, this circuit has a third logic state, a high impedance state in which both output transistors are off. You can also use the circuit without worrying about clock control because input enable circuitry blocks data from entering the circuit unless it is specifically addressed. If the incoming data is blocked, the flip-flop sees only its own output, which is fed back. In effect, the circuit samples itself until new data is entered. $14.50 ea. (1-24 pcs), available from stock. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, Calif. 95051.

Circle 233 on Inquiry Card

MICROWAVE INTEGRATED CIRCUITS
UHF devices use hybrid technology.

These new devices are the TA7702/7703 wideband UHF power amplifiers and TA7747/7748 UHF three-port hybrid power combiner/dividers. The amplifier typically delivers 16 W at 350 MHz with 6 dB gain. The gain variation across the band (225 to 400 MHz) is ±0.5 dB and the efficiency varies between 50% and 75%. The TA7747/7748 is an equiphase, equiamplitude three-port hybrid that you can use as a power combiner or divider. When used as a divider, the output ports are isolated. The loss of the unit across the 225 to 400 MHz band is < 0.25 dB and the isolation varies between 10 and 40 dB. Commercial Engineering, RCA/Electronic Components, 415 S. Fifth St., Harrison, N.J. 07029 (201) 485-3900

Circle 234 on Inquiry Card
now available... 7 INNOVATIVE APPLICATIONS OF INTEGRATED CIRCUITS TO COMMUNICATIONS

In response to popular demand, we are making available the proceedings of the recent seminar and workshop on the “APPLICATIONS OF INTEGRATED CIRCUITS TO COMMUNICATIONS” which was sponsored by The Electronic Engineer.

Moderated by J. Lightsey Wallace of the Atlantic Research Corporation, the seminar included a series of papers which included 7 innovative approaches to practical applications of the new families of ICs to communications and consumer products.

The papers cover the following 7 subjects:

AGC—It’s the Old Dynamic-Range With Good Signal-to-Noise Trick
Jack Macintosh
Tom Mills
Fairchild Semiconductor

The Phase-Locked Loop
Arthur Fury
Signetics Corp.

AM/FM Receivers with ICs
Ronald W. Lutz
Sprague Electric Co.

Large-scale Integration of TV Circuits
S. Gertzis
Amperex Electronic Corp.

Applications of a Low-Power Operational Transconductance Amplifier (OTA) IC Array in Communications Systems
H. A. Wittinger
RCA Electronic Components

Integration of Complex Functions
Ted Hanna
National Semiconductor Corp.

Modulation, RF/IF Amplification, and Multiplexing
Roy Hejhall
Motorola Semiconductor Products, Inc.

These innovative and practical approaches have attracted so much attention in the technical community that they are now being made available to those who were unable to attend the seminar. Your copy is available now. To get it send the coupon below with your check or money order for $6.00 to The Electronic Engineer. Your copy will be forwarded to you by return mail.

Yes, I want ___ copy(ies) of the papers on the “APPLICATIONS OF INTEGRATED CIRCUITS TO COMMUNICATIONS.” My check in the amount of $______ for ____ copy(ies) is enclosed. Send to me at the following address:

Make check or money order payable to Communications ICs
The Electronic Engineer Magazine
Chestnut & 56th Streets, Phila., Pa. 19139

Name______________________________Title______________________________
Company__________________________Division__________________________
Street______________________________City______________________________State____________________Zip______________________

NEW MICROWORLD PRODUCTS

COUNTER/DISPLAY DRIVER
For seven-segment indicators.

The MEM 1056 is an MTOS (metal-thick oxide silicon) monolithic integrated circuit and contains a one decade up-down BCD counter, a storage register, a BCD-to-seven segment decoding matrix and display drivers. The device features low power consumption, count zero indication, decimal point indication, false code indication, and blanking input. You can cascade the up-down counter sections to form synchronous counting chains. You can achieve asynchronous, 1 MHz, up-down counting irrespective of the number of counter stages cascaded by using external elements. $20 ea. in 100 piece lots. General Instrument Corp., 600 W. John St., Hicksville, N.Y. 11802. (516) 733-3333.

Circle 227 on Inquiry Card

IF AMPLIFIER HAS AGC
Unit minimizes detuning.

The µA757C is designed for use in am and fm communications receivers, where it provides high-gain amplification without detuning the external filter circuits. The amplifier has two gain-controlled sections that you can operate independently or in cascade. The device has an AGC sensitivity of 50 dB/V, with a 70 dB AGC range at 10.7 MHz. The voltage gain at this frequency is 70 dB, while the power gain is 78 dB. Input signal handling capability is 300 mV and the unit operates with an intermodulation distortion of -50 dB. The output current is 5.5 mA peak to peak. It costs $4.85 ea. in quantities of 100 to 999. Fairchild Semiconductor, 313 Fairchild Dr., Mountain View, Calif. 94040. (415) 962-3563.

Circle 228 on Inquiry Card
READ ONLY MEMORY
With 256 words, 10 bits/word.

The EA 3100 uses a two-phase clock, but the outputs appear as steady-state signals as long as the address remains unchanged. An output inhibit control allows the use of multiple memories in a wire-OR'd configuration. One custom mask accomplishes the programming of the memory matrix during fabrication of the device. The only dc supply required is the output buffer supply, which is variable and can be biased to drive bipolar output loads directly. Also available off-the-shelf is the EA3101 with both the ascii to Selectric line code and Selectric line code to ascii code conversions. $83.50 ea. in 100 lot quantities. Electronic Arrays, Inc., 501 Ellis St., Mountain View, Calif. 94040.
Circle 229 on Inquiry Card

POSITIVE LOGIC NAND GATES
Complementary MOS construction.

CD4011
CD4010D

The CD4011 is a quad two-input NAND gate and the CD4012 is a dual four-input NAND gate. Both offer medium speed operation $(t_{\text{del}} = 50 \text{ ns typical with } C_{\text{L}} = 15 \text{ pF})$ and an input impedance of $10^5 \Omega$ (typical). Output impedance for the CD4012 is 4000 in the 1 level and 1000 in the 0 level $(V_{\text{p-p}}=10 \text{ V})$. For the CD4011 the figures are 4000 and 7000 respectively. The devices operate over the full military temp. range and are immediately available in quantity. They come in both flat-pack and ceramic DIP's. Prices range from $4.50 to $5.75 ea. in 1000pc. lots. Commercial Engineering, RCA/Electronic Components, 415 S. Fifth St., Harrison, N.J. 07029. (201) 485-3900.
Circle 230 on Inquiry Card

ANNOUNCING...
A Course in INTEGRATED CIRCUITS

And an important opportunity for all design, equipment and systems engineers to stay ahead of the evolution in integrated circuits.

There is now available a practical and authoritative course in Integrated Circuits. This 10 part course appeared originally in The Electronic Engineer and is now being reprinted by popular demand. The course is designed for engineers who are buying or using, or who plan to use the whole range of integrated circuits—Silicon monolithic, thin-film, MOS, and hybrids. The course describes the function and use of integrated circuits in clear and complete form.

You achieve new skills—This course gives you the required background to properly communicate with device designers. The course will also sharpen your capability to make the right decisions about the selection and use of ICs. In addition, the course traces the history of integrated circuits so you can evaluate new developments and anticipate those now on the drawing board. The course also includes a study of manufacturing details to keep you abreast of the complexities in this area.

The complete 10 part course costs $4.00. To get yours, just fill out the coupon below and send it today. Send your order to The Electronic Engineer, Chestnut and 56th Streets, Philadelphia, Pennsylvania 19139.

Yes, I accept your offer. Send me ___ complete course(s) in Integrated Circuits at a cost of $4.00 each. My check, cash or money order is enclosed. Send as soon as possible to:

Name __________________________ Company __________________________
Address __________________________ Company __________________________
City __________________ State ______ Zip __
Send me special quantity prices □

The Electronic Engineer • June 1970

127
AUTOMATIC COUNTER/TIMER
Features solid state display.

The Model 120A is a 150 MHz universal counter/timer. More than 60% of its components are MSI circuits and the eight-digit readout consists of solid state light-emitting numerics. The instrument incorporates automatic ranging so that all frequency and period measurements are automatically displayed with maximum resolution. Functions include totalizing from dc to 150 MHz, or 0 to 10⁷, measuring frequency ratios from 10⁻⁷ to 10⁷, period averaging from 0.1 µs to 1 s, period measurements from 1 µs to 10⁷ s and measuring time intervals from 0.1 µs to 10³ s. $177.50. Monsanto Electronic Instruments, 620 Passaic Ave., W. Caldwell, N.J. 07006. (201) 228-3800.

Circle 221 on Inquiry Card

BATTERY OPERATED X-Y RECORDER
Gives 75 h of operation on D-cells.

This self-contained recorder, the Model 2745, features low current drain, virtually no drift, and high input impedance (greater than 15 MΩ at 20 mV sensitivity). The unit gives you ±1.0% accuracy and has a response time of 0.5 s for a full scale change on the Y axis and 0.7 s for a full scale X-axis change. Range selection on the two axis is totally independent. A built-in time sweep for the X axis lets you operate it as a Y vs time strip chart recorder. Available for both ink and inkless recording, it is priced at less than $750. Simpson Electric Co., div. of American Gage & Machine Co., 5200 W. Kinzie St., Chicago, Ill. 60644.

Circle 222 on Inquiry Card

REAL-TIME ANALYZER
From dc to 20 kHz.

Model 1922 provides high-resolution constant-bandwidth frequency analysis. Pushbutton operation provides a series of oscilloscope displays that guide the user to make the proper instrument adjustments. The successive displays are input signal, input signal after low-pass filter with measurement trigger point intensified, input signal intensified over the portion of the signal to be analyzed, recorded signal amplitude-vs-spectrum (single and averages), a band of frequency components vs time, and an alphanumeric output of the measurement parameters. The basic single-bay version (shown) is $32,000. General Radio Co., 300 Baker Ave., West Concord, Mass. 01781. (617) 369-4400.

