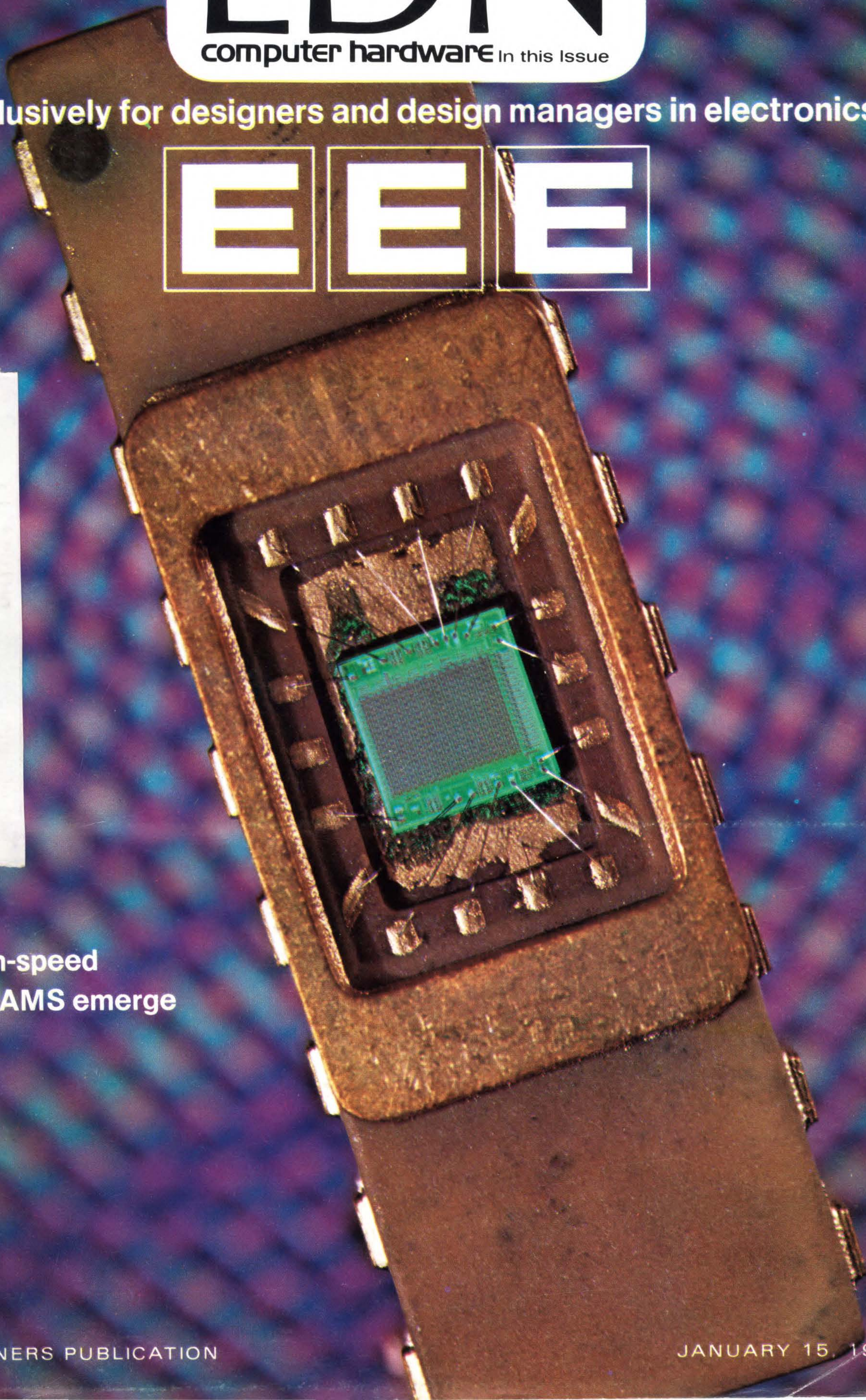
# EDN

computer hardware In this Issue

exclusively for designers and design managers in electronics

EEE

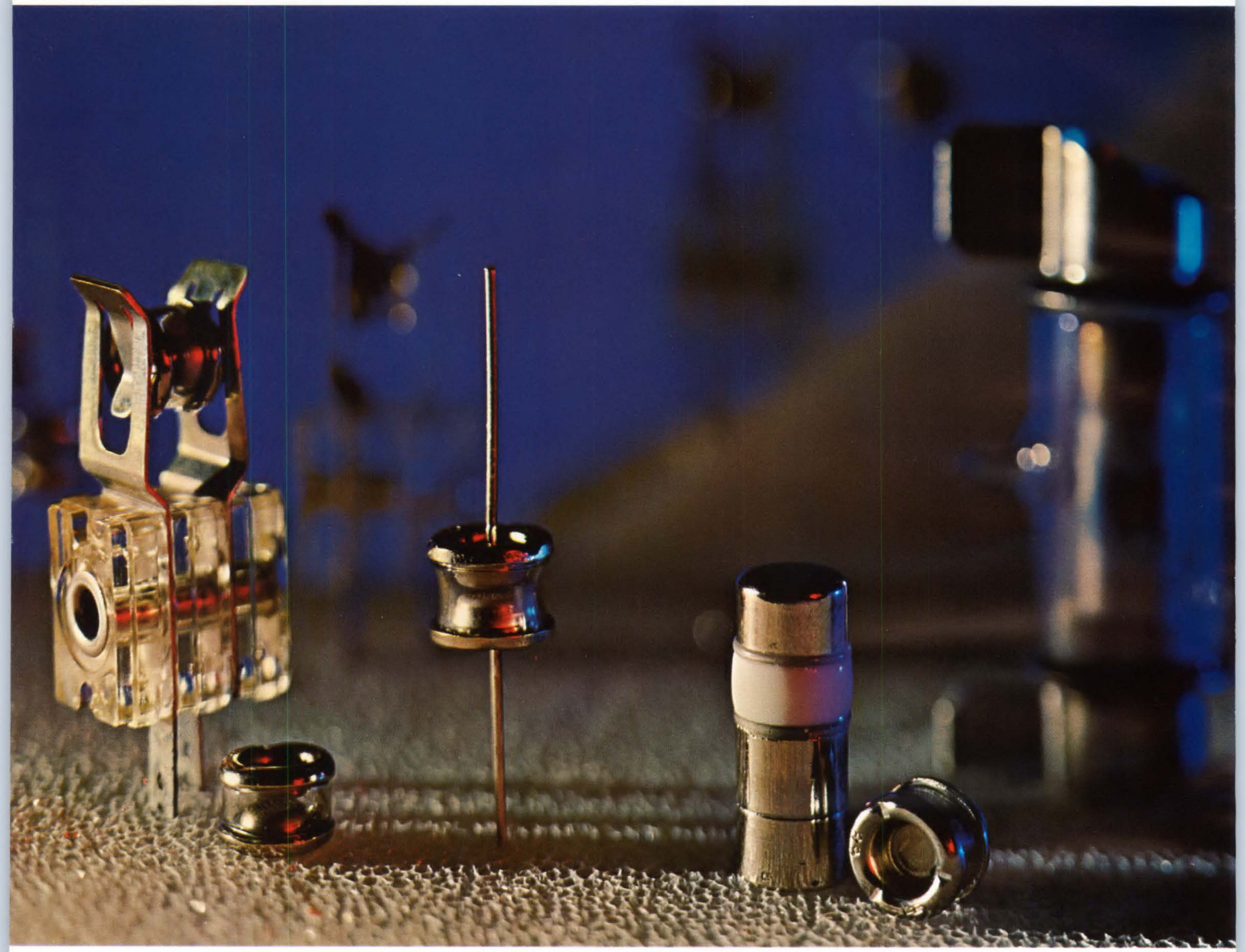


High-speed
1k RAMS emerge

A CAHNERS PUBLICATION

JANUARY 15, 1972

# Siemens



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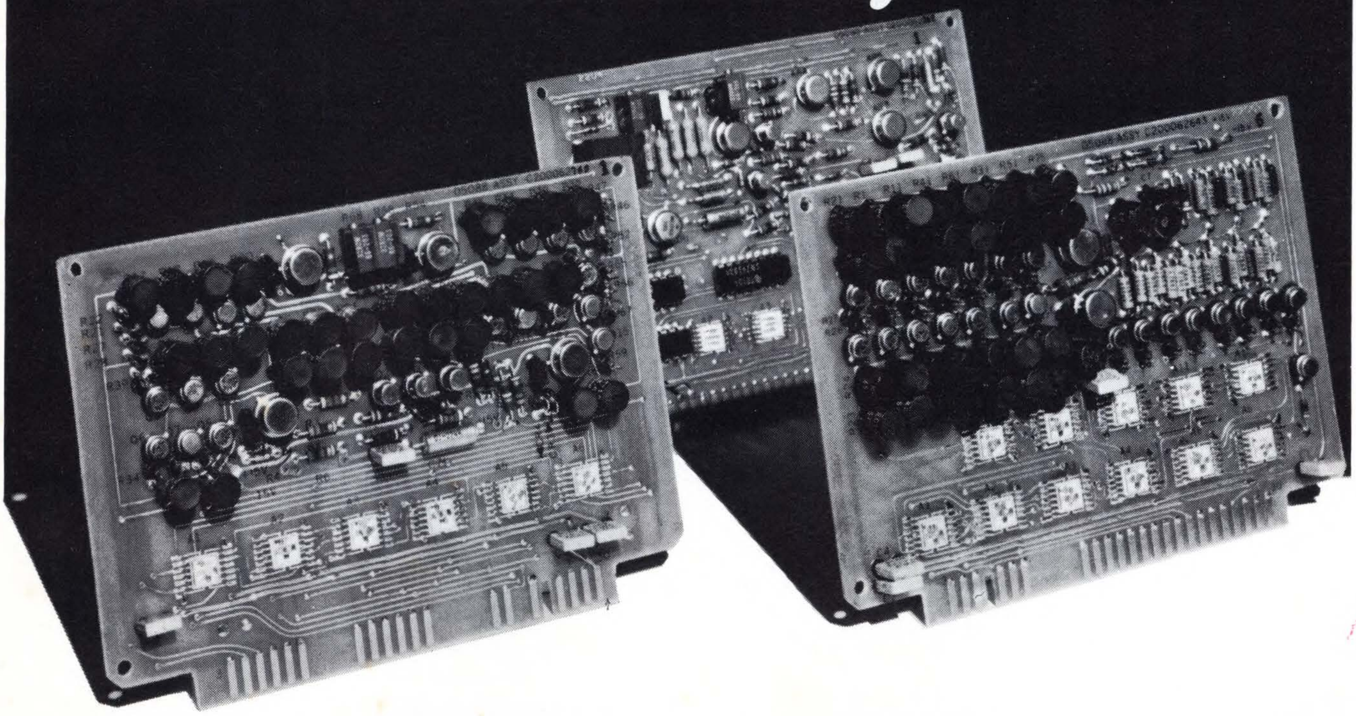
CIRCLE NO. 1

# Mil spec synchro/digital converters:
# We've got 'em in cards. Or cased. For off-the-shelf delivery.



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TRIGAC I—A low cost synchro to digital converter, accurate to 12 minutes.

TRIGAC III—Synchro to digital tracking converter dynamically similar to an electro mechanical follow-up servo.

TRIGAC IV—Digital to synchro converter, accurate to four minutes.

**Typical Characteristics**

| | | TRIGAC I | | TRIGAC III | TRIGAC IV |
|---|---|---|---|---|---|
| Model Number | C70 4773 017 | C70 4773 011 | C70 4773 019 | C70 4773 022 | C70 4773 020 |
| Package | 2 P C cards | metal enclosure | 2 P C cards | 3 P C cards | 3 P C cards |
| Input Signal | 4 wire resolver | 3 wire synchro | 4 wire resolver 4 channels | 3 wire synchro | 12 bit parallel |
| Output | | 13 bit BCD | | 14 bit natural parallel | 3 wire 11.8V 400Hz |
| Resolution | | 6 minutes of arc | | | |
| Accuracy | | 12 minutes of arc | | 4 minutes of arc | |
| Logic Levels | | Logic "1"=±5V±10%, Logic "0"=0-0.5V | | | |

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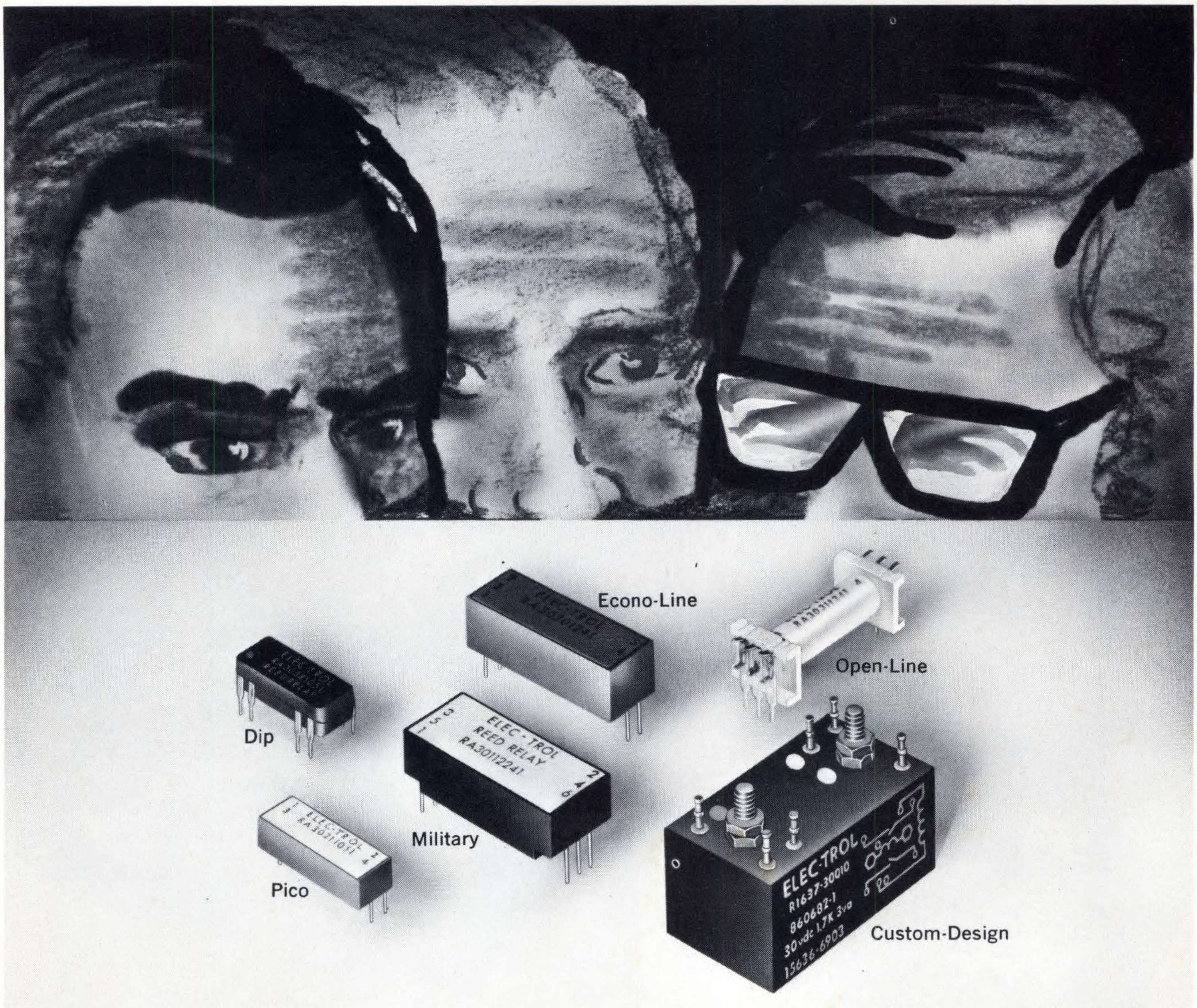
CIRCLE NO. 2




# Thinking engineers prefer Elec-Trol Reed Relays

## Here's why...

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Elec-Trol has long been famous for its engineering leadership and manufacturing techniques used to protect the reed switch and coil in reed relays, providing the assurance of proper performance throughout the relay's application life. We pioneered the DIP reed relay. The know-how of precise bending of reed lead terminals, all welded internal construction, along with expertise in use of special epoxies that have similar temperature coefficients to the reed switch glass enclosure, are outstanding examples. We have available special packaging techniques to make customized relay configurations.

**CIRCLE NO. 3**

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Whether your decision to buy is based on switching speed, long life, light weight, reliability, circuit isolation, power handling, special packaging, or otherwise, one of our five reed relay lines: Econo-line . . . Open-line . . . Dip . . . Pico . . . Military . . . or a customized design is sure to fill the bill. Our automated production line guarantees high performance reed relays at low cost. You can be certain that Elec-Trol is doing a better job.

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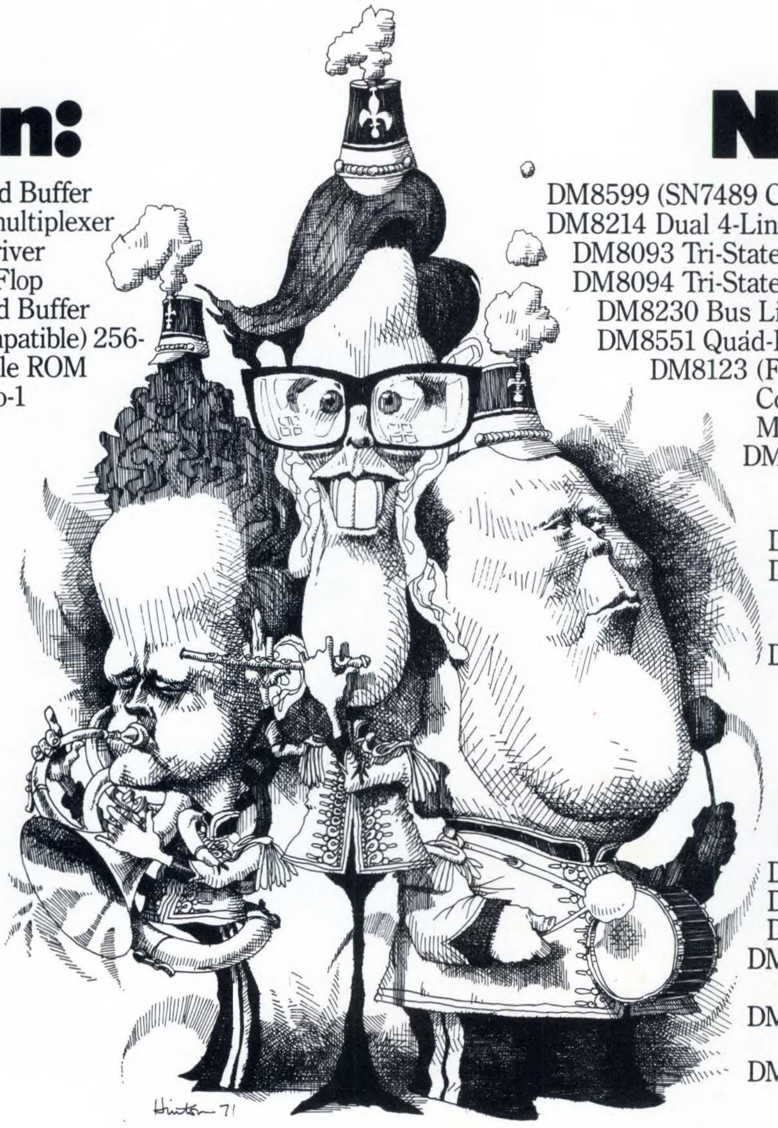

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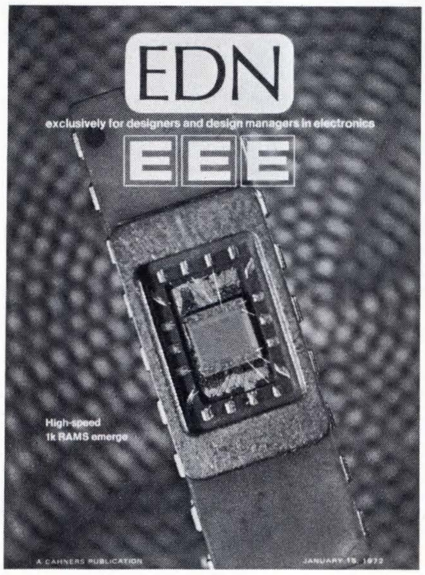
CIRCLE NO. 5

JANUARY 15, 1972
VOLUME 17, NUMBER 2

# EDN/EEE

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS




## COVER

Photo, courtesy of Electronic Arrays, Inc., Mountain View, Calif., shows their 1024-bit MOS RAM—the first on the market. See story on p. 12.

## DESIGN NEWS



## DESIGN FEATURES



## PROGRESS IN PRODUCTS



## DESIGN PRODUCTS



## DESIGN DEPARTMENTS



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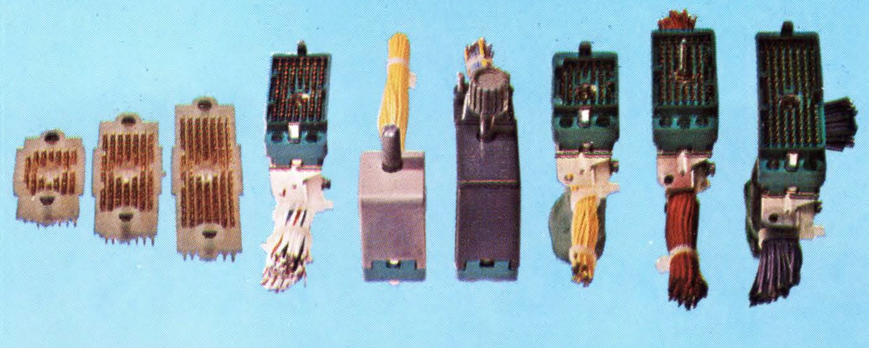

A line-up of input-output rack and panel and cable-to-cable connectors with contact spacing on .100" centers. Elco's solution to the burgeoning packaging squeeze in electronic circuitry.

Let's take muster. First, the Series 8026 R/P and cable-to-cable connector that's equipped with the Elco high-reliability crimp-and-insert mini Varilok™ contact. Team a Series 8026 117-contact plug with its corresponding receptacle, and you have a 117-contact connector that's in the same envelope as a 56-contact connector on .150" spacing. But packing more than twice the contacts in the same space.

Then, by the numbers. The 75-contact 8026 connector will fit in the same space as a 38-contact connector on .150" spacing. And the 8026 33-contact connector is one of the smallest 33-contact R/P connectors you've ever seen. And for back-up, we offer Series 8026 connector with 55 and 79 contacts on .125" square grid.

For your I/O back-panel applications, Elco Series 5540 connectors are available in the same sizes as the 8026, but use the field-proven Varicon™ contact with .025" square wire wrappable posts. They incorporate—as do the 8026's—a new female turnable jackscrew that eliminates any possibility of damage to plate contacts in difficult or blind mating situations. Both series use standardized polarizing and keying hardware to prevent unmatched plugs and receptacles from being mated.

And by no small coincidence, hardware standardization lets you minimize your in-house and field stocking requirements, and allows you to use the same manufacturing set-up to assemble all sizes.

Besides helping you cope with your close-order circuits, this roster of connectors will help you effect other cost economies. Like using your existing 8016 panel punches. Reducing inventory because they can do duty in R/P and cable-to-cable applications as well as be used as an I/O. On a performance/price basis, these high density connectors are your best buy because quality is equal to or better than, and published prices are much less than those of their pin-and-socket counterparts.

There's one more bonus. Immediate availability. Both Series. All sizes. Another service in keeping with CONNECTRONICS, Elco's Total Connector Capability.

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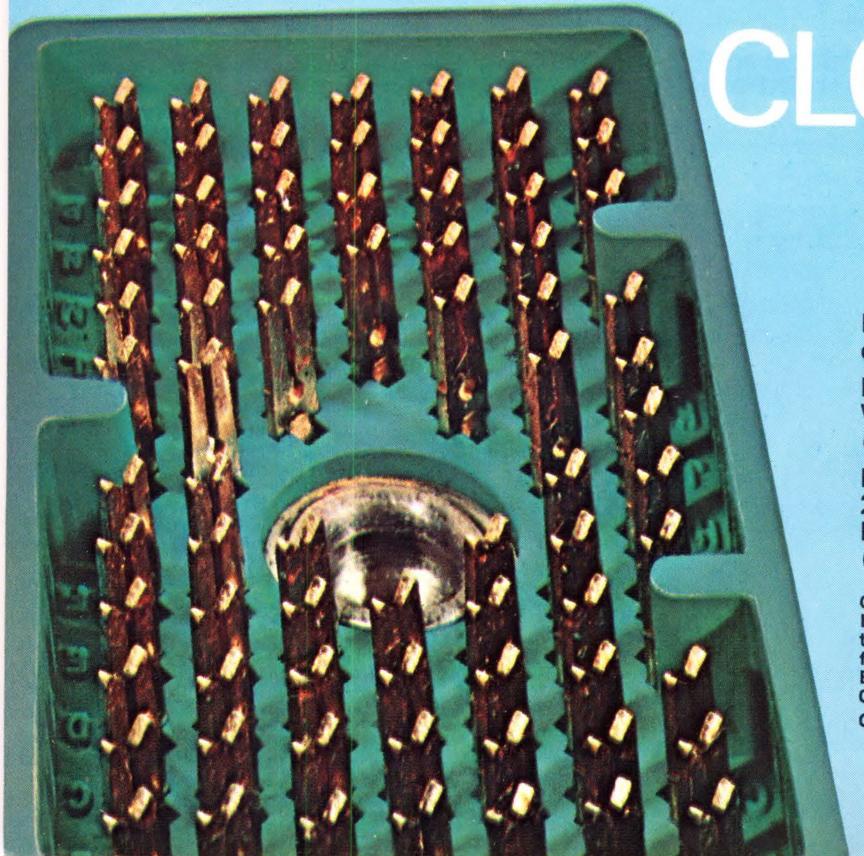

For full details on these new connectors from Elco, contact:

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CIRCLE NO. 7

# Editorial

## It's time to start pulling together

It's a little early to be absolutely certain, but 1972 looks like it will be a good year for business and industry. After the two-year economic squeeze we've all been through such a bright outlook is indeed welcome.

How our own companies fare this year will of course depend on many things, not the least of which will be our personal contribution. This contribution is the complex result of many individual elements, such as time, effort and creativity. One of these elements that is frequently overlooked, because of its subtlety we would guess, is attitude. And this includes attitude towards others in our department, towards other departments, as well as towards the job itself.

