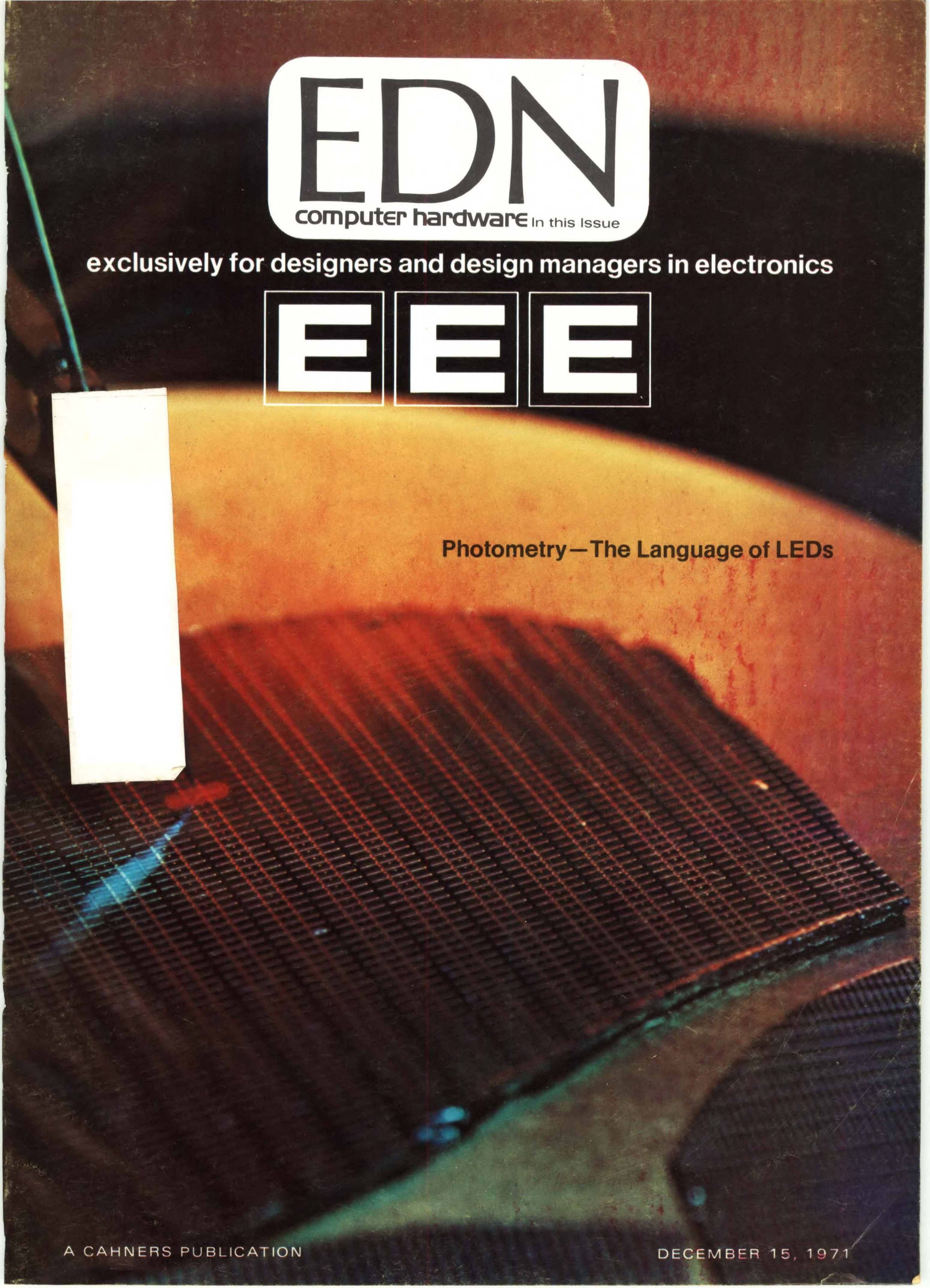
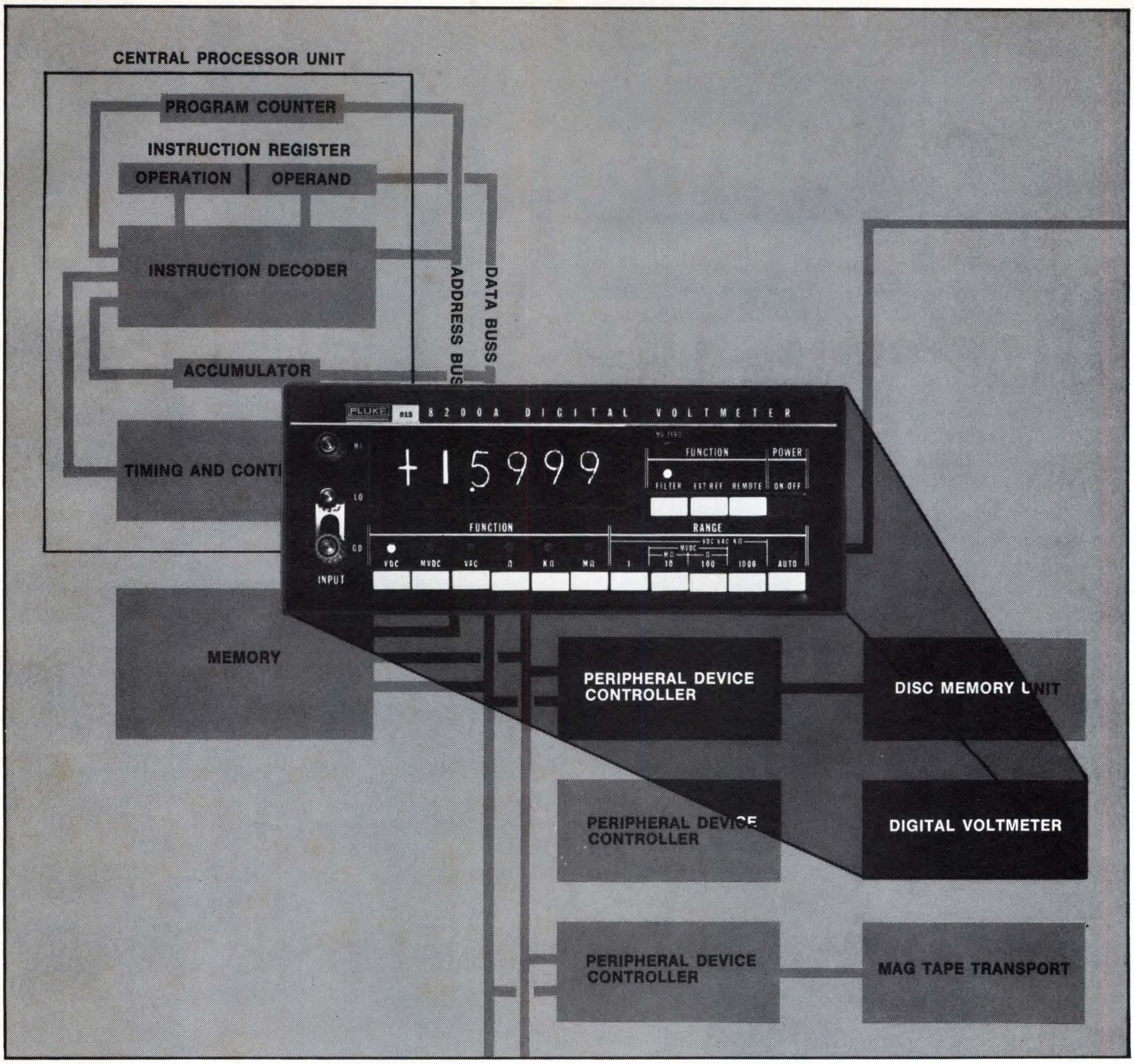
EDN
computer hardware In this Issue
exclusively for designers and design managers in electronics
EEE



Photometry—The Language of LEDs

A CAHNERS PUBLICATION
DECEMBER 15, 1971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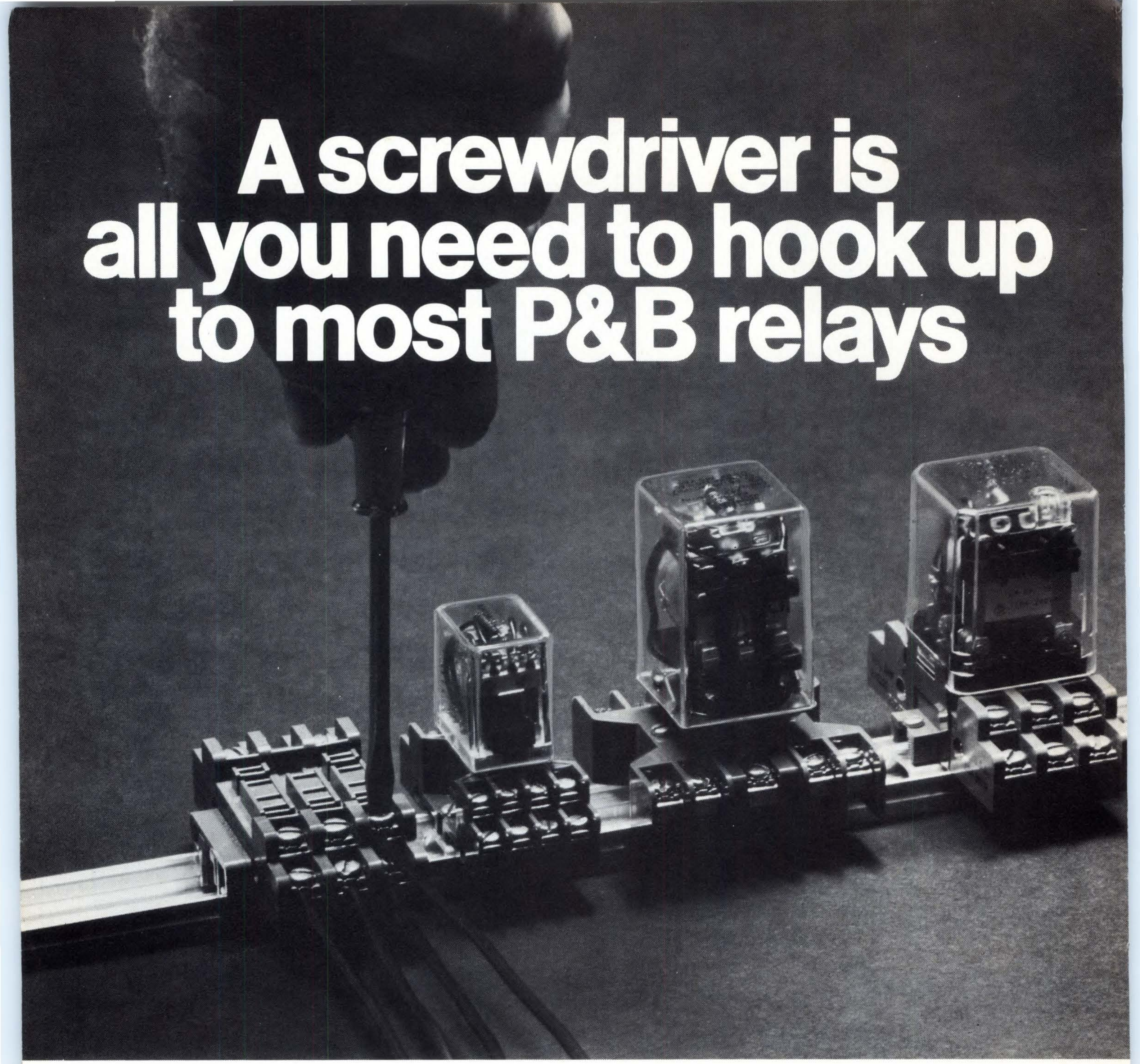
A screwdriver is all you need to hook up to most P&B relays



The new Potter & Brumfield socket system with screw terminals gives you a whole new world of relays to choose from.

How?

By converting octal and quick-disconnect tab termination relays to screw terminals.

Quickly. Simply.

Our system comes complete with mounting channel. Brackets. Retainers. Spacers. And sockets made of virtually indestructible Lexan.

Think of it!

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Just as compatible as the ones you've been using. And every bit as reliable.

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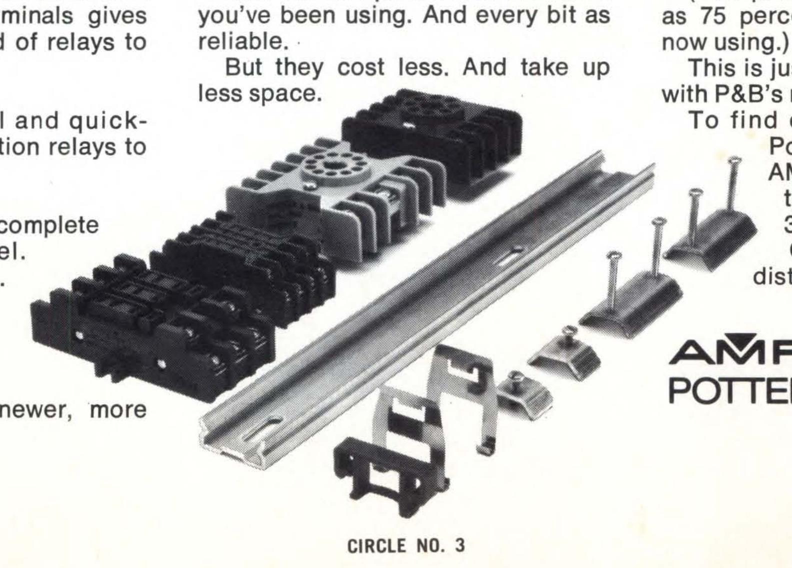

(You probably can save as much as 75 percent of the space you're now using.)

This is just part of what's possible with P&B's new socket system.

To find out more, write or call Potter & Brumfield Division, AMF Incorporated. Princeton, Indiana 47670, (812) 385-5251.

Or talk to your local P&B distributor or representative.

AMF
POTTER & BRUMFIELD

CIRCLE NO. 3

COMPARE CALCULATORS!

If you're looking for a programmable calculator, ask these questions:

YES NO

- ☐ ☐ Can you write equations directly on the keyboard in mathematical form, bypassing computer languages?
- ☐ ☐ Is correct algebraic hierarchy automatically observed in performing all functions? Press 2 X 3 + 4 X 5 =. Do you get the correct result (26) instead of 50?
- ☐ ☐ Will it solve complicated problems and still be easy enough to operate without special training?
- ☐ ☐ Is every function and program clearly and uniquely defined by the key sequence (without modification by toggle or rotary switches)?
- ☐ ☐ Does it have individual left and right parentheses keys that allow you to solve directly expressions such as: $((a+b) - c \div d) X (f-g) = ?$

YES NO

- ☐ ☐ Does it have a true *equals* key to display partial sums or total results immediately?
- ☐ ☐ After a questionable procedure, does operation continue using the best available data? (With an unmistakable indicator showing an assumption was made?)
- ☐ ☐ Is 10 significant-figure accuracy maintained after repetitive sequences such as $\ln x - e^x - \ln x - e^x \ldots$?
- ☐ ☐ Are there a sufficient number of stored constants (26 or 100) that are separate and independent from the program steps?
- ☐ ☐ When data such as $6378.388125 X 10^{-13}$ are entered, does the data appear correctly, or as $6.378388125 X 10^{-13}$?

YES NO

- ☐ ☐ Does it have hard-wired x^y, $\sqrt{x^2 + y^2 + z^2 + \ldots}$, trigonometric, hyperbolic and other functions?
- ☐ ☐ Can you write, store and recall constants and equalities through direct and indirect addressing?
- ☐ ☐ Does it have simple key access to a wide range of peripherals including a 5120-step programmer, printer, X-Y plotter and TTY interface?
- ☐ ☐ Will the calculator serve as the heart of a data acquisition system or minicomputer for on-line data processing?
- ☐ ☐ Can you get prompt, reliable factory service?
- ☐ ☐ Is the basic calculator priced at no more than $3200?
- ☐ ☐ Is it still a money-saver if you add on the "cost of learning" for the people who will operate it?

Every answer is yes for one calculator...

The TEKTRONIX Scientist 909

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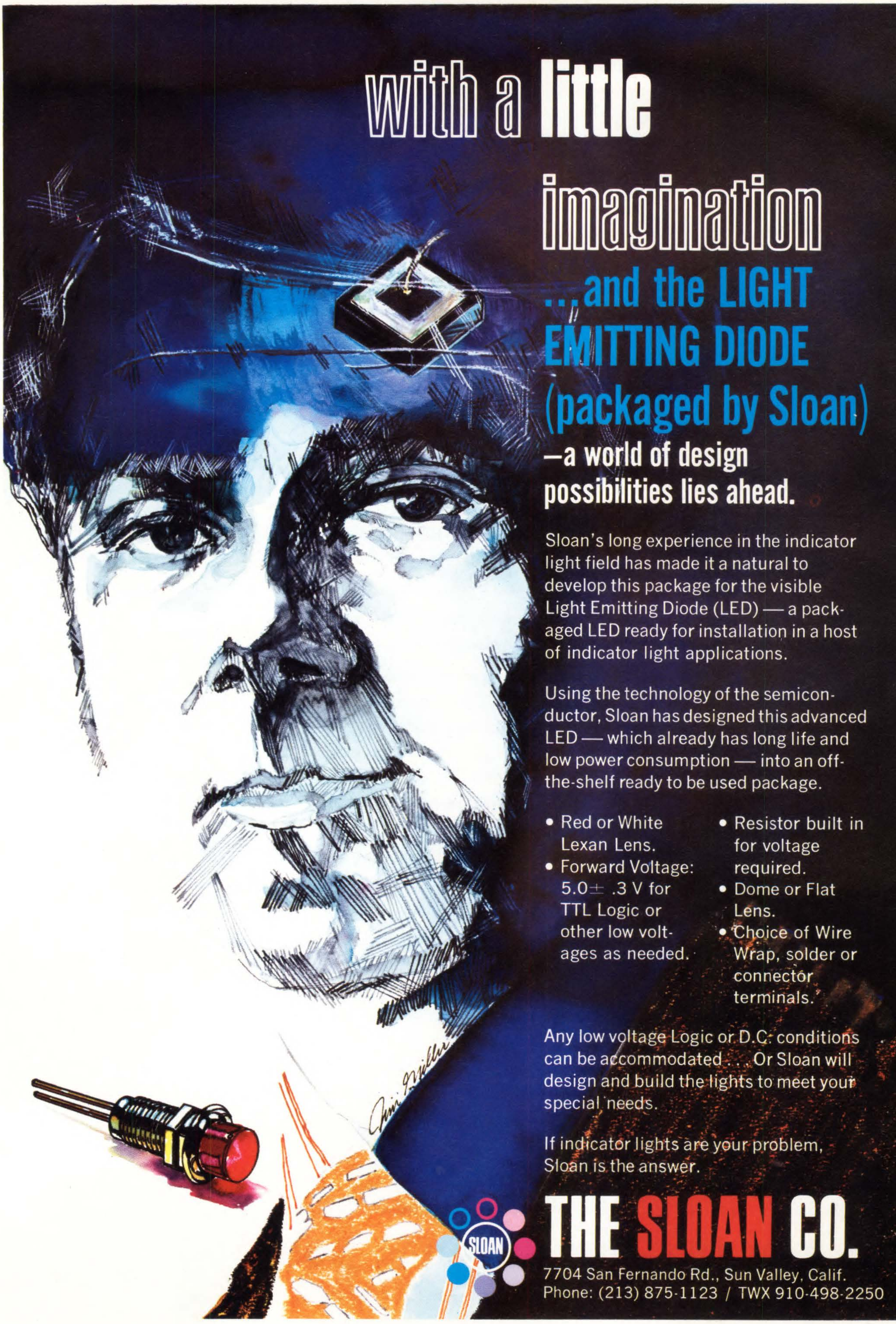
CIRCLE NO. 4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CIRCLE NO. 5

DECEMBER 15, 1971
VOLUME 16, NUMBER 24

EDN/EEE

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

Cover

Cover photo, courtesy of Litronix, Inc., shows an LED wafer being probed during testing. Photo by Dick Steinheimer. (For a look at the language of LED measurements, see "LEDs and Photometry" on p. 34.)

Design News

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Handwriting Transmitted Over Telephone Lines . . . Portable Transceiver Foils Eavesdroppers . . . Design Briefs

Design Features

Choose the Right Commutating Diode for Switching Regulators 22
Fast-recovery diodes offer improved efficiency—and other important advantages as this article explains.

LEDs and Photometry 34
To make sensible use of LEDs you must be able to evaluate them in terms of visual response. Photometric units provide you with the only meaningful way to make this evaluation.

One Instrument Wears Many Hats 40
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Critical Op Amp Considerations for Designing Active Filters 46
If you think that active filters are plug-in substitutes for their passive counterparts, you'd better take a look at this article.

Design Ideas

Inexpensive Inverters Generate V_{GG} for Portable MOS Applications 51
These circuits let you design portable MOS equipment that operates from a single battery supply voltage.

Open-Ended RC Line Model Predicts MOSFET IC Response 53
Investigation of the response time of a string of RC devices, such as a MOS-RAM, can lead to some surprising results. As the string gets longer, the step-response time approaches 1 RC.

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Clock driver for MOS shift registers . . . Simple dc voltmeter uses single op amp.

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Doing Design the Team Way 60
If you really care about the success of development projects you are involved in, you should read this one.

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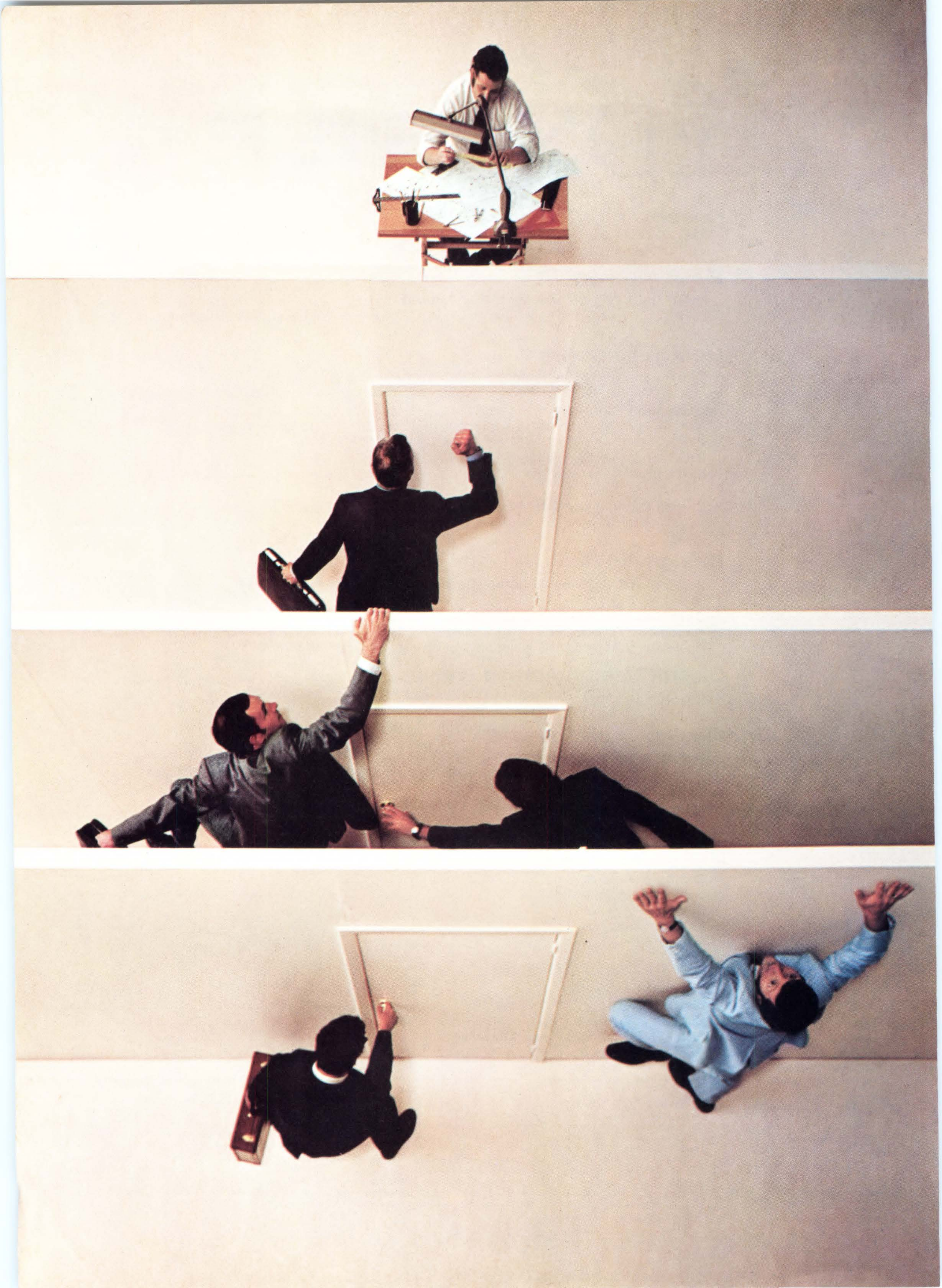

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CIRCLE NO. 7

NEW DIMENSION ELECTRONICS
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Editorial

Any Magazine Is Only As Good As Its Readers

The end of the year has a way of sneaking up on us and this one is no different. All of a sudden here we are working on the last issue of the year, and it just doesn't seem that 23 others have already preceded it in 1971.

At times like this we naturally think back about the many words, articles, and stories we've put together since January and ponder what things we could have done better and what lessons we learned. All of these thoughts about self-improvement are tempered, though, by the realization that a magazine is only as good as its readers. A magazine with a readership of dullards will be dull and lack vitality. And one read by discriminating people who know what they want to read and will exert some effort to obtain it will be lively, interesting and useful.

Most magazines and most readers, of course, fall somewhere between these two extremes. And it's a shame that this is the case, since becoming a turned-on, involved reader is not a difficult task, and has rewards far greater than the effort required.

Consider the average design engineer. He probably receives between 6 and 10 technical and professional magazines every month. And he spends anywhere from 15 minutes to 2-1/2 hours reading each magazine. Conservatively, then, he could spend 8 or 9 hours per month reading these magazines, or approximately 100 hours in a year. This is the equivalent of three weeks of his time, which most would agree is appreciable.

When someone spends this amount of time with the technical press, he is being foolish and less than careful with his time if he is a passive, uninvolved reader. This isn't to say that readers should try to dictate specific magazine content or philosophy. Editors and publishers wouldn't allow this. But they should make their feelings known, and strongly, when they feel that their interests or reasons for reading a magazine are being forgotten or compromised. This applies not only to editorial, and its quality and direction, but to things like advertising and response to reader service requests as well. Magazines may not respond the way you would like to all of your complaints, suggestions and gripes, since they have many readers with various interests to serve. But with no dialogue, the partnership between magazine and reader can one day become bankrupt.

So if you're going to spend three weeks in 1972 reading technical and professional magazines, it should be worth just a little extra of your time to become an involved reader.

Frank Egan

EDITOR

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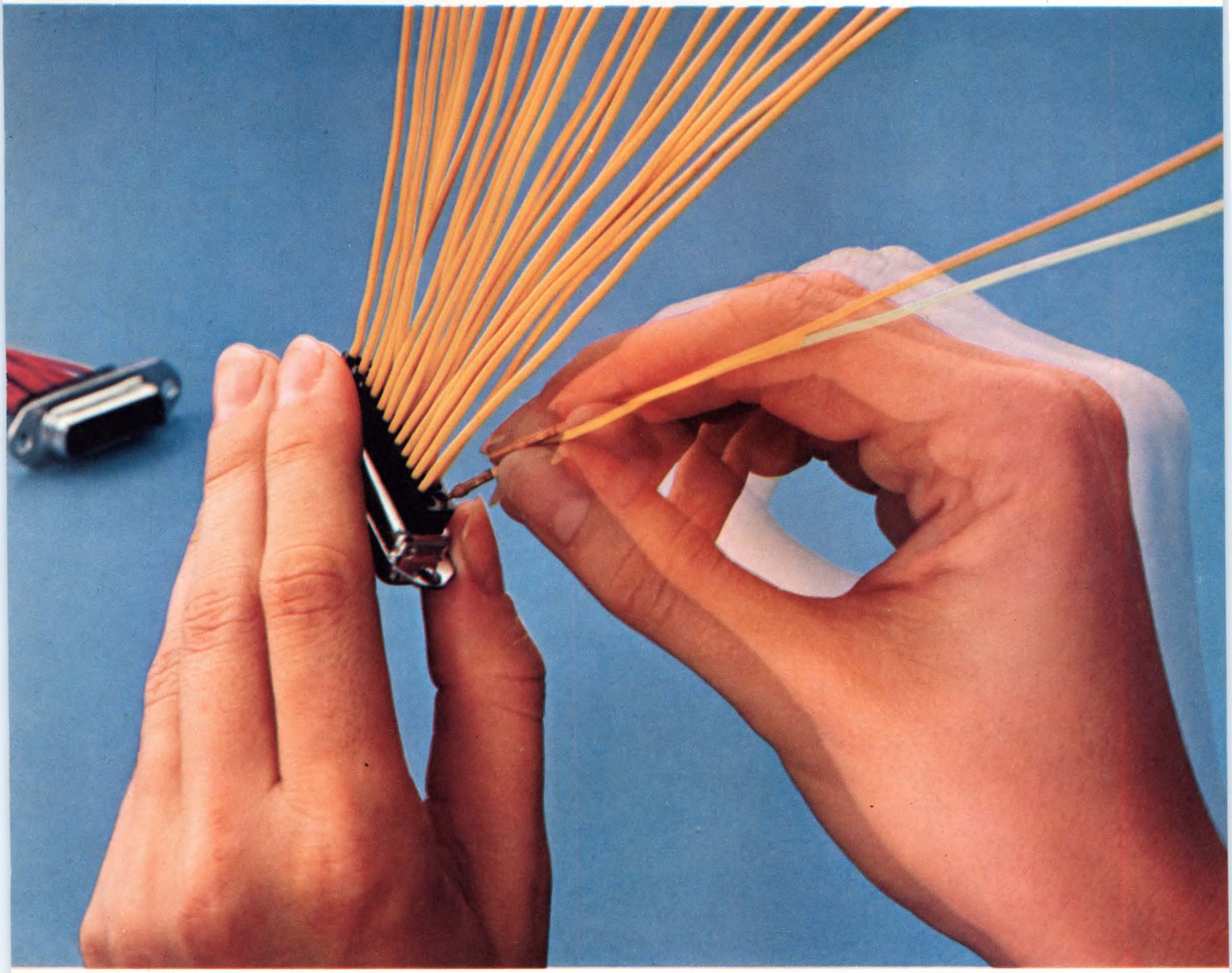
Make the simple move



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CIRCLE NO. 9

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Solid State Screens Display X-Ray Patterns

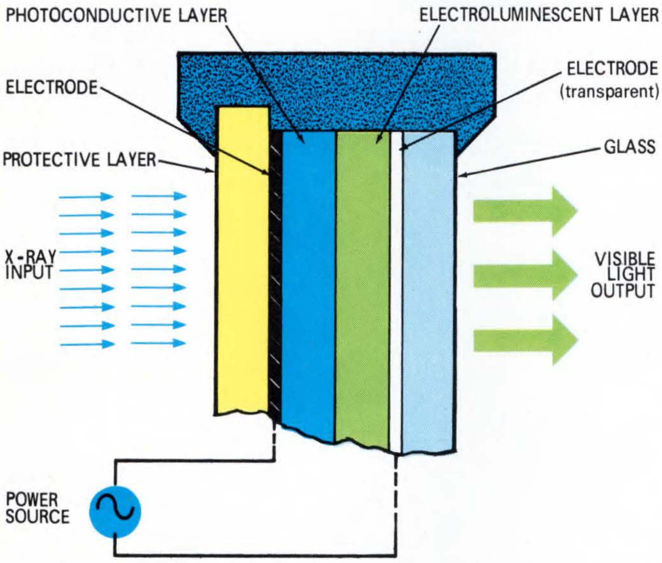

Fig. 1—Basic construction of X-ray image converting panel is shown in this cross section. Due to light amplification, the panel produces images with much greater brightness and contrast than is possible with fluoroscopic screens.

Storage screen held by Dr. Zoltan Szepesi of Westinghouse is one of three sizes offered in both storage and nonstorage types.

Two electronic manufacturers, one foreign and one domestic, have announced plans to market X-ray image-converting panels for use in nondestructive testing.

Westinghouse Electric Corporation's Electronic Tube Division, Elmira, N.Y. is offering both a storage and nonstorage type of screen in various sizes ranging from 10 by 10 inch to 3 by 3 inch. National Panasonic, Matsushita Electric Industrial Co. Ltd., Osaka, Japan will enter the market with a 4.75- by 6.5-inch panel and a desktop inspection system that houses an X-ray generator and viewing screen.

The panels are designed to be direct replacements for existing fluoroscopic screens according to Westinghouse. The advantage of the solid-state devices is that they provide light amplification, and thus give higher brightness and contrast. Resolution is also said to be improved. In addition, with the storage-type screen, images may be studied for long periods without continuous exposure of the subject to radiation. Storage time is several hours, or until an image is erased electrically.

Although the principle of operation has been known for more than 10 years, it has not been put to practical use until now. Conventional fluoroscopic screens provide visible light directly when a luminescent material (calcium tungstate or zinc sulfide) is energized by X-ray radiation. The solid-state panels, however, consist of a combination of photoconductive material and electroluminescent material (**Fig. 1**). Electrical resistance of the photoconductive layer decreases when it is exposed to X-rays. The electroluminescent layer, which is applied next to the photoconductive layer emits light when a voltage is applied. In use a voltage is applied across the two layers. When the photoconductive layer is exposed to X-rays, its resistance decreases, thus more of the applied voltage is dropped across the electroluminescent layer causing it to emit more light. The light pattern emitted exactly corresponds to the pattern of incident X-rays.

The panels are reusable and require no delay for photographic processing, thus providing a time and cost-saving alternative to X-ray photographic equipment. The manufacturers suggest that they might also replace X-ray image intensifier and TV systems because of high performance capabilities and low cost.

In addition to applications in nondestructive testing, it has been suggested that the panels could be used for baggage and food inspection and for some medical applications.

Think Twice:

If your job depends on your ability to make measurements... check out HP's new scopes.

You owe it to yourself. The days of the "gravy train" in the electronics industry are over. Today, you have to do a really outstanding job to get ahead—or even just to hold on to what you've already got.

That's why it's imperative that you *double-check* before making purchase decisions today — especially decisions on something as important as a new scope. Because, if you *do* make comparisons between the available alternatives, you'll be in an unassailable position to justify your choice—whatever it is—and in a pretty poor position, if you don't.

This is important because, today, as never before, you're going to be judged on your ability to do the best possible job at the lowest possible cost. Pinched for profits, management is now demanding hard-nosed justifications for every decision. They're examining *total acquisition costs,* as they've never done before.

As a result, doing things just because "you've always done them that way" can be deadly. Because now, it's a whole new ball game. The old reasons for "sticking with the tried and true" are out the window.

Take scopes, for instance. The current generation is so different from the last generation that the decision to buy *any* new scope—whether ours or our competitor's—involves a whole battery of related changes. New test procedures. New calibration setups. New parts inventories.

Thus, to be sure that you're getting the best buy, in terms of performance vs. total acquisition cost, you should thoroughly check *both* manufacturers' offerings.

Check prices. Find out exactly how much it will cost to get the measurement capabilities you need, including all accessories. In many cases, you'll find that Hewlett-Packard can save you a significant amount.

Check Performance. Call us for a "hands-on" demonstration of the scopes or systems that are *most relevant to your particular needs.* Remember—what counts is the ability to meet *your* frequency, accuracy, and sensitivity requirements... not technological "fireworks displays" in areas far from your own concerns.

Check ease of use. Compare simplicity of controls, display size, error-prevention devices. Does the scope you're considering have *useful, time-saving* features, like selectable input impedance, variable persistence storage, bandwidth to meet your current and near-future requirements, and simplified sampling...or just flashy "bells and whistles" that add little to usability, and a lot to the price?

When you make these comparisons, we think you'll choose Hewlett-Packard. We've found that once people get the facts, they usually do. For a revealing package of information on H-P's new scopes, send for a free copy of our "No-Nonsense Guide to Oscilloscope Selection." Or contact your local H-P field engineer for a demonstration. Check before you choose. Hewlett-Packard, Palo Alto, California 94304. In Europe: 1217 Meyrin-Geneva, Switzerland.

Scopes Are Changing;
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082/1

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OSCILLOSCOPES

CIRCLE NO. 11

IR laser communicator provides secure point-to-point communications to a range of four miles.

Portable Transceiver Foils Eavesdroppers

A new hand-held laser communicator, designed to be as simple to use as binoculars, has been developed and demonstrated by the Santa Barbara Research Center, a subsidiary of Hughes Aircraft Company.

The self-contained 3-lb transceiver uses a gallium-arsenide laser, with output in the infrared, to provide a directional beam that assures secure point-to-point communications. Low power consumption permits operation from a small rechargeable battery mounted within the body of the receiver unit.

Because of its wide-angle transmitter beam design, the communicator may be used under any conditions that allow the use of binoculars. Range of the communicator depends on visibility and degree of divergence desired. For example, when visibility is ten miles or greater, a version with 2° divergence will have a maximum clear communications range of four miles. A 3° version has a 2.5-mile range under the same atmospheric conditions.

During signal transmission, the gallium-arsenide laser diode is pulsed at a reference pulse-repetition rate which is frequency modulated by the voice signal inputs. Each light pulse has a period of 100 nsec and reaches a peak power of 10W. Pulse transmission is started by talking into a built-in microphone.

The receiving portion of the unit is optically aligned to receive the transmitted pulses through a 2.5-inch aperture. The received energy is then processed using special techniques to enhance the signal-to-noise ratio. The pulses are then amplified and the repetition rate is demodulated to convert the received pulses into audio or data signals.

Modular design of the communicator permits field replacement of the transmitter or receiver optics assemblies.

One 500-mA-hour, 6V dc nickel-cadmium battery provides power for the communicator. Transmitter consumption is approximately 100 mA during transmission only, and receiver drain is less than 3 mA. Battery recharge inputs and an earphone set are provided.

The manufacturer forsees applications for the units in ship-to-ship communications, riot control, tower-to-tower transmission in the forestry service and a variety of battlefield uses.

Handwriting Transmitted Over Telephone Lines

Handwritten information may one day be routinely transmitted and received over the same telephone lines that now carry conversations. Engineers at Bell Telephone Laboratories have put together an experimental system that demonstrates the feasibility of such a device. They call it the "remote blackboard".

In order to transmit handwriting and graphic information, the system uses a tiny location indicator attached to a writing instrument, such as a pen or chalk, to determine all movements performed on a writing surface. The indicator is a commercial electronic device that provides a steady series of ultrasonic pulses as it is moved over a writing surface bounded by two continuous-strip or bar-shaped microphones. The microphones accurately detect the location of the chalk or stylus at any point on the writing area. Lifting the location detector from the writing surface interrupts the pulse signal. Handwriting motions in the system generate a stream of electrical pulses that are fed to a data set. Here they are converted to signals that are easily transmitted over telephone lines. At the receiving terminal, another data set translates the incoming signals back to electrical pulses to drive two galvanometers which deflect an untraviolet light beam in accordance with the signals received. As the beam moves across a special photosensitive film, the original handwriting is reproduced and simultaneously projected onto a wall or a screen.

Bell Labs engineers envision the system's use to bring classroom instruction to bedridden or invalid students, and to be used with a recently introduced portable conference telephone to transmit both audio and graphic information to distant classrooms, conference rooms and offices.

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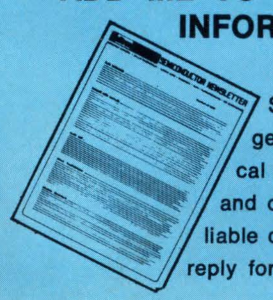

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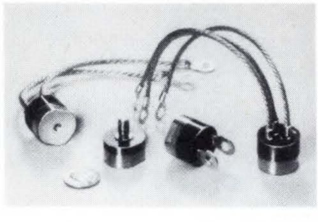
LO-VF CUPAC-150



New high current silicon rectifier with fast (t_{rr}100ns) recovery and low forward voltage characteristics. The OFHC insert base and stud allow the internal Metoxilite rectifiers to be heat sunk from cathode, anode or both.

New LO-VF CUPAC-150 are available in doublers, center taps and 3 phase ½ wave bridge with PIV of 30 and 50 volts per leg.

Designed for industrial, military and space applications where high frequency and high power are essential.

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For over a decade Semtech Corporation has been the leader in rectifier design and development. Many of these designs have become industry standards, unequalled for reliability and performance. Both the SLIMPAC and ALPAC series are typical, with proven records of excellence and dependability in the most difficult space, military and industrial applications.

SLIMPAC®- High Voltage, High Current Rectifiers

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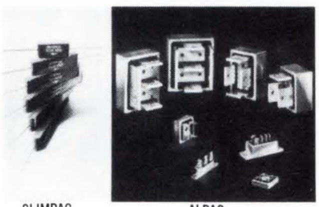
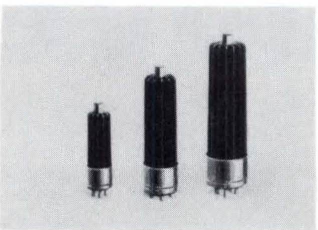
The entire SLIMPAC series has corona free construction and meets the most stringent life and environmental requirements.

ALPAC®- Power Rectifiers

The ALPAC series is a complete line of silicon bridges, doublers and center taps. These power rectifiers offer PIV ratings from 50 to 600 volts and average rectified current from 25 to 250 amps. All ALPAC devices offer the superior thermal characteristics of aluminum cases. Terminals are completely insulated. ALPAC is economical, small and easy to mount. The entire ALPAC series is field tested and available for immediate delivery.



SLIMPAC ALPAC

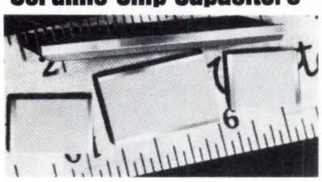


Replace High Voltage Mercury Tube Rectifiers with TUBEPAC

For the first time you can now replace a large selection of obsolete high voltage Mercury and Vacuum glass tube Rectifiers with Semtech's Solid State Silicon Rectifier Stacks called TUBEPAC.