Circle 223 on Inquiry Card

MICROWAVE SWEEPER
All rf elements are hybrid microcircuits.

Model 8620A uses plug-in modules to determine its frequency range. Presently, modules up to 4 GHz are available using Yig-tuned transistor oscillators and heterodyne techniques. Yig-tuned bulk effect devices will be used in up to 18 GHz modules which are scheduled for later deliveries. Modular circuit boards for the mainframe give you a sweeper that's optimum in convenience for use on the bench, without the expense of programmable functions. With other options, the instrument can be wholly or partly programmable for automatic operation. Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94304.

Circle 224 on Inquiry Card

DIGITAL ELECTROMETER MULTIMETER
Has 3½ digit display with 100% overrange.

Model 615 gives you 4 voltage ranges, 12 current ranges, 11 linear resistance ranges and 7 charge ranges. Measurement capabilities are 100 µV to 100 V, 10⁻¹⁵ to 0.1 A, 100 to 10¹⁴ Ω and 10⁻¹⁴ to 10⁻⁵ coulomb. You can adjust the display rate from 24 readings/s to 2 readings/s and the decimal point is automatically positioned when changing ranges. The unit operates up to 100 V off ground, and it recovers almost immediately from overloads up to 500 V. Prices start at $1195 for the basic rack-mounted unit. Keithley Instruments, Inc., 28775 Aurora Rd., Cleveland, Ohio 44139. (216) 248-0400.

Circle 225 on Inquiry Card

WIDE-BAND FREQUENCY METER
Features "hands-off" operation.

The Model 6421 has a sensitivity of -10 dBm (50 mV rms) and a dynamic range to +33 dBm (10 V rms). Because it can count directly across the entire band, the meter provides the most accurate method of measurement in the shortest time. Time base factors for frequency measurements range from 1 µs to 10 s in decade steps. A front panel which allows the instrument to count its own internal 1 MHz reference, to assure that all counter dividing circuits are operating properly. Price is $1575 with delivery in 90 days. Technical Information Section, Electronic Instruments Div., Beckman Instruments, Inc., 2200 Wright Ave., Richmond, Calif. 94804.

Circle 226 on Inquiry Card

NEW LAB INSTRUMENTS

The Electronic Engineer • June 1970
WHERE

can you get a time delay relay that won't false operate, that will give you ±3% repeatability, will switch 10 amperes and costs only $16.50?

HERE

This compact time delay, our CL Series, provides a delay on operate. Its reliable solid state circuit will time as little as 0.1 second and as much as 120 seconds. Three types are offered in AC or DC versions: fixed delay on operate, resistor adjustable and knob adjustable.

An integral part of the package, our field-proven KU relay handles the DPDT output switching up to 10 amperes. Transient protection is provided up to twice the rated input voltage for 8 milliseconds. Reset and recycle times are 150 milliseconds. Polarity reversal protection is provided.

A wide variety of mountings give you many design options. Nylon sockets are available with solder, quick-connect or printed circuit terminals. Also, cases with brackets for mounting the CL time delays directly to a chassis can be provided. Manual push-to-test buttons are also available. The plain case measures 1.53" x 1.40" x 1.90" high.

The CL Series is but one in a large family of solid state/relay time delays. Some have screw terminals and will switch 30 amperes. Others are combined with dry reed relays in an exceptionally compact package. Delays on operate, on release, or "interval on" may be ordered. Nearly 1300 listings are shown in our catalog.


STANDARD P&B TIME DELAYS ARE AVAILABLE FROM LEADING ELECTRONIC PARTS DISTRIBUTORS.
These two new Sprague plastic transistors give you 20% more power dissipation, 15°C higher junction temperature, and industry standard TO-18 pinning when used as direct electrically interchangeable replacements for 2N3904 and 2N3906.

The 2N5381 and 2N5383 are two of twenty new TO-18 pinned plastic transistors from Sprague. Check the replacement chart, then make your move. Sprague industrial distributors have stock. The sales offices listed below can supply samples. Call them now. Or get complete specifications by writing Technical Literature Service, Sprague Electric Company, 233 Marshall Street, North Adams, Mass. 01247, or use the reader service number below.

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SPRAGUE ELECTRIC CO., SEMICONDUCTOR DIV., CONCORD, N.H. 03301 (603) 224-1961

NEW LAB INSTRUMENTS

LOGARITHMIC TIMER
Uses digital techniques.

Model DLT-1 accepts start/stop signals and measures the time interval between them logarithmically. The basic unit reads in 0.1 dB steps up to a max. reading of 60 dB, with the reference (0 dB interval) selected as 10 µs, 100 µs, 1 ms, 10 ms, 100 ms, or 1 s. Microwave/Systems, 1 Adler Dr., East Syracuse, N.Y. 13057.

Circle 212 on Inquiry Card

IC TESTER
With 4 x 16 program matrix.

Model 101 performs dc and functional testing of most digital ic's. Panel layout follows typical data sheets for fast programming. Model 101A has a test socket for TO-5s and flat packs as well as 14- and 16-pin pins. $295 (Model 101) and $315 (101A). Spectrum Dynamics, 2300 E. Oakland Park Blvd., Ft. Lauderdale, Fla. 33306. (305) 566-4467.

Circle 213 on Inquiry Card

DIFFERENTIAL VOLTMETER
Has accuracy of 0.01% of reading.

The DC 110C has a 6-digit readout and a guarded 100 µV null detector. The voltmeter gives you a recorder output of 0 to 1 V at ½ mA. Also included is a voltage reference source (from 0 to 11 V) that has an accuracy of 0.01% of setting. $675. Precision Standards Corp., 1701 Reynolds (Irvine Industrial Complex) Santa Ana, Calif. (714) 546-0431.

Circle 214 on Inquiry Card

RF NOISE SOURCE
From 1 to 500 MHz.

Model NS-C has a stabilized white noise output that is continually variable from 0-16 dB excess noise in two ranges. A resonant line output-coupling circuit ensures low vswr and gives you high accuracy over the full range. Available from stock, it costs $495. Aerospace Research, Inc., 130 Lincoln St., Boston, Mass. 02135.

Circle 215 on Inquiry Card

DIGITAL VOLTMETER
with 3½ digits.

Features of the VT 300 include automatic zero, overrange indicator, internal calibration voltage, BCD output, end of measurement signal output, and an external trigger input. Accuracy is ±0.1% of reading, ±0.1% of full scale. $199 with delivery from stock, Dixon, Inc., Box 1449, Dept. 227, Grand Junction, Colo. 81501. (303) 242-8863.

Circle 216 on Inquiry Card

MODEL TESTER
Provides direct error readout.

This pre-set, bit-count modem tester determines error rates on asynchronous modems to 240 bps and synchronous modems to 200,000 bps. Designed for both local and remote looped, full duplex modems, it is compatible with all RS232B interfaced modems. Sanders Associates, Inc., Daniel Webster Hwy. So., Nashua, N.H. 03060. (603) 885-2816.

Circle 217 on Inquiry Card

TIME DELAY GENERATOR
With ±0.1 µs accuracy.

Model 413, gives you three independently delayed output pulses (from 1.0 to 9,999.9 µs). You can vary input pulse sensitivity from ±10 to ±1200 V, and the generator produces a pulse of ±100 V into 50Ω with a rise time of 100 ns (10-90% points) and with a duration of 100 µs. Cordin Co., 2230 So. 3270 W, Salt Lake City, Utah 84119.

Circle 220 on Inquiry Card

The Electronic Engineer • June 1970
**DIGITAL PRINTER**
Fed with 4, 5, or 6-line BCD data.

Model AN72 digital printer can be fed with 4-, 5-, or 6-line BCD data.

With a 6-line input, a full complement of 64 alphanumeric characters as well as all std. signs, symbols and punctuation marks can be printed. For standardization, input follows an ASCII format.


Circle 203 on Inquiry Card

**A/D CONVERTER**
With optional numeric display.

Model 281 is a self-contained converter that operates on 115 Vac. Basic input sens. is 199.9 mV with conversion made at 0.1% of signal ±1 digit. Model 282 Numeric Display is usable with the 281 where visual readout is needed. It displays 5 full digits, decimal point, overrange and error indicators.

United Systems Corp., 918 Woodley Rd., Dayton, Ohio 45403.

Circle 206 on Inquiry Card

**AUDIo RESPONSE SYSTEM**
It's tc compatible.

Model 636 Speechmaker is a real-time system that interfaces with computers to give spoken answers in words, phrases or numbers to a request for information. Up to 31 words are stored and, on command, are spoken back singularly or in any group sequence.


Circle 209 on Inquiry Card

**READ ONLY MEMORY**
Electrically alterable.

The MSI approach makes use of the inherent fast NDRO properties of plated wire to achieve a 200 ns Read cycle. The EAROM is organized in such a way to make the write function very tolerant of timing, drive current variations, and line recovery, as a tradeoff for high read speed. Even so, it has a 1 µs write cycle.


Circle 204 on Inquiry Card

**DELAY LINES**
Two lumped constant units.

The XNS-208 is a 50 ns unit tapped at 5 ns increments with a rise time of 5 ns and a Z of 50 Ω. The XNS-209 is a 100 ns unit tapped at 10 ns increments with a rise time of 10 ns and a Z of 100 Ω. Delay to rise-time ratios of both units is 10:1; attenuation is <2% and max, distortion is 3%. Engineered Components Co., 2134 Rosecrans Ave., Gardena, Calif. 90249. (213) 321-6565.