The reason that attitude is so important is because it effects not only the contribution of the individual involved, but the contributions made by many others. No one says that all members of an organization have to love each other. But for maximum effectiveness they all have to be working towards the same overall goal, and respect the role played by each other in the attaining of that goal.

In effect, an organization blessed with positive attitudes throughout its ranks represents synergism at its best—the old story of two plus two equaling a lot more than four.

Engineers generally do have positive attitudes towards engineering and other engineers. There is often much room for improvement, though, when it comes to other departments or disciplines within their company. With this in mind, we offer the following impressions:

The marketing department is not staffed exclusively with finger-snapping, glib-talking types who sell used cars on weekends. A salesman's job is not easy. He may push and prod engineering for Cadillac products at Volkswagon prices, but remember, he's out there competing for sales against salesmen who have engineering departments as good as, and possibly even better than, yours.

The manufacturing department has to make that little widget of yours—and make it cheap. They have to apply modern, efficient production techniques, and they can't afford a lengthy tweaking of each unit as it comes off the line. If they can't make it cheap enough, it might as well have never been developed.

We could go on and give similar impressions of purchasing agents and administrative management, among others. To do so, though, would belabor our point. Suffice to say that a little more appreciation of other departments and their aims and objectives can help us all increase our own on-the-job contributions.

Frank Egan
Editor

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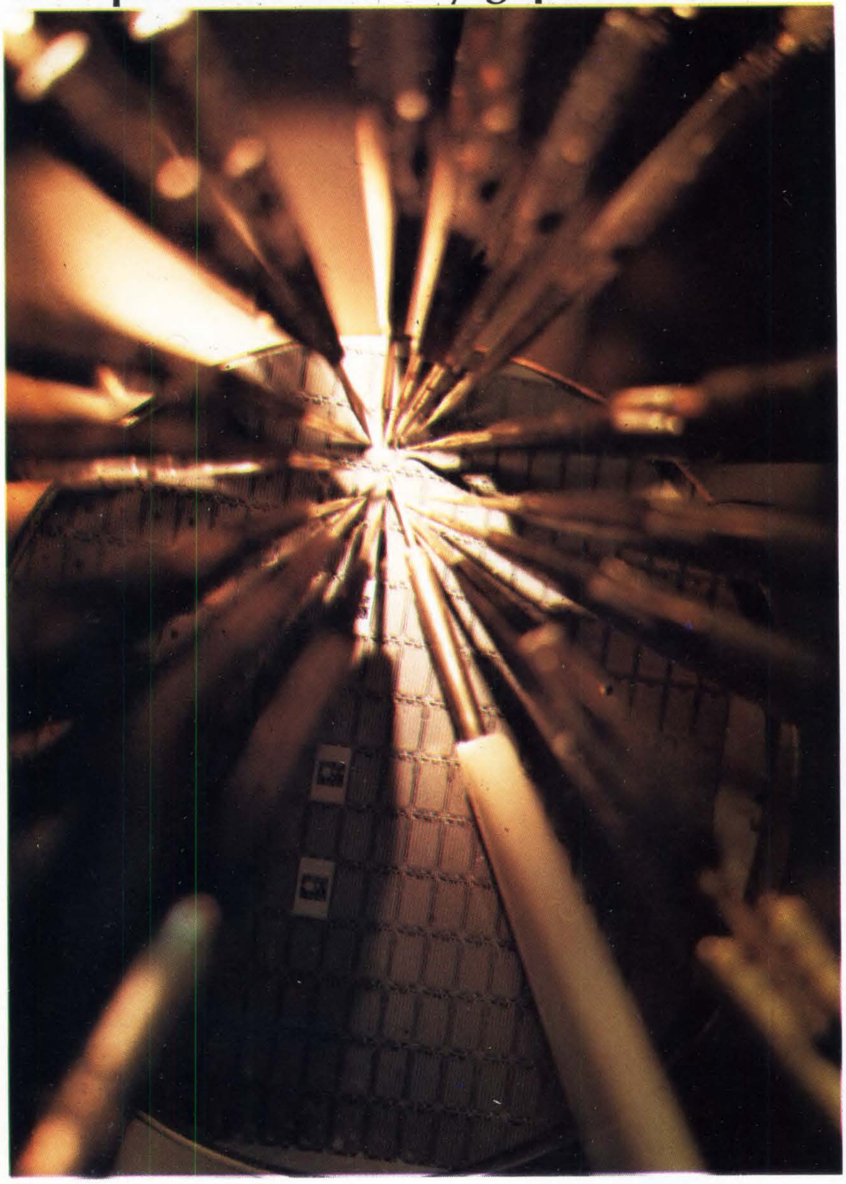
# Semiconductor memories—

## the speed and density gaps close



**The first pilot wafer** of Signetics Corp.'s 1024-bit bipolar RAM is shown during wafer probe testing. This memory device employs Schottky-barrier diode clamps, is fully TTL-compatible and can be operated in a power-down mode.

In the hectic world of semiconductor memories two things were always clear—for speed use bipolar, for density use MOS.

With the start of a new year comes the introduction of a memory that breaks the rules. Electronic Arrays, Inc. has just announced the first n-channel silicon gate MOS RAM.

Access time of the new 1024-bit RAM is typically 100 nsec. Electronic Arrays guarantee 85 nsec access time for the EA1500 if it is operated at ±15V. Normal operation is at ±12V.

The introduction of the EA1500 does not mean the end for high-speed bipolar memories. Just across the street from Electronic Arrays in Mountain View, Calif., both Fairchild Semiconductor and Raytheon Semiconductor are getting ready to announce 1024-bit bipolar RAMs that are as fast or faster than the EA1500, and as small as the 1024-bit MOS RAMs already on the market. Both of these companies developed new processes in 1971 that drastically reduce memory cell size. Fairchild's process is called Isoplanar while Raytheon's is named V-8 (for Vertical Anisotropic Etch).

The first high-density bipolar RAM to be offered as a standard product will probably not come from Fairchild or Raytheon. Intersil, Inc. and Monolithic Memories, Inc. have developed 1024-bit RAMs using standard processes. Both companies expect to be marketing them before Fairchild or Raytheon.

Two other Sunnyvale companies, Signetics Corp. and Computer Microtechnology Inc., are well along on the development of bipolar 1024-bit RAMs.

According to Dick Eiler, Electronic Array's product marketing manager, the EA1500 fulfills predictions that n-channel silicon gate technology would make MOS RAMs as fast as bipolar RAMs. And, he adds, with much lower power dissipation than conventional p-channel silicon-gate RAMs.

Very few n-channel devices have appeared in the past, primarily because of the processing problems (see "Making Sense Out of the MOS Muddle—Part I," EDN/EEE Sept. 1, 1971, pp. 23-32). Electronic Arrays' solution is to "keep it simple and clear," says Eiler. They are using the same number of masks as for p-channel, and add a silicon nitride layer as a barrier against contamination, he reports.

In active operation, the EA1500 dissipates only 100 mW—25 to 33% of p-channel dissipation. Most of the power reduction is the result of new circuit design and low operating voltages.

In addition, the EA1500 can be logically turned-off between accesses by bringing all inputs (except power) to zero with single gating. This reduces standby power dissipation to a few mw.

Conventional precharge is not used to bring the RAM out of standby and into active operation. Any address input will override the standby gating and the EA1500 then turns ON in several nanoseconds.

Refresh addressing is eliminated by a new storage array design. All 1024 storage cells are simultaneously refreshed by any write pulse. (Only the specific cell addressed will accept a new data input.)

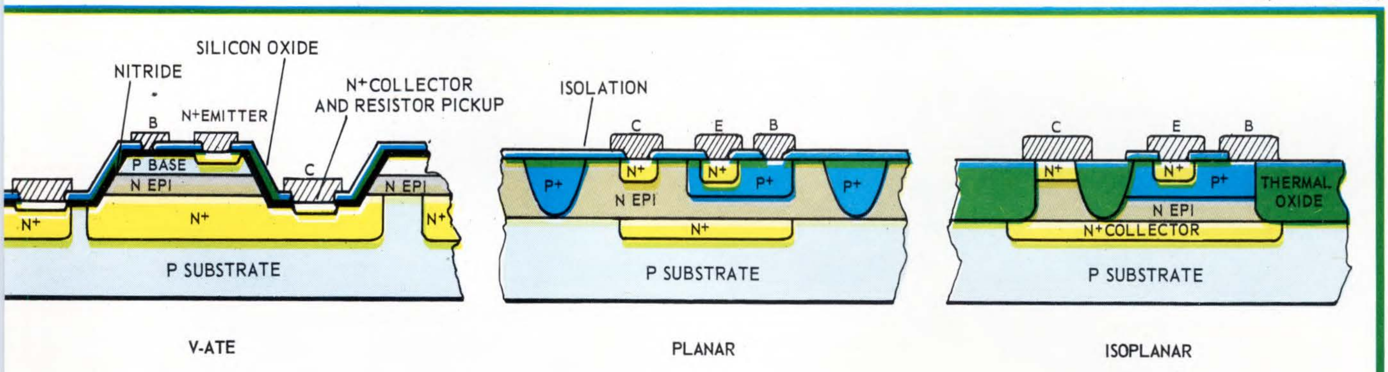
Conventional dynamic RAMs cannot be refreshed with a single pulse because they require a refresh buffer for each column in the array of storage cells. Most 1024-bit RAMs are arranged in 32 by 32 arrays, and up to 32 refresh pulses are required.

The n-channel silicon-gate process developed by Electronic Arrays permits buffering to be incorporated in each cell. Consequently, it is not necessary to logically determine which columns in a memory are scheduled for refresh and then address refresh pulses to those columns.

Refresh intervals in dynamic MOS RAMs depend on charge storage time in the storage FETs. For the Intel 1103 and Advanced Memory Systems 6002, this is 2 msec. The n-channel process developed by Electronic Arrays results in very slow charge leakage, extending the storage time to 5 to 10 msec, depending on operating temperature.

Timing and control logic for memory systems built with the EA1500 is greatly simplified by the elimination of precharge and refresh addressing. Because of the long charge-storage time and the single-pulse refresh method, the memory-busy duty cycle in a typical system design will be once in every 10,000 to 20,000 cycles, says Eiler.

For more information, Circle **260.**




**Both the Isoplanar and V-ATE** (vertical anisotropic etch) processes, developed by Fairchild Semiconductor and Raytheon Semiconductor respectively, are more complex than the standard Planar process, but they result in reductions of as much as 60 percent in memory cell area.


PERT CPM

# New semiconductor devices promise efficient, economical transient suppression

Power line transients, with their often insidious way of causing circuit and system damage, are a problem to designers in practically all areas of electronics. Now, thanks to a new type of semiconductor device from General Electric Co., Syracuse, N.Y., protection against these transients may take on a new dimension.

The new varistor devices are based on a recently-developed polycrystalline technology, and are called metal-oxide varistors, trademarked GE-MOV.

Essentially, the GE-MOV varistor is a voltage-dependent, symmetrical resistor which performs somewhat like an inverse series zener diode in circuit protective functions.

When exposed to high-voltage transients, the impedance of the GE-MOV varistor changes from a very high standby value to a low conducting value, clamping the line voltage to a safe value. The dangerous energy of the incoming high-voltage pulse is thus prevented from passing through the voltage-sensitive circuit components.

Relative performance of the new devices can be seen from their alpha figures (**Fig. 1**), which are frequently used as the figure of merit for devices of this type. The alpha figure is the log/log slope of the device EI characteristic. GE-MOV varistor alpha values range up to 70, with a guaranteed minimum alpha of 25. This compares to alpha values of 1 for a resistor, about 5 for a Thyrite varistor, 5 to 15 for a selenium thyrector and about 35 for a power zener diode.

The GE-MOV varistor is fabricated from a ceramic powder by a pressing operation (**Fig. 2**). The devices to be offered initially are disc-shaped, and have metalized faces to which the leads are attached. The thickness of the disc determines the device voltage rating. All GE-MOV varistors are encapsulated in epoxy.

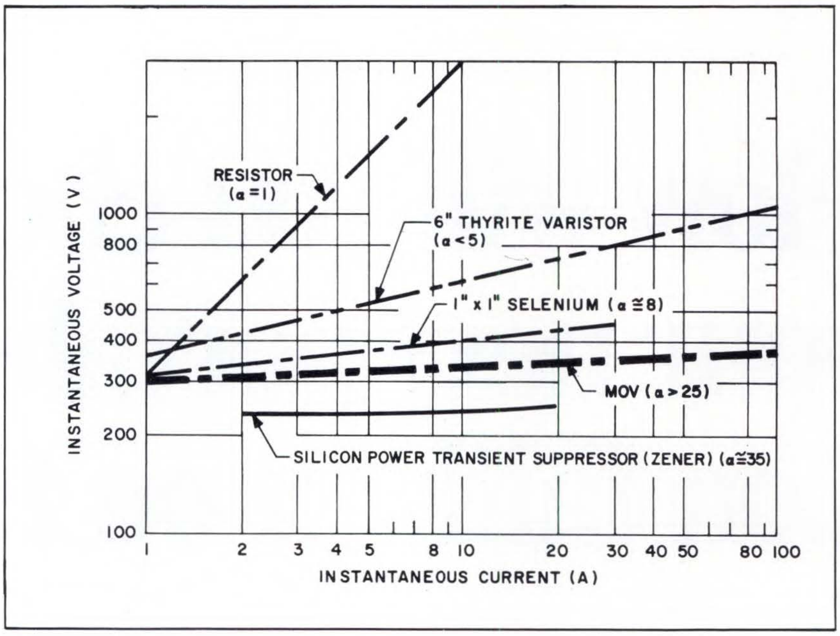
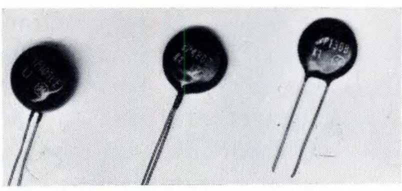



Fig. 1 – **Log-log volt/ampere characteristics** of common voltage-transient suppressors show the relative performance of the GE-MOV varistor.



**The GE-MOV varistors** are based on a recently-developed polycrystalline technology for which the Japanese hold the basic material patents. A licensing agreement covering the material was signed by GE this year with Matsushita Electric Co. of Japan.

In operation, the GE-MOV varistor usually is connected in parallel with the component or network it is protecting, stabilizing, or regulating. When a high-voltage transient appears, the resistance of the varistor changes from that of a good insulator to that of a conductor. The incoming power surge is thus prevented from reaching the protected equipment. According to GE, the nonconducting-to-conducting change in resistance can cover a range of 100 million to one.

Nineteen standard GE-MOV varistors for use in ac circuitry are being introduced. They range in maximum energy-handling capability from 10 watt-seconds, or joules, to 160 watt-seconds. Maximum peak current rating is 1250 amperes. Ac voltage ratings range from 130V to 1000V RMS. Devices for lower voltage applications are expected in the near future.

Prices, according to GE, will be comparable to those of present silicon carbide varistors.

For more information circle **261**.

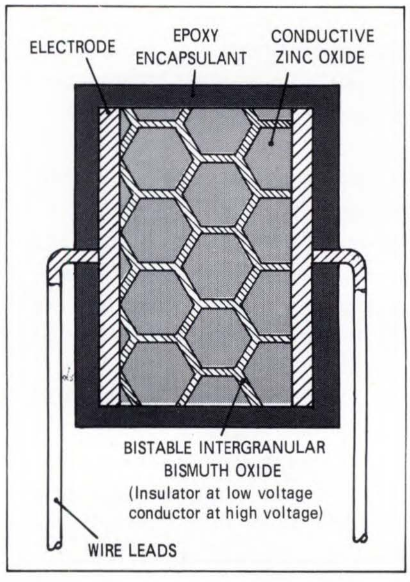



Fig. 2 – **The GE-MOV varistor is a polycrystalline ceramic** consisting of conductive zinc-oxide grains with a thin, intergranular bismuth-oxide film that is insulating at low voltage and conducting at high voltage. The latter completely surrounds and isolates the individual grains of the zinc oxide. The ceramic disc contains literally millions of tiny thin-film devices at the zinc oxide grain boundaries, which are connected in three-dimensional, series-parallel networks. The voltage sensitive resistance of the thin films is the key to the operation.

## Computer to help make typing lessons easy

A computer is being used to reduce the number of hours required to teach future typing students. The project is being carried out at New Jersey's County College of Morris County under the direction of R. D. Chenoweth, chairman of the college's data processing division.

Student programmers are compiling a master file of 74,000 words analyzed for the motions and time required to produce them. This is possible because the motions and strokes necessary for each letter or number have been coded into the memory of the college's NCR Century 200 computer.

Typewriting copy being studied is key-punched, loaded onto magnetic tape and run through the Century 200 at 165 words a minute. The computer catches misspellings, adds those words not already there into its file, and processes the words through two or more sortings.

It then measures the complexity of the copy in terms of the number of strokes and motions needed for its production. Finally, it classifies the copy in terms of its difficulty and the required dexterity.

Processed copy is returned to the Gregg Division of McGraw-Hill Inc., a sponsor of the project, where it is used in compiling a program and textbook that aim to reduce the number of hours a typing student needs to spend in learning the skill.

## Flying clocks test relativity theory

Time dilatation—the special part of Einstein's relativity theory that predicts more time will pass for stay-at-homes than for fast-moving space travelers returning to earth—underwent a new test recently. Also tested by the experiment was the interaction of gravity and time, a part of the General Theory. It was the first known experimental demonstration of these effects using actual time-recording clocks. The preliminary results seem to support Einstein.

Professor Joseph C. Hafele of Washington University, St. Louis, Mo., and Richard Keating of the U.S. Naval Observatory, Washington, D. C., flew a set of four Hewlett-Packard precision atomic clocks around the world. They flew the route once eastward and once westward, measuring how much time the clocks recorded during their trips, relative to the time observed on earth by the ensemble of atomic clocks at the Naval Observatory which are the United States' official timekeeper. The experiment was funded by the Observatory. Preliminary, uncorrected results for the experiment indicate a slight loss for the eastward trip and a definite gain for the westward trip, as Einstein's theory would predict for paths similarly flown.

To test the theory, the results of the experiment must be compared with the results the theory would predict. The expected results depend on the actual paths, velocities, and altitudes during the flights. For a total flight time of about 38 hours at 650 miles an hour, at an altitude of 35,000 ft around the equator, the predicted results are a loss for the eastward flight of about 110 nsec relative to the clocks on earth, and a gain of about 300 nsec for the westward flight. The only quantity man can measure with anything like this precision is, fortunately, time.

**Precision atomic clocks** were flown around the world to test the time dilatation part of Einstein's relativity theory. Prof. F. C. Hafele, Washington Univ. (left) and Richard Keating, U.S. Naval Observatory (right) who flew with the clocks, discuss the experiment with Al Walker of Hewlett-Packard Co.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IN THYRISTORS

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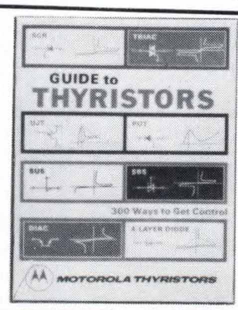


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# Don't leave system grounding to chance

*Put the elements of system grounding high on your system design priority list, and use these broad grounding guidelines to steer clear of ground noise problems.*

*Harry Brown, Westinghouse Electric*

The successful design of a modern, sophisticated electronic system requires careful attention to the details of its ground and power distribution. This need should be approached by first viewing the complete system and its physical environment, then working down to the smallest identifiable circuit in the system.

Lack of forethought in system grounding can result in months of "debugging" during the integration and test of the system, and this in turn leads to "trial and error" solutions. At best, these solutions are often marginal, and are constrained by designed-in obstacles that prevent incorporation of a truly satisfactory solution. This article presents basic principles that are sometimes overlooked by designers.

### Mass grounded systems and the basic problem

Part of a simple mass grounded system, consisting of several independent transistor stages along with a high-gain, high-input-impedance voltage amplifier connected to the output of Q1, are shown in (**Fig. 1**). Each stage has a voltage drop between its ground point and power source ground termination due to current drawn through the unwanted, but unavoidable, resistance existing in the path back to the power source.

In addition, differential ac voltages exist across the impedances between each ground and power supply node in the system. These result from the imperfect shunting of signal current by the individual stage bypassing capacitors, and from large signal currents returned from heavy, remotely located loads such as RL1.

If the circuits are individually grounded to a chassis which has currents from other sources and loads, such as $v_n$, flowing through it, these other currents also produce unwanted signals between ground points. In this illustration, four differential noise sources exist between AR1 and its source Q1, assuming that the signal current to A1 from Q1 is negligibly small. Within a small chassis, these differential noise sources could easily be on the order of several millivolts of noise while the desired signal might be on the order of a few microvolts.

In complex systems, microvolt signal voltages may have to coexist with signal and power currents on the order of amperes. Actual system measurements across power supply leads and subsystem grounds have shown switching transients on the order of several volts resulting from fast-rising waveforms.

To understand how this could occur, we only have to examine some typical ground conductors. One foot of AWG No. 20 copper wire has 0.01 Ω of resistance; thus 100 mA signal passing through it will produce a 1mV voltage drop. The self inductance of this same length of wire is 0.44 μH, so a 100 mA pulse with a 20 nsec rise time (10-90%) will produce a 1.75V voltage "spike" – enough to trip almost any logic circuit, drive an integrator far off, and raise havoc in a dozen other ways.

An 18-gauge aluminum chassis 4 inches wide by 8 inches long has a dc resistance from end to end of $56 \times 10^{-6}\Omega$. If it is rigidly attached at its ends to a frame or structure carrying large currents, such as system prime power, it will carry its proportional share of these currents. If this share is one ampere, a voltage drop of 56 μV will exist across the chassis. Again, high frequency signals will produce even greater drops across this chassis.

Consider also an aircraft in which prime power is distributed to units which are grounded to the airframe near the tail of the aircraft and also to units which are grounded to the airframe near the nose. The potential difference between the two ground points is typically greater than one volt rms at 400 Hz.

From these examples, it should be obvious that the grounding of any reasonably complex system cannot be left to chance.

### Single-point ground systems

One approach to eliminate grounding problems is to use a "single point" ground system, where each stage is connected via its own independent ground path back to a single termination point, or root, somewhere in the system. In this case, the ground return path from each stage contains the ground return current from no other stage. However, power supply voltage is still connected to the various stages via a common line, so some of the benefit of the power supply regulator's low output impedance in keeping ripple from one stage out of another is lost. In addition, some fraction of the noise voltage between each stage and the ground point is coupled back to each ground return through the decoupling networks, so the full benefit of single point grounding is not achieved.

The problem of noise coupled through the power supply lines is corrected in **Fig. 2** by using single point ground and power feeds. Here the source resistance of the power supply must be sufficiently low, and $R_p1$ and $R_p2$ must be small enough so that load currents drop a negligible voltage between the ground and supply roots. Thus it is essential that supply and ground roots be as close to the power supply regulator as possible. In both approaches, signal ground must be isolated from the chassis everywhere but at the ground root.

In a system of any degree of complexity, a pure single-point ground down to the smallest identifiable circuit is physically impossible. A reasonable compromise is to provide a single-point ground return and power supply for each plug-in assembly, and to distribute the supply voltage and ground return by one of the methods described under "grounding internal to unit," which is discussed later.

## Signal transmission between units

Signal inteconnection between various units in a single-point grounded system requires special consideration. The two basic requirements of interfacing between units are: (1) that the single-point grounding philosophy not be violated, and (2) that the signal being transmitted not be disturbed by ground potential differences. If noise caused by differential ground voltages between transmitting and receiving units will have a negligible effect on the signal, and if noise in the ground path between each unit and the system ground node (caused by signal-return current being drawn through the two ground paths) also has a negligible effect on the system, then the only precaution necessary is to assure that a signal-return wire is not connected between the two grounds.

"Large signals" require special precautions to keep their signal-return currents and the effects of imperfect bypassing out of the ground system. "Small signals" may be degraded by the differential voltage that exists between ground legs and may also require special precautions to eliminate ground noise. To increase noise immunity, switching thresholds of digital circuits should be kept as high as possible, provided that switching power can be kept low. Noise level can be decreased by keeping switching speeds as low as possible. Analog signals may be bandwidth limited at the source and load ends to minimize the noise power radiated and received.

When a signal transmitted between two units must be isolated from the ground system which exists between them, one of the several methods shown in **Fig. 3** may be employed. In the case of a remote transducer such as a microphone, accelerometer, pressure transducer or servo follow pot, the device may be isolated from local ground at its source and grounded through a return wire at the load to which it is connected. Standard IC differential transmitters and receivers are available for transmission of digital information, or special circuits may be devised.

Where several signals are transmitted from one unit to another, and these signals will not intefere with one another, a separate ground return for each signal isn't necessary. A single wire, grounded at the sending end, can carry the ground reference between units. Where electromagnetic isolation is required, this ground plus the signal wires associated with it should be twisted together as a group. Where high frequency or broadband video signals are transmitted, the use of coaxial cable with the shield grounded at the source end only, and a transformer or other ground isolation device at the load is recommended. The cable should be terminated in its characteristic impedance at the load end. Insulators are available for coaxial bulkhead connectors, and electrostatically shielded transformers are sometimes employed in this case.