Designed to last the life of the equipment, Semtech's Stacks are smaller, corona free, dissipate heat more effectively and eliminate filament power. No special adaptors are required to use Semtech's Stacks.

High Voltage Multilayer Ceramic Chip Capacitors



Semtech introduces a new line of high voltage energy storage ceramic capacitors for high density packaging.

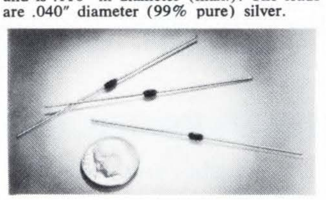
With voltage ratings from 400 to 1,600 V and capacitance from 1,000 to 270,000 pf, the chips are available in single and multiple styles.

Low Dynamic Impedance ZENERS–

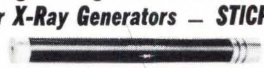
Semtech's new low dynamic impedance zeners offer voltages of 30 to 120 Volts for 1, 3 and 5 watt applications.

This new series of devices offers ⅓ lower dynamic impedance when compared at the same operating current to those presently available.

The Zener measures .165" long (max.) and is .110" in diameter (max.). The leads are .040" diameter (99% pure) silver.



A High Voltage Silicon Rectifier for X-Ray Generators – STICPAC



Design engineers faced with the problem of selecting high voltage rectifiers for X-ray generators and other stringent applications will be interested in our new STICPAC silicon rectifier.

Measuring .695" in diameter by 3.38 to 8.50 inches in length, STICPAC is ideal for replacement of vacuum tube type rectifiers.

STICPAC is available in five voltages: 50, 75, 100, 125 and 150 kV; average output, 100 mA/55°C in an oil environment.

METOXILITE

The new standard – "Look, no cavities"

Introduced less than three years ago, non-cavity METOXILITE has revolutionized reliability and packaging in the high voltage rectifier field.

Through utilization of new design and manufacturing techniques, the METOXILITE device provides the ultimate in hermeticity and ruggedness. The metal oxides which form the outer case material are fused directly to the high temperature metallurgically bonded assembly.

METOXILITE has proven itself through 1 and 3 amp devices with PIV ratings up to 1000 volts in both medium and fast recovery characteristics.

The METOXILITE device exceeds environmental requirements of current military and space specifications. A general purpose rectifier suitable for all applications.

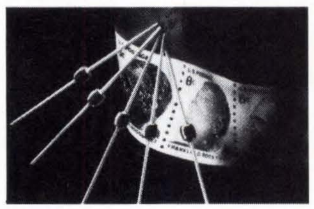
New - LO-VF METOXILITE (T_{rr} 100ns)

These new LO-VF METOXILITE silicon rectifiers permit working at higher frequencies and higher forward efficiencies.

The components are ideally suited for small electronic package design particularly for communication, navigation and other uses in the aircraft, automotive and railroad fields.

LO-VF METOXILITE is available with 3 amp ratings at peak inverse voltages of 30 and 50 volts. Can provide an average rectified current of 6 amps if mounted per MIL-STD-750. Capable of exceeding environmental requirements of military and space programs.

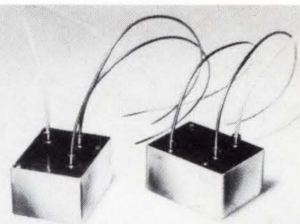
In addition, higher current rectifiers and high power assemblies such as doublers, center taps and bridges are available with these new parameters.



METOXILITE to 3000 Volts

A new high voltage rectifier is offered for the first time as a general purpose device in METOXILITE.

Peak Inverse Voltage: 2000 to 3000 V.
Average Rectifed Current: 250 mA
Maximum Static Reverse Current @PIV
35°C: 1 μ amp
100°C: 25 μ amps
One Cycle Surge: 10 amps



New High Voltage Multiplier Goes Anywhere!

Semtech's new high voltage multipliers feature a metal case to shield RFI and permit latitude in its mounting in equipment using cathode ray tubes. These devices now can be supplied as a tripler or quadrupler, with output voltages up to 36,000 volts. The external environment no longer need have an effect upon the reliability and electrical performance of high voltage multipliers, according to Semtech engineers. Advantages include: better display; increased reliability; longer life; elimination of the X-Ray problems of high voltage vacuum tubes; simplified circuitry, and improved over-all performance. The device eliminates high voltage vacuum tubes, critical transformer windings and associated hardware, and all of the corona problems normally thought of in connection with these items. CRT Pac Multiplier can be mounted anywhere on the chassis. This new series of devices complements Semtech's existing line of custom-made high voltage multiplier assemblies.

MINISTAC® High Voltage – High Frequency

MINISTAC is a fast-recovery, silicon, microminiature rectifier that can replace vacuum tubes and selenium sticks. Offering easier mounting and a smaller package, MINISTAC is competitively priced. Due to Semtech's high-volume production techniques, MINISTAC is being produced without sacrificing quality or reliability.

Peak Inverse Voltage: 3kV to 7kV
Average Rectified Current: 10mA
Leakage Current: 100nA
Junction Capacitance: 1pF max.
Recovery Time: 100ns
Dimensions: .120"D x .400"L

MINISTIC® to 40kV

For even higher voltages — from 10kV to 40kV. MINISTIC measures a little larger, .250" in diameter and from 1.125" to 4.275" long, depending on the PIV specified.

Circle Reader Service #97

$$SAVERS$$

IMPAC — (50 to 600 V) Low cost epoxy rectifier.

KVPAC — (5 to 15kV per leg) Commercial high voltage rectifier assembly.

SEMTECH CORPORATION

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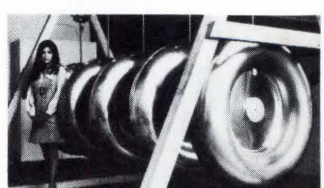
EUROPEAN SALES — Bourns A. G. Baarerstrasse 8, 6301 Zug, Switzerland — (042) 21-78-77

ONE MILLION VOLT CAPACITY

Semtech's STACPAC completely eliminates all external component parts and solder joints — all components are encapsulated and connected to aluminum discs. These discs serve as compensation, cooling fins and corona protection.

By utilizing METOXILITE silicon rectifiers only, Semtech has reduced the number of temperature sensitive components and simplified the overall configuration.

Semtech offers STACPAC in Voltages of 4kV, 5kV, 7kV, 25kV, 32kV, as well as a 840,000 volt (3 amp) device.



CIRCLE NO. 13

Ion-Implantation Moves Ahead

Ion implantation technology continues to advance. This was borne out at the recent International Electron Devices Meeting in Washington, D. C. where, of the twelve papers presented on the subject, nine described applications other than the most commonly known ones.

A. Y. Jaddam of GTE Laboratories, Bayside, N.Y., described a novel way of making complementary-enhancement depletion-mode transistors. The most common approach is to start with high threshold (V_T) p-channel devices, adjust the V_T of the enhancement device by ion implantation and then implant the channel of the depletion device until it becomes depleted. However, GTE starts with n-channel devices which are all depleted and then selectively implants the channels of some until they become enhancement mode transistors. The result is increased circuit speed with constant V_T under all substrate-to-source back bias conditions, and ability to operate from a single 3 to 5V power supply.

Hughes Aircraft Company, Newport Beach, Calif. presented two new applications of ion-implantation technology. T. N. Toombs described a new CMOS called CMOS-3 in which one of the previous objections to CMOS density has largely been overcome. Ion implantation is used to form a p-well in an n-type substrate, for source and drain junctions, for threshold shifting and for inversion control. The combination of the above, along with use of planox oxide as a mask and a p-doped silicon gate, gives about triple the original packing density while increasing speed for a given power level. Cell sizes of 8 sq. mils/bit for a dynamic shift register and 16 sq. mils/bit for a static shift register have been achieved. This can be compared to respective cell sizes of 4.5 to 14 sq. mil/bit and 12 to 25 sq. mil/bit for dynamic and static shift registers made by p-channel silicon-gate technology.

D. M. Erb showed how to make high source-drain breakdown voltage MOSFET's on the same chip with conventional MOS circuitry. What Hughes has done is to create an offset channel by lightly doping an unmetallized gate oxide region between gate and drain junctions, thus giving breakdowns greater than 240V. This now makes it possible to include decoding circuitry on the same chip as the display-tube high voltage drivers.

Bell Telephone Laboratories described a number of advances. Among them was a double-implanted NPN silicon transistor that has high gain and excellent β uniformity across a slice, thus giving high yields. High gains also can be achieved by double diffusion but yields are low. New design concepts are expected from this technology.

NEREM Covers All Disciplines

In an effort to beef up the basic conference and to more efficiently utilize conference attendants' time, NEREM '71 combined several smaller conferences with the main one. Part one combined the Pollution Measurement and Control Conference which covered all aspects of water and air pollution; a Transportation Conference which looked at various aspects of mass transportation; Solid State Devices and Circuits Conference covering such things as future memory systems, the newest linear and digital circuits, and solid-state microwave power generation; and a Computer Applications Conference where minicomputers, circuit analysis CAD and computer graphics were discussed. Other areas covered were communications, laser applications, digital signal processing, educational technology, and various professional career guidance sessions.

Part two of NEREM '71 was a Medical Engineering Seminar dealing with all aspects of electronics in medical engineering. The 1971 Eastern Electronic Packaging Conference made up part three and looked at packaging from the microcircuit to equipment levels in addition to machine aids to design and automated manufacturing techniques.

Copies of conference papers are available in three parts; $10 for part 1, $20 each for parts 2 and 3. Write to: Business Manager NEREM, Boston Section IEEE, 31 Channing St., Newton, MA 02158.

Some straight talk about MECL 10,000...

Perhaps you have already evaluated MECL 10,000 and discovered the many ways your system performance can be improved. Or, you may have questions concerning its application and you are considering various logic options. Here are a few answers to questions commonly asked. And if you don't know the answers, don't worry, we'll show you how to become a MECL 10,000 expert.

Q. How fast is MECL 10,000 and can it be adapted to very high speed systems?

A. MECL 10,000 offers 2 ns gate delays combined with low power dissipation (25 mW/gate). Where necessary, MECL 10,000 is compatible with MECL III to "shift up" for the high data rates required in critical timing chains.

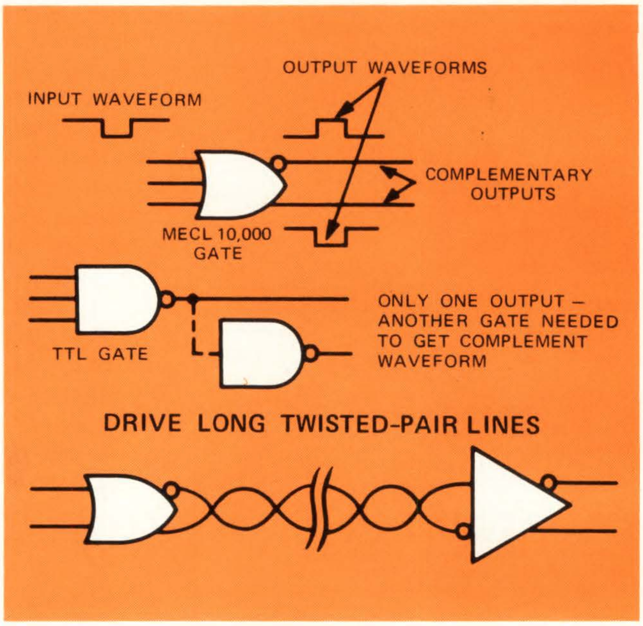
Q. Are special PC boards required?

A. No. Although toggle rates are as high as 150 MHz, switching rise and fall times are slow enough (edge speed 3.0 ns) so that conventional system layouts such as two sided PC boards can be used. Also, the slow edge speeds allow the added flexibility of driving open wire, wire over a ground plane, wirewrap, or coax.

Q. How can MECL 10,000 improve system performance and cut costs?

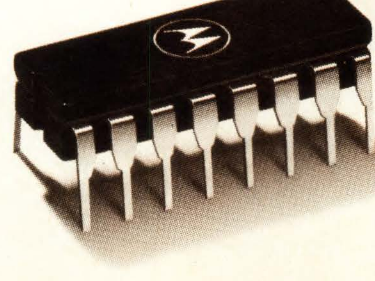
A. MECL 10,000 provides design flexibility in many ways. For instance, the open emitter outputs and high impedance inputs allow wire-"OR"ing of several levels of gating, with a marked savings in gate and package count. Open emitter outputs allow data "bussing" and two-way data transfer. Also, the open emitter outputs allow complete flexibility in the choice of terminating schemes and logic interconnects.

Complementary (OR/NOR) outputs provide simultaneous "true" and "complement" functions, minimizing gate and package count in a system. And the complementary outputs provide excellent twisted pair (differential) line drivers at standard gate prices.



Q. How many functions are available in MECL 10,000?

A. Motorola has introduced 16 devices to date and now two more are available; the MC10116 Triple Line Receiver and the MC10160 Twelve-Bit Parity Generator/Checker.



CHOOSE THE RIGHT COMMUTATING DIODE FOR SWITCHING REGULATORS

Improved diodes with extremely fast recovery times have an important application in switching regulators. The design engineer should understand the effects of diode speed on circuit behavior.

ED EBY, TRW Semiconductor Div.

Switching-regulator circuits usually include a commutating diode (also referred to as a "free-wheeling" or "catch" diode). **Fig. 1** shows the power section of a typical switching regulator in which CR_1 is the commutating diode. The function of the diode is to provide current to inductor L during the time when Q_1 is not conducting.

The transistor is alternately switched on and off by the control circuitry. Thus the current "commutates" between the transistor and the diode. The relationships between the transistor current I_{Q1} and the diode current I_f are shown in **Fig. 2**.

Ideally, the current waveforms would not have the spikes (with magnitude I_{pr}) shown in **Fig. 2**. These spikes occur because the diode is non-ideal and has a finite switching speed, or reverse recovery.

Reverse Recovery

All pn junction diodes exhibit a phenomenon known as "minority-carrier sweepout." The effect is that, immediately after forward conduction, the reverse-biased diode essentially acts as a short-circuit for a finite period of time T_R (see **Fig. 2**). In a switching regulator, this means that the transistor must supply the nominal load current, I_{load}, plus the peak reverse-recovery current I_{pr}. As was illustrated in **Fig. 2**, extremely large current spikes can occur during the recovery period, T_R.

In a switching regulator circuit, therefore, a slow commutating diode can adversely affect circuit performance in three ways:

−1. The transistor must pass excessive currents at full power-supply voltage for finite periods of time. This overstresses the transistor and cause premature failure.

−2. Excessive "short-circuit" current pulses may upset the primary power source, thus causing noise elsewhere in the system.

−3. Efficiency of the switching regulator decreases with increasing operating frequency. This is because the period of excessive current (*i.e.* power loss) becomes a predominant portion of the transistor's on time.

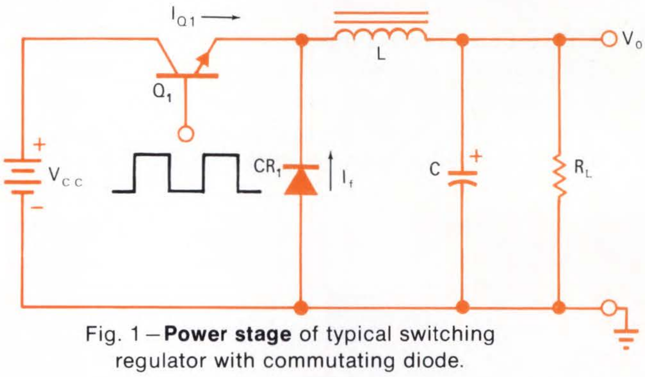


Fig. 1 — **Power stage** of typical switching regulator with commutating diode.

A useful figure of merit for switching diodes is known as T_{RR}. This parameter is normalized and it takes into account both I_{pr} and T_R. It is measured by forcing 1A in the diode's forward direction, reverse biasing the diode while limiting peak reverse current to 1A, and then measuring the time required for recovery to −0.5A. This procedure is illustrated in **Fig. 3**.

Recovery and Efficiency

Experience has established that diode recovery time affects the efficiency of a switching regulator. But how much effect does the diode have and what sort of efficiencies can be realistically expected with commercially available diodes?

To determine the answers to this question, the author built an experimental circuit similar to that shown in **Fig. 1**. Several different types of diodes were tested in this circuit. The circuit delivered 95W to the load and was operated at a 50% duty cycle. The nominal load current was 3A. For each diode, the forward drop was measured at the nominal load current. The parameter T_{RR}, as defined in **Fig. 3**, was measured for each device.

In **Fig. 4**, we see a dramatic illustration of the relation of T_{RR} to the amplitude I_{pr} of the excess-current spikes. So called "fast" diodes with T_{RR} Of 200 nsec

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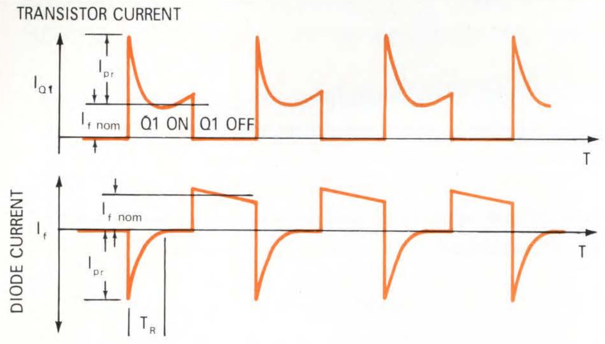

Fig. 2—**Relationship between currents** in switching transistor (top) and commutating diode (bottom).

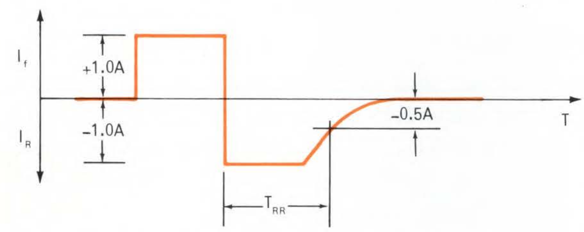

Fig. 3—**Current waveofrm through diode** during test of normalized reverse recover time, T_{RR}.

produced peak reverse currents over five times greater than the forward current (see **Fig. 4a**. As shown in **Figs. 4b**, **4c** and **4d**, the amplitude of the excess current spikes steadily decreased as faster and faster diodes were used. With a 12-nsec diode, the current ratio I_{pr}/I_f was reduced to less than one.

Using the same test circuit, it was confirmed that the ratio I_{pr}/I_f remains constant over broad ranges of I_f and switching frequency. Thus, if you know I_f and T_{RR} you can predict the peak recovery current. Alternatively, if you know the worst ratio that can be tolerated, you can select a diode with suitable T_{RR}. The curve in **Fig. 5** relates the current ratio to T_{RR} to facilitate the calculation.

Regulator Efficiency

Overall efficiency of a switching regulator obviously will decrease as the switching frequency is increased. This is partially because the commutating diode's recovery time occupies a greater portion of the switching period. As shown earlier, at any given frequency, the device causing the shortest T_R (hence, having the shortest T_{RR}) will yield the most efficient circuit.

Normally, regulator efficiency would be defined by the following well-known equation:

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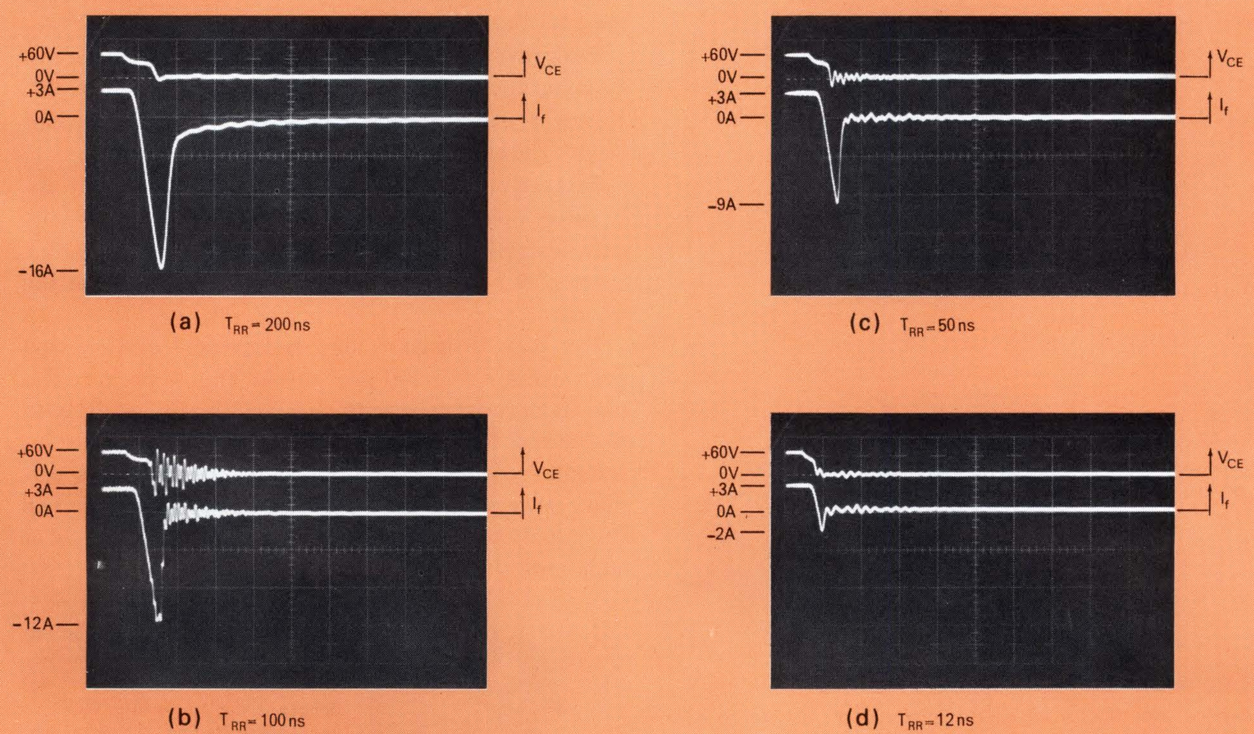

Fig. 4—**Scope pictures showing peak values of reverse current** when diodes with various values of T_{RR} are used in the same switching regulator circuit. A so called "fast" diode with T_{RR} of 200 nsec produces a peak reverse current of 16A (A). Excess peak current gets smaller and smaller as faster diodes are used, until a 12-nsec diode (D) produces peak reverse current under 2A. Time-base for all pictures was 100 nsec per division.

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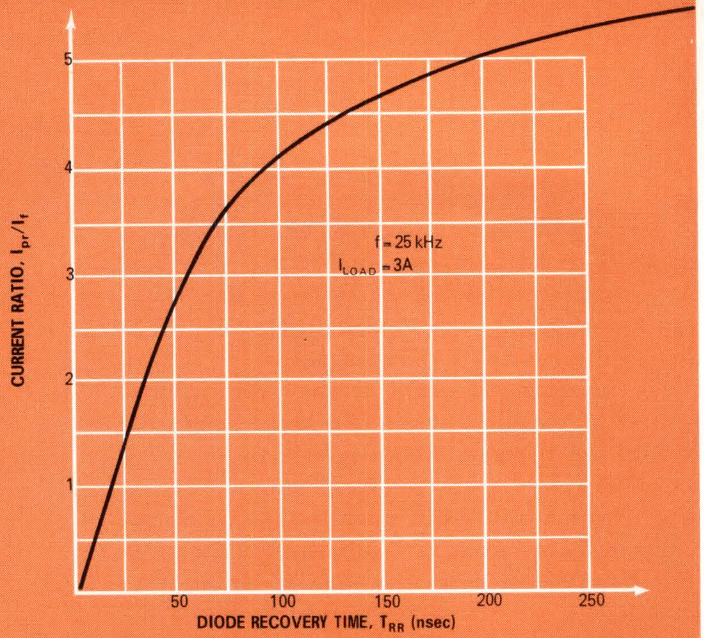


Fig. 5—**Relationship between current ratio and diode reverse recovery time.** Slow diodes give poor current ratios because of the large reverse current spikes.

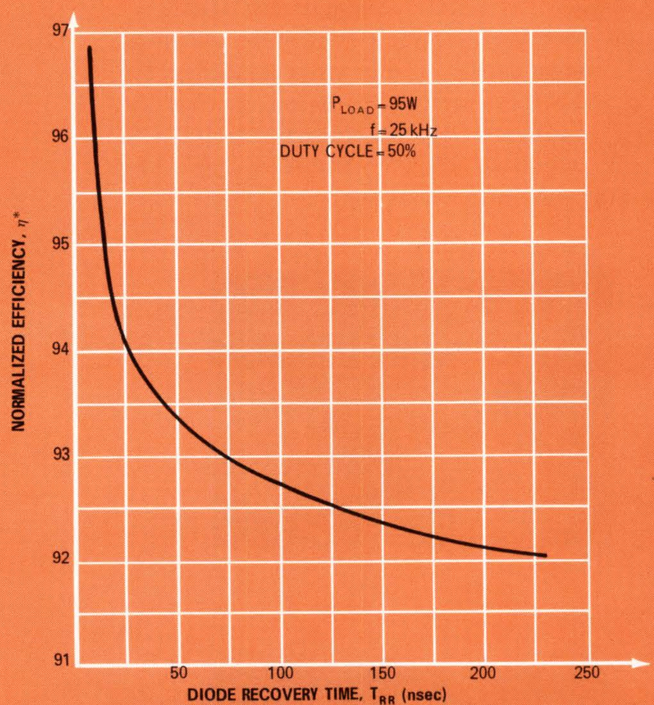


Fig. 6—**Effect of diode recovery speed** on regulator efficiency. For this test, the effects of diode forward drop were excluded from the efficiency calculation to show more clearly the effects of diode speed.

$$\eta = \frac{P_{load}}{P_{in}} \qquad (1)$$

But we would like to eliminate the influence of device-to-device variations in diode forward drop and to examine primarily the effect of recovery time on efficiency.

The input power P_{in} contributes to the output power plus various losses as shown in the following equation:

$$P_{in} = P_{load} + P_{circuit\ loss} + P_{diode\ sat} + P_{diode\ switch} \qquad (2)$$

where $P_{diode\ switch}$ is the switching loss caused by the

Commutating Diode (Cont'd)

T_{RR} of the diode. Other losses consist of diode forward drop at the rated load current and miscellaneous circuit losses.

If the diode saturation losses are subtracted from P_{in} we can derive a modified value P^*_{in}:

$$P^*_{in} = P_{in} - P_{diode\ sat} \qquad (3)$$

Then we can modify Equation (1) to produce a normalized efficiency η^*:

$$\eta^* = \frac{P_{load}}{P^*_{in}} \qquad (4)$$

Finally, we can plot η^* against T_{RR} to show the effect of normalized recovery time *alone* on switching regulator efficiency. The resulting curve is shown in **Fig. 6**.

Summing Up

As has been demonstrated, the commutating diode is one of the most critical components in a conventional switching regulator. Poor recovery speed can have serious effects on circuit performance. Fortunately, new high-speed diodes can virtually eliminate these circuit problems.

Summarized, these are the most significant effects of diode recovery time on circuit behavior:

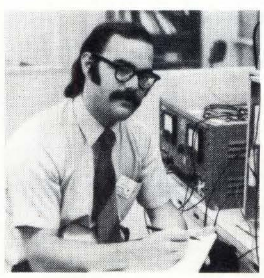
—Both peak recovery current, I_{pr}, and total recovery time, T_R, are directly related to the standard reverse recovery parameter T_{RR}.

—Peak reverse-current pulses for a 200-nsec diode can be many times greater than the nominal load current. However, a really fast diode with T_{RR} of 12 nsec can reduce the current ratio to less than one.

—Excessively large current pulses will almost certainly cause noise elsewhere in the system. (For the circuit described using a 200 nsec diode, a stray inductance of 0.1 μH could cause a 32-V noise spike at the input.)

—The pass transistor may be severely overstressed even using a 100-200 nsec diode. This is because the transistor must deliver the peak current in addition to the normal load current.

—Peak recovery currents must be supplied by a primary power supply or by an input filter supply. Either the supply or the filter capacitor may be incapable of supplying the necessary peak current. ▭



Ed Eby is a senior applications engineer for TRW Semiconductor Division in Lawndale, California. Prior to joining TRW, he was with Bendix, General Dynamics and Hughes Aircraft. He has an extensive background in digital systems, electro-optical systems and power-control circuits. He holds a B.S.E. and M.S.E. from UCLA where he studied under a Hughes Masters Fellowship.

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hp MEASUREMENT NEWS

information for better measurement

in this issue

1300 MHz RF sweeper covers seven octaves

HP's "total solution" computing counter system

Low-cost digital 'scopes

Finally: a synthesizer anyone can afford

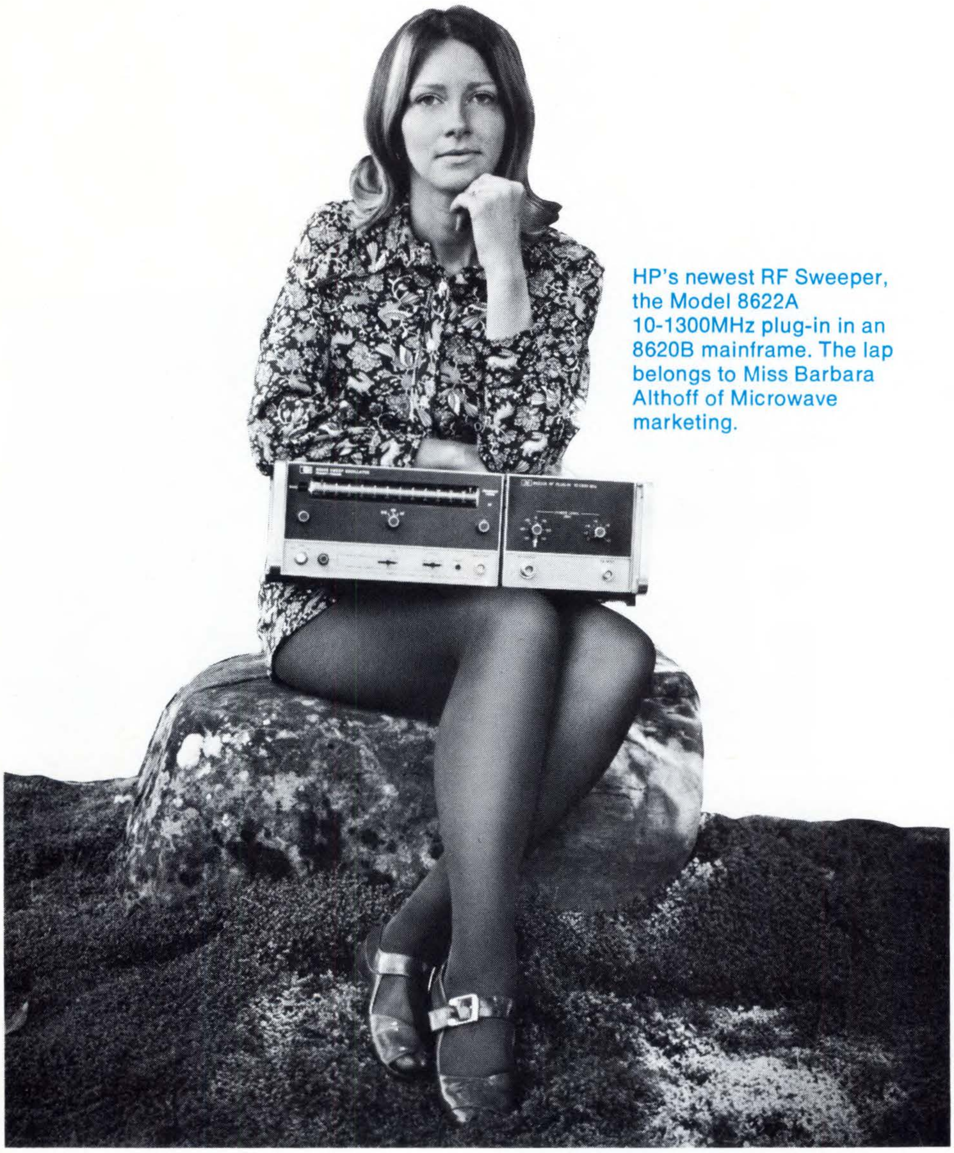
Get a quality frequency synthesizer at a truly low price, without sacrificing signal purity. Its many virtues include full digital remote control.

When HP was founded in 1939 its first product was an RC Wien Bridge oscillator invented by William R. Hewlett, now the firm's chief executive. Direct descendant of those first products (the 200 series RC oscillators), the new 3320A/B Frequency Synthesizer has the frequency accuracy and stability of synthesizers, and the spectral purity of oscillators—all at a very low price.

3320A/B stability depends on a *single* fixed-frequency oscillator, so you can tailor your choice exactly to the job. Standard equipment is an ambient crystal with drift below ± 10 parts in 10^6 per year. An oven reference is op-

(continued on page 3)

Sweep seven octaves of RF in 10 milliseconds flat



HP's newest RF Sweeper, the Model 8622A 10-1300MHz plug-in in an 8620B mainframe. The lap belongs to Miss Barbara Althoff of Microwave marketing.

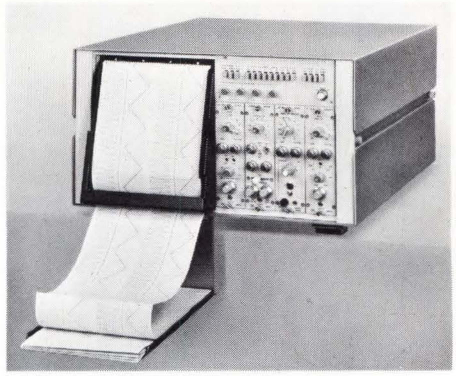
Just some of the reasons we think you'll like our new 1300 MHz Sweep Oscillator are:

- 10-1300 MHz coverage—in one continuous sweep.
- 10 milliwatts calibrated output, leveled to ±0.5 dB full range.
- Clean, stable CW signals—less than 5 KHz peak residual FM.
- Solid-state reliability and compactness.
- Low $2750 price for the **complete** sweeper (RF plug-in and mainframe).

Calibrated start/stop and ΔF sweeps commend the 86220A (RF Unit) and 8620B (Mainframe) for both broadband and narrow band sweep testing of RF components, networks and systems. And stable CW with low spurious, plus the capability for low distortion AM and FM permit this sweeper to be used in signal simulation applications. An optional 70 dB attenuator adds more flexibility of use.

Although we're talking about the value of the 86220A/8620B just for its 10-1300 MHz coverage, don't overlook the point that the 8620B mainframe also accepts our other solid-state RF plug-ins for coverage to 12.4 GHz. *Info on the 86220A RF Unit ($1775) and 8620B Mainframe ($975) is yours simply by checking the Reply Card.*

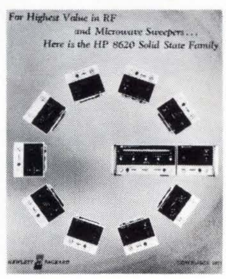
Make Z-fold recordings without ink



HP Model 7414A four-channel thermal tip oscillographic recorder.

Ever tried to find part of a chart recording on a 500-foot roll of chart paper? Compare with flipping the pages of a book and you'll see how much easier it is to handle the Z-fold charts from the new HP 7414A Oscillographic Recorder. It's a thermal (no ink), four-channel recorder featuring pushbutton chart speed change. Response is within ±0.5 dB from dc to 50 MHz, and falls off less than 3 dB at 100 MHz. The full range of HP 8800 series plug-ins can be used. Price is $4500 without plug-ins. *There's more; check the Reply Card.*

Meet the "Value Family" of HP sweepers



From the "simplest," low-cost sweeper to a sophisticated, multi-octave, programmable source, the 8620 family offers the highest value in solid-state RF sweepers.

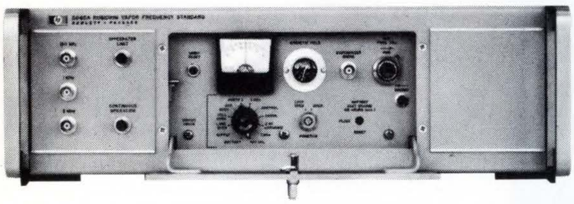
And it's easy to select the precise configuration for **your** job; this attractive brochure presents the entire family in concise, logical format.

For your copy, check the Card.

Need more stability? Step up to rubidium

Quartz oscillators rank high in frequency stability, but many systems need something better, like the HP 5065A Rubidium Frequency Standard. This atomic standard has 100 times the long-term stability of quartz. Besides upgrading system performance, increased stability may simplify the design of other parts of the system. In PCM communications, for example, switching from quartz to rubidium may eliminate the need for "bit stuffing" pulses needed for synchronization when less stable frequency sources are used. Navigation systems, color television systems, and calibration labs can also benefit by upgrading to rubidium.

The HP 5065A has the best guaranteed rubidium specifications available. Long-term stability is better than 1×10^{-11} per month. Short-term stability for a one-second averaging time is 5×10^{-12}. The 5065A is more rugged than a quartz oscillator, too. HP now gives an unconditional 3-year warranty on the rubidium vapor frequency reference—not just the gas cell, which hardly ever fails, but the *entire* module including oscillator, lamp, filter cell, and photodetector. At $7500, the 5065A offers unsurpassed price/performance. *For more information, check the Card.*



In frequency standards, the next step beyond quartz is rubidium. This one has the best guaranteed specs, plus an unmatched warranty.

Continued from page 1

tional and retrofittable. Or you can phase-lock to an external reference.

Both instruments have a range of 0.01 Hz to 13 MHz (the two lower ranges are optional).

3320A adds synthesizer quality to production and design work, yet keeps you out of trouble with the budgetmasters. It will put a volt rms into 50Ω and it has a continuous +13 dBm-to-0-dBm vernier, so it's most useful where level control is not a critical item.

3320B is the super-synthesizer. It has a 4-digit leveling loop with 0.01 dB resolution of a calibrated output from +26.99 dBm to −69.99 dBm (−73.00 under remote control). It's flat ±0.05 dB from 10 Hz to 13 MHz, and level accuracy is ±0.05 dB absolute at 10 kHz.

Because the 3320A/B is a synthesizer with ranges, its signal-to-phase noise is improved as the instrument is downranged. Its low spurious content (>60 dB down) and low harmonic distortion (−60 to −40 dB, depending on frequency) bespeak its high-quality spectral output.

Programmable/Remote Control

Digital remote control is an option on both instruments, and it can be a retrofit later. On 3320A Option 003 gives you parallel BCD remote control over frequency only. There are two remote control options for 3320B. Both give you control over all functions except the last vernier digit and the line switch. Option 004 is parallel BCD. Option 005 is a unique bit-parallel/word-serial ASCII option; with it, one program device can control several 3320B's. With Option 005, 3320B interfaces directly with the HP 3260A Marked Card Programmer, a photo reader, or any other 8-bit controller.

Price: 3320A ranges from $1900 to $2715, depending on options. 3320B prices are from $2400 to $3910. The 3260A Marked Card Programmer is $750. *For further information, check the Card.*

Locate faulty IC's with less time and effort

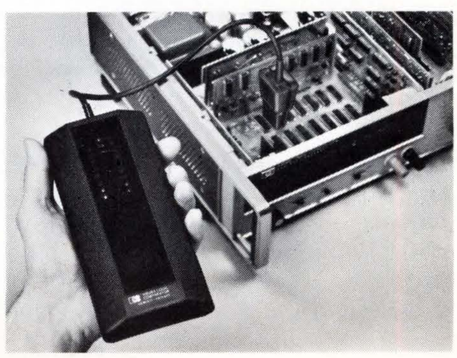
HP's 10529A Logic Comparator is a clever gadget that's extremely useful in design, production testing, and servicing digital integrated-circuit equipment. The comparator locates faulty IC's in malfunctioning equipment as quickly as possible. It's simple to use, self-powered, adjustment-free, requires no tools, and costs only $295.

The logic comparator clips onto powered TTL or DTL IC's and instantly identifies any pins where the logic states don't match those at corresponding pins of a known-good reference IC. Logic differences are indicated on the comparator's 16 light-emitting diodes. There's one diode for each pin of 14-pin or 16-pin dual in-line IC packages, and a lighted diode indicates a logic difference at the corresponding pin, therefore a faulty IC.

When the user also wants to see specific logic operation, the HP 10525A Logic Probe and 10528A Logic Clip nicely complement the comparator. The logic clip will display all the actual states of 14- or 16-pin DIP IC's at a glance. When pulses are involved, the logic probe is handy; it has pulse detecting and stretching capability. HP's 5010A IC Troubleshooting Kit consists of comparator, probe, and clip in a carrying case. Price is $495, or $20 less than if the three are purchased separately.

To learn more, check the Reply Card.

Here's a rapid, low-cost way to zero in on faulty IC's. The logic comparator simply clips onto your in-circuit IC's and lights LED's for any IC pins associated with faults.



Scan up to 1,000 channels without a computer

High-speed data acquisition doesn't always need a computer. Two new options enable this DVM to measure fast-changing signals, scan up to 50 channels at 1,000 per second, and then print.

There are two new options that give HP's 3480 DVM and 2070A Data Logger even **more** can-do for the dollar. 2070A is the little system you form by combining a fast 3480A/B DVM (1,000 readings a second) with a plug-in scanner and a digital printer. All in 7" of rack space, for $4475 plus options, of which two are new:

For $500, Option 001 **Sample and Hold** gives the 3480A/B DVM's the ability to measure fast-changing signals accurately. Trigger the 3480 now, and it will remember the value of the instant long enough to digitize it. Trigger it, if you like, with the delayed sweep on your scope, and digitize a whole LF waveform, point by point.

For $1000, Option 005 **Data Storage** makes the 3480's speed more usable. Store up to 50 complete readings at that 1,000/s rate, then tick them out later at 10 lines/s on the printer. Scan 50 transducers in only 50 milliseconds, yet preserve every digit.

