Scopes and cameras abound, making selection a difficult task. Modular scopes can be tailored for special jobs, but costs can soar. And some portable scopes offer the performance of larger units. Cameras are available for most scopes, but some storage scopes may lessen the need for them. Get the details on p. 48.
ultra-miniature transformers

1/4" x 1/4"

SPECIFICATIONS
- MIL-T-27D: All Units Are Designed to MIL-T-27D and Are Hermetically Sealed in a Metal Case. PICO is a QPL source.
- Frequency Response: ±3 db. 400 Hz-250 KHz at 1.0 milliwatt.
- Maximum Distortion: 5% When Rated Power Level at 1 KHz.
- Dielectric Strength: All Units Tested at 200 V RMS.
- Insulation Resistance: Greater than 10,000 Megohms at 300 V DC.
- Weight: 1.1 GRAMS.
- Operating Temperature: -55°C to 105°C (All Units Can Be Supplied to Class S Requirements 130°C maximum).
- Terminals: .012 Diameter Gold Plated Domet Wire In Accordance With MIL-STD-1276 Type D. Leads May Be Welded or Soldered.

Send today for PICO's Designers Kit!

PICO now offers a Designer's Kit containing ten (10) representational 1/4" x 1/4" transformers. The kit contains PICO's F5710 and G6025; F5730 and G6045; F5755 and G6065; F5770 and G6090; F5795 and G6110.

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INFORMATION RETRIEVAL NUMBER 262
Starting now, the function generator market does a 180.

This is where Wavetek turns it around again. With three new high-performance, low-cost generators.

The Model 180 Sweep/Function Generator $275

Believe it or not, this is a full sweeper—from 0.01 Hz to 2 MHz—with internal 1000 to 1 sweep. The 180 has sine, square and triangle wave outputs (20v output p-p), plus dc voltage, dc offset, and a separate TTL output. It also has a full attenuator which means you get super-clean signals down to -50dB. If you measure price vs. performance, no other instrument even comes close.

The Model 184 Sweep Generator $495

The 184 has all of the above, plus some other features that you wouldn't expect for the price. First of all, the 184 goes all the way up to 5 MHz, and provides continuous, triggered and gated operation. For precise adjustment of continuous sweep, there's a control to individually set start and stop points. There's also a variable symmetry control and another for amplitude—down to -60 dB. Like the rest of the instruments in this series, the 184 comes in a tough, lightweight package.

The Model 185 Lin/Log Sweep Generator $595

As you can see, the 185 has two frequency dials, which give you the ultimate in precise sweep start/stop settability. Now you can sweep up or down the frequency range, which goes from 100 µHz to 5 MHz with continuous and triggered ramps or discrete steps. Like the 184, this model has continuous, triggered and gated operation. Of course, there are both linear and logarithmic modes, and log sweep width is an incredible 100,000 to 1.

We haven't told you everything.

There's a lot more to the 180 series than the three instruments described here. But that's another story.

When we let that out, the market may just do a 360.

For more information, contact Wavetek, P.O. Box 651, San Diego, California 92112. Phone (714) 279-2200. TWX 910-335-2007.
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Paralleling transistors doesn't pay—not when an inherently rugged single device can do the job far more reliably, using much less space, weight, and at lower total system cost. That's why PowerTech's unique single-chip NPN silicon high-power transistor is the one way to go.

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<table>
<thead>
<tr>
<th>Type</th>
<th>(pk)</th>
<th>( I_c )</th>
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<th>( h_{fe} = 10 )</th>
<th>( V_{ce} ) (sat)</th>
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<tr>
<td>JAN-TX 2N5926</td>
<td>90A</td>
<td>120V</td>
<td>0.6V @ 50A</td>
<td>90A</td>
<td>200V</td>
<td>0.6V @ 50A</td>
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<td>120V</td>
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<td>500A</td>
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<td>0.5V @ 300A</td>
<td>820 mil diam.</td>
<td>500A</td>
<td>0.5V @ 300A</td>
</tr>
</tbody>
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350 Watt Power Rating
*625 Watt Power Rating
Guaranteed SOAR

TO UNPARALLEL IS TO SAVE:

Silicon transistors to 500 amps with lowest \( V_{CE} \) (sat)

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"BIG IDEAS IN BIG POWER"
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Cover: Designed by Art Director Bill Kelly. Photos courtesy of Dynascan, Heath, Hewlett-Packard, Philips, Tektronix and Vu-Data.
"If you're an OEM, I'd like you to join in an exciting new sales building program."

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VP OEM Group
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It's our brand-new catalog of OEM systems.
A book Digital salesmen will be using regularly to point out Digital OEMs to potential users of OEM systems.
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We're compiling a catalog of information supplied by our OEM customers on their systems.
With the total support of our worldwide sales force, backed by an advertising campaign in industrial magazines, we're offering help to anyone contemplating the purchase of major equipment.
That help takes the form of detailed suggestions on how to buy computerized equipment. Sugges­tions on where to buy the type of equipment they need, and who they can buy it from.
The systems we suggest, of course, are systems sold by Digital OEMs.
What the catalog does is to categorize these systems (which span virtually the entire spectrum of OEM systems on the market today) so our salesmen can match prospects' needs with appropriate OEM systems.
The catalog, like the whole program, is serious business. It has only one purpose: to help your sales effort. After all, every system you sell to your customers is one more computer we sell to you.
But while the OEM Referral Program will be an increasingly important part of our own marketing strategy, it's not the whole story by any means.
We will continue to come out with new breakthroughs in the areas of price and performance.
And we will continue to work with our OEMs in every way we can to help keep us both profitable in these profit-squeezed times.
In short, we will continue the policies that have kept us the leader in the OEM computer field ever since it started. Because in all that experience, we've learned something about the OEM marketplace: We're a success only if you are.
Any design—Ribbon Cable, IC Interconnects, Custom Harnesses. Woven Electronics produces flat woven cable assemblies to your specs for conductors, spacing, insulation, color coding, marking, all requirements including special features such as breakout, fold lines, tinning, connectors. Don't accept cable compromises. Let us assist in design stages and get the exact interconnect your system needs.

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A reader bugged by 'obiter dicta'

Alan J. Rider's article on the techniques of interviewing engineers is amazing, to say the least ("Meet" the Applicant Before Talking to Him," ED No. 25, Dec. 6, 1974, pp. 86-88). A close analysis reveals that the author has done nothing more than package his own prejudices into a collection of obiter dicta.

His example of the worthless Ph.D. is atypical, trite and certainly does not attest to his expertise regarding hiring practices. He seems to exhibit a contempt for educated engineers, noticeable in the absence of any degree notations in his background description.

The article explains in great detail how to exploit the engineer, but it mentions nothing about what the company should give the engineer in return, save the unrealistic salary of 12 k to 13 k a year and all the unpaid overtime one can work.

The sort of philosophy created by this sort of mentality is the reason I have left the logic/circuit design field for areas of technology that are state-of-the-art but not exploitive in nature.

Charles Zabilski
Video Tape Engineer
Consolidated Film Industries
959 North Seward St.
Hollywood, CA 90038

The author replies

I found Mr. Zabilski's letter somewhat difficult to comprehend, though I am pleased that he found our article "amazing."

It is unfortunate that he failed to grasp the implicit message; therefore I shall state it explicitly.

The process of hiring engineers and other personnel is treated too casually and too ineptly in our industry. The result is that the compatibility of candidates and positions is left to chance more often than is necessary. Predictability of a good match between the two can be significantly improved.

One of my first experiences as a manager was in hiring a Ph.D in theoretical physics to design circuits, only to have him turn out to be ineffective. Mr. Zabilski will be pleased to know that I also supervised another Ph.D who was truly a superb circuit designer.

I consider my educational background irrelevant to the value of the ideas contained in the article. However, if it will put Mr. Zabilski's mind at ease, I hold a BSEE from George Washington University, plus about 20 credits.

I don't understand how he could interpret the article as explaining how to "exploit" the engineer. The fact is it suggests how to lessen the chance the engineer will be exploited in the hiring process. A cruel hoax practiced too frequently in our industry is the hiring of people on a trial basis without informing them of the fact—the "let's see how he works out" technique.

Mr. Zabilski did turn up a glaring error in the article. The 12-k and 13-k figures refer to starting salaries.

Alan J. Rider
Reston Consulting Group
12206 Quorn Lane
Reston, VA 22091

That perfect gift

Editor-in-Chief George Rostky normally gets lots of phone calls and letters in response to his edi-

(continued on page 14)
FMC has developed a very fast switching, high power diode, having a low Vf of .90* volts at 60 amp peak. Designed specifically for UPS systems requiring reliability and high efficiency operation.

For detailed information, contact:
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(412) 479-8011

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Another technical knockout

the first rugged, 50V, SSB device

The biggest RF power chip — 150 W PEP — in production today now makes base station/marine linear amplifiers small enough to fit into one single desk top cabinet.

The MRF428 is state-of-the-art 50 volt \( V_{cc} \) supply, drive and output stages for 1 KW SSB linear amps can now be single-unit designs. No more separate, outsized high-current power supplies.

The '428 offers unprecedented ruggedness: 30:1 VSWR at all phase angles and load-pull tests to 50 volts.

Computer-designed, the single-chip package ensures minimized die and wire bonding, controllable assembly techniques, ruggedness and consistency.

Performance runs out to 320 W power dissipation, 13 dB minimum gain at 150 W PEP and 0.5°C/W \( \theta_{JC} \) for excellent heat dissipation under stress. And cooler chips mean improved linearity, enhanced IMD.

Big is small now with the MRF428. See your Motorola rep for OEM applications help in building HV SSB radio. Be first with the first...

from Motorola, the RF producer.
Breakthrough in mass termination.

Lower-cost coaxial ribbon cable assemblies. In any length.

New AMP coaxial ribbon cable is just that—true coax in ribbon form. With no compromises.
No degradation in system performance.
Solves the long-existing coaxial cable termination problem.

We can provide complete assemblies for your specific requirements. In any length, with 6 to 26 positions. The assemblies come in 50-, 75- or 93-ohm ratings, on .100-inch grid spacing. And 95-ohm rating on .125-inch spacing. Connectors mate with .025² posts—either 90° board-mount pin headers or I-O posts.

Revolutionary patented concept with drain wire parallel to center conductor, permits low-cost gang stripping and terminating, and still further demonstrates AMP's leadership in quality solutions to termination problems.

For information on AMP coaxial ribbon cable that gives you true coaxial performance, and reasonable price, call (717) 564-0100, circle the Reader Service Number, or write AMP Incorporated, Harrisburg, PA 17105.

AMP is a trademark of AMP Incorporated.
The ribbon is made up of individual coaxial cables, each with a solid center conductor and a foil-wrapped drain wire shield. The drain wire is not spirally wound around the dielectric, but runs parallel with the center conductor. This feature allows the cable to be cut anywhere and yet be consistently and reliably terminated.
Microcomputer

A new six-volume programmed learning course from Iasis tells you EVERYTHING about what microcomputers are and how you can design and implement a microprocessor-based system.

Since the transistor was invented, no single electronics innovation has made such an impact as the microcomputer. Powered by tiny semiconductor chips containing computing elements with the same powers and functions previously found only in large scale digital computers, these dedicated microcomputer systems are now being applied to literally thousands of applications. Microcomputers are automating assembly lines, providing the heart of sophisticated electronic games, making "intelligent" computer peripherals even smarter, and are going so far as streamlining the operations of the fastest food chains. This revolution is occurring because microcomputers are very inexpensive—costing as little as $30 in production volume—easy to implement into a system, and significantly reduce the time and cost of product development. But there has been one serious drawback to this exploding industry:

Training materials and courses in the basics of microcomputer technology have been virtually non-existent, and the various published manuals and texts have been undecipherable to those not already intimately familiar with ultra-sophisticated logic design.

Once a designer has the hang of it, microcomputer design is a snap. But without the fundamentals—never before available in such a readable, understandable and simplified format—microcomputer design has been unbelievably difficult. The comprehensive, step-by-step six-volume Programmed Learning Course on Microcomputers from Iasis makes the unbelievably difficult almost ridiculously simple. The authors of these texts have been involved on a professional level in the microcomputer industry since it became an industry. Their direct, first-hand experience in the whys, hows, wherefores and potentials of microcomputers

Finally, you can get a comprehensive training course on microcomputers that puts all the hard-to-get information at your fingertips in an easy-to-read, easy-to-understand and even easier-to-implement manner. You can get it here...now.

Iasis Texts:
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2. Microcomputer Architecture
3. The 4-Bit Microcomputer
4. The 8-Bit Microcomputer
5. Assemblers and Prototyping Systems
6. 8-Bit Assemblers and Compilers
design is a snap.

have made this six-volume collection the most valuable and meaningful series ever published on microcomputer design. The books combine the most effective methods of programmed instruction with the entire gamut of essential information vital to the designer of a micro-based system. You begin with the ABC's of microcomputers and go through a virtual post-doctoral course...and the unique, self-testing programmed learning Iasis course enables you to understand and absorb every bit of the information every step of the way through the six volumes.

The Iasis course gives you more than 700 pages of detailed, illustrated microcomputer information—including more than 1,700 self-tests you use to evaluate your progress—plus programming and design aids that make the design of practical systems very, very easy for you.

Specific details are provided on four of the industry's most versatile microcomputers—the 4004, 4040, 8008 and 8080 from Intel Corporation—but the basic design information will apply to any and all microprocessors. The six volumes you receive with the course are: 1) BINARY ARITHMETIC; 2) MICROCOMPUTER ARCHITECTURE; 3) THE 4-BIT MICROCOMPUTER; 4) THE 8-BIT MICROCOMPUTER; 5) ASSEMBLERS AND PROTOTYPING SYSTEMS; and 6) 8-BIT ASSEMBLERS AND COMPILERS. Plus, this detailed course provides you with two programming pads and two simplified design aids so you may quickly and easily develop both 4-bit and 8-bit microcomputer systems. Use the coupon below to order your course from Iasis, Inc., 770 Welch Road, Suite 154, Palo Alto, California 94304.

Special introductory price on this remarkable new course is just $99.50...and if it isn't everything we say it is or even more, return it within 15 days for a full refund!

Order before May 31, and you'll save a full $25 on the Programmed Learning Course on Microcomputers! In addition, all introductory orders will include a bonus seventh volume, the Microcomputer Applications Handbook!

(After May 31, 1975, price for the complete Iasis course will be $124.50, plus $2.50 for postage and handling.)

Mail today to: Iasis, Inc., 770 Welch Road, Suite 154, Palo Alto, California 94304.
OUR NEW C9370 DEFLECTION YOKE

gives you a lot more performance for just a little more money.

Instead of a TV yoke that was designed for someone else—or even for another type of tube—and is limited by that design, now you can get a custom yoke to match your drive circuitry. You can get better resolution, superior geometry correction and 100% reliability, since every yoke we ship has been tested and approved.

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Our engineers are ready to customize a C9370 for your precise needs. Call us for engineering service and design advice, or send for information about the Syntronic Instrument yoke that gives you a lot more for only a little more money.

ACROSS THE DESK
(continued from page 7)

torials. But he doesn’t often get a parcel. He did, though, in response to his editorial “Service With a Smile” (ED No. 2, Jan. 18, 1975, p. 47), in which he commented unfavorably on the shower head and shower curtain in his room at a London hotel.

On reading the editorial, Jack Kompan, marketing communications manager at Harris Semiconductor, rained good wishes and a gift—a white shower curtain—on Rostky.

Rostky didn’t know about it until he found the curtain mounted across the entrance to his office, placed there by his secretary, Evelyn Morris. Embazoned across the curtain was the Harris logotype and greeting, “George, Harris loves you.”

Rostky reaction: (Guffaw. Guf- faw. Guffaw.) “That’s terrific. I wonder what he’d send if I wrote an editorial on love?”

Oops! Typo inflates cost of s/d converter

In “S/d Converter Operates at Rates Up to 3600°/s” (ED No. 25, Dec. 6, 1974, p. 111) you announced our 168B synchro-to-digital converter.

But the selling price, which was stated as $5500, should have read $550. We cannot now expect much response for a product that was developed to be price competitive and is announced at a price nine to 10 times the competition!

Harold C. Ericsson
Control Sciences, Inc.
10315 Woodley Ave.
Granada Hills, CA 91344
ED Note: We apologize to Mr. Ericsson for our not catching the printer’s typographical error.

Correction

In “Focus on Graphic RECORD­ ers,” ED No. 3, Feb. 1, 1975, p. 65, the address for Houston Instruments is incorrect. The correct address is One Houston Square, Austin, TX 78753.

(continued on page 16)
Multiple choice

1,700 answers
to electrical enclosure needs
by Hoffman.

Quick answers too. Hoffman offers you "off-the-shelf" shipment on most of over 1,700 standard electrical/electronic enclosures.

Each of them is built to meet the quality standards that made Hoffman's reputation. They include:

1. NEMA 1, 3, 4, 9 and 12 enclosures

2. JIC-type boxes

3. Pushbutton enclosures

4. Wireways

5. Consoles and consoles

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8. Transformer cabinets

If you have a need that isn't met by one of our over 1,700 standard enclosures, we can modify them or custom engineer and fabricate per your specifications. Our free catalog gives details on quality Hoffman enclosures and is available on request. Put Hoffman to the test.

Dialight sees a need:

(Need: The widest choice for your every application.)

LED, INCANDESCENT OR NEON
ULTRA-MINIATURE DATALITES™—Meet or exceed MIL-L-3661. Replaceable plug-in cartridges for 1.35-125V operation. Indicators mount as close as 1/2" centers; available with red, green, amber, blue, while translucent, light yellow or colorless lenses in wide range of lens shapes, legends and finishes. Stocked by local distributors.

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See Dialight.
If you are now using 24k gold for contacts and connectors, you can save 63% on gold costs by specifying selective, precision-clad inlay stripes with the new "TMI 55" lower density gold alloy to give you more quality contacts per unit weight.

Developed after years of research by the Battelle Institute and thoroughly tested by TMI, this new 55% gold, silver, indium, cadmium alloy provides precision-clad advantages of superior formability and freedom from porosity. "TMI 55" also exhibits low contact resistance, excellent corrosion resistance, and high wearability to meet electronic contact and connector specifications.

So get in on the savings. Call TMI, the leader in specialty clads, at 401 • 728-7200 or write for our technical data sheet describing "TMI 55" in detail.

ACROSS THE DESK
(continued from page 14)

A rap at foreign reps by a would-be buyer

Your editorial "Making It Tough for European Engineers" gave a very exact picture of the poor performance of local representatives in our South American market (ED No. 26, Dec. 20, 1974, p. 49). American suppliers should be more strict when selecting these agents.

Lots of orders are lost because the representative doesn't know anything about the manufacturer's product. We have also encountered many difficulties when trying to order sample quantities of a component for prototype construction.

A. M. Ferrari  
Technical Manager
Ericsson do Brasil  
Rua da Consolacao  
Sao Paulo, Brazil 01416

... And a further word on graphic recorders

Your article on graphic recorders was terrific ("Focus on Graphic Recorders," ED No. 3, Feb. 1, 1975, p. 54). As manufacturers of a very fine general-purpose chart recorder, and as specialists in analog data recording in general, we were disappointed that our product wasn't mentioned.

We make a two-pen, three-channel, 10-inch scanning recorder.

Kathy Zika  
Office Manager
Tetrahedron Associates, Inc.  
7605 Convoy Court  
San Diego, CA 92111

A thorough study of the recorder market would have revealed that Soltec Corp.'s Rikadenki and San-Ei recorders as the most desirable. Both of these companies are the largest in their field in the Orient. Rikadenki is in the servo graphic recorder market, including recorders from single-pen to 10-pen, with all 10 pens overlapping and writing the full 10-in. (250-mm) chart width. San-Ei is in the oscillographic market.

Marvin R. Solomon  
President
Soltec Corp.  
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THERMAL FATIGUE INSPECTION

Mounting silicon chip on a molybdenum header bounds mechanical constraints and provides maximum insurance against thermal fatigue (for 150 and 250 W series)

Pulsed test:
(10 000 cycles)
"on": 2 minutes
"off": 1 minute

T case: 125 °C max.
At case: 110 °C max.

FORWARD OPERATION:
SAFE OPERATING AREA

REVERSE OPERATION:
TESTING CIRCUIT

High performances:
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BUX 20→25 (250 W)

Economical:
BUX 39→45 (120 W)

Fast switching:
Low switching losses

High voltage: →500 V
High intensity: →50 A

Industrial and professionnal applications:
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- rapid inverter
- chopper
   (directly supplied from 220 V mains)
- ultrasonic system

This is a new generation of high reliable switching power transistors.
Our Cup Runneth Over

...with the brightest LED lights.

Green, yellow, amber and red LEDs... panel or PCB types... ½" to ⅛" mounting diameters... with or without current limiting resistors... brighter than incandescent at ½ the current.

Incandescents and neons too (including green neons)... some with built-in lamp drivers and keep alive bias... some with life ratings equivalent to LEDs... all with a wide choice of colors and styles, plus unmatched performance.

We're your "one-stop-shop" for indicator lights. Send for our Catalog today: Data Display Products, 5428 W. 104th Street, Los Angeles, Ca. 90045, (213) 641-1232.

The original "little light" people.
Two sophisticated methods of identifying people automatically have been developed for high-security applications.

In one, identification is made through analysis of the pressure pattern produced when a person writes his name. In the other, the transfer function of the human body for acoustic signals is determined.

In the signature approach, the person writes his name with a special pen. Analysis of the written signature was deemed too easy for forgers to overcome. Instead, the new system checks the signature dynamics—a measure, with respect to time, of the pressure applied to the pen.

Known as Signac—for signature access control—the system was developed by Veripen Inc. of New York City and is being considered for use by the Electronic Systems Div. of the Air Force at Hanscom Air Force Base in Massachusetts.

According to Capt. Gregory A. Cieciwa, project engineer at the division's Base and Installation Security Systems Program Office, statistical evaluation has proved that each person's pressure pattern is unique to the individual and reasonably constant from one signature to the next.

Since the pressure applied is only indirectly related to signature appearance, he goes on, the pressure pattern of a forgery will appear different from the genuine signature. An individual's pressure pattern is virtually impossible to duplicate, Captain Cieciwa says.

Using the special pen, a person first records between three and six samples of his signature. His writing pressure is converted into an electrical signal by a transducer in the pen. This signal is then digitized and processed by a National Semiconductor IMP-16C/300 microprocessor, which forms a signature standard for each person.

To gain access to a protected area, each person must first punch in an identifying number that allows the system to retrieve his standard from memory and compares it with the sample. If the samples match, entrance is permitted.

Accuracy of the system is reported to be high. It is said to reject qualified users incorrectly 1% of the time and to accept unqualified users 2% of the time.

The basic system, which can handle 1000 names and up to four remote entry stations, costs $32,000. For applications requiring control of as many as 10,000 people, the microprocessor is replaced by a mini. In such a system as many input stations as needed can be accommodated.

In the body-measurement approach, Novar Electronics Corp. of Barberton, OH, makes use of the fact that the human body acts as a filter for acoustic energy and that each body has its own unique transfer function. The company's identification system measures an individual's frequency response.

According to James H. Ott, president of Novar, acoustical energy is transferred to the body by a transducer placed in a door mat, door handle or other convenient area. The induced energy is then modified by the bones of the body, and the signal, which is retrieved by another transducer, has a different amplitude, phase shift and frequency content than the original. By comparison of the input and output, it is possible to get the transfer function of the body.

In a working system, Ott notes, a person stands on a door mat that contains the transmitting transducer. When the door knob is touched, the signal picked up from the body by the receiving transducer is analyzed to see how it has changed. The results of these measurements are then passed through an analog-to-digital converter. The resulting digital data can then be stored in a computer memory and used as a template for screening people.

Ott indicates that, like fingerprints, the human transfer function is unique to each person. This is because no two human skeletons are the same. Even in twins, he notes, there are differences caused by modifications in bone growth, which depends on living and working patterns.

Although the identification system is still in the prototype stage, Ott says that commercially available equipment should be ready by the first quarter of 1976.

New OTH-B radar to be cw bistatic

The Air Force will build a cw bistatic over-the-horizon backscatter (OTH-B) radar system in Maine. A developmental prototype, the system is part of the Defense Dept.'s on-going program, begun in the 1950s, to create a network of sensors to detect approaching enemy bombers far from U.S. coasts (see "Backscatter Radar on 2 Coasts to Detect Planes Over Horizon," ED 14, July 6, 1972, p. 30).

OTH radar, which bounces its signals from the ionosphere to earth and back several times, can detect bombers even at low altitudes. A good OTH radar, the Air Force says, should give the U.S. as much
as two hours’ warning. Conventional line-of-sight radars, on the other hand, see only about 200 miles, which boils down to a warning of several minutes.

The new system, to be built by General Electric, will be a high-power, high-frequency (5 to 30 MHz) cw bistatic system. The last three OTH-B experimental systems the Air Force built and tested (in Maine, Virginia and the polar region of Canada) were hf, pulsed-doppler, monostatic systems.