Circle 207 on Inquiry Card

**DATA TERMINAL**
Hard copy output available.

Fast, high quality hard copy output for crt terminals is available as an integral feature of the '45' desk-top crt Data Terminal. The electro-optical printout process produces a 5 x 5 in. photoprint of the data displayed on the crt in <7 s after pressing the print button, with additional copies at 2 s intervals. $15,000. Photophysics Data Systems, 1255 Terra Bella Ave., Mountain View, Calif. 94040.

Circle 210 on Inquiry Card

**MINI-COMPUTER**
750 ns cycle time.

The new Varian 620/f features an extended set of instructions, an optional 300 ns rom, for an effective processor time of 500 ns, a Priority Memory Access (PMA) mode that permits data transfers asynchronously to and from memory at rates to 1.3 MHz, and a compact packaging design that allows up to 8 k of memory.

Varian Data Machines, 2722 Michelleon Dr., Irvine, Calif. 92664. (714) 833-2400.

Circle 205 on Inquiry Card

**MINIATURE RECORDER**
It's inkless.

The Minigraph recorder offers a choice of 14 chart speeds ranging from ¼ in. to 60 in./h. Accuracy is ±2% and full scale response is 1 s. Sensitivity is 10 µA full scale. The Minigraph has four basic movements—from 0 to 10 µA, 50 µA, 100 µA and 1 mA. The six dc ranges range from 1 to 500 V. The ac ranges are 150, 300 or 600 V. $99.50 and up. Esteline Angola, div. of Esteline Corp., Box 24000, Indianapolis, Ind. 46224.

Circle 208 on Inquiry Card

**D/A CONVERTER**
Output settling time is 25 ns.

The 25 ns settling time to within 0.1% of the final value in these DAC-H converters allows for an update word rate of 40 MHz. Full scale output is ±2.5 mA with a max. voltage compliance of ±1.2 V. Output linearity is ±2.5 µA with a current resolution of 5 µA. Overall accuracy is ±0.005% with a tc of ±15 ppm/°C. Total volume is only 1.6 in.³ Datel Systems Corp., 943 Turnpike St., Canton, Mass. 02021.

Circle 211 on Inquiry Card

Circle 59 on Inquiry Card
Trading off performance for cost in conversion equipment?

Stop!

Raytheon Computer just cut prices 33%

Now you don't have to make any cost/performance trade-offs in A-to-D and D-to-A conversion or interface equipment. We've taken the best price/performance ratio in the industry and made it even better. With price reductions from 15% to 50%.

So now you can pick from the industry's broadest line of conversion equipment. With ADC's, DAC's, Multiplexers. Sample-and-holds. All at new low prices. All available now. Off-the-shelf.

Take our 12-bit, multiplexed ADC. Case-mounted with 32 channels, this unit was a good buy for $3,640. The new price is only $2,300. Want more capacity? It's available with up to 256 channels. With savings to match.

Or choose our high performance 0.05% sample-and-hold amplifier card. It's yours for only $125. And that's a savings of more than 33%.

And we'll throw in wiring lists, test results, and technical manuals. Free. We'll deliver your conversion equipment and documentation cheaper and faster than you could do it yourself.

And, if your systems need computer power, try one of ours. Choose from a family of 16-bit machines. With cycle times from 900ns to 1.75μs, including our new 1.0μs 704 mini for under $10,000. All are software compatible with over 400 proven off-the-shelf programs.

Get the best price/performance bargain in the industry for your system, today. Call or write and ask for Data File E-188.

Raytheon Computer, 2700 S.Fairview Street, Santa Ana, California 92704. Phone (714) 546-7160.

The only thing Raytheon Computer does is your job. Cheaper.
MATCH

With an optimization feature.

With MATCH you specify a desired frequency response, giving either the magnitude or phase. It will then take a "ballpark" design and vary its element values to fit the response to that desired. The optimization feature makes it easier to solve broadbanding, equalization, and synthesis problems. This feature is also useful for correcting designs to account for parasitics. This interactive program is applicable to any practical cascade circuit, including a wide variety of active filters. It will calculate $Z$, $Y$, $G$, $H$, ABCD and scattering parameters. It also calculates group delay and lets you describe sections with either empirical frequency response data or rational functions. You can also compute a variety of exact sensitivities and partial derivatives.

You can plot results against linear or logarithmic frequency, as well as on normal or expanded Smith charts.


Circle 262 on Inquiry Card

LOGIC

Digital system simulation.

This program simulates digital systems containing logic gates. Flip-flops, clocks, registers and other special purpose modules. Give it a description of your logic block diagram and it will produce tables showing the logical state of selected modules at designated points in time. You can use this printout as a timing diagram.

The printout, in addition to being keyed to specified periods of time, can also be keyed to the state changes of various modules giving you considerable latitude in your design analysis. This program has a conversational data input model for the experienced user. It will simulate a digital system having up to 500 logic modules. Propagation delays can be specified for each module.

General Electric, Information Service Dept., 7735 Old Georgetown Rd., Bethesda, Md. 20014.

Circle 263 on Inquiry Card

MICRONET

For designing microwave circuits.

MICRONET is used on a remote interactive basis. It provides a program for frequency domain analysis of distributed parameter circuits and includes modeling and analysis flexibility. Applicon Incorporated, 83 Second Ave., Burlington, Mass. 01803. (617) 272-7070.

Circle 264 on Inquiry Card

ACNET and DCNET

For linear circuit analysis.

These two programs perform ac and dc linear network analysis, respectively. By building a data file describing the circuit you can "breadboard" your circuit on the computer. The programs then perform analysis and tests on the "breadboard" circuit so that you can evaluate circuit performance. The programs' interactive conversational mode lets you direct the course of analysis and alter circuit parameters "on-line" during the run.

A useful feature of these programs is their ability to produce a sensitivity analysis.

ACNET and DCNET also have the capability to provide information on the production yield in circuit manufacturing. This is done through a Monte Carlo analysis. General Electric, Information Service Dept., 7735 Old Georgetown Rd., Bethesda, Md. 20014.

Circle 265 on Inquiry Card

NLNET

For non-linear circuit analysis.

NLNET is an on-line application program for analyzing electronic circuits. It quickly performs non-linear ac analysis with non-linear models for transistors and diodes. With it you can create a file of stored transistor models for referencing. Thus, you need to model a specific transistor only once. It not only readily calculates steady-state voltages, currents, and powers, but also produces statistical analysis of your circuit's performance.

It also has the capability to provide information on the production yield in circuit manufacture. This is done through a Monte Carlo analysis. General Electric, Information Service Dept., 7735 Old Georgetown Rd., Bethesda, Md. 20014.

Circle 266 on Inquiry Card

ALICE

Logic simulation for digital analysis.

This program simulates the behavior of asynchronous and synchronous digital logic networks as well as verifying the behavior of a logic net. It is particularly useful for designing MSI or LSI circuits where bread-boarding is difficult. Rise and fall time can be specified for each logic element. Clock logic elements are also allowed.

This three-value (logic simulators are typically bistable) look ahead simulates undefined inputs, checks result sequences and allows undefined inputs, checks result sequences and allows several types of timing analysis to be performed. Applicon Incorporated, 83 Second Ave., Burlington, Mass. 01803. (617) 272-7070.

Circle 267 on Inquiry Card

MOFACS

Calculate feedback parameters.

MOFACS (Multi Order Feedback and Compensation Synthesis) is a digital computer program for synthesizing the linear and/or non-linear feedback parameters needed to achieve a desired transient response. With it you can calculate the best possible feedback parameters and compensation time constants in one pass. This differs from the analysis and CAD programs where you must continually re-select hardware and parameters and analyze them to get the desired performance.

Because MOFACS input is in the form of a transient response, it can be used as an off-line adaptive controller. It can be applied to R&D designs and also to applications, instrumention, process control and DDC engineering. Compro Associates Inc., 825 N. Church St., Room 201, Rockford, Ill. 61103. (815) 964-7224.

Circle 268 on Inquiry Card

ANALG

Dynamic system simulation.

ANALG simulates the operation of an analog computer. Thus, it can be used to produce the transient response of a system which has been modeled using linear or non-linear differential equations. With it you can store system descriptions in a data file instead of having to build a patchboard. Once the simulated "patchboard" has been created, the program will determine the time-domain response at any point within your system over any interval of time.

ANALG has 31 different types of functional blocks which allow you to build all types of functional generators and also allow you to describe system non-linearities. Another feature is that configuration and parameter changes can be made on-line. General Electric, Information Service Dept., 7735 Old Georgetown Rd., Bethesda, Md.

Circle 269 on Inquiry Card

TRANS

Dynamic system simulation.

TRANS is used to quickly and easily invert Laplace transforms to obtain either numerical or plotted transient response of dynamic systems. You merely enter the coefficients of the transform into the program, and the transient response is produced. It provides you with an accurate method to study the performance of a proposed system and investigate differences in existing systems. General Electric, Information Service Dept., 7735 Old Georgetown Rd., Bethesda, Md.

Circle 270 on Inquiry Card

Circle 60 on Inquiry Card
Time-sharing is like trying to add $2 + 2$ on a typewriter.

Most service bureaus give you a teleprinter terminal and expect you to solve your problems with a computer many miles away. So when their computer gets busy, your teleprinter goes dead. And a dead teleprinter is just another typewriter. But now there's a different kind of time-sharing that only you can use. It's called the Interplex System I. It's an in-house system with a 12K general-purpose computer, hard-wired to as many as 16 specially designed terminals. So you don't need phone lines. And because it's your own in-house system, you can use it as much as you want without paying an extra cent for it. It's easy. Our new time-sharing terminal is the first to combine BASIC language programming with an electronic calculator in a single desktop unit. So you can do up to 90% of your time-sharing jobs in BASIC without leaving your desk. And for a lot less than you're paying now. You won't need any more equipment, because the terminal's also an electronic calculator. So you can even stop in the middle of your own program to run your calculations. And you don't have to wait for anybody else. The Interplex System I. It's a different kind of time-sharing. You share it with yourself.
For continuous lacing...