To learn about all the options open to you with the 3480 DVM's— like true rms, multi-ranges and Ω, and to learn how a low-cost 2070A Data Logger might do the job of a $10k or $15k system for you, *check the Card for data sheets or three similarly relevant Application Notes.*

Programmable DC power line grows again

The 6129B is the most recent addition to the HP line of Digitally Controlled Power Sources (DCPS's), which along with HP D/A's and Multiprogrammer/analog power supply combinations, represents an extensive digitally programmable dc power capability.

The new addition ($2700) is rated at ±50V/5A, five times the output power of the existing DCPS's (6130B, ±50V/1A; 6131B, ±100V/0.5A). All three of these DCPS's meet all requirements for systems use.

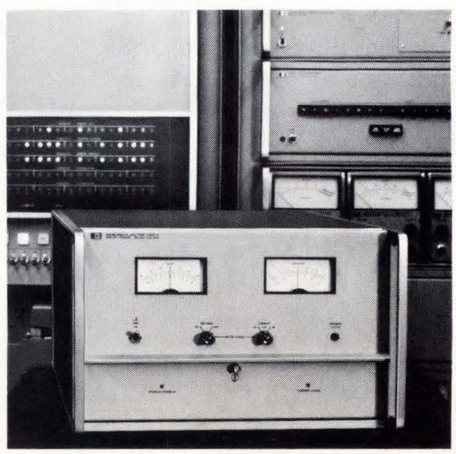
Typical applications for these DCPS's include stressing power semiconductor devices on high-speed production lines, and establishing signal and bias parameters on electronic modules under test.

For applications requiring more than 250W, or where the DCPS's 300μsec programming speed and 0.01% accuracy are not required, combining the 6936A Multiprogrammer with up to 240 standard analog power supplies can provide dc power outputs to 10kW, with 0.1% accuracy and programming speeds from 10msec.

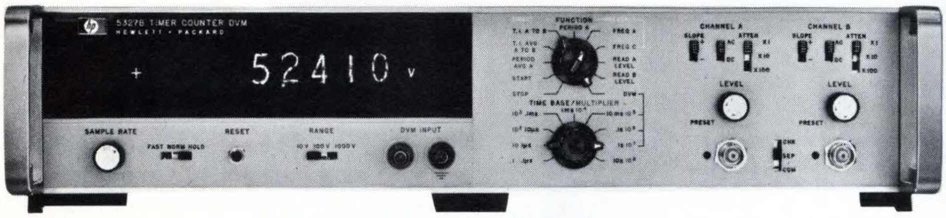
Finally, in applications where high programming speed and lower output power are required, HP DA's can provide 50μsec programming speed with power outputs of ±10V/5mA (69321A) and ±10V/20mA (6933B).

For more information, check the Card.

The 6129B extends HP's digitally programmable dc power capability with its 250W output, 300μsec programming speed, and 0.01% accuracy.



Timer/Counter/DVM team up for unique measurements



The HP 5327B universal timer/counter measures frequency to 550MHz, sub-nanosecond time intervals, and has a built-in DVM.

A universal counter and digital voltmeter in one package? Yes, but the HP 5326B/5327B Timer/Counter/DVM's are considerably more than that. They're really an entirely new type of counter, capable of making measurements no other counter can make.

First, there's the built-in 3-range integrating DVM. It'll measure external DC voltages, but, because of unique design it can measure the counter's trigger levels. Thus you can measure things like 10%-to-90% rise times, with the start and stop levels set with DVM accuracy. It's faster and more accurate than using a scope with intensity markers to show the start and stop points.

Even without the DVM these counters are special. They **average** repetitive time intervals to get improved resolution—like 100 picoseconds, good enough to measure propagation delays in logic circuits and other short intervals. Unique synchronizers found only in these counters permit measuring sub nanosecond intervals! Try to beat all this performance at double the price of the 5326B and 5327B.

There are two new optional high-stability time bases: aging rates are $< 3 \times 10^{-9}$/day and $< 5 \times 10^{-10}$/day. Both change $< 1 \times 10^{-8}$ from -20°C to $+65$°C. Prices: $300 and $450. Another option for the 5327 is high input sensitivity: 25mV rms, 0 to 50°C; 10 − 15mV typical at 25°C. Price $125.

Models 5326B ($1595) and 5327B ($2150) are members of a six counter family. Other models omit the DVM, time interval capability, or both. Prices are $950 to $1795. *Check the Card for full details.*

Low-cost, functional pulse generators

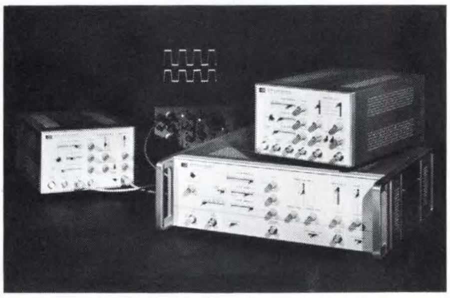
HP's budget-stretching family of pulse generators now offers repetition rates to 100MHz, amplitudes from 0.2 to 5V from a 50Ω source. These fast pulsers, with a wide range of pulse widths and transistion times, are useful for testing both analog and digital circuits—including digital IC's. Newest:

- **8007A.** 100MHz max rep rate; rise and fall times controllable from 2.5ns to 250μs; $1600.
- **8012A.** 50MHz max rate; transition times, 10ns–500ms; $875.
- **8013A.** 50MHz max, 3.5ns transition times; pos, neg outputs; $625.

All three models have an external input for reshaping and amplifying pulses generated elsewhere.

These generators are valuable performers; for more info, check the Card.

Three new members of HP's budget-stretching pulse-generator family—the 8007A, the 8012A, and the 8013A.



A computer that expands with your needs

The HP 2100A "thoroughly modern mini"

The HP 2100A minicomputer—more powerful and lower in cost than its predecessors—gives OEM's and end users new flexibility in tailoring a computer to specific needs.

Merely by plugging in more memory and adding peripherals, a 2100A can grow from an OEM controller to a multi-language stand-alone computer, or become the nucleus of time-sharing or batch processing systems.

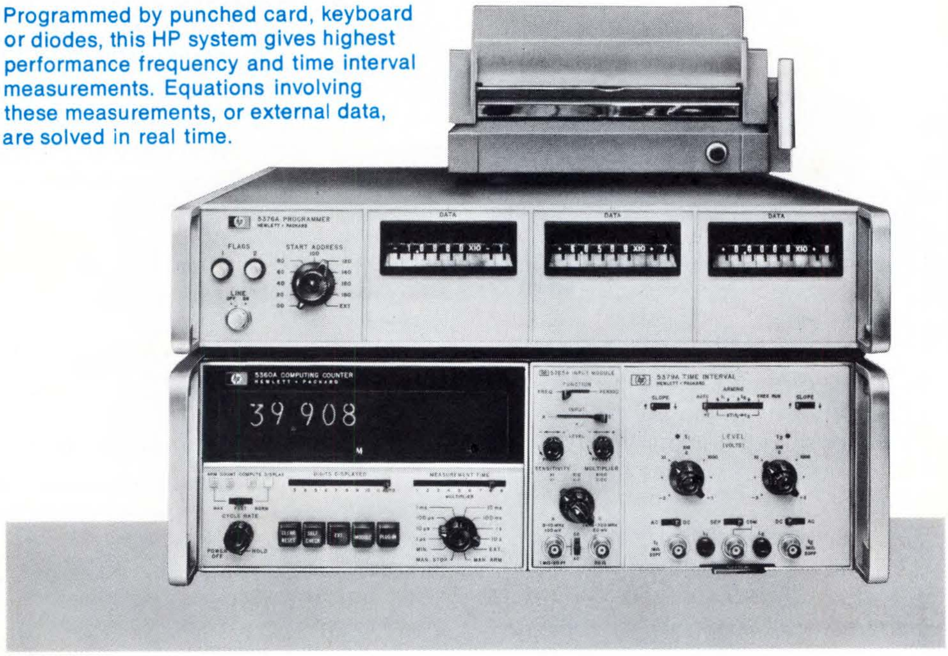
The 2100A has a 16-bit word length and can expand from 4K to 32K of core memory within its 12-inch high mainframe. With a memory cycle time of 980ns, it is 40 to 100 per cent faster than previous HP models.

It's an entirely new design except for the instruction set and I/O structure. Keeping these the same makes the 2100A compatible with HP's existing peripherals and large software library.

Other features include FORTRAN, ALGOL, BASIC and Assembly software modules; 14 I/O channels, or up to 45 with an extender; plus floating point arithmetic and microprogramming capability. Prices begin at $6,900.

This brief description only scratches the surface; for more information, check the Reply Card.

Desk-top computing counter system is versatile and economical



Programmed by punched card, keyboard or diodes, this HP system gives highest performance frequency and time interval measurements. Equations involving these measurements, or external data, are solved in real time.

Better measurements, plus a total solution to measurement and computation problems—in seconds, and economically. That's what the HP 5360A/5376A Computing Counter System—a desktop measuring and computing center for electrical measurements—gives you. It puts unmatched frequency and time-interval measuring power *and* real-time arithmetic capability at your fingertips. To duplicate its capabilities you'd have to buy a counter and computer, interface them and write software. Cost? About $25,000, not including software. The 5360A/5376A does it all for $7850!

It will solve equations involving its own measured data or that from other digital sources (DVM's etc.). For example, it will linearize transducers, calculate phase differences, calculate mean, standard deviation, and fractional frequency deviation, calculate maximum access time, and generate control signals. Final solutions are displayed directly on the 5360A Computing Counter readout.

The 5360A Computing Counter portion measures frequency to 320 MHz (to 18 GHz with accessories) and time interval with a resolution of 100 picoseconds. Its frequency measurements are 10 to 1000 times faster than ordinary counters.

The 5376A Programmer automatically sequences the 5360A through a predetermined series of measurements and computations. Operations include $+$, $-$, $\times$, $\div$, and $\sqrt{\ }$. It also provides facilities for the interchange of control signals and data between the 5360A Computing Counter and various other instruments and output devices, such as DVM's, signal generators, printers, and recorders.

Programs can have up to 200 steps, and may include branching, looping, subroutines, and constants. Programs are entered by punched card or by plug-in-diode read-only-memory.

The 5360A has 3 registers for accumulating data, 2 for storage. The 5376A can provide up to 6 additional storage registers. Program constants can be stored in up to three optional thumb-wheel switches. These are useful, for example, in production testing, for specifying upper and lower limits or nominal values and tolerances.

Optional D to A converters can provide analog outputs under program control for plotting results, or as test stimulus or feedback signals in closed-loop control systems.

5360A/5376A Systems start at $7850. *For full details, check the Card.*

Communications links get IF/RF sweeper

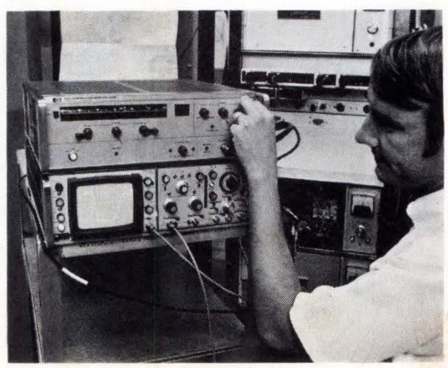
For fast, efficient alignment of microwave radio links, use the HP 8605A Communications Sweeper, a CW and swept signal source, covering both IF (47-100MHz) and RF (up to three communications bands can be selected from within the 1.7–13.25 GHz range). The 8605A features the excellent frequency accuracy and flat power output needed for stringent communications systems measurements. This high-performance capability comes in a rugged portable package, making the 8605A equally suitable for lab and field tests. The RF (microwave) coverage employs economical microelectronic modules, which means you can tailor the sweeper just for the band (or bands) of interest.

The 8605A is easy to use; IF and RF controls are separate and independently adjustable. The operator can shift back and forth between IF and RF measurements without readjusting any source settings or changing any cables or plug-ins.

Output power is flat within 0.01dB via internal leveling for the IF band and via external leveling for the RF bands, using the recommended 784A Directional Detector ($625) and 11675A Leveling Cable Assembly ($50). Price of the 8605A varies from $3875 up, depending on frequency and number of RF bands selected.

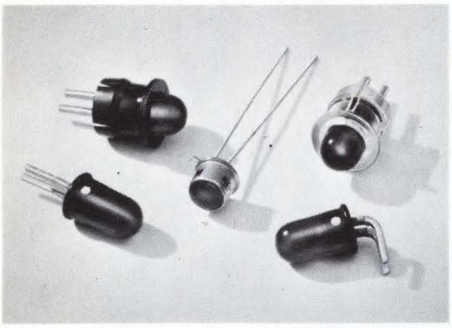
For specifications and more information on the 8605A Communications Sweeper, check the Reply Card.

Extremely flat-output Communications Sweep Oscillator offers both 70MHz IF and multiband RF (microwave) coverage in the same all-solid-state instrument.



COMPONENT NEWS

A free LED is yours for the asking



Our gallium arsenide phosphide lamp is offered in both plastic and hermetic packages.

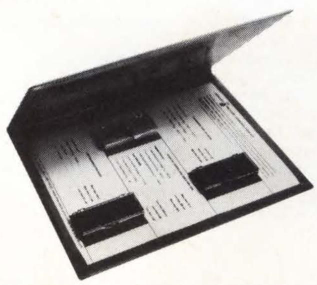
If you'd like to have one of our solid-state lamps to try, just ask. All we ask in return is that you tell us briefly about your application. You'll receive a free LED with a panel mounting clip. These HP light-emitting diodes have a 100,000 hour life with low power requirements—1.6 volts at 2 to 10 mA. They also have a wide viewing angle of 180 degrees with high brightness. *For comprehensive data and order coupon, check the Reply Card.* Try one, you'll like it!

Communications kit offers new components

Now, at paltry cost, you can get a solid handle on what those premium solid-state components can do for you. For just $19.40 you get **seventeen** high-technology components, for breadboarding, that would cost you $34 if you bought them separately.

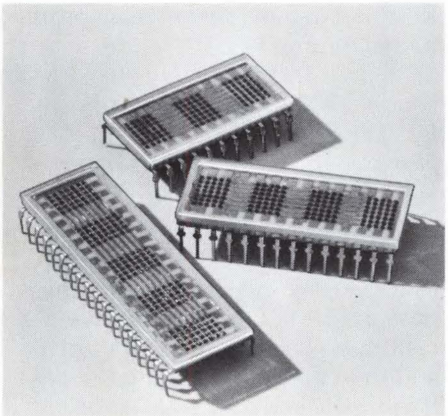
The kit (HP 5082-0051) contains a new transistor in a TO-72 can with 12 dB gain and a 3 dB noise figure **at 1 GHz.** You also get eight fast-recovery (< 100 ps) Schottky diodes, good for low-noise UHF mixers, switches and clamps (HP 5082-2835), four high-breakdown (70 V) Schottky diodes for such uses as high-level detectors, and four 5082-3080 p-i-n diodes for low-distortion attenuation and switching at high frequencies.

For comprehensive data and order coupon, check the Card.



Here's the Communications Sample Kit that gives you a low-cost introduction to HP's high-technology semiconductors.

Lower prices announced for alphanumerics



Lower prices are now in effect for HP's line of alphanumeric LED displays. For example, in quantities of 1,000, prices are cut from $20 per digit to only $11. These Model 5082-7100 series displays are 5 x 7 dot displays. They are IC compatible and come in dual-in-line (DIP) packages of three, four or five characters. Characters are ¼-inch high on ⅓-inch spacings. Display packages are end stackable, thin and lightweight. Maximum voltage required is 1.6 volts.

Quantity	Price
1–9	$22.50
10–99	18.00
100–499	15.50
500–999	13.50
1,000	11.00

For more specifics, check the Card.

Affordable radar: how to put it to work

The Doppler output and return signal is channeled through a single coupler in each of the packages shown here—one with X-band waveguide, the other with a miniature coaxial connector.

A mere palm-full of hardware is the heart of a microwave Doppler radar, lacking only antenna, power supply, and readout. Because it's a thin-film hybrid microcircuit (and all solid state), it's rugged and reliable. Inexpensive, too: $200 for small quantities, significantly less in large volume.

To the designer who has the problem of detecting and measuring motion — or acceleration — the 35200 Doppler Radar module is the perfect prescription. Detect subtle movements of an unwelcome intruder, or track a diesel train. For traffic control, count passing cars and measure their speed. Build an anti-crash system to keep cars from colliding (trucks, trains or boats, too). Feed an airborne navigational system all it needs to know about landing velocity and deceleration rate.

Within the compact module is the microwave power source (i.e., transmitter); plus the circuitry to detect the return and generate an audio output containing all the motion information.

To see how 35200 can work for you, check the Card for our new 16-page engineering bulletin. Applications, system design considerations, readout needs, test procedures, options and detailed specs are presented.

LEDs AND PHOTOMETRY

Output from an LED isn't perceived by the eye unless it is at a visible wavelength. Therefore correlation between radiated power and the visual result is essential for intelligent application of these devices.

GEORGE SMITH, Litronix, Inc.

Electromagnetic radiation as observed by man extends roughly from a few Hz to beyond 10^{24} Hz, covering some 80 octaves. The narrow segment of this spectrum between 430 and 750 THz is of so much importance because these frequencies are visible to the human eye. Thus more information is communicated to humans by these frequencies than they obtain from all the rest of the spectrum combined.

Measurements of the physical properties of light and light sources, can be described in the same terms as any other form of electromagnetic energy. These are commonly called *radiometric* measurements. Measurements of the psychophysical attributes of light, on the other hand, are made in units modified to reflect the response of the human eye. Those attributes which relate to the luminosity (sometimes called visibility) of light and light sources are called *photometric* quantities, and their measurement is the subject of photometry.

Photometry and the EE

When exploring light-emitting diodes and other optoelectronic devices you will find the subject of photometry to be a mix of strange units, confusing names for photometric quantities, and general disagreement as to what the important requirements are for a given application.

Photometric quantities are related to the corresponding radiometric quantities by the C.I.E. standard luminosity function (**Fig. 1**), which we may colloquially refer to as the "standard eyeball." We can think of the luminosity function as the transfer function of a filter that approximates the behavior of the human eye under good lighting conditions.

A human eye responds to the rate at which radiant energy falls on the retina, i.e., to the radiant flux density expressed as watts/m^2. The nearest photometric quantity is lumens/m^2. The standard luminosity function is, then, a plot of lumens/watt as a function of wavelength. This function has a maximum value of 680 lumens/watt at 5555 nm, and the half-power points occur at 510 and 610 nm (**Fig. 2**).

Determining LED Efficiency

The lumen is the unit of Luminous Flux and corresponds to the watt as the unit of radiant flux. Thus the total luminous flux emitted by a light source in all directions is measured in lumens, and can be related to the power consumed by the source to obtain an efficiency number.

Because it is generally impractical to collect all the flux from a light source and direct it in some desired direction, it is desirable to know how the flux is distributed spatially about the source. If we treat the source as a point (far-field measurement), we can divide the space around the source into elements of solid angle ($d\omega$), and inquire as to the luminous flux (dF) contained in each element of solid angle ($dF/d\omega$). The resulting quantity is lumens/steradian and is called luminous intensity (I), (**Fig. 3**). The standard unit of luminous intensity is called the candela.

Because the space surrounding a point contains 4π steradians an isotropic radiator of one candela intensity emits a total luminous flux of 4π lumens.

No actual light source is isotropic, so it is quite common to plot luminous intensity versus angle off the axis (**Fig. 4**). Of course, if the source has no axis of symmetry, a more complex diagram is required.

For an extended radiating surface, (such as a LED chip), each element of area contributes to the luminous intensity of the source, in any given direction. The luminous intensity contribution in the given direction, divided by the projected area of the surface element in that direction, is called the luminance (B) of the source (in that direction), (**Fig. 5**). This quantity is sometimes called photometric brightness, or simply brightness. Using the term brightness on its own should be discouraged, as brightness involves various subjective properties like texture, color, apparent size, etc. that have psychological implications. **The standard of luminance is the fundamental quantitative standard of the photometric system.**

A black body radiator at the temperature of freezing platinum (2043.8°K) has a luminance of 60 candela/cm^2 (A blackbody radiator is a perfect absorber of all electromagnetic energy incident on it). When at thermal equilibrium at a given temperature, it emits radiation that is spectrally distributed according to Plancks Formula:

$$\left(W_\lambda = \frac{c_1 \lambda^{-5}}{\exp\left(\frac{c_2}{\lambda}\right) - 1}\right) \qquad c_1 = 2\pi\, hC^2 \qquad c_2 = \frac{hc}{kT}$$

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Fig. 1—**Relationship between radiometric and photmetric units** requires a "translation factor"—the luminosity function—to correlate radiated power, wavelength and relative response.

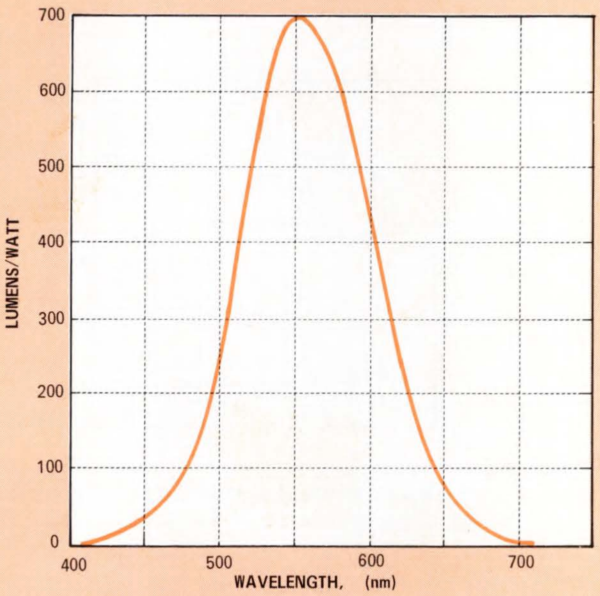

Fig. 2—CIE **Standard photopic luminosity function** defines the accepted standard response of the human eye to electromagnetic radiation.

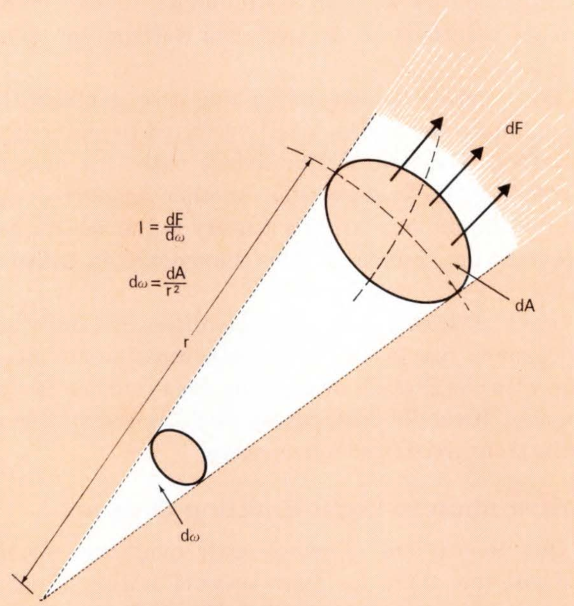

Fig. 3—**Solid angles and luminous intensity** per unit of area are used to calculate total luminous emittance since it is generally impractical to gather all flux from a light source.

Units Defined Luminance units in present use are an engineering nightmare.

1 candela/cm^2 is called a stilb

$1/\pi$ candela/cm^2 is called a lambert

1 candela/m^2 is called a nit

$1/\pi$ candela/m^2 is called an apostilb

$1/\pi$ candela/ft^2 is called a foot-lambert

Of these, the foot-lambert is most commonly used in this country.

Of particular interest is a source whose angular distribution pattern is a circle (**Fig. 6**). For such a source we have $I\theta = I_o \text{ Cos } \theta$. The luminance of such a source in a given direction θ, is then given by

$$B\theta = \frac{d\, I\theta}{d\, A \text{ Cos } \theta} = \frac{d\, I_o \text{ Cos } \theta}{d\, A \text{ Cos } \theta} = \frac{d\, I_o}{dA}$$

The luminance is seen to be the same in all directions. Such a source is called a Lambertian source. It can be shown that a perfectly diffusing surface behaves in this fashion. This formula governing a diffusing surface—$I\theta = I_o \text{ Cos } \theta$—is called Lambert's Cosine Law. A flat LED chip is a very good approximation of a Lambertian source.

If we take a surface element (dA) and determine the intensity contribution in each direction we can determine the total flux (dF) emitted by the surface element. The resultant ratio (dF/dA) lumens/m^2 is called the luminous emittance (L). For a flat surface we may calculate L from

$$L = 2\pi \int_o^{\pi/2} B(\theta) \text{ Sin } \theta \text{ Cos } \theta \, d\, \theta$$

The corresponding radiant emittance in watts/m^2 is of considerable interest for GaAs infrared LEDs where total output power is an important parameter. The total luminous flux emitted by a light source can then be calculated from $F_{total} = \int LdA$.

(continued)

LEDs (Cont'd)

We have covered only basic photometric quantities here, but they are sufficient to describe the properties of light sources such as light-emitting diodes.

Light Receptors

When light falls on a receiving surface, it is either partially reflected in the case of a purely passive surface, or partly converted into some other form of energy by an active surface (such as a phototransistor or photomultiplier cathode). In either instance we are interested in how much flux falls on each element of the surface that we wish to illuminate; lumens/m^2 for a passive surface (or the eye); and watts/m^2 for active surfaces.

The quantity lumens/m^2 in this case is called the illuminance sometimes loosely referred to as the illumination. The unit of illuminance is the lux also referred to as the metercandle. Another commonly used unit of illuminance, in this country is the foot candle, equal to one lumen/ft^2. One lumen/cm^2 is called a phot.

Many of these photometric quantities and units are in common use in the field of illumination engineering, with the English units being most common in this country. It should be apparent that a mixed system of units is involved in common usage.

Application to Light-Emitting Diodes

Our descriptions of photometric quantities should indicate that there are many ways of stating the photometric properties of LEDs. There is no general agreement among LED makers and users as to the best way to specify LED performance, and this has lead to much confusion and misunderstanding.

Many factors must be considered when evaluating LED specifications for a particular application, and electronic engineers will need to develop a knowledge of these factors to use LEDs effectively.

Presently-available light emitting diodes are made from the so-called III-V compound semiconductors, with gallium arsenide phosphide and gallium phosphide being the major materials. Gallium aluminum arsenide is also used, but is less common. Gallium arsenide is commonly included in this group, but it should be remembered that GaAs emits only infrared radiation around 900 nm, which is not visible to the eye, and is thus not properly called light. All specifications of GaAs emitters must be in radiometric units.

GaP emits green light between 520 and 570 nm peaking at 550 nm which is very close to the peak eye sensitivity. It also can emit red light between 630 and 790 nm peaking at 690 nm.

$GaAs_{(1-x)}\ P_x$ emits light that can vary over a broad orange-red range depending on the percentage of GaP in the material (x). For x in the 0.4 region, red light between 640 and 700 nm peaking at 660 nm, is obtained. For x = 0.5, amber light peaking around 610 nm is obtained.

$Ga_{(1-x)}\ Al_xAs$, as presently available, emits red light between 650 and 700 nm peaking at 670 nm.

The efficiency (emission vs. drive power) of these materials is very dependent on the emitted wavelength, with drastic fall off in efficiency as the wavelength gets shorter. Fortunately, the standard-eye filter favors the shorter wavelength (down to 555 nm)

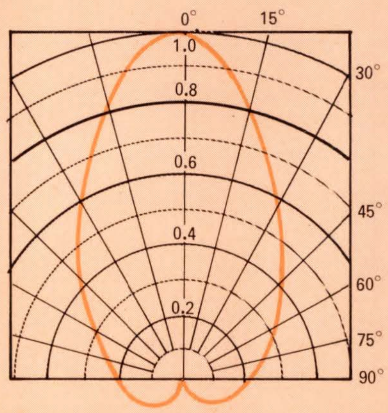

Fig. 4—**Spatial distribution pattern** of a nonisotopic light source shows that intensity varies with viewing angle.

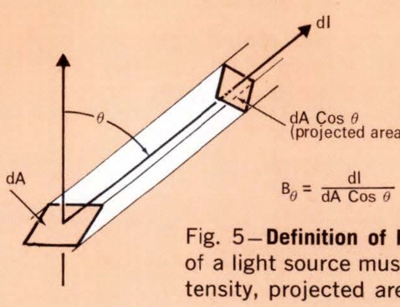

Fig. 5—**Definition of luminance** (B) of a light source must consider intensity, projected area and angle.

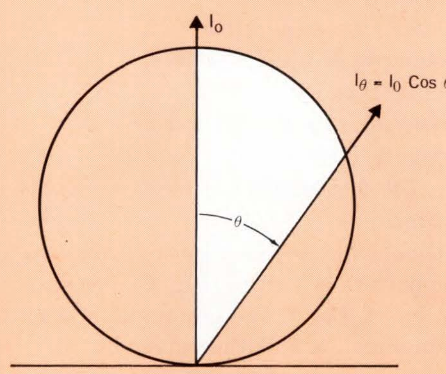

Fig. 6—**The radiation pattern described** by Lambert's Cosine Law is closely approximated by flat LED chips.

and gives some measure of compensation. Some typical efficiencies reported by device makers, and the resulting overall luminous efficiency (Lumens/electrical watt) are as shown in **Fig. 7**.

MATERIAL	COLOR	PEAK WAVELENGTH (nm)	EFFICIENCY ($P_{OUT}/P_{IN} \times 100$)	LUMENS PER RADIATED WATT	OVERALL EFFICIENCY (lumens/watt input)
GaP	Red	690	1.0%	20	0.2
	Green	550	0.006%	675	0.04
$GaAs_{.6}P_{.4}$	Red	660	0.3%	50	0.15
$GaAs_{.5}P_{.5}$	Amber	610	0.044%	340	0.015
GaAlAs	Red	670	0.06%	40	0.024

Fig. 7—**Tabulation of efficiencies** of various LED materials shows electrical input vs radiated output and visual response to radiated power at that wavelength.

Important Considerations

When using LEDs as simple status indicators, front panel lamps or for similar applications, several factors must be taken into account:

1—Color. Generally the designer has Henry Ford's one color choice—various similar shades of red. Amber and green are available in small quantity, because of limited availability of suitable raw material.

2—Apparent source size. Various combinations of chip size and optical systems are available, so that apparent source sizes varying from about 5 to 300 mils in diameter are available as standard products. Other factors being equal, a larger source is more visible.

3—Angular distribution. Radiation from GaAsP diode chips is nearly Lambertian, but that from GaP is nearly isotropic. With suitable optical design, the angular distribution pattern can be changed from very broad to quite narrow. By placing the chip at the focus of the lens system a narrow, high-intensity beam is obtained. The off-axis visibility is then drastically reduced. Alternatively, by using diffusing lens materials a large area source with good off-axis visibility is obtained. In this case the luminance is reduced.

4—Luminous intensity. This will govern the visibility under optimum background contrast conditions, when viewed at normal distances. One millicandela is typical for red lamps made from either GaAsP or GaP at normal operating conditions.

5—Luminance. When it is not possible to provide a dark contrasting background, or when the source is viewed close-up, the luminance becomes important. Values from 100 to 5000 ft-L are typical.

All of these factors are related to the design of the device and you should understand the tradeoffs. High luminance values in excess of 10,000 ft-L are easily obtained by running very high current densities in the LED chip, but if carried too far this can lead to shortened life.

For a given drive current, the luminous intensity of two different chips will be similar while the luminance will be inversely proportional to the active area of the chip.

Enhancement Techniques

If you can use filter screens or circularly-polarizing filters in front of the light source, you can obtain excellent protection from background illumination. In this case a diffusive lens giving a large apparent source, with lower luminance, is more visible than a high-luminance point source.

When a LED is used with an optical system to activate a remote sensor such as a cadmium-sulphide or cadmium-selenide cell (red light), or a GaAs IR emitter is used with a silicon photo detector, the performance requirements are somewhat different. For a given optical arrangement the irradiance of the detector determines the detected signal, and this is proportional to the radiance of the source—which is comparable to the luminance (brightness) of the source.

When average power consumption must be minimized but good visibility is required, or detection at a considerable distance is required, pulsed operation can be used. With GaAs and GaAsP emitters using low-duty-cycle short pulses, very high peak-intensity levels can be reached, permitting communication over considerable distances. This technique is not as useful with GaP diodes because they do not exhibit as linear a relationship between optical output and instantaneous forward current, that is, they become saturated at moderate current levels. GaP also has a 50% greater falloff in light output with temperature increase than GaAsP, further inhibiting its use in high power applications.

Using LEDs to give a projected display, such as for an automobile speedometer readout, or aircraft cockpit application, places severe requirements on the display luminance. For easy visibility, the projected image must offer sufficient contrast with the ambient illumination. This requires very high luminance values for the LEDs, together with the use of photochromic windshields and probably polarizing screens.

Our presentation has been, of necessity, very simplified. Photometry is a complex subject. Many textbooks are available and should be consulted when more detailed information is required. ▭

George E. Smith is manager of applications engineering at Litronix, Inc., Cupertino, Calif. where he has been employed for 2 years.

Mr. Smith graduated from the University of Auckland, New Zealand with a B.S.C. (Physics) degree. He presently holds four patents and is a member of the Optical Society of America.

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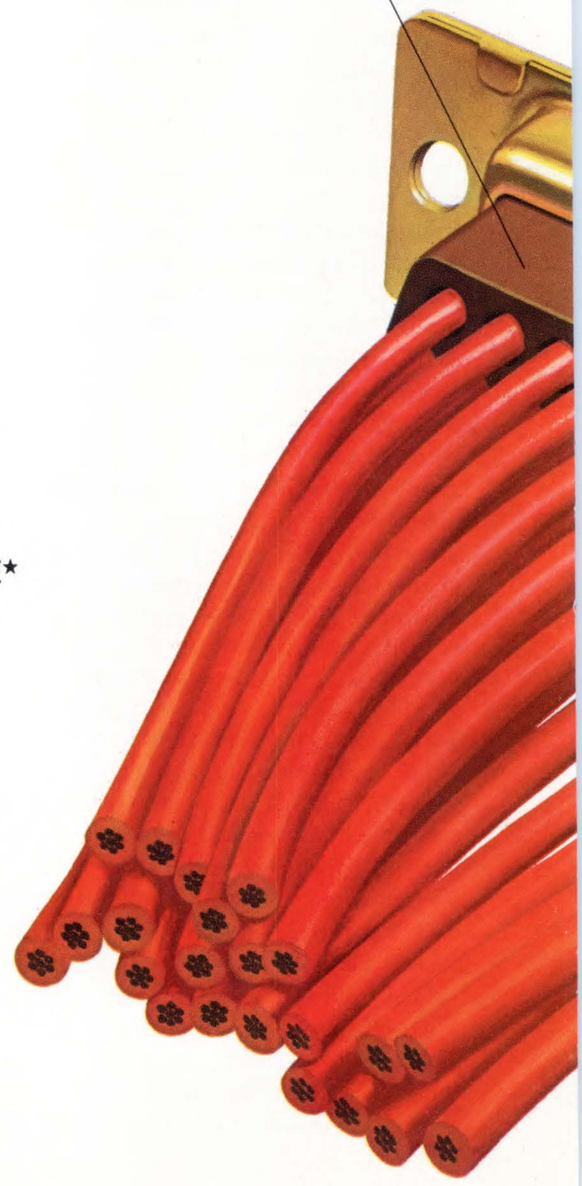

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ONE INSTRUMENT WEARS MANY HATS

A dc secondary voltage standard isn't just a reference source. It can perform many other tasks in precision measurement systems.

AL GRANT, Analogic Corp.

The saturated standard cell is, of necessity, the keystone of fundamental accuracy in electrical measurements. No one has yet come up with a better device, or even an acceptable substitute. Unfortunately, it is a delicate device, and the procedures for making practical use of it as a reference standard are slow and ponderous. All you get to work with is 1.0181+ volts dc—anything else has to be extrapolated through a chain of devices of varying complexity, accuracy, reliability, and cost. When measurement accuracies of a few parts per million are imperative, there is no escape, a fact that is recognized and accepted as a state-of-the-art limitation by everyone in science and industry. It is a mistake, however, to automatically extend primary-standard calibration techniques to situations that require lesser degrees of accuracy.

Though the demands for 1 to 5 parts-per-million accuracy are appreciable and growing, there is a much broader second echelon of demands, an order of magnitude or so lower in accuracy, that embraces the preponderence of today's precision requirements. Here, the need for an accurate calibration reference is quite adequately served by one of the adjustable (or "variable") dc secondary voltage standards now available from a number of manufacturers. These reliable, convenient, wide-range reference standards are not only easy to transport and use directly, but are also inexpensive enough to be used in quantity. In many cases they are even economical enough to build into custom-built production instrumentation. They will by no means obsolete the saturated standard cell, since they must themselves be recalibrated periodically against a standard cell that has NBS traceability, but they enable a single standard-cell reference to do the work of many. With one such reference, any number of these secondary voltage standards can be efficiently maintained as transfer standards for active, portable use throughout a company, and at very modest cost.

Furthermore, as will be seen, these versatile instruments constitute far more than mere reference

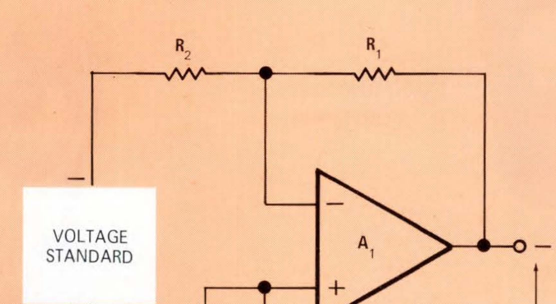

Fig. 1—**Generation of dc voltages above 11.1110V dc** for calibration of instruments and devices of all kinds. The system is governed by the relationship $E_{out} = -E_{std} R_1/R_2$. A voltage-programmable power supply may be substituted for A_1.

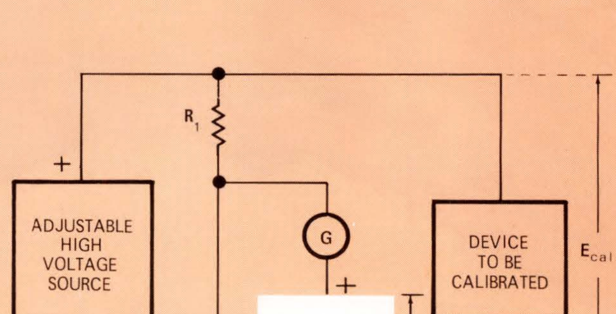

Fig. 2—**Indirect voltage calibration.** A galvanometer or other null detector is used to null the potential at the junction of $R1 - R2$ against the output of the standard using the relationship $E_{cal} = E_{std} \frac{(R_1 + R_2)}{R_2}$.

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sources. Effectively utilized, either alone or in conjunction with another instrument, or with a few external precision components, the adjustable voltage standard becomes one of the most versatile and valuable instruments available anywhere. It is usable, of course, as a conventional fundamental voltage reference, to which other instrumentation is brought for checking and validation, as in the past. But there is no need to treat these sophisticated, modern standards like temperamental prima donnas. No fragile, delicate standard cell is involved, so these voltage standards are not rendered unusable for days by a disruption or disconnection of the input power line. For example, the Analogic AN3100 secondary voltage standard uses an oven-controlled, aged, "pedigreed" zener reference, and achieves rated accuracy within ten minutes of warm-up from a cold start, with a 6-month recalibration interval. It is shortcircuit proof, immune to the effects of load capacitance, and can be operated up to 500V above or below chassis ground without damage or deviation from rated performance. Thus no coddling is required, and, being half-rack size (3-1/2 inches high, and 12 inches deep) it can be easily carried anywhere, and used on-site wherever ac line power is available. These facts, together with the range, resolution, and simple programmability of such instruments, take them out of the category of a laboratory shrine, and release their full capacity for use in dozens of ways as a test, calibration, and measurement device of unlimited application.

An immediately obvious application is in direct, absolute voltage calibration of 3-, 4-, or 5-digit DVMs or digital panel meters, up to the limit of the standard's voltage range. However, this range can be readily extended to much higher levels, with no significant sacrifice in accuracy, by means of an ordinary operational amplifier with an open-loop gain of at least 5×10^5 (preferably greater), as diagrammed in **Fig. 1**. The amplifier must have a rated output voltage swing at least as high as the required output range, and its accuracy is dependent only on the accuracy of the resistance ratio (and of the standard), provided amplifier gain is sufficiently high.

When very high voltages and/or wide ranges are required for precision calibration, the scheme shown in **Fig. 2** can be used. An adjustable DC voltage source of adequate range is used, together with R_1R_2, a stable, known, ratio divider which has been previously calibrated by the method shown in **Fig. 3**. Again, calibration accuracy is contingent upon the accuracy of the resistance ratio.

Calibration of resistive voltage dividers for accuracy and linearity can be accomplished as indicated in **Fig. 3**.

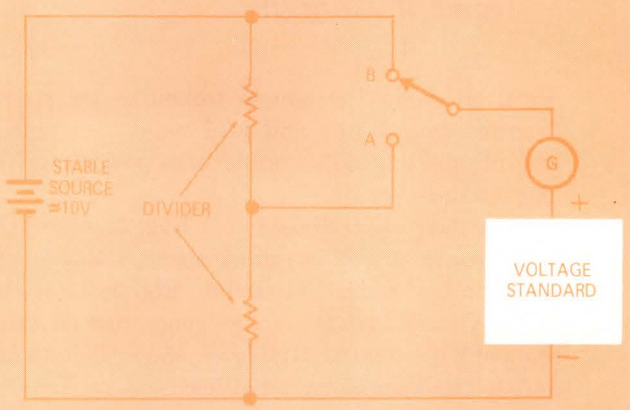

Fig. 3—**Calibration of voltage dividers and resistance ratios.** The dc power supply is adjusted to some convenient value, say 10.000V, with the galvanometer connected to (**B**). Then the divider is set to its cardinal value or values and the voltage standard is nulled against the voltage at each divider setting when the galvanometer is connected to (**A**).

$$R_{ratio} = E_{std}\ (\mathbf{A})/E_{std}\ (\mathbf{B})$$

For highest accuracy, the voltage at (**B**) should be checked for each measurement.