A cw system was chosen to avoid the extremely high bursts of power that pulse radar systems require. With cw, off-the-shelf transmitters can be used, and there should be less interference with heart pacemakers and other electronic equipment.

If the prototype cw system performs well, two operational systems are to be built, one in Maine and the other in the state of Washington.

The transmitter for the new system will be built in a relatively uninhabited area near Moscow, ME. The receiver—105 miles away, to avoid ground-wave interference from the transmitter—will be near Township, ME.

**PLZT may challenge established displays**

Numeric displays made from PLZT ceramic, a transparent electro-optic material developed at Sandia Laboratories in 1970, are nearing the point where they may do battle with the more established liquid-crystal and light-emitting-diode displays.

According to Cecil E. Land, principal investigator in the project at Albuquerque, NM, the PLZT display is now potentially competitive in a number of applications “where voltage levels are available to drive it.” One example Land gives is the hand-held calculator.

PLZT ceramic material 3 mils thick requires an initial turn-on voltage of 90—or, for a 1-mil-thick sample, 30 V. Liquid crystals require from 5 to 20 V, and LEDs from 2 to 3 V. Offsetting PLZT’s high turn-on voltage requirement, however, is its ability to stay illuminated without sustaining power. Due to its electrostatic memory, the material will maintain a light for several days.

PLZT also has these other advantages, Land says:

- High contrast ratios—nearly 100 to 1 with 90 V applied for 50 µs. Nominally liquid crystals have a ratio of from 10 to 1 or 20 to 1.
- Fast switching speeds—10 to 50 µs at 16 kV/cm. Liquid crystals require 10 ms.
- Long life. The material has been cycled up to 100 billion times without degradation.

The solid-state, seven-segment PLZT displays use a transverse quadratic electro-optic effect (Kerr effect), or fringe-field effect, that is created in a thin plate of the ceramic. This effect, produced by application of a voltage between electrodes on opposite surfaces of the plate, allows use of the PLZT devices in both the transmission and reflective modes.

The transmission-mode devices, for use where backlighting—such as a luminescent panel—is possible, consist of a polarizer, solid transparent electrode, PLZT plate, seven-segment numeric mesh electrode and a second polarizer (analyzer) crossed at 90° to the first polarizer. The analyzer serves as the viewing face of the thin sandwich.

The reflective-mode devices, which use ambient light, consist of a polarizer, 1/4-wave retarder, mesh electrode, PLZT plate and a solid metal reflective electrode. Ambient light passes through the sandwich and is reflected back to the surface by the metal electrode, obviating the need for backlighting.

The prototype devices built thus far have 5-mil-wide mesh electrodes separated by 5-mil gaps. The electrodes are sputter-deposited metal or indium-tin oxide. The transparent electrode in the transmission-mode device is indium-tin oxide, while the metal electrode in the reflective-mode device is an aluminum film.

**Opto-electronic switch handles 100 V in 10 ps**

By using laser light beams to start and stop an electrical signal, a researcher at Bell Telephone Laboratories, Murray Hill, NJ, has produced a switch that operates at 10 ps and can switch as much as 100 V.

Until now, the fastest switching device available has been the Josephson junction device. But it is capable of switching only a few volts and must be operated at cryogenic temperatures. In addition it needs fast electronic control pulses. These are difficult to get, but the optical pulses for the laser switch are easily generated with off-the-shelf equipment.

According to David H. Auston, developer of the new switching technique, “the device should work at speeds as fast as 1 ps.” The switching speed is limited only by the duration of the optical pulses.

In describing how the new switch works, Auston explains that beams of laser light are focused on a piece of light-sensitive semiconductor. The semiconductor exhibits both surface and bulk photoconductivity.

The semiconductor chip contains a microstrip transmission line that has a gap of high resistance, which prevents the signal from being propagated. The other side of the chip contains a ground plane.

Two optical pulses of different wavelengths are used to turn the switch on and off. The pulses are generated when a single pulse is extracted from a neodymium glass laser and then doubled in a KDP crystal to get a second pulse at half the wavelength.

The two pulses are then separated by a beam splitter, delayed and focused onto the gap in the silicon microstrip structure. The shorter, 0.53-µm pulse brings the surface photoconductivity mechanism into play and causes a thin layer of high conductivity near the surface of the silicon, turning the switch on. The longer, 1.06-µm pulse is delayed and then used to turn the switch off. The longer absorption depth of this pulse penetrates to the ground plane, shorting the transmission line and preventing propagation.

According to Auston, peak transmission through the gate is better than 95% when it is on and less than 5% when it is off. Signal levels as high as 100 V have been switched, he reports.
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Each of the four MSB current switches must be analyzed to find the error sources that can degrade a/d converter performance.

can even monitor the wideband noise, which in this example is about 30 $\mu$V pk-pk.

The circuit of Fig. 5 reduces the thermal-transient effects further. The first stage has a gain of 10, so the output can easily be handled by any IC comparator. The settling time from overdrive down to 0.25 mV is less than 250 ns.

Aside from input-circuit thermal problems, you'll find many other headaches—for instance, the MSB current switches in the d/a or the voltage-to-current converter circuit. These switches have several important constraints: settling in 500 ns or less, accuracy adjustable to within 50 nA, stability with less than 10 nA/°C drift and noise of less than 80 nA pk-pk at the operating bandwidth of the a/d.

A typical diode switch consists of a current source and diode steering logic (Fig. 6). The current source has an op amp, two transistors and three very stable resistors. The op amp, $A_1$, operates in the noninverting mode.

A logic input to the anode of $D_3$ steers $I_o$ through either $D_1$ (thus cutting off $D_2$) or through $D_2$ (cutting off $D_1$). This bucks the current source against the input current.

With this arrangement, thermal transients are minimized, since there is no power change across the current source, except in the transconductance elements $Q_1$ and $Q_2$. Also, because these two transistors are in a closed-loop feedback system with $A_1$, any power changes caused by voltage variations at the collectors are immediately compensated by the open loop gain of $A_1$.

Hot-carrier diodes help provide the high speed needed for fast settling. The worst-case settling occurs when the MSB current flows through $D_2$ to the summing point. At this time the combined capacitance of $D_2$, $Q_1$ and $Q_2$ add to about 8 pF and a settling time about 300 ns, or 0.0015%.

In addition to temperature drift accuracy, stability and noise are three major problems that have to be solved to ensure proper a/d converter operation. As a start, use 0.01% precision resistors for $R_1$, $R_2$, $R$ and other critical trim resistors. For good stability, you can temperature-compensate the MSB switching circuit. This is done by adjusting the offset voltage of $A_1$ to counteract any drift caused by $Q_1$, $Q_2$ or the current-determining resistors.

To minimize the noise, use a discrete component design for $A_1$. This will reduce the noise to about 0.1 LSB.

The last major section of the a/d—the voltage-to-current converter—also has some critical specs (Fig. 7). Accuracy must be tighter than 1 part in 130,000 and linearity the same; stability should be 2 ppm/°C or tighter; and the wideband noise should be less than 50 nA when referred to a full-scale current of 32 mA.

Changes in power dissipation have to be minimized to eliminate any thermal transients that could add or subtract from the input. Speed or settling capability should be fast—no more than 0.5 µs to reach 1 part in 130,000. Reflections back into the signal source pose another problem that is often neglected. When this happens, any output from the converter cannot be trusted.

The voltage-current converter uses a transconductance circuit that transforms the voltage input into a proportional current (Fig. 7). Amplifier $A_1$ feeds transistor $Q_1$, which operates as a common-base amplifier. If you assume the amplifier has an infinite open-loop gain and zero bias current, the voltage across $R_b$ becomes

$$V_{R_b} = V_{b} R_b / (R_b + R_c).$$

In addition assume that $Q_1$ has infinite current
If you follow the thermal path in the front end of a comparator circuit, you will see the trouble spots (Fig. 3). At time, \( t_0 \), \( D_1 \) is on and \( D_2 \) is cut off. The negative input through \( R_{in} \) turns on \( D_2 \) and reverse-biases \( Q_1 \) at \(-0.7\) V. Transistors \( Q_1 \) and \( Q_2 \) form a differential input circuit that is similar to comparator front ends.

Since the base of \( Q_2 \) is grounded, \( Q_1 \) is off and \( Q_2 \) is on. The power dissipation for \( Q_1 \) is zero, while that for \( Q_2 \) rises to \((V_{cc} - IR_L - V_{be})I\). After time \( t_1 \) elapses, the logic input rises to \(+1\) V. This turns off \( D_1 \) and turns on \( D_2 \), and current through \( R_1 \) is bucked by the input current. The base of \( Q_1 \) now sits at \( 0 \) V and if the offsets of the transistors are equal to zero, the current, \( I \), splits equally between the two transistors. Each transistor now has power dissipation equal to \((V_{cc} - IR_L/2 + V_{be})I/2\).

The differences in power dissipation for the transistors are:

For \( Q_1 \), \( P = (V_{cc} - IR_L/2 + V_{be})I/2; \)

For \( Q_2 \), \( P = (V_{cc} - 3IR_L/2 + V_{be})I/2. \)

Thus when \( Q_1 \) turns on, it warms up and changes the thermal gradient of the circuit as well as its own emitter-base voltage. At the same time \( Q_2 \) starts to cool, since it loses half of the current it carried. You can approximate the heating effect as follows: For every 5-mW change in transistor power dissipation, the base emitter temperature varies by \( 1 \) C and \( V_{be} \) changes by 2.2 mV. Thus you can calculate the error caused by thermal changes and referred back to the input.

The thermal changes are transient

The thermal change lasts anywhere from 20 \( \mu s \) to milliseconds, depending upon the physical mass of the transistors. With this knowledge, you can now estimate the thermal change across the base-emitter junctions of \( Q_1 \) and \( Q_2 \):

\[
V_{be} = [(V_{cc} - IR_L/2 + V_{be}) + (V_{cc} - 3IR_L/2 + V_{be})] (1/2) (2.2\text{mV}/5\text{mW})
\]

\[= V_{th} \text{ (thermal change referred back to the input).} \]

This equation can be simplified to:

\[
V_{be} = (2.2\text{mV}/5\text{mW}) (V_{cc} - IR_L/2 + V_{be})I
\]

\[= V_{th}. \quad (1) \]

If, in the circuit of Fig. 3, you assign the values \( I = 2\) mA, \( R_L = 1\) k\( \Omega \) and \( V_{cc} = 15\) V, you would get a thermal change of 12.1 mV in \( V_{be} \).

To get a signal-to-thermal-transient ratio of 2 to 1, the signal resolution should be not less than 24 mV. As you can see, thermal considerations in the comparator are critical, and any change in power dissipation of the input transistors should be minimized.

Design your own comparator

Eq. 1 can be rearranged to solve for the current flowing in the common-emitter resistor:

\[
I = (V_{cc}/2R_i) (1 - \sqrt{1 + 4KV_{th}R_L/V_{cc}^2}),
\]

where \( K = 5\) mW/2.2 mV and \( V_{cc} = V_{cc} - V_{be}. \)

This can be reduced to

\[I = KV_{th}/V_{cc}. \]

Thus if you want to resolve \( 0.5\) mV and you have \( V_{th} = 2\) mV, by referring to Fig. 4, you can set the collector voltage equal to a minimum of \( +1\) V and calculate from Eq. 2 that the emitter resistor current is 300 \( \mu A \).

You can also calculate the differential voltage gain of this stage as

\[A_v = R_i/(r_b + R_i) / (1 + \beta). \]

For large values of \( \beta \), this can reduce to \( A_v = R_i/r_b. \) For an emitter current of \( 0.5\) mA and a load resistor of 1 k\( \Omega \), the voltage gain is only 6.

The time-constant associated with the differential stage can be approximated by

\[t_a + R_i [C_{be} + C_{ch}(R_L + r_e)r_e]. \]

For maximum speed, use hot carrier diodes for \( D_1 \) and \( D_2 \). These clamp the input at \( \pm 0.4\) V, with input currents of \( \pm 2\) mA and keep the input capacitance to less than 2.4 pF.

Three stages with gains of \( 6 \) will provide total gain of 216, amplify the 0.5-mV signal input to 108 mV and allow for settling-time measurements down to 0.01\% in less than 250 ns. You
1. Break down the 16-bit a/d converter into functional blocks. This helps simplify the analysis.

2. Use of a monolithic dual-transistor in the a/d comparator circuit helps to reduce the bias current needed from the source and to lower the offset current.

3. Input signal voltages to D, control the current flow, and thus the on or off state of Q1.

4. The front-end design of the comparator circuit is the most critical step. Additional gain stages following the first stage amplify the signal to TTL levels.

Comparison of common a/d conversion methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Complexity</th>
<th>Achievable accuracy</th>
<th>Typical size (in.)</th>
<th>Typical cost ($)</th>
<th>Typical &quot;high&quot; speeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial</td>
<td>Simple</td>
<td>16</td>
<td>2 × 4 × 0.4</td>
<td>$ 250</td>
<td>20 ms</td>
</tr>
<tr>
<td>Successive</td>
<td>Medium</td>
<td>16</td>
<td>1.75 × 5.5 × 4.5</td>
<td>1300</td>
<td>8 μs</td>
</tr>
<tr>
<td>*Cyclic</td>
<td>Complicated</td>
<td>10</td>
<td>3 × 5 × 0.4</td>
<td>1000</td>
<td>200 ns</td>
</tr>
<tr>
<td>Serial</td>
<td>Complicated</td>
<td>16</td>
<td>4 × 5.5 × 4.5</td>
<td>4000</td>
<td>3 μs</td>
</tr>
</tbody>
</table>

*Cyclic converters are not usually available with accuracies greater than 10 bits due to absolute amplifier design limitations.
Design a precision a/d converter. You can build a 16-bit successive-approximation unit that's accurate to 0.005% with controlled thermal transients and noise.

You face a string of problems when you design a precision, 16-bit analog-to-digital converter. Noise, accuracy, speed, stability, temperature drift and cost are all important. Of the common conversion schemes, the successive-approximation method offers the best combination of design parameters for many applications (See table).

A 16-bit a/d must resolve to 1 part in 65,000. Thus for an input signal that might typically fall anywhere in a -10 to +10 V range, 1 bit is only 320 µV. And if a total conversion time of 8 µs is allowed, each bit must be determined within 0.5 µs.

In successive-approximation converters the worst-case condition for settling time will occur when the input signal reaches half scale. In the circuit of Fig. 1 the input is first converted from a bipolar voltage to a unipolar current of, say, 0 to 32 mA. At half scale the input current is exactly 16 mA, and it gets balanced against the MSB current, which is also 16 mA. And, as we've seen, this balancing must take place in less than 0.5 µs, including the settling time for MSB turn on. This permits settling of the comparator, the MSB current and any logic delays.

For accurate conversion, the sum of the wideband noise in the amplifier, voltage-to-current converter, digital-to-analog converter and comparator must not exceed 0.5 LSB or 160 µV pk-pk.

The current to be resolved will fall between 0 and 32 mA, and the answer must be given in 500 ns. The comparator detects any deviation from exact balance. Not only must the comparator make a decision to drive logic, it must also monitor the voltage at the junction of the d/a and voltage-to-current converters.

Start the design with packaging

To achieve precision and ease construction, use a modular approach. The circuit can be divided into 11 basic modules (Fig. 1). Due to the inherently low input impedance of this type a/d converter (600 to 1000 Ω), you must include a sample-and-hold amplifier in the input circuit. The s/h should provide an input impedance of around 1000 MΩ, and acquire a signal to within 0.002% in 1 µs to prevent slowing down the conversion.

Other sections of the modularized circuit might include the voltage-to-current converter, +12-V and -12-V reference regulators, a 12-bit d/a (used for the lower 12 bits), four matched MSB current switches, a high-speed comparator and a logic block with all the control circuitry and storage functions.

Over-all thermal stability must be better than 7.5 ppm (0.5 LSB) for the a/d to be useful over 0 to 60 C. So all modules must be temperature-compensated between 0 to 60 C, so temperature gradients do not affect accuracy.

In a 16-bit converter one of the most important sections is the comparator. This module must determine to within half a bit or less, when the input current balances the current output of the d/a inside the a/d. For example, if the input current is 16 mA, the comparator must establish within 0.35 µs of the convert signal whether the current output of the first MSB current switch nulls the input. Since the maximum input current is 32 mA, the LSB equals 0.5 µA.

The comparator determines the polarity of the difference current and also drives the d/a control logic. Both currents are summed by the comparator in a 1-kΩ resistor. The resulting input to the comparator can be as small as 0.25 µA (0.25 mV), and it must be amplified to a TTL logic swing.

Thus the comparator has some pretty tough specs: A_v of 12,000, settling in less than 0.35 µs to within 0.25 mV, input bias current of 100 nA or less and offset voltage drift of 20 µV/°C or less.

A typical IC comparator (Fig. 2) with an extra dual transistor input circuit can meet all these conditions. But it fails in one important area—thermal transients.

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INFORMATION RETRIEVAL NUMBER 51
The fractional transfer loss of 500-stage, two-phase CCDs with 30% bias charge is obtained for different channel widths and substrate resistivities.

in surface-channel CCDs. A signal-to-noise ratio of 60 to 80 dB should still be possible with CCDs.

Several low-noise input techniques are available. They have thermal-noise fluctuations that are comparable to those associated with charging of the capacitance of the input potential well.

Noise associated with the resetting of the output floating diffusion can be considerably reduced by a technique of synchronous double sampling.

Output circuits in the form of a floating-gate amplifier (FGA) or a distributed FGA are expected to lead to still smaller noise levels in the output circuit.

Analytical and experimental studies indicate that noise inherent in the charge-transfer action of CCDs won't impose any limitation on the size of memory elements in the foreseeable future.

What about CCD performance?

The two most important performance characteristics of CCDs are dark current and transfer inefficiency, or transfer losses, as a function of clock frequency. Charge-transfer efficiency, which was 0.99 for a three-phase SCCD in 1970, has reached 0.99999 for two and three-phase CCDs in 1974.

The dark-current characteristics of a CCD include the average thermally generated background charge as well as localized dark-current spikes that are very sensitive to the applied gate voltage. Dark current background levels as low as 5 to 10 nA/cm² have been reported. However, the control of dark current and its spikes remains one of the critical aspects of CCD manufacturing.

The typical performance of an SCCD is shown in Fig. 9. Transfer efficiency varies inversely with the density of fast-interface states. The lowest fractional transfer loss for an SCCD has been reported by Bell Laboratories: A 1600-stage 40 µm-wide triple-polysilicon-gate line imager had a loss of $1 \times 10^{-5}$ at a clock frequency of 0.3 MHz.

For BCCDs, fractional transfer losses in the range of $10^{-4}$ to $10^{-5}$ have been reported by several companies. A fractional loss of $5 \times 10^{-5}$ at a clock frequency of 135 MHz was reported by Philips.

The output waveform for a 500-stage, two-phase BCCD with and without fat zero are shown in Fig. 10. These waveforms illustrate the capability of BCCDs for high charge-transfer efficiency.
The charge-coupled device can be constructed as a surface-channel device (SCCD) or as a buried-channel device (BCCD), as shown in Figs. 7 and 8, respectively.

The potential wells of an SCCD are formed at the Si-SiO₂ interface. In contrast, the BCCD forms wells below the silicon surface to avoid charge trapping by surface states. The silicon substrate has an additional thin layer whose conductivity type is the opposite of that of the substrate. During the operation of a BCCD and with no signal charge—\( Q_{\text{sig}} = 0 \)—the top layer is depleted of mobile charge. Hence the potential minimum forms below the surface of silicon.

Although the analysis and the design of BCCDs are somewhat more involved than that of SCCDs, the external operation of the two may differ only by the dc level of the clock voltage pulses. However, a BCCD doesn't require a fat zero—bias charge—for high efficiency, or \( \eta > 0.9999 \). Also, it doesn't exhibit noise caused by the trapping of charge by the fast interface states, and it has a higher frequency response than an SCCD with the same dimensions.

In fact, a BCCD with a thick epitaxial top layer can achieve \( \eta > 0.9999 \) with clock frequencies in excess of 100 MHz. However, the maximum charge signal in a BCCD is up to three times smaller than that of SCCD. Also, the BCCD can have a higher dark current—a type of leakage—than the SCCD.

As with most other ICs, noise represents an important consideration in the evaluation of CCDs. Such applications as signal processing and imagers can require either very low signals or large dynamic range. Also, the theoretical minimum size of a CCD memory element depends on noise characteristics, since a memory's error rate is a function of the signal-to-noise ratio.

The general conclusions on noise in CCDs are as follows:
- Transfer noise due to free-charge transfer is quite low. Usually it involves only the small amount of charge left behind.
- Noise associated with trapping of charge by fast interface states and that caused by a fat-zero signal represent the major noise fluctuations...
5. Signals can be introduced in one of three ways. The current-input method (a) has critical requirements, while a sampling approach (b) relaxes some of the conditions. A linear method (c) features low noise.

6. Signals can be detected in one of several ways. Current sensing (a) employs the drain diffusion of the output stage. Voltage or charge-sensing is obtained with an internal floating-diffusion amplifier (b). And nondestructive sensing can be obtained with an internal floating-gate amplifier, in either single (c) or distributed form (d). With a floating-gate amplifier, only transfer noise is introduced into the signal.

A charge-presetting input method is linear, has the advantage of low noise, and it doesn't depend on threshold (Fig. 5c). The basic concept is to form a potential well at gates G1 and G2, with input gate G1 acting as a barrier between the source diffusion and the input well under G2. The input is applied as the relative voltage between gates G1 and G2.

The input well is first overfilled by raising the source potential above the G1 barrier. The excess input charge returns to the source diffusion when its potential is lowered. If the same channel oxide is used for both gates G1 and G2, the input charge signal, \( q_s \), is

\[
q_s = V_{\text{in}} C_{\text{ox}2} - 2 \Delta \phi_s
\]

where \( C_{\text{ox}2} \) is the oxide capacitance of gate G2.

Three methods are also available for the detection of charge signals at the output (Fig. 6). Current sensing measures current flow in the drain of a CCD (Fig. 6a). The current results from charge signals coupled to the drain diffusion by the last gate electrode. And the output signal takes the form of a current spike at a relatively high capacitance terminal. In theory, the method provides a highly linear detection scheme.

Amplifier comes on the chip

The floating diffusion amplifier (Fig. 6b) is the most popular detection approach when an on-chip amplifier is used. The output circuit periodically resets the floating diffusion to a reference potential. The floating diffusion, in turn, is connected to the gate of an on-chip inverter or source-follower amplifier. The detected signal varies proportionally with the floating-diffusion voltage as a function of the charge signal. Hence the technique is referred to as a voltage, or charge-sensing, method.

With a floating-gate amplifier (Fig. 6c or 6d),
Two-phase push-clock operation employs overlapping clock pulses. Charge is "pushed" across the barrier. Charge by the interface states can be avoided by buried-channel construction. In this type of CCD, however, small trapping losses may be observed. They are attributed to charge trapping by stationary bulk states.

Up to 3 gate levels used

The most common CCD structures employ sealed-channel construction involving one, two or three levels of polysilicon (Fig. 2). The selectively doped single-layer structure (Fig. 2a) passivates the interelectrode spaces with high-resistivity polysilicon. A second-layer metallization (aluminum) forms interconnections.

Polysilicon-aluminum, or two levels of polysilicon gates (Fig. 2b), represents a self-aligning, overlapping gate structure. Gate separation is formed by thermally grown SiO₂ that has a thickness comparable to that of the channel oxide. This gate structure can be used for construction of two-phase as well as four-phase CCDs.

The triple-polysilicon structure (Fig. 2c) represents another alternative. It has the unique feature of a separate polysilicon level for each phase.

The number of clock phases can be reduced to two, or even one, if the potential wells are made directional with an asymmetrical CCD-gate structure. This can be accomplished by connection of separate storage and barrier gates to a common clock voltage. In turn, the storage and barrier regions can be formed with two different thicknesses of channel oxide or by modification of the substrate doping level through ion implantation.

Push clocks vs drop clocks

Unlike three or four-phase CCDs, two-phase devices can operate with nonoverlapping positive clock-voltage pulses. Overlapping clock pulses are referred to as push clocks, while nonoverlapping clock pulses are called drop clocks.

In two-phase drop-clock operation (Fig. 3), the transfer barriers are formed by ion-implanted p-type regions under transfer gates. The shift of charge from the potential well under the φ₁ storage electrode to a well under φ₂ occurs during the positive φ₂ pulse. A similar process moves charge from φ₂ to φ₁ during the positive φ₁ pulse to complete the cycle.

In two-phase push-clock operation (Fig. 4), charge is "pushed" across the potential barrier during the fall time of the clock waveform.

The two-phase structure also may be operated from a single clock line by application of a dc bias to one of the phases. Then half of the transfers involve drop-clock operation, and the other half are push-clock.

Input stages accept electrical signals

Of course, for applications, means must be provided to introduce charge into the CCD register and then to detect signals at the output. An electrical input is usually introduced by one of the three ways shown in Fig. 5.