* that CABLE-LACER brake speeds the work too!

The experienced harness worker can quickly guide the hooked needle of the Gudebrod Cable-Lacer® across narrow break-out points between pins to grasp the loop. This is where work is speeded first. But then, the pressure of four fingers on the lacing break allows a swift, single pull for firm knot setting—further speeding the job. No need for wrapping around the fist—no need for a second pull. It all becomes a naturally fast procedure. What's more, the special Gudebrod lacing tape bobbins are helpful when all-hand tying seems required! Use Gudebrod Cable-Lacer, Gudebrod's Bobbins for improved accuracy and time saving.

*T.M. Union Special Machine Co.

Save money & time with

GUDEBROD SYSTEM “C”

For continuous lacing Gudebrod offers a four part system to reduce your harnessing costs. The Cable-Lacer and Bobbins are the first two parts. Add to them Gudebrod's specially made, case hardened, extra long, wire holding pins and the Gudebrod Swivel-Tilt Harness Board Mount. The pins make wire threading easier and sharply reduce the need for redressing. The Gudebrod Mount brings any part of the harness within easy reach. Gudebrod System “C” makes harnessing go faster, cost less. Write for details. (For spot ties, ask about System “S”)

Gudebrod Swivel-Tilt Harness Board Mounts available in several sizes

GUDEBROD BROS. SILK CO., INC. Founded 1870, 12 South 12th Street, Philadelphia, Pa. 19107
NEW PRODUCTS

CERAMIC FILTERS
For broad use.

Series 800 units filter ac and dc lines in aircraft, aerospace and industrial avionic systems, power supplies, communication, navigation and guidance equipment. Models are available with ratings from 50 Vdc to 120 Vac, 400 Hz., and from 40 mA to 15 A. A typ. 50 Vdc, 40 mA unit would display an insertion loss of over 80 dB at 1 MHz. About $12 ea. Filters & Capacitors, Inc., 425 N. Fox St., Box 1272, San Fernando, Calif. 91341.

Circle 244 on Inquiry Card

SOLID-STATE LAMP
Only $0.50 in quantity.

New HP 5082-4403 red light-emitting diode (LED) is designed to displace miniature incandescent and glow lamps in indicator applications. The GaAsP lamp is for self-mounting in panels or pc boards, and has a rugged lead-frame and plastic construction. It has a typ. life of 1,000,000 hrs. Operating on 1.8 V at 20 mA, it is compatible with tcs. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304. (415) 326-7000.

Circle 247 on Inquiry Card

DIGITAL PANEL METER
Accurate 10,000 count resolution.

DP400 Series 10,000 count meters are high-accuracy (±0.02%, ±1 count) dc voltage measuring devices that provide direct digital readout of the value of the applied input voltage. Three models are available with full-scale input ranges of 1.0, 10.0 or 100.0 V. Range is 30°F to 140°F, and tc is 0.003%/°F. $273.00 and up. Computer Products, 2709 Dixie Hwy, Box 23849, Ft. Lauderdale, Fla. 33307. (305) 565-9565.

Circle 250 on Inquiry Card

LOW POWER PIN DIODES
Fast switching and high dynamic Q.

These pin diodes provide up to 1.0 kW peak power with 5 ns switching time and dynamic Q of 300. Minimum breakdown of 100 V and lifetime of 75 ns are other characteristics. These diodes, characterized at 1 GHz, are for use in fast switches and modulators in waveguide, stripline or coaxial circuits. Microwave Associates, Burlington, Mass. 01803. (617) 272-3000.

Circle 245 on Inquiry Card

IC SOCKET ASSEMBLIES
Track-mounted.

New CS16 assemblies are for testing, breadboarding and packaging 16-pin DIL modules. They feature a pc design, a 16-pin DIL socket, and SE Series barrier terminal blocks. Up to 21 sockets can be mounted to a 48 in. length of prepunched track. $2.85/assembly, including track, in lots of 1000. Curtis Development & Mfg. Co., 3250 N. 33rd St., Milwaukee, Wis. 53216.

Circle 248 on Inquiry Card

DIGITAL INDICATOR
Wide spectral bandwidth.

DG-12H seven segment indicator is a low voltage, low current drain, planar readout device. Digits, symbols, and letters are composed of highly efficient phosphor coated segments providing clarity between digits up to 40 ft. distances. Wide spectral sw makes available different color outputs using proper filtering. Legitron Corp., 3118 W. Jefferson Blvd., Los Angeles, Calif. 90018. (213) 733-9105.

Circle 251 on Inquiry Card

EDGEBOARD CONNECTOR
Matched impedance for h-f uses.

This connector offers you an inexpensive system mechanically similar to std. edgeboard connectors, yet electrically equivalent to coaxial connectors. It has quick connect-disconnect capability, and costs about 80% less than traditional coaxial connector systems. Texas Instruments Incorporated, 34 Forest St., Attleboro, Mass. 02703.

Circle 246 on Inquiry Card

TANTALUM CAPACITOR
Seal prevents leakage.

A positive hermetic glass-to-metal seal on this wet anode tantalum electrolytic capacitor prevents electrolyte leakage. The new TLW capacitor has voltage ratings of from 6 to 125 V and a capacitance of 560 µF at 6 V to 25 µF at 125 V. P.R. Mallory & Co. Inc., 3029 E. Washington St., Indianapolis, Ind. 46206. (317) 636-5333.

Circle 249 on Inquiry Card

MULTI-PURPOSE EPOXY
Cures in < 1 min.

Minit-Cure epoxy is well suited for jobs that require fast curing time at room temp. (75°F). It bonds metals, woods, plastics, rubber and glass. Almost instantaneous use can be obtained from the item being bonded. Its tensile strength is 2900 psi. Tescom Corp., Instrument Div., 2633 S.E. 4th St., Minneapolis, Minn. 55414.

Circle 252 on Inquiry Card
NEW PRODUCTS

DECADE MODULES
For mounting in test panels.

These resistance decades are very accurate (±0.005% at the terminals) with a long-term stability up to 5 ppm/yr. They can be used at incoming inspection stations, in the stds. lab. and for component evaluation. Their TC is 2 ppm/°C, and they are usable to 100 MHz. Set point resolution is available up to 0.010 over the 100,000 Ω range. Vishay Resistor Products, 63 Lincoln Highway, Malvern, Pa.

Circle 253 on Inquiry Card

QUARTZ CRYSTAL
With 2.0 to 4.0 MHz freq. range.

New, series resonance AT precision cut crystal is available in small HC-18/U-or HC-25/U holders. The fundamental mode crystal holds tolerances as low as ±0.003% over a range of −55 through 105°C. Rs max. varies from 500 Ω at 2.0 MHz to 75 Ω at 4.0 MHz. Drive level is 1 mW with a Co of 4.0 pF. McCoy Electronics Co., a subsidiary of Oak Electro/Netics Corp., Mt. Holly Springs, Pa. 17065.

Circle 256 on Inquiry Card

SINGLE LITE SWITCH
With snap-in housing.

Snap-in housing of the 01-600 series switches is available in bezel, single barrier or double barrier design. Indicator, momentary and alternate action units are available, also 1 or 2-pole switch packages using the 10 A Butterfly® double break switch mechanism. Lamp does not move during switch operation. Licon Div., Illinois Tool Works Inc., 6615 W. Irving Park Rd., Chicago, Ill. 60645. (312) AV 2-4040.

Circle 259 on Inquiry Card

HAND ENCODER
Simplified, lower cost.

Model DCN-64 “Commander” is useful where the volume of programs or messages is small or sporadic, for backup in case of major equipment downtime, and for making corrections. It can be programmed with up to 64 individual codes in eight channels, plus feed holes, providing capability for virtually any hole-punch system. Robins Industries Corp., 15-58 127th St., College Point, N.Y. 11356.

Circle 254 on Inquiry Card

VIDEO AMPLIFIERS
Low noise, broadband.

These video preamplifiers are suitable for use in CCTV and CATV as well as high resolution video detection, low light level TV, pulse studies, and general lab use. Features include 1 V pk-pk into 50 Ω, 50 MHz bandwidth, 0-40 dB gain, Zs: 50 or 75 Ω, Zi: 50 Ω to 1 kMΩ, and a rugged aluminum case. AMF Alexandria Div., 1025 N. Royal St., Alexandria, Va. 22314. (703) 548-7221.

Circle 255 on Inquiry Card

FIBER OPTICS ILLUMINATOR
Provides light for difficult areas.

Illuminator’s intensive, but cool, spot of light penetrates into cavities and other hard-to-illuminate areas. It provides 800 ft. candles of non-glare illumination within a 7 in. dia. circle up to 6 in. from the end of its fiber optics probe. The optical system is housed completely in the light box source. Under $300. Bausch & Lomb, 635 St. Paul St., Rochester, N.Y. 14602. (716) 232-6000.

Circle 258 on Inquiry Card

CURRENT REGULATOR
Screw driver adjustable.

Constant current regulator provides current reg. of 1% over wide ranges of input voltage and temp. A two terminal regulator, it can be used in series with the current line and needs no ref. to ground. TC is 0.03%/° C. Current stab, with voltage 1%. Maximum power diss. ranges from 1 to 3 W at 25°C case. Electronic Modules Inc., 2560 East Foothill Blvd., Pasadena, Calif. 91107.

Circle 261 on Inquiry Card

CERMET TRIMMERS
Low tc and sealed construction.