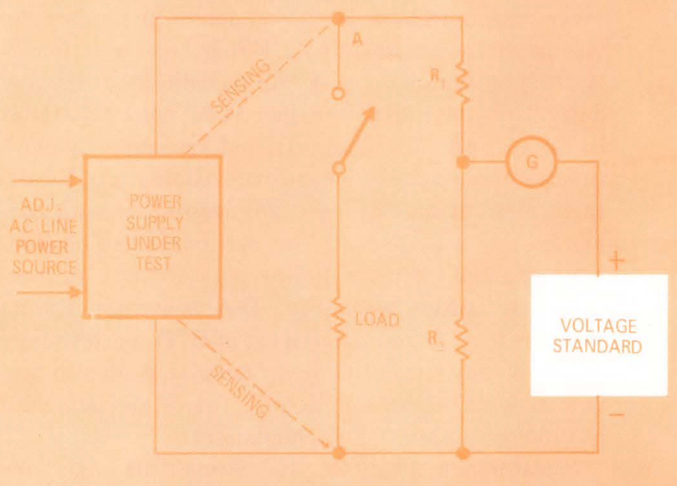

Fig. 4—**Indirect measurement of power supply line/load regulation and stability.** $R_1 - R_2$ constitute a voltage divider of known, stable value, calibrated as in **Fig. 3**. For voltages within the range of the voltage standard, this divider may be omitted and the galvanometer connected directly to (**A**). With the switch open, the ac input to the supply is adjusted to maximum rated ac line voltage. DC output of the supply is adjusted to its rated value, and the voltage standard is adjusted for a galvanometer null. The ac input is then adjusted to minimum rated line voltage, and the voltage standard is again nulled (recording its settings each time). Similar measurements are made with the switch open and closed, using a resistive load that has been selected to draw full rated load current from the supply when the ac input is adjusted to nominal line voltage. Stability (output drift) is measured by nulling the standard twice: first against the initial dc output, and again after a specified interval of time has elapsed. From such recorded measurements, it is a simple matter to calculate the regulation and stability of the dc supply under any desired combination of operating conditions and environment.

Fig. 4 shows the simple technique for precision measurement of line and load regulation, stability, and internal impedance (at dc) of dc power supplies at any voltage level.

The ability of an adjustable voltage standard to deliver current as well as voltage opens other avenues of precision test and measurement. **Fig. 5**, for example, shows a simple system for the generation of test currents of high accuracy, linearity, and resolution, using a high-gain operational amplifier.

A secondary voltage standard is equally useful as a device for measurement of external currents (ac or dc) with great precision. Using the ubiquitous operational amplifier in the manner shown in **Fig. 6**, the circuit presents essentially zero voltage drop to the circuit under measurement provided that the amplifier gain is high. Resistor R, as in the previous example, determines the current range; at null, $E_{std} = -1_X R$. The amplifier should be battery operated, or should use a floating, isolated power supply.

The easy programmability of the dc secondary voltage standard, its ability to deliver current, and its immunity to short-circuits and external load capacitance recommend its use as an active calibration device in many circumstances. Either bipolar or unipolar A/D converters (**Fig. 7**) can be calibrated digit-by-digit, if required, to better than 14-bit accuracy, 15-bit linearity, and 16-bit stability and repeatability, with input/output comparisons direct-reading up to the range limit of the standard. Voltage-to-frequency converters and voltage-controlled oscillators can be similarly checked, using a digital counter/timer to measure the output frequency. D/A converter testing reverses the process, using a set of BCD-coded thumbwheel switches or other programming means to provide selected digital inputs, with the voltage standard nulling the output in a galvanometer.

Measurement of offset, and offset drift with time and temperature in dc and operational amplifiers can be obtained with great accuracy by the method shown in **Fig. 8**.

The previous examples show some of the more prosaic, though enterprising, uses of dc secondary voltage standards. Many others are possible with only a little effort and ingenuity—for example, **Fig. 9** shows the use of a CRO as null detector for the standard, enabling its use in precise measurement of peak amplitude and other critical magnitudes on ac signals and pulses.

The use of two units as a team offers further facility for high-precision measurement and test. One unit serves as a programmable, high-resolution input source; the other is nulled against the resultant output from the device under test. Amplifier gain and lineari-

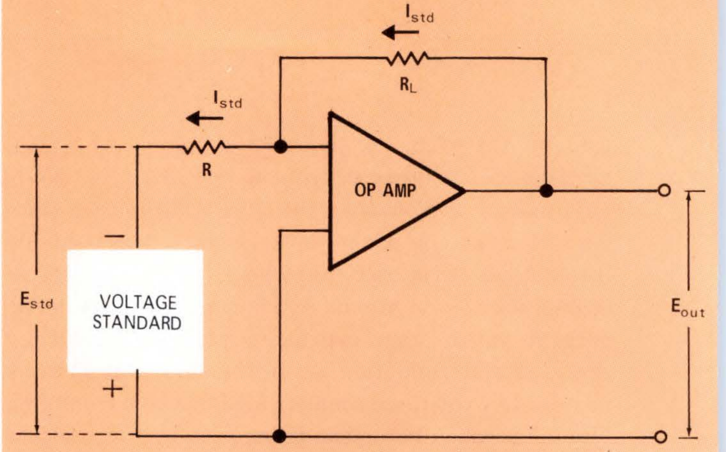

Fig. 5—**Generation of high accuracy, linearity and resolution test currents.** Resistor R_L is the device under test; resistor R is a range-determining resistor, that establishes the standard test current range as follows:

R	I_{std} Range
1k	0 - 11.1110 mA
10k	0 - 1.11110 mA
100k	0 - 0.111110 mA

After selection of the appropriate range resistor, current values within that range are directly dialable on the standard. Maximum usable value of R_L = max E_o/I_{std}.

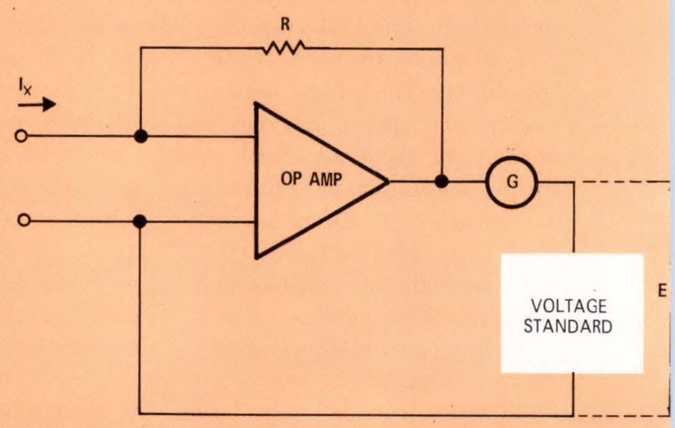

Fig. 6—**Measurement of currents with very low IR drop.**

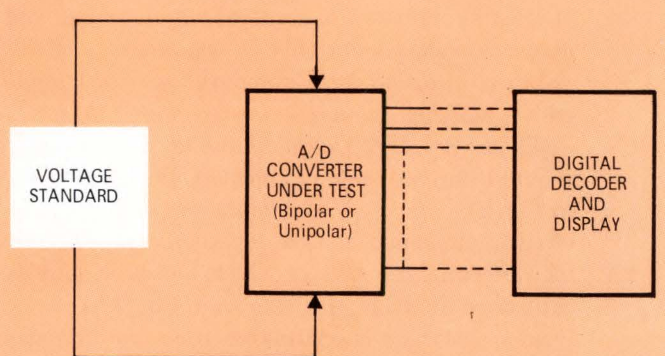

Fig. 7—**Calibration of A/D converters.** Differences between the voltage standard and digital display may be made direct-reading up to 11V.

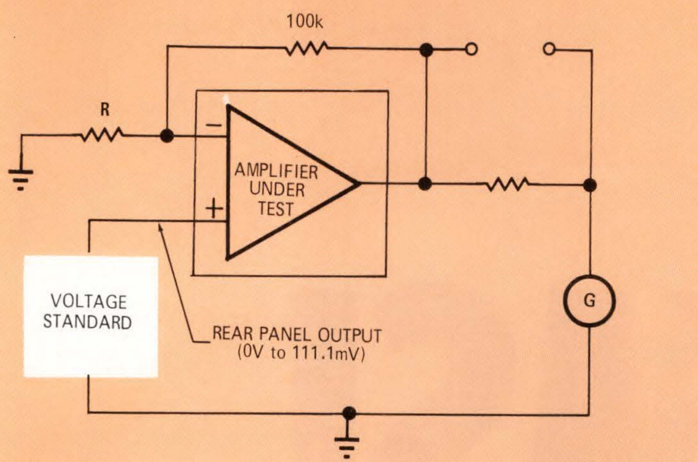

Fig. 8—**Measurement of dc and op amp offsets and offset drifts.** The voltage standard is adjusted to null a galvanometer connected across the output. Offset is read directly, with drift measured either by re-nulling after a 1 hr or longer interval, or by raising the ambient temperature a fixed amount.

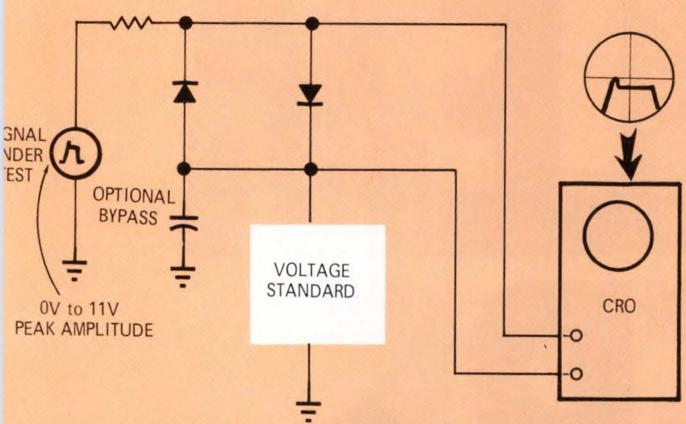

Fig. 9—**Measurement of peak amplitude.** The signal under test may have an amplitude (peak) up the maximum output voltage of the standard. Two clamping diodes (shown) relieve the CRO of overload saturation. The point on the wave form at which the amplitude is to be measured is nulled to zero by adjusting the output of the standard to bring that point into coincidence with the trace baseline. Amplitude is then read directly from the standard's dial setting. Typical null resolution is 1 to 5 mV before saturation occurs, depending upon the scope design.

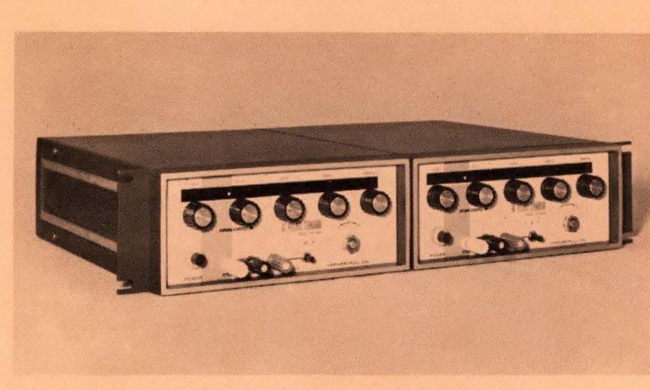

Fig. 10—**Dual dc secondary voltage standards** in rack mount.

ty can be precisely determined in this manner; analog multipliers can be calibrated for linearity, scale factor, and feedthrough; and "piecewise" linear models of nonlinear networks can be set up and calibrated for best conformance to theoretical function. For such applications, rack-mounted dual units are available from some companies (see **Fig. 10**).

There is, obviously, no law against using a Rolls Royce to haul rocks, and some of the above applications may appear to be in this category—particularly wasteful or demeaning occupations for a "DC Secondary Voltage Standard." It must be borne in mind, however, that these are not ivory-tower instruments that we have been discussing. They are for the most part rugged, workaday, bench-type units, with remarkably low price tags for the performance capabilities they exhibit. They are designed for this kind of duty, leaving all of the initial, high-level communication with NBS to the 1-PPM chamber-mounted Weston Cell units. They carry their full share of the accuracy burden and more, yet they are small enough, light enough, cheap enough, and imperturbable enough to sit in on any convocation of instrumentation, as custodians of the Volt, and as fully qualified workhorses, as well.

Analogic's Model AN3100 dc secondary voltage standard has the following features and can perform all of the above tasks. It has a voltage range from zero to ±11.1110V dc, diallable in steps of 100 μV by five rotary decade switches with rear-illuminated readout of the voltage setting, and has a current capability of up to 50 mA. The front-panel output is paralleled by a rear output that incorporates a 100:1 precision divider, giving a simultaneously-available output range from zero to ±111.110 mV with 1 μV resolution. Output polarity is selectable by front panel switch, without need for disconnecting loads, and settling time for a polarity reversal at full-scale voltage is less than 300 msec. Accuracy is 50 PPM of reading ±50 μV, and both a certificate of performance giving NBS traceability, and a test report providing output readings at 16 cardinal settings, are provided with each instrument. ▭

Al Grant is Senior Product Manager for panel instruments at Analogic Corporation, Wakefield, Mass. Prior to holding this position he worked at Baird-Atomic Co. Al is close to receiving his B.S. in Physics at Northeastern University and is a member of IEEE and the Radiological Engineers Society.

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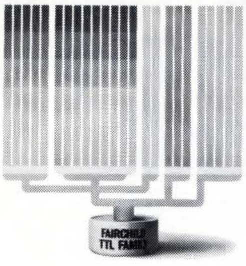

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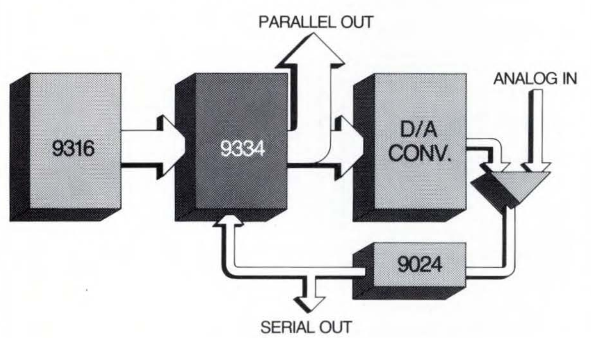

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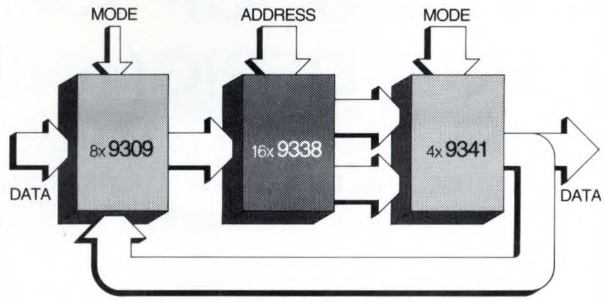

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CIRCLE NO. 16

CRITICAL OP AMP CONSIDERATIONS FOR DESIGNING ACTIVE FILTERS

There's more to designing active filters than just following circuit diagrams and design equations. Input signal characteristics and op amp performance capabilities affect filter response and must be considered.

D. G. RIDGELY & G. C. RUSH, Westinghouse Electric Corp.

The advent of modern integrated circuits has made it possible to achieve small, high-quality low-frequency filter circuits using active-filter techniques. Voluminous literature exists describing numerous circuits for achieving various filter responses. All too often, however, the literature describes the circuit and presents design equations tacitly implying, by omission, that the resulting network is a plug-in substitute for its passive counterpart. This is far from true. While passive circuit response is relatively independent of the nature of the input signal, active circuit response can be seriously affected by the input signal parameters.

To illustrate this point, let's take a look at the design of an active filter that selects a small-amplitude, low-frequency signal in the presence of a high-frequency component that has a considerably greater magnitude.

INIC Circuit Design

The circuit chosen is a low-frequency bandpass filter having the following frequency response:

$$\frac{e_{out}}{e_{in}} = -\frac{K\,\omega_o\,s}{s^2 + 2\,\delta\,\omega_o\,s + \omega_o^2} = -\frac{A'\frac{1}{Q}}{1 + \frac{1}{Q}\frac{s}{\omega_o} + \left(\frac{s}{\omega_o}\right)^2} \quad (1)$$

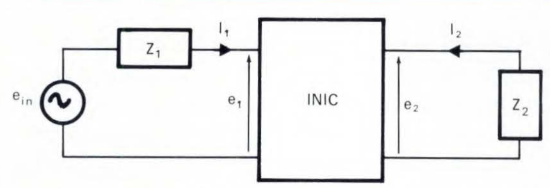


Fig. 1—**Inverting negative impedance converter** is characterized by $\frac{e_2}{e_{IN}} = -\frac{Z_2}{Z_2 - \frac{Z_1}{K}}$

The active circuit used is an inverting, negative-impedance converter (INIC) shown in **Fig. 1**.[1,2] The defining equations for this circuit are as follows:

$$e_1 = e_2 = -i_2\,Z_2 \quad (2)$$

$$i_2 = Ki_1 \quad (3)$$

where K is the gain of the INIC.

[1]Don Kesner, "An Op Amp RC Bandpass Filter," *AN-452 Application Note*, Motorola Semiconductor Products Inc.

[2]*Handbook of Operational Amplifier Active RC Networks*, Chapter 5, Burr-Brown Research Corp.

$$\frac{e_1}{i_1} = -KZ_2 \quad (4)$$

$$i_1 = \frac{e_{in}}{Z_1 - KZ_2} \quad (5)$$

Using **Eqs. 2, 3, 4** and **5**, the transfer function is:

$$\frac{e_2}{e_{in}} = -\frac{Z_2}{Z_2 - \frac{Z_1}{K}} \quad (6)$$

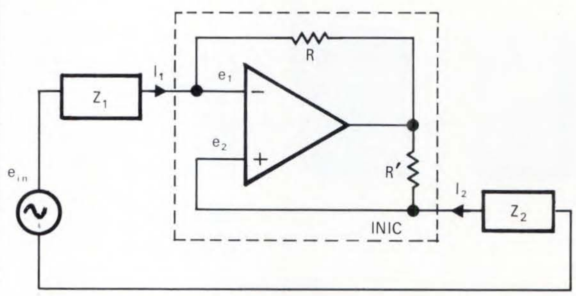


Fig. 2—**INIC circuit** with op amp is used to determine the active filter transfer function.

Because we are using a differential-input op amp in this circuit, **Fig. 1** is rearranged as shown in **Fig. 2**. The op amp is characterized by zero-differential input voltages and high input impedances; therefore, the input voltages e_1 and e_2 can be equated, and the input currents i_1 and i_2 will flow through the feedback resistors R and R'. The defining equations are then:

$$e_1 = e_2 \quad (7)$$

$$i_1\,R = i_2\,R' \quad (8)$$

From **Eqs. 3** and **8**, the gain K is defined as:

$$K = \frac{R}{R'} \quad (9)$$

The bandpass characteristic is obtained by letting

$$Z_1\,(s) = \frac{1 + s\,R_1C_1}{s\,C_1} \quad (10)$$

and

$$Z_2\,(s) = \frac{R_2}{1 + s\,R_2C_2} \quad (11)$$

Substitution of **Eqs. 10** and **11** into **Eq. 6** yields the transfer function:

$$A\,(s) = \frac{\frac{-K\,s}{R_1C_2}}{s^2 + s\left(\frac{1}{R_2C_2} + \frac{1}{R_1C_1} - \frac{K}{R_1C_2}\right) + \frac{1}{R_1C_1R_2C_2}} \quad (12)$$

By letting $R_1 = R_2 = R$, and $C_1 = C_2 = C$, **Eq. 12** becomes:

$$A\ (s) = -\frac{K\frac{s}{\omega_o}}{1 + (2 - K)\frac{s}{\omega_o} + \left(\frac{s}{\omega_o}\right)^2} \qquad \textbf{(13)}$$

where
$$\omega_o = \frac{1}{RC} \qquad \textbf{(14)}$$

and
$$Q = \frac{1}{2 - K} \qquad \textbf{(15)}$$

By comparing **Eqs. 1** and **13**, it is shown that:

$$2\delta = 2 - K = \frac{1}{Q} \qquad \textbf{(16)}$$

It is also noted that at $s = j\ \omega_o$,

$$A\ (\omega_o) = -KQ \qquad \textbf{(17)}$$

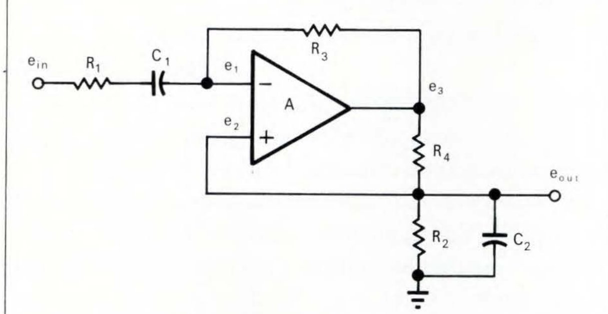


Fig. 3—**RC networks are synthesized** to replace Z_1 and Z_2 of **Fig. 2** to give the desired bandpass characteristics.

Eqs. 10 and **11** can be synthesized by RC networks such that the bandpass filter can be depicted by **Fig. 3**. In this circuit,

$$K = \frac{R_3}{R_4} \qquad \textbf{(18)}$$

The above shows that the center frequency is selected by the proper choice of R and C and that the desired value of the quality factor, Q, is obtained from the ratio of R_3 and R_4.

Op Amp Considerations

Selecting the op amp and determining the magnitude of feedback resistors requires additional investigation. The need for this investigation stems from a consideration of the slew rate and dynamic range requirements, which in turn requires consideration of the expected input signals. A transfer function satisfying **Eq. 13** is desired. However, it may not be attainable because of limitations imposed by the slew-rate capabilities of the op amp and the required output swing, which depends on the gain K and the input signal.

Therefore, an expression for the transfer function of the op amp itself is necessary. Referring to **Fig. 3**, we want an equation for the ratio $\frac{e_3}{e_{in}}$. For ease of component selection let $R_1 = R_2 = R$, $C_1 = C_2 = C$, and $\omega_o = \frac{1}{RC}$. The transfer function can then be expressed as:

$$A\ (s) = -\frac{s^2\left(\frac{R_3\,R_4}{\omega_o}\right) + s\ (R_3\,R_4 + R\,R_3)}{s^2\left(\frac{R\,R_4}{\omega_o}\right) + s\ (2\,R\,R_4 - R\,R_3) + \frac{R_4}{C}} \qquad \textbf{(19)}$$

In order to determine the dynamic range required of an op amp in this circuit, it is necessary to know the frequency response of **Eq. 19**. This equation can be rearranged and simplified to give:

$$A\ (s) = -\frac{\left(\frac{s}{\omega_o}\right)^2\left(\frac{R_3}{R}\right) + \left(\frac{s}{\omega_o}\right)\left(\frac{2Q - 1}{Q} + \frac{R_3}{R}\right)}{\left(\frac{s}{\omega_o}\right)^2 + \left(\frac{s}{\omega_o}\right)\left(\frac{1}{Q}\right) + 1} \qquad \textbf{(20)}$$

The filter will be designed for a given center frequency, ω_o, and quality factor Q. It is apparent that, with ω_o, Q, R and C determined, the frequency response depends on the choice of R_3. If Q is assumed to be large, the response at the center frequency can be approximated by:

$$A\ (\omega_o) = 2\,Q\left[1/2\left(\frac{R_3}{R}\right)^2 + \frac{R_3}{R} + 1\right]^{1/2} \qquad \textbf{(21)}$$

An inspection of **Eq. 20** shows that the gain at high frequencies is equivalent to $\frac{R_3}{R}$. This can also be seen from an inspection of **Fig. 3**.

The most practical method for evaluating **Eq. 19** is by a computer programmed for a Bode plot printout. The frequency response for various values of R_3, is determined to give the maximum gain of the op amp at the center frequency. Knowing the peak input and maximum gain, the peak output can be computed. This can then be compared to the output swing limitations of any op amp under consideration. The subsequent limitations on R_3 are: 1) a maximum value that provides operation in the linear region; i.e. no saturation and distortion, and 2) a minimum value to insure that the op amp load impedance is high enough to be properly driven by the integrated circuit. **Fig. 3** indicates this load impedance to be a function of R_2, R_3 and R_4, and also of C_2 as a function of frequency.

Additional precautions in the selection of an op amp involve the slew-rate requirements. The slew rate required is determined by the product of the peak value of the op amp output signal and its corresponding frequency in radians per second. The critical areas are then the value of the output at the center frequency where maximum gain occurs, and the output in the higher frequency range. These areas would maximize the slew rate equation:

$$\text{slew rate} = e_{out}\ (\text{peak}) \times 2\pi f\ V/\text{sec} \qquad \textbf{(22)}$$

Applying the Principles

As an example, consider a bandpass filter designed for a center frequency of 82 Hz. The input signal has the waveform shown in **Fig. 4**. The dotted lines indi-

(Continued)

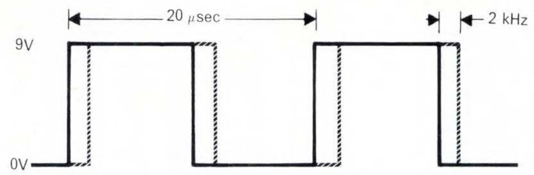


Fig. 4—**Input signal frequency** is 50 ± 2 kHz. The rate of deviation is 82 Hz.

cate that the pulse frequency is 50 ±2 kHz. The rate of deviation is 82 Hz. This results in an 82-Hz signal of 0.18V peak amplitude at a 4.5V dc level. For a desired Q of 14.14:

$$K = 2 - \frac{1}{Q} = 1.9293 \qquad \textbf{(23)}$$

The bandpass frequency of 82 Hz is established by choosing C = 0.22 μF and R = 8.87 kΩ. The value of K given by **Eq. 23** can be obtained by letting R_3 = 6.24 kΩ and R_4 = 3.24 kΩ. Since 6.24 kΩ is not a standard value, R_3 will consist of a 6.04 kΩ resistor and a 500Ω potentiometer. Kesner[1] shows how the actual Q will change depending on how the values of the frequency-determining resistors and capacitors vary due to initial tolerances and temperature changes. As this Q changes, the 500Ω potentiometer can be adjusted initially to maintain the desired K.

With the above values, the op amp is driving an impedance level of slightly over 2 kΩ. The computer printout shows the maximum gain, which occurs at 82 Hz, to be 31.3 dB (A_v = 36.9) while an evaluation of **Eq. 21** gives a gain of 31.9 dB (A_v = 39.4). Therefore, the output is:

$$0.18\text{V peak} \times 36.9 = 6.65\text{V peak} \qquad \textbf{(24)}$$

The slew rate is:

$$6.65\text{V peak} \times 2 \times 3.14 \times 82\text{ Hz} = 3.42 \times 10^{-3}\text{V}/\mu\text{sec} \qquad \textbf{(25)}$$

The values of output swing and slew rate needed to satisfy **Eqs. 24** and **25** are within the range of the average op amp.

The approximation of **Eq. 20** agrees with the computer-calculated response at 50 kHz, that is:

$$A\ (\omega >> \omega_o) = \frac{R_3}{R} = 0.708 \qquad \textbf{(26)}$$

This corresponds to a gain of −3 dB, which gives an output of:

$$9\text{V peak} \times \frac{2}{\pi} \times 0.708 = 4.06\text{V peak} \qquad \textbf{(27)}$$

The factor of $\frac{2}{\pi}$ accounts for the peak value of the 50 kHz fundamental. The slew rate is:

$$4.06\text{V peak} \times 2 \times 3.14 \times 5 \times 10^4\text{ Hz} = 1.275\ \text{V}/\mu\text{sec} \qquad \textbf{(28)}$$

A typical device that would appear suited to this application is the internally-compensated Fairchild μA741. However, for A_v = 1 and $R_L \geq$ 2 kΩ, the slew rate is 0.5V/μsec, a specification which will not satisfy **Eq. 28**. Both the Fairchild μA715C, with a slew rate of 10V/μsec, and the Motorola MCH1539G, with a typical slew rate of 4.2V/μsec, will function satisfactorily in this case.

Consider now the case where feedback resistors of higher magnitudes are chosen. Let R_3 = 28.9 kΩ and be comprised of a 28-kΩ resistor and a 1-kΩ potentiometer, and R_4 = 15 kΩ. In this case, the load resistance is on the order of 10 kΩ. The computer printout indicates a gain at 82 Hz of 38.4 dB (A_v = 83.2). Then the output is:

$$0.18\text{V peak} \times 83.2 = 14.98\text{V peak} \qquad \textbf{(29)}$$

This output level exceeds the capabilities of several popular op amps. The output at 50 kHz, with a gain of 10.3 dB, is also too great, as **Eq. 30** shows.

$$9\text{V peak} \times \frac{2}{\pi} \times 3.27 = 18.72\text{V peak} \qquad \textbf{(30)}$$

The slew rate requirement at 82 Hz is not severe, but at 50 kHz, it is determined as:

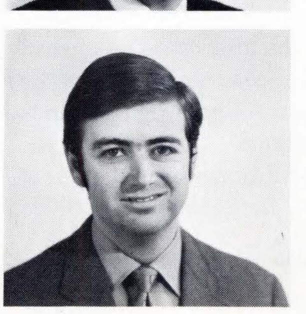
$$18.72\text{V peak} \times 2 \times 3.14 \times 5 \times 10^4\text{ Hz} = 5.88\text{V}/\mu\text{sec} \qquad \textbf{(31)}$$

Here the μA715C meets the slew rate requirement, but it is still incapable of handling the output voltage swing requirements imposed by **Eqs. 29** and **30**.

The examples indicate that for proper operation of the filter for this application, the smaller values of the feedback resistors and either a μA715C or MCH1539G op amp must be employed. This does not imply that an R_3 of 6.24 kΩ and an R_4 of 3.24 kΩ represent maximum values that will allow the filter to operate properly, for larger values, up to a limit, will also work. The intent is to show that the choice of the feedback resistors is critical since they determine the gain characteristics and load resistance of the op amp.

Applying these factors to the input signal determines the dynamic range and slew rate requirements of the circuit, which in turn dictate the selection of the integrated circuit. Thus, for the particular bandpass filter described, it is mandatory to consider the output of the op amp itself in addition to the output of the filter. □

Donald Ridgely is a senior engineer with Westinghouse Electric Corp., Baltimore, Md. where he has been employed for 16 years. He is presently working in the design of airborne radar. Mr. Ridgely is a graduate of Johns Hopkins University with a B.S.E.E.



George Rush has been with Westinghouse for 4 years, with previous experience at Clemson University as a research assistant. His present duties involve preparation of technical systems manuals. Mr. Rush has a B.S. in Engineering-Physics from Loyola College and a M.S.E.E. from Clemson University.

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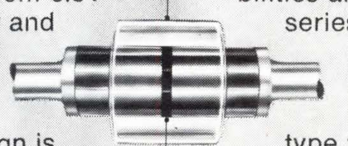

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CIRCLE NO. 18

Inexpensive Inverters Generate V_{GG} for Portable MOS Applications

Either of these multivibrators will provide the second supply voltage required to operate high-threshold MOS logic from portable, automotive or other single battery electrical systems.

BRUCE FETTE, Motorola Semiconductor Products Inc.

High-threshold MOS logic is very attractive to a designer of portable or automotive equipment. Its good noise immunity, low supply current drain and high-density packaging are all definite plus features. Unfortunately, these advantages are often negated by the need for a dual-voltage power supply.

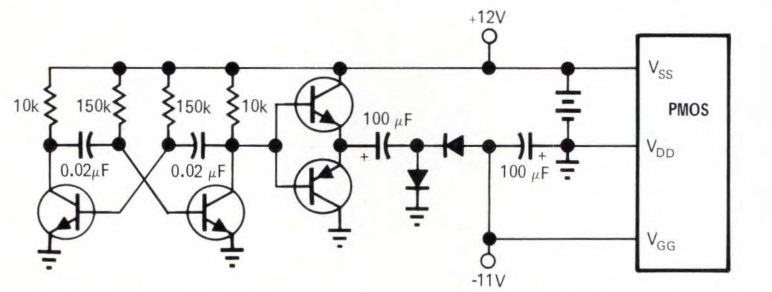


Fig. 1—**Bipolar inverter** is inexpensive, compact and allows portable operation of MOS logic devices from a single battery supply.

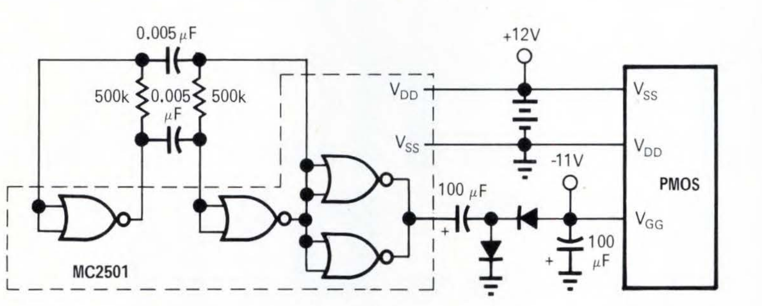
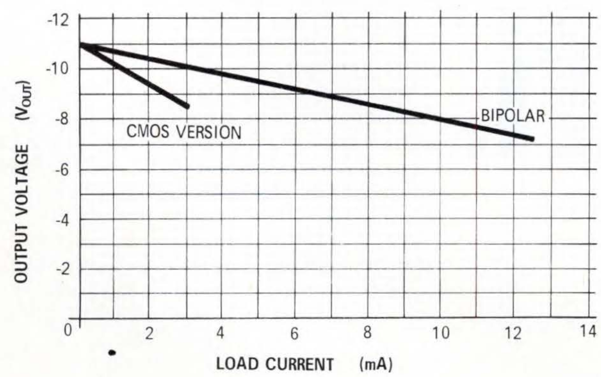


Fig. 2—**CMOS inverter** is more compact than the bipolar design in **Fig. 1** but has a lower current capability, as shown in the regulation curves. Buffer stages can be used to increase output current of this design.

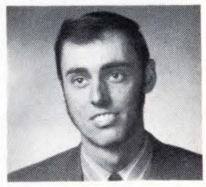


The two inverters described here are small, inexpensive and require only a few components to fulfill the negative voltage needs of the MOS logic.

Bipolar Inverter. The multivibrator circuit shown in **Fig. 1** draws 1.2 mA from the battery in standby operation and easily supplies 12 mA from its V_{GG} terminal. With a +12V electrical system, it generates the necessary −11V. This circuit is also suitable for supplying dual-voltage power to op amps in automotive equipment.

CMOS Inverter. A single Motorola MC2501 CMOS IC was used to build the circuit shown in **Fig. 2**. This inverter draws about 1 mA with no load and will supply 2 mA to the load. Its current capability can be increased by paralleling additional buffers (these buffers do not increase standby current drain). This circuit uses only one IC package, two resistors, four capacitors and two diodes. It makes possible single-battery mobile applications using high complexity PMOS devices.

Voltage regulation curves are shown to help you select the unit best suited to your needs. ▭



Bruce A. Fette is a design engineer with Motorola Semiconductor Products Inc., Phoenix, Ariz. His present duties involve circuit design using MOS devices. He received a B.S.E.E. from the University of Cincinnati and is a member of IEEE.

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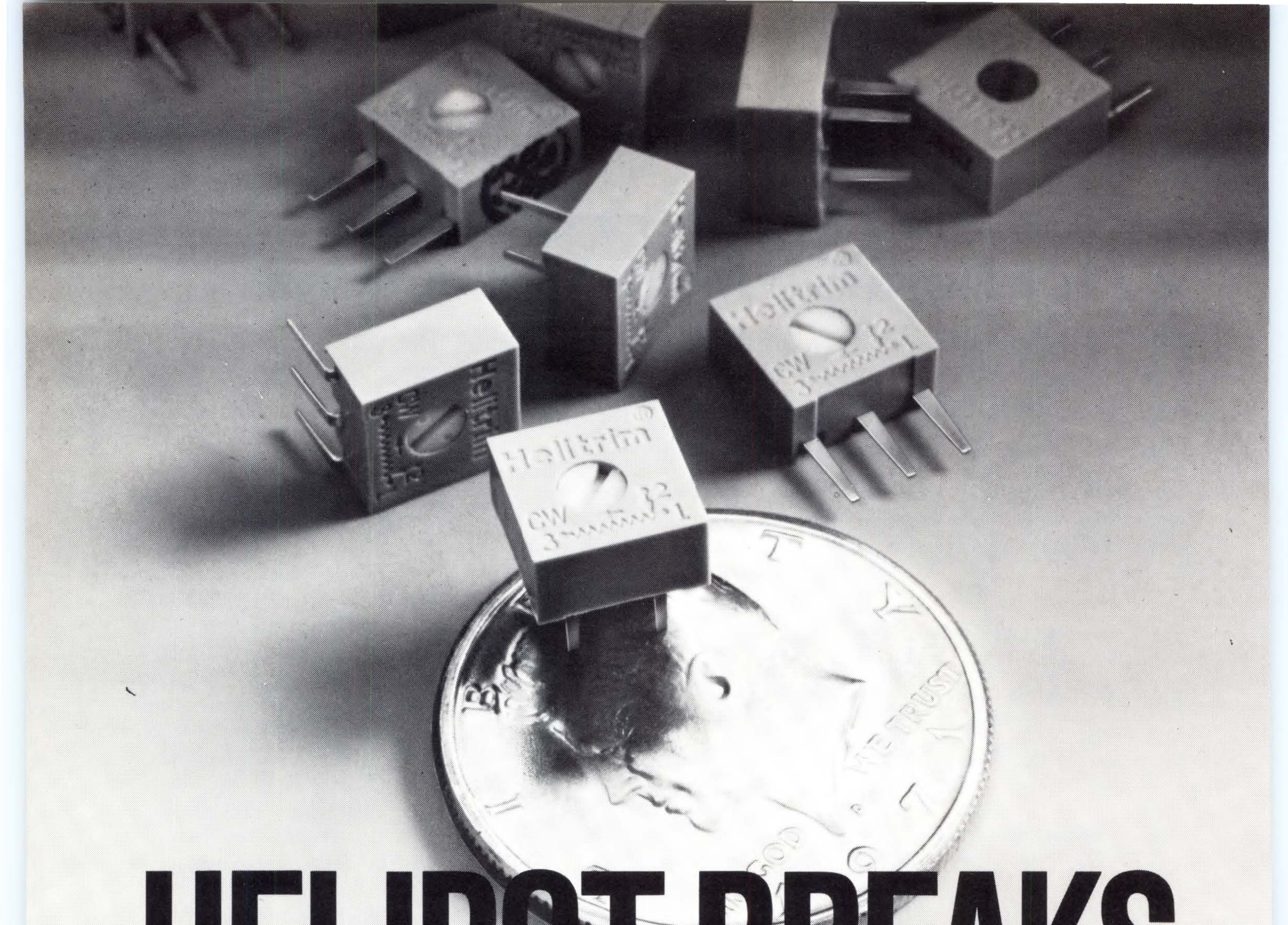

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CIRCLE NO. 19

Open-Ended RC Line Model Predicts MOSFET IC Response

Propagation delay time in a string of MOS Gates may surprise you by being 100% better than you expected.

AMOS WILNAI, Signetics Corp.

A common problem many designers face in modern MOS integrated circuits is how fast a distributed-parameter open-ended RC line will respond to a step voltage excitation. Such a line is constructed when a conducting line is interconnecting many MOS gates, e.g., X or Y select lines in static RAMs, read or write select lines in dynamic RAMs, decode buses, etc. Usually a digital circuit designer is not interested so much in the frequency response equations of the line as in the time response of the line to pulse excitation. In the case of a metal line, with relatively low internal resistance, the time response of the line is usually fast enough. Not so if diffused bed undercrossings are employed in the line or where polysilicon interconnecting lines are being used (as in the case of modern polysilicon gate structures). Propagation delay through such lines can be significant.

We will attempt to determine the response of such a line to a step function excitation. This will give a good idea as to what time delay we should expect before such a line reaches a given voltage. Also having 2.2 *RC* in mind (the time it takes a lumped RC circuit to rise from 10% to 90% of its final voltage), we will find a corresponding number for the distributed line.

The Laplace transformation of the step response of a leakage free, non-inductive open-ended distributed line with lumped time constant *RC* (**Fig. 1**) is found to be

$$V_{out(s)} = \frac{1}{s \cosh \sqrt{sRC}} \qquad (1)$$

when *R* and *C* are the LUMPED values of the line resistance and capacitance, respectively.

The inverse transformation (the real time response) could not be found in close form. We will, therefore, try to arrive at an approximation of the exact response. Recalling that

$$\cosh x = \frac{e^{x} + e^{-x}}{2}$$

$$= 1 + \frac{x^2}{2\,!} + \frac{x^4}{4\,!} + \frac{x^6}{6\,!} + \ldots \qquad (2)$$

for $Re\ x \gg 1$ $\quad \cosh x \simeq \frac{e^{x}}{2}$ (3)

for $Re\ x < 1$

$$\cosh x \simeq 1 + \frac{x^2}{2\,!} + \frac{x^4}{4\,!} \qquad (4)$$

for $Re \sqrt{sRC} \gg 1$ (the response to the high frequency section—leading edge—of the step function), the trans-

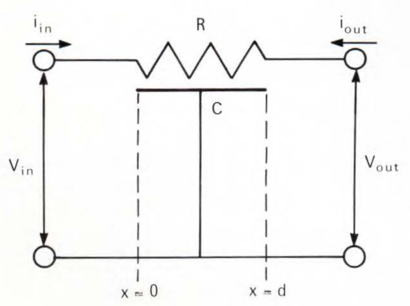

Fig. 1—**Lumped-value** form of an open-ended RC distributed line from which Laplace transforms were derived to approximate pulse-response times.