When this method is employed for cable lengths in excess of 0.05 wavelengths (determined at the highest frequency of interest), it is usually necessary to provide some form of overall shielding to prevent electromagnetic coupling with the floating end of the cable. Triaxial cable with its outer shield tied to both chassis may be used for this purpose. If several coaxial cables are routed between two units, they may be enclosed in a single outer shield grounded at both ends, provided that the level of mutual interfer-

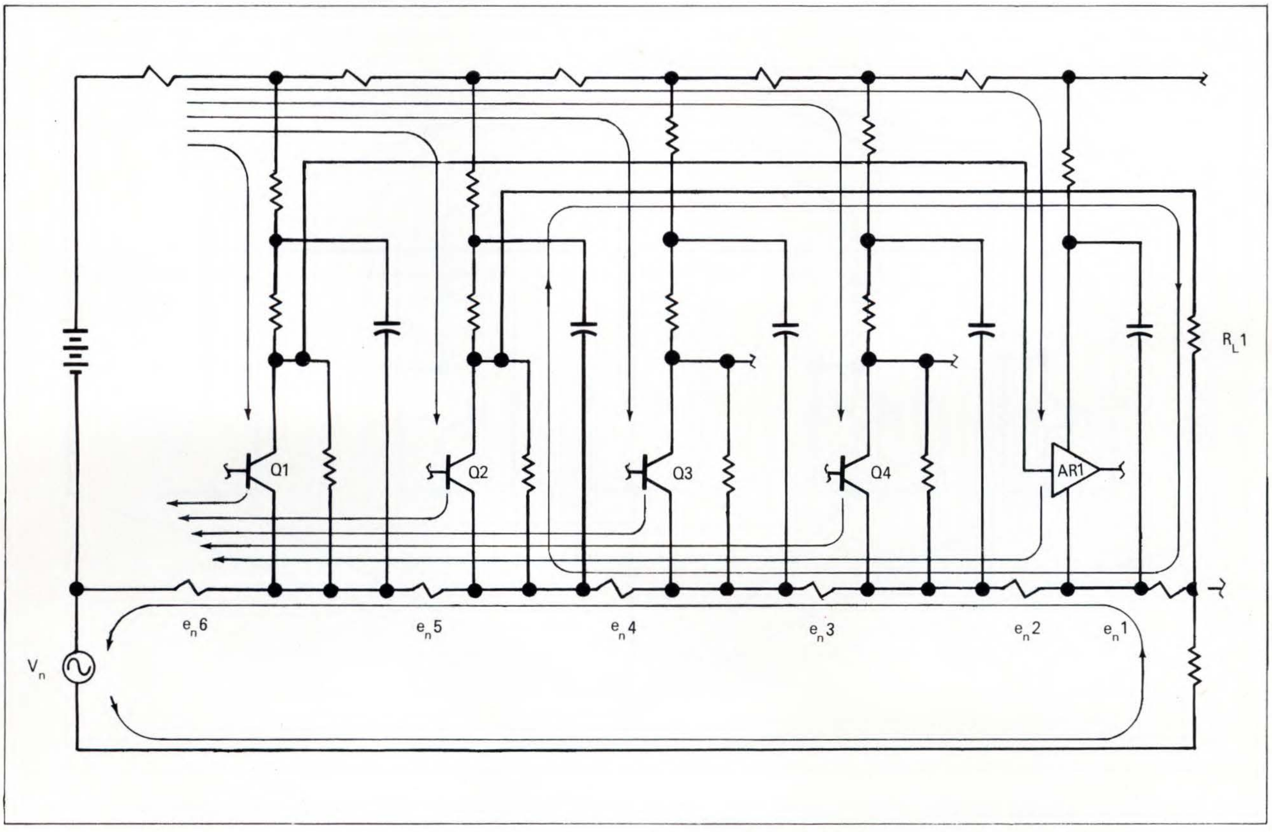



Fig. 1—**Typical mass-ground system** shows the number of noise paths that can exist. Each stage has both ac and dc paths.

ence between the cables will not degrade the system performance.

Where low-level, lower-frequency signals are transmitted, electrostatic shielding and, less often, electromagnetic isolation are required. Shielded wires grounded at one end provide good electrostatic shielding but no electromagnetic shielding. However, twisted wire pairs (signal and signal return), connected per one of the methods of **Fig. 3**, provide both electromagnetic and electrostatic isolation.

## Grounding internal to unit

Within each major chassis, each plug-in unit should be tied to the major chassis power supply and ground wires at one point, the single-point ground for the assembly. Third-layer, single-point distribution is not normally carried onto the plug-in unit unless large geometries, wide ranges of signals, extremely high gains or other special situations exist which cannot be resolved by a different partitioning of circuits among plug-in units.

Care should be taken in laying out the ground and supply leads within the plug-in unit. In general, the leads should proceed from the connector to the highest-level stage first, then work down to the lowest-level stage last to avoid drawing high-level currents between low-level stages. This is shown in **Fig. 4**. Similarly, all grounds within a stage should tie to a common point before being tied to the common ground line (**Fig. 5**).

It is sometimes necessary to violate the single-point ground concept in high-frequency sections of a system, such as 30-MHz IF strips, in order to achieve stable amplifier systems. When this is necessary, extra care is required to assure adequate broadband power supply decoupling and to provide a mechanical mounting structure which prevents the flow of external ground currents through the chassis.

If the chassis is mounted on a frame which may carry significant currents, electrical contact between chassis and frame should occur only at one point. Circuits should be laid out to minimize the chassis area in which any given high-frequency current flows. As a minimum, single point power supply connections should be used to each chassis. However, since the terminal impedance of the power supplies is extremely low, differential ground noise will appear across the power supply inputs to the grounded unit.

As an alternative to very heavy broadband decoupling, a more desirable solution is to use a multiple winding balun to cancel out the differential ground noise (**Fig. 6**). In other cases, like amplitude modulated systems containing class B or C stages, high-frequency decoupling of each stage combined with low and high frequency decoupling of the input power supply leads must be used. Use of shunt regulators for low-frequency decoupling may also be desirable.

## Decoupling considerations

Good broadband decoupling requires careful consideration of details. Capacitor leads are inductive and exhibit a resonant response with the capacitive element. Above the resonant frequency, the capacitor-lead combination appears inductive and will exhibit an antiresonant (impedance maximum) point with any stray capacitance or with an intentionally used lower-value capacitance which appears across it. Therefore, such techniques as placing a 1000-pF capacitor across a 10-$\mu$F capacitor for broad-

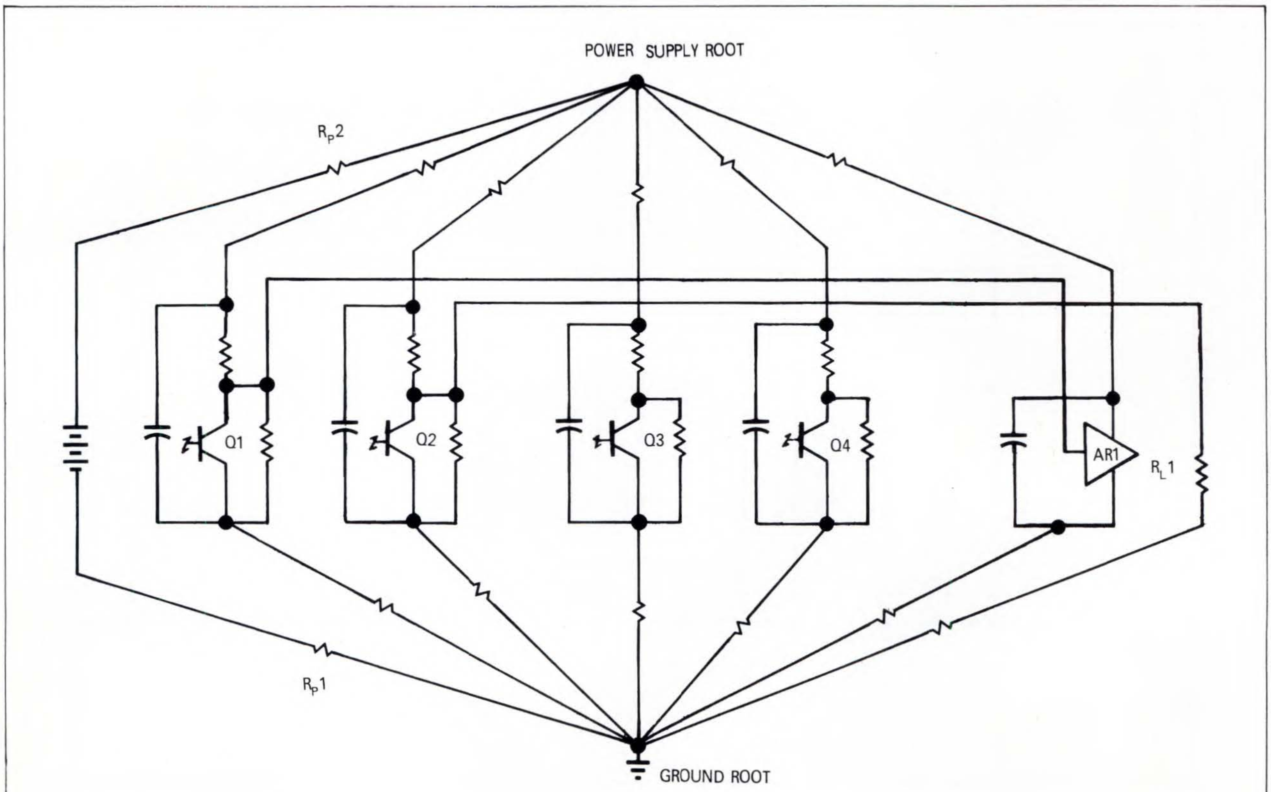
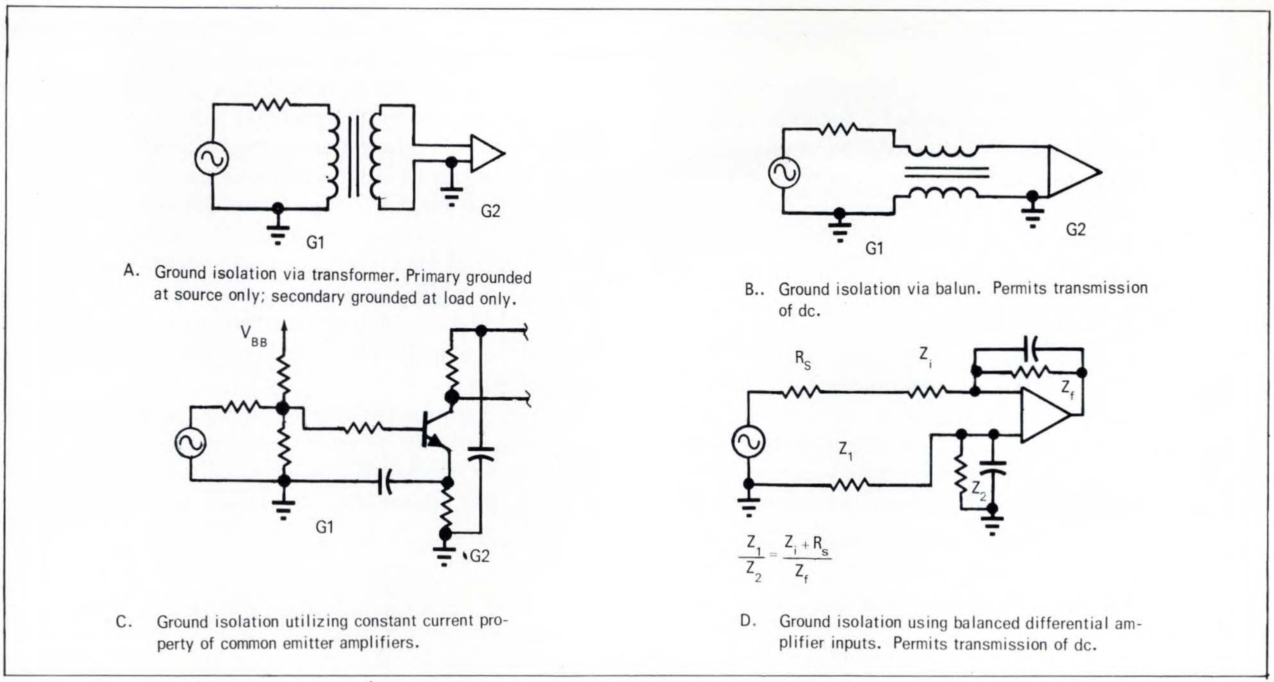



Fig. 2—**Single-point ground and power-feed system** eliminates noise paths between stages that exist through power supply and ground leads. The power supply source resistance and the line drops must be kept as small as possible.




A. Ground isolation via transformer. Primary grounded at source only; secondary grounded at load only.

B.. Ground isolation via balun. Permits transmission of dc.

C. Ground isolation utilizing constant current property of common emitter amplifiers.

D. Ground isolation using balanced differential amplifier inputs. Permits transmission of dc.

Fig. 3 – **Various ground isolation systems** can be used to isolate signals between units from their common ground systems.

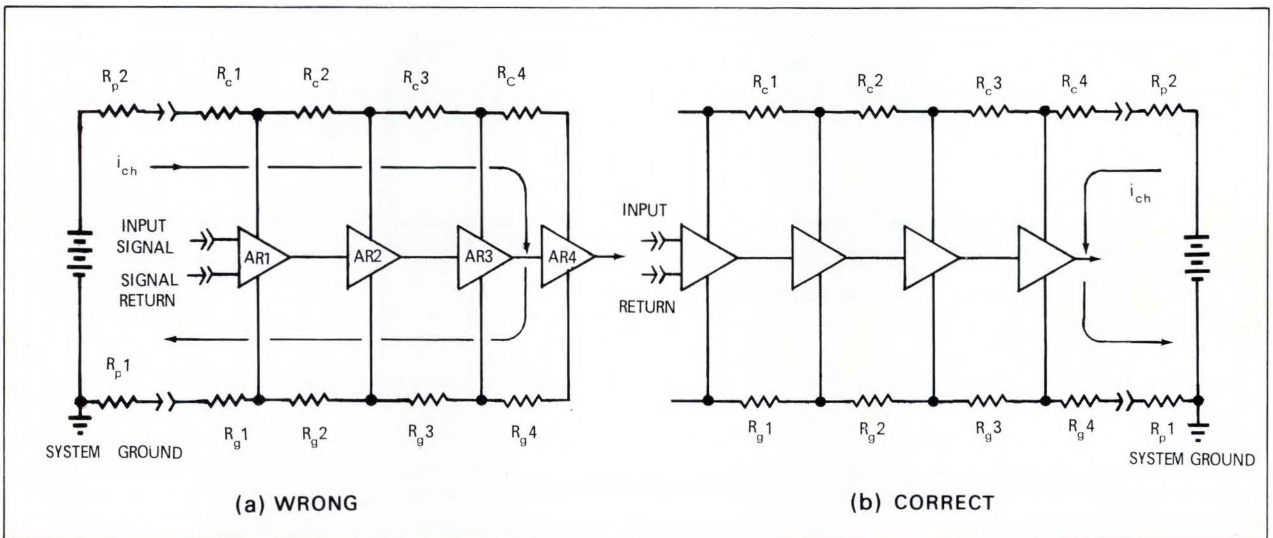



Fig. 4 – **Right and wrong power and ground distribution methods** are shown for cascaded amplifier stages. The impedance between the circuit board connector and the power supply is also shown, because in a typical system the distance from a printed wiring board connector to the power source is much greater than the distance between the connector and the stage farthest removed from it on the board.

**In A.,** power supply source and ground leads are connected to the lowest level stage first. (**Fig. 4a**). For simplicity, consider first the ac current, $i_{ch}$, which flows from the power supply to the highest level amplifier. Ignore for the moment the components of this current which will be shunted by the decoupling networks of each succeeding stage. This current produces an unwanted ripple voltage in the ground impedance that exists between each stage, which will affect the amplifier chain performance to some extent – indeed it could make it unstable. Further, unless the bypassing of the lower-level stages is sufficent to keep voltages resulting from ripple currents to a very low level, $i_{ch}$ will produce a large ripple component across these stages. Each succeeding stage produces its own ac component on the path from its supply point to the power supply, so the ripple becomes quite complex as the number of stages increases. In most cases, a floating signal return has to be used as a ground reference for the input signal to eliminate the effects of the ripple existing on $R_p1$.

**In B**, the power-supply source and ground leads are connected to the highest-level stage first, and proceed in order toward the lowest-level stage. With this arrangment, the ripple current from any given stage does not flow through the ground or supply paths connecting it to any lower level stage. This minimizes decoupling requirements on lower-level stages, eliminates unwanted ripple feedback between stages, and puts the highest dc supply voltage on the last stage, where it is normally needed. Since the ground impedance from the input stage to the board connector is typically much less than the impedance from that connector to system ground, the requirements placed on the floating return for the input signal have not been made much more severe.

**One might be tempted in the circuit of B** to tie the ground from the lowest-level stage back to the connector ground pin, with the mistaken idea that this will improve circuit grounding. This would in fact *degrade* performance almost as badly as the circuit of **A**.

band decoupling will result in a transmission peak somewhere in the "rejection" band.

The solution is to break-up the decoupling circuit into two series RC sections. In applying LC sections, an upper limit must be placed on the value of C for a given corner frequency ($\omega 1$) and load resistance to prevent excessive peaking and thus "ringing" on transients. For 3 dB peaking, $C = 2/\omega_1 R$ where $1/\sqrt{LC} = \omega_1$ and R is the load seen by the filter at $\omega_1$.

## Be careful with active filters

The use of active filtering techniques should be approached carefully. While such techniques as active low-pass filters and local series regulators can remove the effects of line noise upon the circuit in question, they provide no energy storage in themselves, so they can neither remove the effects of deep spikes toward ground on a power supply, nor can they remove the varying load currents which exist in the line back to the power supply.

Simple zener diodes or active shunt regulators, although inefficient, do remove the effects of varying load currents and noise on the power supply line but again, can furnish no energy when the supply line voltage drops below the level at which they can draw current. The only way to suppress the effects of deep power supply spikes on a circuit is to use a passive filter having sufficient energy storage to furnish current to the circuit during the spike. An LC, RC, or RL filter can be used to sustain sufficient current into an active filter to virtually eliminate the effects of deep power supply spikes.

In large systems it is difficult to maintain the single-point grounding philosophy between major units. These major units may be distributed throughout an aircraft or ship, for example, and appreciable differential ground noise may

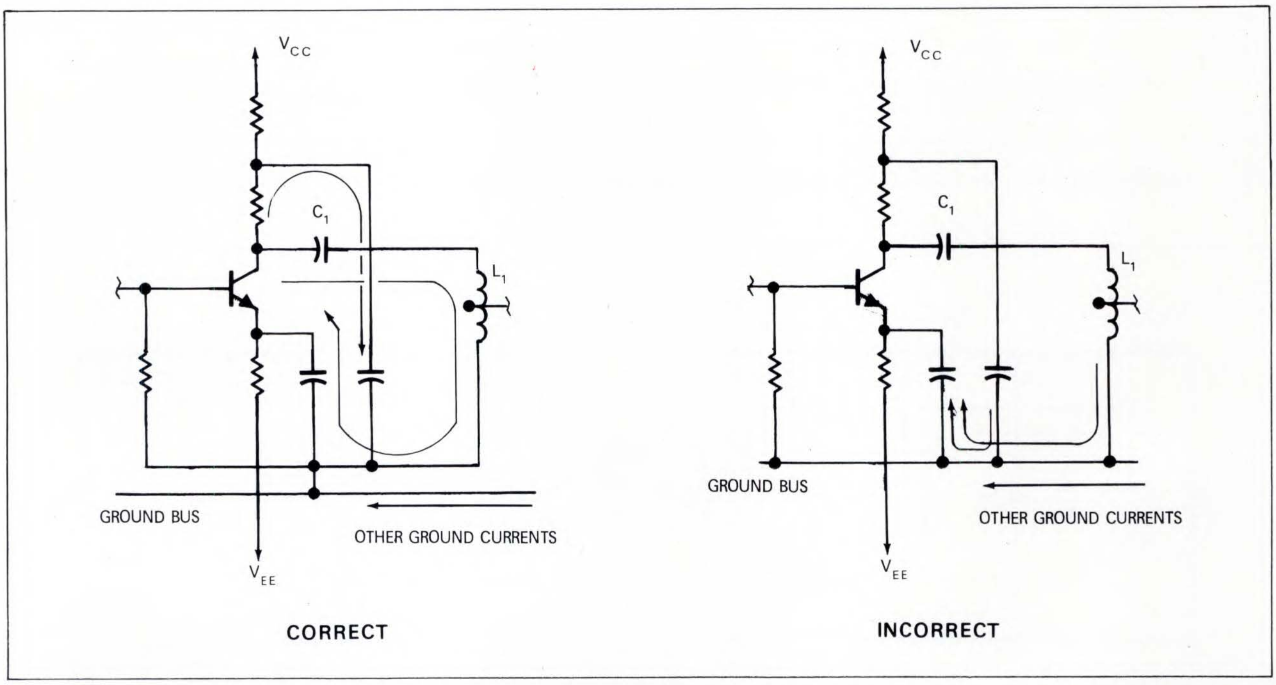



Fig. 5—**Ground connections for plug-in units** are important considerations in order to prevent built-in noise paths. As shown here, all grounds within any stage should be tied to a common point before being tied to the common ground line.

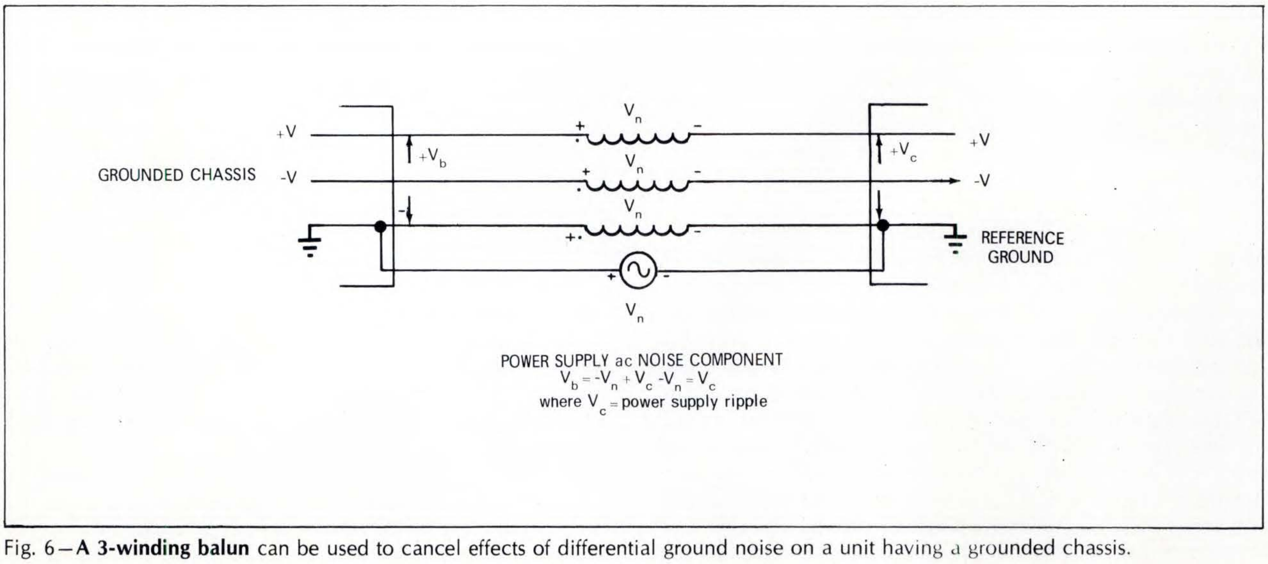



Fig. 6—**A 3-winding balun** can be used to cancel effects of differential ground noise on a unit having a grounded chassis.

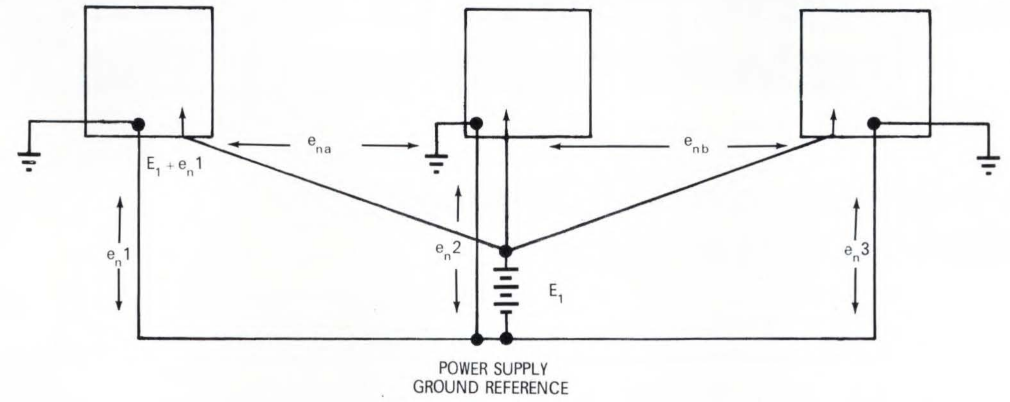



Fig. 7—**Common power supply used with independently grounded units** results in a differential ground noise between power-supply ground reference and each major unit ground. This is caused by the ground noise differential between each major unit ground.

develop between the locally grounded chassis or enclosure and the ground root of the system. Circuitry contained within the enclosure can suffer from severe noise pickup problems as a result.

One solution is to treat the grounds of each major unit as if the unit were a system in itself. Thus, a single-point ground is established within the unit, as close to the power connector as possible. Then a heavy wire is brought through the connector on multiple pins and attached to a bonding point on the frame to which the unit is mounted, at a point close to the connector.

## Don't rely on chassis contacts

It is important to bring the ground through the connector, since the contact resistance of chassis mounting surfaces is essentially uncontrolled, being a function of surface finish, corrosion, etc. This presents no particular problem in transmitting signals from unit to unit provided that a ground isolation technique such as one of those shown in **Fig. 3** is employed. Power supply distribution can become a problem with this technique, however, where it is desired to use a central power supply for cost and packaging efficiency. The problem is that each supply voltage gets its return from the several major units, each one being tied to the frame at a different ground point.

This is illustrated in **Fig.** 7. It can be seen that this noise winds up across the supply voltage at each major unit ($E_1 + e_{n1}$, etc.). Although this could conceivably be removed by heavy decoupling in the unit, the advantage of the power supply regulator in suppressing low frequency noise is lost, and the loop formed by the power supply leads and returns can radiate interference to signal lines.

One solution to the problem is to employ the multiple winding balun technique illustrated in **Fig. 6** for all power supplies entering the unit. The balun should be sufficiently broadband to suppress all noise in the frequency band of interest. Note, though, that the balun introduces some series resistance in the power leads, and saturation effects in the balun core could render it ineffective. Therefore care should be taken to employ a balun rated for the maximum dc current to be carried.

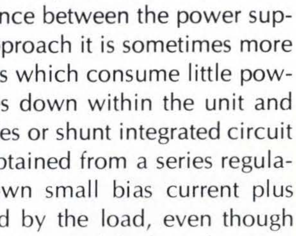
An alternative approach is to use a separate power transformer winding, rectifier bridge and regulator for each major unit, and ground the return lead only at the major unit. The power transformer thus provides the required isolation, and the regulators could be packaged in the central supply unit or in the major unit for which they supply power.

Locating the regulators in the major unit has the advantage of lower insertion impedance between the power supply and the loads. With this approach it is sometimes more cost effective to obtain voltages which consume little power by dropping higher voltages down within the unit and regulating them with small series or shunt integrated circuit regulators. Best efficiency is obtained from a series regulator since it draws only its own small bias current plus whatever current is demanded by the load, even though some power is wasted by either type and the heat thus generated adds to the heat load to be removed from the unit.

A third approach is to distribute unregulated power in the same manner as regulated power was distributed in **Fig. 7** and to locate filters and regulators in each major unit to suppress ground noise. A common power supply used with independently-grounded units results in a differential ground noise between power-supply ground reference and each major unit ground ($e_{nl}$, $e_n2$, etc.). This is caused by the ground noise differential between each major unit ground ($e_{na}$, $e_{nb}$, etc.). ☐

## Author's biography


**Harry Brown**, an engineer at Westinghouse, Baltimore, Md., for 11 years is currently section manager working in the field of signal processors, digital computers and control systems. He received his B.S.E.E. from New York University and has had two patents granted to him.