Series 190 ¾ inch rectilinear 20-turn units come in three types: Type 190, 0.100 in. wide and 0.500 in. length pin spacing; Type 191, 0.200 and 0.500 in., and Type 192, 0.100 and 0.700 in. All have low ±150 ppm/°C TC for most values, ½ W rating at 85°C and clutch stops. Standard range is from 50 Ω to 500 kΩ. Under $1.00 (in quan.). CTS of Berne, Ind. 46711. (219) 589-3111.

Circle 260 on Inquiry Card
Any DC VOM with 0.1% accuracy should cost more.

Model 1241
$289 complete.

We wanted the price low enough that anyone taking DC voltage or resistance readings wouldn't have to think twice about choosing our new Model 1241. As it turned out, we can give you an even bigger break. Because most of the circuitry, as well as the rugged housing and many convenience features, had been developed previously for the Weston 1240 DMM which we introduced last November.

Here's a proprietary-designed Weston instrument you can pack in your tote case, use on the bench, or mount in a standard 3½” panel. The only "extra" you may ever need is an optional battery pack for remote field applications. Model 1241 gives you high-impedance measuring capability to 3½ digits on five voltage and six ohm ranges.

In addition to its outstanding accuracy of 0.1% of reading ±0.05% F.S. on Volts (0.5% ±1 digit on Ohms), this advanced meter features complete circuit overload protection. Fuses are replaceable without opening the rugged, glass-filled thermoplastic case. And, of course, there's Weston's patented dual slope* integration, automatic decimal positioning, and non-blinking display.

If you want to see how much quality a dollar will buy today, contact your Weston Distributor. He also has in stock our 1240 DMM, with 26 AC-DC ranges plus all the above features. Or write today for complete specifications.

WESTON INSTRUMENTS DIVISION,
Weston Instruments, Inc., Newark, N.J. 07114, a Schlumberger company
Unitek Bonders Stack Up Best

Build your bonding line with the source that's proven best in the field...take UNITEK.

In case after case of tough on-line comparison testing, more leading firms take UNITEK because they've proved that when the chips are down you get the Best Chance for the Best Choice...here's why...flexibility, repeatability, and service in-depth.

First, you get wider work-choice options. Each UNITEK bonder is built for production-versatility...handles all package types by simply interchanging optional accessories. Single units, rack-feed or automatic strip-feed handling of conventional packages...hybrids, too, all available on virtually every bonder. Take exactly the options you need now...add later when you need to...the closest thing yet to custom making your production line.

Pinpoint repeatability is another very big reason. Prototype work or line work, it's guaranteed by exclusive rugged, durable UNITEK construction, perfect process controllability and ultra-simple operation. Training and maintenance stay low...rates and yields stay up...lot-run after lot-run.

Third...service...expert guidance you can count on; after you specify as well as before. Your

UNITEK man and the entire UNITEK Applications Laboratory team of bonding specialists can make life a lot easier out there on the line.

UNITEK stacks-up best...has for over twenty years...there's bound to be a proven UNITEK bonder for you...get more facts by contacting your nearby UNITEK man or UNITEK/Weldmatic Division, 1820 So. Myrtle Avenue, Monrovia, California 91016. Telephone: (213) 358-0123; TWX: 910 585-3236.

The Best Chance
for the Best Choice

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The Electronic Engineer • June 1970
NEW PRODUCTS

INDICATOR LIGHTS
For integrated circuits.

This subminiature transistorized light, specially designed for ICs, needs no power supply and interface circuitry. It operates directly from standard TTL, DTL, and RTL micrologic modules. Signal level requirements and power supply voltage for these units are completely compatible with ICs. All driving circuitry is within the indicator light itself. Dialight Corp., 60 Stewart Ave., Brooklyn, N.Y. 11237. (212) 497-7600.

Circle 271 on Inquiry Card

IC PACKAGING SYSTEM
Low cost, solderless.

New packaging system, DipStik II, provides high capacitance and low impedance ground and power planes. With it you can mount DILs, remove or replace them and change logic circuitry, all in a few seconds—without the use of solder. Its high density packaging capability allows 1000 DILs to be mounted in a 5 1/4 in. rack. ACS Industries, 13726 Saticoy St., Van Nuys, Calif. 91402. (213) 988-5310.

Circle 272 on Inquiry Card

SLIDE SWITCH
Smaller mass.

New miniature slide switch is about half the mass of a regular slide switch. Typical overall length is reduced from 1 3/8 in. for a std. sized switch to 1 in. for a comparable miniature switch. The multi-purpose switch is available in all combinations from SPST to double pole—three position. Initial ratings are 1 A at 125 Vac (ind. load). Stackpole Components Co., Box 14466, Raleigh, N.C. 27610.

Circle 273 on Inquiry Card

WIRE STRIPPER
Self-adjusts to different wire sizes.

This new tool (ABMK-1) is completely self-adjusting to the point where it is not necessary to know the wire size. Different diameter wires can be stripped consecutively without changing or adjusting the stripping jaws. The tool takes wire dia. from AWG #30 through #12, both copper and aluminum. $28.00. The Thomas & Betts Co., 36 Butler St., Elizabeth, N.J. 07207. (201) 354-4321.

Circle 276 on Inquiry Card

TIMING MODULES
From milliseconds to hours.

By adding ext. resistors and capacitors to the TM series modules, you can obtain timing ranges from milliseconds to hours. Timing is fixed or adjustable with delay or interval modes of operation. Outputs are pulse, continuous, or complementary. Repeat accuracy is ±1% at constant temp. Series also features on/off voltage level control. Chronologics Inc., 24 Martin St., Webster, N.Y. 14580. (716) 782-1470.

Circle 274 on Inquiry Card

MICA CAPACITORS
For improved circuit stability.

Lead spacings of these single-film silvered mica capacitors are interchangeable with those of normal ceramic disc capacitors. Thus you can have the advantages of silvered mica dielectric without having to completely revise pc boards. Type 91M capacitors come in 45 ratings ranging from 10 pF to 68 pF at 500 V. Sprague Electric Co., 233 Marshall St., North Adams, Mass. 01247.

Circle 275 on Inquiry Card

WIRE STRIPPER
Self-adjusts to different wire sizes.

This new tool (ABMK-1) is completely self-adjusting to the point where it is not necessary to know the wire size. Different diameter wires can be stripped consecutively without changing or adjusting the stripping jaws. The tool takes wire dia. from AWG #30 through #12, both copper and aluminum. $28.00. The Thomas & Betts Co., 36 Butler St., Elizabeth, N.J. 07207. (201) 354-4321.

Circle 276 on Inquiry Card

CIRCUIT BOARD
Grooved for modular assembly.

Miniature 10 x 10 solderless boards, grooved for lock-in assembly, provide any number of groupings consisting of 100 terminal holes on 0.100 in. centers. Each “Miniboard” module is 0.147 in.2 and 27/32 in. thick. Units mount on aluminum framing rails. Contact rating is 3 A. Voltage rating is 300 Vdc max. Programming Devices Div., Sealectro Corp., 225 Hoyt St., Mamaroneck, N.Y. 10543.

Circle 279 on Inquiry Card

CAPACITOR KIT
Contains over 400 ceramics.

AlSiMag® kit contains both single layer and multi-layer capacitors. Diced chip capacitors range from 18 pF to 1500 pF in sizes from 0.020 in.2 to 0.350 in.2 Multi-Cap® capacitors range from 10 pF to 0.085 µF in sizes from 0.085 x 0.055 in. to 0.220 x 0.250 in. Materials range from TC to high K. Tolerances are ±5%, ±10% and ±20%. $50. American Lava Corp., Chattanooga, Tenn. 37405. (615) 265-3411.

Circle 277 on Inquiry Card

COPPER-CLAD LAMINATE
For pc boards.

Insulstruc® copper clad X2FR-PG glass polyester sheet is for applications requiring superior toughness at low cost. High density Insulstruc has Izod impact strength of 7 ft. lbs., solder dip resistance of 20 s (Mil-P-13949D), and other excellent mechanical and electrical characteristics typical of glass polyester. Cincinnati Development & Mfg. Co., 5614 Wooster Pike, Cincinnati, Ohio 45227.

Circle 278 on Inquiry Card

THE ELECTRONIC ENGINEER • June 1970
**NEW PRODUCTS**

**PORCELAIN CAPACITORS**
With tight tolerance.

These capacitors come in eight different series which include 22 styles. Available in a range of 0.24 pF through 10,000 pF, they have tolerances of either ±0.1 pF or ±1%. All styles have failure rates of < 0.15%/1000 h at a 90% confidence level at rated temp. and voltage conditions.