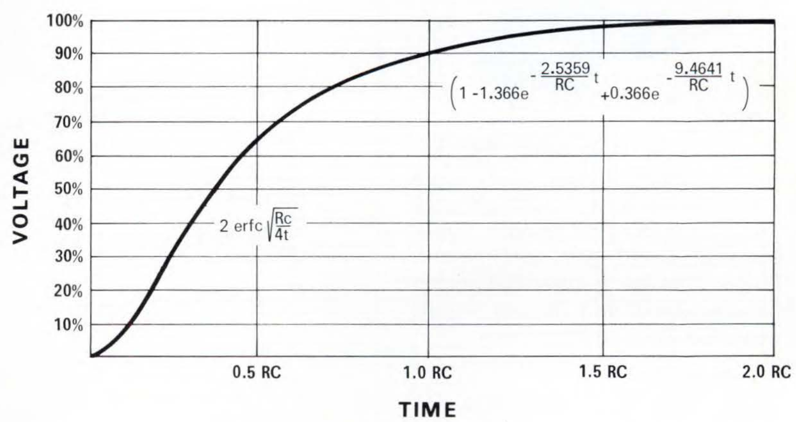

Fig. 2—**Response time** of the distributed RC line as calculated from the inverse Laplace.

(Continued)

RC Line (Cont'd)

formed step response becomes

$$V_{out_{(s)}} = 2\,\frac{e^{-\sqrt{sRC}}}{s} \qquad (5)$$

and the time response is found in standard Laplace transforms table to be

$$v_{out_{(t)}} = 2\,erfc\,\sqrt{\frac{RC}{4t}} \qquad (6)$$

for $Re\,\sqrt{sRC} \ll 1$ (the response to the low frequency section of the step function) the transformed step response becomes

$$V_{out_{(s)}} = \frac{1}{s\left(1+\frac{sRC}{2!}+\frac{(sRC)^2}{4!}\right)} = \frac{24/\,(RC)^2}{s\left(s+\frac{2.5359}{RC}\right)\left(s-\frac{9.4641}{RC}\right)} \qquad (7)$$

with time response

$$v_{out_{(t)}} = 1 - 1.3660\,e^{-\frac{2.5359}{RC}t} + 0.3660\,e^{-\frac{9.4641}{RC}t} \qquad (8)$$

The complete approximate response based on **Eqs. 6** and **8** is plotted in **Fig. 2**.

Note that the time it takes the line to reach from 0 to 90% of its final voltage is 1.0 *RC*; from 10% to 90% (rise time) is 0.89 *RC*; and from 0 to 10% (delay time) is 0.13 *RC*. Compare that with the 2.3 *RC* it takes a corresponding lumped RC circuit to rise from 0 to 90%; 2.2 *RC* from 10% to 90%, and 0.11 *RC* from 0 to the 10% point.

Experimental Results. Because of the relative difficulty of constructing and measuring a purely distributed RC line, we tried to simulate such a line with an increasing number of discrete RC sections. The plot of the time it took these circuits to rise from 0 and 10% to the 90% point of their final value is shown in **Fig. 3**. Here the transition time in total lumped RC units is plotted as a function of the number of discrete RC sections from which the line was constructed. Note the conversion of the graph to the 1 RC line. □

Amos Wilnai was employed at Signetics Corp. when he prepared this article. He has since moved to Monolithic Memories, Inc. in Sunnyvale, Calif. where he is in IC design.

He holds a B.S.E.E. from Technion, Israel Institute of Technology in Haifa, Israel and a M.S.E.E. from the Polytechnic Institute of Brooklyn. He has done additional graduate work at the University of California at Berkeley.

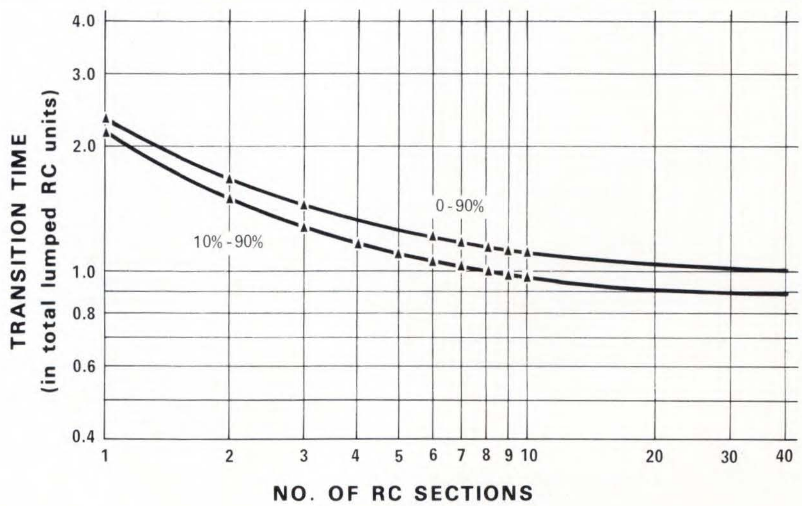

Fig. 3—**Empirical results** clearly depict that response time is not the normally anticipated 2.2 RC, but approaches 1.0 RC as predicted by the author.

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Readers have voted John C. Freeborn winner of the September 1 Savings Bond Award. His winning circuit was called "Simple sinewave oscillator". Mr. Freeborn is with Honeywell, West Covina, Calif.

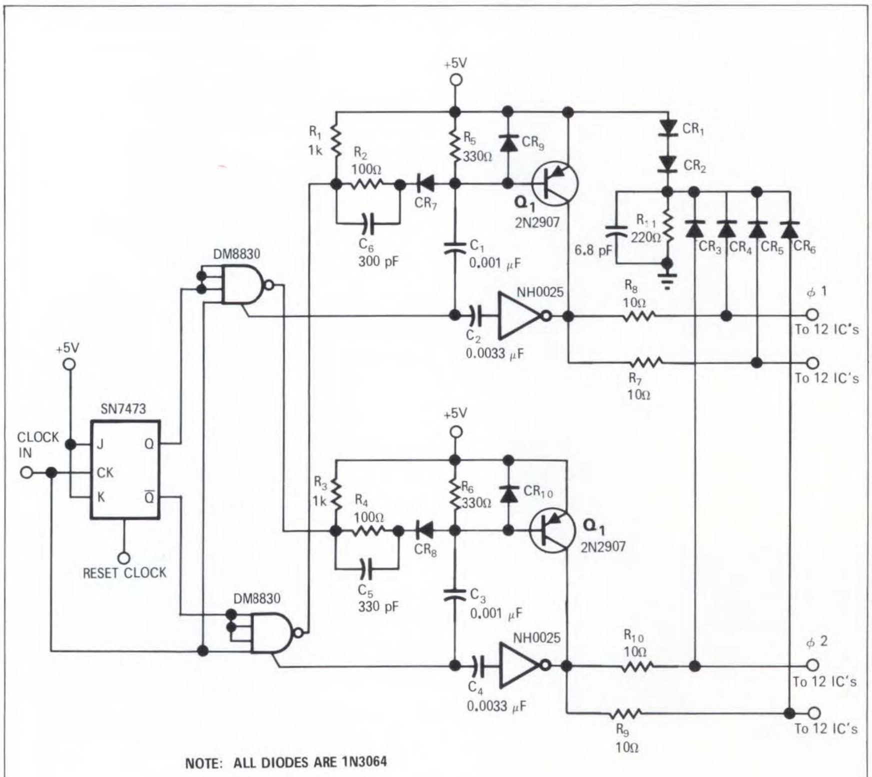
Clock driver for MOS shift registers

To Vote For This Circuit Circle 161

by Robert D. Hoose and Gary L. Anderson
Trans-A-File Systems Co.
Cupertino, Calif.

Clock-driving circuitry can form one of the major expenses for serial MOS memories. The circuit shown here, however, has a large-quantity component cost of under $5. As the circuit drives 24 MOS registers, the cost per bit is less than $0.0002. The circuit operates at clock rates up to 1.5 MHz, and has been used with Signetics 1024-bit dynamic accumulators and Intel, Intersil and MIL 1024-bit serial shift registers.

Circuit operation is as follows: The input-phase clock is preshaped to a width of approximately 150 nsec. It is then steered by the Q output of the flip-flop into one DM8830 driver and by the $\bar{Q}$ output into a second driver. The outputs of the drivers are capacitively coupled to an NH0025 dual



Inexpensive clock driver can supply up to 24 MOS serial shift registers, thus adding under $0.0002/bit to the cost of a memory.

clock driver which generates the 17V, 1.5A clock signal needed to drive the MOS circuits.

The portion of the circuit already described would be adequate for driving just a few MOS circuits. To drive as many as 24 circuits, additional discrete-component compensation circuitry is needed. Transistors Q_1 and Q_2 are turned on at two intervals during each cycle. When the ϕ_1 clock is ON (−12V), the ϕ_2 clock line is clamped to 5V through Q_2. Without the clamp, the cumulative parasitic coupling within the MOS devices can inject enough ϕ_1 noise into the ϕ_2 clock line to cause errors and loss of information in the dynamic accumulator.

As the ϕ_1 clock turns off (transition from −12 to 5V), Q_1 is turned on via C_1 to speed up the trailing edge of the output from the clock driver. A similar sequence applies in reverse when the ϕ_2 clock turns on. Then Q_1 clamps ϕ_1 to 5V, and Q_2 speeds up the trailing edge of ϕ_2.

The remaining components bias and drive transistors Q_1 and Q_2 (R_1 thru R_6, C_5, C_6), damp the MOS clock lines (R_7, R_8, R_9, R_{10}) and clamp the MOS clock lines (CR_1 thru CR_6, C_7, R_{11}). ▭

Simple DC voltmeter uses single op amp

To Vote For This Circuit
Circle 162

by Richard S. Burwen
Analog Devices, Inc.
Norwood, Mass.

A low-input-current op amp, such as the AD503K, can be used to build a simple dc voltmeter. This voltmeter circuit is useful as a general-purpose laboratory meter.

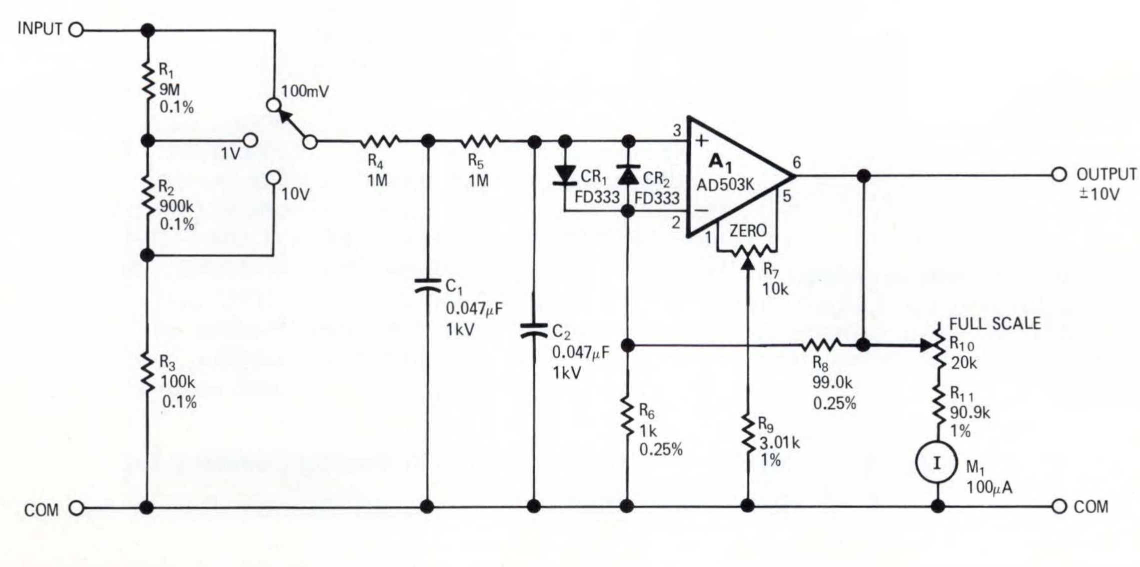
With the attenuator network shown in the schematic, the voltmeter has full-scale input ranges of 10V, 1V or 100 mV. Higher and intermediate voltage ranges can be added if required. Voltage is displayed on a 0-to-100 μA meter. Also, an output terminal simultaneously provides a full-scale output of ±10V for driving a chart recorder.

Basically the voltmeter circuit consists of the op amp connected for a closed-loop gain of 100. Limiting within the amplifier protects meter M_1 against overloads. Resistors R_4 and R_5, together with capacitors C_1 and C_2, form a low-pass filter that prevents the amplifier from overloading on large ac input signals and allows the circuit to read the dc component alone. The series resistance of this filter, in conjunction with diodes CR_1 and CR_3, protects the amplifier from input overloads up to 1000V.

Potentiometer R_7 zeros the amplifier over a span of approximately 50 mV, with the range limited by resistor R_9. Variable resistor R_{10} adjusts the full-scale reading to compensate for the tolerance of the micrommeter.

Circuit stability is such that, in a typical laboratory environment, potentiometers will not have to be reset after the initial calibration. ▭

Simple dc voltmeter circuit uses a FET-input, hybrid-IC op amp. Higher voltage ranges can be added if needed.



here it is
the 1st annual EDN/EEE creative design contest

How to enter

Any reader of EDN/EEE may enter this contest. All you need do is study this issue of EDN/EEE very carefully . . . then set your imagination at work on designing a new device or circuit using the products advertised. Send schematics, drawings, diagrams, etc. to:

EDN/EEE
Design Contest
221 Columbus Avenue
Boston, Mass. 02116

Your entry must be sent by March 1st, 1972.

How your entry will be judged

All entries will be judged by the Publisher and editors of EDN/EEE on the basis of 3 criteria:

1. Technical competence and utility

Is the design real . . . will it work?

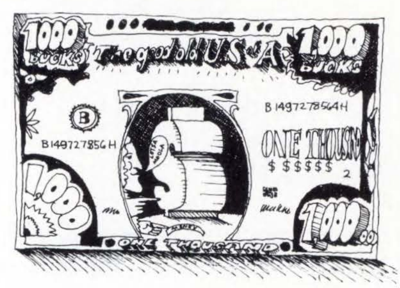
2. Creative imagination

How unique and original is your idea? Does it perform a much needed function? Is it a source of fun! Will other designers get a real charge out of it?

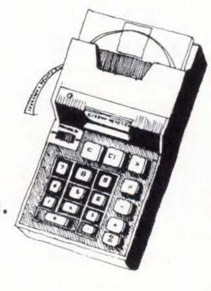
3. Number of different advertised products used

Have you really studied the January 1st, 1972 issue of EDN/EEE. Have you imaginatively used components throughout the design? The more advertised products your design uses, the greater is your chance of winning.

Here are the prizes



1st prize:
$1,000 cash money



10 2nd prizes:
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here's your entry blank

Fill it in, attach it to your schematics or diagrams, and mail to:
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Parts used in your design

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Other Products
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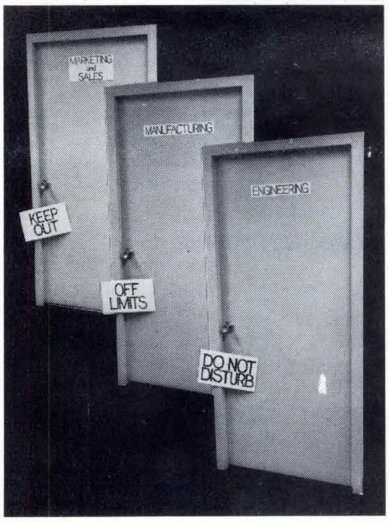


DOING DESIGN THE TEAM WAY

How does a leading electronic manufacturer go about evolving a new product? The answer lies in a team approach involving engineering, manufacturing and marketing decision-makers.

ROBERT H. CUSHMAN, New York Editor

Recently Hewlett-Packard introduced a new and different analog X-Y recorder aimed at the OEM market. The San Diego division of H-P that developed this new recorder is justifiably proud of the interdepartmental teamwork that produced it. In this we see some valuable lessons that may benefit others.

As we interpret the H-P team approach, it consists of insurance by company management that individual specialists will cross their departmental boundaries as frequently as necessary in order to carry the signal around the profit-making loop. The profit-making loop is the feedback system diagrammed at the bottom of **Fig. 1**. Its goal is to sell the customer something that will make a profit for the company.

All too often, the specialists who man the departmental blocks shown in the loop—marketing, engineering, manufacturing and sales—shut themselves comfortably up in their blocks and speak only to other department members. Sterile interdepartmental memos carry the signal haphazardly and weakly from block to block. The total loop performance is at best mediocre, even if there is superlative performance in each of the departmental blocks.

H-P management sees that the departmental specialists are prodded out of their closets so they personally can carry the signal on to the other blocks. Once this personal messenger system is instituted, regenerative enthusiasm sets in and the loop performance goes up markedly. Its results showed up in all phases of the X-Y recorder project.

Effect on Planning

"At the very beginning," recalls Tom Daniels, the EE who led the actual design work, "we asked field engineers from the four H-P sales regions in the U.S. to come to our San Diego plant for an idea-inter-

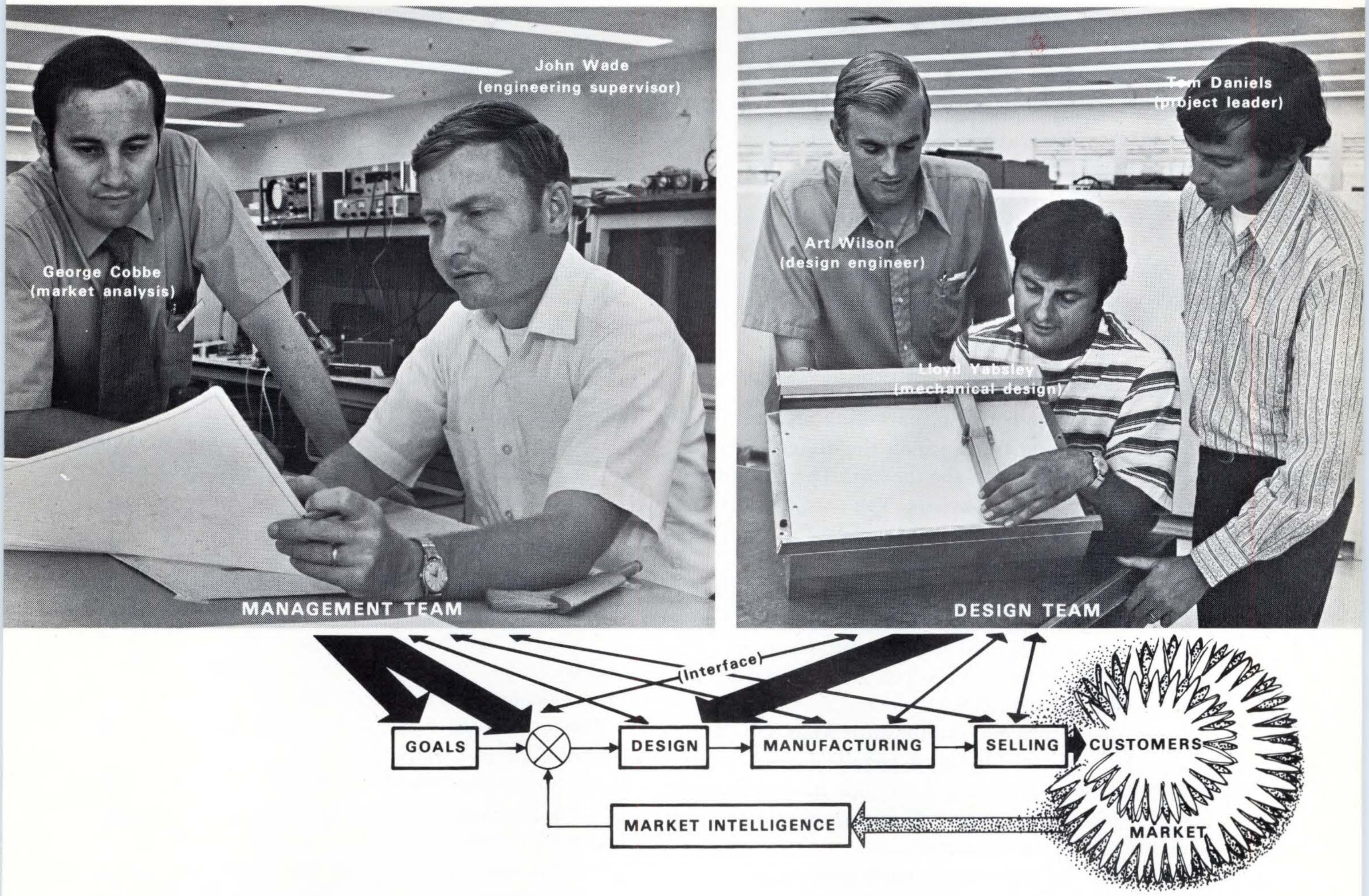


Fig. 1 – **Interfacing is what makes a project proceed successfully** around the creative loop. The H-P management team (left) had many discussions in their initial efforts to take the feedback they were getting from field sales (depicted on diagram) and interpret it into a product concept. The members of the design team (right) worked both with each other as shown and with "upstream" and "downstream" functions in the loop while carrying the product concept to fruition.

change meeting. We wanted the men who had been selling our X-Y recorders out there to tell us what customers were asking for."

This turned out to be a very good meeting. Thanks to the fresh, straight-from-the-horse's-mouth inputs from the field men, the home office men found out that H-P was missing one new and growing market segment – that for OEM recorders. Although H-P was the acknowledged leader in analog X-Y recorders generally, one of their competitors, Houston Instruments, Inc., had stolen a march on them by bringing out a no-nonsense, stripped recorder. The Houston 2000 was a more versatile system building block than anything H-P had to offer. George Cobbe, the team's market analyst, learned that the Houston product was sold with substantial OEM discounts.

These frank field inputs gave the product team the conviction needed for them to propose to top H-P management that they come out with a new X-Y recorder specifically for the OEM market.

Interfacing with Reality

But the team had to do its homework, then go convince management. First they had to use the data they obtained from the field salesmen to estimate what the total market for these OEM recorders would be. Then they had to spec out the needed attributes of the proposed OEM recorder and estimate the engineering and tooling investment needed to produce it.

"At H-P we have to estimate what our total market will be, and what profits we expect to make on that market," explained John Wade, the section engineer-

(Continued)

ing manager. "Then we have to see if we can engineer the product at a cost within a tenth to a fifth of the expected profits."

He illustrated these economics with some hypothetical figures: "Say we expected $2 million annual sales for a product over a 5-year product life. This would provide a total of $10 million. Say the expected profits before taxes were 10%. Then the product would produce a profit of $1 million. Using the one tenth or one fifth sort of ratio we use at H-P, this gives from $100,000 to $200,000 as the correct engineering investment.

Influence on Design

The interchange between marketing and engineering had a profound influence on the design. You can see this by looking at the photos. The disciplined clean-cut simplicity is obvious. You can just imagine how complex it might have been had the engineers been left entirely on their own.

"We really had to restrain our design engineers," Wade said, "we had to keep after them to put in just the essential things, and to leave out the frills. The marketing people helped us decide what the OEM customer really needed. There is always that inner drive in an engineer that makes him want what he is doing to be the very best from a technical performance standpoint. We had to stress that, for this OEM product, *best* meant *most value to the customer*, not that last little bit of performance."

"But don't let the simple appearance of the model 7040A fool you," Cobbe said. "Getting it to look that way was a very tough engineering feat, probably tougher than producing the sophisticated performance advances in some of our regular laboratory-instrument recorders.

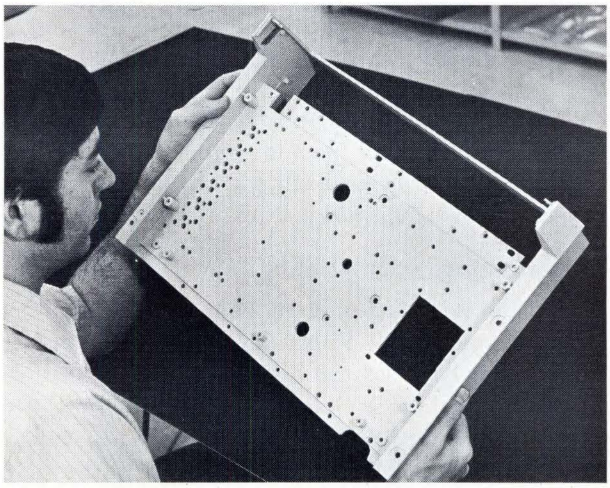


Fig. 2–**Foundation for the new product** was this die-cast aluminum main frame. It was the toughest part of the engineering design and represented a $35,000 tooling investment.

Tom Daniels, who directed the actual design, recalls how it was: "Cobbe kept dropping in on myself and Lloyd Yabsley practically every day to help keep us driving towards the planned product objective." (Yabsley was the product design engineer.) "Our efforts were aimed at low production costs. Our philosophy was to start out using the least expensive techniques for each function, then if they would not do the job, reluctantly going to more elaborate techniques. We didn't mind calling for a tooling investment—as we did in the case of the frame and the motor—if that meant production savings. But all the while we kept to our schedule. This project was the most punctual of any I've been on."

Looking at the Pieces

Die-cast frame: This part played the feature role in the OEM product concept. Once tooled, it was to be an inexpensive, mass-producible part that would be a building block, both for the basic recorder and for all future elaborations and modifications.

While the economies of a one-piece universal frame are obvious, the design approach to such a part is anything but obvious. Daniels recalled: "we had the nearly impossible task of trying to visualize all the holes necessary to take care of future product variations—even those not yet thought of. When you are going to hit management with a $35,000 tooling bill for a die casting, you'd better be pretty darn sure you've got the universal part you say you've got.

"Here we interfaced with an outside vendor who did the actual tool design. But to play it safe we made a sand casting first. The tooling cost for this was a few hundred dollars. This gave us a part we could assemble to see if we had forgotten anything."

The payoff from developing a universal frame came later when the product was put on the production line. It was possible to chop a couple of hours from the recorder assembly time—for the additional time needed to bolt the previous multipiece frames together. The die casting also saved time otherwise needed for final alignment, for it came out of the die with precision mounting surfaces. The mechanical precision of this main frame would, of course, later save the customer time when mounting the recorders into his assemblies or when repairing them.

Servo motors: This is another situation where additional design time and tooling expenses yielded production economies. In an X-Y recorder it is important that the motor won't be damaged if gain adjustments drive the pen off scale. Without some sort of protection, the type of dc servo motors usually used for recorders will overheat and burn out when stalled.

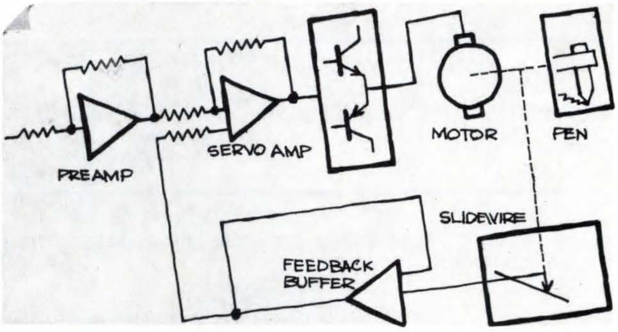
"The usual ploy is to put a clutch between the motor and the pen axes, or to add an electronic loop that detects the overdrive condition and reduces drive power to the motor," said Wade. "But clutches wear out and electronic loops represent expensive additional complexity. Marketing took a dim view of both."

The design team analyzed the situation and found that if the motors could be made to withstand a 200°C temperature rise (the heat rise upon stalling), no protection would be necessary at all. No such heat-resistant motor was commercially available—at least not at a reasonable price. So the H-P team designed its own motor, using another die-cast part for the motor frame.

"Again, we felt that the engineering and special tooling paid off," said Wade. "We now have the most foolproof overload protection imaginable. Doing our own motor like this, we've been able to work in luxury features such as long-life brushes and ball bearings. Yet, we can make these new motors at lower cost.

Electronics: Two identical boards were provided for the electronics. "Marketing told us that nowadays all customers want from a subsystem like this is that it accept a 100-mV/inch signal and convert it to an X-Y plot," Daniels said. "In fact, they told us, extra recorder gain could cause shielding problems."

"So we came up with a universal approach here, too," Daniels said. "We used three LM301 IC op amps like so:"



"The preamp is normally set at unity gain and merely serves as a buffer so that we can deliver our specified performance regardless of his source impedance. However, if the customer does want additional gain, it is a small matter for us to change three resistors and improve the sensitivity to 1/2-mV/inch."

"Marketing wanted these circuits replaceable for easy maintenance," Daniels said. "So we put the complete X and Y electronics on two separate but identical boards, fastened them down with four standard bolts, and used push-on connections for the signal terminals."

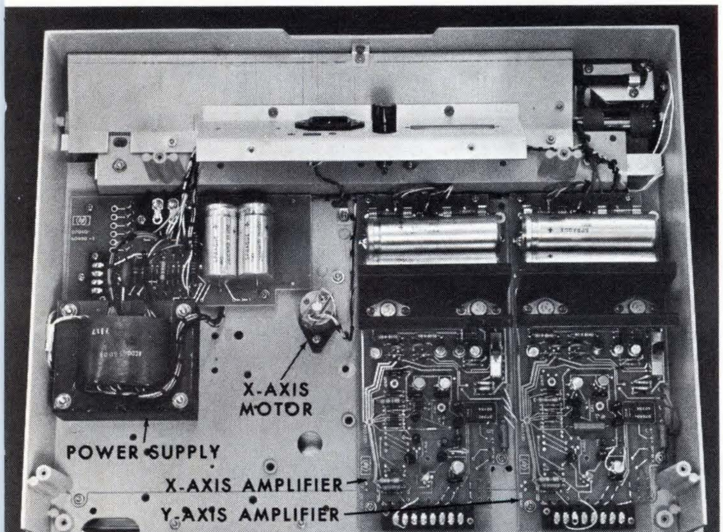


Fig. 3—**Electronic modularity.** Everything fits into molded-in holes and cutouts, etc., in the die-cast aluminum main frame. Each electronic function—such as power supply and X- or Y-axis amplifier—has its own PC board, and can be readily replaced.

Completing the Loop

Following the design phase, teamwork efforts were continued into the initial marketing phase. "As soon as we get our first product off the pilot line we take one of the units and make up a video training tape," said Daniels. "In this, we tell the field salesmen about the features and benefits of the product. Then we, ourselves, hit the road. We take the tape and demonstrators and go off to H-P's four main regional sales locations and hold training classes with the salesmen. We try to let some of our excitement about our baby rub off on the field salesmen."

Cobbe explained the philosophy behind the sales messages developed at these sessions: "We help the salesmen translate these technical features into convincing benefits to the customers. That's where these final "interfacing" sessions between the home office and the field salesmen really do a job." ▭

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computer hardware

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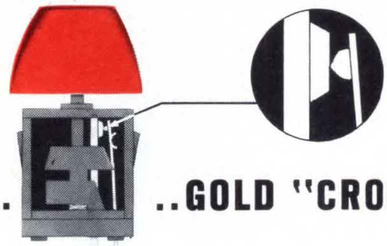

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SIGNAL SOURCES

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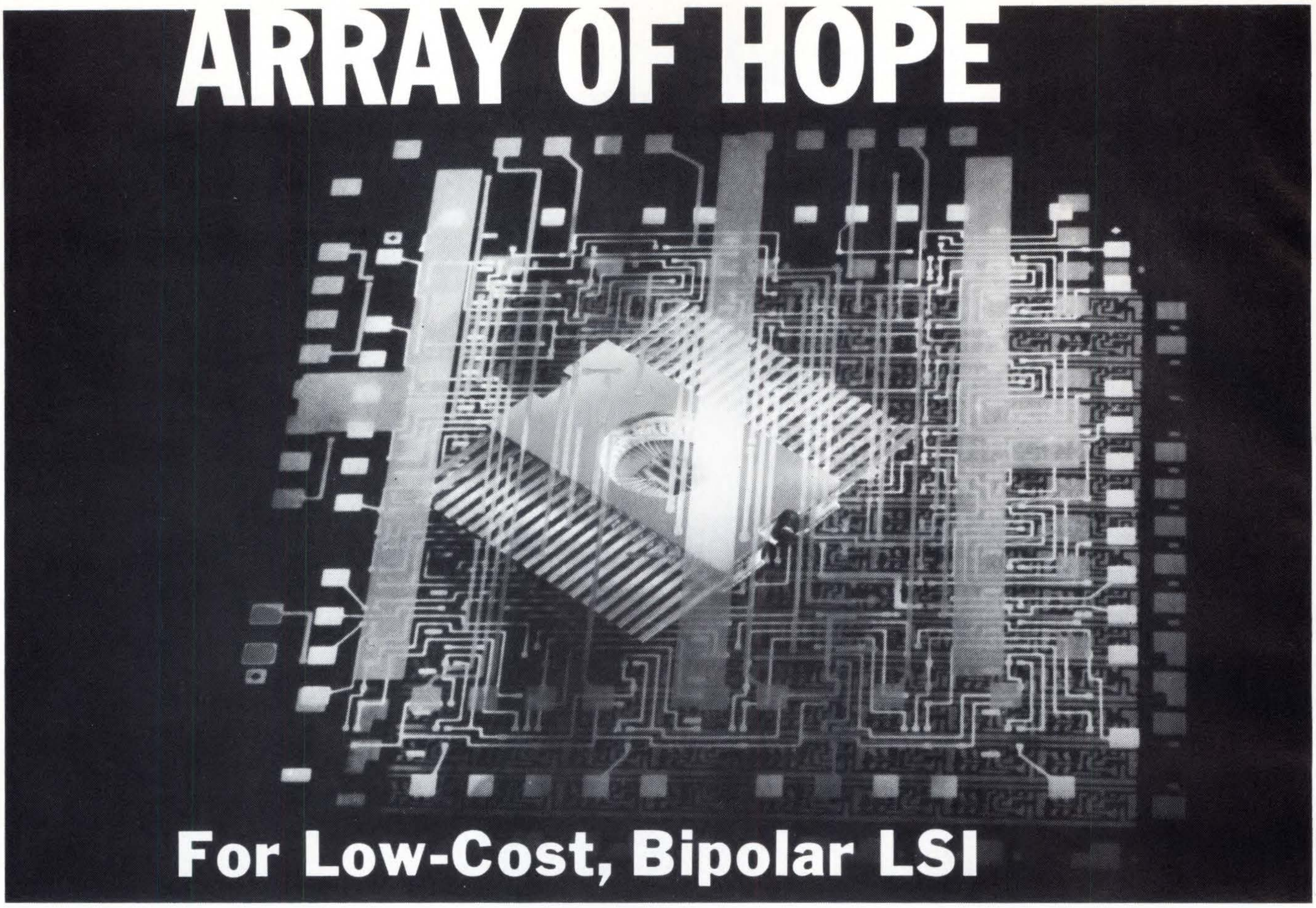

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Using the array design, prototype samples can be available within three months ARO, with limited production quantities following six weeks later. And non-recurring design costs range from $6 - $12,000 depending on extent of computer analysis required. Unit cost of finished parts ranges from $45.00 (1K) to $23.00 (25K). Design cycles are shortened by months and costs by one-third through application of the array concept.

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cover

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directions

capacitors make efficient ROM .... CH 5
Grumman introduces automated tape library system .... CH 6

features

a new computer expert takes form .... CH 8
The circuit designer was the computer expert in the days of the vacuum tube. Soon he was followed by the logic designer—the expert of the diode-transistor era. Now MSI and LSI ushers in another—the subject of this article.
select the right A/C conversion technique .... CH 12
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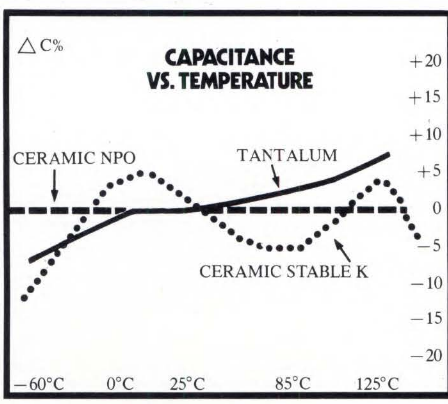

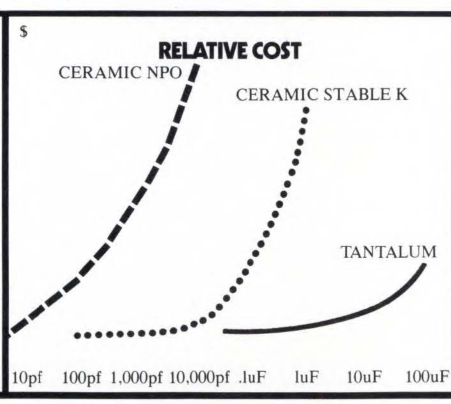

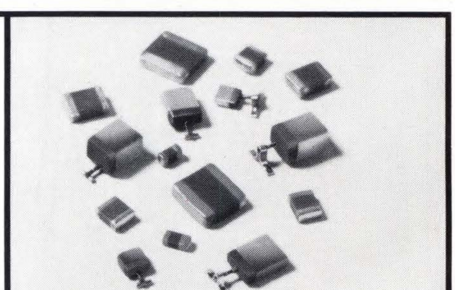

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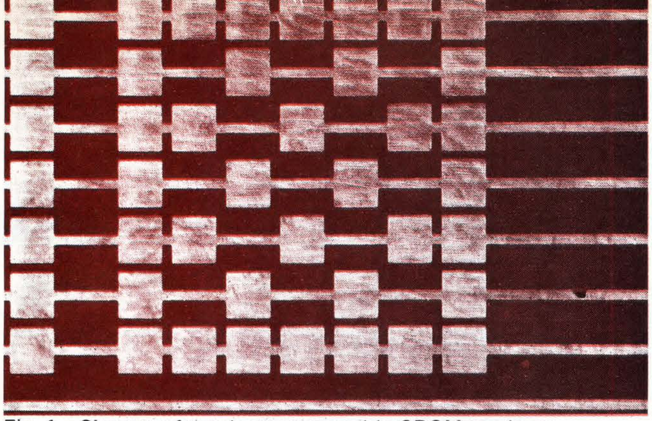


Fig. 1—**Closeup** of mask-programmable CROM top layer.

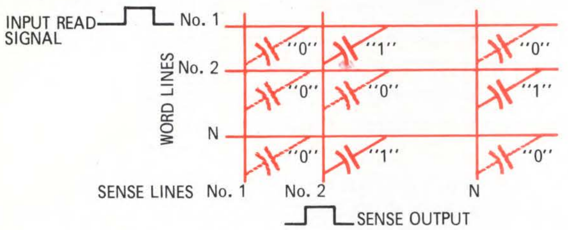


Fig. 2—**Diagram shows** how CROM works. Wherever a square is present on the sense line (at the intersection of the word and sense lines), it forms a capacitor with the word line and stores a logical '1'. Thus when the word line is pulsed, a voltage is capacitively coupled to the sense line.

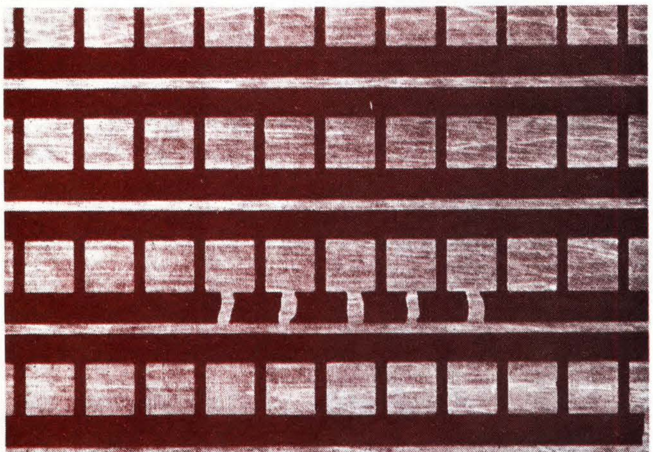


Fig. 3—**Close-up** of field-alterable CROM. Note how some of the '0's have been changed to '1' by connecting squares to the 'x' line.

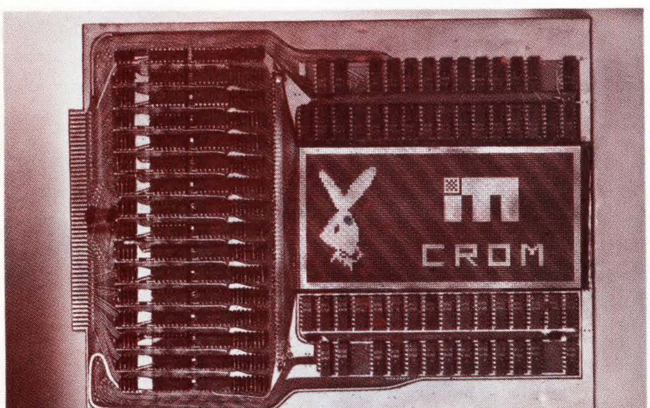


Fig. 4—**This 16K mask-programmable CROM** contains all input buffers, timing and control, address decoding and output data registers.

capacitors make efficient ROM

Dubbed CROM by Integrated Memories Inc., Wilmington, Mass., this is not a new concept, but a new and efficient realization of an old idea. The basic idea is quite simple and this latest utilization of it is even simpler, resulting in a fast, flexible and low cost ROM. The CROM is inherently nonvolatile and has NDRO, yet one version can be reprogrammed in the field any number of times.

The memory array is essentially an 'x' and 'y' matrix of etched lines separated by dielectric material. The 'y' (word) lines form the bottom plate of the capacitor while the 'x' (sense) lines complete the top plate. In the mask programmable version, the 'x' lines will become a series of tiny squares at each 'y' line intersection wherever a '1' is desired (**Fig. 1**). Thus when the word line is pulsed, a voltage is capacitively coupled to the sense line wherever a square is present (**Fig. 2**). The field programmable version has squares at every 'x-y' intersection (**Fig 3**). To field change a '0' in a location where a '1' presently resides, one simply cuts the square connection to the 'x' line. Conductive ink or epoxy can subsequently restore a '0' to a '1' if necessary. To enhance the ease of making field changes, the bit density of the field-programmable version is half that of the mask programmable version, which can be more than a 1000 bits per square inch.

Simplicity of the design allows the entire contents of the mask-programmable version to be changed by IMI within 48 hours by replacing the top 'x' array with a newly etched array. Cost for this is about 0.1¢ per bit.

Access time, which can be as fast as 42 ns, is largely governed by the type of logic gates selected to drive the word lines. The storage array itself dissipates no power, so that when the capacity of a 16K ROM which dissipates less than 10W is doubled, power only increases to about 11W. This power consumption includes all input buffering, timing and control, address decoding, and output data registers (**Fig. 4**). The memory can be organized in words of 8-64 bits.