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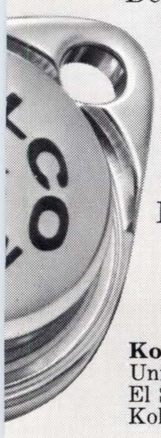

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# IC op amps simplify regulator design

*Regulator design can be simple if you have ICs in your design arsenal. The three regulators described will make you want to design one yourself.*

With many voltage regulators on the market today including discrete, hybrid and monolithic types, you are often able to purchase one at a fraction of the cost of developing it yourself. However, when a regulator with the desired specifications is not readily available, the only practical solution may be to design your own.

Using op amps that are available today, this is an easier task than it was when discretes were the only devices at hand. A look at three simple regulators and their design considerations will illustrate this point.

The basic building blocks arranged as shown in **Fig. 1** make up the feedback regulator. Several types of voltage reference sources can be used depending on the stability required. "Choosing a Reference Source" (see box) describes four different types. The error-detecting amplifier is an integrated circuit op amp. A $\mu$A741 was chosen for the regulators described because of its low cost, small size, high open-loop gain and high ripple rejection. Low-cost plastic transistors are used in the output section. Low-frequency devices reduce the risk of regulator oscillation. A conventional full-wave bridge rectifier with a capacitor input filter provides unregulated dc.

### Start with design requirements

Several parameters must be specified in order to arrive at some simple design equations. They are:

1. Required output voltage and current, $V_{OUT}$ and $I_{OUT}$.
2. $V_{IN}$ with regulator under both no load and full load conditions.
3. Power rating and $h_{fe}$ of the series pass transistor.
4. Thermal resistance, junction to case, $\theta_{jc}$ of the pass transistor.
5. Zener-diode breakdown voltage, $V_z$.

### Good regulation and short-circuit protection too

A good regulator with short-circuit protection is shown in **Fig. 3** along with the design parameters. The reference voltage is chosen to be slightly less than the output voltage to give a large feedback ratio and consequently a closed-loop gain approaching unity. This large feedback ratio will insure tight output regulation.

A look at the parameters allows us to determine the base-drive requirements of the op amp, the heat-sink requirements of the pass transistor and the values of the voltage-divider resistors. The total output current, $I_{OUT} \approx I_{C1} = 200$ mA. $A_1$ must then provide a base drive to $Q_2$ of:

$$I_B = I_{C1}/h_{fe} = 200 \text{ mA}/80 = 2.5 \text{ mA}$$

A safety factor of approximately two should be allowed, making the drive requirement 5 mA which is within the $\mu$A741 capabilities. If we assume maximum power dissipation in the pass transistor at full rated load current, then:

$$P_d = (V_{IN} - V_{OUT})\ (I_{OUT}) = (5\text{V})\ (200 \text{ mA}) = 1.0\text{W}$$

The maximum allowable junction temperature of the MJE520 is 150°C. However, experience has shown that with plastic devices, the junction temperature should not exceed 100°C. Heat-sink requirements can be determined from the relationship of junction temperature to dissipated power, thermal resistances and ambient temperature as follows:

$T_j = P_d\ (\theta_{jc} + \theta_{sa} + \theta_{cs}) + Ta$
$\theta_{jc}$ = thermal resistance, junction to case = 5°C/W
$\theta_{sa}$ = thermal resistance, heat sink to ambient = unknown
$\theta_{cs}$ = thermal resistance, case to heat sink = 0.5° C/W
$T_a$ = ambient temperature = 25°C

If we set $T_j$ equal to 50°C and solve for $\theta_{sa}$ we get a thermal resistance—heat sink to ambient—of 20.5°C/W. This value is used to determine the required heat-sink area from **Fig. 4**. The graph shows that a black-anodized aluminum sink with a total area (side 1 plus side 2) of 1.5 in$^2$ will be adequate to maintain the junction at 50°C.

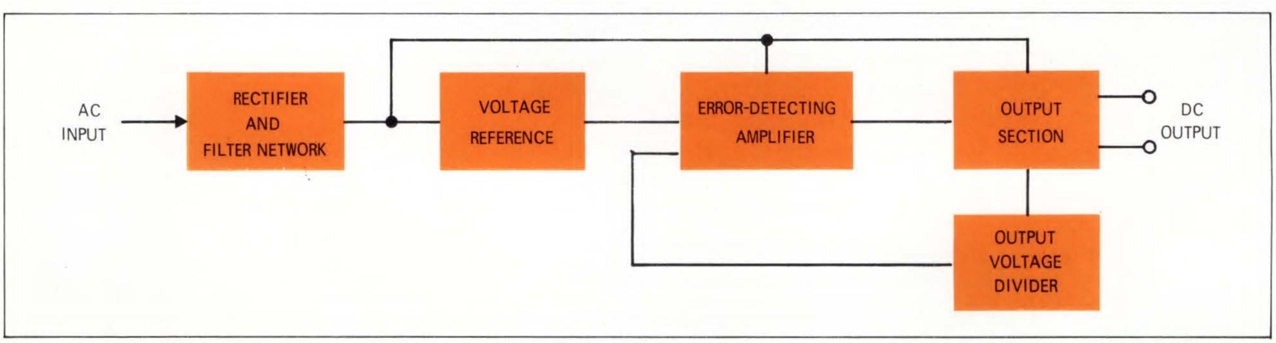


Fig. 1—**Feedback voltage regulators** are made up of these basic building blocks. An IC op amp can be used as the error detector.

To determine the divider resistor values, we will assume divider current of 1mA. We can neglect the small voltage drop at the op amp input, therefore;

$R_1 = V_{OUT} - V_{ref}/1\text{ma} = 0.7\text{V}/1\text{mA} = 700\Omega$ (use 680)
$R_2 = V_{ref}/1\text{mA} = 4.3\text{V}/1\text{mA} = 4.3\text{k}\Omega$

The feedback ratio is approximately 0.87 and the closed-loop gain is 1.11. Output capacitor $C_{out}$ is selected to provide stable regulator operation.

Short-circuit protection is provided by $R_3$ and $Q_3$. $R_3$ sets the point of current limiting. Its value is determined by

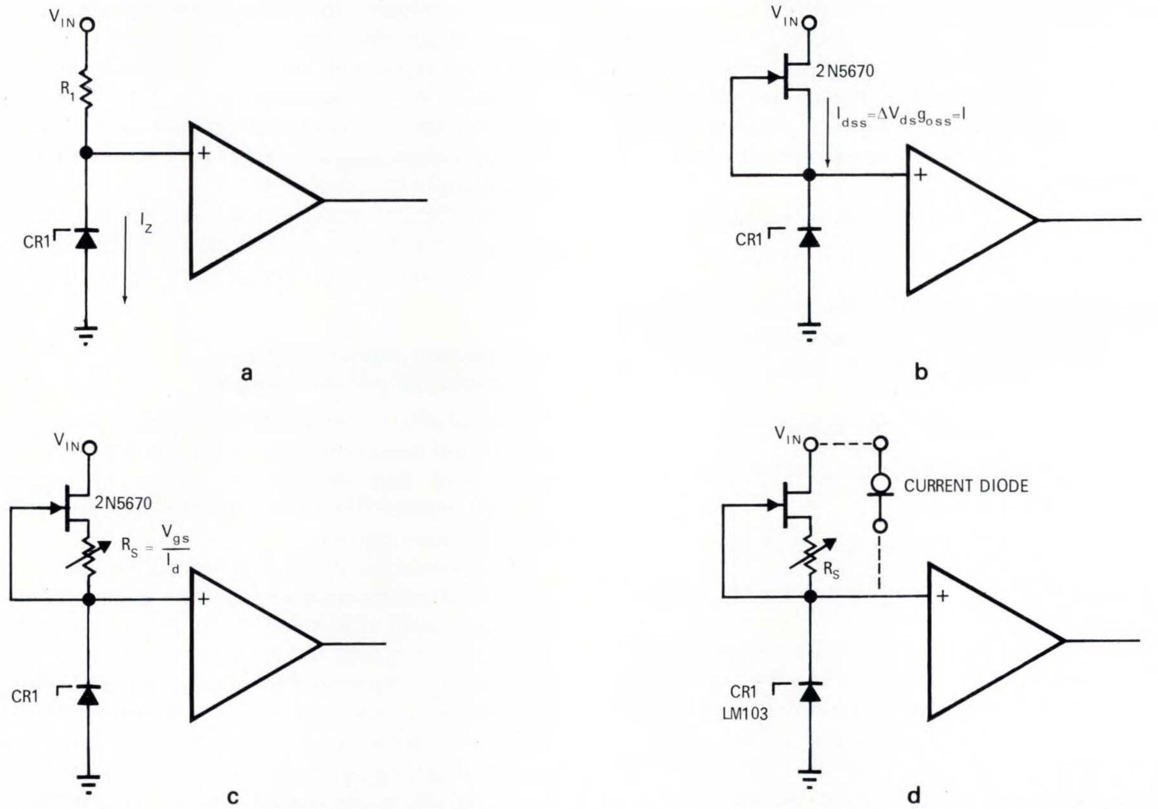


Fig. 2—**Reference sources** with greatest stability use a constant current source to minimize changes due to $\Delta V_{IN}$.

## Choosing a reference source

Various methods are available for obtaining a voltage reference for the input of an error detector amplifier. They include dividers, standard cells, primary batteries and zener diodes. The use of zener diodes is, of course, the most widely used method in modern equipment requiring reference voltages. Several different zener reference circuits are shown here in order of increasing stability with respect to changes in input voltage.

The simplest source, shown in **Fig. 2A**, consists of a zener and a series resistor. $R_1$ is chosen to supply the necessary current to $CR_1$ and keep it in the breakdown region. $V_{in}$ will vary as a function of load current in a regulator circuit, therefore, $V_z$ will also vary according to the expression:

$$\Delta V_z = \Delta V_{IN} \frac{R_z}{R_z + R_1}$$

where $R_z$ is the dynamic impedance of the zener diode. Typical values of $R_z$ are 30Ω or more, therefore, it is possible to have undesirable changes in the reference voltage with changes in $V_{IN}$. Better results can be obtained by using a voltage-reference diode such as National's LM103 Series, in series with a resistor. These diodes are characterized by an extremely sharp knee from 10 μA to 10 mA resulting in only a 200 mV change in the reference voltage when the current is varied from 10 μA to 10 mA. Diodes in the 5 to 6V range will provide near zero temperature coefficient.

An improved circuit is that of **Fig. 2b**. This combination of a constant-current source feeding a zener diode produces excellent results. It is characterized by low cost and a high degree of immunity to changes in $V_{IN}$. This immunity is the result of using a FET with low output conductance as the current source. A 2N5670 has an $I_{dss}$ of 8 to 20 mA and a typical output conductance ($g_{oss}$) of 35 μmhos. The circuit output conductance is equal to the $g_{oss}$ of the FET. A $\Delta V_{IN}$ does not cause any appreciable change in the drain current $I_{dss}$ because of the low $g_{oss}$. Current stability, which is equal to $\Delta V_{ds} \times g_{oss}$ is 35 μA/V in this case. **Fig. 2c** is similar except that a bias resistor $R_s$, is used to provide an adjustable current. The FET parameters $I_{dss}$ and $V$ pinch-off are used to determine the value of $R_s$ according to the formula:

$$R_s = \frac{V_{gs}/I_d}{1 - \frac{1}{I_d/I_{dss}}}$$

where $V_{gs} = V_p$. As $R_s$ is increased, $I_d$ decreases which lower the FET $g_{oss}$. $I_d$ should be somewhat less than $I_{dss}$ for best regulation.

Finally, by using a constant-current or a FET current source feeding a LM103 voltage-reference diode, as shown in **Fig. 2d**, a very stable reference source is provided. With this circuit, 50% change in supply voltage will produce less than a 5 mV change in the reference voltage.

$R_3 = V_{be}/I_{limit}$. As the maximum current is approached, $Q_3$ starts to turn on, bringing the base of $Q_2$ down to approximately 1.4V.

In the reference supply circuit, $R_s$ is selected to supply 10 to 15 mA to $CR_1$. The high input impedance of the op amp prevents loading of the reference supply.

## Darlington output handles more power

If more power is required, the previous circuit can be modified at the output with a npn-pnp Darlington. In addition to increased power capability, let's assume that over-voltage protection is required in case of collector-to-emitter short in the pass transistor. The circuit and design parameters are shown in **Fig. 5**.

Base drive requirement for $Q_6$, the pass transistor, is:

$$I_{B1} = I_{OUT}/h_{fe} = 1\text{A}/50 = 20 \text{ mA}$$

$Q_5$ must be biased to supply base drive to $Q_6$ under full load conditions. $R_4$ which biases $Q_5$ is approximately equal to the $V_{be}$ of $Q_6$ divided by $I_{C1} - I_{B1}$. Assuming 25 mA through $Q_5$:

$$R_4 = 0.7\text{V}/5 \text{ mA} = 140\ \Omega \text{ (use 130)}$$

We can calculate the base drive for $Q_5$ in the same manner as we did for $Q_6$:

$$I_{B2} = I_{C1}/h_{fe} = 25 \text{ mA}/60 = 0.41 \text{ mA}$$

It is obvious that the op amp has sufficient output to drive $Q_5$.

If we assume that the maximum power dissipation of $Q_6$ occurs at full rated load current, when the voltage drop across the transistor is 5V, then $P_d$ equals 5W. In order to limit the physical size of the heat sink we will assume a junction temperature of 85°C. Using the method described in the previous circuit, for determining the heat sink area, a total area of approximately 6 in$^2$ is found to be adequate with black anodized aluminum. Values for the voltage divider are calculated as they were in the previous circuit assuming approximately 2 mA divider current. Short-circuit protection is also implemented in the same manner as was done in the previous circuit.

Biasing of the over-voltage protection circuit is approached as it was done for the Darlington output. In operation, if $Q_6$ shorts, $V_{IN}$ appears at the base of $Q_1$. $Q_1$, which has been off, then turns on—clamping the base of $Q_2$ to $V_{z1} + Q_1V_{be}$ or 6.2V and $V_{IN2}$ to approximately the same value. This will protect most ICs from failure. Under normal operating conditions, $Q_3$ will have approximately 1.5 to 2.0V from collector to emitter. When $Q_6$ shorts, $Q_3$ will have a voltage drop equal to $V_{IN1} - V_{z1} + Q_1V_{be}$ divided by $R_{load}$ in parallel with the zener dynamic impedance. We will neglect the $V_{be}$ impedance of $Q_1$. Therefore, assuming maximum power dissipated at full load current, $Q_3$ will be required to dissipate more power if $Q_6$ shorts. Thus, proper heat sinking of $Q_3$ is required.

This method of protection provides no indication if $Q_6$ does short, nor does it protect against switching of line transients, because turn-on time of $Q_1$ is approximately 100 μsec.

## Two-op-amp regulator gives balanced dual-polarity output

A dual-polarity, tracking voltage regulator with a balanced positive and negative output is shown in **Fig. 6**. This circuit uses two op amps and provides outputs that can be balanced to within millivolts of each other or can be offset as the application requires.

This is a tracking regulator in which the negative voltage is regulated and the positive output tracks the negative. The reference supply is identical to the ones used in the previous circuits except for its polarity, which is negative. Amplifier $A_1$ is referenced to ground forcing its other input to ground also. This input (2) is tied between two equal resistors that are connected across the positive and negative outputs, thus the positive output is equal in value but opposite in polarity to the negative output. By adjusting these resistors, you can obtain a balanced or offset output on the positive side. Adjusting the negative output voltage divider causes the positive output to change by the same amount as the negative output.

With the non-inverting input of $A_1$ tied to ground, the negative $V_{cc}$ must be tied to a negative potential. One must

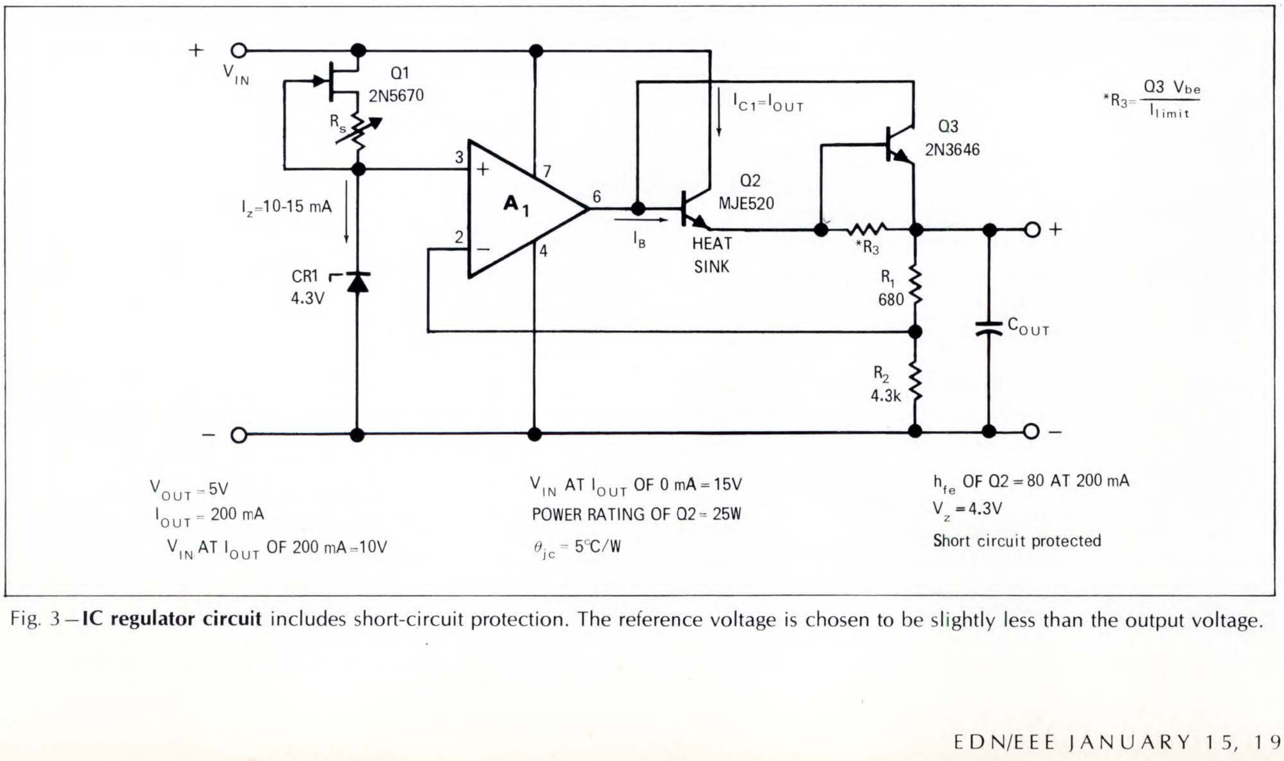


Fig. 3—**IC regulator circuit** includes short-circuit protection. The reference voltage is chosen to be slightly less than the output voltage.

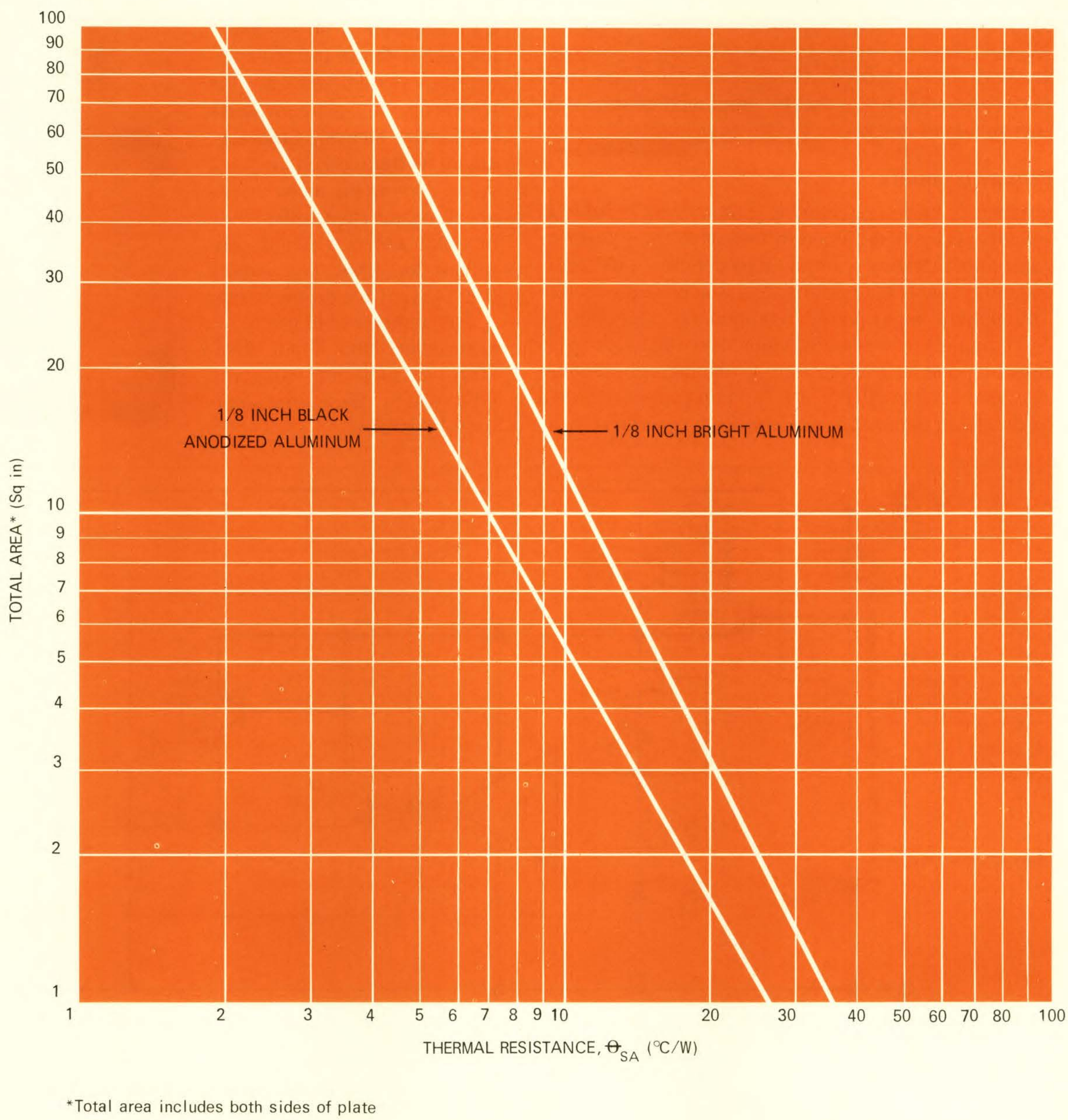


Fig. 4—**Heat-sink area is determined** for bright or black anodized aluminum from the calculated value of $\theta_{sa}$.

| | LOAD REGULATION 115V ac INPUT | | | | "LINE" REGULATION (VARIABLE dc INPUT) | | |
|---|---|---|---|---|---|---|---|
| **REGULATOR** | LOAD CONDITION | $+V_{OUT}$ | $-V_{OUT}$ | ac RIPPLE | $V_{IN}$(dc) | $+V_{OUT}$ | $-V_{OUT}$ |
| **1 Fig .3)** | NO LOAD | 5.005 | | ≤1 mVp-p | 8 | 5.005 | |
| **1 (Fig. 3)** | 200 mA FULL LOAD | 5.004 | | ≤2 mVp-p | 20 | 5.007 | |
| **2 (Fig . 5)** | NO LOAD | 5.010 | | ≤1 mVp-p | 11 | 5.010 | |
| **2 (Fig. 5)** | 1A FULL LOAD | 5.007 | | ≤2 mVp-p | 30 | 5.011 | |
| **3 (Fig. 6)** | NO LOAD | 15.005 | 15.008 | ≤1 mVp-p | ±18 | 15.005 | 15.008 |
| **3 (Fig. 6)** | 200 mA FULL LOAD | 15.003 | 15.006 | ≤2 mVp-p | ±36 | 15.004 | 15.007 |

Table I—**Good regulation and low ripple** is provided by each regulator design.

be careful not to exceed the maximum supply voltages of $A_1$ which are ±18V. With a $V_{IN}$ of 10V, a negative potential of 5.1V was chosen. This gives approximately 33V across $A_1$. No short-circuit or over-voltage protection is provided in this circuit. However, it can be employed as shown in the other regulator designs.

### Performance counts

Performance of these regulators is summarized in **Table I**. These figures were determined in testing at an ambient of 25°C and further testing is required to determine temperature instability. Excellent performance is achieved with this type of regulator with very few components. Designing is simple compared to designing equivalent regulators with discrete components, thus custom IC regulator design may be a reasonable alternative if you can't fill your need with a standard catalog item. □

### Author's biography

**Carl Brogado** is an engineering technician in the bio-engineering department at the University of Colorado Medical Center, Denver, Colorado, where he has worked for 1-1/2 years. Among his many activities, Brogado attends the Univ. of Colo. and is a junior consultant for BMK Engineering Lab. He is also a prolific writer

The author would like to acknowledge NIH Grant #NS-08511 for support of work projects where these regulators have been used.

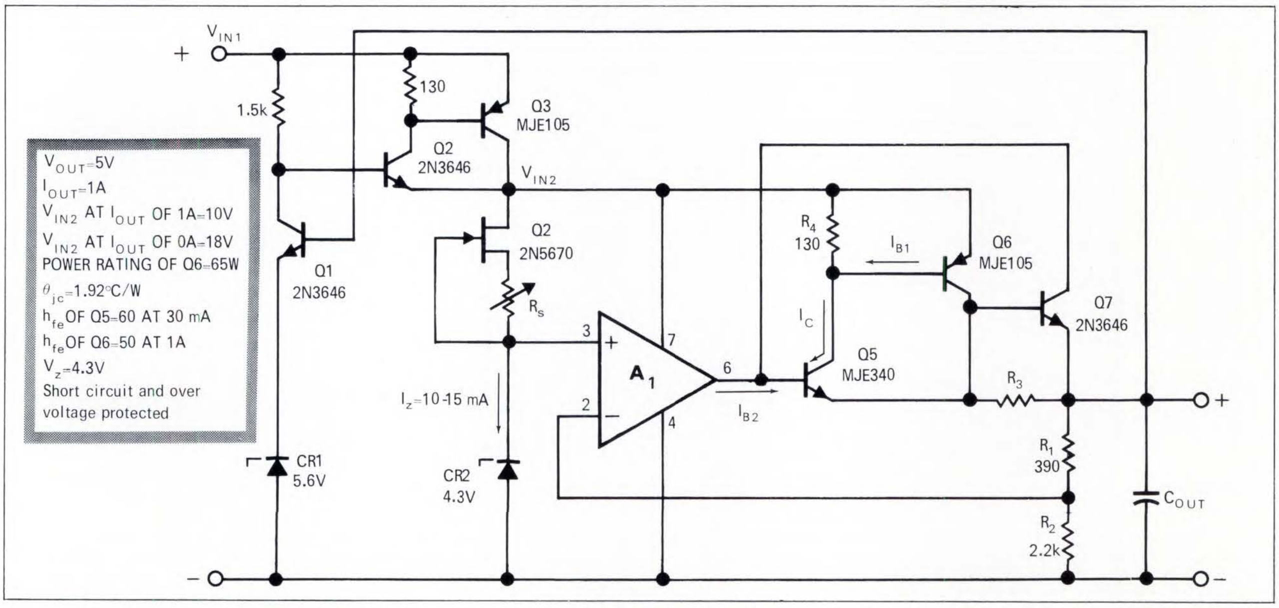


Fig. 5—**Darlington circuits** provide high current output and over-voltage protection if $Q_6$ shorts. There is no indication if $Q_6$ does short.