In the current-input method (Fig. 5a), the source diffusion, S, is dc-biased, and an input voltage pulse, V₀₁, is applied to the first gate, G₁. The combination forms an MOS current source that fills the first potential well under φ₁ for the duration, Δt₁, of the input pulse. This method is relatively critical, since the amount of charge introduced depends on the MOS threshold voltage as well as the amplitude and duration of the input pulse, V₀₁.

A more controlled method samples the input signal voltage, and the first potential well then fills to the voltage of the source diffusion (Fig. 5b). The input is applied as the source-diffusion voltage, while input gate G₁ isolates the first potential well from the source.

This method works best with a relatively slow fall time for the input-gate clock pulse. And though input charge isn't determined by the sample-pulse amplitude or duration, it does depend on the MOS threshold of gate φ₁.
fer efficiency, \( \eta \). The fraction left behind is the transfer loss, or transfer inefficiency, and it is denoted by \( \epsilon \), so that \( \eta + \epsilon = 1 \). Because \( \eta \) determines how many transfers can be made before the signal seriously distorts and becomes delayed, it is the most important performance parameter.

**Boosting transfer efficiency**

If a single charge pulse with an initial amplitude \( P_0 \) transfers down a CCD register, after \( n \) transfers the amplitude, \( P_n \), will be

\[
P_n = P_0 \eta^n = P_0 (1 - \epsilon^n) \quad \text{(for small \( \epsilon \))}
\]

Clearly \( \epsilon \) must be very small if many transfers are required. If you allow an \( n \epsilon \) product of 0.1 and an overall loss of 10\%, a three-phase, 330-stage shift register requires \( \epsilon < 10^{-4} \), or a transfer efficiency of 99.99\%.

The maximum achievable value for \( \eta \) depends on two factors: how fast the free charge can transfer between adjacent gates and how much of the charge gets trapped at each gate location by stationary states. In surface-channel devices, charge trapping usually results from the fast states at the Si-SiO\(_2\) interface. The trapping of

1. A three-phase, n-channel MOS charge-coupled device (a) stores and transfers electrons between potential wells (b). Different phases of the clocking waveform control transfer (c), and channel stops laterally confine the charge signals (d).

2. CCD structures generally employ sealed-channel construction. This can involve a single level of doped polysilicon gates (a), polysilicon-aluminum or two polysilicon levels (b), or three levels of polysilicon (c).

3. Two-phase drop-clock operation uses nonoverlapping clock pulses.
The ABCs of CCDs. They're basically MOS analog registers that can be employed in either analog or digital applications. Here are pointers in evaluating them.

If you haven't designed with CCDs yet, it's probably only a question of time before you do. Charge-coupled devices are turning up in photo-sensor arrays, large-storage memories and such signal-processing components as variable delay lines, transversal filters and signal correlators.

In most applications you probably won't be involved in specifying the construction of a CCD. However, a basic knowledge of CCD operation will help you evaluate the devices from different manufacturers. And system design can be optimized around a specific device.

Actually a CCD is a simple device. In essence, it is a shift register formed by a string of closely spaced MOS capacitors. A CCD can store and transfer analog-charge signals—either electrons or holes—that may be introduced electrically or optically.

Charges stored and shifted

The storing and transferring of charge occurs between potential wells at or near a silicon-silicon dioxide interface. The MOS capacitors, pulsed by a multiphase clock voltage, form these wells. For a three-phase, n-channel CCD (Fig. 1), the charges transferred between potential wells are electrons.

The application of a positive step voltage to a gate electrode (like \( \phi_1 \) at time \( t_1 \)) forms a depletion region in the p-type silicon beneath a gate. The particular gate is the one that causes a minimum of electron energy—a potential well—to exist at the Si-SiO\(_2\) interface (Fig. 1b). However, the potential well doesn't last indefinitely, and thermally generated electrons eventually fill the well completely. Thus the CCD is basically a dynamic device in which charge can be stored for much shorter times than the thermal relaxation time of the CCD's capacitors. Depending on device processing, this time may vary from one second to several minutes at room temperature.

The introduction of minority-carrier signals reduces the depth of the well, much like the way a fluid fills up a container. Charges transfer from wells under the \( \phi_1 \) electrodes to wells under \( \phi_2 \) because of the surface potential changes due to clocking (Fig. 1c). A similar transfer moves charges from \( \phi_2 \) to \( \phi_3 \) and then from \( \phi_3 \) to \( \phi_1 \). After one complete clock cycle, the charge pattern has moved one stage (three gates) to the right. No significant amount of thermal charge accumulates in a particular well because the charges are continually being swept out.

Note that the three-phase structure is symmetrical and the direction of charge flow is determined by the clock-phase sequence. For example, by an interchange of the \( \phi_1 \) and \( \phi_3 \) clock lines, the charge could be made to transfer to the left. Operation with less than three-phase clocks requires an asymmetry in the CCD structure to determine the direction of signal flow.

The charge signals are laterally confined into a channel by means of channel stops (Fig. 1d). These can be heavily doped diffusions, thick-field oxides or another gate level (field shield) under the phase electrodes to which a dc bias is applied.

Charges transfer in 3 ways

Free charge moves from one well to another by three separate mechanisms: self-induced drift, thermal diffusion and fringing field drift. Self-induced drift, a charge-repulsion effect, is only important at relatively large signal-charge densities. It is the dominant mechanism in the transfer of the first 99% or so of charge signal.

Thermal diffusion results in an exponential decay of the remaining charge under the transferring electrode. The decay has a time constant that increases as the square of the center-to-center electrode spacing. Fringing field drift can help speed the charge-transfer process considerably. The fringing field is the electric field in the direction of charge flow, and it depends on process parameters and device geometry.

The fraction of charge transferred from one well to the next is referred to as the charge-trans-
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However, it is probably Polaroid's 107 film pack, which has an ASA rating of 3000.

Polaroid film does have disadvantages, though. It is difficult to write on the prints, they do not reproduce well on office copiers, cannot be obtained in rolls or packs of more than eight, and the film is expensive.

In the last five years a new type of scope camera has appeared: the inexpensive hand-held camera. It does not offer the sophisticated photographic capabilities of the "bolt on" cameras, but it is useful for many applications. While the bolt-on cameras sell for about $700 each, the hand-held cameras can be purchased for less than $200.

But whether you use a hand-held or bolt-on camera, if you use it with the newer internal graphic capabilities of the "bolt on" cameras, it does not offer the sophisticated photographic capabilities of the "bolt on" cameras, but it is useful for many applications. While the bolt-on cameras sell for about $700 each, the hand-held cameras can be purchased for less than $200.

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A portable scope camera that has a viewing hood to permit monitoring of the waveform on the CRT is the Model SC02 from Vu-Data.

The HP 197A scope camera has a built-in UV light which can be used to record the black lines of internal-graticule scopes. The electronically controlled shutter of this Hewlett-Packard camera provides exposure times from 1/30 to 4 seconds.

Multimode scopes have been made that combine both storage modes and add other improvements to provide an additional mode: fast-transfer bistable.

When specifying storage scopes, don't forget that one of the most important parameters is storage writing speed. This tells how fast the electron beam can draw a usable picture across the CRT in the storage mode. It is specified in units of length—generally centimeters—per unit of time.

Writing speed can be measured by single sweeping at increasingly faster horizontal rates until a single shot is barely visible in the stored mode. But this is a subjective measurement; two people performing the same test on the same scope could come up with different answers.

To determine the maximum frequency at which a storage scope can capture a single-shot event, divide the writing speed by 10 to determine the approximate frequency in megahertz. For example, if the writing speed is 100 cm/µs, a 10-MHz single-shot signal can be captured and displayed.

If your measurement requirement exceeds this guideline, ask for a demonstration of the scope, since most instruments can be tweaked to capture, faster signals. (For more information on storage scopes, see "Choose the Right Storage Oscilloscope," ED No. 24, Nov. 22, 1974, p. 150.)

For permanent records use a camera

New storage scopes that can capture and store very-high-speed data for long periods have reduced the need for oscilloscope cameras. But for a hard-copy record of a scope trace, cameras are still a must. Also, if you want to record an event that occurs too fast for the storage scope to capture, you can use a camera and a nonstorage scope.

When choosing a camera, consider first what type of waveform will be recorded. Will it be a stored, repetitive or single-shot event? Stored and repetitive traces require the least capability in writing speed, while the single-shot requires the highest.

Within the camera, writing speed is determined by two things: maximum lens opening and the reduction ratio of the lens system. As the image size is reduced, the same amount of light is concentrated on a smaller area of the film. The best compromise between writing rate and image size comes at a magnification ratio of approximately 0.5:1. Prefogging, or partially exposing the film before it is used, can increase the effective speed of any system twofold to fourfold.

The shutter requirements of the scope camera must also be considered. For remote operation, an electric shutter is desirable, while a more economical mechanical shutter may be preferable for the occasional user of scope cameras.

Because of the range of CRT display sizes, it is important to consider the field of view of the camera. Just because a camera will fit on a scope does not mean that the system will have an adequate field of view.

For maximum photographic flexibility, cameras with interchangeable film backs should be used. While these are more expensive, they give the user a choice of roll, pack or sheet film. Polaroid Type 410 roll film has a film speed, or ASA, of 10,000 and is the obvious choice for high-speed work. The most commonly used film,
A low cost bolt-on camera that fits all standard scopes with a 6 × 10 cm screen is available from Ballantine. Known as the 7000A the camera features a pre-focused lens and a preset aperture.

Bolt-on cameras like the C-51 from Tektronix, are designed to work with specific scopes. The C-51 has an electronically controlled shutter, fast writing rate and an automatic single sweep control.

an error of about 2%.

Vertical deflection systems that have a rise time that is equal to the fastest rising signal applied are often considered adequate.

Errors in measuring very fast rise times directly may come from several sources: linearity limitations of the vertical amplifier and of the sweep circuit, and visual errors caused by display of the waveform on only a small part of the full screen.

**Triggered sweep eliminates ‘dancing’**

Did you ever have a problem with your television set at home where the vertical oscillator was getting old and you had to readjust it each time the line voltage changed? A similar problem can occur in an oscilloscope. If the sweep generator is not properly triggered, you'll get a dancing waveform.

In early scopes the sweep generator free-ran continuously at a frequency just below that of the input signal or one of its submultiples. When the input signal was applied to the free-running sweep generator, it increased its output frequency. While this was an easy way of synchronizing the sweep generator to the input waveform, it required careful adjustment of controls to lock in the signal.

This early form of triggering had several problems. Included were loss of sync as a result of drift and difficulty in synchronizing to a signal that varied in amplitude or frequency.

These problems have been overcome, however, with the development of triggered sweep scopes. In these units the input signal determines the start of each sweep by triggering the sweep generator. Not only does this triggered sweep give a steady, drift-free display, but it also permits accurate control of the starting point on a given waveform.

There are two key parameters in triggering: sensitivity and frequency range. Trigger sensitivity indicates how small the signal can be on the CRT and yet remain stable, while trigger bandwidth is an indication of the range of signal frequency that can be displayed in a triggered mode.

When you evaluate a scope, look at the trigger levels used and see how easy it is to get a stable trace on the scope. First, get a source for a 1-kHz sine wave. Display two or three cycles across the full screen. Now vary the trigger level control so the trace starts at different points on the waveform. Now change the amplitude to see if this has any effect on triggering.

If you're going to be working with slow signals, be sure the scope has a de-coupled trigger. The lower-priced scopes—generally those below $800—don’t have this capability.

**Storage scopes capture high-speed data**

Storage scopes can retain and display the image of an electrical waveform on their tube face, even after the waveform ceases to exist. This image retention may be for only a few minutes or it may be for days. This makes storage scopes ideal for capturing high-speed signals.

Storage scopes operate in one of two modes: variable-persistence and bistable. The variable-persistence mode allows selection of the time during which a stored image can be viewed.

Bistable operation allows waveforms to be stored and displayed until they are erased. A special phosphor having two stable states is used.
ing. As a matter of fact, some scopes have no shielding at all, while others use cold-rolled steel. The best shielding is of mu metal. Check to see what shielding it has before you buy it. If you're going to use a scope in a laboratory where there aren't too many stray magnetic fields and you want to save money, you can always opt for the cheaper scope without shielding.

To make scopes less susceptible to noise, some manufacturers have taken a leaf from the voltmeter and counter manufacturer's notebook and have included a bandwidth-reduction switch. This cuts frequency-related noise.

When noise does appear in scopes, it shows up as fuzziness or extra traces on the screen and as false trigger signals.

Noise specifications are available for many high-frequency scopes expressed as voltage, equivalent-resistance or scale divisions. Beware of rms noise specs. These can be as much as six times lower than the actual peak values and thus downplay the real problem. Be especially careful if the application involves short, precise or hard-to-capture signals.

**Sensitivity is increasing**

The input sensitivity of a scope is an indication of how much voltage is necessary to deflect a CRT beam a given distance. Sensitivities are increasing, but be careful when you compare the input sensitivities of two scopes. The specs are not always given in the same units. The sensitivity of most scopes is given in millivolts per centimeter. However, some give it in millivolts per division.

Even if you determine the correct units for sensitivity, you still may not know much about it. Chances are the figure listed for sensitivity on the data sheet is not the figure at the scope's rated bandwidth, but at some lower frequency.

It's particularly important that you be wary of sensitivity specs on dual-channel scopes. On some it is possible to cascade the two input amplifiers to get greater sensitivity. Make sure you're not comparing the sensitivity of a single amplifier on one scope with cascaded amplifiers on another.

Another important thing to remember is that when you talk about sensitivity, you're talking about a voltage that appears at the scope's input terminal and not at the probe tip.

**Rise time explained**

With today's heavy emphasis on digital circuits, one of the most important specs to consider in oscilloscope selection is rise time. This is defined as the amount of time it takes for a step function to go from 10% to 90% of the final amplitude of the step.

If the vertical amplifier of a scope is designed for optimum transient response—which is the fastest rise with minimum overshoot—the product of the rise time and bandwidth should be a factor whose value lies between 0.33 and 0.35. A larger product indicates the likelihood of substantial overshoot and ringing.

If you're measuring fast signal rise times, you would naturally like a scope with an infinitesimal rise time, but you can do quite well if the scope's rise time is no more than 20% of the signal's rise time. If sweep-contributed errors are neglected, the scope would then show

(continued on page 54)
high-frequency units—are designed for 50-Ω loads. For tests on such equipment, the 50-Ω input offers not only its usual advantages, but also maintains the impedance match of the system, minimizing distortion and insertion loss.

While scopes generally have either 1-MΩ or 50-Ω inputs, some units have a switchable input that can give both.

**Probes: They're precision instruments, too**

Too many engineers forget that oscilloscope probes are also precision instruments. Although most probes are relatively hardy, if dropped, squashed or fried with high voltage, both passive and active probes can be damaged.

Passive probes are harmed most often by physical abuse. Engineers have been known to use them as substitute pliers, component holders or oxide scrapers. Fortunately their tips are often replaceable. And while their cases are fairly strong, they can be cracked by heavy loads—such as feet, a misplaced heavy instrument or a fall. Cables, too, can be overstressed or twisted.

Overvoltages can damage passive probes. Both the voltage and power ratings of probes are there for a reason. Exceeding them may cause temporary inaccuracies or permanent damage due to heating or dielectric breakdown. In fact, some high-voltage probes require special insulation fluids, and an underfilled condition can also be damaging.

One thing to watch out for when you're using a probe is compensation. Probes require compensation at all times. For passive probes, this is simply a matter of bringing the capacitance-resistance ratio of the probe in line with that of the scope. When either is changed or stressed, the compensation must be checked. In most cases the only adjustment needed is to a variable capacitor built into the probe.

Active probes—which use active devices such as FETs, to achieve high input impedance and low input capacitance—are more vulnerable. The overvoltage tolerance is smaller, and permanent destruction of a component may result. At $100 to $200 a probe, that can get to be expensive.

Active probes may need more adjustments than passive ones. The adjustments may include dc offset, balance, range and capacitance.

But active probes have two major advantages:

1. The isolation is high between the measurement point and the probe cable and scope, allowing for high input resistance and low capacitance, and
2. Full bandwidth is obtained without input signal attenuation.

Most active probes are compatible with either 1-MΩ or 50-Ω scope inputs without use of adapters. When working in the 50-Ω mode, use 50-Ω cable to extend the probe length without increasing capacitive loading. The longer cables, however, will slow the rise time.

One very important point to remember when you're using active probes: They require external power. While some oscilloscopes have a separate probe power supply, most do not.

Also, as you move up in frequency, the probes become more expensive. At 100 MHz the cost of an active probe is about 25% of the price of the scope.

**As frequency goes up, so does noise**

Some noise is inevitable in any scope, but as bandwidths and sensitivities increase, noise becomes a more significant factor. Several types can affect a scope. There is power-supply noise, component noise, thermal noise and pickup of man-made noise, such as ignition interference. There is also 1/f noise, which becomes greater as the frequency decreases, and there is white noise.

White noise has constant energy and therefore is reproduced much more strongly as bandwidth increases. But it is not the big problem; 1/f noise, power-supply noise and interference from stray magnetic fields are. Above 10 kHz, 1/f noise ceases to be a major problem. Elimination of the other noise problems requires the use of special input circuits, short connecting cables and good shielding.

Unfortunately not all scopes have good shield-
Medium price and performance are available with the PS163 dual-trace scope from Sencore. It features 5-mV sensitivity and less than 2 degrees of phase shift between channels.

vides a low degree of circuit loading, a measure of protection for the scope and a good degree of accuracy. When frequencies increase, however, the combination of input capacitance and high resistance results in a long time constant. This seriously affects both time measurements, such as pulse rise time, and amplitude measurements of short pulses.

The high input impedance is only high for frequencies below about 1 MHz. Above that point, the shunt capacitance takes over. For example, a 1-MΩ input with 10 pF of input capacitance across it has an effective impedance of only 50 Ω at 320 MHz.

Low-impedance 50-Ω inputs were developed for such high-frequency applications. Instead of having an extremely variable impedance over a range of frequencies, 50-Ω inputs provide stable loads over a wide frequency range and virtually eliminate the effects of capacitive loading.

Of course, with its low impedance, the 50-Ω input draws more power from the circuit. This means that amplitude measurements may be significantly affected. Time measurements are better because of the lower RC time constant.

Since 50-Ω inputs do not limit the power dissipation inside the scope as much as do 1-MΩ inputs, manufacturers generally supply some additional protection, such as fuses or relays.

But if you're going to use a 50-Ω input to measure high-speed logic circuits, you're in for trouble. Most IC logic families are high-imped-
An inexpensive dual-trace scope that has a bandwidth of 10 MHz is the Model 1470 from Dynascan.

For example, if the chopping rate is 100 kHz and the sweep duration 1 ms, there will be 100 segments in each trace. How well these separate segments depict all the detail in the two waveforms establishes the usefulness of the chopped mode compared with the alternate mode or dual-beam scope.

When using dual-channel scopes it is important to remember that two simultaneous, non-recurrent signals of short duration may be displayed on a dual beam scope, but can’t be displayed on a dual trace scope. When looking at recurrent signals that can be displayed on dual-trace units remember that phase errors can arise.

This problem can be overcome by use of the chopped mode, but a limitation is imposed by the finite chop frequency that may well interfere with the signals to be measured. Of course, these errors can be completely avoided with a dual-beam scope that has two electron guns. Such a scope would have two time-base generators that sweep the two signals at different rates.

Most dual-beam scopes available today, however, use a single gun with a split cathode. These scopes have tubes that contain one set of horizontal deflection plates and two sets of vertical plates. The split-beam approach requires that each of the two inputs have separate amplifier chains. This technique, like the dual-gun approach, eliminates the need for chopped and alternate display modes, and it allows twice the usual light-energy levels to be employed.

Modular scopes cost more

Although for many applications a modular scope offers great versatility, having both standard and special measurement capabilities, it is more expensive than a stand-alone unit. Plug-in scopes generally have a large power supply to accommodate the modules used. This adds to the cost. So does the special mechanical design of the scope mainframe.

The main problem with modular scopes is that often many expensive, surplus modules are sitting on the shelf, doing nothing simply because there aren’t enough mainframes in the place. Often owners of plug-in scopes use the modules 10 minutes a year, and then only to calibrate them. Manufacturers push modular scopes for two reasons. A mainframe owner becomes a captive customer for modules, and a standardized mainframe can be made in quantity—leading to mass-production economies.

Another disadvantage of modular scopes is that they’re expensive to maintain. Individual modules are usually very densely packed and have to be pulled apart to service them. Of course, the entire module can be replaced by a spare, but that adds to system cost. In contrast, most stand-alone scopes are easily serviced.

On the positive side, plug-in scopes do offer a wide range of measurements that might otherwise be unavailable or very costly to obtain in a stand-alone scope. These specialty requirements include sampling to 18 GHz, logic-state analysis and spectrum analysis, to name a few.

A handle doesn’t make it portable

What is a portable oscilloscope? Not any scope that has a handle on it. A scope is portable, most manufacturers say, if it weighs less than 25 lb. The design should include an impact-resistant case and lightweight power supplies.

In general, portable scopes do not represent any compromise in performance; often the contrary is true. Because of their system design, many portable scopes have better performance than their modular counterparts.

But a portable scope is not always a good buy, especially if it is going to be used a lot in the laboratory. One drawback is its small screen size. While this is not an inherent feature of portables—some have screens as big as those of lab models—most have smaller screens that limit resolution.

Front-panel layout is another problem with portable scopes. Since there is less room than there is on the front panels of lab scopes, it’s important to check that the controls are not so close together that you practically need a pair of tweezers to operate them.

Recently there has been much controversy over the merits and demerits of 50-Ω and 1-MΩ input impedance. The key issue when making a comparison is input impedance vs frequency.

For most applications, the 1-MΩ input pro-
trace scopes can be used for all but a handful of applications, and they don't cost much more than the single-trace instruments. The cost for the additional circuitry ranges from 10 to 15% of the total instrument price, and it is well spent. With the dual-trace scope, one waveform can be compared with another—something that has become increasingly important with the growing use of digital logic.

**Dual trace vs dual beam**

Don't confuse dual-trace scopes with dual-beam scopes. In the former you have one electron beam that is time-shared between two input signals; in the latter, two electron beams are produced either by use of two electron guns or one gun with a split cathode. Whether the time-shared beam or the dual-beam approach is used, each has advantages and disadvantages.

The most common approach to two-channel scopes is the one that uses a single beam and one set of vertical deflection plates that are time-shared between two vertical deflection channels. One advantage of this method is that there are no convergence problems, since only one vertical deflection system is used. Dual-trace scopes cost less than dual-beam, and they offer better comparison capabilities.

The electronic switching circuitry in a dual-trace scope should be capable of operating in two modes: rapidly during sweeps or synchronously during sweep-retrace intervals. The first mode is called “chopped,” the second “alternate.” The alternate mode is used more frequently and is preferred for displays that have fast sweeps. The chopped mode is usually reserved for comparing low-frequency recurrent signals or non-recurrent signals of long duration.

When two very bright traces are displayed in the chopped mode, faint lines connecting the two traces may show up. These are chopping waveform transients. You can eliminate them either by turning down the intensity or using a scope that blanks the CRT beam during these transition intervals. The chopping rate should be as high as possible, so long as the resulting traces are not broadened significantly by distortion of the chopped signal. The chopping frequency can vary from as low as 80 kHz to as high as 1 MHz, depending on which scope you use.

The disadvantages of the dual-trace, time-shared approach include the availability of only half of the light output of the CRT, because of the time-sharing process. Also, when the chopped mode is used with relatively fast nonrecurrent sweeps, the traces are not continuous but are made up of separate segments. The number of segments depends on the chopping rate and the sweep duration.

Improved measurement accuracy is possible with Hewlett-Packard's 1722A microprocessor scope. This 275-MHz scope gives direct readout of time interval, frequency, dc and instantaneous voltage and percent.

Delayed sweep and mixed sweep operation are two of the key features of Ballantine's 1040A. It is a portable 40-MHz dual-channel scope.

Increased measuring capability results when the DM 43 digital multimeter module from Tektronix is added to any of the 464, 465, 466 or 475 portable scopes. The module makes it possible to measure temperature, time resistance and voltage.
Oscilloscopes are among the least misused, least misunderstood and least mis-specified pieces of test equipment around. But this doesn't mean there are no problems for the buyer. If you're choosing a scope, you still have to weigh these tradeoffs:

- Single trace vs dual trace vs dual beam.
- Modular vs stand-alone.
- Portable vs nonportable.
- Low input impedance vs high impedance.
- Storage vs nonstorage.

And the problem is compounded if you're thinking of using a camera with the scope. This requires dealing with alien parameters, such as lens and film speed, and depth of field.

Other problems that crop up when you consider a camera for use with your scope include deciding what kind of film to use, what the picture format should be and whether the camera should be purchased from the scope manufacturer.