Cost (in OEM volume) is about 1¢ per bit, including all the above functions, however this can be reduced if the user wishes to buy just the PC board with the memory array, and install all other components himself.

Relative simplicity of the memory also enhances reliability, with MTBF calculated to be greater than 135,000 hours. Such reliability, flexibility and low cost make the CROM ideal for a wide variety of applications like microprogramming, control memory, peripheral control, machine tool control, look-up tables, character generators, code conversion, and dot pattern generators.

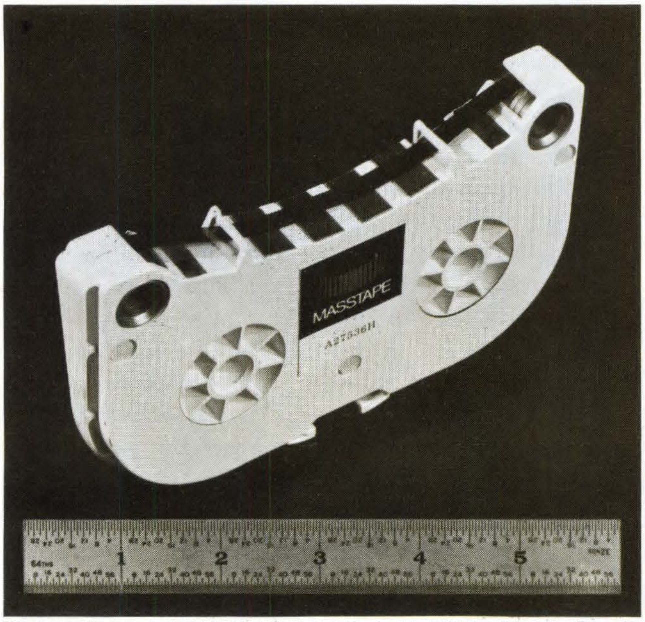
Grumman introduces automated tape library system

Grumman Data Systems Corp., Bethpage, New York has developed a new, on-line modular mass storage system with over a trillion bits of data. This system, designed for computer installations with large data bases, is called "MASSTAPE". The system is based on high-performance cartridges—custom-made for Grumman by Leach—carried in carousel-type magazines. The Grumman system incorporates a Data General minicomputer to interpret standard instructions from a host computer.

Grumman says that the average access to data is less than one second for a file and an average of 6 sec to a record. It takes from 1/2 to 1 sec to rotate the carousel and 0 to 11 sec to locate a record on the tape. The systems will sell for $300 thousand to $2 million, depending on the number of drive stations and data accesses required.

Mr. Peter E. Viemeister, President of Grumman Data Systems Corp., outlined reasons why MASSTAPE would be a desirable alternative to previously developed storage systems: "The cost is comparable to that of large tape systems with 20-30 times the storage capacity. Each MASSTAPE Storage Unit provides a ten-to-one reduction in storage space compared to an average tape library."

The systems may be interfaced to a variety of host computers simultaneously. MASSTAPE can be operated as an independent file management system freeing up host computer time, and the system can be expanded for data base growth by the addition of storage units to provide over one trillion bits on-line.



High-performance MASSTAPE Cartridge holds 260 ft of 1/2-inch tape, with 44-1/2-million bytes.

Cartridges fit into MASSTAPE Pacs, providing a half-billion bytes of removable storage.

MASSTAPE Pacs are loaded into drive stations that contain the access logic drives.

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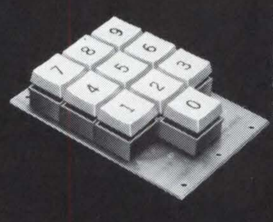

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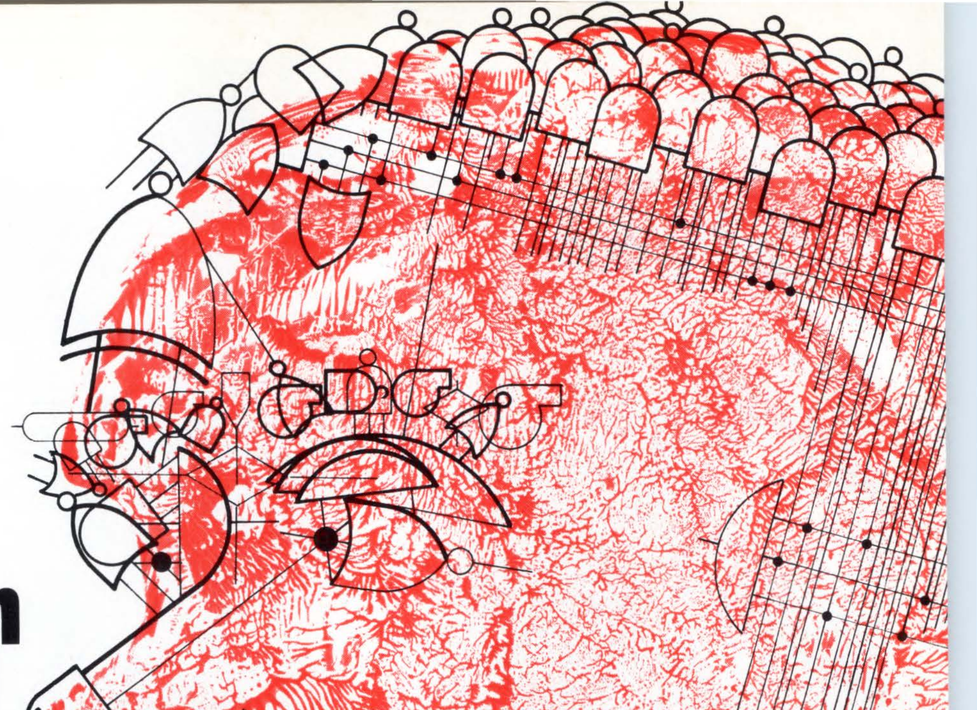
Reshaping concepts in electronic components and systems!



a new computer expert takes form

The hardware evolution has created a new species of computer expert — user or designer who develops an optimal organization from a variety of computer system modules that best satisfies selected applications.

Table 1 — Performance Factors of Twenty Minicomputers

COMPANY	MODEL	$K	$P_h = \frac{\$K}{P}$	$P = \frac{\$K}{P_h}$
Compiler System	CSI-16	12.95	1.40	9.25
Computer Automation	PDC-216	7.99	1.21	6.60
Data General	NOVA	7.95	1.10	7.23
Data General	SUPER NOVA	11.70	1.04	11.25
Datamate	-16	14.90	1.53	9.73
Digital Equipment	PDP-8i	12.80	1.90	6.73
Digital Equipment	PDP-11	9.30	1.22	7.62
General Automation	SPC-16	10.00	0.84	11.90
GRI Inc.	909	9.74	1.15	8.47
Hewlett Packard	2114A	9.95	1.34	7.43
Hewlett Packard	2155A	14.50	1.95	7.43
Honeywell	316	9.70	1.23	7.88
Interdata	3	10.80	1.38	7.82
Interdata	4	13.80	1.52	9.07
Lockheed Electronics	MAC 16	11.95	1.31	9.12
Raytheon	703	11.25	1.44	7.81
Rebcor	RC-70	13.90	1.25	11.12
Scientific Controls	4700	14.80	1.51	9.80
Tempo	1	13.50	1.49	9.06
Varian	620	9.95	1.39	7.16

Table 2 — Performance Comparison of Twenty Minicomputers

	Column 1	Column 2	Column 3
Price $K			
Range	8-15	8-11	11-15
Average	11.6	9.5	13.3
Standard Deviation	2.2	1.1	1.3
Price/Performance P_h			
Range	0.84-1.95	0.84-1.39	1.04-1.95
Average	1.36	1.20	1.48
Standard Deviation	0.24	0.20	0.26
Performance P			
Range	6.60-11.90	6.60-11.90	6.73-11.25
Average	8.62	8.01	9.12
Standard Deviation	1.52	1.47	1.37
Sample Size	20	9	11

Specifications emphasizing performance features of the minicomputer processor do not give the potential customer enough information to select the best machine for his job. Advancements in semiconductor technology have spawned a large number of minicomputers with more than adequate performance for most applications. The use of medium- and large-scale integrated circuits has caused new minis to be introduced with higher performance at a lower cost. Further advancements in LSI will cause the processor to become a minor, purchased component within a minicomputer system.

The minicomputer specifications must emphasize the ability of the system to be optimally tailored to a specific use. This is more important in the minicomputer market than in the larger computer market because of the diversity in applications for the minis. The minicomputer manufacturer must produce a variety of computer system modules which can be organized into a system that will give each customer the right amount of performance at the lowest cost. To bridge the gap between general specifications and specific application requirements, the marketing efforts must include a systems analysis approach.

Popular Features. To demonstrate the impact of semiconductors, the number of ICs used in the logic design of a powerful central processor 18 months ago was reduced by one half. Furthermore, the cost of these elements has decreased considerably within the last few years.

Arithmetic logic units (ALUs) and multiple flip-flops represent some of the MSI components that more than one supplier offers in identical packages. In addition, LSI devices such as read-only memories (ROMs) are being used for microprogram control. With different minicomputer designers using these components a commonality in processor architecture exists, as seen in many of today's miniprocessors, with multiple hardware registers, performing equivalent arithmetic and logic functions via ALU and under control of a small ROM.

Execution rates of these processors are at the common hardware limit, although some processors may be slightly faster than others because there is more parallelism in the execution of a microprogram. However, execution rates approaching 10 MHz fulfill most requirements, and this rate is compatible with available semiconductor memory devices and magnetic core memories.

Basic instruction sets can be economically expanded to contain more complex functions. This results from lower cost ICs and microprogram control organizations. Obviously, each manufacturer will include instructions that are equivalent to his competitors. However, options such as special instructions for specific applications will be provided at additional cost by an increase in the capacity of the control memory.

Comparative Analysis. Analysis of the specifications for present minicomputers indicate small differences in their performance. As an illustration, **Table 1** lists 20 machines within the approximately $8000 to $15,000 price range. The averages and standard deviations of price, $k, price/hardware performance, P_h, and performance, P ($\$k/P_h$), were calculated and the results are shown in column 1 of **Table 2**. The small standard deviation about the average performance factor indicates that approximately 70% of the models have a performance factor within 20% of each other.

This list was then divided into two smaller groups—nine machines within the $8000 to $11,000 price range and 11 models between $11,000 and $15,000. Statistics for these two samples, columns 2 and 3 of **Table 2**, indicate even smaller deviations from the average performance factor for closer priced computers.

As LSI technology advances, the future processors of the minicomputer will be available as an off-the-shelf item, and it will provide higher performance at a lower cost. Several minicomputer manufacturers will use the same components, thus achieving even more uniform performance specifications. Undoubtedly these manufacturers will not invest heavily in producing their own LSI components. Instead, the LSI supplier that makes the investment must sell to several customers because of the very high production yields required. In fact, one supplier will probably be able to produce a year's demand of miniprocessors in a few weeks. On the other hand, the LSI supplier probably will not enter the minicomputer market because he will not have the marketing and systems analysis capability to be successful. In addition, the processor and memory components will represent the least profitable items of the minicomputer system.

Market Characteristics. The nature of the minicomputer market is much different from the market of larger computers and it is still changing. The customer, an expert in a specific field, knows where the computer system grants economies and efficiencies as compared to methods used in the past. He is interested in obtaining this system, or part of it, from a minicomputer manufacturer at the lowest price.

Special minicomputer applications normally require major software development. This may be the only

(Continued)

value added when the customer purchases the total hardware system from the minicomputer manufacturer. Usually the manufacturer has the hardware production capability and the customer has the application expertise. It is thus necessary for both to mutually develop the system for the unique application.

Sometimes, an application cannot be disclosed to a mini manufacturer by the customer until the customer's hardware system is ready for announcement and demonstration. In this event, the minicomputer specifications should be adequate for the customer to configure his own system for pricing information.

The competitive nature of the minicomputer market supports the shift of emphasis from performance features to minimum cost for a complete system. If an alternate minicomputer provides adequate performance at a lower cost, the customer will disregard the system with the highest performance. Also, the customer need not "make do" with off-the-shelf hardware from the computer supplier. There are minicomputer manufacturers who will tailor their hardware for the customer. This includes modification of mechanical form factors, development of special cabinets and inclusion of the right amount of memory and power supply modules that satisfy the need and the expected growth.

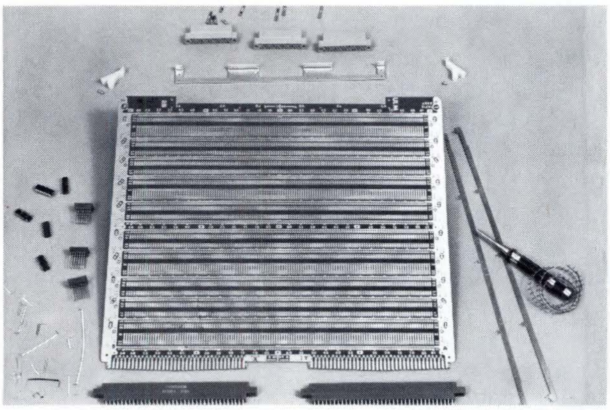


Fig. 1—**Universal logic module** holds a variety of IC and discrete components. Jumpers, wire-wrapping terminals or sockets provide the necessary interconnect.

There is another characteristic of the minicomputer market that necessitates a flexible product. Many customers purchase an initial system for evaluation and software development. Usually this system is large and sophisticated, with normal data processing input and output devices. Systems purchased in quantity at a later date represent scaled down versions of the initial system. Sometimes, the customer already has a large computer system and the initial system is not provided. In these instances, the minimanufacturer must supply cross assemblers and simulators written in a compiler language (FORTRAN).

System Flexibility. Adaptability of minicomputer systems to special occasions means that the minimanufacturer must have more than a high-performance processor in his product line. He must offer a complete line of peripheral devices, a range of memory sizes and a large number of special options. Also, he must have a documentation system so that factory personnel can assemble and test a variety of systems with minimum confusion.

For example, the processor chassis of MAC-16 (Lockheed Electronics Minicomputer) has space for either 30 or 39 PC boards. The processor itself requires only eight card slots. Thus, cards for extra memory, processor options, I/O control or an internal and pluggable power supply can be inserted into the remaining card slots. Excluding memory and processor cards, there are 25 different card types for performance options. When a chassis is full, another chassis is added to the system. Power supplies are

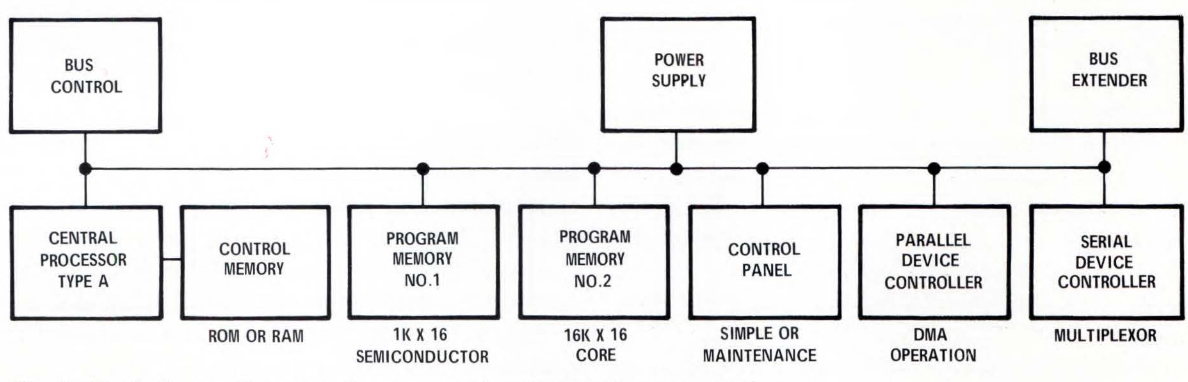


Fig. 2—**Block diagram** illustrates the concept of modular system organization.

provided for additional power requirement or for customer's use. The processor chassis may contain an internal memory of 2k words up to 16k words in 2 or 4k increments. An external chassis expands the memory capacity up to 64k words (k = 1024).

The control panel comes in several variations: It can be excluded; it can be three basic switches; it can be a full maintenance and control panel that is portable; or it can be remotely located.

Occasionally, a customer wants a hardware function that is unavailable in the product line. Then it is necessary either to design and build a special logic card or to provide the customer with a kit so that he can develop his own special function. One typical solution is shown in **Fig. 1**—a universal logic module. This board is compatible with MAC-16 cards.

System of the Future. Modularization will be the future concept of the minicomputer. System modules will vary in performance specifications and will be developed as separate building blocks. Some examples of these blocks are processors, memories, power supplies, control panels, I/O device controllers and special function options. Processors with different functional capabilities will be offered for system selection. Memory modules will range from 1 to 16k words and will be used for small size and high-speed along with the larger and slower core memories. It will be possible to mix different processor modules within the same system.

The printed-circuit backplane—mother board—will be the modern accommodation for a variety of pluggable system modules. A common bus structure will provide the necessary interconnection, with data lines, address lines, control and timing signals. Each system module will communicate with other modules via this common bus. A special system module, the bus controller, will be required to control and determine the priorities on the bus. The block diagram in **Fig. 2** represents such a typical modular system.

A modular approach has several advantages, the most important being flexibility. A large range of performance specifications can be satisfied in a convenient manner. System modules fulfilling the customer's requirements plug into any location in the common backplane.

Future field expandability is another advantage. And finally, a modular system is not subject to obsolescence because of hardware technological advancements. It can undergo gradual change. The processor module may be converted to LSI components at a later date. But it continues to be compatible with other, prior system modules.

It should be noted that there are also disadvantages to the modular concept. There is an overhead cost for communication via a common bus. Each module must have buffering hardware to be independent of the others. The bus controller is also a new system component and represents added cost. Furthermore, the modular component approach invites outside manufacturers to build system components that are direct replacements of the modules offered by the minicomputer manufacturer.

Past Experts The rapidly changing technology of computer hardware is known to be the catalyst of the minicomputer industry. Further advancements are changing marketing techniques. Processor performance is easy to attain and the emphasis is swinging to the development of special low-cost systems. This also introduces a new species of computer expert to evolve at the expense of a fading species of computer specialist.

This change is not new. In the vacuum tube generation, the circuit designer was the recognized computer expert. In the diode-transistor generation, the logic designer was in the forefront and he employed his skills to minimize the diode requirement for a standard architecture. Integrated circuits brought about machine organization changes and competition among computer architecture in developing a product with the highest performance. Medium- and large-scale integrated circuits have made processor design a mechanical packaging problem. The new computer expert is the systems man that can develop the optimal organization using a variety of computer system modules that best satisfies a selected application.

F. Gerald Synder is Chief Engineer for Computer Systems at Lockheed Electronics Co., Inc., Los Angles, Calif. One of Jerry's major responsibilities is the design and development of the hardware and software for the minicomputers MAC 16 and MAC Jr. Mr. Snyder received his B.S. degree from the University of Oregon and his M.S. from the University of Southern California. He is a member of IEEE and ACM.

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select the right A/D conversion technique

A comparison of several different methods of analog-to-digital conversion shows that successive-approximation converters are the most versatile. Other techniques, though, have their place, too.

In data-recording and instrumentation systems, there are many situations where an analog signal must interface directly with a digital computer. The engineer should be aware of the advantages and disadvantages of various types of analog-to-digital converters so that he can specify or design the right converter for a given interface situation.

The majority of commercially available A/D converters employ the circuit technique of successive approximation. This type of converter is the most versatile in the sense that it offers the best combination of performance characteristics in the widest range of possible applications. Thus the successive-approximation technique allows packaged-circuit vendors to manufacture "general-purpose" A/D converters having a large potential market. Usually, special custom requirements can be satisfied by adding "optional features" rather than by changing the basic circuit.

Let's look now at some of the different circuit techniques for A/D conversion and examine their major advantages and disadvantages. The following methods are all compatible with today's semiconductor technology:

—Ramp type

(a) Using simple integrator

(b) Using integrator and bucket-counter combination.

(c) Using digital-to-analog resistor network

– Servo type
– Successive-approximation type

Ramp-Type Converter. With the ramp technique (see **Fig. 1**), the converter is basically a resetable integrator whose output is compared to the analog input voltage. Another key part of the converter is a binary counter which is initially set to zero.

To start a conversion cycle, the counter is allowed to start counting upwards while an accurate step function is simultaneously applied to the input of the integrator. When the integrator output voltage (a ramp function) reaches the analog input level, the comparator generates a signal which freezes the counter.

This basic version of the ramp-type converter suffers from two drawbacks:

First, the circuit is relatively slow for input voltages at the high end of its range. This is because the counter must count all the way from zero to a relatively high number. For example, a 10-bit converter with a 500-kHz clock would take something like 1 or 2 msec to count up to the most significant bits.

Second, it is difficult to achieve good stability with this type of circuit. To maintain a stable clock frequency, a crystal-controlled oscillator must be used. To insure stable integration, a good quality capacitor is required. Also, the reference voltage and its series resistor must be stable.

Improved Ramp Types. A more elegant approach to ramp-type conversion is shown in **Fig. 2**. This approach uses a bucket counter and reduces the problems caused by poor clock stability in the basic circuit.

With the bucket-counter method, the rate of rise of the integrator's output ramp is proportional to clock frequency. And, of course, the rate of increase of the counter's output word is also proportional to clock frequency. Therefore, the effect of clock frequency is automatically cancelled and converter performance becomes virtually independent of the clock. As with the basic ramp-type converter, however, the bucket-counter version has the disadvantage of low speed. Also, stability still depends on the integrator capacitor.

The capacitor-stability problem can be avoided by using another variation of the ramp-type converter, as shown in **Fig. 3**. In this version, the ramp is generated by a D/A switched resistor network rather than by an integrator.

In the circuit of **Fig. 3**, the counter outputs switch the D/A network. This continues until the D/A output

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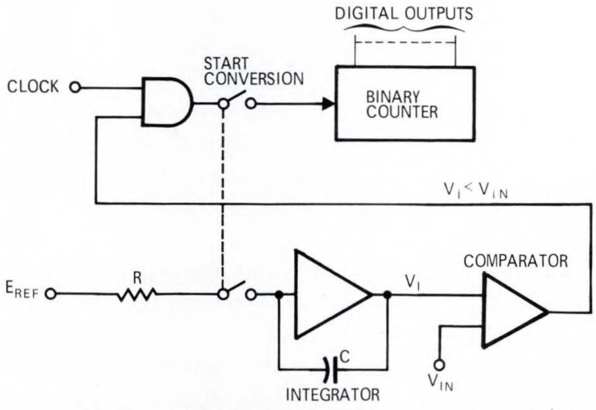


Fig. 1 – **Simple ramp-type converter** consists of a resetable integrator with its output compared to the analog input voltage.

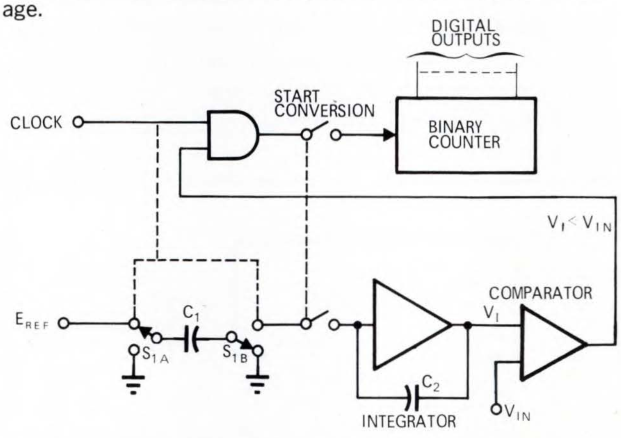


Fig. 2 – **Improved ramp-type converter** uses a bucket counter instead of a simple binary counter. This approach eliminates the requirement for a stable clock frequency.

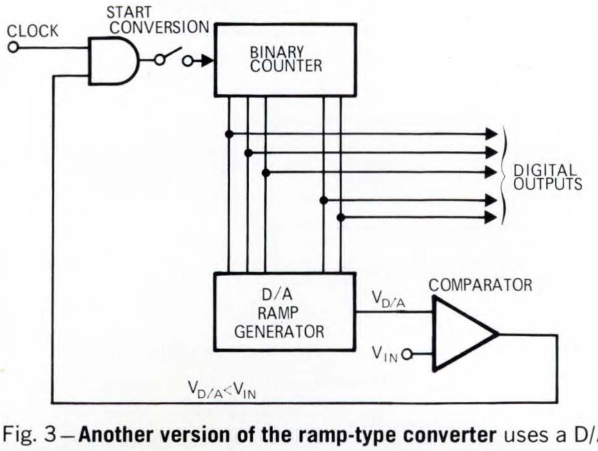


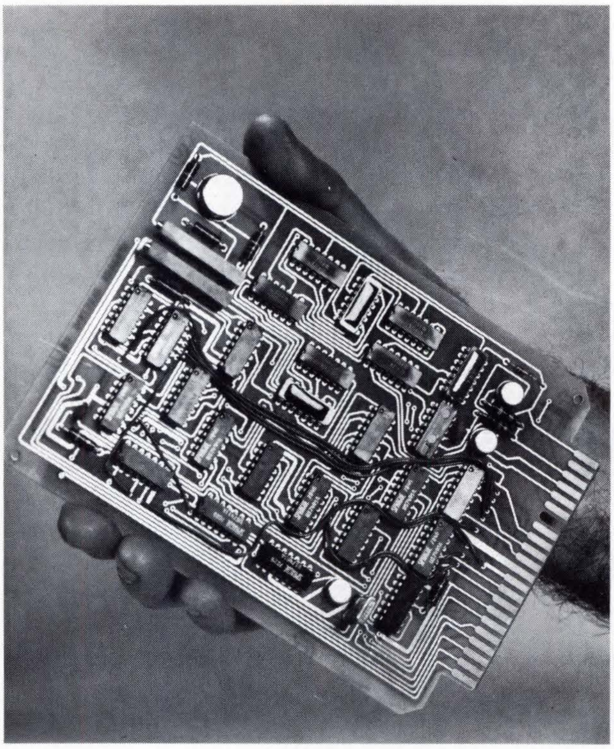
Fig. 3 – **Another version of the ramp-type converter** uses a D/A conversion network rather than an integrator. Because the circuit has no capacitor, stability depends primarily on resistor tracking and switch offsets.

voltage equals the analog input. When this occurs, the clock is gated off. The parallel output word of the counter is held until a reset command is given.

With this type of A/D converter, stability does not depend on clock frequency. Stability depends only on resistor tracking and offset in the D/A network. These errors can be made small enough for 12-bit accuracy. Conversion speed of this type of converter, however, is still as slow as the other ramp types discussed.

Servo-Type Converter. The circuit of **Fig.** 3 can be modified to form a servo-type converter. In this arrangement an up-down counter replaces the up-only counter shown. Also, two comparators are added. One initiates count down when V_{in} is greater than $V_{D/A}$, and the other initiates count up when V_{in} is less than $V_{D/A}$.

With this scheme, the time for initial acquisition is still rather long. But, once the converter acquires the input voltage, a small change in input voltage can be rapidly re-acquired. Thus, this type of converter virtually eliminates the speed problem by allowing high-speed conversion for small input-voltage changes. For widely varying voltages, however, it offers little speed advantage over the ramp-type converter.



A/D converter (type UHM610) developed by Sprague, uses successive-approximation technique and has 10-bit resolution. Modular assembly allows the same basic unit to be easily modified to incorporate or eliminate various circuit options.

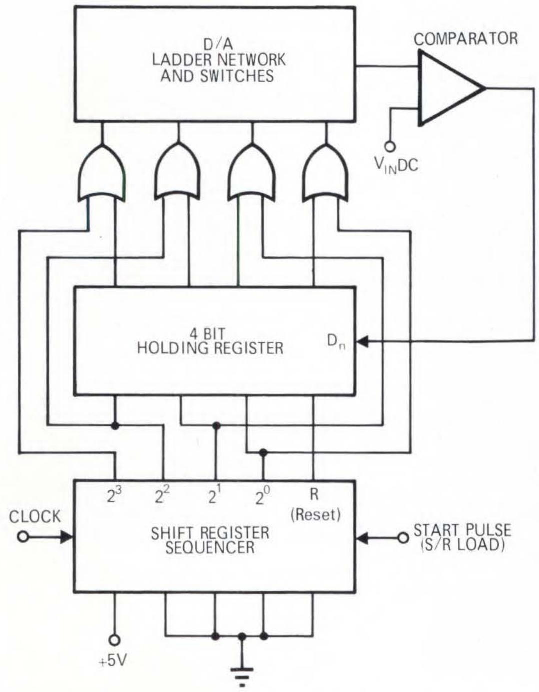


Fig. 4—**Successive-approximation converter** allows fast conversion with widely varying input voltages. Acquisition time is drastically reduced because the output is initially incremented in large jumps instead of step-by-step.

Successive Approximation. The successive-approximation converter also uses D/A resistor network but, instead of being switched through 2^n counts (*i.e.* 1024 counts for a 10-bit servo-type converter), the network is sequenced through n counts by sampling each network bit in succession. This renders a typical 10-bit converter a hundred times faster for a random voltage input.

The theory of operation for a successive-approximation converter can be explained as follows:

For simplicity, consider the 4-bit converter shown in the block diagram (**Fig. 4**). When the shift-register load pulse appears, a **1** is loaded into the 2^3 slot in the shift-register sequencer and all other slots (2^2 thru R) are loaded with a **0**. When the load pulse becomes zero, the sequencer clock steps the **1** (which is in the 2^3 position) through all of the remaining shift-register positions in sequence. In the first (2^3) position, the most significant bit (MSB) of the D/A ladder is connected via its gate and fed to the comparator.

If the ladder network's output voltage is less than the analog input voltage, the holding-register clock D_n (comparator output) goes high and a 1 is clocked into the holding register during the 2^2 sampling period. If the 2^2 sample indicates a ladder output greater than the input voltage, a 1 will not be clocked and stored in the holding register.

This sampling process continues until another sampled bit indicates a ladder output less than the input. This bit is then clocked into the holding register. After the least significant bit (LSB) is sampled, the holding register contains the complete digital representation of the input voltage and provides the required parallel digital output.

Circuit Comparison. When the different A/D conversion schemes are compared, the successive-approximation type proves to be the logical choice to provide greatest versatility. Factors favoring successive-approximation include the following:

– Highest speed for widely varying inputs.

– Stability depends only on D/A networks.

– Performance substantially independent of clock frequency.

– Provides serial output (in addition to parallel outputs) during conversion.

Advantages and disadvantages of the various types of converters are summarized in **Table I**, which also shows some typical performance figures.

To enhance their versatility, packaged "general-purpose" A/D converters are usually offered in versions incorporating features selected from a range of options. Here is a typical list of options offered:

– Choice of internal or external clock source.

– Use of internal or external reference source.

– Offset binary and 2's-complement capability.

– Optional output shift register.

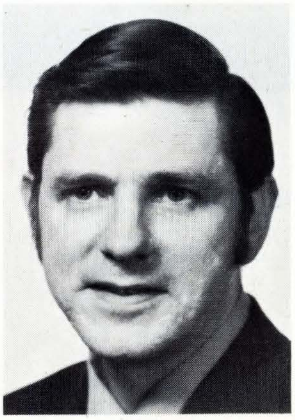
– Single or continuous conversion.

To lower the cost of meeting custom requirements, the manufacturer of general-purpose A/D converters usually employs a modular fabrication technique in which a single PC board suffices for all versions. Optional features are added or deleted by installing or not installing modular subassemblies on the board, as required, and by adding jumper wires on the PC board or rewiring the connector.

As we've seen, successive-approximation type converters provide high accuracy, speed and versatility. This does not mean, however, that other schemes are entirely unsatisfactory. The servo type, for example, is excellent in applications where small deviations from an initial output occur, and where one is not concerned with initial acquisition time. Other schemes, such as the various ramp types, can be used for applications requiring lower speed and lower accuracy.

TABLE I COMPARISON OF DIFFERENT TYPES OF A/D CONVERTERS

PARAMETER	SIMPLE INTEGRATOR	INTEGRATOR WITH BUCKET COUNTER	D/A RESISTOR NETWORK	SERVO TYPE	SUCCESSIVE APPROXIMATION
RESOLUTION	12 bits	12 bits	12 bits	12 bits	12 bits
STABILITY (0-70 °C)	±0.5%	±0.5%	± 0.05%	±0.05%	±0.05%
CLOCK DEPENDENCY	SCALE FACTOR PROPORTIONAL TO CLOCK FREQUENCY	INDEPENDENT	INDEPENDENT	INDEPENDENT	INDEPENDENT
WORST-CASE CONVERSION TIME (10-BIT UNIT)	2 msec	2 msec	2 msec	2 msec	20 μsec
PARALLEL OUTPUT	YES	YES	YES	YES	YES
SERIAL OUTPUT	NO	NO	NO	NO	YES



Walter Schopfer was an engineering group leader with Sprague Electric in Worcester, Mass. at the time he wrote this article. He is now a senior scientist at Singer Corporate Research, Little Falls, N. J. Mr. Schopfer received his B.S.E.E. from New York University in 1957.

termination is the key to wired-OR capability

With a little thought and a handful of components, several IC line drivers can be wired-OR on one data line.

Occasionally, a data transmission system requires wired OR output capability. A majority of the balanced monolithic line drivers, however, are not designed for this type of application. If certain conditions are considered, they can be used very successfully with the addition of a few components.

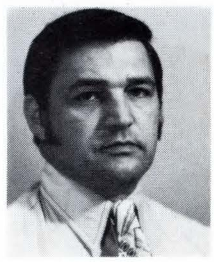
When a system has wired-OR capability, the receiver output is a logical "1" if all drivers are transmitting a logical "1." If any one or all of the drivers transmit a logical "0," the output is a logical "0." The circuit shown permits the ORing of several drivers on one data bus.

The feature that permits a proper signal to reach the receiver is the termination network. It provides a 100Ω match to the transmission line and a 2.5V common-mode voltage with no drivers connected to the line. Several balanced drivers, like the one illustrated, will function as an OR system when connected to the line with their **A** and **B** outputs tied together.

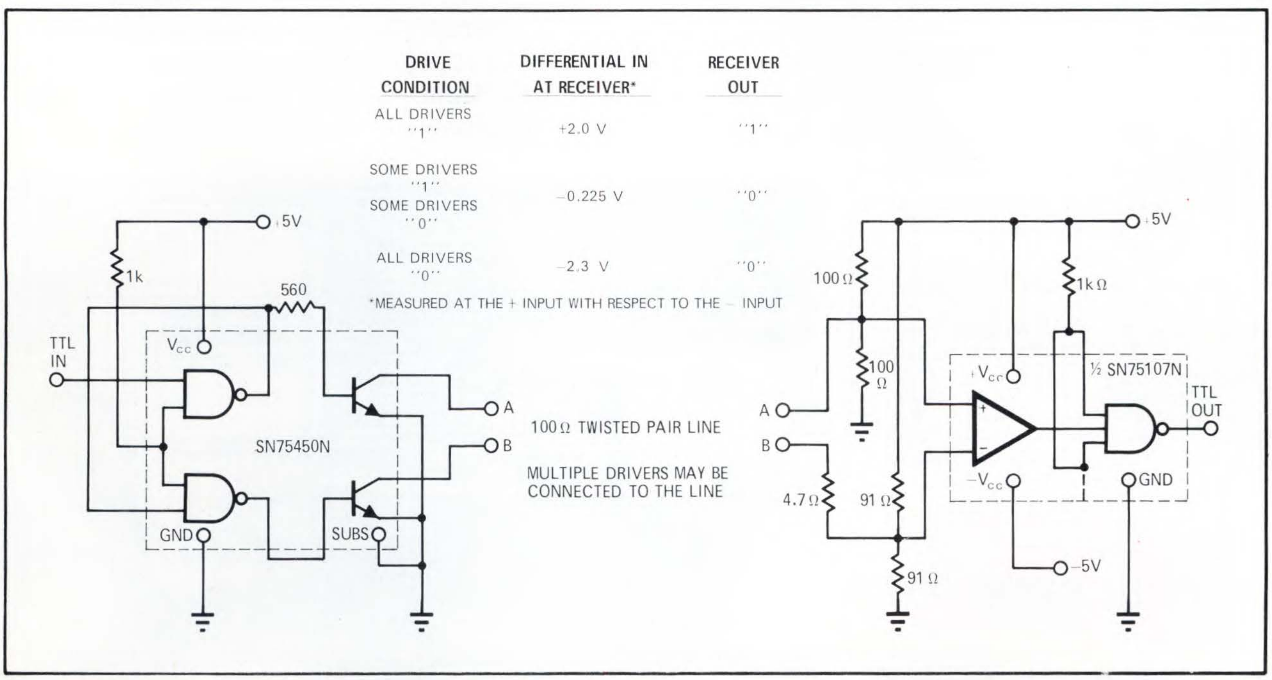
When all drivers have a logical "1" input, their **A** outputs will be high and the **B** outputs will be ON, pulling the **B** line to ground. This applies 2.5V to the positive terminal of the receiver and about 0.5V to the negative. This differential generates a TTL "1" level at the output of the receiver.

When a logical "0" is applied to all drivers, the **A** line approaches ground and the **B** outputs are OFF. The results are a full 2.5V at the negative input of the receiver and a TTL "0" output.

A third condition occurs when one driver has a logical "1" input and another a logical "0." Both lines **A** and **B** will approach ground. Typical $V_{CE(sat)}$ of the SN75450 is approximately 0.2V. Therefore, the positive input of the receiver will be approximately 0.2V (neglecting line resistance). Current being sunk in line **B** must flow through the series resistor (4.7Ω), resulting in an additional voltage at the negative input of about 225 mV. Applied to the negative input, this voltage causes the receiver to generate a TTL "0"—as it should in an OR application.



Dale Pippenger is a senior engineer with Texas Instruments Incorporated, Dallas, Tex. His duties involve linear and computer interface, IC applications and product evaluation. Pippenger received a B.A. in mathematics from Memphis State University.



DRIVE CONDITION	DIFFERENTIAL IN AT RECEIVER*	RECEIVER OUT
ALL DRIVERS "1"	+2.0 V	"1"
SOME DRIVERS "1" SOME DRIVERS "0"	−0.225 V	"0"
ALL DRIVERS "0"	−2.3 V	"0"

*MEASURED AT THE + INPUT WITH RESPECT TO THE − INPUT

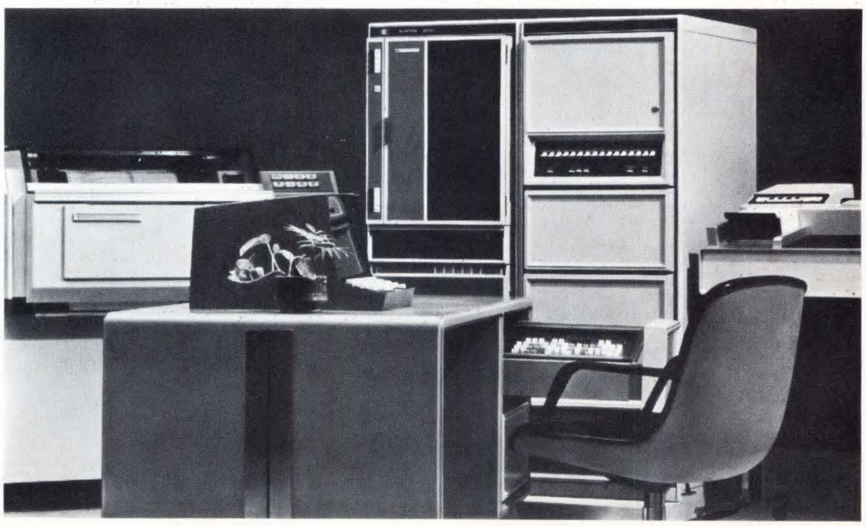
it's small, but sophisticated

In the past, the performing of time-sharing, real-time multiprogrammed batch and on-line terminal operations simultaneously called for a $500,000 to $1-million computer system. Recently, Hewlett-Packard unveiled a small-scale computer system at Fall Joint Computer Conference with true multiprogramming and multilingual capabilities—and it sells for only $100,000 to $300,000. Designated System/3000, this disc-based system represents a radical new architectural approach to the design of small central processors. Also, this system is the first to be designed from inception for the total marriage of hardware and software to achieve total flexibility in operation.

An important key to the abilities of the System/3000 is the newly developed high-level system programming language, SPL/3000. This language accomplishes program encoding three to six times faster than the traditional assembly languages. In fact, the software development for the System/3000 was reduced by a factor of five using SPL/3000 exclusively. Other available languages include a new version of FORTRAN IV and BASIC/3000, which is a more powerful extension of HP's BASIC. These languages are for all operating modes (time-sharing, real-time and batch). Also, System/3000 software incorporates text editing and formatting, statistical analysis, system diagnosis, flowcharting and user program diagnosis.

Computer Profits From Features System architecture permits multiprogramming operation and efficient dynamic allocation of resources. Concurrent I/O and CPU operations are easily realized. Central processor hardware yields inherent reentrant code, relative addressing, memory protection and virtual memory through variable length code segments. Operational features of the system are:

- Multiprogramming capability for time-sharing, real-time processing and general-purpose batch.
- Modular hardware structure using a central data bus with a 5.7 megabyte/sec transfer rate.
- Stack-oriented CPU architecture providing 18 μsec microprogrammed environment switching and 170 instructions.
- A complete line of standard computer peripherals.
- Multilingual capability plus utilities and diagnostics.
- Modular hardware construction for easy system expansion of I/O and memory.



Another highlight is a microprocessor based on a large-scale integrated circuit ROM (read-only memory) with an instruction time of 175 nsec. The system accommodates up to four independent memory modules having a combined capacity of 131,000 bytes. A high-speed data path yields a system data rate of up to 2.85 megawords between subsystems.

Storage Enhances Capabilities Plug-in boards enable the user to expand the core memory capacity of System/3000 from 32,000 to 131,000 bytes in 16,000 byte increments. The memory is a folded planar-core type with two- or four-way module interleaving.

For mass storage, disc files (similar to IBM 2314) range in capacity from 5- to 50-million bytes, with fast access and data transfer rates of up to 250,000 bytes/sec. Online storage is expandable to 1-billion bytes. For improved system performance, a new high-speed swapping drum is available that stores up to 4-million bytes with average access of only 8.7 msec and a data transfer rate of 470,000 bytes/sec.