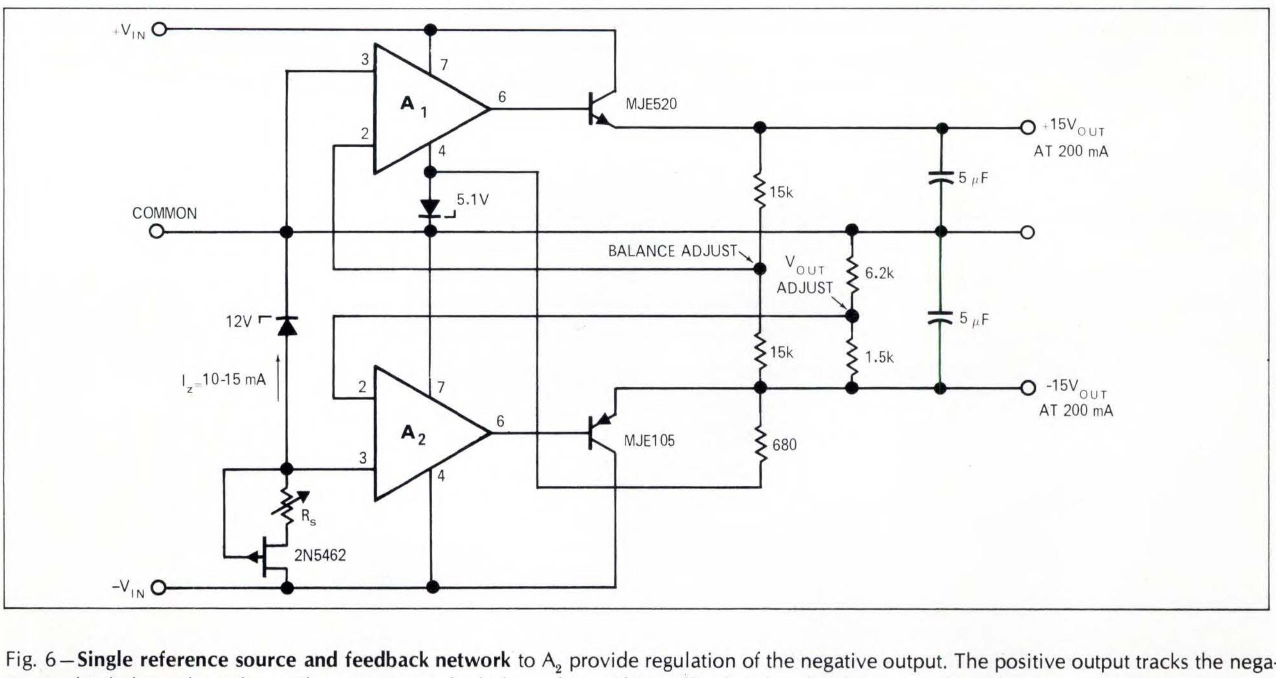


Fig. 6—**Single reference source and feedback network** to $A_2$ provide regulation of the negative output. The positive output tracks the negative in this balanced regulator. The outputs can be balanced to within millivolts of each other or can be offset.

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In addition to the standard internal dc reference, an external reference option allows any external ac or dc signal to be used as the reference for the bi-polar D-to-A ladder network. The Power-DAC can perform many different functions within the test system. Operate it as a programmable amplifier, attenuator or multiplying DAC for either ac or dc signals up to 30 kHz. Amplitude of fixed level function generators and special purpose signal sources can be precisely controlled from microvolt levels up to 50v rms at 0.7 amp rms. By accurately controlling the level of the external reference, programming resolution can be varied from 1 millivolt to several microvolts. Either the internal or external reference is selected by a 1-bit control line. The 100 μsec settling time includes polarity change, range change and selecting either the internal or external reference.

**3. Fast programmable current limiting protects circuits under test**

Standard models provide a gross 1.2 amp current limit as an overload protection feature. One option provides a programmable current limit in two ranges, 100 ma and 1 amp. Each range is programmable in 10 percent steps, yielding 10 ma or 100 ma resolution. When the overload occurs, transition from the constant voltage mode to the current mode requires less

Model 4265A

than 20 microseconds, the crossover time being a function of the load. The larger the overload, the faster the transition. This fast crossover capability minimizes the energy transients to the circuits under test.

**4. Programming glitch reduction**

A unique track-and-hold technique during the programming interval reduces the peak glitch and transient excursions to less than 50 mv in the 16 volt range, and less than 100 mv in the 65 volt range. Transitions from computer generated waveforms or incremental slewing operations take place smoothly.

**5. Isolation and guarding reduces noise and ground loops**

Digital and analog portions of the 4200s are separated by a metal guard to eliminate both ground loops and digital noise which severely affect the system performance of conventional power supplies and D-to-A converters. With the isolated control logic option, impedance between the digital control logic and the analog circuits is $10^9$ ohms in parallel with 3 picofarads. This isolation provides significant rejection of system noise on the analog output. Up to 1000 volts of common mode voltage can be applied between chassis ground and the guard terminal without harming the instrument, or causing severe common mode errors.

**Prices and options**

For $1295, the basic 4250A and 4265A are equipped with direct coupled control logic and blank front panel. The isolated control logic option which also contains a memory register for storing the program command is $300. The external reference, programmable current limit and front panel digital display options are priced at $200 each. Delivery is 30 days. For complete specifications on all 4200 Series Power-DACs, write Fluke, P. O. Box 7428, Seattle, WA 98133.

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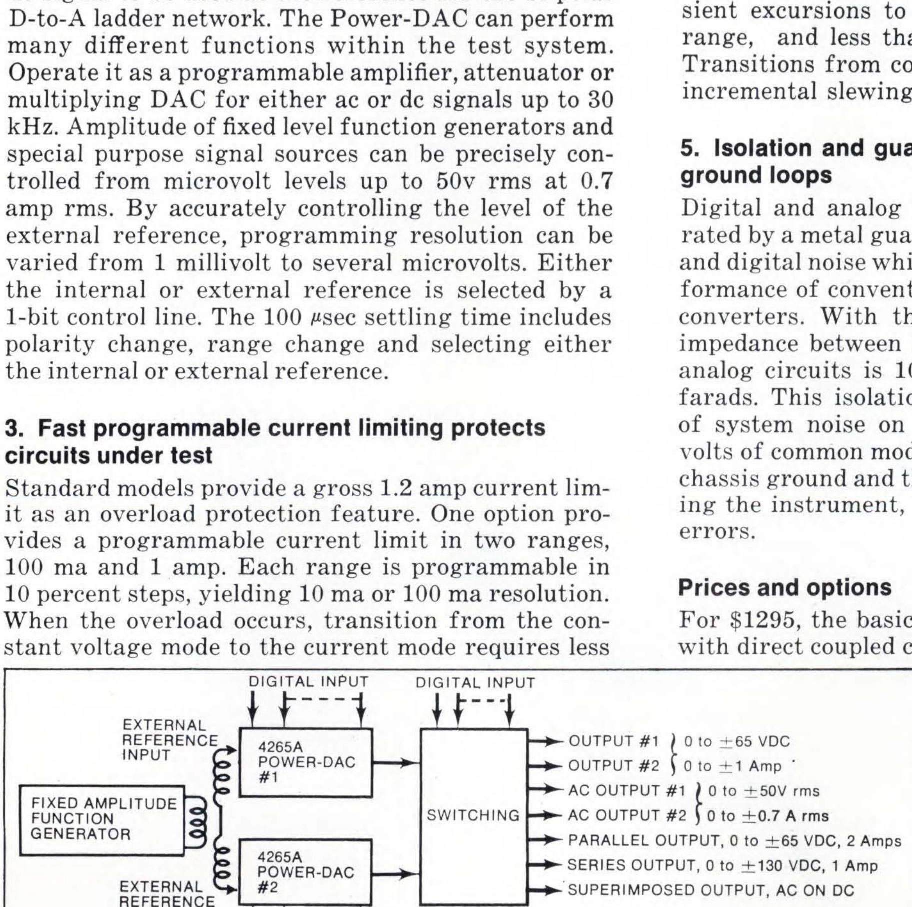



The 4200 Series POWER-DACs provide a wide range of automatic test system capability. With the equipment shown above, note the different types of output obtainable.

CIRCLE NO. 18

# The magnetoresistor: A very simple solid-state transducer

*A run-down on a useful noncontact motion and current sensor from the German electronics giant, Siemens. Also, a brief laboratory evaluation by EDN/EEE.*

Magnetoresistors (MRs)—semiconductor resistors that increase their resistivity in a magnetic field—have been popular in Germany for several years. They are simple, two-terminal replacements for the four-terminal Hall-effect devices. Though their response is not as inherently linear and sensitive as that from Hall devices, MRs are often better suited to run-of-the-mill applications.

One reason for their popularity is that they produce the right level of resistance variations for solid-state circuits. They will produce 1V signal swings in elementary bridge circuits when subjected to the fields produced by inexpensive permanent magnets. As they are two-terminal devices, they can replace regular resistors almost anywhere in a low-voltage circuit. Their two-terminal simplicity makes them ideal for remote probes. Another reason they are popular is that MRs can be obtained for about $1 in production quantities. This, coupled with the fact that they need minimal additional support circuitry, makes them relatively inexpensive transducers.

These qualities contrast with those of Hall devices. The Hall devices, though better suited to sensing and measuring low-level magnetic fields, are rarely able to produce more than 10-mV signal swings—so must always be augmented with amplification. Also, because Hall devices are four-terminal, they cannot be placed anywhere in a circuit but must be provided with a biasing network. Even some of the recent integrated-circuit Hall devices (which contain both the Hall device and its amplifier on a single silicon chip) do not free the designer from these restrictions.

MRs have fairly wide operating ranges (−40 to 150°C and dc to 10 MHz) so they can be used for many types of noncontact sensing:

- Mechanical position.
- Magnetic fields.
- Currents.

Like a Hall device, the MR will sense steady-state as well as changing values. Thus the MR can be used in solid-state relays, keyboard switches, machinery limit switches, brushless dc motors and similar applications.

### How they work

Magnetoresistors increase their resistance when a per-

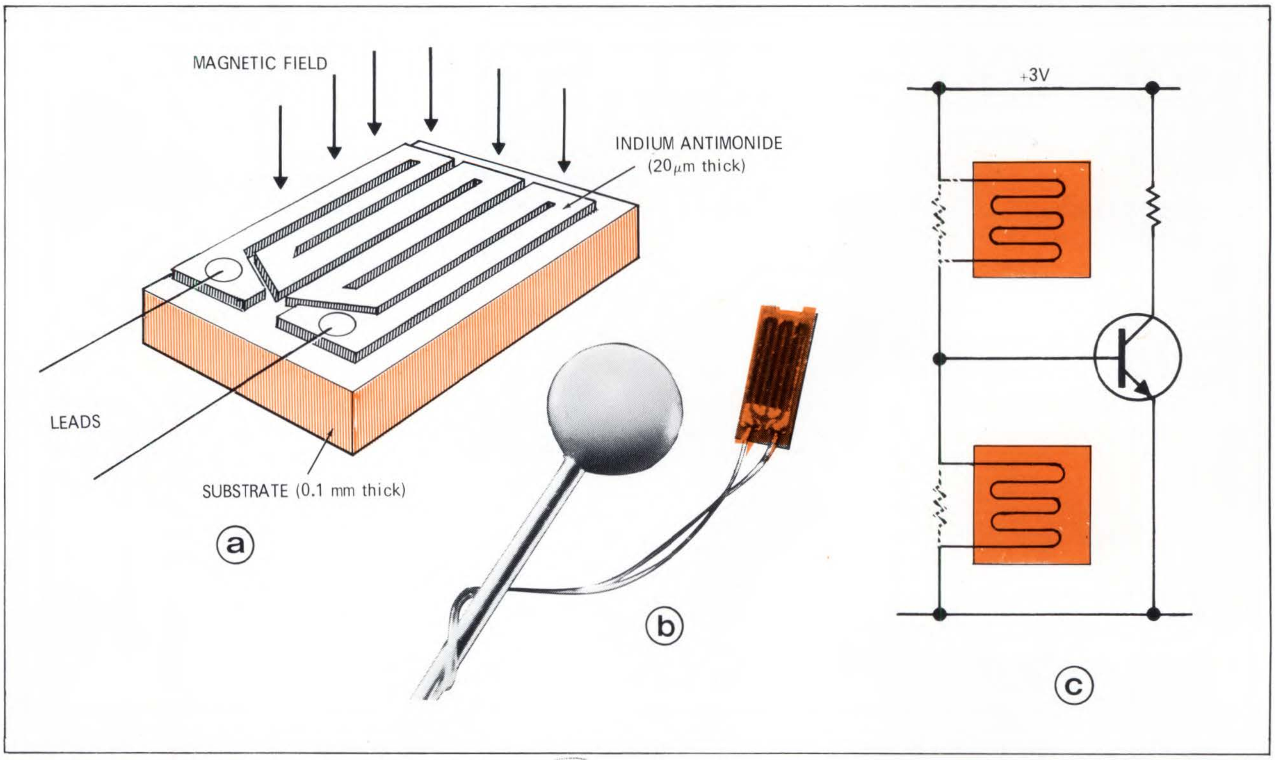
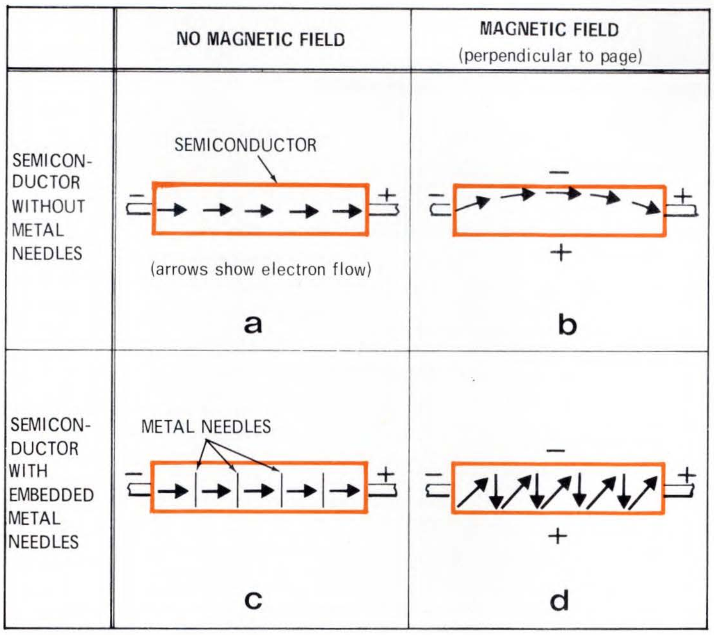



Fig. 1—**Magnetoresistors** typically are etched into serpentine patterns (a and b). A perpendicular magnetic field will increase their resistivity. Because they are two-terminal devices they can be substituted for regular resistors in circuits (c).



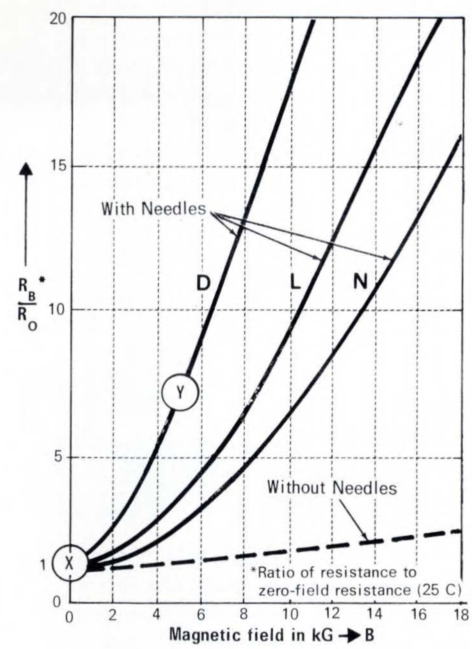




Fig. 2—**Sensitivity of MRs** can be much improved by embedding nickel needles that are aligned cross-ways to the current flow. These low-resistance paths allow carriers that are crowded to one side by the magnetic field to escape back to the other side. Thus the effect can be repeated many times in the MR's length.

Fig. 3—**Response of a magnetoresistor** is square-law up to about 3 kG (curve D with pure indium antimonide material), and relatively linear from there up to very strong fields (100 kG). Magnetoresistors with embedded metal needles are many times more sensitive to magnetic fields than those without.

pendicular magnetic field is applied, because the lateral Lorentz force of the field upon the current squeezes the carriers to one side, narrowing the effective cross section. This is shown in **Figs. 2a** and **2b**. It is most pronounced in certain semiconductors such as bismuth and indium.

The phenomenon has been known for some time but early MR devices were impractical, either because their sensitivity was low and erratic or because it was overshadowed by the device's high temperature sensitivity. Siemens have developed a way of enhancing the effect. Many small metal needles are embedded in the semiconductor crossways to the current flow as shown in **Fig. 2b** with **Fig. 2d**.

When an ordinary MR semiconductor that has no embedded needles is subjected to a magnetic field (**Figs. 2a and 2b**), the current carriers (electrons are shown) are crowded to one side causing an opposing voltage to build up laterally (the Hall voltage). This voltage fights the effect. But when the needles are present, as in **Figs. 2c** and **2d**, they form low-resistance "escape" paths for the crowded carriers. The needles typically have two-orders-of-magnitude lower resistance than the semiconductor. The very Hall voltage created by the crowding can now return the carriers to the other side, so the Lorentz deflection can occur all over again in the next segment of semiconductor. The Lorentz deflection of the carriers can be as high as 80° in a 10-kG field. The process repeats again and again down the length of the MR, and the resulting longer zigzag path of these improved devices provides a greater change of resistivity for a given change in magnetic field. **Fig. 3** indicates how much more sensitive the MRs made with embedded needles are than previous ones without. **Fig. 3** also shows that these devices have a square-law response to fields of up to 3 kG—and more or less linear responses from there on up to large 100-kG fields. Clearly sensitivity is much greater with the new version then with the old.

These devices use indium antimonide as the semiconductor and nickel antimonide for the metal needles. The needles are lined up, as the melt is solidified, by a patented process. The various curves in **Fig. 3** are for varying sensitivity-temperature coefficient tradeoffs. The most sensitive (upper curve D) is for pure indium antimonide semiconductor material. The lower two curves (L and N) are for various extents of tellurium doping to increase the temperature stability. However, it is possible to counterbalance the MR's temperature coefficient with a transistor's TC. MRs of L material can be matched with silicon, and MRs of D material can be matched with germanium. Finished MRs are fabricated to specific resistance values by combinations of grinding and etching. The resulting meandering patterns are then affixed to substrates for support.

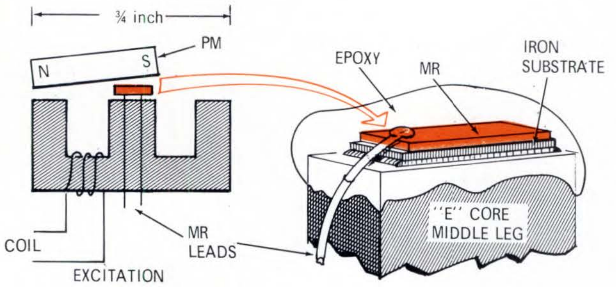
## Mounting suggestions

The art of reliably applying MR's hinges to a large degree on a proper magnetic circuit and on proper mounting. MRs like other transducers, can be disappointing until they are put in effective configurations.

The first step is to mount the MR securely and in a way that protects the delicate serpentine and its leadwire connections. This is particularly important for such industrial applications as position- and motion-sensing on machines. Magnetoresistors that come mounted on iron substrates can be fastened to any metal surface using a suitable commercial epoxy resin and hardener (such as RP103 and H992 from Ren Plastics, Inc., 5656 S. Cedar, Lansing,

## MR's work, we find

We examined the performance of several Siemens 500Ω FP 17D 500E magnetoresistors in some elementary application circuits. The MR was mounted on a small ferrite "E" core as shown: using epoxy ("5-minute" by Devcon Corp., Danvers, Mass.) both to cement the device down and to protect the 12-leg serpentine pattern.

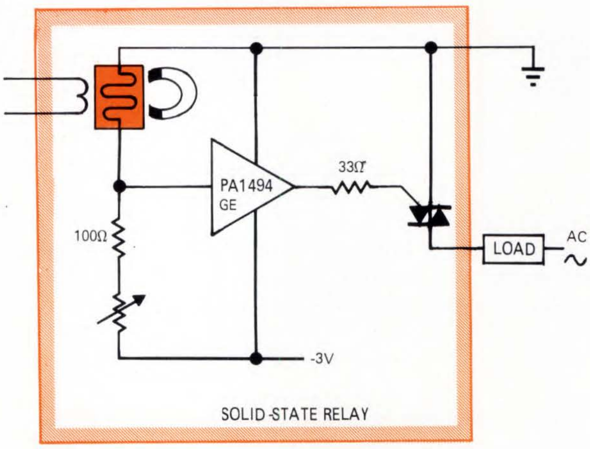



We found that small permanent magnets would produce 10% increases in resistance and that stronger magnets such as the types used in ordinary small speakers would raise the device's resistance from 500Ω to 1kΩ. Half an ampere through the approximately 100-turn coil would produce a 3% change in resistance. It was important, we noted, to concentrate the magnetic flux across the MR by bringing the north and south ends of the magnet up close to the "E" core legs.

With amplification, we showed that these MRs can be used to sense moderately-small magnetic field changes. We used a form of Schmitt trigger (right): Using magnetic prebias to put the MR on the sensitive part of its response curve, we could actuate the switch with a 1/8-inch motion of small PMs close by the "E" core gap, or by larger motions of strong PMs several inches away. We found that just a few volts across the coil would trigger the switch, meaning that we had created a true fully-isolated solid-state relay (see Feb. 15, 1970 EDN p. 22).

We also found these MRs useful for limited-range gain control of op amps. For this, we used the MRs as a variable input resistance.

Comparing these results with those of similar experiments performed on Hall-effect devices (from F. W. Bell, Columbus, Ohio) and magnetically-sensitive transistors (from the Hudson Corp., Manchester, N. H.), we concluded that the similar two-terminal MRs should be better for applications where neither extreme sensitivity nor low-level linearity are important. Comparing the Siemens units with a bismuth MR (one that did not have embedded crosswise metal needles) from American Aerospace Controls, Inc., Farmingdale, N.Y., we found the Siemens MRs much more sensitive. But Robert Gitland of American Aerospace says his units are just as good at the cryogenic temperatures where many of them are being used.




However, it may be well to remember that where only occasional actuation is required, it is hard to beat a small reed switch actuated by a PM. Too, where there is no need to sense steady-state conditions, it is hard to beat a small pickup coil.

Mich. 48909). It is a good idea to grind or polish the mating surface to eliminate the possibility of magnetic field discontinuities.

In certain cases, it may be desirable to encapsulate the device in silicone rubber to seal it against contamination and improve its ability to withstand shock and stress. Electronic-grade, room-temperature-vulcanizing (RTV) silicone rubber is recommended. Bear in mind that the elements mounted on iron substrates may be exposed to strong forces from the concentrated magnetic fields of many applications. If these fields are continuously alternating and the units are not fastened down securely, you can expect fatigue failure.

MRs mounted on nonmagnetic or plastic substrates will not be subjected to the physical forces of magnetic fields, so are more suitable for being moved about to probe such fields. However, they too should be protected. Excessive bending can cause their delicate leads to separate from the ends of the serpentine. The mounting surfaces for these don't have to be ground or polished; and as long as they are clean, the units can be epoxied on directly.

### Driving transistors with MRs

In most applications, the resistance change of the MR must be amplified. This can easily be done with a simple transistor stage by replacing one of the transistor's bias resistors with the MR as was shown in **Fig. 1c**. If the MR is in the lower bias leg, the transistor is normally cut off as long as the low resistance of the MR at zero field holds the base at ground potential. The application of a magnetic field will raise the MR's resistance and turn the transistor ON.

If the MR is in the upper bias leg, the transistor will normally be ON and a magnetic field will turn it off. This latter circuit is the more sensitive of the two, because the MR is directly controlling the base drive to the transistor, but it has the disadvantage of consuming more power because of the MR's relatively low resistance.

### Sensitivity enhancement

Your application may require more sensitivity than can be obtained with the basic element in low-strength fields or it may require bidirectional resistance changes. In this case you should consider adding a bias to raise the operating point from "X" in **Fig. 3** to "Y", putting the MR into the steeper, more sensitive, portion of its response. This also makes the response more linear and allows you to detect the polarity of the magnetic field (when the MR starts from zero magnetic bias its resistance can only go up).

The magnetic bias can be produced by permanent magnets or electromagnetics (coils). The permanent magnets are usually the easiest to use. There is now a wide variety of relatively small, inexpensive PMs such as those made from Alnico, barium ferrite or strontium ferrite that will produce the necessary 5 kG or so fields. The simplest approach is to epoxy cement the MR to the end of a small ceramic magnet as shown in **Fig. 4a**. The PM field will raise the operating point so that smaller field variations will produce useful resistance changes in the MR. Fields of the same direction as the bias field, will increase the MR's resistance and fields of the opposite direction will decrease the MR's resistance. This arrangement will help you conserve power, for it raises the quiescent resistance of the MR (another reason for using a PM for the biasing since the PM itself will not use power).

A more efficient and practical biasing circuit is shown in **Fig. 4b**. Additional soft iron pieces carry the magnetic field around and concentrate it on the MR. This allows a smaller PM to be used. **Figs. 4c** and **4d** show how the field to be measured, $F_2$, would be added.