It's like buying a car

Choosing an oscilloscope is like buying a car. Very often brand name and horsepower (or bandwidth, in the case of a scope) influence the choice. Many engineers have a tendency to overspecify when it comes to oscilloscopes. This results in the purchase of unnecessarily expensive equipment that is often more difficult to operate. A good analysis of what you really want the scope to do will save you money.

Many factors should enter into the selection of scopes. These may range from frequency response to layout of the front panel. Among the parameters most often considered are configuration, bandwidth, sensitivity and triggering, and time-base capability.

Configuration relates to the physical characteristics of the instrument—whether it will have one or two channels, be modular or stand-alone and laboratory or portable.

In most cases you're better off buying a dual-trace scope rather than a single-trace unit. Dual-

Dual-trace oscilloscope from Philips has a bandwidth of 120 MHz. Using a special power supply, the PM 3260 can operate from almost any line voltage and frequency. It consumes only 45 W and needs no fan for cooling.
asking about INDICATORS?

Our answers come in any size or configuration you're likely to need. They're CM and Drake LED, incandescent or neon indicators. Backed by more than 65 years experience in lamp and lighting technology, plus on-site help in solving your tough application problems. Give us a call at (312) 867-7227, or write us at 4626 N. Olcott Avenue, Harwood Heights, Illinois 60656.

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INFORMATION RETRIEVAL NUMBER 34

INFORMATION RETRIEVAL NUMBER 71
Let's climb out of the hole

I got a letter the other day from a reader who was really pissed off. "We all know," he wrote, "that business isn't as good as it was a couple of years ago. But why the hell do the news media keep on rubbing our noses in that fact? Are they making things any better? Are they telling us something we don't know?"

This reader, Larry Collins, went on that "as usual" the news media are behind the times, and, in fact, business in some areas has begun to pick up. The improvement isn't sensational yet and we're far from a seller's market, but there are certainly signs of recovery. Yet the media in the electronics industry as well as other industries seem to act on the premise that bad news is good news. They assume that bad news sells papers.

Well, I agree with Mr. Collins. I think there's been entirely too much yakking about how bad things are and too much neglect of signs of improvement. Electronic Design, I hope you've noticed, has been absent from the chorus of doomsayers. It's not that we didn't know the situation was bad but that we figured you knew it already. We didn't feel obligated to tell you what you already knew and we didn't feel there was anything to be gained by yelling about how bad things were unless we had a solution—which we didn't.

But we have some thoughts now. We warned in the past that it's possible to talk ourselves into a deeper recession. Now I'd like to urge that it's possible also to talk ourselves more quickly out of one. I don't want to seem like a Pollyanna and I don't believe that if we think only nice thoughts then only nice things will happen. Yet I am convinced that we can actively help ourselves pull out of the recession faster.

We can talk up the good news and we can act as if, in fact, there is going to be a tomorrow. We can, for example, release that purchase order we've been sitting on in the expectation of lower prices. If we get rid of the attitude of despair that some of us have developed, we may be able to inspire enough confidence in our customers so that we'll be able to move some of our own products which, in turn, will force us to buy more products from our vendors.

I think we can all help if we can kick the bad-news habit.

GEORGE ROSTKY
Editor-in-Chief
Build a switching regulator in half the time.

You know that a switching regulator can quadruple the efficiency of your power supply. It'll save power, cut heat loss, simplify your design, save board space, weigh less, and maybe cost less than a linear regulator.

But until now, if you wanted a switching regulator, you had to start from scratch. It took a lot of time and a lot of effort.

Our power switching circuit is the breakthrough you've been waiting for.

The power circuit is the trickiest part of the switching regulator to design, since it involves choosing the commutating diode and switching transistors, then fiddling with the circuit to get the best drive and bias conditions.

We've taken care of all that. And the power circuit is the one that can contribute most in terms of improving the regulator's performance.

We've taken care of that, too. Thanks to our special design and packaging, you can expect faster response time and lower noise than you could design in yourself. And because of the faster switching time, you can reduce the size and cost of other components and operate at frequencies up to 100KHz.

Our PIC-600 Series power switching circuits are available with positive and negative outputs, in current ranges from 5 to 15 amps and voltage capabilities up to 80 volts.

To make your life even easier, we've got a 24-page booklet that'll tell you everything you need to know about designing a switching regulator. It's the only booklet of its kind available, and it's free. To get yours, along with detailed specs for our power switching circuits, circle our number on the reader service card.

Unitrode Corporation, 580 Pleasant St., Watertown, Mass. 02172.
IS YOUR AC METER TELLING YOU LIES?

If you're measuring anything other than undistorted sine waves, you need an instrument that reads out true RMS values.

Most people think any old AC DPM or DMM does this. Fact is, they don't. Unless they're an expensive true RMS DMM, they read the rectified average value of the input, calibrated to the RMS value of a sine wave. Which usually results in gross errors.

But now there's the AD2011.

The first DPM to use implicit computing techniques to read true RMS values of AC signals.

And it costs just $295.

The AD2011 also features 30Hz to 300kHz frequency response, 3-digit Beckman displays, four input ranges (1V, 10V, 100V, and 1,000V RMS full scale), and BCD data outputs.

So why not write for the data sheet, for the truth about true RMS.

Analog Devices, Inc.
Norwood, Mass. 02062.
Electronic components for test and measurement instruments and control systems, including a complete line of 5V and AC DPMs, from 2½ to 4½ digits, with LED, Numitron, and Beckman displays.
East Coast: 617-329-4700.
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West Coast: 213-595-1783.
Texas: 214-231-5094.
an offer for sale and was prohibited if the unit had not been certified—even if it was a dummy.

The commission plainly doesn't intend to permit a manufacturer or vendor to create a market for a product that may not comply with its requirements.

Importation for test and evaluation, according to the FCC, means only for compliance with FCC requirements and "does not mean for evaluation for sale purposes."

Marketing strictures of this kind have had a significant impact on manufacturers of rf devices covered by commission rules.

To reduce "spectrum pollution" and "electromagnetic smog" to tolerable levels, the agency says it "will be taking an increased role in the regulation of rf devices with an interference potential for which the commission does not presently prescribe technical standards."

A new U.S. Dept. of Research proposed

Research and technology will be upgraded in Government operations if legislation proposed by the House Committee on Science and Technology makes it through Congress. Titled "The National Science Policy and Organization Act of 1975," the bill would create, among other things, a Dept. of Research and Technology Operations.

Presenting strong arguments for the proposal, Rep. Olin E. Teague (D-TX), chairman of the committee, said: "Science and technology are an element of our contemporary culture as pervasive and important as economics or education or labor or environment. . . . Science and technology should be fabricated concretely and statutorily into the managerial structure of our National Government."

Included in the new department would be the National Aeronautics and Space Administration, the Energy Research and Development Administration, National Science Foundation and such sections of other departments as the National Bureau of Standards, Weather Service and National Oceanic and Atmospheric Administration. In addition the legislation would create a Government corporation to ensure maximum use of scientific and technological information generated at public expense.

The bill would also enunciate a national science policy as well as establish a council of Advisers on Science and Technology in the Office of the President.

Capital Capsules:  Sen. William Proxmire (D-WI), chairman of the Senate's appropriation subcommittee on Housing and Urban Development and Space and Science, believes the $16-billion space-shuttle program may be on the verge of a financial breakdown. The Senator bases his most recent "overrun" scare on General Accounting Office studies that say NASA's repeated use of the $10.5-million-per-launch estimate is misleading, since it doesn't include any research funding or the costs of payloads placed in orbit by the shuttle. . . . The Energy Research and Development Administration is investing $2.6-million with Hughes Research Laboratories to develop a new type of mercury valve that would be used to convert between alternating and direct current at the terminals of high-voltage dc transmission lines. A spinoff from the spacecraft ion engine that Hughes developed for NASA, the new device promises to be smaller and more reliable than the old mercury-arc devices. . . . A NASA scientist has found that black chrome, once used for plating cameras and decorating other objects, is some 20 per cent more efficient than current coatings for solar collectors. Black chrome is as solar-selective and much cheaper than the other prime candidate, black nickel.
ELF submarine network to get home base

Sanguine, the homeless Navy communication system (Wisconsin and other states have said “thanks, but no thanks”) is changing physically, technically and by name. As Seafarer, the controversial shore-to-submarine communications system will be installed either at Nellis Air Force Base in Nevada or at the Ft. Bliss (TX)-White Sands (NM) military complex.

The Dept. of Defense has given the Navy approval to go ahead with additional design validation work on the new version of the Extremely Low Frequency (ELF) system, which will be a surface variation of the Sanguine. Research and development effort will continue on an underground hardened and dispersed system and on an even harder deep underground complex. All three use the same ELF frequency band and receiver equipment.

Environmental studies to date by the Defense Dept. have indicated no adverse environmental impact from the strong electromagnetic radiation, but steady static from ecologists have made the Navy system an unwelcome neighbor wherever it tried to settle.

Breaking the ice via microwaves

Side-looking radar may be the ice breaker that will allow 12-month shipping operations on the Great Lakes. Shippers now, more or less, forget the whole thing for three and a half months. “Icewarn,” a microwave information system developed by the National Aeronautics and Space Administration, uses airborne side-looking radar to find ice weak enough for a ship to break through. In tests last winter, such data were transmitted via a ground station or satellite to the National Oceanic and Atmospheric Administration at Wallops Island, VA, and from there to the Coast Guard Ice Navigation Center in Cleveland. In current tests the Cleveland station is beaming facsimile maps to the ships by radiotelephone. The system could be operational in the Great Lakes by next December, ready for the annual ice season.

FCC maintains strict stance on rf equipment

The Federal Communications Commission continues to refine its marketing rules and is leaving little doubt about its strict attitude on rf devices. In response recently to the Electronic Industries Association, the agency said that the display of a receiver at a trade show constituted
High-Level (+17dBm LO)
Double-Balanced Mixers $15.95

- Frequency range, dc to 1000 MHz
- Two-tone performance: Third order product 50 dB below desired i-f
- Conversion compression: 1 dB at +10 dBm rf input
- From $15.95 in five-unit quantities
- Units from stock, one-week delivery

CONVERSION LOSS VS FREQUENCY

<table>
<thead>
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<th>Model No.</th>
<th>Frequency range, MHz</th>
<th>Conversion loss, dB</th>
<th>Isolation, dB</th>
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<tr>
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<tr>
<td>ZLW 3H</td>
<td>5-1000</td>
<td>0.5</td>
<td>25</td>
</tr>
</tbody>
</table>

DESIGNERS KIT AVAILABLE: 1 model of each type.

SRA 1H, SRA 1WH, SRA 2H, SRA 3H
ZAD 1H, ZAD 1WH, ZAD 3H
KIT # DBK 1...$59.95
KIT # DBK 2...$79.95

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ISRAEL Vectronics, Ltd., 69 Gordon Street, Tel-Aviv, Israel;
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For complete U.S. Rep listing and product line see MicroWaves’ Product Data Directory

INFORMATION RETRIEVAL NUMBER 31

Electronic Design 8, April 12, 1975
in the beginning
there was
quartz . . .

... and then there was Apollo 11 and the
flawless performance of McCoy crystals from
blast-off through splash-down.

... tomorrow there will be the Viking Lander
and the mind-boggling implications of life on
Mars. McCoy crystals will be there of course
... superb performance a foregone

... conclusion.

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generation of devotion and dedication to the
frequency art. From the uncomplicated times
of our ham crystals (which for sentimental
reasons, we still produce) to the sophisticated
items we placed aboard Apollo 11, engineering
progress has marked our days.

We at McCoy are proud of our association with
the electronics community. We are extremely
grateful for the relentless demands it places
upon us ... demands that beget a humility that
allows us to try the unreasonable and do the
impossible.

Whether your problems be of Apollo/Viking
proportions or something less we welcome the
opportunity to share in their solution.

Please write for our new catalog.

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A regular and constant output whatever the input

with low cost voltage regulators ex-stock

The L129, L130 and L131 are fixed voltage regulators in TO-126 plastic package. Now available from stock, these devices are suitable for low cost applications in professional, industrial and consumer equipment requiring compact components with low/medium output current.

Special features:
- tight tolerance on the output voltage
- load regulation less than 1%
- ripple rejection 60 dB typical
- internal overload protection
- short circuit protection.

<table>
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<tr>
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<th>99-999 $</th>
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<td>1.28</td>
<td>0.85</td>
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</tr>
</tbody>
</table>

SGS-ATES Semiconductor Corporation - Newtonville, Mass. 02160 - 435 Newtonville Avenue - Tel: 617-9691610 - Telex: 922482

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  Montreal 357, Quebec
  Tel: (514) 389-8051
Two video disc systems to be marketed in 1976

Three large corporations—RCA, N. V. Philips and MCA Inc.—plan to begin marketing next year a long-promised home-entertainment product—the video disc playback system.

RCA Corp. recently demonstrated its SelectaVision video-disc system (“RCA Video-Disc Entry Gives Hour of Inexpensive Viewing,” ED No. 6, March 15, 1975, p. 19). It uses a pickup stylus that detects variations in capacitance between its tip and a grooved metallic dielectrically coated vinyl disc.

N. V. Philips of the Netherlands and California-based MCA Inc., which owns Universal Pictures and Decca Records, recently displayed their jointly sponsored Videodisc system. In contrast to the RCA unit, it uses optical techniques—a low-power laser beam—both to record the images on a master disc and to pick up the recorded signals on a mass-produced polyvinyl disc and play them back through a TV set.

Both the RCA and Philips-MCA playback units are attached to the input antenna terminals of any home TV receiver. They display both color or black-and-white pictures and sound from video discs.

Both discs are 12 in. diam and can hold 30 minutes of programming on each side.

Philips-MCA and RCA plan to sell their Videodisc players for about $500, with pre-recorded albums priced at $2 to $10.

No Offense

Non-PCB (polychlorinated biphenyl) . . . non-toxic . . . non-polluting. That’s new Sprague ECCOL® A-C Capacitors . . . developed for today’s ecology-conscious world.

Equipment manufacturers using capacitors with polychlorinated biphenyl impregnants are finding that some nations have prohibited the import of products containing PCB.

ECCOL® capacitors have been designed to meet industry needs for PCB-free capacitors. They exhibit essentially identical electrical performance characteristics to those of long-used askarel capacitors. Their operating life and reliability are also equivalent. Even the size of ECCOL® Capacitors is similar to previous designs, except for a slight increase in case height.

Drawn-case ECCOL® Capacitors are available in a wide range of capacitance values from 1 to 55µF, with four voltage ratings from 300 to 660 VAC.

For complete technical data, write for Engineering Bulletin 4550 to:
Technical Literature Service
Sprague Electric Company
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North Adams, Mass. 01247

SPRAGUE - THE MARK OF RELIABILITY
THE BROAD-LINE PRODUCER OF ELECTRONIC PARTS

INFORMATION RETRIEVAL NUMBER 28

Electronic Design 8, April 12, 1975
on the control panel signal if the preset parameters are violated.

Outputs permit the print scanner to control the number of labels printed and to indicate visually when the press run is 95 per cent completed. Print-out terminals for periodic digital readout of press quality and production control information are available as an option.

The laser, a helium-neon device that emits a bright red light (6328 Å), is exactly like the one supermarkets will use to scan a customer's packages. The laser is focused on a prism mounted on a constant speed motor. The motor repetitively moves the beam across the moving paper. The scanned beam appears on the paper as a solid red line.

As the beam moves from light to dark areas, the photodetector emits a voltage that goes from high to low. The signal processor and digitizer separate the signal from background and other interfering light and digitize the signal into a series of "1's" and "0's," which correspond to the light and dark areas of the printed material.

The "1's" and "0's" are constantly being monitored while the computer looks for the UPC pattern. When the light and dark patches begin to match the pattern, the computer interprets the digits into decimal numbers. By knowing how fast the line is scanning, the computer can measure line width by clocking the length of time it takes to scan the middle bar of the UPC symbol.

The keyboard, similar to that on a calculator or telephone, is used by the operator to store numbers in the memory of the computer. The computer constantly compares the information it receives from the head with the corresponding information in its memory. Memory data are constantly updated. When the computer senses that something is wrong in the printing, such as line width, print contrast or the number of rejects, the appropriate alarm is made.

Reading an entire UPC symbol takes less than 0.001 second. The computer analyzes the "1's" and "0's" in much less than 1 millionth of a second.

A 12-digit array displays information selected by the panel switches in bright 0.3-inch-high numbers which may be read at 20 feet.

The unit is expected to sell for $5874.

Display panel of the Monitor 101 provides a keyboard (right) for entering numbers into the computer's memory and selector buttons (lower left) for displaying desired data.
There are a few other 12-bit D/A converters around that sell for $39 in 100's, but it's a real hassle to make them work. For openers, you usually have to add your own reference and output amplifiers and all the associated components. These 15 to 19 extra parts could cost you from $15 to over $60, not to mention your assembly and test time. And, you have to use a lot of PC board real estate for each converter you use in your system.

Take heart! Our new DAC80 Series IC 12-bit D/A converter is designed to solve your problems. It has its own built-in reference and output amplifiers, and it takes only three passive components to decouple the power supply. If you want to trim the offset and gain, you'll need only five more. At most, these parts will cost you about $4, and your assembly and test time will be minimal. Not only does our $39 price in 100's match the lowest around, but DAC80's are more complete, easier to use, and take up less total space.

Hermetically sealed in a compact 24-pin dual-in-line ceramic package, the DAC80 is laser trimmed to a maximum linearity error of ±0.012% (±12 LSB) over a 0° to +70°C operating temperature range. Its maximum gain drift is ±30 ppm/°C and monotonicity is guaranteed over the full temperature range. The DAC80 is offered with a choice of DTL/TTL compatible complementary 12-bit binary, or 3-digit BCD input codes. Our voltage output models provide user selectable ranges of ±2.5, ±5.0, ±10.0 to +5.0, and 0 to +10 volts, and the current output models provide ranges of ±1mA or ±2mA. And, for a 10 volt step change, voltage models settle to ±0.01% in just 3 microseconds, while the current models take only 300 nanoseconds.

If you'd like to take a closer look at the DAC80, just give us a call. We've got yours right on the shelf. Burr-Brown, International Airport Industrial Park, Tucson, Arizona 85715. Telephone: (602) 294-1431.

Our tiny IC 12-Bit D/A Converter is $39 in 100's, too.

But, ours doesn't need an external reference or output amplifier.

The DAC80... Another exceptional D/A converter from Burr-Brown
Laser-computer system rejects defective POS codes at the press

Those little black lines on your packages at the grocery store are telling the laser at the cash register what you've bought, and a point-of-sale computer is filling in the price. But if those lines are not printed right—too far apart, too wide, or too narrow—the checkout operation grinds to a halt. And the POS system is supposed to speed it up.

A solution is at hand. A laser-based computer system called Monitor 101 has been developed that can analyze Universal Product Code (UPC) symbols at tremendous speeds before they get to the store. It will do it as soon as the imprinted boxes or labels leave the press. The system was developed and built by Metrologic Instruments, Inc., Bellmawr, NJ, in cooperation with Surescan, Inc., Westville, NJ, which will market it.

"The system simply represents advanced laser-scanner technology applied to UPC symbol printing," says Metrologic's president, C. Harry Knowles.

The design consists of three parts: laser scanner head, detector head and computer. Each part is modular, flexible and programmable, which, Knowles says, makes them adaptable to a variety of totally different tasks—"such as case control in warehouses, parts positioning and carton identification."

The Monitor 101 has been designed not only to identify a good or bad UPC symbol on each printed item, but also to record the total number of packages being printed for purposes of inventory control.

The scanner also verifies line resolution and compares the measured line width with automatically computed UPC line-width tolerances. The unit measures ink density and background "whiteness" and computes the print-contrast ratio.

Even while the press is operating, Monitor 101 is computing the number of good labels. It then displays the percentage of good labels based upon the last 1000 packages run.

The labels are compared with a reference standard issued to individual manufacturers by the Uniform Product Code Council. In addition the scanner checks each label for UPC parity coding.

What the hardware is like

The print scanner consists of two electromechanical components: an aluminum-encased scanner, which can be mounted on any printing press, and its computer counterpart, which is installed alongside the press or in a remote-control room.

As the printed item leaves the final-impression cylinder and heads for the drying section of the press, a laser beam scans across each newly printed UPC symbol several times at 50,000 feet per minute. In combination with the scanning laser light, the UPC symbol generates a pattern of reflected light, which strikes a photomultiplier tube and is converted into a digital output.

At the same time the scanner's head measures line-width directly in thousandths of an inch. Press operators can monitor this function to adjust their press for cylinder impression and ink quantity. Pushbutton switches on the Monitor 101's control panel allow the setting of upper and lower limits of UPC line-width acceptability.

Encoded lines can be measured directly or as a percentage of the standard number. Indicator lights
He just completed half a day's testing before his morning coffee break.

The secret? His new 3312A Function Generator—the new-generation source that's actually two function generators in one box. It took the hassle out of his input-signal set-ups. He simply pushed a few buttons and had the functions he needed. No custom equipment...or a kludge of instruments to get a complex waveform.

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*Domestic USA price only.

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Electronics Design 8, April 12, 1975
Need an ‘invisible’ vhf antenna in a vehicle? Open the door a bit

How can the police or the military conduct secret vhf communications from a vehicle without advertising the fact by using a whip antenna?

The answer, according to Dr. Kurty Ikrath, an Army research physicist and specialist in antennas that don’t look like antennas, is to leave the rear door of the vehicle slightly ajar, thus forming a slot antenna.

The biggest problem, Ikrath points out, is in coupling energy so the vehicle is an efficient radiator of vhf energy. The use of hybrid electromagnetic antenna couplers (HEMACs) is promising, he says (see “It’s a Tree . . . a Pole . . . a Man; No! a Short-Range Antenna,” ED No. 26, Dec. 20, 1973, p. 52), but this approach also has problems.

Tests of HEMACs have been made on vehicles equipped with the Army’s PRC-25 and VC-12 vhf transceivers. The couplers proved to have matching problems.

The door-slot antenna, besides having simplicity of design, has relatively good tuning characteristics, Ikrath says. Powered by a VC-12 transmitter, the antenna has been tested and found effective within a seven-mile range. And the installation of this antenna on metal trucks appears to be relatively simple.

At medium and high-frequency bands, a vehicle or a helicopter can be used as a large radio antenna rather than as a counterpoise for a conventional whip antenna, Ikrath says. This is done by coupling with HEMACs to produce suitable rf surface current distribution.

These couplers worked well at medium and high frequencies because the dimensions of the vehicle were small compared with a wavelength. However, at vhf frequencies between 30 and 80 MHz the problem is complicated, because the vehicle dimensions are close enough to the wavelength to make placement of nonconventional antennas critical.

Because of HEMAC coupling problems in the vhf region, the door-slot approach was tried, Ikrath explains. The dimensions of three sides of a metal body on the rear of a 3/4-ton truck were on the order of one-half the wavelength at 60 MHz, he says.

Initial efforts involved the use of a 2-to-5-cm slot in the door frame, in the form of a tapered gap between the frame and the slightly opened door. To test this concept, Ikrath reports, two holes were drilled at the center of the vertical edge of the open door and the door jamb, and terminals were implanted.

Impedance measurements made from outside the truck with the tailgate down revealed a resonance at 44 MHz with an impedance of 400 Ω. Because of the relatively high impedance—50 Ω was desirable—two additional terminal holes were drilled some 37 cm above the center terminal. A tuned circuit laced across these upper terminals aided in optimum matching, while the signal was fed into the two center terminals. A third set of terminals, 37 cm below the center, were tuned to provide best performance.

The experiments with this setup resulted in discovery that the signal strength improved appreciably when the tailgate of the truck was raised. In a voice communications test the door-slot antenna of the truck was fed with the output of a VRC-12 transmitter, with low power of 2 to 3 W and high power of 25 to 30 W at 49.9 MHz.

Communication with a local receiving station that had a vhf antenna on the roof was effective for seven miles, Ikrath notes.
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INFORMATION RETRIEVAL NUMBER 24
Small $10 magnetometer reported a rival of bulky kilo-buck units

An alkali-vapor magnetometer, pocket-sized and costing about $10, is reported to be as sensitive as bulky vapor units costing thousands of dollars in locating oil fields, mineral deposits and archeological treasures.

Developed by researchers at the Columbia University Radiation Laboratory, the new magnetometer operates on a variation of the principle used in costly alkali-vapor magnetometers that respond to a magnetic field by measuring the rotation of atomic particles. Whereas previous designs have used low-density metal vapors to provide a readily measurable indication, the Columbia model uses vapor under high pressure—a feat heretofore thought impossible.

Prof. William Happer, inventor of the device, explains that the magnetically induced rotation of atoms in vapor magnetometers is measured when light is passed from a laser or vapor lamp through a cell containing that same vapor under low pressure. The vapor cell is excited with rf on the order of 122 kHz per gauss.

Absorption of light takes place in the cell at a frequency that is dependent on both the strength of the magnetic field and the frequency of the applied rf field. This decrease in light output is measured by photomultiplier tubes in conventional equipment and by a silicon photosensor in Professor Happer's design.