Vitramon, Inc., Box 544, Bridgeport, Conn. 06601. (203) 268-6261.
Circle 280 on Inquiry Card

**COAXIAL CIRCULATOR**
For low power applications.

Three-port L-band, Model CLL 83 operates in freq. range of 1200-1400 MHz, with a max. input vswr of 1:20. Maximum insertion loss is 0.3 dB, and min. isolation is 20 dB over the band. It is 3¼ in. in dia. and 1-5/32 in. long, excluding connectors. It comes in either Y- or T-configurations. Raytheon Co., 190 Willow St., Waltham, Mass. 02154.
Circle 283 on Inquiry Card

**FASTENERS**
For PC boards.

Eight variations of this Speed Clip® fastener accommodate the full range of hardware uses in PCB rack applications. The clips snap to the board rack flanges without tools. Tabs on the clips engage mounting holes in the flanges, and, once installed, the clips remain in place if the connectors must later be removed. Tinnerman Products, Inc., Box 6688, Cleveland, Ohio 44101.
Circle 286 on Inquiry Card

**THUMBWHEEL SWITCHES**
Mount on ½ in. centers.

Series RSM mini thumbwheel switches retrofit most miniature thumbwheel switch openings. They can be furnished with decimal, binary, and binary with complement outputs as well as specifically specified codes. They have large, easily read numerals, positive detent, and 10 and 12 positions, $6 to $8/module. Chicago Dynamic Industries, Inc., Precision Products Div., 1725 Diversey Blvd., Chicago, Ill. 60614. (312) WE 5-4600.
Circle 281 on Inquiry Card

**GENERAL PURPOSE RELAYS**
Three series available.

RGP series plug-in type is available in spdt, dpdt, tpdt with coil voltages of 6 to 230 V. The RGO is the open type. Both series have contact ratings of 10 A resistive with silver cadmium oxide contacts for a min. of 1 million operations at rated load. RMC series min. relay is for PCB mounting. It comes with spdt, 3 A contacts and coil voltages from 6 to 48 Vdc. Syracuse Electronics Corp., Box 566, Syracuse, N.Y. 13201. (305) 488-4911.
Circle 284 on Inquiry Card

**INTERCONNECTION SYSTEM**
Solves many connection problems.

BergCon interconnection system includes the male and female connectors, removable crimp-to-wire housing assemblies, card connectors and headers for direct board mounting. It offers an infinite variety of interconnections between staked 0.025 in.² pins (Berg-Post) and PV connectors, min-PV connectors, molded connector housings, card connectors and headers. Berg Electronics, Inc., New Cumberland, Pa. 17070. (717) 938-6711.
Circle 287 on Inquiry Card

**FAULT INDICATOR**
Only 0.320 in. max. dia.

Connected to key circuit elements, these microminiature fault isolation indicators respond to a fault signal—transient or continuous—by a color transfer of its display mode. The display latches into place magnetically until reset. Reset is accomplished by momentarily energizing a reset coil. They are for pulse operation and do not require continuous power. The A. W. Haydon Co., 232 N. Elm St., Waterbury, Conn. 06720.
Circle 282 on Inquiry Card

**LONG LIFE NEON**
For numeric displays.

The A297 lamp is made with 7mm electrodes enclosed in a glass envelope which is much longer than necessary for an ordinary neon lamp. The long envelope with shorter electrodes eliminates the possibility of a change in characteristics of the device due to sputtering. Breakdown rating is 215 V max. and a maintaining voltage 128 to 148 V. Design current is 5 mA. Signa-lite Inc., 1933 Heck Ave., Neptune, N.J. 07753. (201) 775-2490.
Circle 285 on Inquiry Card

**CRYSTAL OSCILLATOR**
Features low power.

OSC 18 series proportional oven controlled oscillators range in stability from 1 x 10⁹/day through 1 x 10⁻⁸/day. Oscillator and oven together need only 3 W power (12 Vdc or 24 Vdc) in steady state condition, at +25°C. Available with |< 2 x 10⁻¹⁰ change in freq./°C amb. change. Frequencies from 500 kHz to 30 MHz. Plug-in or PCB mounting. Ovenaire, Inc., Charlotteville, Va. 22902. (703) 293-5148.
Circle 288 on Inquiry Card
Stack
These Up
Against The Others

your best buys in meters
come from Heath

For over 20 years, Heath has been the first choice in meters for tens of thousands of service technicians, schools and home labs. There's a reason for this continued popularity — Heath meters are designed to have that balance of versatility, needed features and low cost that make them your best buy. For the price of just a couple of meters from others, you can buy every meter Heath makes. We believe that you should still be able to get a stack of meters without spending a pile of money. When you need a meter, look to Heath. For performance, versatility and top dollar value, the others just don't stack up.

1. **$21.95** Buys A Portable Solid-State Volt-Ohm-Meter. Four ranges on AC & DC volts measure 1-1000 volts full scale. Four resistance ranges measure 0.1 ohm to 1000 megohms. Features convenient battery operation... zero & ohms adj. controls... DC polarity reversing switch... spare jack for HV & RF probes... rugged polypropylene carrying case. IM-17, 4 lbs.

2. **$31.95** Buys A Portable Volt-Ohm Milliammeter. Measures AC & DC volts 1.5-5000 full scale. DC current from 150 μA to 15A. Resistance mid-scale from 15-150,000 ohms. Large 4½" 50 μA movement meter for extra accuracy. MM-1, 5 lbs.

3. **$29.95** Buys An Accurate VTVM. 7 AC & DC ranges measure RMS volts from 1.5-15000 full scale... AC P-P from 4.0-4000... 7 resistance ranges from 0.1 ohms to 1000 megohms. 25 Hz-1 MHz response. Single probe makes all measurements. IM-18, 5 lbs. Assembled IMW-18, 5 lbs. ... $49.95*

4. **$41.95** Buys A Laboratory AC VTVM. Especially useful for low-level AC & audio work. Ten RMS ranges from 0.01-300 V full scale... measures dB from -52 to +58. ± 1 dB response from 10 Hz-500 kHz. 10 meg. input impedance. IM-38, 4 lbs. Assembled IMW-38, 5 lbs. ... $49.95*

5. **$39.95** Buys A Big Service Bench VTVM. Has the same high performance as the IM-18 above, plus added features to make it more useful for service work... separate 1.5 & 5 VAC scales... calibration controls that are adjustable from the front panel... versatile gimbals mounting... large 7" meter. IM-28, 7 lbs. Assembled IMW-28, 7 lbs. ... $59.95*

6. **$46.95** Buys A Big Solid-State Volt-Ohm Meter. Battery-powered portability plus built-in AC supply. 8 AC & DC ranges 0.5-1500 full scale... 7 resistance ranges (10 ohm center scale) x1-x1 meg. High input impedance & 6" meter for greater accuracy. IM-16, 10 lbs. Assembled IMW-16, 11 lbs. ... $69.95*

7. **$85.00** Buys A Deluxe Solid-State Volt-Ohm Milliammeter. 9 AC & DC ranges from 150 mV-1500 V full scale... 7 resistance ranges measure from 1 ohm to 1000 megohms... 11 current ranges from 15 μA-1.5 A full scale. 100 kHz response... high input impedance... large 6" meter with zero center. IM-25, 10 lbs. Assembled IMW-25, 10 lbs. ... $120.00*

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The Electronic Engineer • June 1970

Circle 64 on Inquiry Card

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We’re the ones who put the flux on the outside of solder preforms . . .

. . . because that’s where it belongs

The advantages are obvious. Flux on the outer surface of the preform liquefies first and flows onto the base metal before the solder melts. With flux-filled preforms, the solder must melt before the flux can escape and there’s a good chance liquid solder will come in contact with the metal surface before it has been properly cleaned.

Flux-coated preforms also provide other advantages over solid solder or flux filled solid preforms: a quicker, more even spread rate, 100% flux coverage and consistently reproducible dimensional control upon melting. You can choose from a wide variety of standard and special shapes, coated with the finest grade of water-white rosin flux in all degrees of activation.

Flux-coated preforms join a long list of Alpha product innovations for better soldering, including oxide-free, Vaculoy® processed bar solders and anodes, a foam flux that meets MIL-F-14256, Type A specification, a complete line of neutral pH, electronic grade cleaners and a host of others.

Back these with our full range of quality industrial solders, fluxes and soldering chemicals, the largest research staff and the most proficient technical service and assistance in the industry, and you have a supplier you can really rely on. Call or write for full information today.

Alpha Solder Creams cut costs in mass production operations. (Ill: attaching feed throughs and dividers in tuner box.)

Alpha bar solders and solder and tin anodes are Vaculoy® processed to be oxide-free.

ALPHA METALS, INC.

6 WATER STREET, JERSEY CITY, N. J. 07304 • 201 • 434-6778
Alpha Metals, Inc., Los Angeles, Calif.
Alphaloy Corp. (Div.) Chicago, Ill.
Alpha Metals, Inc. (U.K.), Ltd., London, England

Circle 65 on Inquiry Card

The Electronic Engineer • June 1970
Feature article abstracts

Published information is vital to your job. To save time in finding this information, we have abstracted the important technical features from eight electronic engineering publications. Should any of these articles interest you, contact the magazine—names and addresses are listed below. Reprints of articles with an asterisk are available free. Save this section for future reference.

Charts and Nomographs


Guide to CAD, "Electronics," Vol. 43, No. 8, April 13, 1970, pp. 109-112. This is a full color, 4-page chart listing first and second generation Computer-Aided Design programs known today. Each is compared on a table to aid in the selection of one for your requirements.

Circuit Design

*Three-pole active filter, Russell Kincaid, Sanders Associates Inc., "The Electronic Engineer," Vol. 29, No. 6, p. 46. Here is a circuit that gives you six different filter responses with just three capacitor changes. Included is a graph of all six responses.

Top performance from analog multipliers? Much depends on errors gauged in your circuit, Tom Cate, Burr-Brown, "Electronics," Vol. 43, No. 8, April 13, 1970, pp. 114-117. At one time analog multipliers were only for analog computers. Today they are used in signal processing and telemetry. Correct selection and application of these devices is based on your signal requirements. The author guides you through some of the methods used to decide your requirements.

Choose magnetic deflection, William Peterson, ITL Research Corp., "Electronic Design," Vol. 18, No. 9, April 26, 1970, pp. 80-82. Circuit diagrams accompany a discussion of the advantages of magnetic deflection over electrostatic deflection in CRT displays. Small spot size and large deflection angles are the biggest benefits. Magnetic deflection is current-controlled, which gives higher system reliability and matches solid-state amplifiers better. It works up to 5 MHz with little trouble. Distortion due to series resistance is overcome with feedback techniques.

Communications

Transmission delay and echo suppression, Richard G. Gould, Office of Telecommunications Management, and George K. Helder, Bell Telephone Laboratories, "Spectrum," Vol. 7, No. 4, April 1970, pp. 47-54. Although the promise of satellite communication is great, the authors point out the inherent problems of transmission delay and echo in telephony. Advances in echo control are presented with proposed standards for acceptable and unacceptable delays for telephone circuits.