There are, however, situations where electromagnets are better for this biasing. One such is where it is desired to use an alternating field to cancel out temperature variations of the MR and other dc shifts of the necessary system. In this case a solenoid coil is used with a soft-iron core, as shown in **Fig. 4e**. The MR is exposed to the sum of the coil-generated field and the external field being measured. The variations in the MR's resistance then add and subtract from the ac-induced excursions to produce the waveform shown in **Fig. 4e**. As can be seen, the detected change will be twice the value that would have been obtained with a dc bias. It is possible to measure fields as weak as the Earth's 1/2G with this approach. Another reason for going to electromagnetic biasing would be to enable program changes in the MR's quiescent resistance. For example, it would be possible to maintain a self-balance on a measuring bridge by having a servo loop that would vary the coil current. □

## Author's Biography

*Klaus Bahr* is an engineer who turned into a marketing manager. He handles the U.S. sales of Siemens components. He also is an accomplished glider pilot, having been at the sport of soaring since he was a teenager.

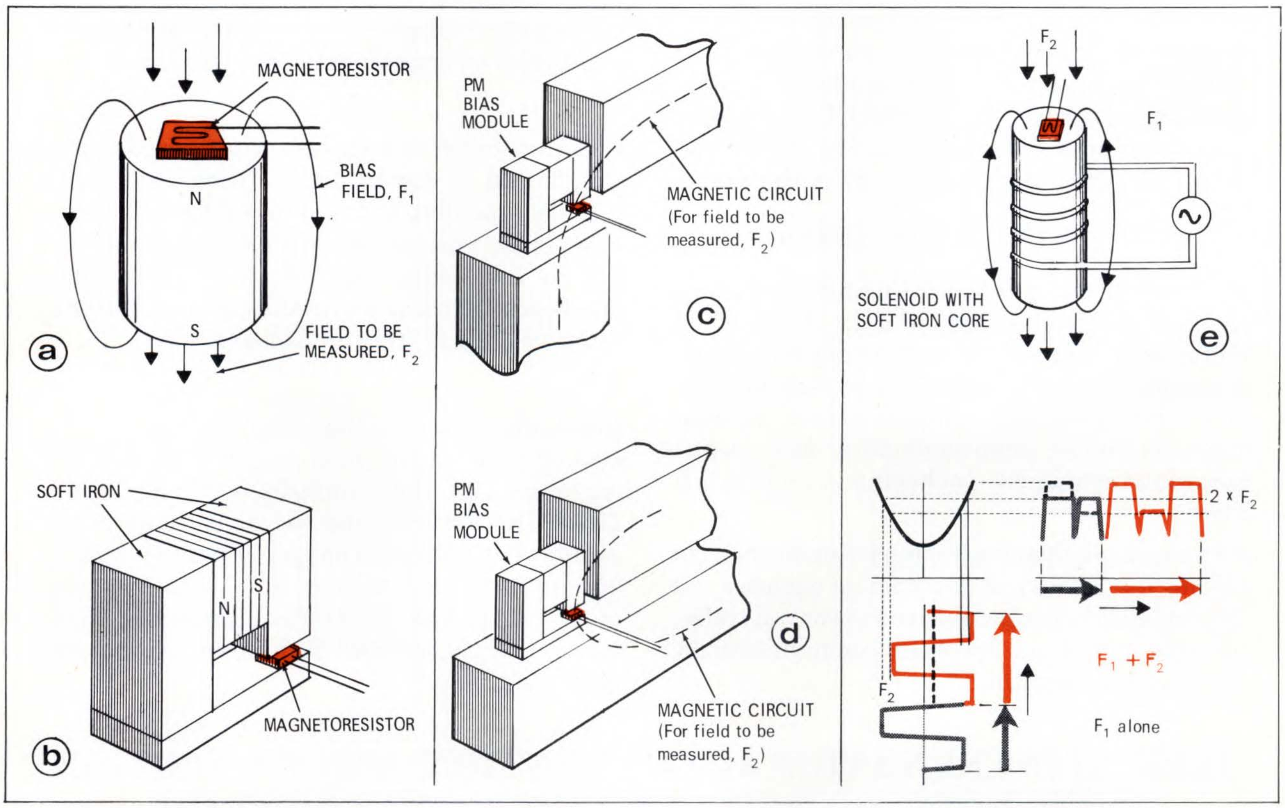



Fig. 4—**Magnetic Bias for MR's** improves both their sensitivity and linearity. It is not difficult to accomplish with either small permanent magnets or ac-excited solenoid coils. The permanent magnets are usually the easiest to use.

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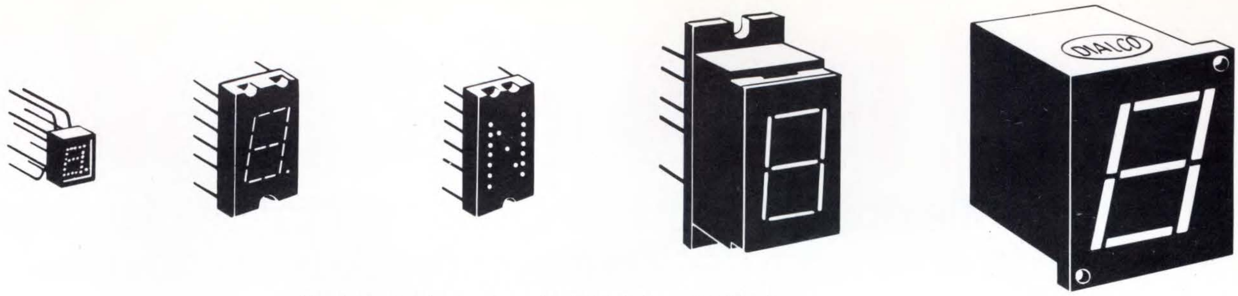

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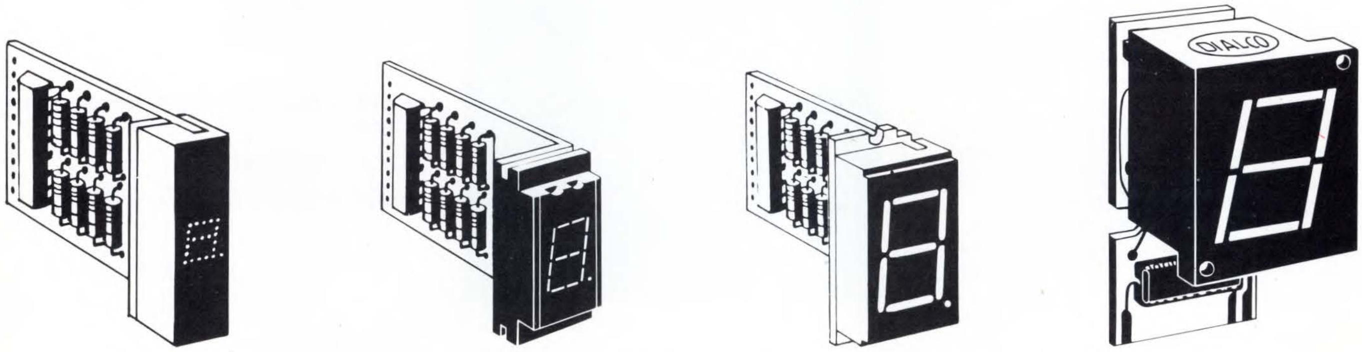

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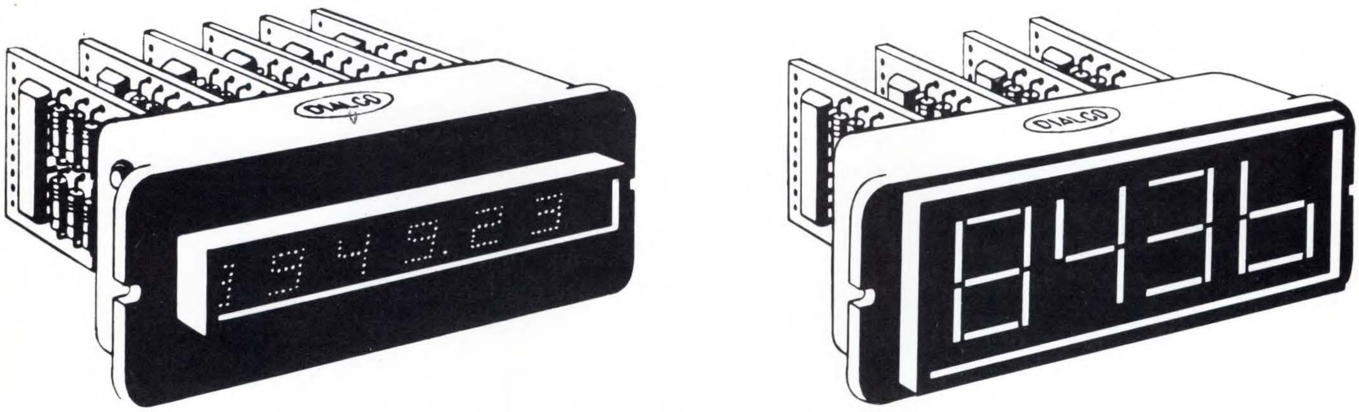

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**CIRCLE NO. 19**

# Do you really need fast ladder switches in your D/A converter?

*Slower switches can be used in many applications with a technique that disconnects the output amplifier from the ladder until switching is completed.*

In digital-to-analog (D/A) converters, high-speed ladder switches are desirable because they help minimize the effects of imperfect switching coincidence between bits of the converter ladder. This is important, since noncoincidence in ladder switching, particularly among higher-order bits, can produce significant errors in the converter's analog output voltage.

In some applications, though, high-speed ladder switches are either unavailable or are impractical for various reasons. For these cases, a technique can be used whereby the output amplifier "remembers" the previous output voltage until the ladder has settled to its new value. This eliminates the transient output error caused by noncoincident switching and allows the use of slower-speed ladder switches.

One way of implementing such a technique is shown in the illustration. In the diagram, $R_0$ is the Thevenin equivalent output resistance of the converter's resistance ladder, and $V_o$ is the equivalent output voltage. $A_1$ is a differential amplifier with low input current, and $A_2$ is a broadband amplifier having a gain of five. Frequency compensation is achieved with $C_1$ and $C_2$. (Both capacitors are required in order to eliminate a residue with a long time constant.) The result, essentially, is an inverting amplifier having a feedback resistor, $R_f$, and an input resistance, $R_o$, all of which are driven from a source, $V_o$.

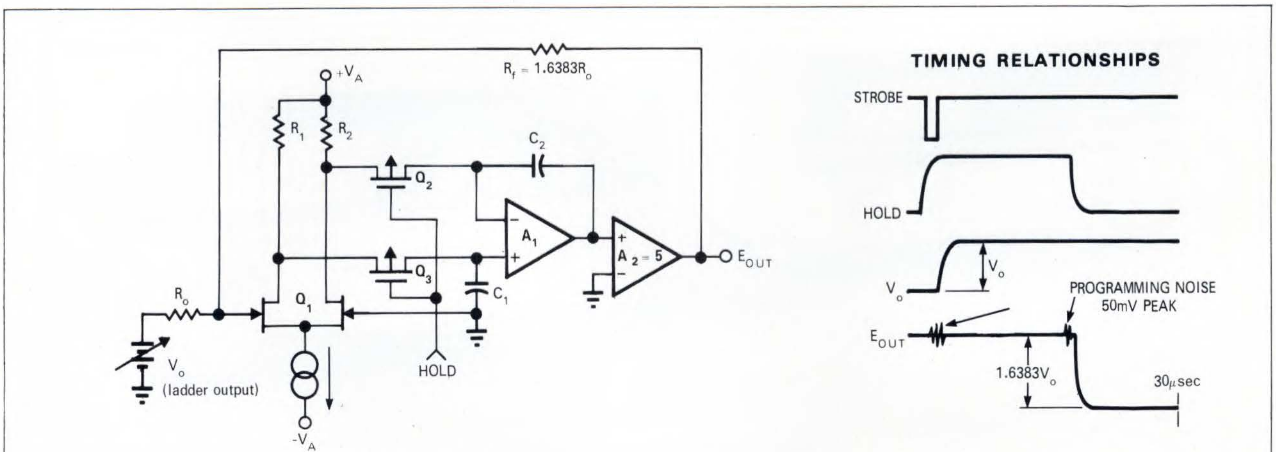
Immediately before the ladder output voltage, $V_o$, starts changing as a result of a command change, amplifier $A_1$ is disconnected from FET transistor $Q_1$ by MOSFETs $Q_2$ and $Q_3$. This is done by the HOLD signal. Because the frequency-compensating capacitors have equal values, and because MOSFETs $Q_2$ and $Q_3$ are identical devices, the errors caused by these switching signals are converted into common-mode signals for $A_1$, and because $A_1$ has good high-frequency common-mode rejection, the programming noise caused by the "hold" signal is kept quite small (<50 mV). With the large output transition errors eliminated, the converter can be used as a complex function generator having less than 50 mV of noise at any transition point.

Besides allowing the use of a slow ladder switch, this "holding" feature can provide other cost savings. For example, it eliminates the necessity for delay-equalizing circuitry for the command signals arriving at the ladder switches. This delay equalizing is normally needed to provide good switching coincidence if an analog hold technique is not used.

The technique described here is used in the 4200 Series of Programmable Voltage Supplies developed by the John Fluke Mfg. Co. □

## Author's biography


**Joe Reedholm** is a senior design engineer who currently is project engineer on John Fluke Mfg. Co.'s 4200 Series programmable voltage supplies. Prior to his 3 years with Fluke he was with Hewlett-Packard. Mr. Reedholm has a B.S.E.E. from Iowa State Univ.


**Output amplifier ($A_1$ and $A_2$)** is disconnected from the ladder output by the "hold" signal immediately before the ladder output voltage, $V_o$, begins changing. The amplifier is not reconnected to the ladder until ladder switching is completed.

# Front-panel magic sells a product

*A redesign of a functionally-important pushbutton control paid off where it counts—in favorable comments from potential customers.*

The "before" and "after" of a product that had a pretty good front panel design to begin with is shown in **Fig. 1**. The redesign centered on the pushbutton controls on the left side of the panel. The objective was to make the instrument's operation "obvious" to factory workers.

**Problem:** The product pictured was the main console of an ultrasonic welder made by the Dukane Corp., Ultrasonic Div., St. Charles, Ill. The unit houses a transistor inverter that generates a 20-kHz, 350W sinewave. This is fed to a transducer mounted in a hand gun or press that in turn delivers 20-kHz mechanical vibrations to plastic parts. The ultrasonic vibrations cause the plastic parts to heat where they touch and to fuse together.

The product's use in the plastics industry has an important bearing on the panel redesign, according to Dukane's designer, Phillip C. Harwood. "If you've ever been in a plastic fabricating shop, you'll know that our product would be surrounded by a lot of very noisy machines—grinders, extrusion molders, mills, etc. The operator is hardly able to hear himself think and our machine's normal soundless, motionless operation will give him little audible, visual or tactile indication of what is going on. Our objective is to use lighted pushbuttons to tell the operator what the machine is doing."

**Solution:** Dukane had worked out some successful man-machine concepts using lighted switches in its earlier model (left in **Fig. 1**). But the lever switches on the older design had several drawbacks. The levers stuck out beyond the front panel and so their light had to compete with the ambient light in the shop. The leaf-type contacts had a soft, gradual wiping action that would send a series of false triggers to our timing circuitry and would not give the operator any tactile indication of when the contact was made.

The redesign uses compact, flush pushbutton switches. This permits the switches to be recessed (as shown) back in an alcove where the lights shine distinctly. Large, 3/4-inch$^2$ buttons are used, with bold, 5/16-inch high identification lettering. The switches are positioned on a 45-degree slope angled towards the user. Now a workman standing before the console finds it much easier to see and hit the right button.

The switches have snap-action contacts so the workman now receives a positive tactile feedback when the contact is made, and the circuitry receives a much shorter duration of switching noise.

Another desirable feature for the raucous plastics shop environment is that the recessed buttons of the new design are much less apt to be broken or inadvertently actuated by objects brushing past the face of the console or by heavy-handed workmen. They will withstand up to 25-lb forces—


Fig. 1—**The redesigned front panel (right)** does not look much different than it did before the redesign (left). But the five new pushbuttons are a lot easier to use than the three older lever switches.

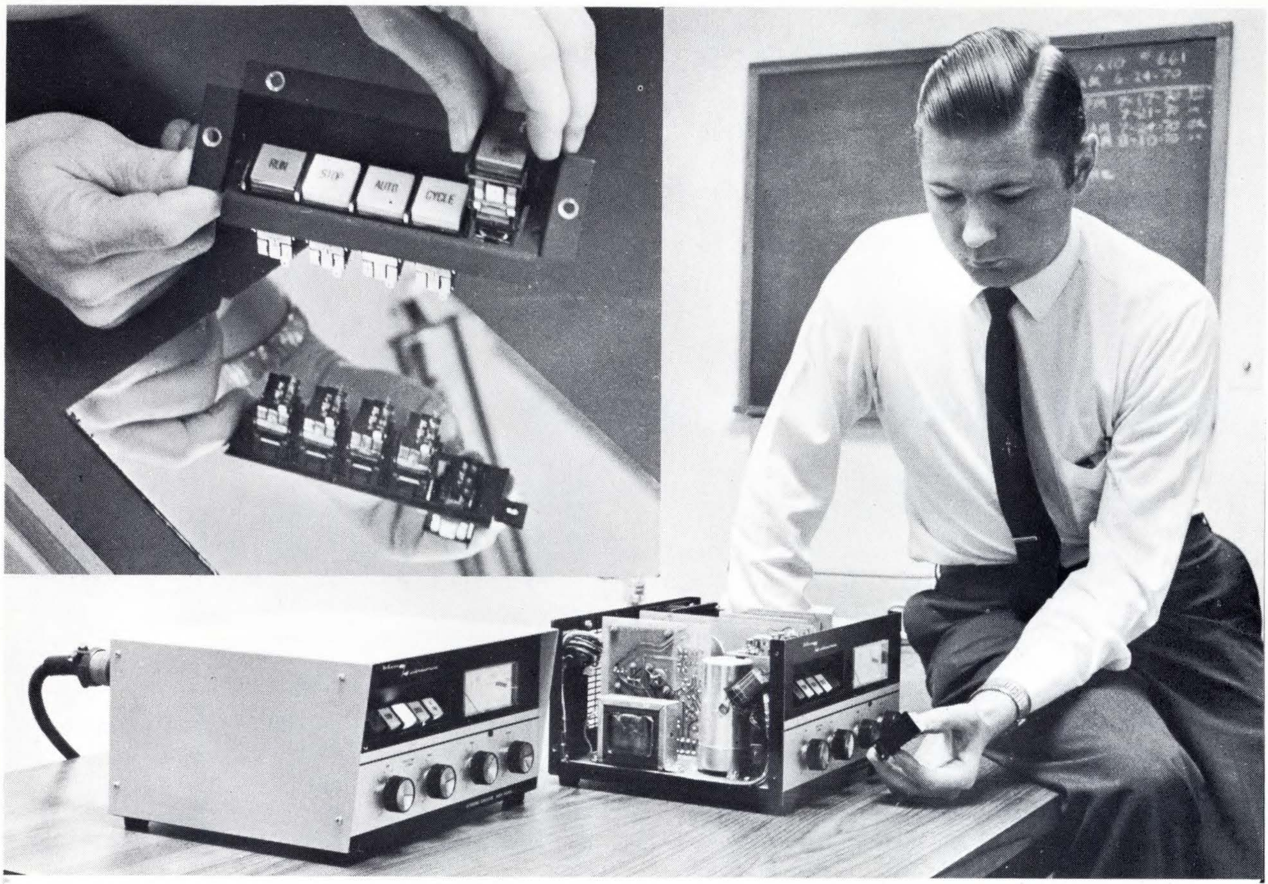


Fig. 2—**The switches are Licon type-16 units.** They have single-pole, double-throw contacts rated at 10A. They snap into a subassembly that is mounted on a 45-degree angle in a recess in the front panel.

or substantially more than the cantelevered levers.

As a bonus, the supplier of the switches, the Licon Div. of Illinois Tool Works could provide up to 10A current ratings in the style used. Therefore Dukane was able to clean up the design by incorporating the ac power control in the same switch lineup.

**Meaning to user:** The amount of man-machine communication that the company has been able to squeeze out of this row of five lighted and labeled pushbuttons can be illustrated by some typical operating sequences.

To start the welder, the operator pushes the ac power switch. This is a push-to-turn-on, push-to-turn-off switch and it indicates ON by shining green. At the same time, the STOP button lights up shining white (for maximum visibility) to indicate that, while the machine may be powered, and the inverter running, its 20-kHz energy is being safely withheld from the work head.

Now if the operator were using a hand gun he might push the RUN button. The STOP button light would then go off and the RUN button would light up red, indicating the 20-kHz was being applied steadily to the transducer (via output relay contacts). The RUN button actuates a momentary-contact switch that sets a flip-flop-type memory circuit which then holds the RUN lamp lit. The operator can remove power from the head by pushing the STOP button. The STOP button actuates a master override command that resets the solid-state memory and timing circuits that the other buttons trigger.

To go to cycling operation, the operator first presses the AUTO button, which glows amber and also turns out the STOP button light. This sets the welder up for the cycling mode. Now each time the CYCLE button is pressed, the RUN button will flash its red and the CYCLE button will flash its white. The RUN's red flash will indicate that a burst of 20-kHz has been applied to the work head and the CYCLE's longer white flash will indicate the length of cooling dwell on each cycle. The operator can adjust the cycle durations by the knobs at the bottom of the panel.

All of these commands can be actuated remotely. The RUN and CYCLE commands can be initiated by triggers on hand guns or foot switches. The STOP commands can be initiated by safety interlocks. But even when the commands come from remote locations, the pushbutton lamps still light to indicate what is going on.

**Payoff:** According to designer Harwood, "the time we spent working out these man-machine details was justified, we felt, by the favorable reception we've received from customers. Men who actually used these machines in their shops—foremen and operators—have told us, "It looks nice . . . controls feel good . . . . It lets me know what is happening." □

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*Robert H. Cushman, New York Editor*

FOR A FREE COPY OF THIS ARTICLE, **CIRCLE L65**

## Selective filter for low frequencies

Entry by Paul Gheorghiu
Optomechanisms, Inc., Plainview, N.Y.

When used as a filter, a single RC network usually exhibits poor selectivity. The popular Wien-bridge configuration allows an RC network to be converted into a null-balance bridge. But though this configuration offers an improvement in selectivity, the improvement is not as great as might be expected, because of relatively slow phase changes in the vicinity of $\omega_0$.

The lattice filter, shown in **Fig. 1**, offers a net improvement in performance when compared with the Wien bridge and other passive selective filters in this class.

Like the Wien bridge, the lattice-type bridge is also a balanced network with four terminals. But it is easier to adjust because it has more tuning elements. This configuration has applications in frequency measurement or as a frequency-selective filter.

In **Fig. 2**, the response of a lattice filter is compared with that of a Wien bridge. We see that the lattice filter offers greatly superior selectivity and about three times the output voltage in the pass band.

The optimum relationship between component values is indicated in **Fig. 1**. It can be shown that, for best performance, the value of coefficient X should be selected to be equal or superior to 10. Notch frequency $f_c$ can then be calculated using the following equation:

$$2\pi \ CRf_c = 1$$

As a design example, let's calculate the component values for a 400-Hz selective filter. If we assume that 0.1 $\mu$F is a practical capacitance value as far as size is concerned, then the equation yields a resistor value R equal to 39.5 k$\Omega$. Then, using a value of 10 for the factor X, the other resistor values are as follows:

$(X - 1)R = 35.55$ k$\Omega$
$(X + 1)R = 43.45$ k$\Omega$

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Circle 161

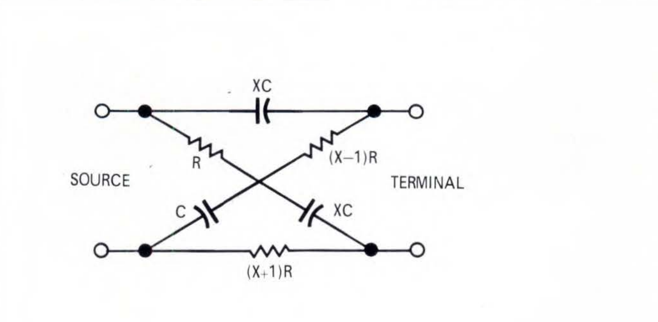



Fig. 1—**Lattice configuration offers better performance** than other passive-component selective filters. Factor X should be 10 or larger.

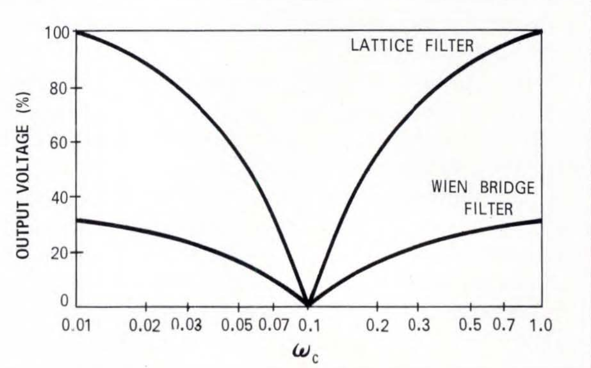



Fig. 2—**Note the improved selectivity** and greater output voltage of lattice filter compared with that for Wien bridge.

## Reduce integrator transients with synchronized gate signals

Entry by Roland J. Turner
RCA Missile and Surface Radar Div. Moorestown, N. J.

When new signals are gated into a high-Q tank circuit serving as a bandpass integrator, ac gating transients may cause adverse ringing of the integrator. This is especially true if the series signal gate is closed when the ac input signal is at its peak level. When this happens the integrator will have a long settling time and will not properly represent the integrated value of the input until after this transient dies out—which may take considerable time, because by definition the bandpass integrator has a high Q and a long memory.

The circuit shown in **Fig. 1** reduces ringing significantly by the following process:

1. The ac input signal to be integrated is amplified in two broadband differential amplifier stages, $A_1$ and $A_2$.
2. The amplified signals are differentiated and selected by diodes $D_1$ and $D_2$.
3. The input gate pulse, $P_1$, and the differentiated pulses then drive "and" logic which generates an output pulse, $P_S$, coincident with the zero crossings of the ac input signal. The leading edge of $P_S$ will always occur at the first signal zero crossing after $P_1$ initiates the gating action.