Components of the mini-magnetometer, held by the inventor, are compared with present bulky units.

Fields measured to .01 gamma

Present costly vapor magnetometers, used for aerial surveys, measure fields down to 0.01 gamma. (The earth's field ranges from 25 to 70,000 gamma.) Happer predicts that his magnetometer will be as sensitive.

In previous experiments with low-pressure vapor cells, an increase in the pressure of an order of magnitude or so has increased random electron collisions and created system noise that masked the measurement.

But Happer discovered that by increasing cell pressure from about $10^{-6}$ Torr to 10 Torr—an increase of $10^{11}$—the atomic collisions tend to average out, and a sharp resonance point proportional to the external magnetic field reappears.

Using a tiny, capillary tube filled with cesium under the high pressure, as well as a gallium-arsenide laser for the optical source and a silicon photocell for the output, Happer miniaturized the system. The critical element can be contained in a package the size of a ballpoint pen. A transistor oscillator provides the rf energy.

The development, funded by grants from the military's Joint Services Electronics Program and the Air Force Office of Scientific Research is still in the laboratory stage. But Happer says that his magnetometer has been demonstrated feasible in the laboratory.

"We have successfully pumped very small samples with cw gallium-arsenide lasers," he reports. "Eventually we hope to have a device which consists of a gallium-arsenide pumping laser and a capillary absorption cell. This combination should be very cheap and should lend itself to mass production."

A tiny cell with high-pressure cesium vapor is the key component of the alkali-vapor miniature magnetometer. Optical absorption by the cell is produced by a magnetic field and rf excitation.
Noise at the front-end of an otherwise tight low frequency design is terribly frustrating. And we don't blame you for sounding off if you want to specify for lower noise and can't come up with an FET to suit your purpose.

Crystalonics' new 2N6550 is a silicon, N-Channel, junction FET designed for low frequency amplifier applications, with an ultra low noise figure of 2n V/√Hz at 1KHz. You won't find one quieter! This device is designed to produce the cleanest signal possible at the front-end, for pure follow-through and ultimate signal clarity, so critical to military field communications. It's as silent as current technology allows, and with Crystalonics' 2N6550, you'll note a marked improvement in your prototype.

Crystalonics has been in the business of helping to solve designers' problems for over a decade. While other companies have abandoned military applications and opted for the production of commercial standards, we've stuck by our trade: high quality, innovative production with the designer in mind. Direct communication between the designer and our applications engineers is our mark.

We're at your elbow to ease your design.

Send for our new condensed catalog of Junction FETs, Fotofets, and Low Level Bipolars, including the 2N6550 at $15, 1-99; $10, 100-999. Samples on request. Or for immediate design assistance, give us a call. Ask for Jack Senoski, Art Pauk or Richard Antalik, of our applications engineering squad.

Crystalonics. We listen.

Give us a little of your noise
the power supply consists of three silver-zinc batteries.

A frequency band of 450 to 500 MHz is being used for the alarm transmissions. An 8-digit (32-bit) BCD code is transmitted 15 times in 1 s. Then there is a 30-s delay and the code is retransmitted 15 more times. About 1/100 mW of power is transmitted.

The bandwidth of the FM transmission is about 1 MHz, and the estimated range is about 50 ft. The batteries should last at least a year. All timing and coding circuitry is on a hybrid ceramic substrate.

In the receiver, a small processor makes a majority decision on the identity of the code, to eliminate errors caused by noise or RFI. Then a location code is added. The result is transmitted on electric power lines on a 350-kHz carrier to the central dispatcher. The central dispatcher, a microcomputer, then analyzes the received data, searches its data banks for related information about the victim, decides on the action and notifies the correct agency over a dedicated communication link.

Some problems

"We don't yet have enough information about the effects of the human body on antennas that are worn close to the skin," Shollenberger notes. "In the current system the capacitance of the body causes about a 10-MHz frequency shift. We also have a 2-s delay built in after the button is pushed, to allow the hand to be moved away from the antenna."

Another problem is variable range, affected by such local conditions as tall buildings and vehicular traffic.

Other problems center on locating a signal in a high-rise apartment complex, preventing misuse by children and guarding against criminal use of the alarm as a decoy. In addition the best method has not yet been selected for differentiating between different types of emergencies.

The Federal agency is looking to private industry to help in developing the system. Shollenberger says: "We are interested in helping private, profit-making organizations get involved in this concept."

Satellite altimeter to measure wave heights to 10% accuracy

When NASA launches Seasat in 1978, the satellite is to be capable of measuring wave height in the oceans to an accuracy of ±10%. In addition it will measure mean sea level and ocean radar backscatter coefficients (the variances in radar waves reflected back from the ocean). A radar altimeter linked to a minicomputer will make it possible to get such accuracy.

The prototype of the altimeter is undergoing system tests. It is designed to fly on a C-54 test aircraft, and the initial accuracy goal is modest: wave-height accuracy of only ±25%.

Developed by Hughes Aircraft Co. in Fullerton, CA, the altimeter uses a chirp-pulse technique. According to Richard Sidlo, program manager at Hughes: "We transmit a 3-μs pulse containing a chirped signal centered on 13.9 GHz. The chirped signal varies in frequency over a 360-MHz band."

The pulse hits the ocean surface and bounces back to the altimeter. Waves stretch the time duration of the return pulse. The pulse-stretching must be measured accurately to determine wave height. This is done by correlating the position of the frequencies in the return pulse with those in the transmitted pulse.

When the pulse is received at the altimeter, it goes through a triple conversion mixer with an output of 1.08 GHz. At this point, it is compared with a sample of the transmitted pulse that has also been converted to the 1.08-GHz range. The output of this correlator is a square pulse in time containing a signal that is the beat frequency correlation of the two chirped signals.

On to the range bin

Sidlo explains that this pulse of rf goes to a continuous filter bank, which contains 24 filters, each of 330-kHz bandwidth. These are the range-bin filters. Each corresponds to a discrete step of altitude. To keep track of this pulse of rf with a minicomputer, an additional pair of filters are used. They are known as early-gate and late-gate filters.

The early-gate filter tracks the leading edge of the pulse, and the late-gate filter serves as a reference toward the rear of the pulse. The early-gate filter is tuned by the minicomputer to the half-power point of the leading edge of the pulse.

A 12-bit analog-to-digital converter takes the outputs of the early-gate, late-gate and range-bin filters and sends the digital outputs to a multiplexer. The multiplexed signals go directly to the minicomputer.

The minicomputer is programmed to tune and adjust the tracking filters and do real-time analysis of such information as wave height and ocean backscatter. In addition, on the C-54, it will control the real-time display of these parameters.

Only a small horn antenna is needed on the C-54, while a 1-m reflector will be needed on the satellite. Peak power of the breadboard prototype is 1 W. On the satellite, 2400 W will be transmitted.

The antenna beamwidth will be 1.5° on the satellite.
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INFORMATION RETRIEVAL NUMBER 22
U.S. seeking a wrist transmitter for citizen use in emergencies

A wrist-mounted alarm for use by citizens is being investigated by the Law Enforcement Assistance Administration in Washington, DC.

If you were the victim of a crime, a push on the button of the alarm would summon the police. If your emergency were medical, it could call the first aid squad. Or if your house was on fire, it could bring the fire company to the scene.

"We are in the earliest stages of system concept and prototype development," says George Shollenberger, manager of development at the Law Enforcement Assistance Administration. Hardware is being built to test the concept and to see what the most serious problems are.

"We know that there will be many bugs in the system," Shollenberger concedes. "The current system engineering is being done by Aerospace Corp., El Segundo, CA, and the prototype hardware is being built by Compu­Guard, Pittsburgh.

Location a problem

The problem most open for alternate approaches is how to pinpoint the victim's location. An approach under consideration now is that of a grid system of receivers. When the alarm button is pushed, a coded signal is transmitted. The receiver or receivers that pick up the signal on a grid would locate the alarm to within the spacing of the receivers. Thus, if the receivers were spaced every hundred feet and the range of the trans­mitter was 50 ft, location of the alarm would be to within 50 ft of the receiver detecting the signal. If more than one receiver picked it up, the location could be more closely determined by triangulation.

How it works

There are three parts to the system, as now conceived: the alarm actuator, the receiver and the central dispatcher.

The actuator sends a coded signal to the receiver. The receiver adds a location code and sends the signal on to the central dispatcher. Finally the nature of the emergency is determined and the proper emergency service is dispatched.

The alarm actuator is mounted in a wristwatch case. It contains an oscillator, an antenna, a power supply and some timing and coding circuitry. The antenna is a 1-1/4-in. loop. Timing and coding circuitry is standard CMOS, and

(continued on p. 28)
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<table>
<thead>
<tr>
<th>Annuals Consulted Within Past Month</th>
<th>Annuals Preferred</th>
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<tbody>
<tr>
<td>Electronic Design's GOLD BOOK</td>
<td>85%</td>
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<tr>
<td>Electronic Engineer Master (EEM)</td>
<td>63%</td>
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<tr>
<td>Electronic Buyer's Guide (EBG)</td>
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<tr>
<td>Thomas Register</td>
<td>16%</td>
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<tr>
<td>Conover-Mast Purchasing Directory</td>
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</table>

SOURCE: Study by Dr. Eugene D. Jaffe, Associate Professor of Marketing, St. John's University, Nov. 1974. Base: respondents using directories. Totals exceed 100% due to multiple mentions.

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<tr>
<th>COMPARISON OF ELECTRONICS INDUSTRY DIRECTORIES (1974-75 editions)</th>
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<tr>
<td><strong>EBG ELECTRONICS BUYERS' GUIDE</strong></td>
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<td>Number of manufacturers listed</td>
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<td>Number of cross-reference products listed</td>
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<td>Number of distributors listed in Distributors Directory — Alphabetic</td>
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<td>Number of distributors listed in Distributors Directory — Geographic</td>
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<td>Does manufacturers listing include facsimile equipment by make and call number?</td>
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<td>Total Circulation</td>
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<td>Overseas Circulation</td>
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<td>Number of ad pages</td>
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</table>

| **EEM ELECTRONIC ENGINEERS MASTER**                            |
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| Total number of products listed                               | 3,235 |
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| Number of distributors listed in Distributors Directory — Geographic | 1,720 |
| Is complete mailing address given each time a company is listed in product directory? | No |
| Is telephone number given for each company listed in product directory? | No |
| Are distributors listed for each manufacturer?                 | No |
| Does manufacturers listing include FSCM numbers?               | No |
| Does manufacturers listing include facsimile equipment by make and call number? | No |
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| Overseas Circulation                                           | 0 |
| Number of ad pages                                             | 2,752 |

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| Number of direct products listed                              | 2,925 |
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| Number of distributors listed in Distributors Directory — Alphabetic | 5,780 |
| Number of distributors listed in Distributors Directory — Geographic | 5,780 |
| Is complete mailing address given each time a company is listed in product directory? | Yes |
| Is telephone number given for each company listed in product directory? | Yes |
| Are distributors listed for each manufacturer?                 | Yes |
| Does manufacturers listing include FSCM numbers?               | Yes |
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<tr>
<td>TMS4050NL</td>
<td>$19.64</td>
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<tr>
<td>TMS4050-2NL</td>
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<td>TMS4050JL</td>
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<td>TMS4050-1JL</td>
<td>$25.07</td>
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<tr>
<td>TMS4050-2JL</td>
<td>$28.56</td>
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</table>

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INFORMATION RETRIEVAL NUMBER 18

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Too often it's like seeding a lawn. We throw some seed at the earth and hope that it comes up as grass. We tend to assume that if we throw enough seed at the earth, we will get something that looks like a lawn. When seed is cheap, that may not be a bad way to grow a lawn. But R&D is not cheap. It costs a great deal of money to employ good researchers and development engineers.

Though there's never a guarantee that your research will bear fruit, you can dramatically improve the odds if you keep corporate policy concerning it flexible.

Much depends on R&D in our business. Plessey is an international billion-dollar company, acknowledged as a world leader in communications and electronics. We apply high-technology to all forms of information handling. Our current expenditure for R&D is $96 million per year—and it is increasing steadily. But we watch the return on our R&D investment. At 10 per cent of sales, this represents a substantial investment and insurance for the future growth of Plessey.

How does a company like Plessey make R&D pay off? First—let's see how other companies handle R&D.

Research and development labs in most companies are funded by corporate management. The lab manager often arbitrarily decides which of several projects he'd like his staff to work on. If his research later suggests that a project may have commercial possibilities, the project at some stage or another is turned over to another group for commercial exploitation. Usually, however, the main benefit derived from research is that it allows someone to present a paper to some learned society. That's not much of a payoff.

A policy of persuasion

At Plessey, we decided that all of our research and development lab managers must persuade someone to give them money before a project is started. Put simply—we want our researchers to sell their efforts. They have to pull themselves away from the blue sky and sell their concepts to potential customers. They have four sources of funds. They can:

- Persuade the Government to sponsor a project. Come up with a new idea for handling mail, for example, and get the Government to pay for the R&D on it.
- Persuade one of the "businesses" in the company to fund them—businesses like semiconductors, capacitors, memories, hydraulics and telecommunications. They might offer, for example, the possibility of a new component, or a new technique for making something better or cheaper, or new technology that might boost the performance of older products.
- Conduct research that's not covered by an existing business. In that case, they'll have to persuade the 12 people who administer the corporate fund. Perhaps they'll create a product that necessitates the creation of a whole new division.
- Dip into a small fund that's available for "crazy ideas." We try to guard against the immediate rejection of wild whims. In fact we want to encourage them to some extent. So each lab has some "crazy money" for offbeat projects. It's not a great deal of money, but it's enough to enable somebody to fool around with something for a few months. If the idea doesn't work out, it can be dropped without embarrassment. But if it does show promise, the lab manager can then try to persuade one of the three customers I've mentioned to sponsor it. But then he'll have some evidence to support his hunches.

Probably the most vexing aspect of R&D is that you have to nurse it for a long time before it pays off. If you send a brand new baby prod-


ELECTRONIC DESIGN 8, April 12, 1975
Sir John Clark is Chairman and Chief Executive of The Plessey Company Limited. He was knighted in 1971 for export services. Of special interest to American readers is that Sir John, whose father was an American citizen before becoming a naturalized British subject in 1927, is a member of the Sons of the Revolution. The aims of this society include perpetuation of the memory of men who “in military, naval or civil service, by their acts or council, achieved American Independence.”

Sir John, who is 49, was previously Deputy Chairman and Managing Director of Plessey until appointed Chairman in November, 1970 in succession to Lord Harding. He is President of the Telecommunication Engineering and Manufacturing Association, an office he also held in 1965-66.

And he is one of two Plessey representatives on the Board of International Computers (Holdings) Limited, the British computer company formed jointly by ICT, English Electric Computers, Plessey and the then Ministry of Technology in 1968. ICL is the largest company outside the USA specializing in commercial and scientific computers.

Sir John is Vice President of the Engineering Employers’ Federation, Fellow of the Institute of Management, Companion of the Institution of Electrical Engineers, Vice President of the Institution of Works Managers and a member of the National Defence Industries Council.

Educated at Harrow and Cambridge, Sir John saw service with the Royal Naval Volunteer Reserves during WW II. After demobilization he received his early industrial training with Metropolitan Vickers and the Ford Motor Company and then spent a year in the USA studying the American electronics industry.

In 1962 Sir John was appointed Managing Director of Plessey, which by then included Garrard Engineering Limited and two telephone companies—Automatic Telephone and Electric Company Limited and Ericsson Telephone Limited.

In April, 1973, he was invested with the Order of Henry the Navigator (Infante de Henrique) by the President of Portugal.

His principal recreations are shooting and golf. He’s a qualified helicopter pilot and often flies himself on business.

Too often, we keep our engineers in boxes. We have an engineer, call him Charlie, involved in research, and he stays in the lab and never leaves. Many times it happens that Charlie develops a product, and somebody decides that Division X would be best equipped to manufacture and sell the product. So Charlie, back at the lab, says goodbye to his “baby” and Harry at Division X is given responsibility for the new product.

Well, Harry had been pretty busy on his own...
project and he wasn't overly fond of this new thing anyway, so he's going to spend most of his effort on the products he knows better. And if something goes wrong with the new product, well, heck, he knew all along it wasn't that good. He could have told the brass in the first place that it didn't have much future.

But if Charlie were there, he might recognize that a minor change could fix the product. "Oh," he might say, "you like 5-volts output instead of 12-volts output? No sweat. That's easy." Charlie has an emotional stake in the product. He wants to make it work. He wants to make it succeed—just as all of us want our babies to grow up strong and healthy.

So we decided to let Charlie stay with his "baby," instead of sending it to a division as an orphan. When his product is sufficiently mature to be taken to the marketplace, we let Charlie do it. He controls his own purchasing, his own production, his own marketing, sales and distribution. He leaves the lab to run this new business.

Sometimes he comes back to the lab after his business fails to make money. He returns sadder and wiser, and this helps prevent the growth of intellectual arrogance in the lab.

And sometimes he comes back to the lab after several years of success with a new business because he has the creative itch again. He wants to develop something new.

But sometimes he stays out there with his new business and the business flourishes. In the case of one product that came out of the lab—with its "father"—we're now doing about $4 million a year and enjoying a 60% annual growth.

In most cases, the challenge in handling these new products as separate financial units is in knowing how long to keep them as parts of a new business and when to assimilate them into an existing division—if at all.

Notice that we have people flowing out of the R&D labs (and sometimes back into it). This movement is good because it pumps new blood into projects. It creates vacancies for new people, about 80% of whom are recent college graduates. We really don't want the R&D lab to expand. If we didn't contain its size, ideas would grow stagnant and people would not produce enough good products to justify the lab's existence. The average age for the R&D engineer is about 32. Most of them peak, creatively, at about 30.

Boards help 'spring' new products

Now there's another aspect of managing R&D, especially in a large corporation. How do you make sure it's flowing smoothly? And how do you make sure that different groups are not duplicating each other?

We found the solution in "product boards," organizations designed specifically to deal with product development. The product boards are charged, among other things, with learning about and nursing promising new products. They are specifically prohibited from worrying about day-to-day management problems. They don't worry about last month's bookings or snags in the production line. They push for tomorrow's products.

In essence the role of the product boards is to bring top management into the labs so that top-management decisions can be made quickly.

Four years ago we looked at our management organization and found that, like many other large companies, we had too much weight in staff positions relative to line positions. We had an overconcentration of management in the center, rather than in the wings, to the detriment of efficiency on the line, where the money is made. At headquarters, there's too much of a tendency for people to spin their wheels and play politics.

On the other side of this coin, we found that, back at the labs, people can't get decisions quickly enough from top management. So we decided to bring top management to these people by means of product boards.

We have 10 of these boards, each containing six to 10 individuals. Each board includes Plessey's Managing Director and Director of Finance. In addition, each has a division's manufacturing director and several engineers selected from that division.

Since several people on each board travel from division to division, boards can quickly spot duplication of effort and possibilities for synergy. They might find, for example, that two divisions in different parts of the world are working on identical research. They might then decide to redirect one project or, perhaps, to allow both to continue. Or they might find that one group, say, semiconductors, is developing a product that can prove extremely valuable to another, say, communications.

The real key to making R&D pay off is to make Charlie, the developer of a product, also responsible for it. Give him an emotional stake. That means getting him to persuade someone else to sponsor the product, and getting him to nurse the product along personally by controlling its business.

And when you have a number of Charlies involved, make sure you don't rob them of the authority it takes to do their job. Bring Mohammed to the mountain. Make quick top-management decisions available in the labs.
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“Extra Margin” Fast Switching Power Transistors.

If you're chopping line voltages at 20 KHz or inverting and stepping down at high frequency, you should consider IR's two new families of fast switching, glass passivated power transistors. They can mean better reliability and lower cost in line operated power supplies.

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High Second Breakdown — High Reliability...adds to our broad safe-operating area for an extra margin of safety.

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<th>VCEO (max) V</th>
<th>IC Peak (A)</th>
<th>NF (min,max)</th>
<th>VCE (sat) (max) V</th>
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INFORMATION RETRIEVAL NUMBER 41

Electronic Design 8, April 12, 1975
Intersil's IM6508 1024 bit CMOS RAM.

With the best speed/power product you can buy.

The world's first 1024x1 static CMOS RAM.

We've been producing and delivering the IM6508 for six months now, in industrial (-40°C to +85°C) and military (-55°C to +125°C) versions. Check the specs and you'll get as excited about it as we are:

Power is only 5μW total in standby, 10mW at 1MHz. Typical access speed at 5 volts Vcc is 200nS. And the price is right. At 100+ quantities the industrial version is $28, the military is $70.

It has TTL-compatible inputs and outputs, works directly with bus-oriented microprocessors without additional power supplies or interfaces. It's a pin-for-pin replacement for existing RAMs such as the IM5508 and the 93415.

It has on-chip address registers controlled by the chip-enable line, and is packaged in a 16 pin DIP. A variation, the IM6518, comes in an 18 pin DIP and has three chip enables—two for write-enable and output buffering and one for address registers.
The IM6508-1: Supply current 10μA.

Now it really gets interesting. While the IM6508 has an $I_{cc}$ of 100μA, we deliver a "dash-one" version that requires one-tenth that much — that is, 10μA $I_{cc}$. It also has significantly faster access, as shown in this speed/voltage graph comparing the IM6508 and IM6508-1 across their 4- to 7-volt supply voltage range.

Or the IM6508A: Access time below 100nS.

There's more. In addition to the above, we also are delivering the IM6508A, which operates at supply voltages up to 11 volts. At that voltage, its access time is speeded up to 150nS.

And to really blow your mind, there's the IM6508A-1. You guessed it: it not only has an $I_{cc}$ of 10μA, its access time drops down below 100nS. This graph compares access times for both versions (standard and -1) of the IM6508A across the supply voltage range.

Not to mention the i38510/IM6508.

We also sell a military high-rel version made with MIL-M-38510A processing and MIL-STD-883 test methods, with electrical test conditions and limits guaranteed to Intersil's i38510 in-house program specifications. Every such device is analyzed by scanning electron microscope, marked with its wafer-lot number for traceability, and delivered from bonded inventory.

From the world leader in CMOS memory.

Surprised? Intersil delivers more CMOS memory product than anyone. And our family of CMOS silicon-gate RAMs will soon be joined by the first CMOS ROMs, microprocessors and I/O circuitry... making us the first all-CMOS system components manufacturer. Intersil, 10900 North Tantau Ave., Cupertino, CA 95014.
Squaring circuit generates second harmonic for controlled-distortion test signal

To introduce controlled second-harmonic distortion into a test signal, use a four-quadrant linear multiplier to square the input test signal and produce a doubled frequency term. The dc component also produced is balanced out with output-offset control \( Z \) after the second-harmonic frequency is adjusted with controls \( X \) and \( Y \) for best sine-wave output from \( A_1 \).

The diode wave-shaping networks usually used for generating second-harmonic distorted signals are generally limited to fixed signal amplitudes with fixed distortion. By contrast, the squaring circuit produces almost any desired amount of distortion, and it operates over a wide amplitude range.

A 5558 dual op amp amplifies and sums the original input with the selected level of second-harmonic distortion. The \( Z \) offset control is adjusted so the signal at the output of \( A_1 \) is symmetrical with respect to ground. Finally, attenuator \( K \) adjusts the relative amount of second-harmonic to fundamental to determine the percentage of harmonic distortion at the output of \( A_2 \).

Arthur B. Williams, Manager, Analog Development, Coherent Communications Systems Corp., 85 D Hoffman Lane South, Central Islip, NY 11722.

CIRCLE NO. 311

To control the ratio of second harmonic to fundamental, control \( K \) is varied. Controls \( X \) and \( Y \) adjust the purity of the second-harmonic input to amplifier \( A_1 \).
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ELECTRONIC DESIGN 8, April 12, 1975
Circuit converts single-trace scope to dual-trace display for logic signals

The circuit shown enables the display of two digital pulse trains on a single-trace scope. A dual display is almost essential in the diagnosis of logic-circuit problems.

The circuit can be understood more easily with the help of a simplified diagram (Fig. 1). Gates G1, G2, and G3 are open-collector AND gates. The collectors of these gates are connected to 5, 10 and 15 V, respectively, via separate pull-up resistors. Three diodes and resistor Rf form a triple-input OR gate. The binary output levels of the OR gate are approximately zero to 5, 10 or 15 V, as determined by the particular AND gate that is ON. Gates G2 and G3 are switched alternately by the complementary outputs of the flip-flop. The rate of switching depends on the clock frequency. And the resolution of the display improves with a fast clock. But the upper clock frequency is limited by the circuit components and the scope bandwidth characteristics.

When both input A and B are at ZERO, only gate G2 switches ON and OFF, and a square wave of approximately 10-V pk-pk amplitude appears at the output. The zero level of this square wave becomes the zero level for input A, and the 10-V level becomes the zero level for input B. When input A is a logic ONE, approximately 5 V appears at the output. A logic ONE at input B produces a 15-V level at the output. Thus digital signals at input A are displayed between zero and 5 V, and signals at input B are displayed between 10 and 15 V.