Bell's money is riding on millimeter waves for future communications, Laurence Altman, "Electronics," Vol. 43, No. 8, April 13, 1970, pp. 96-105. Waveguides and solid state microwave devices are what Bell is working with to increase circuit requirements. Their system designs rest on dielectric-clad waveguides. Impatt and pin diodes. This article describes the decisions that were and still have to be made along with some of the technical problems and some solutions.

Computers and Peripherals

There's a better way to design a character generator, Gene Carter and Dale Mrozek, National Semiconductor, "Electronics," Vol. 43, No. 9, April 27, 1970, pp. 107-112. With the increased need of computer terminal equipment, all kinds of methods are being tried to get better, cheaper readout displays. This article describes a display which uses MOS read-only memories and shift registers. Through these devices alphanumeric displays are generated that are simple and inexpensive.

Four-phase LSI logic offers new approach to computer design, Lee Boysel and Joseph Murphy, Four Phase Systems, Inc., "Computer Design," Vol. 9, No. 4, April 1970, pp. 141-146. According to the authors, the development of MOS/LSI cells for a new four-phase logic that focused attention on areas that were not previously critical. Thus, they discuss both circuit design and the strategy of partitioning system architecture to minimize cost. They also describe the main LSI block of a low-cost fourth-generation computer currently in pilot production.

Magazine publishers and their addresses

Computer Design

EDN
Cahners Publishing Company 270 St. Paul Street Denver, Colo. 80206

EEE
Mactier Publishing Co. 820 Second Avenue New York, N. Y. 10017

Electronic Design
Hayden Publishing Co. 850 Third Avenue New York, N. Y. 10022

Electronic Products
United Technical Publications 645 Stewart Avenue Garden City, N. Y. 11530

Electronics
McGraw-Hill, Inc. 330 W. 42nd Street New York, N. Y. 10036

IEEE Spectrum
Institute of Electrical & Electronic Engineers 345 East 47th Street New York, N. Y. 10017

The Electronic Engineer
Chilton Company 56th & Chestnut Streets Philadelphia, Pa. 19139

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ABSTRACTS

Small computer design using microprogramming and multifunction LSI arrays, Frank J. Langley, Raytheon Co., "Computer Design," Vol. 9, No. 4, April 1970, pp. 151-157. Although not new in basic concept, microprogram control in digital computers presents new challenges. The result is an LSI-MSI computer design with currently available circuits. Advantages are simplicity, orderliness, and modularity. Flexibility in instruction repertory and instruction length complement other big advantage of microprogram control was that the computer prototype model was designed, built and checked out in only five months.

Phase state diagrams and hardware equations for sequential logic design, Alfred Pestone, and Stephan M. Koenig, Information Displays Inc., "Computer Design," Vol. 9, No. 4, April 1970, pp. 161-164. This design approach broadens the application of the design engineer's mapping and equation tools, making them more useful than in the past. Thus, modification of the Karnaugh map and Boolean equations has resulted in a reduction in design and documentation costs and time.

Integrated Circuits

*Static or dynamic—two ways to remember, Morison E. Hoff, Jr., Intel Corp., "The Electronic Engineer," Vol. 29, No. 6, pp. 72-74. MOS RAMs use two different techniques to store information. The first, static storage, uses flip-flops as storage elements just as bipolar memories do. The other technique, dynamic storage, uses a unique characteristic of the MOS device to gain some definite advantages. In this article, Dr. Hoff looks at the technology and describes the advantages and disadvantages of both.

*MOS random access memories, Warren Crews, Motorola Semiconductor, "The Electronic Engineer," Vol. 29, No. 6, pp. 76-78. The most promising areas for the application of MOS Integrated circuits is in the construction of random access memories. Mr. Crews discusses the different types of RAMs used today and describes the MOS RAM and its special features.

*Performance and cost trade-offs for MOS RAMs, Vernon G. McKenny, Mostek Corp., "The Electronic Engineer," Vol. 29, No. 6, pp. 76-78. The characteristics of MOS RAMs depend to a large extent on the configuration of the memory. In this article, Mr. McKenny looks at some of the most popular configurations and describes just what trade-offs are required.

*Frequency synthesizing with the phase locked loop, Ed Renachler and Brent Welsch, Motorola Semiconductor Products Inc., "The Electronic Engineer," Vol. 29, No. 6, pp. 84-90. The advancement of IC technology has made the phase locked loop circuit feasible. And, an ideal application of the PLL is a multichannel frequency synthesizer because many precise frequencies can be generated with only one reference frequency. In this article the PLL is the basis for a new, somewhat unconventional digital frequency synthesizer design.

*Speed/power chart for digital ICs, Staff Report, "The Electronic Engineer," Vol. 29, No. 6, June 1970, pp. 58-59. This chart allows the reader to make a "ballpark" selection of those digital integrated circuits that are best suited for his application. The chart shows how technology form the two most important parameters-power dissipation and propagation delay.

Boost your DTL efficiency with wired-OR, Gilbert Storrs, QED Systems Inc., "Electronic Design," Vol. 18, No. 8, April 1970, pp. 89-91. NAND gates are the most widely available type, though many two-stage functions can be reduced to one-stage logic by other types. Decreased propagation delay is an immediate benefit. If you sacrifice fan-in capability, wired-OR is a way out. The method is to express functions in Boolean algebra and manipulate them into a form suited to AND/NOR implementation. On the logic diagram, substitute NAND gates for AND gates and wired-OR connections for NOR gates to get an equivalent NAND/wired-OR circuit. Examples are given.

Semiconductors

Watt-megahertz ratings run second to high reliability for four ICs, Richard M. Magill, "Electronics," Vol. 43, No. 9, April 27 1970, pp. 80-89. Here is the chance to learn whether the four new high-speed digital power transistor fields. The state-of-the-art in various countries is described.

Three ways to build low-threshold MOS, Warner Bridwell, American Microsystems, Inc., "Electronics," Vol. 43, No. 8, April 13, 1970, pp. 118-123. Low threshold MOS is important for interfacing with bipolar ICs, and is being used. There are three methods of obtaining low-threshold MOS described in this article, along with the trade-offs that you must make in selecting one of the methods.

Systems

System design means trade-offs, Jack Jurson, North American Rockwell Corp., "Electronic Design," Vol. 18, No. 7, April 1, 1970, pp. 60-64. A master computer for the Short Range Attack Missile (SRAM) is used as the system design example. It performs the computation and missile fire-control computations. The author treats the basic trade-offs of number of modules vs volume, processor complexity vs price, arithmetic operations vs computation speed, word length vs precision and efficient use of memory. The memory is the most important cost and complexity factor. Several considerations lead to a choice of a 3D, coincident current, core memory with a cycle time of 3.6 microseconds. Other aircraft design considerations are also described.

Test and Measurement

Check flip-flops automatically, Kenneth C. Walne, Honeywell, "Electronic Design," Vol. 18, No. 7, April 1, 1970, pp. 66-68. Rapid, accurate testing must be done to obtain repeatable, reliable IC flip-flop present times, clock thresholds, and input gate thresholds. The problem to overcome is performance change as a function of time, temperature, and supply voltage. The author discusses the test equipment needed to perform a variety of tests in a closed-loop system with the flip-flop under test to perform the required measurements.

Techniques for true-rms conversion in DVMs, Kenneth J. Hesset, Hewlett-Packard. "EEE," Vol. 18, No. 4, April 1970, pp. 50-52. The author discusses the advantages—both using thermostats to obtain the rms value of a waveform or the differential (differential) thermocouple method, and the single thermocouple technique. It compares the performance and range of application of both methods. Most of the discussion is on the single thermocouple method. The author discusses H-P's 3450A digital voltmeter. The article does not mention, however, the method employed in H-P's newest DVM, the 3400, which uses a thermocouple (a multiple-element thermocouple) connected as a differential thermocouple. Nor does it mention explicitly the slow response of thermocouples, which has prompted the development of other methods to approximate rms measurements.

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Functional test philosophy for a limited funded digital computer, M. Bruce Hack, IBM Electronics Systems Ctr., "Computer Design," Vol. 9, No. 4, April 1970, pp. 179-183. If your funding is limited, you can keep test hardware and software to a minimum without sacrificing reliable performance. A properly designed, single, external test program can meet all test environment needs.

Techniques for true-rms conversion in DVMs, Kenneth J. Hessett, Hewlett-Packard. "EEE," Vol. 18, No. 4, April 1970, pp. 50-52. The author discusses the advantages—both using thermostats to obtain the rms value of a waveform or the differential thermocouple method, and the single thermocouple technique. It compares the performance and range of application of both methods. Most of the discussion is on the single thermocouple method. The author discusses H-P's 3450A digital voltmeter. The article does not mention, however, the method employed in H-P's newest DVM, the 3400, which uses a thermocouple (a multiple-element thermocouple) connected as a differential thermocouple. Nor does it mention explicitly the slow response of thermocouples, which has prompted the development of other methods to approximate rms measurements.

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Two application reports discussing the use of MOS ICs bring you important information on "MOS circulating memories" and "MOS character generators." More specifically, the first report discusses how MOS shift registers can be combined with TTL ICs to form economical data memories (16 pages), and the second describes TTLs.

Relay information

Ohmite Manufacturing Co. has been running a series of seminars which they call "Think-ins," devoted to the proper application of relays and related devices. Copies of the papers from all three "Think-ins" are now available to our readers. The booklets contain the complete text of the papers delivered and a transcript of the question and answer periods which followed the presentations of papers. For copies of these booklets write on company letterhead to Mr. H. J. Roesser, Ohmite Manufacturing Co., 3662 Howard St., Skokie, Ill. 60076.