Word size in the memories is 16 bits with a 17th bit for parity. Code segments stored in memory contain no absolute addresses. All addressing of data is relative to the registers of the central processor.

A large selection of peripheral devices is at hand for prospective System/3000 users. These devices include 600 or 1200 cpm card readers, 40 or 250 cpm card punchs and 132 column, 96 character, 200 or 600 lpm drum printers. In the magnetic tape line, either 7-track, 45 ips or 9-track, 45 ips, 800 or 1600 cpi units are available. Also, provisions for asynchronous multiplexors (to 2400 bps) and synchronous interfaces (to 1.5-million bps) are obtainable for data communications. Hewlett-Packard Co., 1601 Calif. Ave., Palo Alto, CA 94304. **419**

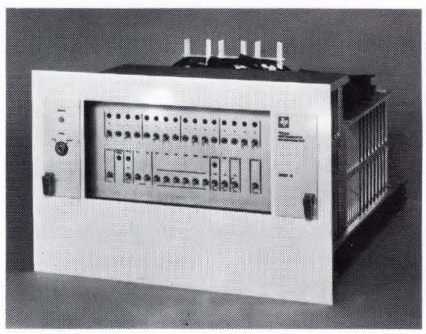
computer meets manufacturer needs

Texas Instruments Incorporated unveiled their latest development in their 900 Series computers at FJCC – a 16-bit minicomputer with a selling price of $2850. Designated Model 960A, the hardware and software design featuring a dual-mode architecture makes the 960A appropriate for manufacturing automation, process control and data collection systems application. Included in the price is the power supply, a DMA (direct memory access) channel, automatic parity checking, memory write protect and a complete lockable front panel. Additional 4k memories are available for $1500.

The basic 4k MOS memory, 750 nsec cycle time, is expandable to 32k words in the same chassis with additional external 32k available. Other operational features include a combination of up to 512 I/O lines in the basic chassis that are expandable to 8192 I/O lines, hardware multiply and divide, and a memory refresh battery pack that is good for two weeks without external power.

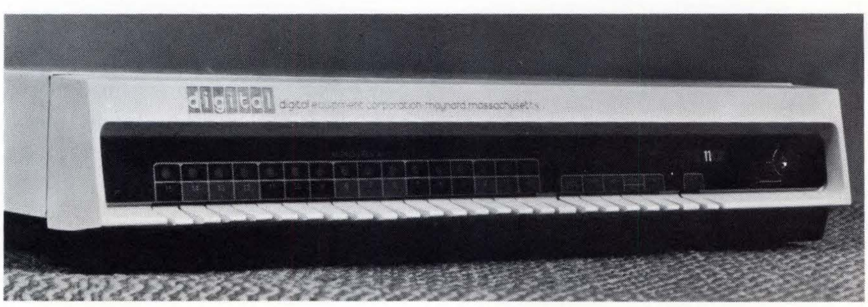
The computer interfaces quickly and inexpensively with existing equipment. In fact, the manufacturing personnel can operate the 960A without extensive training. Because the hardware and software were designed together, the software is easily adapted to on-line, real-time operations, thus reducing downtime during manufacturing or process changes.

An important contribution to the efficiency and performance is the "Communications Register Unit" (CRU). The CRU interfaces the user's devices to the central processor with simple software instructions and eliminates the need for expensive



PDP-11 goes small scale –

A 3.5-inch-high, communication-oriented computer was introduced by Digital Equipment Corp. at the 1971 FJCC. Designated the PDP-11/03, this 16-bit processor sells for as little as $2560 in quantity ($3995 in single quantity) and comes with either 2k, 4k, 8k or 16k bytes of memory. The computer is completely compatible with all members of the PDP-11 family, including the recently announced PDP-11/45 medium-scale computer.



hardware controllers. A combination of up to 8192 I/O lines can be controlled individually or in groups. Standard plug-in cards permit direct communication using only the number of input and output lines necessary for any given control instrument, device or sensor.

The software lends itself to writing or modifying programs in the user's "shop" language such as "close relay". A single instruction will start a motor, operate a valve or read the process variables. Other available items include a comprehensive array of powerful user-oriented software packages including FORTRAN, monitors, loaders, macro processors, an overlay link editor, an advanced disc operating system, and assemblers and cross-assemblers for large computers.

Deliveries begin in late 1971 and the price of $2850 is for 1 to 100 quantities. A wide selection of peripherals and support equipment is available. Texas Instruments Incorporated, Box 1444, Houston, TX 77001. **420**

Included within the miniature enclosure is a central processor, with 1.2 μsec cycle time memory, complete power supply, serial communications interface and programmer's console. In addition, other features such as power fail/auto-restart, direct memory access (DMA), automatic priority interrupt and hardware stacks are standard items. A variety of software including assemblers, editors, I/O executives and on-line debugging packages is being offered. Deliveries are scheduled for the 2nd quarter of 1972. Digital Equipment Corp., 146 Main St., Maynard, Ma. 01754. **421**

Monolithic Multiplying DAC Offers Fast Switching

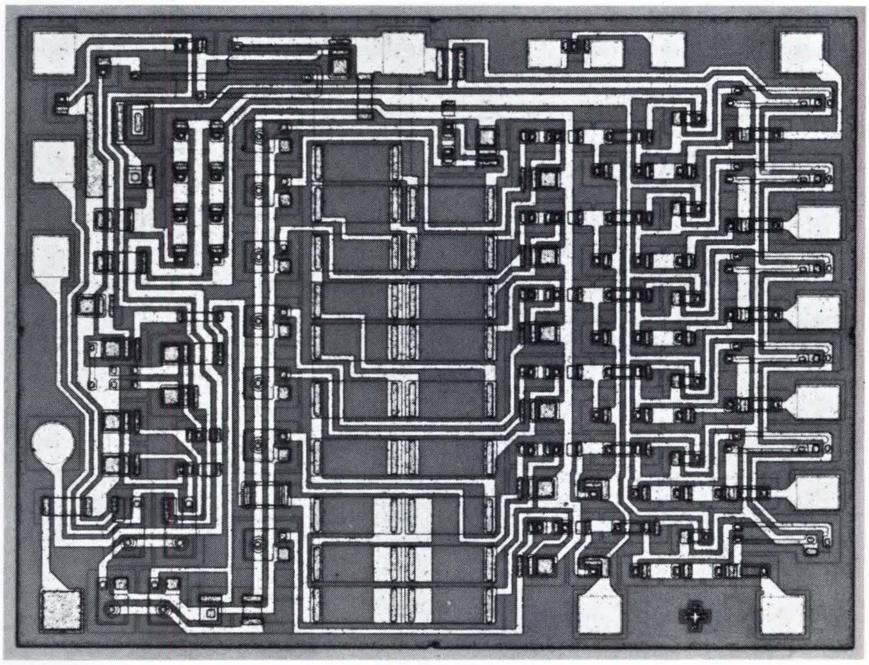
PROGRESS IN MICROELECTRONICS

A new low-cost monolithic six-bit digital-to-analog converter from Motorola has switching speed of only 300 ns. The IC, Type MC1406L, includes a diffused-resistor ladder network and all necessary switching circuitry. It does not, however, include an output amplifier or reference regulator.

Only one other company, Precision Monolithics, manufactures a monolithic DAC using diffused resistors. The Precision Monolithics monoDAC-01, however, also includes a reference circuit and output amplifier on the chip in addition to the ladder and switches. The monoDAC-01 has a settling time of 3 μs to within a half LSB.

Both the MC1406L and the monoDAC-01 provide six-bit resolution. According to the designers of the two ICs, diffused resistors offer adequate uniformity and stability for fabrication of DACs with greater resolution. Both companies expect to introduce higher resolution versions later.

While thin-film resistors are much more stable than diffused resistors, the latter are compatible with conventional IC fabrication techniques and, hence, offer much lower costs in volume production. In a monolithic ladder configuration, the poor stability of diffused resistors proves less of a problem than one might expect. This is because the individual resistors tend to drift at the same rate, thus minimizing errors in the current ratios that are defined by the network.



Motorola's MC1406L is a 6-bit D/A converter IC with switching circuitry and a diffused-resistor ladder network on the same chip. Chip size is 79 mil by 91 mil. The IC comes in a 14-pin ceramic DIP case.

Flexibility versus Completeness

Compared with the monoDAC-01, the most important advantages of the MC1406L are lower cost and faster switching. With the monoDAC-01, switching speed is limited primarily by the speed of the on-chip out-put amplifier. According to the designers of the monoDAC-01, the switching speed without the output amplifier would have been about 300 ns (same as for the Motorola unit). Thus, while Precision Monolithics offers a complete converter with guaranteed performance, Motorola offers a more versatile circuit that can be tailored (by suitable choice of the external circuitry) to provide either higher speeds or lower cost.

In quantities of 100 up, the MC1406L sells for $3.95. A comparable version of the monoDAC-01 (with the same industrial temperature range and hermetically sealed package) costs $17.50 in quantities of 100 up. Of course, the cost of a complete converter circuit using the MC1406L will be higher than the basic cost of the IC because of the external circuitry required.

An even more flexible approach to

D/A conversion is offered by the many companies now selling monolithic D/A switches which require external ladder networks. With this approach, one can select resistor networks having accuracy and stability compatible with desired overall converter performance. But, for 6-bit converters, monolithic units with diffused resistors will probably prove more cost effective.

Multiplying Capability

One important aspect of the MC1406L's greater flexibility is that, unlike the monoDAC-01, it can be operated in the multiplying mode (with a varying reference voltage which forms one of the two input signals). This opens up a whole field of additional circuit applications (see *EEE*, September 1970, pp. 52-57).

Of course to operate the MC1406L as a conventional dc-reference converter one need only use reference circuitry that is adequate for the application. For room-temperature operation, a simple zener diode may be sufficient, whereas a more sophisticated reference source will be needed to operate over the full temperature range of zero to +70°C.

The MC1406L's current-mode output proves to be an advantage in many A/D converter applications. When a DAC forms part of an ADC circuit, the DAC output can be directly summed at the input to a high-speed comparator. Because there is no intervening linear amplifier, conversion speed is then limited primarily by the comparator and the associated logic.

Unusual Circuitry

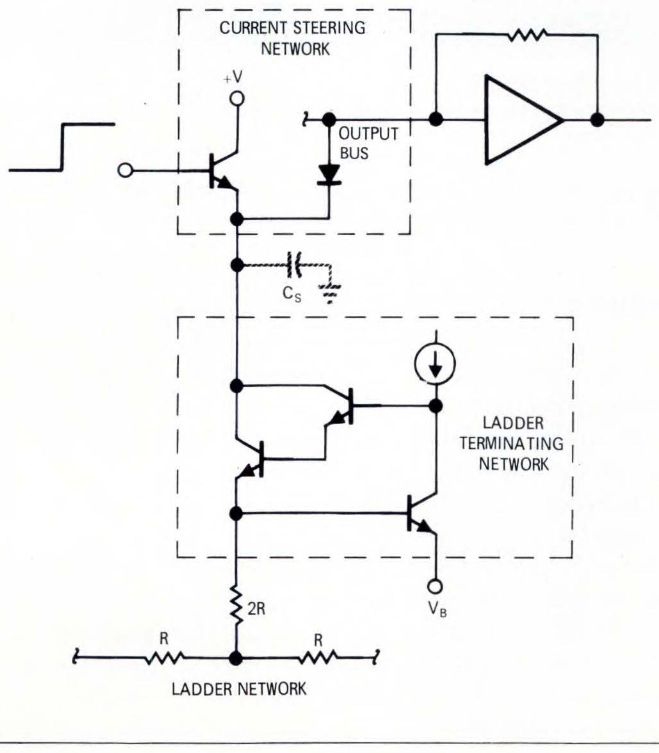
The new Motorola circuit uses an R-2R ladder network with a constant ladder current. This minimizes the effects of parasitic capacitance (inherent with diffused resistors) on device switching speed. Also, because of current drive, termination voltages at the individual ladder legs are unimportant provided they all match. This matching is easily accomplished in an IC.

Switching of the ladder outputs is achieved by a current-steering network that operates like a differential amplifier. An unusual ladder-terminating circuit provides a low terminating impedance and near-unity current gain to the output bus.

At present, the MC1406L is available only in an industrial-temperature-range version. The monoDAC-01 is available in versions for the military or industrial temperature ranges. Motorola currently offers a ceramic 14-pin DIP package whereas Precision Monolithic offers either sealed or plastic DIPs. Both companies can deliver from stock.

Motorola Semiconductor Products Incorporated, Box 20912, Phoenix, AZ 85036 **R.S. No. 163**

Precision Monolithics Incorporated, 1500 Space Park Drive, Santa Clara, CA 95050 **R.S. No. 164**



Section of schematic for MC1406L shows the unusual current-steering and ladder-terminating networks. The ladder terminating network is basically a common-emitter amplifier with unity feedback through emitter followers. This configuration provides low terminating resistance and unity current gain from the branch current to the output bus. The current-steering network (simplified in this diagram) passes current either to the output bus via the diode or to the power supply via the transistor, depending on the digital-input state.

MC1406L Typical Characteristics

(V_{cc} = +5V, V_{EE} = −5V, I_{ref} = 2.0 mA)

Relative Accuracy (0°C to 70°C)	0.7%
Settling Time (within ½ LSB)	300 ns
Digital Input Current	50 uA
Output-Current Drift	0.002%/°C
Power-Supply Sensitivity	0.1%/V

Plated-Wire Enters Add-On Market

PROGRESS IN MEMORIES

Plated wire has now joined the plug-to-plug compatible group of memories. Three models of the NM-8000 Series plated-wire memories are available from Nemonic Data Systems, Inc. Attributes of these systems, NM-8011, (4k × 16 expandable to 16k × 16), NM-8316 (16k × 16) and NM-8332 (32k × 16), include speed, lower cost and a unique partitioning feature—thanks to plated-wire's NDRO property. All units are compatible with the PDP-11 computer, manufactured by Digital Equipment Corp.

The partitioning feature is standard with the NM-8011 and optional in the NM-8316 and NM-8332. This feature guarantees protection against unexpected destruction of data. Switches, located on the rear panel of the cabinet, activate this capability.

ROM or RAM, it's your choice

In the NM-8011 system, the user can select in 1/4th increments of the memory to be read-only, or ROM. After loading the desired program, a switch is positioned to protect that specific part of memory. Essentially, the switch removes dc power from the write amplifiers associated with the ROM portion. The balance of the memory still operates in the normal read/write mode. Each 1/4th increment of memory has an associated switch.

For the NM-8316 and NM-8332, the write lock-out option is somewhat different, in that address decoding and logic inhibiting of the write command accomplishes this task. The four-most-significant bits are preselectable such that the memory is protected in 1/16th increments of the total memory. For example, the smallest increment for a 16k memory is 1024 words, and for a 32k the increment is 2048 words. When purchasing either model, it is necessary to specify the amount of memory that is to be locked out.

Why plated-wire?

Plated wire exhibits thin-film switching speed and has a wide temperature range of operation. The NM-8000 Series uses a magnetic thin-film plating on 0.005-inch-diam wire. Equal read and write NDRO word currents are used with this wire. With plated wire there is no need for restoring information after a readout, thus reducing the read cycle time by approximately one-third that of a read-restore memory. Also, plated wire permits the multiplexing of many wires into one set of electronics—drastically reducing the costs of a 2-D selection memory system. Life expectancy for wire has been shown to be more than 10^5 hours without failure.

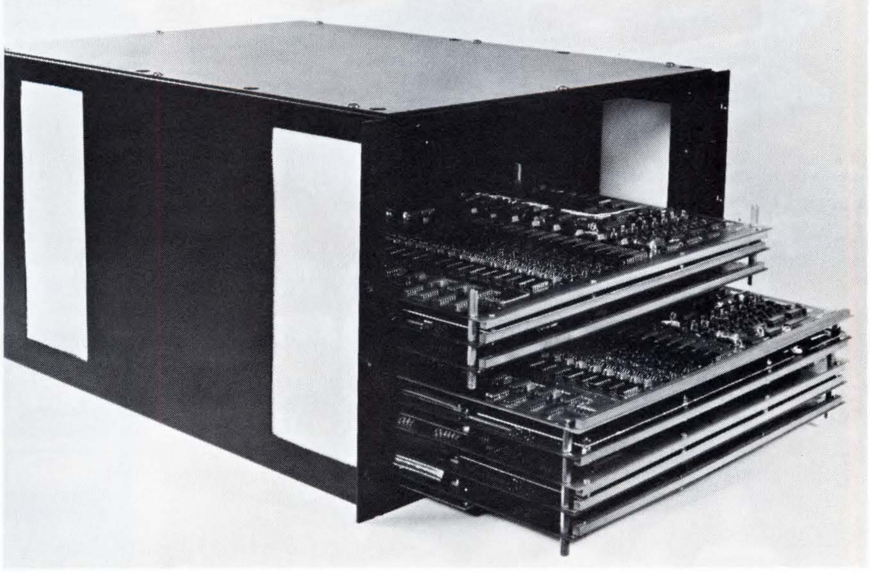
Peering Inside the Box

Because of the modularity designed into the stack and associated circuits, the NM-8000 Series can be organized into systems of 4k to 131k words by 16- to 18-bits/word. Minimum size is 4k × 16. Modules are mounted within the cabinet through the use of card guides and may be easily removed for repair or maintenance.

Maximum operational times for the NM-8011 while connected to the PDP-11 are 230-nsec read access, 350-nsec read cycle, 500-nsec write cycle and 650-nsec read/write cycle. Maximum times for the NM-8316 and NM-8332 are 300-nsec read access, 500-nsec read cycle, 500-nsec write cycle and 800-nsec read/write cycle. Power dissipation for a 16k × 16 system is 200W. Environmental specifications include 0 to 50°C operating and −55 to 85°C storage.

Before delivery, the systems are subjected to worst case pattern tests at the specified temperature limits. These tests include history, single write, interleaved NDRO and adjacent bit disturbs, and verification of each bit at the specified maximum speeds.

Price for the high-speed version NM-8011 ranges from $4065 (4k × 16) to $10,288 (16k × 16). Slower version, high-density systems are priced at $9873 (NM-8316) and $13,202 (NM-8332) and the write lock-out option is $200. Quantity discounts are as high as 20% (lots of 100). Nemonic Data Systems, Inc., 1301 W. Third Ave., Denver, CO 80223.



Precision Wire-Wound Resistor Chips

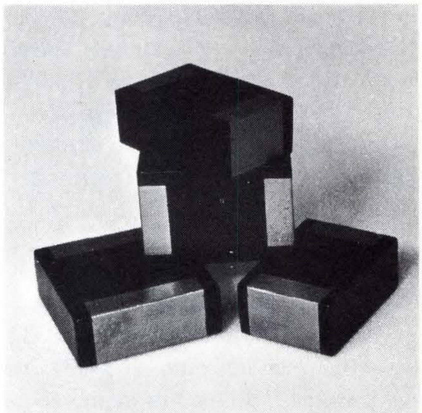
PROGRESS IN RESISTORS

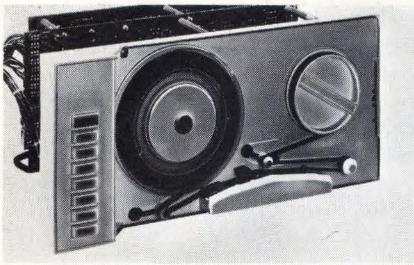
Although not the first wire-wound resistor chips to be offered, the units now being made by KRL Electronics are the most precise, and the first ones to meet the environmental requirements of MIL-R-93D. These chips, which range in size from 100 × 150 mils to 200 × 300 mils can be had in resistance values from 10Ω to 1.5 MΩ with standard tolerances of 5%, 1% and 0.1% (0.05% and 0.01% on special order). Why bother with wire-wounds when thick-film chips can match the above specs? Excellent long-term drift and temperature coefficient are two of the reasons. Thick-film chips have a TC of ±100 ppm to ±50 ppm and tracking of 1 ppm for special applications. Stability is less than 200 ppm/year. In contrast, the KRL wire-wound resistor chips are guaranteed at 10 ppm and available to 1 ppm/°C. The above specs combined with TC tracking of ±1 ppm and ratio matching down to ±0.5 ppm make these chips ideal for high-accuracy large bit resistor ladders and for voltage dividers.

This high performance would be expected to carry a high price tag. It isn't so, however, thanks to a new automatic winding machine. It maintains constant wire tension control, so does not alter wire characteristics during winding.

Terminations on the chip are designed for high-density packaging. They are electro-tin plated so they can be reflow-soldered, welded or even bonded with conductive epoxy. The terminations do not extend to the edge of the chip, which allows chips to be butted side-by-side without shorting of terminals.

KRL is supplying small production orders right now and plans to be ready for high volume production by the first of the year. KRL Electronics, Inc., 28 Bridge St., Manchester, N. H. 03101. **162**



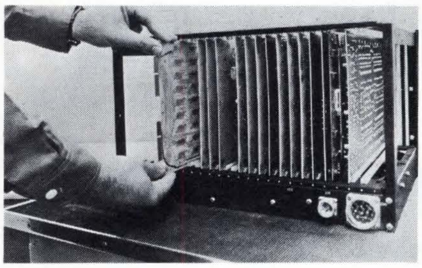


7-inch tape transports attain speeds of 25 ips and are primarily designed for data entry and data terminal applications. Designated the 7000 Series, the units have an unusual loading feature that eliminates the need for a take-up reel. Purchased in quantities of 100, the 1600 cpi read-after-write transport sells for $3010, and the 1600 cpi write/read for $2630. Pertec, Corp., 9600 Irondale Ave., Chatsworth, CA 91311. **165**

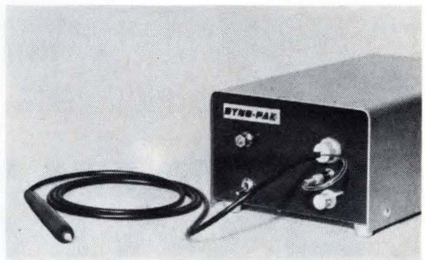
Bit/block error rate analyzer, Model 3000, offers full duplex operation up to 10 megabits/sec, 3-digit LED display and selectable block sizes of 10^2 through 10^9 bits. Using front-panel switches and remote computer commands, data in the form of 63-, 511-, or 2047-bit pseudo-random patterns are transmitted, received and analyzed. Price is $2950 each. International Data Sciences, Inc., 100 Nashua St., Providence, RI 02904. **168**

Cassette drive C-2000 is ANSI/ECMA compatible and operates with most minicomputers. Other features include read-after-write capability, record and file back-spacing, high-speed file load and bidirectional search. The read-after-write avoids permanent write errors by bypassing bad tape, and customary backspace and retry techniques reduce read errors. Pricing starts at $2450. Cipher Data Products, 7655 Convoy Ct., San Diego, CA 92111. **171**

Printers designated Videojet, are now available for the PDP-8 and 11 computer systems. Unbuffered modules (for PDP-8i and -8e) permit data transfer via either programmed I/O or a three-cycle data break option. Buffer version contains a 256 character buffer and provides data transfer via programmed I/O for asynchronous operation. Print density is adjustable from 5 to 17 cpi, or 200 characters/print line. A.B. Dick Co., 5700 Touhy Ave., Chicago, IL 60648. **166**



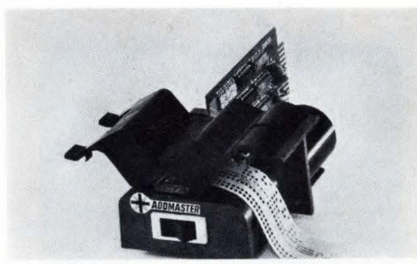
Universal asynchronous serial controllers, Model E-2184, interface any Varian 620 minicomputer to any peripheral device having an asynchronous serial interface. Three versions are available ranging from 40 to 10,000 bps, with 5-, 6-, 7-, or 8-bits including parity and in cable lengths from 20 ft to a maximum of 1 mi. Order the controller by specifying serial rate, character size, stop bits and cable lengths. Varian Data Machines, 2722 Michelson Dr., Irvine, CA 92664. **169**



Light pen, Series 6000, finds use with CRT display terminals that require fast data positioning control capabilities. Having no external switch arrangement, the pen tip itself activates the system when lightly pressed against the face of the CRT screen. The pen, operating from 115V ac, can be used for character sensing and edition operations. Pen assembly is 5 inches long, 0.4375 inches in diameter. Norman-Jones, Inc., South Merrimack, N H 03083. **172**

Magnetic-tape subsystem UNISERVO 12, operates with all UNIVAC 9200 and 9300 computer systems that have selector channels. Features include in-flight single-track error correction and the use of phase-encoding to achieve 1600 bpi. The speed is 42.7 ips and the data transfer rates are up to 68,320 frames/sec. Unit can be purchased for $11,745 or rented for $340 a month including maintenance. Univac, Box 500, Blue Bell, PA 19422. **167**

Magnetic-tape transports, CDS 340, is an automatic-load, single-capstan device that provides bidirectional speeds up to 200 ips, and packing densities of 1600 bpi (PE), and/or 800 bpi (9 track); and 800, 556, or 200 bpi NRZ-I (7 track). Transfer rate is 320 kilobytes/sec at 200 ips. Unit rewinds 2400 ft of tape in 45 sec. Vacuum sensing controls the servo action of the reel. Century Data Systems, Inc., 1270 N. Kraemer Blvd., Anaheim, CA 92806. **170**



Paper-tape reader, Model 601, is a photoelectric solid-state unit that has only one moving part. The reader operates asynchronously at 10, 15, 30 and up to 120 characters/sec and with 5-, 6-, 7- or 8-level tape in the standard width, fanfold or on reels. Weight is <1 lb. and the dimensions are 2 by 3.875 by 3.125 inches. It stops on character and automatically detects EOT or taut tape. Addmaster Corp., San Gabriel, CA 91776. **173**

Programmable coaxial relay matrix accepts up to a 16-bit parallel word and decodes to set or reset any of 200 switchpoints. Matrix modules are: BCD decoding, relay latching plus drive logic, coaxial relays and push-on cross straps. Matrix Systems Corp., 20426 Corisco St., Chatsworth, CA 91311. **174**

Printer/plotters LP 3058 and LP 3358 plot 14,784 and 32,340 points/sec respectively, and provide standard line printing in addition to high-speed plotting. Both units operate with standard fanfold or multipart forms and have plotting width of 13.2 inches. Potter Instrument Co., Inc., 532 Broad Hollow Rd., Melville, NY 11746. **175**

Auto-Answer teletype terminal is a replacement for the Bell 101C, but has a maximum of two control buttons instead of six. A one-control-button model is available if the half-full duplex switch is not required. Anderson Jacobson, Inc., 1065 Morse Ave., Sunnyvale, CA 94086. **176**

Magnetic-tape drive, BI 2610, uses IBM-compatible tape guides and geometry, and records 7-track IBM and 9-track ASCII NRZI formats at 200/556/800 bpi, and 9-track phase-encoded format at 1600 bpi. Recording and data read out is bidirectional at 4 to 37.5 ips. Maximum data transfer rate is 60k characters/sec. Bright Industries, 1 Maritime Plaza, San Francisco, CA 94111. **177**

Magnetic heads read and encode magnetic credit cards under proposed standards by American Banking Association and the International Air Transport Association. Encoding heads write a 0.12-inch wide track and the read heads operate on a small track width. Nortronics Co., Inc., 8101 10th Ave. N., Minneapolis, MN 55427. **178**

Programmable terminal, Series 100, features ROM program storage. The data terminal consists of a data entry and control keyboard (64 keys), two standard Phillips-type cassettes (50,000 ASCII character capacity), 30 cps incremental impact printer, 4800 baud data channel and a microprogrammed processor. Price is $9500. Computek, Inc., 143 Albany St., Cambridge, MA 02139. **179**

Cartridge-loaded minitape unit, CartriFile 20 system, transfers 16-bit computer words at a 1000 per second rate during read or write. Tape cartridges are in standard lengths of 10, 25, 50 and 150 ft. Price for the system is $3650. (OEM discounts available). Tri-Data, 800 Maude Ave., Mountain View, CA 94040. **180**

Five disc-oriented computer systems 9000 Series D are complete with processor, card reader, printer, card punch and disc subsystem. All Series-D systems are compatible with the full line of proven software and peripherals being used with other models of the UNIVAC 9000 family. Sperry Rand Corp., Univac Div., Box 500, Blue Bell, PA 19422. **181**

Photoelectric reader N105 responds to all paper-tape-reader commands and interfaces with the NOVA computer. Operating speeds are 300 cps (incremental), 500 cps (slew) and 1200 cps (rewind). Pivan Data Systems, 6955 N. Hamlin Ave., Lincolnwood, IL 60645. **182**

Off-line, card-to-tape converter CMC 8080 accepts Hollerith-code from 80-column cards and converts the data to either 8-bit plus parity EBCDIC for 9-track tape or 6-bit plus parity for 7-track tapes. The system consists of a 300 cpm card reader, magnetic tape unit and a central controller. Computer Machinery Corp., 2231 Barrington Ave., Los Angeles, CA 90064. **183**

Data-acquisition controller, DATOS 305, is a programmable coupler that provides data for an off-line recording device, a calculator or a minicomputer. The output device determines the data rate, which can be as high as 100k words/sec. Throughput is 3 μsec. Price each is $900. Data Graphics Corp., 8402 Speedway Dr., San Antonio, TX 78230. **184**

Punched-tape readers 9000 Series consists of five basic models, all bidirectional. These units include a basic "mini-reader" without power supply, complete reader unit with all electronics, fan-fold reader with up to 150 ft. of tape storage and two reader/spooler combinations. Electronic Co. of Calif., Instrument Products Dept., 1441 E. Chestnut Ave., Santa Ana, CA 92701. **185**

Core memory Store/235 is a basic 4k-word by 18-bit planar system that has a 235 nsec access time and a 500 nsec full cycle time. Organized as 3D, 3-wire, the capacity can be extended in a standard chassis to 16k by 18, in 4k increments. Data Products, 6219 DeSoto Ave., Woodland Hills, CA 91364. **186**

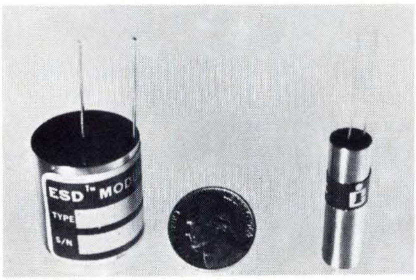
High-density mass storage system called MASSTAPE has a capacity of 128-billion bytes in increments of 16-billion bytes. Up to 32 files can be accessed simultaneously by a host computer. Data can be transferred on up to 16-channels at 1-million bytes/sec. Grumman Data Systems Corp., 711 Stewart Ave., Garden City, NY 11530. **187**

Disc memory systems for small and medium computers come in three basic models with storage capacities from 400k to 6 million bits. Average access time goes down to 8.5 msec. Single unit prices begin at $4250 complete. Tally Corp., 8301 S. 180th St., Kent, WA 98031. **188**

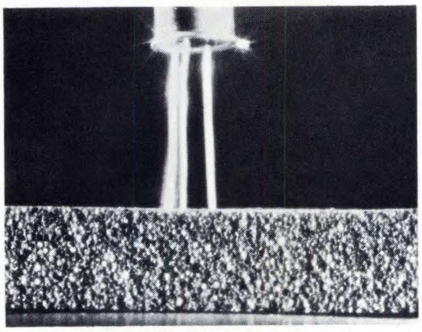
Memory word generator, Model DG-300, produces 8-channels of 64 words each (expandable to 128). Operational frequencies are from 1 Hz to 35 MHz. Programming is achieved through front panel switches, and an 8-digit display verifies the memory content. Tau-Tron Inc., 685 Lawrence St., Lowell, MA 01852. **189**

Terminal/1472 is a modified Selectric typewriter compatible with the IBM 2741 terminal. It features an all-electronic keyboard, providing both half- and full-duplex transmission. Data rate is 14.8 cps with parity check on each character. Price is $2900 each. Compunetics, Inc., 1100 Eldo Rd., Monroeville Industrial Park, Monroeville, PA 15146. **190**

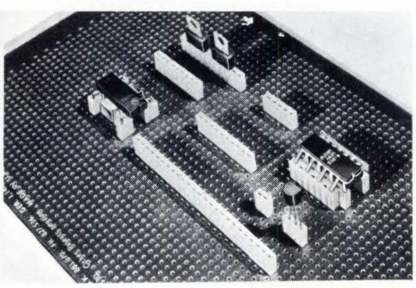
Magnetic heads write 100 in-line tracks on 1-inch tape. Track width is 0.008-inch, spaced on 0.01-inch centers. Dimensions are 1.5 by 1.2 by 1 inches, and typical head inductance is 1.2 mH. Applied Magnetics Corp., 75 Robin Hill Rd., Goleta, CA 93017. **191**



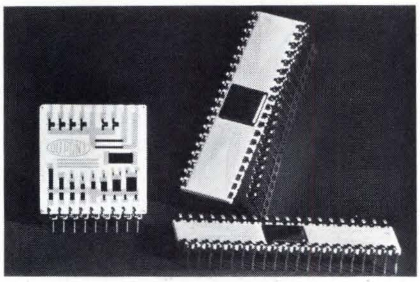
Energy-storage-device "Power Packs" provide emergency power. Circuits susceptible to power line transients can be protected by ESDs, Types 105C6 (3.75V) and 105C9 (5.625V). Both units provide 2.5 mA hrs at 50 mA but do not require trickle charging or periodic cycling as do batteries or capacitors. The C6 is $59 and the C9 $75 in unit quantities. Gould Ionics Inc., Box 1377, Canoga Park, CA 91304. **200**



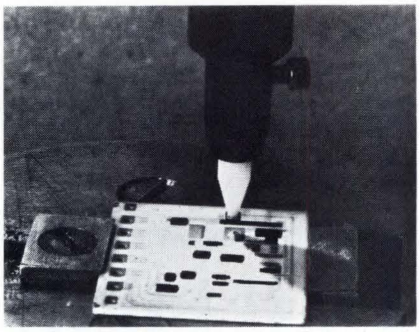
Electrically conductive foam cushioning material, Conducto-Foam, protects circuitry and components from static charge accumulations during shipment and storage. The material provides good protection against mechanical shock and is made in soft and hard versions in 1/4, 1/2 and 1 inch thicknesses. Zippertubing Co., 1300 S. Broadway, Los Angeles, CA 90061. **201**



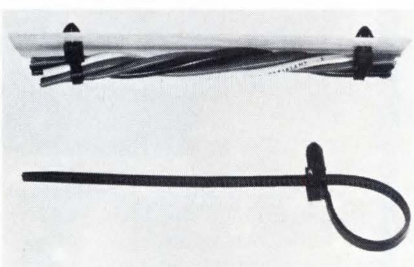
Free sample—strip sockets of glass-filled nylon 12 provide for custom mounting of MSI and LSI devices. Type A23-2033 TR sockets contain 25 gold-flashed phosphor bronze contacts on 0.10 inch spacings and can be cut to any length. Contact resistance is 15 mΩ max. In quantities of 1-24, they cost $2 each. Jermyn, 712 Montgomery St., San Francisco, CA 94111. **202**



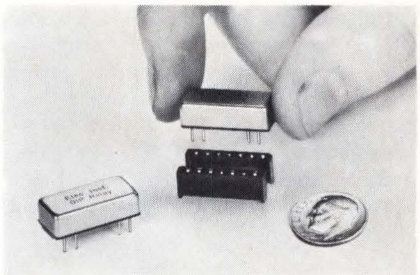
Lead frame terminals are designed for automatic attachment to ceramic hybrid microcircuits. "Solok" terminals are available in two basic configurations for edgemount terminals or standard dual-in-line. The terminals are on 0.10 inch centers and come in two sizes to fit substrates from 25-35 mils and 55-65 mils. Du Pont Co., Electronic Products Div., Wilmington, DE 19898. **203**



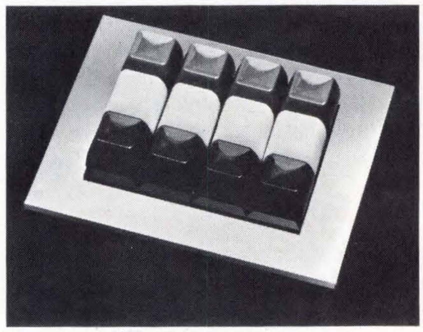
Gold-filled epoxy bonds hybrid-circuit chips at low temperatures. Epo-Tek H80 is a two-component epoxy that cures in 3 hrs at 50°C and can pass NASA standard tests for outgassing. Volume resistivity is 0.001 to 0.002Ω/cm and lap shear strength is 2000 psi. A 1/2-oz trial kit is available at $70. Epoxy Technology, Inc., 65 Grove St., Watertown, MA 02172. **204**



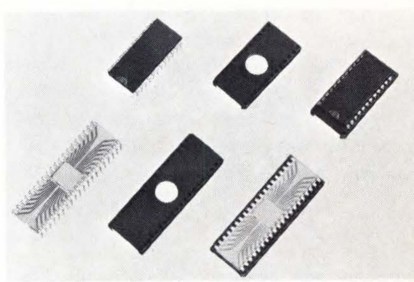
One-piece tie straps are self mounting. These wire and tube holding self-locking tie straps are made of no-stretch nylon and feature a molded "arrowhead" end for snap-in insertion into 1/4-inch holes in panels or walls up to 3/32 inch thick. Type "A" is available in three sizes to hold wire bundles from 1/16 to 1-3/4 inches. Thogus Products Co., Box 682, 1374 W. 117th St., Lakewood, OH 44107. **205**



DIP reed relays permit up to 28W switching between the limits of 100V and 1A in the mercury-wetted version, or 10W between 1/4A and 28V in the dry-reed model. Available in SPST, SPDT and DPST versions with nominal coil ratings of 5, 6, 12 and 24V, they mount in standard 14-pin DIP sockets or directly to the PC board. Electronic Instrument & Specialty Corp., 42 Pleasant St., Stoneham, MA 02180. **206**



Illuminated keyboard switch matrix features front panel lamp replacement. The SPST switch units have bifurcated wiping double-break contacts rated at 1/2A resistive load at 30V dc. Contact resistance is less than 25 mΩ. Lamps are standard T1-3/4 midget flange base incandescent, or T2 neon. Marco-Oak Industries, 207 S. Helena, Anaheim, CA 92803. **207**



Evaluation samples—plastic shunts eliminate static voltage discharge damage to dual-in-line MOS packages. The Series DIL conductive shunts are of injection-molded polyethylene and carbon, and provide positive contact to all leads. Free samples and data sheets are available from the manufacturer. Clover Industries Div., GTI Corp., 600 Young St., Tonawanda, NY 14150. **208**

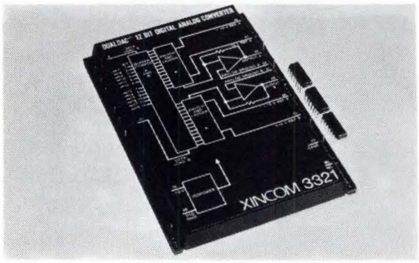
PC board-edge connectors provide interconnection of "daughter" to mother board at a 55 degree angle. The MC-1-55 "Digi-Klip" is designed to accept 0.062 inch plug-in board and allow high packaging density. Typical contact resistance is 3 mΩ maintained through a guaranteed minimum insertion/withdrawal life of 1000 cycles. Price is approximately $0.02 each in large quantities. Components Corp., Denville, N J 07834. **209**

Totally solid-state, non-contact proximity switch, Model 3001, provides digitally-compatible output signals for computer interfacing. The presence or absence of a wide range of materials can be detected, including transparent and non-metallic objects. Maximum range is 3 inches; optimum distance is 1 inch. Available from stock at $48 to $98 each. Scientific Technology Inc., 655 Skyway, San Carlos, CA 94070. **210**

Thermostat combines snap-action switching and positive visual indication of temperature anomalies. A colored button extends from the top of the "Klixon" when the switch contacts first open. Contacts automatically reset when temperature returns to normal but the indicator must be reset manually. Available in temperature settings from 100 to 300°F, the devices switch up to 5A at 115V ac. Texas Instruments Incorporated, Attleboro, MA 02703. **211**

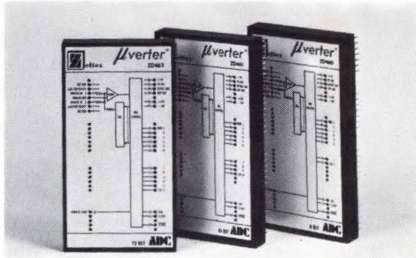
Wafer thermistors are calibrated to standardized resistance curves. They are epoxy coated and measure 0.07 to 0.18 inch square, depending upon resistance values at 25°C. Available from stock in resistance values from 1 to 100 kΩ at 25°C, they have a useable temperature range of −55 to +150°C with typical accuracy of ±0.2°C. Price is $4.75 each in minimum quantities. Gulton Industries, Inc., Metuchen, N J 08840. **212**

Miniature light source (Model L-5), photocell (P-5) and scanner (S-5), are side-view (rather than end-view) to meet unusual space limitations. The light source and photocell measure 1.0 by 0.5 by 0.25 inches, the scanner 1.5 by 1.0 by 0.25 inches. The light source is rated at 40,000 hrs at 5.0V. Operating range of the light source and photocell is 4 inches, and range of the scanner is 1/4 inch. Scanning Devices Co., 245 Sixth St., Cambridge, MA 02142. **213**

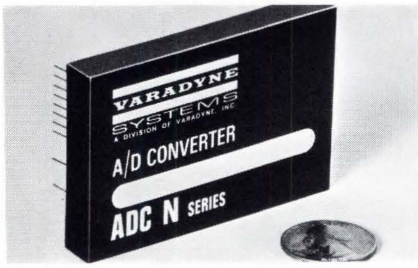


Dual 4-quadrant multiplying D/A converters, Model 3321, feature a reference bandwidth of 200 kHz. and the maximum settling time is 10 μsec (6 μsec typical) to 0.025% of full scale. The output is ±10V, ±10 mA. These 12-bit converters are incorporated into one 4- by 5.6- by 0.55-inch module. Prices range from $395 (1-9) to $347 (50-100). Xincom Corp., Box 648, 20931 Nordoff St., Chatsworth, CA 91311. **225**

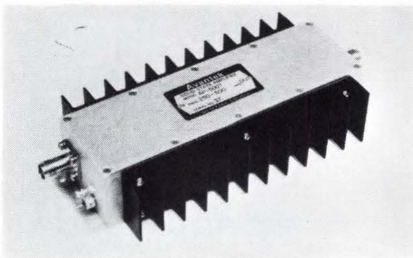
Solid-state switches, ST Series, use a 3-wire design that separates the sensing element from the power section. These self-contained units use a triac as the switching element. Operating is with a normally-open or a normally-closed circuit. The operating voltage range is from 100 to 130V ac, 50 to 60 Hz, with maximum load of 1A inductive, 10A inrush. R. B. Denison Inc., 103 Broadway, Bedford, OH 44146. **228**



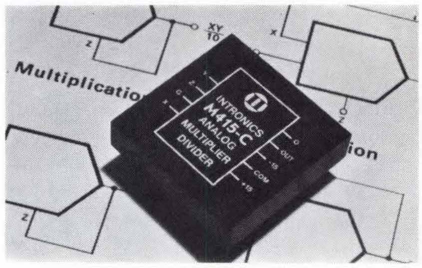
A/D converter, Model ZD 462, features 12-bit resolution and 100 μsec maximum conversion time. Quantizing error is ±1/2 LSB. Full scale input voltage range is ±10, ±5 or 0 to 10V selectable by pin connection. Input overvoltage protection is rated at ±50V. Output can be either NRZ serial or 12-bit (binary) parallel. For 1 to 9, the price is $99 each. Zeltex Inc., 1000 Chalomar Rd., Concord, CA 94520. **231**



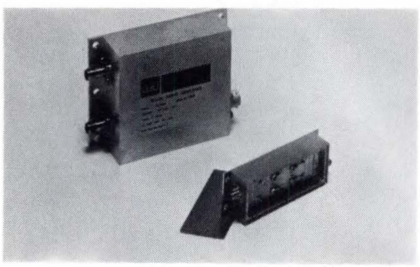
A/D converter Model ADC-N-10B is a 10-bit unit that accepts either unipolar or bipolar inputs (0 to 5V, 0 to 10V, or ±5V, ±10V) at an input impedance of 2 kΩ. The 3.2 cubic inch module has a bit rate of 400 nsec/bit. Overall accuracy is ±0.1%, and temperature coefficient is ±50 ppm/°C. Single quantity price is $495. Varadyne Systems, 1020 Turnpike St., Canton, MA 02021. **226**



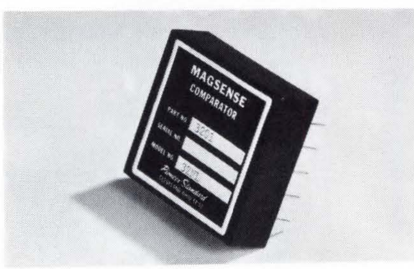
Solid-state amplifier Model AP-500T delivers 1W linear, Class A power across the 250 to 500 MHz frequency range. Other specifications include 30 dB minimum gain, ±1 dB maximum gain flatness, 10 dB maximum noise figure, maximum VSWR (in and out) of 2:1 and 15V dc, 450 mA input power. Price is approximately $900. Avantek, Inc., 2981 Copper Rd., Santa Clara, CA 95051. **229**



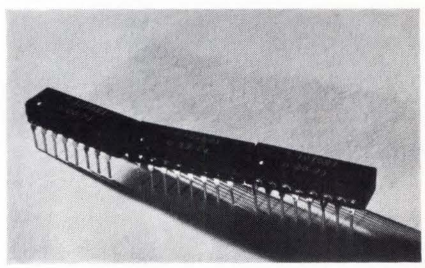
Analog multiplier/divider Model M415C features 1% pre-trimmed accuracy for $38. The device is capable of multiplication, division, squaring and square root operations. Other characteristics include 500 kHz bandwidth and 5V/μsec minimum output slewing rate. Dimensions of the encapsulated module are 1.75 by 1.75 by 0.4 inches. Intronics, 57 Chapel St., Newton, MA 02158. **232**



Thin-film amplifiers WJ-5201 Series operate in the 1 to 4 GHz frequency range with noise figures from 4.5 to 7.5 dB. With a reduction in size by 70% over previous standard solid-state amplifiers, and the computer-optimized modular design these amplifiers are ideal for applications requiring small size, uniformity of performance and versatility of integration. Watkins-Johnson Co., 3333 Hillview Ave., Stanford Industrial Park, Palo Alto, CA 94304. **227**



Single-channel voltage comparator, Model 32, is insensitive to ±10% power supply variations. The basic 0 to 1V dc input range is extendable with an external voltage divider. Control output is either in latching or nonlatching modes (up to 0.5A) or in an optional binary mode (0 or positive supply voltage). Dimensions of the 4 oz unit are 1.86 by 2 by 0.625 inches. Price is $35 in 1-24 quantities. Pioneer/Instrumentation, 4800 E. 131st St., Cleveland, OH 44105. **230**



Standard hybrid circuits provide universal interfacing to and from standard logic and give the users an off-the-shelf item. Three devices make up the line—quad current driver, quad dc interface and dual level shifter. Each comes in a standard 16-pin DIP. Circuits are available from stock. In quantities of 1000, unit prices are $3.45 (current driver), $4.05 (dc interface) and $4.45 (level shifter). Film Microelectronics, Inc., 17 A St., Burlington, MA 01803. **233**

You're invited to a private screening

of the National Semiconductor Memory Seminar Film.