In the actual circuit (Fig. 2), two 2N2924 emitter followers at inputs A and B reduce the load on the circuits under test. Three 1N914 diodes form a triple-input OR gate. Timer 555 generates a 50%-duty-cycle square wave with about a 2-µs pulse width. Open-collector 7405 hex inverters complement the output of the timer and drive the diodes.

Vijay B. Tandon, Electro-Mechanical Designer, American Foundation for the Blind, 15 W. 16th St., New York, NY 10011.

CIRCLE No. 312

1. A simplified electronic-switch circuit helps to explain how two digital signals can be viewed simultaneously on a single-trace scope.

2. The switching rate is controlled by a 555 timer, which supplies a 2-µs width square wave.
After all the noise, the quiet logic of HiNIL and 74C CMOS keeps you on the right track.

May 10, 1869. Promontory, Utah. The rumble of wheels, the hiss of escaping steam, the shouts of the celebrating crowd filled the skies with a deafening roar when they drove the golden spike that joined the Central Pacific and Union Pacific Railroads.

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Just put HiNIL on input-output lines to block heavy noise transients and drive high current peripheral devices. And use CMOS in the middle to minimize power dissipation and increase speed and circuit density. The combination of HiNIL's guaranteed 3.5V noise margin and 74C's low power dissipation lets them quiet almost any kind of system with high noise problems.

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Additional offices in West Germany, Hong Kong and the United States. Representatives and distributors worldwide.
Calculate capacitor tap impedance with correct expression and avoid errors

The relationship frequently used in calculating capacitor-tap impedance-matching networks,

\[ R' = R \left( \frac{C_1 + C_2}{C_1} \right)^2, \]  

is only an approximation and often leads to large errors. The correct expression is

\[ R' = \frac{(X_{C1})^2}{R} + R \left( \frac{C_1 + C_2}{C_1} \right)^2. \]  

The often-omitted term, \((X_{C1})^2/R\), can be extremely significant for such commonly used values of R as 50 Ω. For example, let’s transform a 50-Ω source impedance to 2500 Ω to establish the proper loaded Q for a 20-MHz tank circuit that contains a coil of 2 µH. The approximate expression yields

\[ 2500 = 50 \left( \frac{C_1 + C_2}{C_1} \right)^2, \]

At resonance

\[ f_0 = \frac{1}{2\pi\sqrt{LC_T}}, \]

\[ C_T = \frac{1}{(2\pi f_0)^2 L}, \]

\[ C_T = 31.69 \text{ pF} \approx \frac{C_1 C_2}{C_1 + C_2} \]

\[ \cdot \frac{31.69 C_1 + 31.69 (6.07C_1)}{C_1 + C_2} \]

\[ C_1 = 36.91 \text{ pF} \]

\[ C_2 = 224 \text{ pF}. \]

But these values for \(C_1\) and \(C_2\) produce an error of approximately 40%. A more exact calculation, by use of Eq. 2, yields

\[ R' = \frac{(X_{C1})^2}{50} + 50 \left( \frac{C_1 + C_2}{C_1} \right)^2 \]

\[ R' = 930.6 + 2500 = 3430.6 \text{ Ω}. \]

The error is even more pronounced if the value \(C_1\) incorporates capacitors other than \(C_1\) and \(C_2\), such as a trimmer, a voltage-variable capacitor or just stray capacitance. Suppose the extra capacitance is such that the contribution from \(C_1\) and \(C_2\) is only 20 pF rather than 31.69 pF. Then

\[ C_1 = \frac{20 + 20(6.07)}{6.07} = 23.3 \text{ pF} \]

and \(C_2 = 141.4 \text{ pF}.\)

These values of \(C_1\) and \(C_2\) in Eq. 2 make \(R' = 4884 \text{ Ω—an error of over 90%}. \)


SEND US YOUR IDEAS FOR DESIGN. You may win a grand total of $1050 (cash)! Here’s how. Submit your IFD describing a new or important circuit or design technique, the clever use of a new component or test equipment, packaging tips, cost-saving ideas to our Ideas for Design editor. Ideas can only be considered for publication if they are submitted exclusively to ELECTRONIC DESIGN. You will receive $20 for each published idea, $30 more if it is voted best of issue by our readers. The best-of-issue winners become eligible for the Idea of the Year award of $1000.

IFD Winner of December 6, 1974

Nyle A. Steiner, 334 “L” St., Salt Lake City, UT 84103. His idea “Voltage-Tunable Active Filter Features Low, High and Bandpass Modes” has been voted the most valuable of Issue Award.

Vote for the Best Idea in this issue by circling the number of your selection on the Information Retrieval Card at the back of this issue.

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We're adding more and more models to the RESNET™ DIP resistor line to make things easier for you.

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Beckman® HELIPOT DIVISION
The varactor-diode tuning range of a Gunn oscillator has been almost doubled at Chelsea College, London, through use of reactance-compensation elements that can be added to or removed from the oscillator without disturbing it electrically or mechanically.

An X-band coaxial Gunn oscillator modified by the college's Dept. of Electronics has been tuned over a range of 440 MHz, compared with 230 MHz without modification.

In the unmodified oscillator, the Gunn diode was shunted across a 50-Ω coaxial line feeding a quarter-wave 15-Ω transformer, terminated in a 50-Ω load. The tuning varactor was connected across the end of the coaxial line 1 cm from the Gunn diode.

In the modified version, reactance compensation was provided by a shunt-resonant circuit consisting of two 50-Ω coaxial lines, each terminating in a short-circuit. The two lines were connected to an additional quarter-wavelength line between the Gunn diode and the transformer. The positions of the short-circuits can be altered to adjust the Q factor of the compensating circuit without change in the resonance frequency.

At a zero-bias frequency of 8.825 GHz, the compensation extended the tuning range from 230 to 440 MHz with outputs of 78 and 64 mW, respectively.

Simple transmitter built for EEG frequencies

A simple, low-cost biotelemetry transmitter for low electroencephalograph (EEG) frequencies and neuronal spike trains has been designed at the University of Amsterdam in the Netherlands (see figure). The input stage uses a low-noise FET for high impedance. Transistor Q₁ is a 100-MHz oscillator. Radiation is emitted from tuning coil L.

Capacitor C₁, a ceramic unit, is included for fine tuning. Varactor-diode D₁ in the tank circuit frequency-modulates a 100-MHz carrier. The modulation, applied to the drain of Q₁, varies the voltage drop across R, and hence the diode bias.

Transmitter signals are picked up on a household FM receiver. Two receiver modifications are necessary. First, EEG signals must be tapped from the discriminator before the audio stage. And, second, the afe time constant must be increased by the addition of parallel capacitance in the afe line. The transmission range of the device is 30 m, but this can reach 150 m if a Yagi antenna is used with the receiver.

Microscopic materials X-rayed and magnified

Magnified X-ray pictures of microscopic samples of materials are produced by a technique developed at the University of Helsinki in Finland. No vacuum is required with this new method, which uses a series of pinholes and an electronic display.

The beam from an X-ray source is collimated as it passes through pinholes in two metal plates. A sample is mechanically scanned in the beam, using an x-y raster. Rays passing through the sample without diffraction pass through a third pinhole to an X-ray counter.

The counter output intensity modulates an oscilloscope display. Its x and y time bases are synchronized with the sample scan. The relative sizes of the oscilloscope display and the sample scanned give the required magnification. The wavelength of an X-ray beam, in the region of about 5 Å, permits pinholes down to 1-μm diam to be used without undesirable diffraction effects in the pinhole.

The technique is suitable for X-ray examination of materials that are difficult to obtain with the more usual diffraction-pattern methods. A beam collimated by pinholes can travel many meters in air, and it is expected that several practical applications will be possible.
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Think Small.
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Think our three jolly green giants for desk-top electronics. Our two pint-size pigmies for carry-in-the-pocket display designs. But don’t stop there. Think low operating voltages, low power consumption, wafer-thin thickness and dip clip pins for fast glass encapsulation all around, and efficient mounting.

Our jolly green giants

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ic = 4.5mA p-p
ib = 3.5mA p-p

FG-139A2
ec = eb = 30Vp-p
ic = 3.6mA p-p
ib = 2.8mA p-p

Our pint-size pigmies

FG-99A2
ec = eb = 24Vp-p
ic = 3.5mA p-p
ib = 2.0mA p-p

FG-125A2
ec = eb = 24Vp-p
ic = 2.0mA p-p
ib = 2.0mA p-p

FG-95A
ec = eb = 24Vp-p
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new products

32-bit mini with 1 megabyte of core cycles at 450 ns average, 300 ns min

Interdata, 2 Crescent Pl., Oceanport, NJ 07757. (201) 229-4040. $51,900: 128 kilobyte; $179,400: 1 megabyte; June.

The 32-bit Interdata 8/32 Megamini bridges the gap between sophisticated 16-bit units and medium-sized mainframes. Its four-way interleaved memory system, combined with high-speed Schottky logic and 32-bit data paths, achieves an average memory cycle time of 450 ns.

With dual-instruction, look-ahead stacks, the 32-bit memory cycle time is further improved to an average of 300 ns, assuming that most instructions occur in sequential addresses. The 32-bit architecture currently addresses up to 1 megabyte of main memory, with a potential to directly address up to 16 megabytes of main memory.

The 8/32 Megamini has eight stacks of 16 registers, with each register 32 bits wide. These stacks greatly simplify user input/output and operating system programming; they also enable rapid context switching.

The instruction word length is 16, 32 or 48 bits. Data word length is 1, 8, 16 or 32 bits, and arithmetic is two's complement. All data paths are 32 bits wide. The processor cycle time is 240 ns.

The main memory of the 8/32 Megamini consists of 32 kilobyte modules of 750-ns core. Instruction execution times are comparable to those for large mainframes, such as the IBM 370/158.

Of course, the mini does not have the 158's separate I/O computers. Instead the I/O system is of dual-bus architecture. The multiplexer bus, a man-machine channel, supports up to 1024 slow-to-medium-speed devices. High-speed links, such as disc, magnetic or multiple tape and multiple CPU configurations, use the DMA bus.

Each device on the multiplexer bus has its own firmware-imple-mented controller, which provides automatic character input/output under control of a user table without affecting the running software.

The DMA bus has three modes of operation: half-word mode of 2 megabytes per sec, full-word mode of 3.2 megabytes per sec and burst mode of 6 megabytes per sec. The DMA bus can have up to seven selector channels, with each supporting up to 16 high-speed block-transfer devices.

Two operating systems support Interdata's family of 32-bit processors. OS/32-MT is a real-time, multiprogramming, multitask OS with the ability to multiplex the CPU between several development programmers. A subset of OS/32-MT is a serial-task operating system, the OS/32-ST, which is a single-stream, batch-oriented executive.

CIRCLE NO. 303

Plug-in adds graphics output to HP-2000 minis

Intermedia Systems, 20430 Town Center Lane, Cupertino, CA 95014. (408) 986-0900. $2750; 60 days.

The Model 4416 is a single card graphics system which generates a composite video signal for display of a 256 × 256-point matrix on standard television monitors. Color and/or grey scale displays may be generated through internal synchronization with two or more generators. Refresh memory made up of 4-k RAMs permits a plotting rate in excess of 200,000 points/s. Four programmable functions provided are: set points, clear points, clear screen, and reverse video polarity. Additional software is available for character and vector generation.

CIRCLE NO. 304
DATA PROCESSING

Modem series offers 2400 bit/s, dial or lease

Vadic Corp., 505 E. Middlefield Rd., Mountain View, CA 94040. (415) 965-1620. From $800; 60 days.

Modem Models VA2405A, C and D of the VA2400 Series are designed for operation over switched networks and are fully compatible with Bell 201C configurations. Automatic dialing is available. For leased-line applications, the VA-2405G and K offer data transmission at 2400 bps over two-wire (VA2405K) or four-wire (VA-2405G) telephone circuits. Both models are available for use in point-to-point or multidrop applications. RTS/CTS delay is strapable for 7.1 ms for best throughput.

CIRCLE NO. 305

Disc-based system conserves memory use

Computer Automation, 18651 Von Karman, Irvine, CA 92664. (714) 883-8830. $29k to 40k; 90 days.

A typical Disc Operating System includes a Naked Mini LSI Type 2/20 minicomputer with 16K words of 16-bit core memory, a disc system with 4.92 Mbytes of storage, line printer, high-speed paper tape reader/punch, ASR 33 TTY, a paper tape software library and software disc cartridge. The DOS offers unattended batch processing as well as direct operator control at the console. A refined Fortran IV compiler conserves memory space by minimizing routine sizes. Compiled programs can run either under DOS or on Computer Automation's Real-Time Executive program, which occupies only 650 words of memory.

CIRCLE NO. 306

Disc memory system holds 45.9 Mwords

Data General, Route 9, Southboro, MA 01772. (617) 485-9100. See text; stock.

A moving head disc pack system has a capacity of 45.979 M, 16-bit words. The memory includes a controller for three additional disc drives and can transfer data at rates up to 403 kword/s. Features include 30-ms average access time. Only 30 s are needed to replace a disc pack while in operation. Manufactured to Data General specifications by Control Data Corp., the initial disc pack subsystem, which includes master drive and controller, costs $30,500. Additional drives each cost $24,500.

CIRCLE NO. 307

Mini type software now plays on a micro

National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. (408) 732-5000. $5500; stock.

A floppy disc operating system for the IMP-16 Microprocessor Development Systems eliminates paper tape, cards, and other source media. Source programs are written and edited at the system keyboard, then stored directly on floppy disc, using the Source Editor. The source program may then be assembled, under operating system control, with a single command. National's DOS will run on any IMP-16P or -16L Development System with 8 k or more words of memory. A dual-drive floppy disc provides over 5 M bits of storage for system software and application programs. The package price of $5500 includes the dual-drive floppy disc, documentation, software and interface.

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Three processors boost CRT terminal speed

$2255 (100 qty); 90 days.

A CRT terminal, the Model OP-1, contains three microprocessors which provide high speed input/output capabilities. The unit uses a central processor, a display microprocessor and an input/output microprocessor. With the central processor unit, the OP-1 can be programmed by the user for such typical applications as reservations, inventory, ticketing and many others. The system can also operate with various host computers. In less than 2 ms the display microprocessor can perform fast roll/scroll and full screen erase operations. Display functions such as video reversal, blinking and half intensity are program controlled. The input/output microprocessor simultaneously manages all data transfers between memory and input/output devices. All I/O operations are managed on a cycle steal basis. Additional features of the OP-1 are random access MOS memory expandable to 16,834 bytes; asynchronous, program controlled, communications up to 9600 bps; and 14-in. nonglare CRT. A programmable keyboard, arranged in four functional sections, generates unique codes to be read by the CPU.

Portable terminal operates in auto

V-71

International Computer Products, 2925 Merrell Rd., Dallas, TX 75229. (214) 350-6951. $1195 (qty); 60 to 90 days.

The V-71 transaction terminal can be vehicular mounted or portable, and operates from a 10-to-16-V power source. The unit captures data on cassette tape in computer format and saves it for later use at the computer site. Three separate entries are displayed simultaneously to minimize errors. Each cassette can hold about 6000 transactions.

Digital recorder can operate at remote sites

Techtran Industries, 580 Jefferson Rd., Rochester, NY 14623. (716) 271-7953. $760 (qty); 45 days.

A buffered digital cassette recorder, the Model 8410, provides storage for 145,000 characters per cassette; has switch selectable 110/300/1200/2400 baud speeds and allows remote control of all functions. A MOS buffer permits remote interrupt and character editing. The compact recorder can be used as an add-on storage peripheral, or as a communications terminal. It is plug-compatible with keyboard printers, CRT terminals, and other send/receive devices that have serial data interfaces. It is also capable of functioning as an unattended data collection terminal.

Additions to PDP-8/A family use core or semi

Digital recorder can operate at remote sites

Megatek, 1055 Shafer St., San Diego, CA 92106. (714) 224-2721.

A graphics display interface, designated the BP-732, is designed for Computer Automation's ALPHA-16/LSI series of minicomputers. The unit uses standard laboratory oscilloscopes or X-Y monitors as a graphics display. Self-contained semiconductor refresh memory, vector generators, and intensity control circuits provide flicker-free displays (at 50 Hz refresh rate) of points, vectors and alphanumericics. Memory may be expanded from 256 vectors/points to 1024 vectors/points. X-Y resolution is upgradable from 8 bits (±0.2% F.S.) to 10 bits (±0.05% F.S.). Prices range from $1295 for the 256 vector/point, 8 bit model to $2195 for the 1024 vector/point, 10-bit model. All models are compatible with the BP-731 X-Y Recorder Adapter for hard copy.
8-k NMOS ROMs access in 225 ns

Nitron Corp., 10420 Bubb Rd., Cupertino, CA 95014. (408) 255-7550. $18 (100); stock (NCM 6561).

A mask-programmable 8192-bit static ROM, the NCM 6560, uses NMOS fabrication to achieve typical access times of 225 ns, and 350 ns maximum. A preprogrammed version, the NCM6561, has six character conversion codes: ASCII to Hollerith, Selectric EBCDIC; Selectric to ASCII, Hollerith to ASCII and EBCDIC to ASCII. Both versions come in a 24-pin DIP, feature TTL compatibility and have a 1024 x 8-bit organization. Also both are direct replacements for like-numbered Motorola circuits.

CIRCLE NO. 350

S-TTL IC raises speed, cuts power

Advanced Micro Devices, Inc., 901 Thompson Pl., Sunnyvale, CA 94086. (408) 732-2400. $4.00 to $28.31 (100).

A quad, two-input Schottky-TTL circuit—the Am25S09—can replace the 74S157 (quad multiplexer) and 74S175 (quad register). The new IC performs the same function with typical power dissipation of 375 mW for a 32% power savings. This dual port, 4-bit register accepts data from one of two 4-bit input fields and features a positive edge-triggered clock. Additionally, use of this unit can save 7.5 ns in the data-path propagation delay. The new circuit comes in a single 16-pin package.

CIRCLE NO. 354

1-k RAM access time reaches 30 ns

Motorola Semiconductor, P.O. Box 20924, Phoenix, AZ 85036. (602) 244-3468. $14.25 (250 wp); samples from stock.

Complementing the company's MPC1000 positive-voltage regulator, Motorola offers the MPC900 negative-voltage regulator. The output voltage of the new regulator can be adjusted over the range of 0 to ±30 V dc; maximum input voltage is ±35 V dc. Designed to deliver load currents up to 10 A without an external current-boost transistor, the MPC900 has an internal power dissipation capability of 100 W. With operation over a case-temperature range of 0 to 125 C and with an input voltage variation from 0 to ±15 V dc, the circuit holds the output voltage (Vout) to within a maximum of 0.5% of the desired Vref. Over the same temperature range and with a load-current variation from 100 mA to 5 A, the output voltage doesn't vary more than 0.6% of Vref. Temperature coefficient of the output voltage is a maximum of 0.015% Vref/°C, and circuit protection is provided by an adjustable overload circuit.

CIRCLE NO. 350
ECL FROM cuts turnaround

Motorola Semiconductor, P.O. Box 20924, Phoenix, AZ 85038. (602) 244-3466. 839 (100-999).

The MCM10150AL, a 256 × 4-bit factory-programmed ROM (FROM), is said to fall midway between a field ROM and mask ROM in terms of cost and turnaround time. Total turnaround for the ECL FROM can be accomplished in weeks, rather than months. Programming is achieved by electrically opening metalization links on a wafer stocked at the factory; masks aren’t used. The FROM has an address-input-to-data-output access of typically 20 ns and a temperature range of -30 to 85 C. A preprogrammed FROM, in the form of a 4-bit magnitude comparator—the MC10050AL—is available as a standard example.

CIRCLE NO. 357

Calculator performs 286 conversions

Rockwell Microelectronic Device Div., P.O. Box 3669, Anaheim, CA 92803. (714) 632-3729.

With the Universal Conversion circuit, an MOS/LSI chip, it’s possible to compute volume by multiplying meters by inches by millimeters and get the answer in cubic centimeters. The new chip—the A4521—performs 286 different standard conversions as well as five-function calculations. It has three memories and directly accesses area, volume and linear conversions from a 25-key keyboard. As a three-memory calculator, the A4521 circuit provides the basic four functions plus percentage with automatic markup and discount. Constants, chaining and repeat operations can be performed with all functions, and all calculations are algebraic. Powered from a single 15-V power supply, the A4521 circuit includes automatic display encoding and eight-segment parallel output. It is directly compatible with LED, fluorescent and gas-discharge displays. Keyboard decoding and debouncing are performed on the chip, which also has an internal oscillator/clock generator.

CIRCLE NO. 358
INFORMATION RETRIEVAL NUMBER 52
FOR DEMONSTRATION, 181

**INSTRUMENTATION**

**DPM delivers auxiliary output power**

![DPM image]

Digilin, Inc., 3521 W. Pacific, Burbank, CA 91505. (213) 846-1800. $99 (100); stock to 4 wks.

Model 4332 is a 3-1/2-digit OEM DPM and power supply, which features monolithic circuitry and a two-year warranty. The supply provides ±12 V dc at 10 mA and +5 V dc at 250 mA. Display is by 0.43-in. high seven-segment LED digits. The unit offers accuracy of 0.05%, stability of 0.005%, 40-pA input bias current and 1000-mΩ input impedance (199.9 mV to 1.999 V ranges). Power dissipation is 2-1/2 W. Automatic zero and bipolar operation are standard. Panel cutout is 3.74 x 2.05 in.

CIRCLE NO. 326

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**Digital unit diagnoses phone-line problems**

![WaveTek image]

WaveTek, 9045 Balboa Ave., P.O. Box 651, San Diego, CA 92123. $1395; 30 days.

Model 430 digital-transmission multimeter is a diagnostic tool for telephone communications that combines the functions of the frequency counter, noise and level test set, capacitance bridge and decade box with standard voltmeter functions. Pushbutton control and portable battery power are included. Signal level and noise are displayed digitally with built-in voice and program filters. Line capacitance, resistance and current are also measured quickly and accurately.

CIRCLE NO. 327

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**Choose your bandwidth... TAKE YOUR CHOICE!**

120 MHz/5 mV
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- Lightweight: 19.5 lbs
- Bright 20 KV 8 x 10 cm display
- Low 45 Watt power consumption
- X - Y capability
- Easy to use delayed sweep

PM3260E . . . . $1850.00

50 MHz/5 mV
- Dual trace/Delaying sweep
- Lightweight: 18.5 lbs.
- Bright 10 KV 8 x 10 cm display
- Low 23 Watt power consumption
- X - Y capability
- Easy to use delayed sweep

PM3240 . . . . $1470.00

10 MHz/2 mV
- Dual beam to avoid chop/alternate problems
- Brilliant 10 KV 8 x 10 cm display
- Lightweight: 21 lbs.
- TV sync
- X - Y capability

PM3232 . . . . $875.00
PM3233 . . . . $925.00

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PHILIPS
10-in. strip-chart unit uses ‘no wear’ pen

Gould Inc., Instrument Systems Division, 3631 Perkins Avenue, Cleveland, OH 44114. (216) 361-3315. $1650 (2 channels); 90 days.

Model 110 10-in. strip-chart recorder is available with one or two pens and excels at long-term monitoring of low-frequency signals. An outstanding feature of the unit is its fs response time of 250 ms. The unit uses thermal writing to produce clear, blue traces on special paper that does not smudge from pressure or handling. The ceramic pen tip for each channel of the 110 is virtually wear free and has a lifetime guarantee.

CIRCLE NO. 328

Unit checks linear ICs for dc parameters

Teradyne, 183 Essex St., Boston, MA 02111. (617) 482-2700. $11,900; 12-16 wks.

J149 linear circuit test instrument is intended primarily for incoming inspection and component evaluation of linear devices. The unit performs major dc parametric tests on a wide range of linear ICs, including voltage regulators, op amps, and comparators. Sequences can be repeated to test dual, triple and quad devices. Because test circuitry is divided among the mainframe, interchangeable programming boards and plug-in ROM modules, the J149 can be customized to test every device thoroughly.

CIRCLE NO. 329

The closest yet to the real

Keithley’s new current source supplies up to 1.1 amps

The new Model 227 Current Source provides the high-power output needed for modern devices, components and materials. Currents to 1.1 ampere at up to 50 volts compliance and 110 milliamps at up to 300 volts are easy for the 227.

The 227 output is dependable, too. Excellent regulation of 0.005%, stability to 0.01% and low noise combine to assure high output resolution. All this is made possible by the modern technology incorporated into the design of this new source.

The true, bi-polar output of the Model 227 can be modulated, programmed, and even floated up to 500 volts off ground. A special programming option even allows the range and compliance limit to be remotely controlled.

There’s more about the 227 that makes it an outstanding value at only $925. Send for details now. Or phone (216) 248-0400.