Anti-Tohubohu

International Rectifier has organized (perpetrated, they say) a society of users intended to promote their products. If you agree to join the society 1R will send you a copy of the above cartoon, a handy calendar and the first in a series of conversion tables. The company calls this the Anti-Tohubohu society, which we guess is based on the Hebrew word for chaos, mentioned in the first chapter of Genesis. If you want to join this society, circle the number below or write to Bill Wagner at International Rectifier, 233 Kansas St., El Segundo, Calif. 90245 at your own risk.

Computerized design

"Computerized Design — Photomasks and Documentation for Printed Circuit Board Layout" is the title of a brochure describing this company's expanded facilities. Preceded by a two-year software development program, they are now ready to offer the consumer a five-part package including computerized design complying with given requirements, translation into photomask production graphics, numerical control tapes for automated machining, computer printouts of necessary documentation and component assembly drawings. Electronic Graphics Inc., 2834 W. Kingsley Rd., Garland, Tex. 75040.

Engineers and cities

"The Engineer and the City" is the title of the feature article in this issue of "Tomorrow Through Research." It acquaints you with the the projects Southwest Research Institute sponsors and participates in, and keeps you abreast of their experience in the field of engineering research. The publication brings you 8 pages of interesting and informative news and ideas. Southwest Research Institute, 8500 Culebra Rd., San Antonio, Tex. 78228.

Transistor test system

A thorough introduction to the T241 computer-operated transistor test system is offered to you in this 20-page brochure. A brief background of the company's experience in the field encourages you to read on to a description of the test instrument and its features. Next, the testing procedure is explained and you learn of available software and peripheral equipment. This is followed by applications, options and accessories, and all necessary specs. Teradyne, 183 Essex St., Boston, Mass. 02111.

Breakdown voltage testing

Data interface

MOS RAM character generators, indicating the advantages of their use in display systems (12 pages). Other topics covered include internal circuitry and construction, power supply requirements, inputs and dc output characteristics. Texas Instruments Inc., Box 5012, M/S 308, Dallas, Tex. 75222.

Capacitors

Application notes providing practical considerations for selecting and using monolithic chip capacitors are yours with this 28-page manual. Answers are given for electrical and environmental considerations, such as combined voltage and temperature effects and dielectrics. Mounting, handling, chip attachment and testing are also discussed. U.S. Capacitor Corp., 2151 N. Lincoln St., Burbank, Calif. 91504.

Application note

This application note introduces you to a system that provides accurate calibration of bolometer mounts with leveled rf power. If you follow the procedures in the note, you'll find that easy and direct transferring of calibration factors from primary to secondary standards and power meters can be accomplished with less than 1% error. Helpful extras in the note include calibration setup diagram, procedures for both terminating and feed-through bolometer mounts and descriptions of each instrument in the system. Weinschel Engineering, Gaithersburg, Md. 20760.

Digital printers

Complete specs, illustrations and prices are provided for you in this 4-page data sheet on 10 and 20 lines/s alphanumeric printers. The printers, which are all solid state with TR1 logic, include a full 64-character ASCII code. Reliability at low cost? See for yourself by reading spec sheet 3070 on the 722 series of digital printers. Datadyne Corp., Bldg. 37A, Valley Forge Center, King of Prussia, Pa. 19406.

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Optoelectronics

Optically coupled isolators are the subject here, and the 6-page brochure offers you details and diagrams of their significant features. Tables provide current ratios and switching characteristics; diagrams show construction, terminal connections and mechanical data. Texas Instruments Inc., Box 5012, Dallas, Tex. 75222.

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EMI/RFI filters

Four standard filters are covered in this technical brochure: the "L" section filter, the "Pi" capacitive input filter, the "T" inductive input filter, and the "2L" filter. The complete line of subminiature interference control filters are supplemented with diagrams and "insertion loss" chart information. Genisco Technology Corp., 18435 Susana Rd., Compton, Calif. 90221.

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The intent of this 60-page handbook is to provide the systems and logic designer with descriptive information on the company's series 54/74 complex arrays logic family. You'll find the book divided into three sections for easy reference: general design characteristics, electrical characteristics (includes test limit and test condition information for use in device evaluation), and parameter measurement information. Sprague Electric Co., North Adams, Mass. 02147.

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Operational amplifiers

This 32-page reference guide describes the maker's complete line of discrete, hybrid, and monolithic op amps. It starts with a six-page section that lists important specifying parameters, and definitions (with test circuits) of many others, and continues on to the bulk of the brochure's first half of a detailed spec listing for about 80 op amps. The last half of the brochure consists of dimensional drawings, electrical connection diagrams, and some information on accessories such as power supplies, ic regulators, booster amps, sockets, and trimming potentiometers. Fairchild Controls, 423 National Ave., Mountain View, Calif. 94040.

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Hybrid circuit chart

A wall chart, summarizing hybrid circuit design considerations, contains design guidelines, packaging information and data on active devices, substrate materials and capacitors. Typical parameters of key hybrid materials are provided. Sylvania Electric Products Inc., 1100 Main St., Buffalo, N.Y. 14902.

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LITERATURE

Electro-optics

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Infrared micro-sampling techniques, for use in such areas as air pollution, bio-medical studies, criminology, or any research where sample quantities are minute, are contained in an 8-page booklet. Also listed are a line of micro-sampling accessories, including mirror beam condensers, microcells, ultra-micro-cavity cells and variable beam attenuators. Barnes Engineering Co., 30 Commerce Rd., Stamford, Conn. 06902.

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Hybrid circuits

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De servo amplifiers, designed to meet MIL-E-5400 specs (including MIL-STD-704), but differing in size and output, are discussed in three separate data sheets. The amplifiers described are suggested for such applications as driving dc torque motors, due to their wide bandwidths and adjustable current limiting features. They can be utilized as voltage or current amplifiers by terminal selection and their gain can be varied by the addition of external resistors. Working schematics are provided in the sheets, as are typical performance curves and specs. Inland Controls Inc., 250 Alpha Dr., Pittsburgh, Pa. 15238.

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Analog multipliers

A high-speed analog multiplier for use in modulation and demodulation, computation, signal conditioning, and/or multiplexer switching, is described in a 14-page application note. The different types of available multipliers are discussed and schematics are provided. GPS Corp., 14 Burr St., Framingham, Mass. 01701.

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Applications manual

A multiplier applications manual (12 pages) offers data on the operation and applications of multipliers. It includes basic multiplier operation, block diagrams, error curves and details of connecting multipliers for multi-quadrant operations. Application data includes operation of multipliers in squaring, voltage-controlled function generators, suppressed-carrier modulation, frequency doubling, resolution and voltage-controlled time constant configurations. Zeltex Inc., 1000 Chalomar Rd., Concord, Calif. 94520.

Circle 394 on Inquiry Card

Design guide

Four steps are all that are required on your part for leaf switches custom-designed for particular applications. You provide information such as number and type of circuits and actuation required. If you want to do your own designing, you specify the prototype and the company will supply the samples for your approval and handle the production runs. Look over the standard, already-tooled parts, draw a sketch of the prototypes you want made and you're ready to go (6 pages). Chicago Switch Inc., 2035 Wabansia Ave., Chicago, Ill. 60647.

Circle 395 on Inquiry Card
LITERATURE

Master/slave system can scan up to 1000 channels, and multiplexes low-level signals into a single measuring system. Bulletin 141-4 pages. Vidar Corp., 77 Ortega Ave., Mountain View, Calif. 94040. Circle 396 on Inquiry Card

Byte generator, designated EC-22, is low in cost, plugboard-loaded, and easily programmable, and has been designed for simulation and testing of digital equipment—2-page data sheet. Adar Associates Inc., 85 Bolton St., Cambridge, Mass. 02140. Circle 397 on Inquiry Card

Rf voltmeter handles frequency range of 20 kHz to 500 MHz over a potential range from 200 mV to 15 V (2 pages). High Frequency Engineering, 2626 Frontage Rd., Mountain View, Calif. 94040. Circle 398 on Inquiry Card

Solid state time delay relays in an 8-page brochure with circuit applications and definitions of terms. Midtex/Aemco, 10 State St., Mankato, Minn. 56001. Circle 399 on Inquiry Card

Power amplifier can drive low-impedance loads to within 4 V of either supply voltage (2 pages). Beckman Instruments Inc., Fullerton, Calif. 92634. Circle 400 on Inquiry Card

Op amp will operate with supply voltages from ±6 V to ±28 V, and over a temp. range of −55° C to +125° C (2 pages). CTS Microelectronics Inc., West Lafayette, Ind. 47906. Circle 401 on Inquiry Card

400 controller features mA output, adjustable proportional band and manual reset. Applications include batch processes and valve positioning processes —2 pages. Thermo Electric, Saddle Brook, N.J. 07662. Circle 402 on Inquiry Card

Pressure transducers, designed for use under extreme pressure and temperature ranges for a variety of applications, weigh 2.75 oz. and have a maximum diameter of 0.875”—bulletin P692210. Taber Teledyne, 455 Bryan St., North Tonawanda, N.Y. 14120. Circle 403 on Inquiry Card

Miniature broadband transformers feature transmission line techniques and frequency ranges to beyond 500 MHz—pages. Vanguard Electronics, 930 West Hyde Park, Inglewood, Calif. 90302. Circle 404 on Inquiry Card

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Circle 408 on Inquiry Card

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Circle 411 on Inquiry Card

Waveform generators and test oscillators are described with features and applications, illustrations and specs—4 pages. Microdot Inc., 220 Pasadena Ave., South Pasadena, Calif. 91030.

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Circle 414 on Inquiry Card

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Circle 415 on Inquiry Card

Wideband amplifier described in 4-page brochure giving specs, schematics (15) and applications. Halex Inc., 3500 W. Torrance Blvd., Torrance, Calif. 90509.

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The Electronic Engineer • June 1970

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