The leading edge of the output pulse, $P_S$ will always occur at a zero crossing of the ac input signal and will not cause ringing of the bandpass integrator. If pulse $P_S$ is used to drive a balanced diode bridge, both the gating pedestal and the ac signal transient are eliminated, and the high-Q bandpass integrator will have a fast settling time and may be operated at a faster repetition rate.

The timing waveforms of this circuit are shown in **Fig. 2**. The NAND gates in the logic portion of the circuit are Texas Instruments Incorporated or Fairchild IC packages.

To Vote For This Circuit
Circle 162

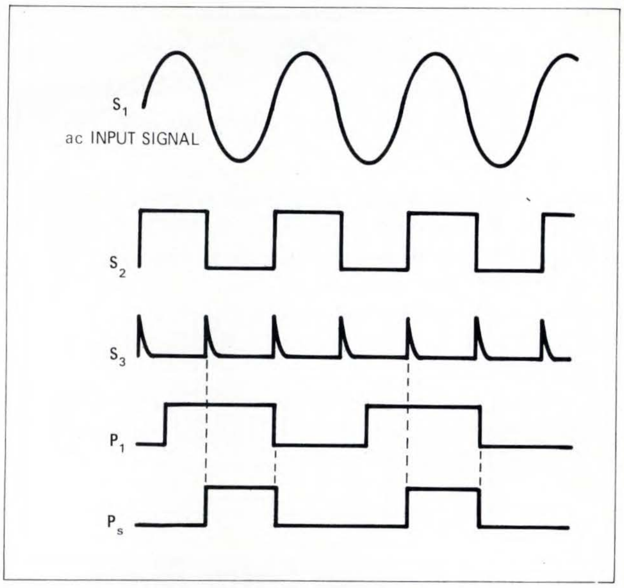



Fig. 2—**Input signals** ($S_1$) generate zero crossing pulses ($S_2$). Normal enable gate pulses ($P_1$) are then withheld from integrator until zero crossing occurs ($S_2$), at which time the zero-crossing gate ($P_S$) enables the integrator tank circuit.

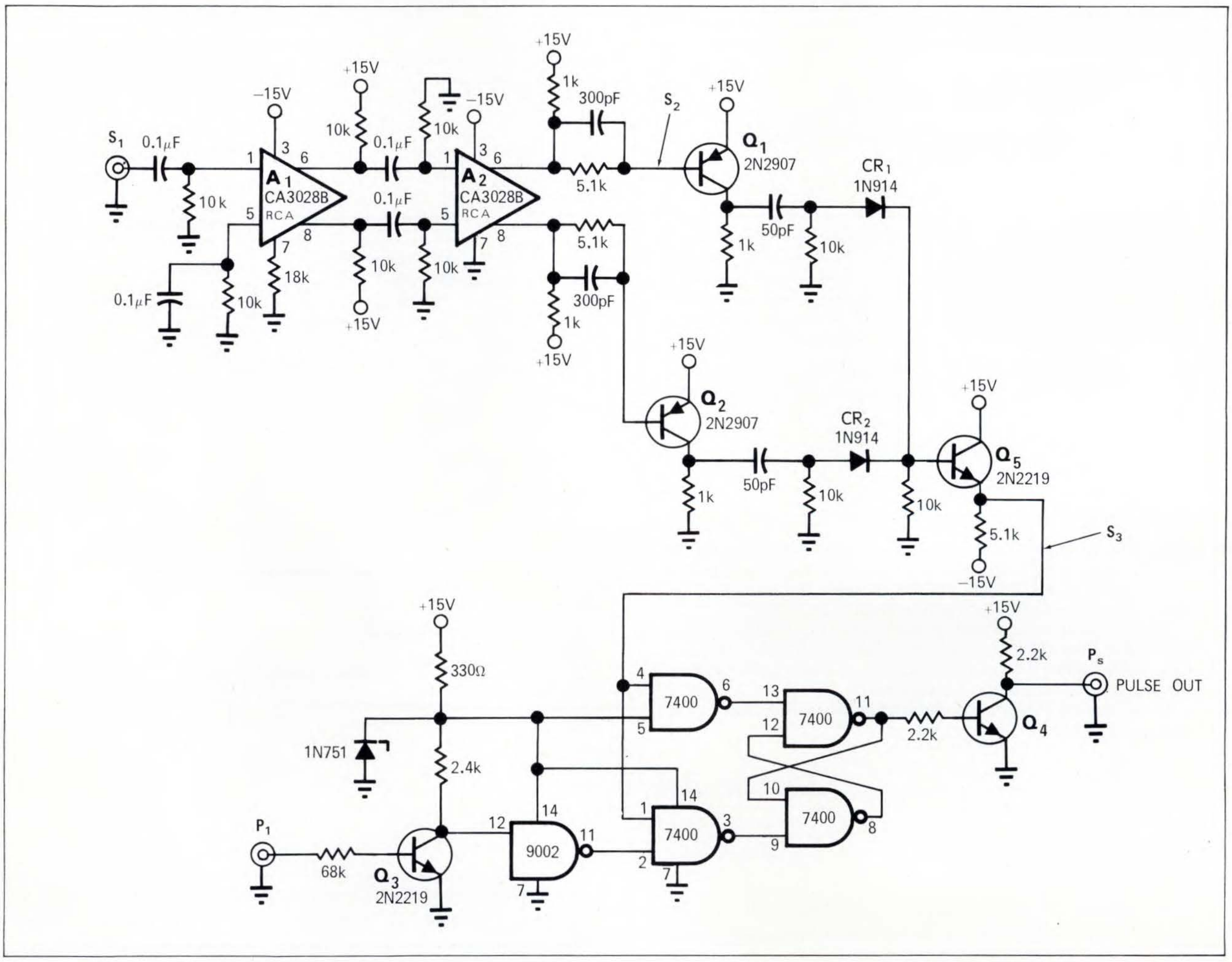



Fig. 1—**Ringing and long settling times**—characteristic of shock-excited high Q tanks—are eliminated in bandpass integrators by this circuit. Inputs are gated into the tank only at input zero crossings, avoiding shock excitation of the high-Q tank.

# DTL delayed one-shot

**Entry by Ronald A. Millar**
Tri-Data Corp. Mountain View, Calif.

This simple edge-driven one-shot employs two expandable DTL NAND gates. The required gates are available in a single IC package—for example, the MC961/861.

The circuit is useful wherever a delay is needed prior to transmission of a pulse to allow for the settling time of other circuits. This circuit costs less than conventional circuits which use two one-shots in tandem.

Capacitors $C_1$ and $C_2$, connected to the expander pins, each cause time delays at their respective gates.

The timing diagram shows the relationship between input and output signals. With capacitance expressed in picofarads, the output pulse period ($T_p$) and delay ($T_d$) are given by the following relationships:

$$T_p \simeq 1.7(C_1 - C_2) \text{ nsec}$$

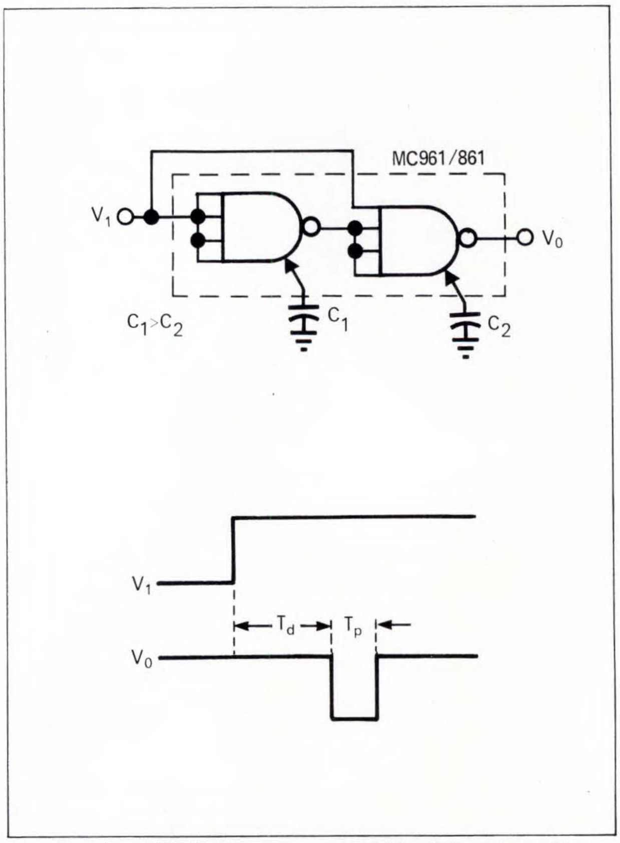
and

$$T_d \simeq 1.7C_2 \text{ nsec.}$$

If $C_1$ is 680 pF and $C_2$ is 100 pF, for example, the circuit produces a 1 $\mu$sec pulse delayed by 0.17 $\mu$sec.

Pulse delays and durations of up to 1 msec ($C_1$ = 1.2 $\mu$F, $C_2$ = 0.6 $\mu$F) can be obtained, but with some degradation of the output pulse shape. The pulse can be sharpened, however, by adding a DTL inverter at the output.

To Vote For This Circuit
Circle 163




**Monostable multivibrator** uses expandable DTL gates with capacitors connected to expander terminals to provide required delay and pulse width. As shown, leading edge of input pulse triggers the circuit to produce delayed output pulse with delay $T_d$ and width $T_p$.

**Your vote determines this issue's winner.** All circuits published win a $25 U.S. Savings Bond: All issue winners receive an additional $50 U.S. Savings Bond and become eligible for the annual $1000 U.S. Savings Bond Grand Prize.

**Vote now,** by circling the appropriate number on the reader inquiry card.

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## Circuit Design Entry Blank

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Print full name (no initials) and home address on line below exactly as you wish it to appear on Bond, if entry is selected for publication.

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Entry blank must accompany all entries. Circuit entered must be submitted exclusively to EDN/EEE, must be original with author(s) and must not have been previously published (limited-distribution house organs excepted).

Circuit must have been constructed and tested. Exclusive publishing rights remain with Cahners Publishing Co., Inc., unless entry is returned to author or editor gives written permission for publication elsewhere.

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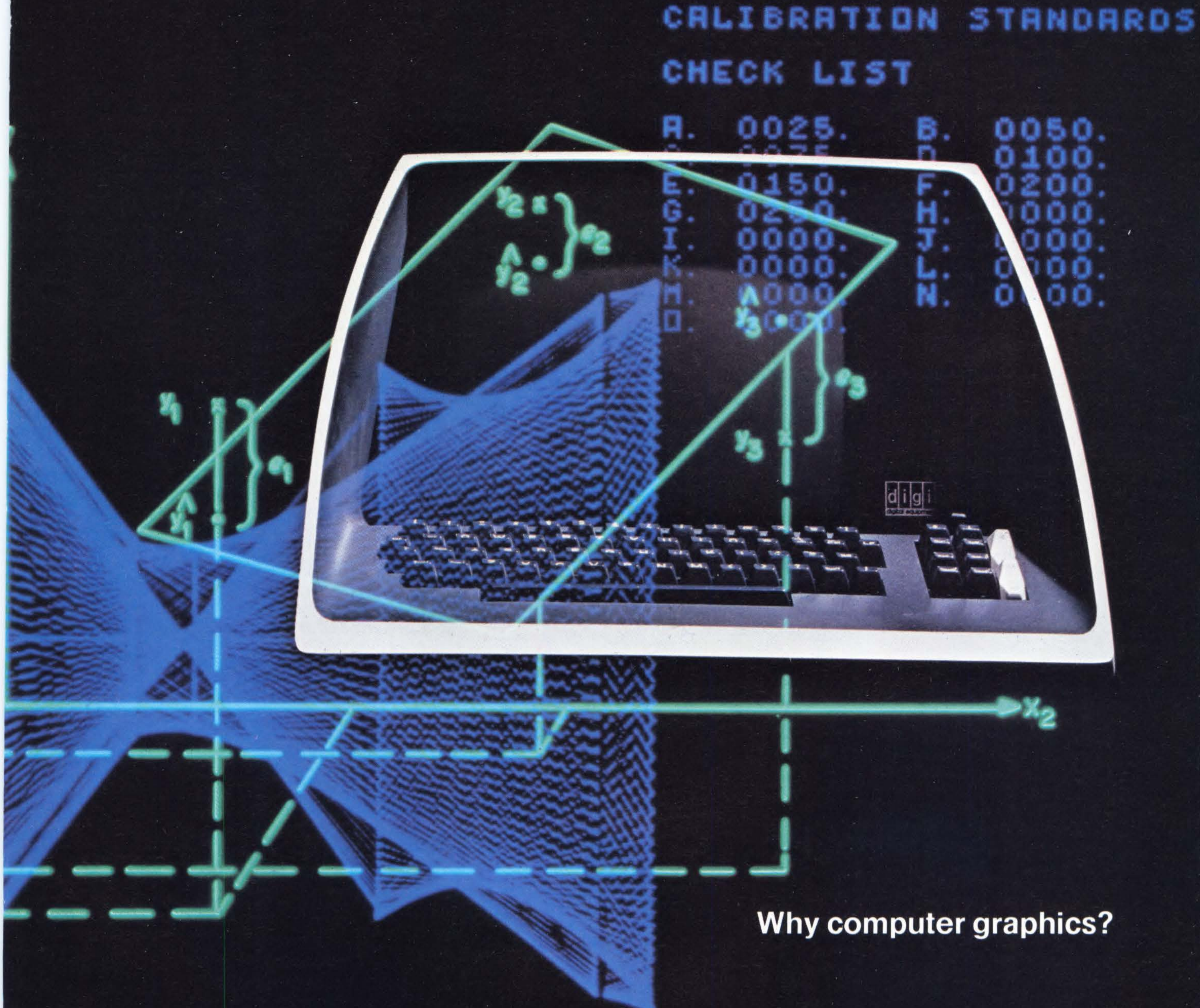
Date____________________

# computer hardware

FOR DESIGNERS OF COMPUTER MAINFRAMES, PERIPHERALS AND SYSTEMS




**Why computer graphics?**

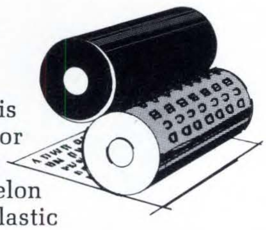
A CAHNERS PUBLICATION / JANUARY 15, 1972

# What can you save if you eliminate ribbons and ink fountains from your printout design?

Other manufacturers are saving 14 to 17% of total manufacturing costs by using Porelon® microporous plastic for type inking. Porelon material contains its own ink supply —enough for millions of impressions with computer printer equipment. So it replaces ink fountains, ribbons, ribbon reversing systems, even ink distribution rollers.

One customer using Porelon material reports an inking capacity of 10,000,000 lines with a 32-column printer using a 2½ inch O.D. x 3½ inch wide Porelon roll.

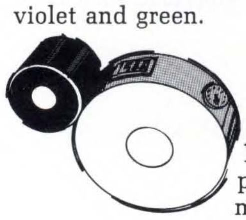
Just think what that means. Replacing this intricate and costly mechanism lets you save right from the drawing board through manufacturing. Your customers save, in maintenance of the completed system, too, because there is nothing to fill or change for the life of the Porelon microporous plastic roller. And the impressions are always crisp, clear and legible because there's nothing between the metal type and the paper to blur or smudge the image.



Porelon materials do all this because they're not just an ink-impregnated material. Ink is blended right into the Porelon material as it's formed, and it's held in interconnected, microscopic pores. Ink flows to the surface of the Porelon microporous plastic by capillary action as it touches the type metal. It flows back by the same type of attraction when pressure is relieved. Nothing is left on the surface to dry. And because the inks in Porelon material dry only by absorption, nothing dries on the type — even overnight.

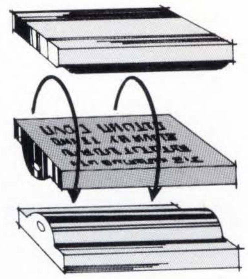
There is just one way Porelon material gives up its ink: capillary action. It doesn't dry out, even during long periods of storage. You can't squeeze it out, so contact pressure with the type is light and friction and wear are minimal. Under normal conditions, you can't spin the ink out of Porelon material by centrifugal force, either, so there is no misting, even at high rotational speeds.

Porelon microporous plastic works efficiently over a broad temperature range of 50° to 110° F. It can be used at peripheral speeds of 17,000 inches per minute. (That's 2,700 rpm on a 2″ roll.) Porelon material is strong and long-wearing, with a standard hardness of 12 to 15 Shore A durometer. Ink formulations are available in black, blue, red, violet and green.

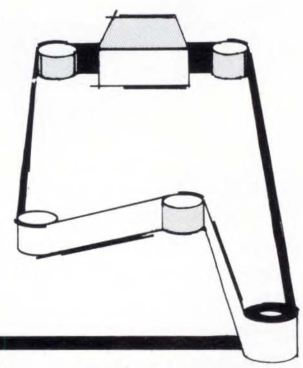


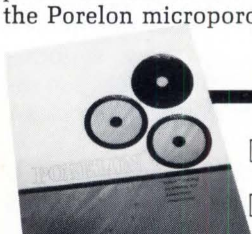
Porelon materials are already at work in hundreds of print-out mechanisms.

In high-speed applications on single and multiple column printers and key punch card machines, it has been used for direct inking and with transfer rolls. Its low-speed applications include ribbon re-inking, postage meters, ink transfer from pads of Porelon material and many others. All have a single common feature — reduced cost through design simplification.



There are many ways to cut design and manufacturing costs by using Porelon inking materials in business machines. Most are listed in a special booklet available from Johnson Wax. If you're ready to save by simplifying your print out systems, just return the enclosed coupon and we'll send you your copy. Remember, we are always ready to help. Just make a check mark in the box below and a Porelon engineer will contact you.





☐ Please send me my copy of the booklet, **PORELON "solid" inking systems for business machines.**
☐ I'd like to talk to a Porelon engineer.

**Johnson WAX**
Porelon Products Dept. CH-1
S. C. Johnson & Son, Inc.
Racine, Wisconsin 53403

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We are considering PORELON materials for the following application:



CIRCLE NO. 402

7954

CONTENTS JANUARY 15, 1972

# computer hardware

EXCLUSIVELY FOR DESIGNERS OF COMPUTER MAINFRAMES, PERIPHERALS AND SYSTEMS

## COVER

Cover photo courtesy of Digital Equipment Corp., Maynard, Mass. For the full story on the many uses of computer graphics, see "Computer graphics—who needs it? A lot more people than you think", on p. CH 16.

## Automated checking of keyboards is a breeze

The steadily increasing production of CRT data terminals prompted Bunker Ramo's Business and Industry Div. to automate the time-consuming task of testing and evaluating electronic keyboards—an integral unit of each terminal. Their overall objectives were cost reduction and quality improvement. The quality assurance department evaluated many approaches, but decided that a systematic pulsing of each key with a small burst of air (simulating normal typing finger pressure) would be an efficient way to go.

Three major elements make up the testing unit:

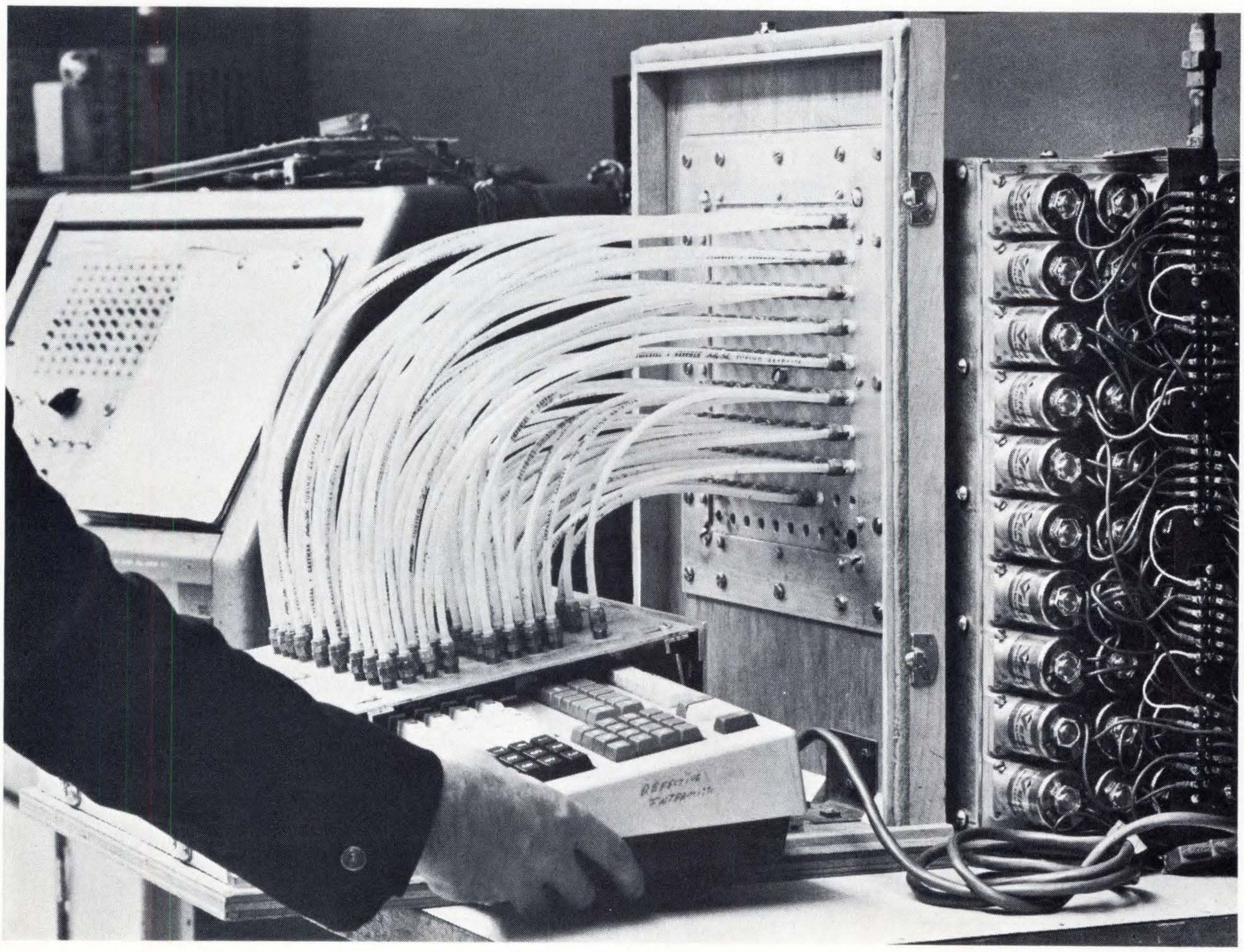
—a keyboard module that holds the keyboards in proper position.

—a manifold that controls the air distribution with electrically operated solenoids.

—a control unit that drives the complete system and provides a readout of any errors.

There are three configurations of the keyboard module, designed to accommodate three of the popular keyboard models now in production. Modules have a firm housing for the keyboard under test and an insulated cover for surpressing the sound of the noisy air jets while the test is in progress. The modules, simple in construction, are made of plywood, pipe fittings and plastic hoses. The photo shows a keyboard being positioned in a manifold for test.

The manifold accommodates 100 electrically operated solenoids. Each solenoid, when operated, provides a path for the air flow toward the keyboard module. A plastic hose directs the jet of air toward a given key and a compressed air line with a variable pressure control connects to the manifold.



The most sophisticated part is the control and error checking unit. When evaluating a completed keyboard, the control unit activates each solenoid consecutively—which, in turn, directs a small burst of air to the desired key. The ASCII output from the keyboard under test is compared with a valid unit and all errors are displayed. A lamp panel contains one lamp per key and accommodates up to 100 keys.

The test cycle continues until each key has been activated and checked ten times. Also there is a "continuous cycle" switch for reliability studies and evaluation of other keyboards. Another switch labeled "cycle on error" allows the operator to establish the cause of a malfunction. This switch causes the control unit to continuously pulse the first key that generated an erroneous output. Once the cause of error is determined, the error switch is released and the control unit proceeds with the testing cycle.

A completely assembled keyboard can be fully tested with this automatic system in approximately three minutes. Previously, boards were checked manually, with the results displayed on a CRT—a technique that required up to 20 min/keyboard.

## PRD enters commercial automatic test market

PRD Electronics Div. of Harris-Intertype Corp., Syosset, N.Y., has unveiled a sophisticated new commercial automatic test system known as CAST—Computerized Automatic Systems Tester. It is said to reduce testing time of a broad spectrum of analog, rf and digital systems, sub-assemblies, modules and components by 20:1.

The CAST system is an outgrowth of PRD's 10 years of experience in developing and building the VAST system—an automatic test system for U.S. Navy avionics facilities. CAST incorporates an integrated hardware and software approach and is modularly designed, allowing easy adaptation to specific testing and maintenance needs.

In describing the new turnkey system, Thomas O'Brien, Vice President and general manager of PRD called it the cost-effective answer to automatic testing, operational maintenance and data monitoring. He predicted that it would quickly pay for itself by eliminating the need for redundant test stations.

A Varian minicomputer is used as the subsystem, augmented by disc storage. Peripherals include paper-tape reader/punch capability, a Teletype Corp. operator terminal plus a system control panel and optional CRT display capability. A simplified English-like software program (VTRAN IV) makes operating the CAST system an easy task.

Measurement capabilities include: audio and rf power output, rf receiver sensitivity and signal-to-noise ratio, frequency response and deviation, phase shift, bandwidth, gain, limiting, voltage, resistance, audio modulation, time interval and deviation percentage. These tests can be carried out at frequencies from 0.01 Hz to 0.5 GHz.

The system is expected to cost from $125,000 to $200,000, depending on the complexity of testing required.

## Future memory systems: monolithic Semiconductor!

At the NEREM '71 session dealing with future memory systems, Dr. R. F. Elfant (see photo) of IBM Corp. gave a summary of how he sees such systems shaping up. Of prime importance, he sees monolithic semiconductor memories as the driving force in all areas of computer design. Further, Dr. Elfant predicts that the CPU will be made up of local stores, writable read-only control stores, distributed memory and just plain larger memories in general. With regard to storage systems, he believes they will tend toward hierarchies of systems (EDN Computer Hardware Feb. 15, 1971 p 001010) with large main memories, and electronic backing stores penetrating the mechanical storage area (EDN Feb. 15, 1971 p. 18).

Among the factors cited by Dr. Elfant for the realization of large SC memories were: the exploitation of LSI, because it is not I/O pad constrained, and regularity of the structure makes it easy to use; capacity; cost; performance and reliability. Costs will go down because of larger functionally organized chips, large volumes of a single part number and ease of testing. Chips will get larger because of advances in photolithography and semiconductor processing; density will improve by a factor 10 to 50 times because linear dimensions will decrease by 2 to 3 times; the number of devices per cell will decrease by a factor of 3 to 6; and power will go down, or remain constant, per chip because of the use of pulsed power or static vs. dynamic cells. All this will increase reliability by 12 to 54 times what it is today. Other papers at the session backed up Dr. Elfant's predictions with regard to memory hierarchies and electronic replacement of mechanical storage devices.