CIRCLE NO. 328

INFORMATION RETRIEVAL NUMBER 53

95
Staco switches stand up to the total test
Design features...Low total cost...Delivery

Check Stacoswitch's total cost...purchase price, installation cost, and maintenance expense...and you'll find it costs nothing extra to buy the finest. Essential design and performance features mean premium grade materials and construction for long dependable service life. Add to this finished goods inventory and expanding manufacturing capacity and you'll know why Stacoswitch's colorful lighted display pushbutton switches and indicators are your best buy. Choice of circuitry, switch action, display style, and mounting method to meet your specific application. Write today for catalog showing complete pushbutton switch line. When you think switch...think STACOSWITCH and save!

INFORMATION RETRIEVAL NUMBER 74

WORLD'S LIGHTWEIGHT CHAMP!

A 9½ pound, dual-trace 20 MHz scope that fits in a briefcase...

- Mini-portable Oscilloscope
- Battery, AC or DC powered
- DC - 20 MHz bandwidth
- 10 mV/div sensitivity
- 21 sweep ranges to 100 nsec/div
- Computerized triggering
- Delay line
- 10 mV/div sensitivity
- 21 sweep ranges to 100 nsec/div
- Computerized triggering guarantees a stable CRT display at all times.

If you're tired of working with the "Heavyweights," but still need a high performance portable scope that can handle your trouble-shooting needs, then consider Model PS940A. This dual-trace "mini-scope" provides all the basic features and quality of a sophisticated lab scope, yet its weight and size make it easy to carry to every job—at the plant or in the field. And it is simple to operate. Computerized triggering guarantees a stable CRT display at all times. Also, both traces can be vertically positioned in the DC coupled trigger mode without the need for trigger level readjustment.

AVAILABLE NOW FOR ONLY $1145

3-digit DPM meets UL, CSA specs

Analogic, Audubon Rd., Wakefield, MA 01880. (617) 246-0300. $70 (1000); 45 days.

AN2531 line powered, 3-digit DPM is intended for stringent environments. The unit includes a UL and CSA approvable, low-leakage power transformer, consumes less than 1 W of power and can be custom mounted in OEM, medical and other instrumentation. The unit converts a 0 to 999 mV fs input into a full 1000-count display (gas discharge) with 0.1% accuracy, and less than 30 ppm/°C range tempco, and ±15 µV/°C offset tempco.

INFORMATION RETRIEVAL NUMBER 75

INSTRUMENTATION

Portable 100-MHz scope works in many modes

Dumont Oscilloscope Labs, Inc., 40 Fairfield Pl., West Caldwell, NJ 07006. (201) 575-8666. $1895 w probes.

This portable, dual-channel scope, the Model 1100P, has a vertical sensitivity to 5 mV/cm, a dc-to-100-MHz frequency response and sweep speeds to 5 ns/cm. The instrument is designed to trouble-shoot digital logic circuits. The scope's 100-MHz response is held across the entire 8 × 10-cm display from 0 to 55 C without degradation. The 1100P has a variety of operating modes: CH 1, CH 2, ALT, CHOP, ADD, MAIN, INT, DLYD, MIXED, and calibrated X-Y—each at the push of a button. The front panel has color-coded pushbuttons and panel areas to simplify operation. Pushbuttons have single functions which are selected only when the button is pressed.

CIRCLE NO. 330

3-digit DPM

From a Leader in Mini-Portables

U-DATA CORPORATION

CIRCLE NO. 331

ELECTRONIC DESIGN 8, April 12, 1975
Automatic ‘C’ meter fits in hand

ECD Corp., 232 Broadway, Cambridge, MA 02139. (617) 492-5672. $289; stock-4 wks.

Model 100 is a hand-held, battery-operated 3-1/2-digit autoranging capacitance meter. The meter measures from 200 pF to 200,000 µF in 10 automatically selected ranges. Maximum resolution is 0.1 pF. Accuracy is 0.1% ± count to 200 µF, and 1% thereafter. Operation is by a single push-to-measure button.

Hand-held tester spots bad semiconductors

Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, OH 44108. (216) 541-8080. $138; $4 for charger; stock.

Model 215 semiconductor tester is a pocket-sized, self-contained test instrument capable of checking npns, pnpS, FETs, diodes, SCR/S and unijunctiOns. The unit instantly and automatically determines proper lead configuration and indicates with LED displays if the semiconductor is good or bad. If good, it further identifies which lead is the base (gate for FET'S) and whether npn or pnp. Solid-state CMOS circuitry greatly extends the life of the two 9-V batteries that power the compact unit.

Precision Thin-Film Resistor Networks

Packaged precision thin-film networks are now available from Hybrid Systems. When you need a TCR of 50 PPM/°C, absolute and 1 PPM/°C tracking, you'll find Hybrid Systems is priced competitive. And with our computer-automated laser-trimming facility, we routinely trim to ratios of 0.01%.

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In Europe: Hybrid Systems GmbH, 61 Darmstadt, Luisenplatz 4, Germany Tel. 6151-291595.

Hybrid Systems Corporation
Burlington, Massachusetts 01803

INFORMATION RETRIEVAL NUMBER 55
FSK data link uses supervised carrier

The ER-125D (transmitter) and ER-125E (receiver) are supervised carrier data links. These links use high frequency phone or ac single phase power lines to transmit and receive digital or analog data. The carrier-current data link consists of two 3 x 5 in. printed circuit cards, is available in eight channels, and all eight can be operated simultaneously on one installation. The transmitter input and receiver output (Schmitt type for chatter elimination) are TTL-compatible, the receiver output a binary duplicate of the transmitter input in locked operation. Power requirements are ac, single phase and +12 V dc for the transmitter, ac single phase and ±5 V for the receiver. The transmitter has one fine tune control; and the receiver one offset control.

CIRCLE NO. 334

Temperature controller plugs into duplex outlet

RFL Industries, Boonton, NJ 07005. (201) 334-3100. From $98.50; stock.

The series TA2 proportional temperature controllers can be installed in minutes and are designed with the plant electrician or maintenance man in mind. These controllers provide operation over a -90 to +500 C process temperature range. Simply plug the controller mounting into a standard duplex 115 or 230-V outlet. The outlet is wired so that the controller input power is fed through one receptacle and the controller output is delivered through the other. The control box contains an on/off switch, power level indicator, sensor receptacle and plug.

CIRCLE NO. 335

Adjustable speed motor drive handles up to 5 hp

Industrial Electronic Controls, 509 Buckbee St., Rockford, IL 61101. (815) 963-8988. From $525; 10 to 12 wk.

The Models 2572-1, -3, and -5 are adjustable frequency ac motor drives. They handle 1, 3 and 5 hp motors, respectively. Input is 230 V ac three-phase power at a constant frequency. The output of the drive is 0 to 230 V ac, 6 to 120 Hz. The drive is current-limited, has short-circuit protection and input/output fuses. Full rated torque is delivered over a 10:1 speed range and speed regulation is ±2%. The 2572 drive is housed in a 14 x 16 x 6 in. cabinet.

CIRCLE NO. 336

Interval timers come in wide delay variations

Syracuse Electronics, P.O. Box 566, Syracuse, NY 13201. (315) 488-4015. Under $10; 8 wk.

The SDS series timers are available in fixed and remote adjustable delay ranges with a lower unit of 0.1 s and an upper limit as high as 480 s. The timer is available for inputs of any value from 24 to 230 V ac or from 24 to 110 V dc. The units have a reset time of 50 ns during and after timing. Maximum power consumption is 2 W. Output rating is 1 A ac and 100 mA dc. The SDS timers will operate according to specs at temperatures ranging from -10 to +60 C.

CIRCLE NO. 337

Telephone tone modules form central office

Kinetic Technology, 3393 De La Cruz Blvd., Santa Clara, CA 95050. (408) 296-9305. $331 set (100 up).

A series of 14 thick film hybrid modules performs together as a central office telephone tone receiver. Space savings of 75% are obtained over previously available passive filter versions. All telephone system requirements are met in the receiver, including twist, dial tone rejection, speech immunity, fast pulsing and rejection of nonlegitimate tones. Voltage requirements are ±12 and +5 V. The modules are available in sets for installation in customer's circuit boards or completely installed and tested on a plug-in PC card. Outputs are directly compatible with TTL/CMOS logic.

CIRCLE NO. 338

ANALOGY

Get the full facts on the A-943 voltage to frequency converter. Streaks your system at 0.1-MHz in a straight line ±0.01%. Neat little 1 x 1 1/2 x 3 package. Run out and get one.

INTECH INCORPORATED
1320 COLEMAN, SANTA CLARA CA 95050
Tone receiver/xmitter operates over phone line

Acco, Datamaster Div., 929 Connecticut Ave., Bridgeport, CT 06602. (203) 225-2511. Stock to 8 wk.

The AR-4010 tone receiver and AT-4010 tone transmitter detect and transmit an amplitude modulated signal used as command or control information. Transmitter input may be either a voltage or contact closure; receiver output either closes a contact, produces a voltage, or passes current through an opto-isolator. Both the receiver and transmitter can be supplied for operation from 350 to 2820 Hz over a telephone line or other transmission medium. Both can be used in conjunction with other receivers and transmitters, each on a different frequency, to perform many functions on a single transmission link. Design features include LEDs for indication of correct signal operation and CMOS logic for low power consumption. The receiver and transmitter have a maximum reception or keying speed of up to 42 Hz, and have battery back-up to assure uninterruptible operation.

Hybrid controller handles up to 3000 W

Electramation, 866 E. 17th St., Suite 300, Santa Ana, CA 92701. (714) 551-4434. $10 (lg. qty.); stock to 4 wk.

A hybrid, thick-film circuit, the Solid-Stat, can control ac voltages from 0 to 240. The unit is available in 5, 10 and 15 A, 120 or 240 V ac versions. The molded package, void free passivation and high thermal conductivity results in a reliable, trouble-free unit, capable of handling up to 3000 W. The unit is completely self-contained and requires no additional components for operation. The Solid-Stat may be operated at full rated current, with no derating, up to 70 C.

Wait watchers special for busy engineers

If you're interested in wait reduction, we urge you to order Triad's combination plate—plug-in transformers, circuit cards and mating connectors—from your industrial electronic distributor. Triad not only gives you more transformers and inductors to plug in, but a versatile line of integrated and universal circuit cards to plug into. And—to save you a search for the applicable connector, you need only put a "CO" prefix ahead of the card number to get the right Winchester connector in the same package with the card—ready for you to put together.

Triad has a standard series of plug-in telephone coupling transformers to interconnect remote data entry and display terminals to computers over voice grade telephone lines. Triad also makes many standard plug-in power transformers for transistorized control and instrumentation with single and dual primaries. Secondaries may be connected in series or parallel to obtain a wide range of voltage and ampere combinations.

Get a catalog from your distributor. Or write Triad Distributor Services, 305 North Briant Street, Huntington, Indiana 46750.
Temperature controllers operate over wide span

**Honeywell, Honeywell Plaza, Minneapolis, MN 55408. (612) 870-5200. $140 up; stock to 6 wk.**

Models W927A, B and C solid-state controllers are designed for computer room air conditioners and have automatic changeover from heating to cooling. They are single-input devices that operate over -40 to +150 F. A secondary sensor is not required in computer room applications because the rapid air circulation eliminates the need for reset. The units are controlled by the company’s T7047 space thermostat or a T7022A1010 return-air thermostat. The W927D, E and F models are single or dual temperature-input step controllers. They are directly controlled by a space or return-air thermostat. The dual-input feature allows the use of a secondary sensor located in the discharge air. This sensor acts as a heat anticipator and provides the proper cycling rate for good temperature control. The W927G, H and J models are also single or dual temperature-input step controllers. The primary sensor is located in the boiler discharge water or discharge air duct. The secondary sensor—located outdoors—resets the discharge temperature as the outdoor temperature changes to save energy.

**Log ratio modules have max error of ±10 mV**

**Intronics, 57 Chapel St., Newton, MA 02158. (617) 332-7350. LR101: $55, LR102: $70 (1-9); 4 wk.**

The LR101 and LR102 are modular log ratio operators that produce an output voltage proportionall to the ratio of two positive input voltages. For input signals from +10 mV to +10 V, the total output error is only ±15 mV (LR101) or ±10 mV (LR102). Internal temperature compensation provides an offset temperature drift of only 100 µV/°C over a 0 to 70 C temperature range. The scale factor is set for an output of 1 V/decade, so that an input ratio of 1000:1 produces a full scale positive output of 3 V, and an input ratio of 1:1000 produces a full scale negative output of -3 V. Output bandwidth is 20 kHz for 10 V input signals. The modules are housed in 1.2 x 1.2 x 0.6 in. epoxy packages with gold-plated circuit pins suitable for either socket or printed circuit board mounting.

**Input/output converters provide 1.5-kV isolation**

**Teledyne Relays, 3155 W. El Segundo Blvd., Hawthorne, CA 90250. (213) 973-4545. From $9.40 (1000-up); stock to 6 wk.**

The 675 series of input/output converter modules includes a full line of ac and dc input and output units. All versions offer 1500 V rms optical isolation to protect logic lines from ac or dc power circuits. Ac output converters use zero-voltage-switching for noise reduction and have high dv/dt ratings to prevent misfires in industrial control environments. The low profile PC configuration allows both economies and great flexibility (including interchangeability) in input/output interface circuitry.

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**S/d converter operates over 50 to 1200 Hz**

**Control Sciences, 10315 Woodley Ave., Granada Hills, CA 91344. (213) 352-3067. From $550.**

The series 168C units are miniature synchro (and resolver) to digital converters. The converters occupy less than 7 in.² and function over the frequency range of 50 to 1200 Hz without external modules. Models may be selected to provide error-free tracking rates to 10 rps (3600°/s). All standard models of the 168C series have a reference voltage range of 10 to 150 V rms. Accuracy is ±4 minutes ±0.9 LSB at 25 C, with 14 bit resolution. Standard tracking rate is 1440°/s (3600°/s optional).

**CIRCLE NO. 339**

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**Log ratio modules have max error of ±10 mV**

**Intronics, 57 Chapel St., Newton, MA 02158. (617) 332-7350. LR101: $55, LR102: $70 (1-9); 4 wk.**

The LR101 and LR102 are modular log ratio operators that produce an output voltage proportionall to the ratio of two positive input voltages. For input signals from +10 mV to +10 V, the total output error is only ±15 mV (LR101) or ±10 mV (LR102). Internal temperature compensation provides an offset temperature drift of only 100 µV/°C over a 0 to 70 C temperature range. The scale factor is set for an output of 1 V/decade, so that an input ratio of 1000:1 produces a full scale positive output of 3 V, and an input ratio of 1:1000 produces a full scale negative output of -3 V. Output bandwidth is 20 kHz for 10 V input signals. The modules are housed in 1.2 x 1.2 x 0.6 in. epoxy packages with gold-plated circuit pins suitable for either socket or printed circuit board mounting.

**CIRCLE NO. 457**

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**Input/output converters provide 1.5-kV isolation**

**Teledyne Relays, 3155 W. El Segundo Blvd., Hawthorne, CA 90250. (213) 973-4545. From $9.40 (1000-up); stock to 6 wk.**

The 675 series of input/output converter modules includes a full line of ac and dc input and output units. All versions offer 1500 V rms optical isolation to protect logic lines from ac or dc power circuits. Ac output converters use zero-voltage-switching for noise reduction and have high dv/dt ratings to prevent misfires in industrial control environments. The low profile PC configuration allows both economies and great flexibility (including interchangeability) in input/output interface circuitry.

**CIRCLE NO. 458**
LOW-COST LED DIGITAL READOUTS
IN RED, ORANGE, YELLOW OR GREEN

Solid State Modules Come Ready to Install and Operate — Include Decoder/Driver and all Circuitry Needed to Hook up to Your System

- Standard 0-9 plus overflow, with character heights of 0.30" and 0.40" — and both sizes at the same low price!
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- Compatible with TTL
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And Immediate Delivery!

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Century Aero Corp., So. California (817) 659-4915
Peerless Radio Corp., Florida (305) 566-5966
Ratel Electronics, No. California (213) 965-2010

0.30" High: MDA-6151 (green), MDA-6171 (red), MDA-6181 (yellow), MDA-6191 (orange)
0.40" High: MDA-7151 (green), MDA-7171 (red), MDA-7181 (yellow), MDA-7191 (orange)

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New PM drive systems

Type DPM permanent magnet SCR adjustable speed/torque drive systems, for demanding applications. Available from stock.
Built for rugged, long term use — controls feature circuitry with wide degree of flexibility for end-use convenience. Chassis-type controls adaptable to any type sub-system.

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Get the facts on Bodine DPM Control Systems.

Bodine Electric Company, 2528 W. Bradley Place, Chicago, IL 60618

INFORMATION RETRIEVAL NUMBER 66

LOW-COST SENSOR
... offers efficiency

Electro Corp., 1845 57th St., Sarasota, Fla. 33580. (813) 355-8411
Less than $2.00 in quantity: Stock
Model 3022 Magnetic Sensor with 7/16-20-UNF-2A plastic threads provides a minimum of 20V, peak-to-peak output at 1.000 inches-per-second. Sensor is ideal for large volume OEM applications where low-cost is a consideration. Two 18" PVC lead wires are provided.

YES... WE'VE BEEN BUSY!
This honey of a new product is but one of many — look for more in the New Product Sections of your favorite publications.
Silvercel rechargeable batteries pack the most useable power into the smallest and lightest weight modular package available today. In fact, this compact, rechargeable power source delivers 3 to 4 times the energy of common rechargeable batteries and does it with flat, non-tapering discharge voltage characteristics.

Silvercel batteries have been custom designed as essential components in aircraft, missiles, torpedoes, submersibles, medical equipment, communications equipment and many other applications where a portable power source is required.

When it comes to dependability and performance, Silvercel produces. And if, by chance, one of our standard sizes doesn't suit your application, we'll design a battery for you. Silvercel is really all you have to know in batteries.

**POWER SOURCES**

**Dc/dc converters tolerate 2:1 input-voltage swing**

*Semiconductor Circuits, 306 River St., Haverhill, MA 01830. (617) 373-9104. See text; stock to 3 wks.*

Dc/dc converters generally don't accept too much variation in input voltage. But two new encapsulated series of supplies from Semiconductor Circuits tolerate a 2:1 span in input. The DR and DC series—specifically aimed at plasma digital displays—deliver either 200 or 250 V at 30 mA.

For the DR series, inputs can range from 9 to 18 V or 18 to 36 V, depending on the model. Input for the DC covers 35 to 70 V.

Apparently the Semiconductor Circuits units are intended to compete with the 900 series from Endicott Coil Co.—units that convert 5, 9, 12 or 15 V to a nominal 250 V at 30 mA. (The 900 replaces Endicott's older 800 series.) Input variation for the unregulated 900 is limited to a maximum of ±10% or ±4% to maintain the units' specifications.

If you need the input regulation (2% line and load) provided by the Semiconductor Circuits units, you'll have to pay extra for it: The DR series sells for $45.95 to $49.95 (1-9) whereas the Endicott 900 sells for $26.60 in the same quantities. Regulators also need room, so the DR fits into a 2.5 × 3.5 × 1.25-in. case, while the 900 squeezes into a smaller 2 × 2.5 × 1.12 in.

One thing to guard against with gas-discharge readouts is power-supply ripple, which raises or lowers the instantaneous nominal voltage. If the excitation voltage drops, you can lose information; if it goes too high, the display can be damaged or its life shortened. So check the readout vendor's ripple spec. In the Endicott units, ripple is listed as 2.5 V pk-pk max; for the Semiconductor Circuits units, expect 7 mV rms.

The price difference between the competing units buys you more than regulation, however. The DR and DC are short-circuit-protected and operate over -25 to 71 C with no derating. The 900 can withstand "momentary" shorts and has a standard range of 0 to 70 C with no derating.

**Semiconductor Circuits**

CIRCLE NO. 301

**Endicott Coil**

CIRCLE NO. 302

Electronic Design 8, April 12, 1975
Regulator holds line to ±1% variations

Tele-Dynamics, 526 Virginia Dr., Fort Washington, PA 19034. (215) 643-3900. $194 (500 VA); stock.

The LR series Varax line conditioner is offered in 500 and 1500-VA models for American, European, and Japanese voltages. It provides ±1% true-rms regulation of both line and load over a broad input range (90 to 125 V for the 115-V models) with less than 5% distortion. The enclosure is designed for either wall or panel mounting. It is insensitive to line-frequency changes, has closed-loop feedback for better regulation than ferroresonant devices, and incorporates a ±3% output adjustment as a standard feature.

CIRCLE NO. 453

OEM units offered for TTL, CMOS systems

Power-One, Inc., 531 Dawson Dr., Camarillo, CA 93010. (805) 484-2806. HBB512: $54.95; HCC512: $86.95; stock.

Two new models of OEM dc power supplies are specially designed for small systems using TTL/DTL and CMOS. Each model features a 5-V output with ovp and a separate 9-to-15-V adjustable output. Line/load regulation is 0.02% and current foldback is built-in. These units are full-rated to 50 C. Output of Model HBB512 is 5 V at 3 A and 9 to 15 V at 1.25 A; that of Model HCC512 is 5 V at 6 A and 9 to 15 V at 2.5 A.

CIRCLE NO. 454

think small... with sub-miniature ceramic capacitors

Thick film hybrid design engineers can choose sub-miniature single and multi-layer ceramic chip capacitors with the widest range in capacitances, sizes, temperature characteristics and terminations in the industry from Centre Engineering.

In frequency critical areas requiring accuracy and stability, consider Centre Engineering's NPO type chip capacitors. Applications requiring less stringent specifications Centre Engineering's WSR and ZSU chip capacitors are economy savers.

Single layer and multi-layer ceramic chip capacitors, as small as .060 x .050 x .55T up to .460 x .420 x .65T with extremely high capacitance to volume ratios are ultra-reliable.

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POWER SOURCES

Open-frame family includes 88 members


"Lomni" series open frame power supplies provide 88 new models with nominal voltage ratings of 5 to 28 V and current ratings from 1.2 to 38.5 A, maximum power of 400 W. The 88 new models have regulation of 0.01%, ripple and noise of 0.01%, and use an integrated circuit regulation system for good thermal and transient performance.

CIRCLE NO. 343

Dual outputs track or operate independently

Grumil Corp., 4226 Idlewilde Lane S.E., Albuquerque, NM 87108. (505) 265-2320. $157; stock.

The GM412 dual-output lab power supply is a constant-voltage, current-limited instrument rated at 20 V dc and 600 mA for both positive and negative supplies. Output circuitry is protected against overload, as well as positive and negative external forcing, within the limits of ±20 V and ±600 mA. Three selectable meter ranges are provided. Characteristics include 0.01% line regulation, 2-mV load regulation (NL-FL), ripple and noise of 500 µV rms, transient recovery time of 50 µs, tracking accuracy of 0.01%, and unconditional stability for all loads.

CIRCLE NO. 344

DC/dc converters work at 75% efficiency

Aaron-Davis Co., Inc., 1720-22nd St., Santa Monica, CA 90404. (213) 829-1834. $175; stock 2 wks.

The G4-25 Series dc/dc converter operates from conventional 24-V battery sources. 28 and 48-V inputs are optional. Efficiencies go up to 75%. The 25-W supply measures 4 x 4 x 2 in. Regulation is 0.5% for line and 2.0% for load. Ripple deviation is less than 0.5% of the output voltage. The converter is conduction cooled and operates over a temperature range of -20 to +71°C measured at the mounting base. Six standard models provide outputs of 5, 6, 12, 15, 24 and 28 V.

CIRCLE NO. 345

Portable Digital Multimeter at an Analog Price

MODEL 280
$99.95

Enjoy the benefits of auto-polarity digital readout plus full overload protection and high-low power ohms for accurate tests in solid-state circuits. Accuracy better than analog VOM's!

22 RANGES
Reads in decades: AC and DC volts and mA, 1-1000; ohms, 100-10 meg.
Resolution: 1mV, 1mA, 0.1 ohm.
Accuracy: DC typically ±1% F.S.; AC and ohms typically ±2% F.S. except ±2.5% on highest range. Uses 'C' cells. Optional AC adapter/charger.
In stock at your local distributor

B&K PRECISION
PRODUCTS OF DYNASCAN
1801 W. Belle Plaine Avenue Chicago, IL 60613

INFORMATION RETRIEVAL NUMBER 67

Automatic transistor tester works in-circuit when others can't

TESTS IN ONLY 9 SECONDS Tests diodes, SCR's and unijunctions, too. Avoids time wasting unsoldering of good transistors that tested bad in circuit and then good out-of-circuit because of erroneous testing. B&K Precision 520 Dynapeak™ even tests automatically in-circuit with shunts of 10 ohms or 50 mfd. Random lead connection; turn the switch—the rest is automatic: Pulsating audio tone and LED indicates good device; PNP/NPN, Ge/Si shown by LED. No-charts leakage tests. Tests transistor action, not just junction or diode characteristics. Write today!

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1801 W. Belle Plaine Avenue Chicago, IL 60613

INFORMATION RETRIEVAL NUMBER 68

ELECTRONIC DESIGN 8, April 12, 1975
Five 150-W switchers join modular line

ACDC Electronics, Oceanside Industrial Center, Oceanside, CA 92054. (714) 757-1880. $275; 2-4 wks.