In your office.

Recently, we captured our best memory spokesmen on film as they discussed the National Semiconductor memory design philosophy, our current broad-based product line, and upcoming new designs, as well as a number of memory *system* applications.

The result is *The National Semiconductor Memory Seminar Film:* an informative, no-holds-barred, no b.s. look at the past, present and future of semiconductor memories.

A 30-minute filmic experience we'd like to share with you in the privacy of your own office.

With up to 25 of your friends and co-workers.

Free crackerjacks.

And one of our best applications engineers as projectionist/answer man.

Five-Part Flick

Before asking you to sign up for a free private screening of The National Semiconductor Memory Seminar Film, we'd like to offer a brief summary (realizing of course that mere words can never fully describe the exact nature of this unique, five-part cinemagraphic work):

Part One: Mainframe Memories

A quick-paced, yet highly significant review of National's mainframe memory capability in which the MM1103 and a couple of dynamic MOS RAM superstars are put into proper focus. Namely, the Tri-State* 1024-bit MM5260 and the 2048-bit MM5262.

Part Two: Scratchpad/Cache Memories

A thought-provoking presentation of scratchpad and cache memory applications featuring the breathtaking (Tri-State, 256 x 1) DM74200 and a bevy of other highly talented National bipolar RAMs.

Part Three: Silicon Store Memories

This highly-informative, slickly-produced portion of the film is devoted to the introduction of the revolutionary new "silicon store" memory; an inertia-less electrically rotating data string ideally suited to the dual 256-bit MM5012 and 1024-bit MM5013, National's up-and-coming pair of new longer length dynamic accumulators with Tri-State logic.

Part Four: Buffer Memories

A hard-hitting, two-fisted recap of commonly known buffer memory applications, liberally sprinkled with appropriate devices from National's arsenal of static MOS RAMs, shift registers and bipolar RAMs.

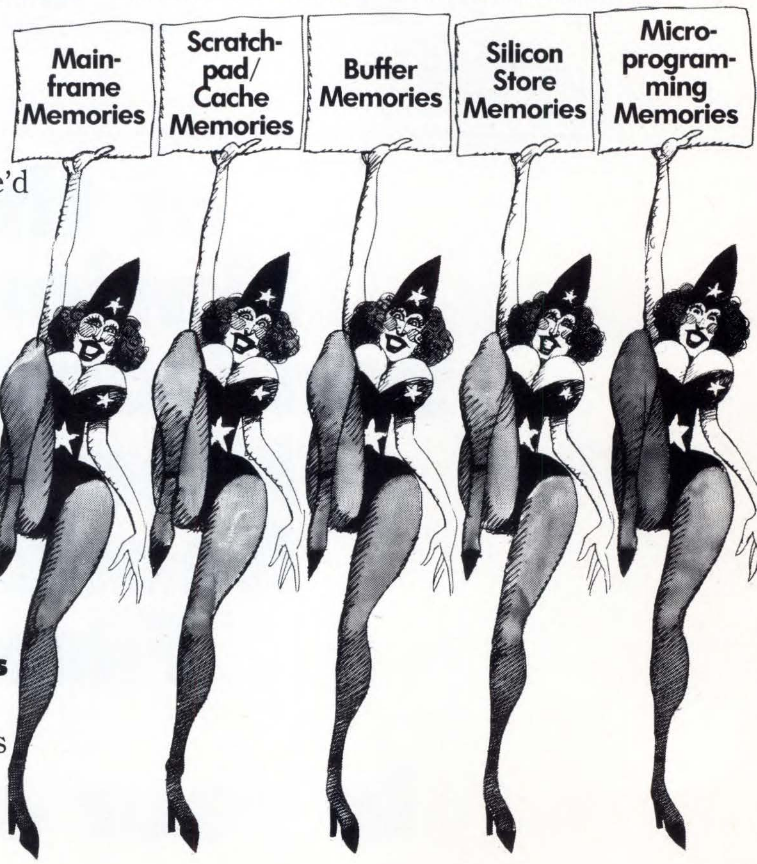
Part Five: Microprogramming Memories

As the proverbial "light at the end of the tunnel" appears, a number of devices are quickly exposed; including the DM8597 (1024-bit bipolar ROM), MM5203 (2048-bit MOS pROM) and the MM5232 (Tri-State 4096-bit static MOS ROM).

(For your convenience, we've taken the liberty of listing our complete line of semiconductor memory devices. Look them over carefully. We'll be glad to send complete specs on any category you wish.)

All you have to do now is fill out and mail us the handy free film coupon.

*Tri-State is a trademark of National Semiconductor Corporation.



Mainframe Memories

MM5260	1024-bit Tri-State MOS RAM
MM1103	1024-bit MOS RAM
MM5262	2048-bit MOS RAM

Scratchpad/Cache Memories

DM7489	16 x 4 bipolar RAM
DM8599	16 x 4 Tri-State bipolar RAM
DM74200	256 x 1 Tri-State bipolar RAM (read-write)
DM86L99	16 x 4 low power bipolar RAM
DM8594	64 x 4 Tri-State bipolar RAM

Buffer Memories

DM7489	16 x 4 bipolar RAM
DM8599	16 x 4 Tri-State bipolar RAM
DM86L99	16 x 4 low power bipolar RAM
MM1101A2	256 x 1 MOS RAM
MM1101	256 x 1 MOS RAM
MM11011	256 x 1 MOS RAM
MM1101A	256 x 1 MOS RAM
MM1101A1	256 x 1 MOS RAM
MM5054	dual 80-bit tapped-static shift register
MM5052	dual 80-bit MOS shift register
MM5053	dual 100-bit MOS shift register

Silicon Store Memories

MM5012	dual 256-bit Tri-State dynamic shift register/accumulator
MM5013	1024-bit Tri-State dynamic shift register/accumulator
MM5016	500/512-bit dynamic shift register
MM5017	Dual 500/512-bit dynamic shift register
MM5019	Dual 256-bit mask programmable dynamic shift register

Microprogramming Memories

DM8598	256-bit Tri-State bipolar ROM
DM7488	256-bit bipolar ROM
DM8597	1024-bit Tri-State bipolar ROM (256 x 4)
DM74187	1024-bit bipolar ROM (256 x 4)
MM5203	2048-bit MOS PROM (256 x 8 or 512 x 4)
MM5231	2048-bit MOS (factory programmable) ROM
MM5241	3072-bit Tri-State static MOS ROM (64 x 6 x 8)
MM5232	4096-bit Tri-State static MOS ROM (512 x 8 or 1024 x 4)

Free Film Coupon. Sirs: sign me up for a free private showing of The National Semiconductor Memory Seminar Film in my office on__________. I understand that crackerjacks and a projectionist/applications engineer will be provided free. Would also like________ complimentary "Admit One" tickets (maximum 25) to pass out to my friends and co-workers.

Name__________ Phone__________

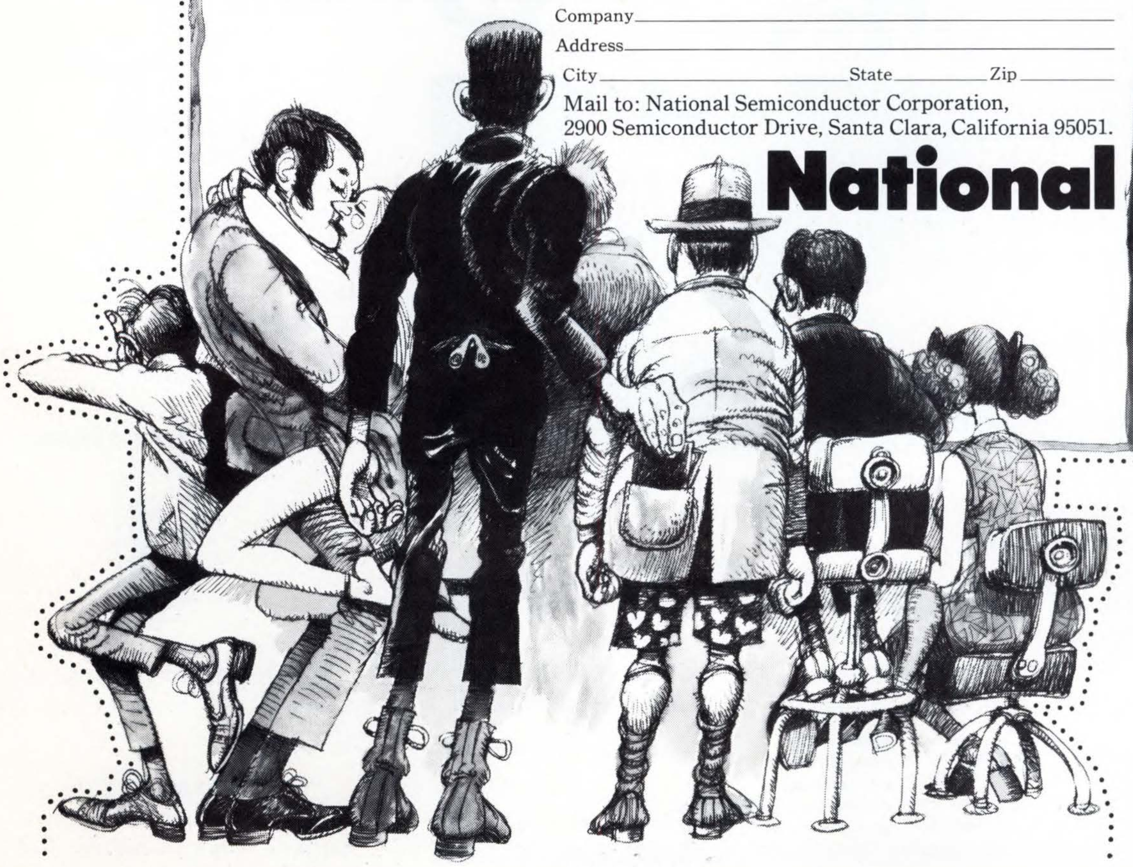
Company__________

Address__________

City__________ State______ Zip______

Mail to: National Semiconductor Corporation,
2900 Semiconductor Drive, Santa Clara, California 95051.

National



CIRCLE NO. 27

Dual-tone multi-frequency converter Model ACA-154-A converts DTMF tones into dialed dc pulses enabling a continuous printout permanent-paper-tape recording. The unit weighs 10 lbs, and its dimensions are 5.5 by 8 by 11 inches. Com-Tech Corp., 11411 Addison St., Franklin Park, IL 60131. **234**

Vibration switch Model 5175 operates when the vibration level exceeds the set point (adjustable between 0 and 10G). Frequency response is flat from 0 to 3000 cpm. Switch contact rating is 480V ac, 15A. Metrix Instrument Co., 5760 Rice Ave., Box 36501, Houston, TX 77036. **235**

Normalized freqmeter, Series 400KF, linearly converts frequency or repetition rates of signals to a proportional dc voltage. Four models cover the 0 to 100 kHz input frequency range—410KF (0 to 100 Hz), 420KF (0 to 1 kHz), 430KF (0 to 10 kHz) and 440KF (0 to 100 kHz). Solid State Electronics Corp., 15321 Rayen St., Sepulveda, CA 91343. **236**

Electronic time reference, Model 800, is accurate within 1 sec/wk at expected temperature variations of the ocean environment. The unit operates on its own standard battery pack for a full year (power drain is <2.3 mW). Marine Systems Div., Preformed Line Products Co., 5349 St. Clair Ave., Cleveland, OH 44103. **237**

Power supplies come in five modular sizes for seven series of regulated dc supplies. Outputs are from 3 to 150V dc with current outputs ranging from 0.01 to 7.8A. Prices are from $40 to $125 for standard models. Power Pac Inc., 24 Stage St., Stamford, CT 06901. **238**

Solid-state counting module, ML 333, may be used as a totalizer or predeterming counter and replaces conventional electro/mechanical counters. Count rate is 30,000/min, and RCA Numitrons provides the readout. Price (1000 quantity) for the 4.5- by 6- by 1.7-inch modules is $75. MFCO, 1910-A Encinal Ave., Alameda, CA 94501. **239**

8-bit D/A converter, Model MN328, is TTL-compatible, and the output voltage (0 to 9.961V) is linear to 1/2 LSB over the temperature range of 0 to 70°C. Housed in a hermetically-sealed 16-pin DIP, the unit requires ±15V and 5V supplies. Price is $59 each. Micro Networks Corp., 5 Barbara Lane, Worcester, MA 01604. **247**

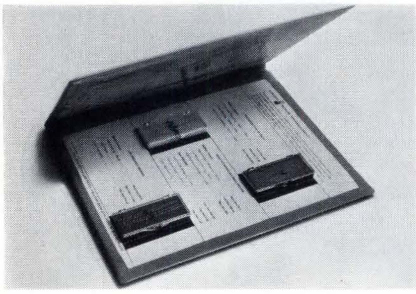
SPST solid-state switches, Models S6C and S7C, operate at <2 and 25 nsec respectively. Frequency range of the S6C is from 0.5 to 200 MHz and for the S7C, 0.3 to 200 MHz. Unit prices are $65 (S6C) and $40 (S7C). Relcom, 3333 Hillview Ave., Palo Alto, CA 94304. **248**

Crystal oscillator Model C120MS generates CMOS-compatible output, using any supply voltage from 5 to 15V dc, at any fixed frequency from 0.01 Hz to 10 MHz. Frequency tolerances are from ±0.01% (20 to 40°C) to ±0.05% (−55 to 125°C). Dimensions are 1.6 by 1.2 by 0.4 inches. Connor-Winfield Corp., Windfield, IL 60190. **249**

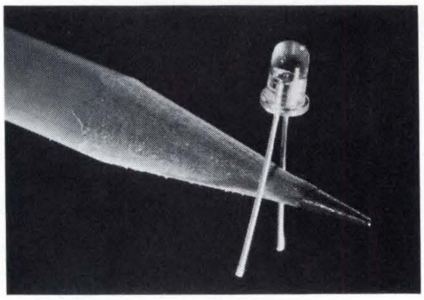
Broadband power amplifier MP-100 comes in kit form that can be assembled in approximately 3 hrs. The all-solid-state amplifier accepts AM, SSB, pulse and other complex modulation inputs. Any signal or sweep source of 0.15V over the 0.5 to 100 MHz frequency range will deliver 2.5W CW without tuning adjustments. Unit will withstand a 15 dB overdrive including short- and open-circuit loads. Larkton Scientific, Box 302, Monroeville, PA 15146. **250**

Power modules "Cirkitblock" Series, offer designers off-the-shelf building blocks comprised of three basic preregulators and eight main power sources. Industrial applications up to 100W require only two, 2-cubic-inch modules. Prices range from $50 to $100 per module (25-unit lots) and $25 to $50 (1000 lots). Powercube Corp., 214 Calvary St., Waltham, MA 02154. **251**

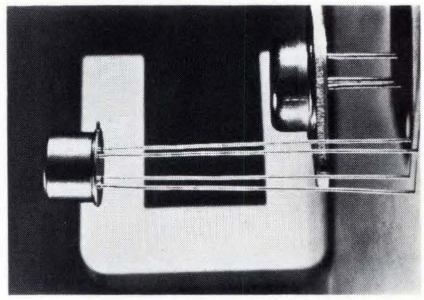
Photocouplers are available in four different models, and in quantities of 1000 are priced at $2.55 each. The devices, enclosed in a 4-lead TO-5 sealed case, operate either in the ON/OFF mode or in proportional control circuits with a wide range of resistance control. Vactec Inc., 2423 Northline Ind. Blvd., Maryland Heights, MO 63043. **252**



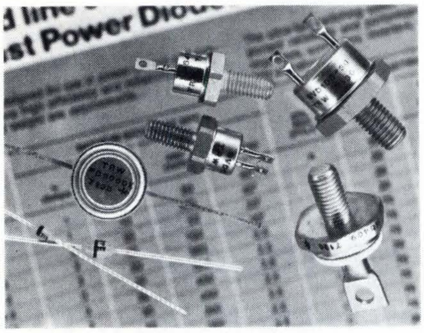
RF Semiconductor sample kit is comprised of one high-gain 2 GHz transistor, 12 Schottky and 4 PIN diodes. The semiconductors are packaged in a vinyl folio together with data sheets and applications literature. Cost of the sample kit is $19.40. Hewlett-Packard Co. 1601 California Ave., Palo Alto, CA 94304. **253**



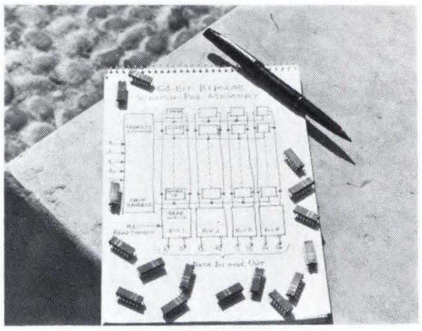
NPN phototransistor, Type TIL 78, features light current of 7 mA at 20 mW/cm² illumination. Dark current is 25 nA at 30V reverse voltage. Continuous power dissipation at 25°C is 50 mW. Delivery is 6 weeks ARO, and price is $0.50 each in 1000 quantities. Texas Instruments Incorporated, Box 5012, Dallas, TX 75222. **256**



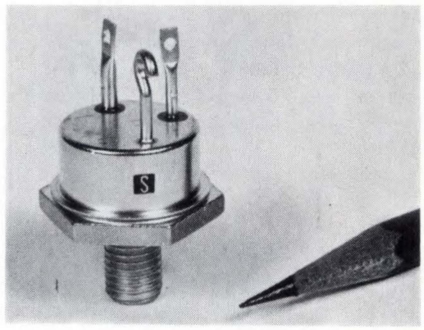
Monolithic Darlington power transistors, Series U2T105/205, offer 10A current capability and minimum V_{CER} of 150V. Current gain at 5A is 1000 min. Available in TO-33 or TO-66 packages, they are priced at $3.03 to $3.25 each in 100 qantities. Unitrode Corp., 580 Pleasant St., Watertown, MA 02172. **259**



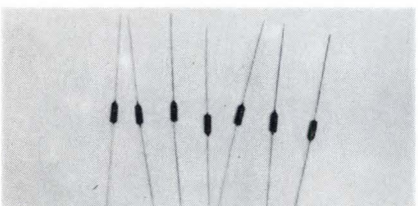
Ultra high speed power diodes with recovery time to 10 nsec, voltages to 800V and currents to 30A, are now available in quantity from TRW Semiconductors. Package configurations including axial leads, isolated case and standard DO-4 and DO-5 offer the designer a broad selection to optimize mechanical design. TRW Semiconductors, 14520 Aviation Blvd., Lawndale, CA 90266. **254**



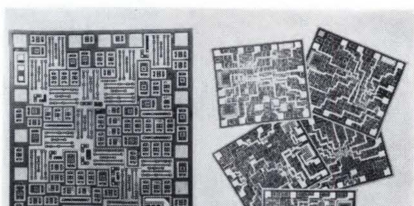
64-bit bipolar RAM is organized as 16 words of 4 bits each for scratch-pad memories. Words are selected through a 4-input binary decoder when the chip select input is at logic "0". Data is written in when the Read Enable is at "0" and read out when RE is at "1." Price of the N8225B (plastic DIP) is $6.94 each in 100 piece orders. Signetics Corp., 811 E. Arques Ave., Sunnyvale, CA 94086. **257**



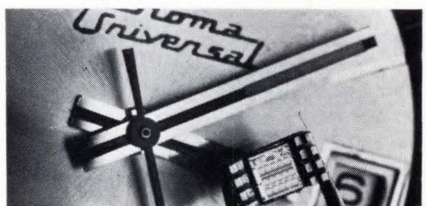
NPN silicon power transistor, Type 2N6215, switches up to 70A. Typical switching time is less than 400 nsec T_{on} and 1.2 μsec T_s, with $30V_{CC}$ and 10A I_C. At 50A I_C, $V_{CE(SAT)}$ is less than 0.8V and H_{FE} is typically 135. Packaged in a TO-63 case, it is priced at $78.60 each in quantities of 100. Solitron Devices, Inc., 1177 Blue Heron Blvd., Riviera Beach, FL 33404. **260**



Voltage reference diodes offer ultra-high stability. The PRD-105 has 5 PPM/year guaranteed stability. All units are screened for a maximum deviation of 2.5 mV between 0, 25 and 75°C and noise level of less than 1 PPM. Available in a hermetically sealed glass DO-7 package, the standard device has a nominal voltage of 6.2V. Codi Semiconductor, Div. of Computer Diode Corp., Pollitt Dr., Fair Lawn, N J 07410. **255**

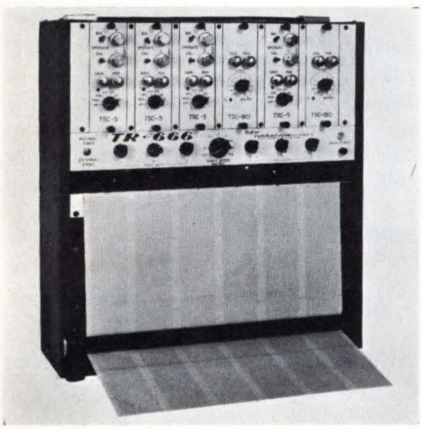


Custom ICs can be delivered in as little as two weeks. Up to 261 integrated components are breadboarded with the MOA-K kit, then the interconnect sketch is delivered to the manufacturer for fabrication of the "Monochip-A." MOA-K kit and manual costs $85. Monochip A, including mask charge, fabrication and packaging to customer's specs for 100 units, costs $2800 total. Qualidyne Corp., 1230 Bordeaux Dr., Sunnyvale, CA 94086. **258**



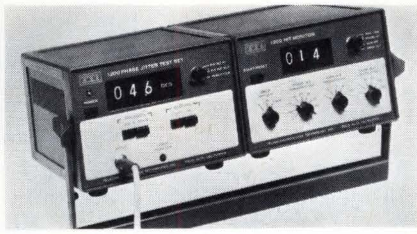
Micropower IC is designed for watch and clock applications. Using an external quartz crystal (not included), this 75-mil-square monolithic circuit provides 1, 2 or 4 pulses/sec output from its motor-drive buffer or direct drive of timepiece mechanisms. It draws less than 10 μA average from a 1.35V battery. Available in LID or TO-5 packages at $7.50 each. Microma Universal Inc., 855 Maude Ave., Mountain View, CA 94040. **261**

Digital temperature indicator can be used with all common thermocouple types. Features include a guarded differential input circuit, linearization to 100 percent with no analog approximation circuits, input impedance as high as 3000Ω and guaranteed accuracy of ±1/4% of range. Price of the Model DS-500 is $595 complete. Omega Engineering Inc., Box 4047 Stamford, CT 06907. **262**

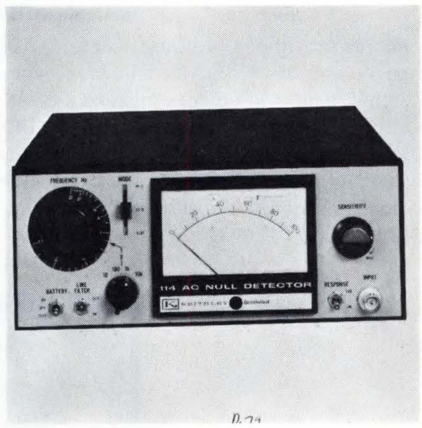


Portable 6-channel recorder with response from dc to 125 Hz offers eight electrically-selectable chart speeds. Model TR-666 uses heated styli and will write in any orientation. Gulton/Techni-Rite, Rte. 2 and Middle Rd., East Greenwich, RI 02818. **263**

5-digit multimeters provide dc voltage measurements between 1 μV and 1000V to 0.005% accuracy, have complete autoranging, and can have optional resistance and ac-measurement capabilities added by plug-in converter boards. Price for the standard Model 5330/700 is $1295. Model 5333/703, providing systems instrument features such as a 100 reading/sec mode, is priced at $2095. Dana Labs, Inc., 2401 Campus Dr., Irvine, CA 92664. **264**

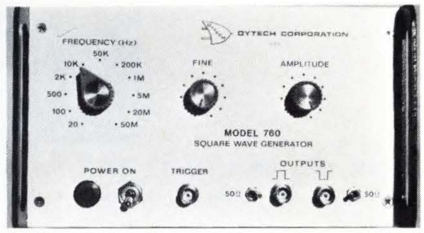


Dropout monitor, Model 1200, counts phase hits, gain hits and dropouts on communications circuits when used in conjunction with the company's Model 1200 phase jitter test set. Phase-hit threshold is adjustable from 5 to 45 degrees, gain-hit threshold from ±1 to ±10 dB and dropout duration from 1 to 300 msec. Telecommunications Technology, Inc., 920 Commercial St., Palo Alto, CA 94303. **265**



Null-detector has sensitivity to 0.1 μV and frequency range of 12 Hz to 150 kHz. The battery-operated Model 114 has a built-in line frequency filter and offers a switched Q of 7 or 27. Price is $575. Keithley Instruments, Inc., 28775 Aurora Rd., Cleveland, OH 44139. **266**

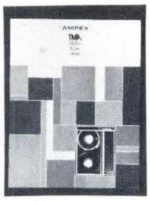
Antenna coupler, Model RF-675, permits 100 to 200W SSB transceivers to be used with a wide variety of antennas at frequencies between 2 and 30 MHz. It incorporates a front panel wattmeter to aid in tuning for a match, a turns counter for presetting, a 50Ω load for transmitter tuning and a pad for transmitter protection during coupler tuning. RF Communications Inc., 1680 University Ave., Rochester, NY 14610. **267**



50-MHz square-wave generator, Model 760, features repetition rates from 20 Hz to 50 MHz in ten overlapping ranges. True and complement outputs are adjustable from 250 mV to 5V across 50Ω and are always a square wave with constant 50 ±1% duty cycle. A trigger output provides +2.5V across 50Ω. Price of the Model 760 is $350. Dytech Corp., 391 Mathew St., Santa Clara, CA 95050. **268**

Thermistor thermometers, priced at $395, incorporate self-check of both zero and calibration. Models of the Series 580 are available to read in either °F or °C. Battery-pack powering is offered as an option. United Systems Corp., 918 Woodley Rd., Dayton, OH 45403. **269**

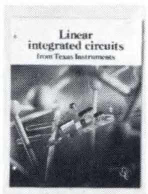
Digital comb filter has its fundamental frequency (notch spacing) adjustable between 20 and 76 Hz, either manually or automatically. The Model DCF IV features hybrid analog-digital design with a 10,240-bit MOS memory to synthesize a band-reject comb filter. Low frequency rejection is 50 dB. Also, the 6-dB notch bandwidths are front-panel adjustable from 0.5 to 20 Hz. Devenco Inc., 150 Broadway, New York, NY 10038. **270**



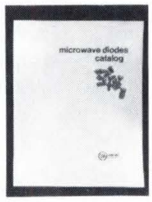
Digital tape drive, Model TMA, is described in an eight-page brochure that provides illustrations, specifications and operation details of this low-cost unit that features vacuum-column buffering and linear-reel servo. Ampex Corp., 401 Broadway, Redwood City, CA 94063. **350**

RFI filters are described in Catalog No. 751. It contains tabulated information on rectangular types effective to 400 MHz and tubular types effective to 10 GHz. Outline drawings and terminal information are also provided. All-Tronics, Inc., 45 Bond St., Westbury, NY 11590. **354**

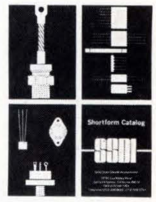
Transistor sockets and hardware for use with TO-3, TO-66, NPN/PNP plastic silicon and new hybrid power transistors are described with illustrations and dimensioned drawings in an eight-page catalog supplement. Keystone Electronics Corp., 49 Bleecker St., New York, NY 10012. **358**



Linear IC Bulletin CB-139 describes the company's complete line incuding differential video amplifiers, op amps, communications circuits, voltage comparators, line drivers and receivers, peripheral drivers, sense amplifiers and memory drivers. Texas Instruments Incorporated, Box 5012, MS/308, Dallas, TX 75222. **351**



Microwave diode catalog contains 24 pages and describes the following types: signal generation diodes including Gunn-effect and impatt; multiplier diodes; PIN switching diodes; tuning varactor diodes including GaAs devices; and parametric amplifier diodes. Varian, Solid State Div., 611 Hansen Way, Palo Alto, CA 94303. **355**



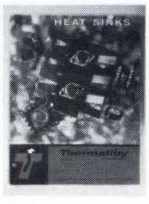
Semiconductor catalog contains eight pages and lists over 300 silicon devices. Included are power and high-voltage rectifiers and transistors, single-phase bridges and hermetically sealed vacuum tube replacements. Solid State Devices, Inc., 12741 Los Nietos Rd., Santa Fe Springs, CA 90607. **359**

Industrial minicomputers of the SPC-12 family are described in a six-page brochure. Key features of three different models are presented along with general specifications that apply to the whole family. General Automation, Inc., 1055 S. East St., Anaheim, CA 92805. **352**

Voice response system that enables the telephone to be used for entering and retrieving computer data is described in a four-page brochure that includes specifications and a flow chart of the data entry and retrieval process. Cubic Corp., 10457 Roselle St., San Diego, CA 92123. **356**

Industrial lasers of the 800 Series are covered in a 12-page brochure. It gives detailed product descriptions, discusses applications such as microwelding and microdrilling, and includes accessory and component descriptions. Hadron Inc., 800 Shames Dr., Westbury, NY 11590. **360**

Tachometer generators and servo motors are described in 24-page catalog RC 100, which contains tabulated performance data and outline and installation dimension drawings. Details are also provided on speed-indicating systems and bi-mode servos for positioning and bidirectional speed indication. Servo-Tek Products Co., 1086 Goffle Rd., Hawthorne, N J 07506. **353**



Heat sink and electronics cooling catalog contains 40 pages with information on DIP, plastic-power, vertical and diamond heat sinks. A new series of brazed compact coolers is presented, and extrusion profiles, liquid-cooling systems and heat sinks for compression-disc SCRs are also covered. Thermalloy Co., 8717 Diplomacy Row, Dallas, TX 75247. **357**

Time-delay relays are featured in a 92-page designers handbook that is intended to assist designers in specifying these relays for specific applications. It includes a glossary of terms, principles of operation, applications, and specifying and testing data. New products are also included. Magnecraft Electric Co., 5575 N. Lynch Ave., Chicago, IL 60630. **361**

Dual-npn transistors for applications requiring tight characteristic matches, high current gain and high breakdown voltage are described in a data sheet from Analog Devices, Inc., Rte. 1 Industrial Park, Box 280, Norwood, MA 02062. **375**

Thin-film resistors made of tantalum on silicon for use in hybrid microcircuits are described in a three-page data sheet that gives information on ratings and electrical and physical characteristics. Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, Ca 94040. **376**

Two-wire transmitter that produces a 4 to 20 mA output signal proportional to the input signal from thermocouples, RTDs and voltage and current sources is described in Bulletin 5520. Kimberly-James, Inc., Box D, Newton Square, PA 19073. **377**

Wire and cable for computer and business machines is covered in Bulletin No. 110. It describes the types available for computers and business machines for back panel wiring or interconnecting cables. Tensolite Insulated Wire Co., Inc., W. Main St., Tarrytown, NY 10591. **378**

Display catalog features 2- to 12-digit display modules with green fluorescent tube and red LED displays. Bezels, test equipment and other display accessories are also described. Star Displays, Inc., 1655 W. 11th Ave., Eugene, OR 97402. **379**

Capacitance and dissipation factor bridges are described in a four-page brochure with specifications and application data. Information on accessory items is also provided. Special Instruments & Machinery Co., 6 Lamesa Ave., Eastchester, NY 10707. **380**

Coaxial connectors of the microminiature non-crimp variety are listed in a 28-page catalog that contains outline drawings, dimensions, ordering details and assembly instructions for each connector type. Microdot Inc., Connector Div., South Pasadena, CA 91030. **381**

Test and measurement instruments and systems are described in Catalog CC-9. Equipment for precision measurement and production testing is covered, including voltage dividers, null detectors, dc voltage and current sources, precision bridges and potentiometers and others. Julie Research Laboratories, Inc., 211 W. 61st St., New York, NY 10023. **382**

D/A converters, Model DAC-10Z and DAC-12QZ, with 10 bit and 12 bit resolution repectively are described in two data sheets. Analog Devices, Inc., Rte. 1 Industrial Park, Box 280, Norwood, MA 02062. **373**

Modular A/D converter with 8-bit resolution and a $49 price tag in lots of 100 is described in a two-page data sheet. Operational details, specifications and applications are discussed. Analog Devices, Inc., Rte. 1 Industrial Park, Box 280, Norwood, MA 02062. **374**

Disc memory systems is the subject of a 16-page brochure that describes the "Fastrack" product line and gives information about the company's production facilities. Pacific Micronetics Inc., 5037 Ruffner St., San Diego, CA 92111. **371**

Resistor package consisting of 13 thick-film resistors, all of equal value and with a common terminal, is described in a four-page brochure that includes application information. Helipot Div., Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, CA 92634. **372**

signals & noise

Signals Or Noise

We all have attended engineering meetings where the noise of outraged guests at the registration desk, squealy sound systems and poor slides masked transfer of the real information. Now EDN/EEE is trying a new thing. We are trying to raise the signals and suppress the noise.

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But that's not all.

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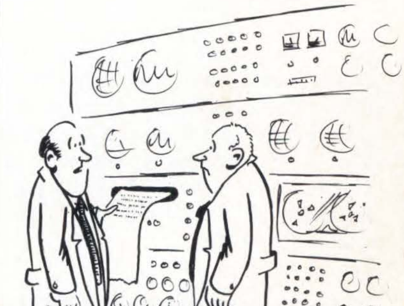

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Application Notes

IC audio amplifier application note discusses the use of the LM352 IC in various audio systems including radios, record players and TV receivers. Circuit descriptions and general operation characteristics are also included in this note. European Electronic Products, Corp., 10150 W. Jefferson Blvd., Culver City, CA 90230. **390**

"Transmission and Multiplexing of Analog or Digital Signals Utilizing the CD4016A Quad Bilateral Switch" is a 12-page note that discusses applications such as: digitally-controlled resistance, capacitance, impedance, frequency or gain-control networks; A/D or D/A conversion; sample-and-hold and squelch control (level detector) circuits. Commercial Engineering, RCA Solid State Div., Box 3200, Somerville, N J 08876. **391**

"Monolithic Regulator Specifications" is the title of Linear Microcircuits Application Note 1. It contains a discussion of the relationship between performance specifications and constraint specifications, and defines all pertinent terms under each category. Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94040. **392**

"Analysis and Design of Snubber Networks for dv/dt Suppression in Thyristor Circuits" analyzes the operation of snubber networks and presents graphs for selecting a network to meet specific requirements. These networks suppress commutation voltage stress that may occur when the load current and voltage are out of phase in a triac-controlled circuit. RCA Solid State Div., Box 3200, Somerville, N J 08876. **393**

Reflective Read-head assembly applications using a LED and a phototransistor are discussed in the four-page New Product Application No. 20. Typical applications described include mark-sense, end-of-tape sense, proximity detection, flaw detection, punched tape reading and reflectance measurement. Optron, Inc., 1201 Tappan Circle, Carrollton, TX 75006. **394**

"Optical Techniques for Measuring Flatness" is a 16-page booklet that explains the technique of using optical standards to measure flatness. It discusses the subjects of light waves and interference; contact method for testing flatness; typical interference patterns and their interpretation; noncontact methods of measurement; and applications. Edmund Scientific Co., 555 Edscorp Building, Barrington, N J 08007. **395**

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L63	One Instrument Wears Many Hats	40
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L65	Inexpensive Inverters Generates V_{GG} for Portable MOS Applications	51
L66	Open-Ended RC Line Model Predicts MOSFET IC Response	53
L67	Doing Design the Team Way	60

New Celanex-917. It has the best of thermoplastics and thermosets.

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That's part of the reason Raritan Engineering, Millville, N.J., is using Celanex-917 for pump components and electric motor domes on their new marine heads.

Just as important, Celanex-917 completely resists strong chemical decontaminants mixed with sea water in the pump. In this part Celanex replaces brass. It replaces phenolic and polyester thermosets in the dome because of its superior combination of electrical, thermal and mechanical properties. Celanex-917 also eliminated the problems of poor finish, cracking, poor uniformity, and tool wear during drilling and tapping of holes.

Celanex-917 is outstandingly machinable for a glass-reinforced plastic. It's rigid, won't crack or become brittle, doesn't distort or creep.

During development, Celanex-917 was called X-917. But by any name it's a strong, tough plastic that can do things no other thermoplastic can. Write on your letterhead for more detailed information.

Celanese Plastics Company, Dept. X-601, 550 Broad Street, Newark, N.J. 07102.

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