Five new 150-W switching-type power supplies have been introduced by the company. Ranging from 5 V at 30 A to 24 V at 7 A, these 20-kHz inaudible switchers operate from a selectable input of 115/220 to 230 V ac, (100 V ac also available) 47 to 63 Hz with 70% to 80% efficiency and 0.1% regulation. Overvoltage and overload protection on this JP Series is standard and radiated and conducted EMI is minimized by shielding and filtering. For systems applications, the output may be turned off by a single contact closure or TTL gate output. JP Series power supplies may be paralleled for high current requirements. The units weigh only 8 lb.

CIRCLE NO. 346

Bench supply gives triple outputs


This compact three-in-one dc power supply, the 6237A, delivers an output of 0 to 18 V at up to 1 A and plus or minus outputs from 0 to 20 V, each at 0.5 A. The 0 to +20 V and 0 to -20 V outputs track one another within 1%. They can also be used to obtain a single 0- to 40-V, 0.5-A current. Regulation is 0.01% ±2 mV, with ripple and noise of 0.35 mV rms/1.5 mV pk-pk.

CIRCLE NO. 347

WHAT PRICE STABILITY?

Tracor Model 308-A Rubidium Frequency Standard. $6,250.

Atomic accuracy at near crystal prices. Utilizes stable quartz crystal oscillator whose frequency is controlled by atomic resonance of rubidium 87. Low cost, high reliability, modular construction.

Tracor Model 304-D Rubidium Frequency Standard. $7,650.

For general lab and field use. Almost entirely unaffected by environmental factors. Provides stable, accurate source of standard frequencies. Integral time scale selector. Modular construction. Tracor has more manufacturing and engineering experience in Rubidium standards than anyone else. Write or call for full technical and application information.

Tracor, Inc. Industrial Instruments
6500 Tractor Lane • Austin, Texas 78721 • AC 512/926-2800
MONOLITHIC CRYSTAL FILTERS

NEW FM DISCRIMINATORS . . .

One hang-up in designing a single-conversion NBFM receiver is demodulation. Until now you've had the option of making a second conversion, using phase-locked loop techniques, or designing your own discriminator. Now PTI has made demodulation simple with two new monolithic crystal discriminators offering low distortion — typically 1% — and high recovered audio — typically 800 mV — when used with the CA3089E IC quadrature detector or equivalent.

Detailed spec sheets are available. Ask for Models 2283F (10.7 MHz) and 2378F (21.4 MHz).

SOME THINGS NEVER CHANGE

Five years ago, when this ad series began, we offered some 20 low-priced standard monolithic crystal filters at 10.7 MHz. Since then the number has grown to 60 at 10.7 and 21.4 MHz (not to mention standards at other frequencies). Even though it's five years later, we still offer those original models — and at prices no higher now than in 1970. Times may be changing, but our quality and price aren't.

SOMETHING OLD, SOMETHING NEW

Our new discriminators and our original standard models are two good examples of PTI's leadership in monolithic crystal filters. If you have a problem calling for monolithics we may have the answer already on the shelf.

The standard in monolithic crystal filters.

COMPONENTS

Bi-pin-based T-1 lamp has precision filament

Gilway Co., Inc., 29B Cummings Park, Woburn, MA 01801. (617) 985-4442. $1.09 (1000 up); stock.

Precision-coiled filament T-1 lamps are now available with bi-pin bases. The lamps feature precision location of straight, rugged, CC-6 filaments. The lamps are suited for critical electro-optical and other close-tolerance applications. Certification to military specifications is available. The 1150-9 lamp is rated at 5 V, 0.115 A for a 40,000-h life and the 1600-9 is rated at 5 V, 0.060 A for 100,000-h life.

Filter chokes range to 100 µH, handle 10 A

Dale Electronics Inc., E. Highway 50, Yankton, SD 57078. (605) 665-9301. Under $1.00 (OEM qty); stock to 4 weeks.

The IH Series, a new standard line of high-current filter chokes for PC mounting, is used for noise filtering in switching regulators, power amplifiers, power supplies and SCR or triac control circuits. The chokes have an inductance range from 10 to 100 µH and a current rating up to 10 A. Custom models are available up to 20 A. The units have a flame-retardant coating and pretinned leads.

Liquid crystal displays large clock characters

Transparent Conductors Inc., 26 Coromar Dr., P.O. Box 549, Goleta, CA 93017. (805) 968-3561. See text.

Large-area liquid-crystal displays are now available in two new one-piece versions for a wide variety of digital wall clock and advertising displays. The 43.5C01 is a transmissive-mode, dynamic-scatter­ing, 3-1/2-digit clock face with 4-in. high characters on one 5 × 14 × 1/4-in. display. This 70-in.² display sells for $37 in lots of 1000. Sample prices are $98. A 2-3/4 × 7 × 1/4-in. clock face, the 23.5C01, with 2-in. high characters sells for $17 in 1000 lots, and samples are $49. Prices include connectors and a one-year warranty. Both models are also available in reflective modes. Available life data projects over a 30,000-h life.

Marked control discs have low inertia

Dynamics Research Corp., 60 Concord St., Wilmington, MA 01887. (617) 658-8100. $20 (unit qty).

Over 100 different line counts and sizes of standard discs are now available. These metrifilm discs are offered without tooling charges, and come in a variety of materials such as glass, quartz, Mylar and bi-metal. For low inertia, discs that use glass substrates only 6-mils thick are available.
**RELIABILITY.**
**100X COMPARABLE RELAYS.**

If you can't stand miscontacts, want sensitive response, long life, a versatile 1 amp to 5 amp operating range plus UL, CSA, and VDE ratings — the K series relay is for you. A patented magnetic system develops an 11 g contact pressure and a wide contact gap. The contact spring assembly on the 2 amp type uses bifurcated contacts along with our unique lift-off system. Results: low, stable contact resistance, typically 25 milliohms; minimized bounce and chatter, approx. 1 msec; controlled arcing;

Relays are available in 2C, 4C, and 8C arrangements and in standard DC, AC, plastic-sealed, and power types. Solder terminal, P/C terminal, plug-in, and panel mounting accessories are also available. Want more information on this remarkable relay series? Call or write Arrow-M Corporation today.

**Introducing the Brush 110 strip chart recorder—with a thermal writing pen guaranteed for life.**

There isn’t another strip chart recorder on the market today that can match the Brush 110’s performance, ruggedness, versatility and writing dependability.

The new hot-tip thermal writing system produces clear, sharp, highly reproducible blue traces with no smudges, no smears, no skips and no puddles. Before you buy, check out the remarkable Brush 110. Contact your nearest Gould sales engineer for a demonstration. Or write Gould Inc., Instrument Systems Division, 3631 Perkins Avenue, Cleveland, Ohio 44114.

**FLASHTUBES and RELATED EQUIPMENT**

Lamps and Equipment for the Generation of Light.

**FEATURES:**
High Volume Production Reliability

We can deliver a reliable product in the quantities required by the OEM user. Our lamps have consistently higher quality, with longer and more uniform life.

In addition, we can solve the problem of having to build your own circuitry with our:

- Trigger Transformers
- Chokes
- Trigger Modules
- Power Modules

All are part of the engineering and manufacturing package Xenon can deliver and we can offer the most advanced technical assistance in the industry.

**NEW PRODUCT ANNOUNCEMENT**
Contact our factory for information on our new inner seal design. Its unique insulating and cooling properties have solved problems in many OEM application areas:

SEND FOR OUR COMPLETE PRODUCT CATALOG. XENON ASSURES QUICK DELIVERY.

39 Commercial St., Medford, Mass. (617) 395-7634.

**Introducing Fluke Model 8000A**

No other DMM offers you all of these outstanding specs in one box:

- Best accuracy statement of any 3½ digit DMM: 0.1% accuracy ± 1 digit; one year accuracy time span; 25° C ± 10° C accuracy temperature span.
- Normal mode rejection: 60 dB at 50 and 60 Hz.
- Common mode rejection: 120 dB with 1 kHz unbalance.
- Overload protection specified for all ranges.
- 26 ranges of volts, amps and ohms.
- More option power than any other DMM. Includes low ohms option with 1 milliohm resolution, 20 amp ac/dc current capability, BCD output. Built-in rechargeable battery pack.
- More accessories than any other DMM. Includes 600 amp AC clamp-on current probe, 40 KV high voltage probe, 100 and 500 MHz rf probes.
- Auto zero (no zeroing necessary).

Add to this the incomparable Fluke reputation. No wonder this is the best selling DMM in the world. Still only $299 (domestic only). For data out today, dial our toll-free hotline, 800-426-0361.

**Brush 110 strip chart recorder**

There isn’t another strip chart recorder on the market today that can match the Brush 110’s performance, ruggedness, versatility and writing dependability.

The new hot-tip thermal writing system produces clear, sharp, highly reproducible blue traces with no smudges, no smears, no skips and no puddles.

Before you buy, check out the remarkable Brush 110. Contact your nearest Gould sales engineer for a demonstration. Or write Gould Inc., Instrument Systems Division, 3631 Perkins Avenue, Cleveland, Ohio 44114.
COMPONENTS

Sensor detects liquid level in sight tubes


A clamp-on photoelectric sensor, the S3090 Skanner, measures the liquid level inside a sight glass of virtually any liquid. The Skanner can sense the capillary edge of the fluid with a positioning accuracy of ±0.003 in. The device clamps around the outside of a sight glass with two thumb screws fitted with tension springs, and the unit can be slid easily up or down the glass. Although the Skanner is designed for a 1/2-in. dia sight glass, it can be modified to fit larger diameter tubes.

SPECIFICATIONS
Input: 105-125V, 47-420 Hz
Regulation: Line—0.005%
Load—0.05%
 Ripple: Less than 250 Microwatts
Temp: Operative —20 to +71 °C
Storage —65 to +85 °C Max.
Coefficient —0.01%/°C Max.
Current Limiting: Fixed Foldback Type
Overvoltage: Optional

CALL (714) 279-1414 FOR DELIVERY AND QUANTITY DISCOUNT

CIRCLE NO. 371

Electro-candescent unit displays large numbers

Digilite Corp., 91 Rome St., Farmingdale, NY 11735. (516) 694-6545.

Constraints in size and cost imposed by conventional LEDs and liquid crystals do not limit the Digilite electro-candescent approach. The N-10 Series of digital readouts, suitable for bezel mounting, range in size from 2 to 18 in. Larger sizes can be provided on special order. Life expectancy exceeds 50,000 h. The display offers a number of interesting properties: a choice of color, or mixed colors; a preset ability to change color, or color change in response to external stimuli; ability to change intensity with changes in the ambient temperature; and many other options. Available units operate on 110 V ac 50/60 cycle or 6, 12, or 24 V dc.

CIRCLE NO. 455

Versatile pushbuttons have to 10 poles

Oak Industries Inc., Crystal Lake, IL 60014. (815) 469-5000.

A family of lighted and non-lighted pushbutton switches, type 130, is available in low-power and power-rated versions. The low-power model can have up to 10 poles with contacts rated at 1 A, 28 V dc. The standard contact material is silver-plated brass, but a wide range of options include the precious metals. The power-rated type is available with DPDT contacts of coin silver rated 6 A, 125 V ac. Operational features include momentary, interlocking and alternate action, and mechanical or electrical lockout. The switches come in multiple banks and as complete subassemblies with lighted pushbuttons.

CIRCLE NO. 372

Switch for PC board has low profile

Stanford Applied Engineering Inc., 340 Martin Ave., Santa Clara, CA 95050. (408) 243-9200. $1.85; 7-SPST (1000 up); stock.

A miniature PC-mounted BCD or four-to-10-position decimal-input switch, the Series 1000 Bit, performs the same functions as slide, thumbwheel or toggle switches but occupies less space with its profile of only 0.280-in. high. The switch features large, easy-to-read characters 0.120-in. high. Custom masking and dust covers can be provided. The switch contact resistance is 100 mΩ.
**Enclosures available in many sizes**

Time Mark Corp., P.O. Box 15127, Tulsa, OK 74115. (918) 939-5811. $0.39 to $0.72: polystyrene cover with 8-pin header (1000); stock.

Time Mark now offers its line of enclosures. The headers are molded in general-purpose phenolic and come in three sizes. Each size includes 8, 9, 11 or 20-pin versions. Dust covers are available in four sizes. They are molded from polystyrene, butyrate, nylon or Lexan in a variety of colors.

**Connector junction shell is all plastic**

ITT Cannon Electric, 666 E. Dyer Rd., P.O. Box 929, Santa Ana, CA 92702. (714) 557-4700.

An all plastic junction shell, D-subminiature universal, is available in all five shell sizes—DA, DB, DC, DD and DE—to fit all D subminiature rectangular connectors including the Original D, Burgun-D, D*M Golden-D Mark I and the D*MA Royal D Mark III. Key features include: two-piece construction for ease of assembly, plastic ties for securing the cable firmly, straight or 90° outlet capability, nonflammable thermoset plastic with 150-C temperature capability and use of existing locking hardware.

**Card edge-connector contacts crimp to wires**

Elco Corp., Willow Grove, PA 19090. (215) 659-7000.

Elco Series 6042/6044 card, edge connectors have crimpable contacts for #22-to-30-gauge round wires. Contacts, loose or 2500 on a reel, are made of high conductivity copper and are insulated with Teflon for high temperature resistance. Insulators and application tooling are provided by the manufacturer for customer assembly. Connectors are available with 0.100 and 0.156-in. centers and dual-50 and dual-22 positions, respectively, with or without mounting holes and suitable for both single-sided and double-sided PC boards. Polarizing inserts on contacts, or between contacts, are available. Insulation material is polyester; contacts, phosphor bronze with gold plating over nickel.

**Plastic tweezers can replace steel units**


Plastic 5-1/2-in. tweezers can replace the more expensive stainless-steel instruments normally used for clean-room work, where small parts and components cannot be touched by hand. The tweezers have a good feel, are easy to squeeze and yet they have firm gripping power. Narrow, non serrated tips and side guides prevent side-slip at the tips. They can be cleaned or sterilized many times, but are also inexpensive enough to be discarded after one use.

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**Packaging & Materials**

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**Electronic Design 8, April 12, 1975**
More power to you... at less cost, with Intrinsics' Modular Power Supplies.

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Intronics
57 Chapel Street, Newton, Massachusetts 02158 USA
617-332-7350. TWX 710-335-6835

PACKAGING & MATERIALS

Stick-on temp recorders now fit TO-5 cans

Telatemp Corp., P.O. Box 5160, Fullerton, CA 92635. (714) 879-2901. Stock to 2 wks.

A new adhesive-backed temperature recorder, Model 505, detects overheated TO-5 components. Only 0.320 in. in dia, Model 505 contains five temperature increments, each calibrated at a specific value between 65 and 125 C. Silver-colored windows turn irreversibly black at their rated value with an accuracy of ±1%. Other Telatemp component temperature recorders are available for use with TO-3, TO-66, LSI flatpacks and DIP packages.

CIRCLE NO. 359

Marker labels fit DIP 0.1-in. center spacing


A new line of press-on marker labels identifies DIP socket pins and circuit-board hole locations. The 14-pin DIP markers, Model MS-9, have numbers from 1 to 7 printed on one side and from 8 to 14 on the adjacent side, and the numbers are spaced on 0.1-in. centers to match the lead spacing of conventional DIP components. Strips for 16-pin DIPs and other configurations are also available.

CIRCLE NO. 360

Solder system provides precision heat control

Circon Corp., 749 Ward Dr., Santa Barbara, CA 93111. (805) 967-0404.

Circon's PDS II Pulse Dot micro-soldering system provides precision control of solder, flux, rise time, temperature and total heat output with controlled heat pulses and interchangeable tips. The unit's Auto-Time control dial can set a heat-pulse interval from 100 ms to 10 s. The temperature-control dial sets heat output from ambient to 2200 F. With each depression of a pulse pedal, identical pulse duration and heat is delivered to the soldering tip.

CIRCLE NO. 361

Light-weight adhesive for honeycomb structure

Emerson & Cuming, Inc., Canton, MA 02021. (617) 828-3300. $38.50/gal; stock.

Fiberglass-resin laminates and honeycomb sandwiches, popular as structural materials in the aerospace industry, feature light weight and high strength-to-weight ratios. Thus it is desirable to use an adhesive that is also light weight and has a high strength-to-weight ratio, such as Eccobond SF40. It can seal the edges of laminates to prevent delamination when they are cut to shape, to fill the edges of honeycomb sandwiches and to patch and modify surface contours. It is an epoxy. The density of Eccobond SF40 is only 40 lb/ft³ and yet its compressive strength is 10,000 psi and tensile-shear strength is 1500 psi.

CIRCLE NO. 362

INFORMATION RETRIEVAL NUMBER 77
Interfacing CMOS logic

Interfacing CMOS logic with the company's integrated d/a converters is described in an application note. An analysis of the input circuitry of various d/a converters is shown and input voltage rules are indicated. Also described is a complete CMOS-compatible voltage output d/a converter and a complete CMOS output 8-bit a/d converter, which can be built for under $30. Precision Monolithics, Santa Clara, CA

CIRCLE NO. 373

Removal of flux residues

Removal of rosin and resin flux residues with aqueous chemistry is the subject of a six-page illustrated bulletin. London Chemical, Bensenville, IL

CIRCLE NO. 374

Sampling oscilloscope

How to derive a maximum benefit from the use of a sampling oscilloscope is explained in a 72-page book. The book is supplemented by circuit diagrams and PC layouts. Philips Test & Measuring Instruments, Woodbury, NY

CIRCLE NO. 375

Meter relay

"Meter Magic" describes a cost-saving way to use the company's ac motor load meter relay. Beede Electrical Instrument, Penacock, NH

CIRCLE NO. 376

HP-45 calculator book

To extend the usefulness of the HP-45 advanced scientific pocket calculator, you can use the 218-page applications book that gives the most efficient keystroke sequences for solving over 200 commonly encountered mathematical problems. The book sells for $10 (plus local sales tax). Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304

CIRCLE NO. 376

Cable interconnection

"Electrical Comparisons of Scotchflex Cables" covers design considerations in the selection of cable interconnection systems for high-speed logic systems. The brochure is illustrated with charts and graphs. 3M, Electronic Products Div., St. Paul, MN

CIRCLE NO. 377

Noise reduction

Tech Tips 2-4 tells how to eliminate 120-cycle line noise and rfi in power-controller circuits that use inexpensive bimetallic switches. Westinghouse Electric, Semiconductor Div., Youngwood, PA

CIRCLE NO. 378

ROM simulator

How simple hardware can be combined with the company's 1000A ROM simulator to create powerful design support instrumentation is described in an application note. Scientific Micro Systems, Mountain View, CA

CIRCLE NO. 379

Resistance measurements

"Keeping Power Dissipation Down in Resistance Measurements" outlines the consequences of excessive power dissipation as well as how that dissipation can be kept to a minimum. Keithley Instruments, Cleveland, OH

CIRCLE NO. 380

Converter codes

A handy summary of various digital codes used in data conversion modules is given in a six-page article reprinted from ELECTRONIC DESIGN. Datel Systems, Canton, MA

CIRCLE NO. 381

Small dc motors

"Physical Properties of Small DC Motors Using an Ironless Rotor" gives a brief yet thorough explanation of these properties. Simple mathematical relations are illustrated by practical calculations. The guide can be obtained from Portescap, 165, rue Numa-Droz, CH-2300 La Chaux-de-Fonds, Suisse, at a price of s. fr. 5. or from Portescap, 730 Fifth Ave., New York, NY 10019, at a price of $7.50.

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CMOS guide
A 200-page guide to CMOS devices includes full technical descriptions. A cross-reference guide tracks alternate sources both by manufacturer and device function, and another guide provides instant access to all of the company's product applications. Harris Semiconductor, Melbourne, FL

CIRCLE NO. 382

Pushbutton switches
Lighted pushbutton switches are featured in a four-color brochure. The switches described are available in either single or two-lamp models in either single or split legend designs. Illuminated Products, Anaheim, CA

CIRCLE NO. 383

Microwave devices

CIRCLE NO. 384

Graphic recorders
The Series 2200 graphic recorders are covered in a four-page catalog. EPC Labs, Beverly, MA

CIRCLE NO. 385

Microcomputer manuals
Two new reference manuals for designers of microcomputer control and processing systems cover design concepts, theory of operation, capabilities and applications of the Intellec 4 and Intellec 8 microcomputer development systems. The two volumes are available for $5 each. Intel Corp., 3065 Bowers Ave., Santa Clara, CA 95051

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Eight series of precision electronic connectors are listed and highlighted in a 16-page catalog with all pertinent specifications for each group. Continental Connector, Woodside, NY
CIRCLE NO. 386

Print/plot system
The electrostatic writing technique of the Statos off-line printer/plotter is described in a six-page brochure. Hardware features are described, as well as the JPR software that supports the system. Varian Data Machines, Palo Alto, CA
CIRCLE NO. 387

Digital panel instruments
Technical specifications and prices for digital panel instruments are contained in a four-page catalog. Nationwide Electronic Systems, Streamwood, IL
CIRCLE NO. 388

BASIC/3000 language
Two publications—a 20-page booklet entitled BASIC/3000 Programming Examples and a 44-page BASIC/3000 Interpreter pocket guide—show computer users the full capability of the HP BASIC/3000 language. Hewlett-Packard, Palo Alto, CA
CIRCLE NO. 389

Wire terminals
An 85-page catalog describes wire terminals. Outline drawings and photographs are included. Malco, Chicago, IL
CIRCLE NO. 390

TTL/MSI devices
A 15-page, looseleaf-sized, fold-out brochure is a guide to 300 bipolar TTL/MSI devices. The guide is divided into eight sections: multiplexers and demultiplexers; counters; display products; memory products; shift registers; latches and storage registers; decoders and comparators; and miscellaneous TTL products. National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051
CIRCLE NO. 391

Accelerometers
Principles of operation of closed-loop linear and angular servo accelerometers, performance specifications and dimensional drawings are included in a bulletin. Schaevitz Engineering, Camden, NJ
CIRCLE NO. 392

Socket logic cards
Mechanical specifications of socket logic cards, basic card dimensions and associated packaging hardware are contained in an eight-page brochure. Cambridge Thermionic, Cambridge, MA
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General-purpose relays
An updated data sheet covers Series 354 (formerly GP-1) general-purpose relays. Contact and coil data, dimensional drawings, schematics and pad layouts are included. C.P. Clare, Chicago, IL
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Microwave components
A 64-page catalog describes and illustrates microwave components and assemblies with special emphasis on stripline devices. Performance characteristics, design data, application information, outline and mounting drawings and photographs are included. Lorch Devices, Englewood, NJ
CIRCLE NO. 395

Expandable voice system
Application information, block diagrams, package dimensions, timing diagrams and I/O connections for an expandable voice annunciator system called EVA are given in a four-page brochure. Master Specialties, Costa Mesa, CA
CIRCLE NO. 396

Digital instrumentation
General specifications for digital printers, both numeric and alphanumeric, are given in a 12-page catalog. Also described are printing digital voltmeters and accessory equipment. Practical Automation, Shelton, CT
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Electronic Design 8, April 12, 1975
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</table>

**Unity gain crossover frequency, MHz**

<table>
<thead>
<tr>
<th>CA3080E</th>
<th>CA3100T</th>
<th>CA3094E</th>
<th>CA3078T</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40</td>
<td>25</td>
<td>300</td>
</tr>
</tbody>
</table>

**Slew Rate, V/μsec**

<table>
<thead>
<tr>
<th>CA3080E</th>
<th>CA3100T</th>
<th>CA3094E</th>
<th>CA3078T</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
<td>300</td>
<td>.0015</td>
</tr>
</tbody>
</table>

**Output, mA (peak)**

<table>
<thead>
<tr>
<th>CA3080E</th>
<th>CA3100T</th>
<th>CA3094E</th>
<th>CA3078T</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>10</td>
<td>22</td>
</tr>
</tbody>
</table>

**Power consumption, mW**

<table>
<thead>
<tr>
<th>CA3080E</th>
<th>CA3100T</th>
<th>CA3094E</th>
<th>CA3078T</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.5</td>
<td>5.0</td>
<td>0.75</td>
</tr>
</tbody>
</table>

**Single supply voltage required, V**

<table>
<thead>
<tr>
<th>CA3080E</th>
<th>CA3100T</th>
<th>CA3094E</th>
<th>CA3078T</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5</td>
<td>1.5</td>
<td>1.25</td>
</tr>
</tbody>
</table>

**Price (1K), $**

<table>
<thead>
<tr>
<th>CA3080E</th>
<th>CA3100T</th>
<th>CA3094E</th>
<th>CA3078T</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.55</td>
<td>1.50</td>
<td>0.90</td>
<td>1.25</td>
</tr>
</tbody>
</table>

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RCA. A full house in linear ICs.

INFORMATION RETRIEVAL NUMBER 264