Dr. C. V. Ramamoorthy of the University of Texas discussed the theory behind, the needs for, and the design and usage considerations for, hierarchical storage organization. By distributing a program over different levels of the hierarchy and keeping only the currently executable procedure and data in the fast memory, Dr. Ramamoorthy expects that average access time to a word in storage will be surprisingly close to that of the fast memory within the hierarchy.

R. J. Spain of Cambridge Memories Inc. and A. H. Bobeck of Bell Telephone Labs both described systems utilizing the concept of controlled magnetic-domain wall motion to replace mechanical storage devices. Cambridge Memories has built a prototype 2-million-bit mass memory using its DOT (domain tip) technology (EDN Nov. 15, 1970, p. 35), while Bell Telephone Labs has the design of a 15 megabit mass memory in progress using its "bubble" technology.

# 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.

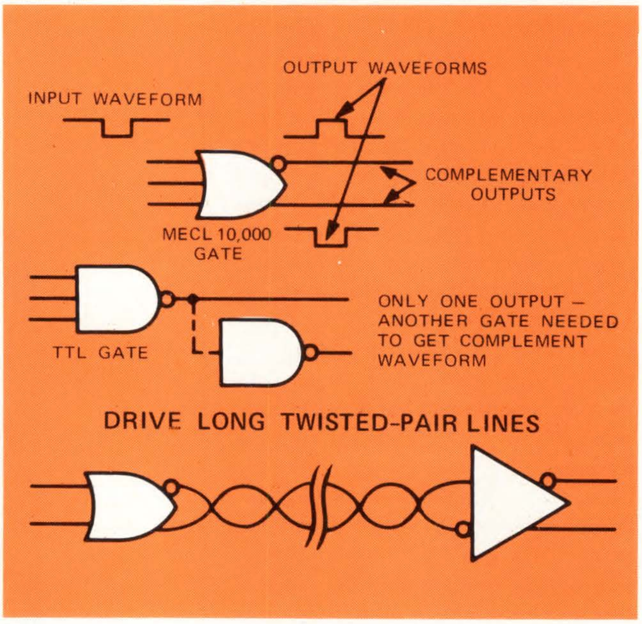
**Q.** Are special PC boards required?

**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?

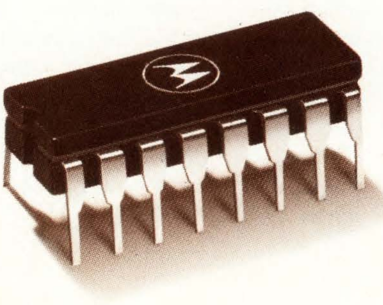
**A.** MECL 10,000 provides design flexibility in many ways. For instance, the open emitter outputs and high impedance inputs allow wire-"OR"ing of several levels of gating, with a marked savings in gate and package count. Open emitter outputs allow data "bussing" and two-way data transfer. Also, the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

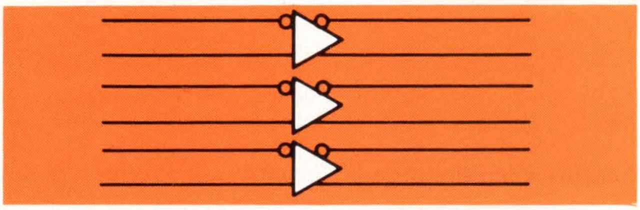



**Q.** How many functions are available in MECL 10,000?

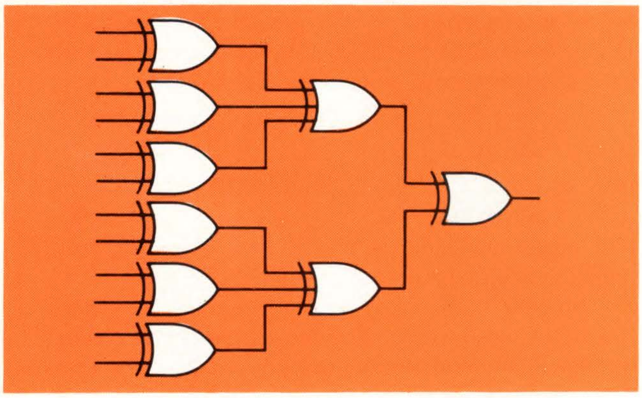
**A.** Motorola has introduced 16 devices to date and now two more are available; the MC10116 Triple Line Receiver and the MC10160 Twelve-Bit Parity Generator/Checker.



# to help you eliminate the alternatives



**MC10116 Triple Line Receiver — A triple differential line amplifier for sensing differential signals over long lines. Also useful as a Schmitt trigger, or in applications where a stable reference voltage is necessary.**



**MC10160 12-Bit Parity Generator/Checker. Useful for high speed detection or generation of parity on long data words with minimum package count. One package offers nine EXCLUSIVE-OR gates internally connected to provide odd parity checking or generation.**

**Additional devices will shortly be introduced including:**
**Multiplexers (Dual 4-to-1, Quad 2-to-1)**
**Universal Counters (Binary and Decade)**
**Universal Shift Registers**
**Flip-Flops (100 MHz, 200 MHz, 500 MHz)**
**MECL-to-MOS Interface (for memory systems)**
**Buss Drivers/Receivers**
**16 x 4 Fast RAM, plus other memory configurations**

**Q.** Is MECL 10,000 a single source logic family?

**A.** Definitely not. MECL 10,000 will be second-sourced by Signetics and several others will be announced shortly.

**Q.** Are special regulated power supplies necessary?

**A.** Not at all. MECL 10,000 operates over a wide range of supply voltages and there is a minimum change in operating characteristics within a ±10% supply voltage. Also, constant noise immunity is guaranteed over the new wide temperature range of −30°C to +85°C.

**Q.** What special cooling requirements are required?

**A.** No special cooling is required. MECL 10,000 low power gates eliminate cooling and power distribution problems and insure long term reliability. Operate in still air or forced air.

You still have questions? We now have a new MECL 10,000 book covering MECL 10,000 specifications, design rules and applications. Be a MECL 10,000 expert, write to Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, Arizona 85036 and ask for "MECL 10,000 Facts." And for immediate evaluation devices call your local Motorola distributor.

**MECL 10,000 eliminates the alternatives. Evaluate and compare!**

**MOTOROLA MECL**

*. . . for faster computers & systems*



CIRCLE NO. 409

# Conserve memory power through switching

*Power dissipation is one strike against bipolar memories. However, an old and well established scheme may overcome this handicap—power switching.*

Because standby and operating power levels of the bipolar memory are approximately equal, power requirements for these systems are relatively high in comparison to their magnetic counterparts. This high power level grants improved system performance at higher speeds. But for the slower systems, this high-power aspect represents a significant disadvantage, especially with the total power distribution system that includes fans, bus bars, large cabinets with long power and signal distribution systems and maintenance. Presently, the power levels of a bipolar memory are within the 1 to 10 mW/bit range, whereas the range for the magnetic systems is 0.1 to 1mW/bit.

Switching the supply voltage is one technique for reducing power. This is not a new concept, especially with aerospace equipment where the standby mode requires the conservation of power. This same idea is applicable to semiconductor memories. The standby power source to the memory component is switched off, or at least reduced below its operating level so that the concurrent decrease in current to the memory stack gives an overall net power reduction. Thus, a lower current power distribution system can be used.

Experimentally, power switching has been used with both read-only (ROM) and read-write (RAM) memories. Detailed aspects of applying power switching to both RAMs and ROMs are described in "How Good Is Power Switching?" (pp CH 11-14).

## Price You Pay

To fully appreciate the money value of power switching, consider the costs for assembly, test and printed-circuit board packaging on a cost/bit basis:

| | **ROM** | **RAM** |
|---|---|---|
| *Parts* | 0.017¢ | 0.088¢ |
| *Assembly, Test* | 0.017¢ | 0.075¢ |
| *PC Board Area* | 0.025¢ | 0.100¢ |
| *Total Cost/Bit* | 0.059¢ | 0.263¢ |

Based on \$1/W for unregulated power and \$2/W for regulated, this yields the following results on a per-bit basis for the ROM and RAM cases:

| | **ROM** | **RAM** |
|---|---|---|
| *Power Saved* | 0.55 mW | 0.40 mW |
| *Uninstalled Power Costs* | 0.055¢ | 0.04¢ |
| *Installed Power Costs* | 0.11¢ | 0.08¢ |

All calculations are based on the use of standard TTL microcircuits for power switching and logic circuits. These results indicate a payoff for the ROM case in terms of costs since the savings in power costs is greater than the cost of the power switching circuits. However, for the RAM, where $V_{cc}$ cannot be zero, the power switching mode of operation is more expensive.

## Another Consideration Is Speed/Power Product

Speed/power product for memory components is the product of the worst-case access time and the maximum operating power/bit. This yields an analogous measure to that obtained for a switching circuit. The large RAM speed/power products indicate an inefficient energy transfer process.

To get some indication of the relative merit of power switching as compared to other systems, the speed/power product for the ROM and RAM systems was derived with and without power switching. The tabulated results are:

| Mode | Speed/Power Product in Pico-Joules | |
|---|---|---|
| | ROM-4106 | RAM-93400 |
| Without power switching | 70 | 540 |
| With power switching | 29 | 720 |
| With power switching and low power TTL | 37 | 590 |

Also calculated was the operating speed/power products for both ROMs and RAMs using MOS and ferrite cores. These results are:

| | Speed/Power Product in Pico-Joules | |
|---|---|---|
| Memory Type | ROM | RAM |
| MOS | 100-300 | 100-Dynamic<br>200-Static |
| Ferrite Core | 30-60 | 1000-2500 |

Although it is true that ferrite-core memories can have a lower standby power than either bipolar or MOS, the operating mode is considered to be more important for a speed/power product.

From the above results it is apparent that there is a significant reduction in the speed/power product with power switching for the bipolar ROM, especially using standard TTL devices. This compares favorably with the best speed/power products attained for braided core systems and is better than that attained for MOS systems. In the case of the bipolar RAM, power switching did not improve the speed/power product with either low power or TTL. However, the values realized without power switching are better than those obtained with static MOS and ferrite core RAMs.

## Let's Not Forget Options

The power switching concept used for the above data was applied externally to the chip. However, a power switch circuit could be added to the memory chip that would be enabled with the chip select input. For those chips with address decoders, and for data line drivers and sense amplifiers, a number of power switching options exist. Some of these options include:

| Options | Chip Interface Circuits | Memory Cells (stack) |
|---|---|---|
| 1 | $V_{cc}$ reduced | $V_{cc}$ not switched |
| 2 | $V_{cc}$ OFF (zero) | $V_{cc}$ not switched |
| 3 | $V_{cc}$ reduced | $V_{cc}$ reduced |
| 4 | $V_{cc}$ OFF (zero) | $V_{cc}$ reduced |

Careful consideration must be given to the particular circuit used and to the power allocation between the memory cells and the interface circuits. Interface circuits for power switching applications should not change the load characteristics or destroy any wired logic functions when the voltage is reduced.

In general, the address decoding circuits that select the power switching circuits can be the same as those that select the substack. However, if the power is switched ON and then OFF for each memory cycle, then many ($10^{10}$ to $10^{14}$) thermal cycles may occur for a memory part. This raises an unanswered question at this time about the long term reliability. The number of ON/OFF thermal cycles can be reduced by at least a factor of 10:100 if advantage is taken of the usual operating mode of a program that is to sequence through a block of consecutive addresses. Thus a flip-flop can be used to store the power switch address from cycle to cycle and changes only as a new memory part is addressed. Also this could speed up the average access time since the second and following accesses to the same memory part would not have to wait for the power switching circuit. One thing seems very clear: the question of the effect of thermal cycling on long term reliability has to be carefully considered and investigated. ▭

## HOW GOOD IS POWER SWITCHING?

Power switching has been applied to both ROM and RAM components. Detailed aspects of applying power switching to both types are described below, along with some experimental results.

### Bipolar ROM

To test the power switching concept on a bipolar ROM, a memory array was made up of Fairchild's M$\mu$L 4106 having the following characteristics:

**Size**—1024-bit, 16-lead DIP, programmed with a metallized base contact.

**Organization**—*256 × 4, binary address decoder, open collector data output circuit.*

**Input/Output**—*TTL*

**Access Time**—*≤50 nsec*

**Power Dissipation**—*625 mW max (5V)*

The experimental configuration, illustrated in **Fig. 1**, has operating and standby bias points of 5V, 85 mA and 0V, 0 mA, respectively. The power strobe enables the output of the switching circuit that is connected between the power supply and the memory chip $V_{cc}$ pin.

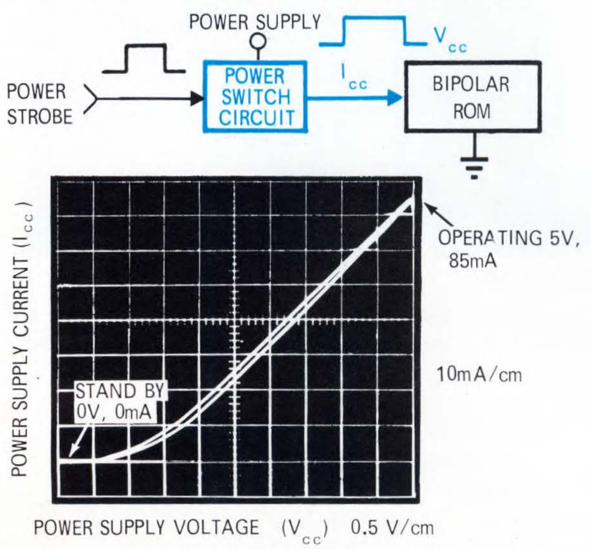



Fig. 1—**A power strobe enables the power switching circuit** connected between the power supply and the $V_{cc}$ of the bipolar ROM M$\mu$L 4106. Operating and standby bias points are indicated on the scope trace ($I_{cc}$ vs $V_{cc}$).

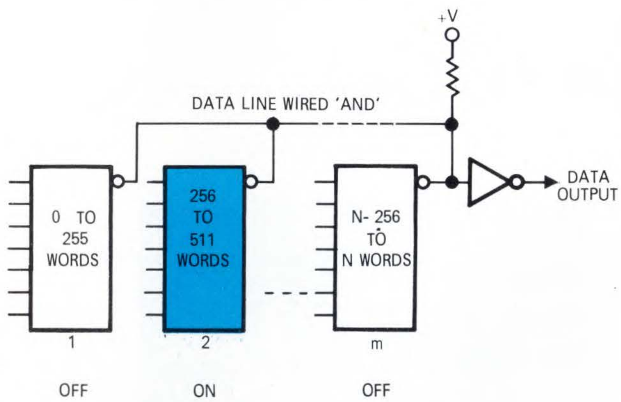



Fig. 2—**Only one memory package operates** when the data output line is in a wired AND connection. For example, if word 389 is addressed, only package 2 is in an operating mode. For this configuration, the OFF (reset state) is a high-voltage level.

Because the ROM is a metal-programmed memory, data is not destroyed when $V_{cc}$ becomes zero. Also, the output data pins of the memory packages are connected to a common bus as a logical *"AND"* function (positive logic convention, High = 1). Therefore, it is important that the output data transistors remain OFF when $V_{cc}$ becomes zero, which is the case for M$\mu$L 4106. Note that for this wired-*AND* operation, the OFF or reset state is a high voltage level. If the output transistors do not remain OFF when $V_{cc}$ is zero, then isolation gates such as diodes are required for each memory package—another cost increase when using power switching.

To verify the switching concept with a memory stack, a power switch circuit was breadboarded with worst-case capacitive loading. It represented part of a 2048-word by 48-bit stack that operates simultaneously with 12 memory packages to attain the 48-bit word. The power switching circuit with package layout is described in **Fig. 3**.

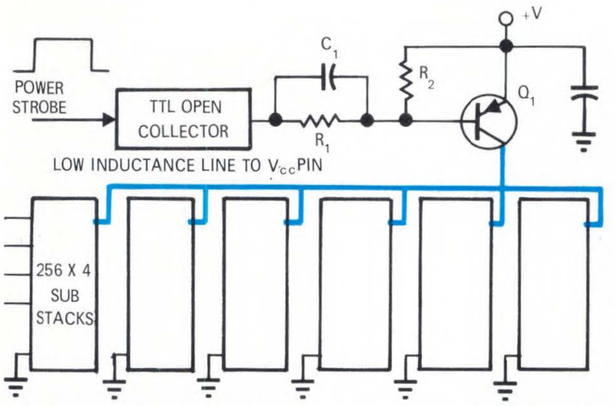



Fig. 3—**A 256 × 24 substrate requires six 4106 elements.** Since maximum $I_{cc}$/device is 125 mA, a single power switching circuit provides the required 750 mA. To minimize the inductive voltage drop in PC board runs, they should be as wide as possible. A group of three open-collector TTL inverters in parallel generates both the logic input to the power strobe and the output drive needed to sink the base current from the power switching transistor Q1. Components R1, R2 and C1 are available in a DIP at about the same parts cost as discrete parts.

For the dynamic operation of the 4106, the power strobe to data output delay is 50 nsec with power switching and 30 nsec without power switching (see **Fig. 4**). In this case, both power switching circuit and the chip select were enabled simultaneously. It is also possible to use the power switching circuit as a chip select. However, the data output recovery time is long because of the voltage decay time of $V_{cc}$ caused by the charge storage time in Q1.

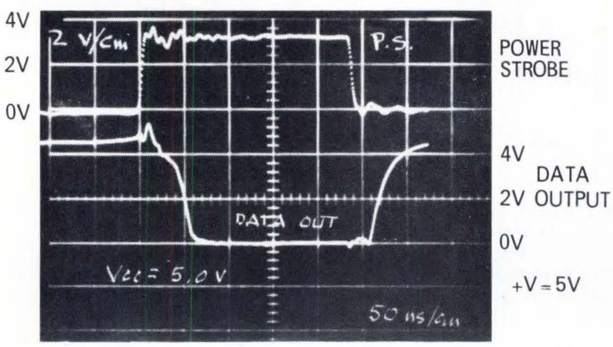



Fig. 4—**In the dynamic operation of a MμL 4106,** the power strobe to data output delay is 50 nsec with power switching (see scope trace) and 30 nsec without.

If the select is employed to enable the chip, then the recovery time of $V_{cc}$ caused by the storage and turn-OFF time of Q1 does not control the output data recovery time but the chip select controls this time. If the chip select is always enabled or disabled, then the output data line function and timing are set by the combination of the chip-select state and the power strobe time, as shown in **Fig. 5**.

Since the output data transistor is OFF (high) when either the power strobe or chip select is OFF, switching the power adds another selection dimension for addressing memory packages within a memory stack. A 2-D structure as shown in **Fig. 6** reduces the number of address drivers.

A 2048-word by 48-bit memory using TTL with one 5V

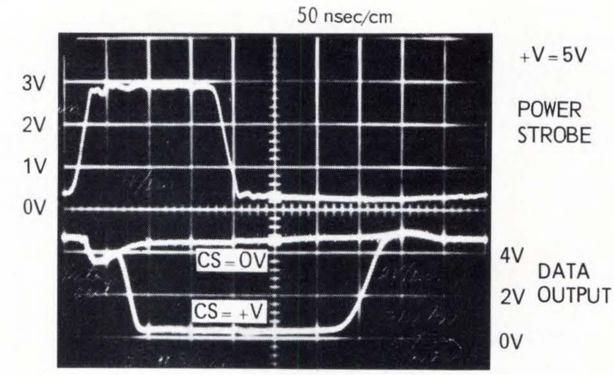



Fig. 5—**Data output** is HIGH, as shown, when the chip-select line is in the OFF state. However, the voltage decay time of $V_{cc}$ decreases the recovery time of the data output upon the enabling of the select line.

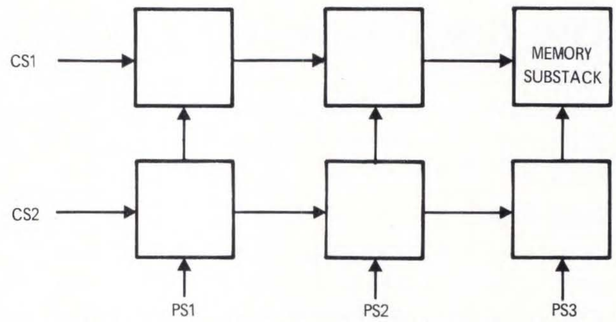



Fig. 6—**Two-dimensional structure** reduces the number of address drivers. Inputs PS1, PS2 and PS3 are separate power strobes and CS1 and CS2 are separate chip selects into the memory array substacks.

power supply for a computer disk-drive controller application has power requirements, including address buffers and data registers, listed in the following table:

| Mode | Standby power | | Operating power | | Max access equals cycle time |
|---|---|---|---|---|---|
| | Total | Per Bit | Total | Per Bit | |
| Without power switching | 65W | 0.65 mW | 65W | 0.65 mW | 105 nsec |
| With power switching | 10W | 0.10 mW | 20W | 0.20 mW | 145 nsec |
| With power switching and low-power TTL | 3W | 0.03 mW | 14W | 0.14 mW | 260 nsec |

## Bipolar RAM

To apply the power switching concept to a bipolar random-access memory, the 93400 with the following characteristics was used.

**Size**—*256-bit, 16-lead DIP*

**Organization**—*256 × 1, 3-out-of-6 decoder, common input/output data pin*

**Input/Output**—*TTL*

**Access Time**—*100 nsec at 5V*

**Power Dissipation**—*625 mW max (5V)*

Power switching constraints for the RAM are:

—Output data transistor must be kept OFF when the power supply voltage is reduced.

—Voltage cannot be reduced beyond the point where data is destroyed

—There must be a significant power reduction in the standby mode to make this worthwhile.

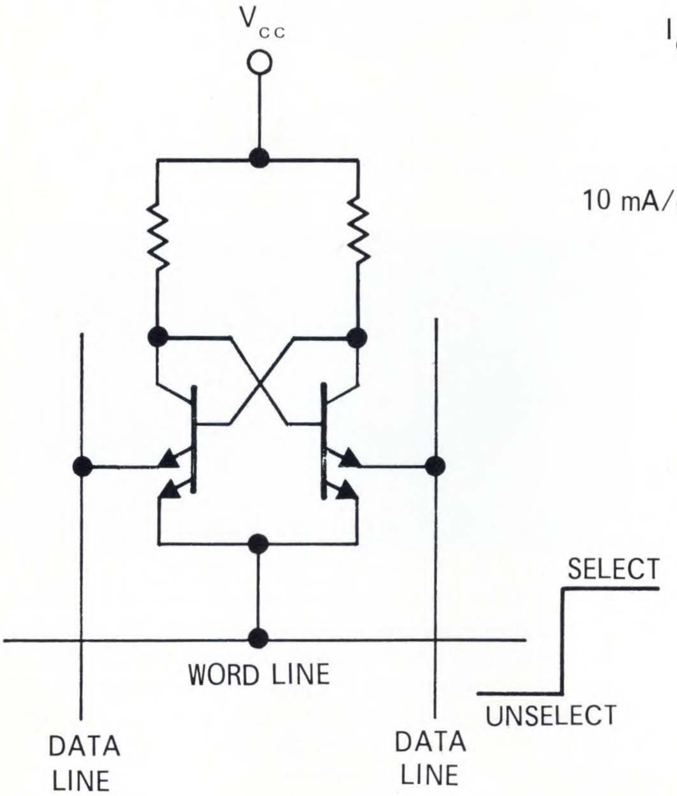
The first consideration of keeping the output data transistor OFF is attained with the same technique used for the bipolar ROM. Now two modes can be employed to reduce the power dissipation in the multiple emitter-type memory cells (**Fig. 7**). The first and most obvious is reducing the power supply voltage. Another less obvious, but also effective, is to select (raise the voltage) all internal chip word lines in the standby state and then disable the unaddressed word lines for the correct address.

When the word-line voltage is high or enabled, the dc voltage and the data line voltage sets the voltage across the memory cell. Whereas, when the word-line is low or disabled, the dc supply and the low word line voltage sets the cell voltage. Thus in the enabled state, the memory-cell power is reduced as compared to the low or disabled state. The scope traces in **Fig. 7** illustrate this condition.

This addressing concept can only be obtained with non-decoded chips or with chips using a decoder like the 3-out-of-6 for the 93400 which has an all ON state. With this type of decoder, all word lines are selected if all six input lines are selected. Note that for a binary decoder, only one word line is selected at a time, hence this type of power reduction cannot be built.

To verify the storage and dynamic operation of a RAM chip in a power switching mode, a set of memory devices was breadboarded in a circuit similar to the one illustrated in **Fig. 3**. Only exception is that the series diode resistor regulator network in parallel with the power-switch transistor Q1 is not used. The dynamic results are shown in **Fig. 8**.

Two possible modes of addressing were examined. The all-address high standby mode was abandoned because disabling the word line and recovering the bit line and the sense amplifiers requires a long time. Data shown in **Fig. 8** was obtained with all of the addresses low in standby. To



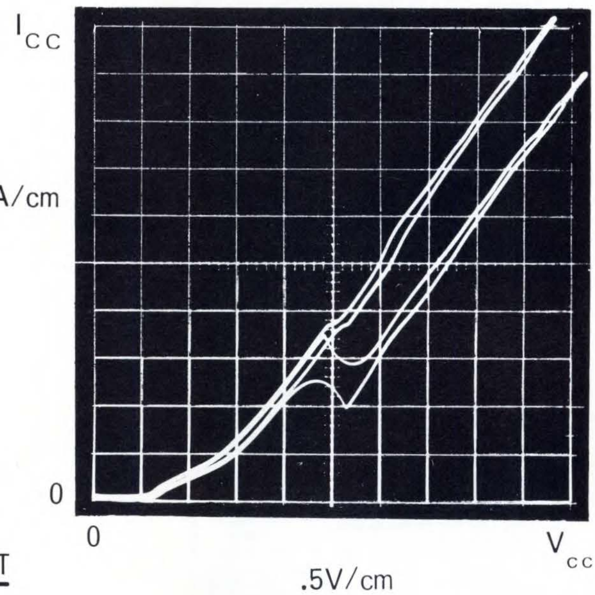




Fig. 7—**In a multiple-emitter memory cell,** the dc supply word line and data line voltage determine the voltage across the memory cell. The scope traces illustrate the effect on the power supply characteristics of the 93400. Top trace represents the condition when all but one-word line are low, and the bottom trace is for all word lines high. Thus when all word lines are high (lower trace), the cell power is lower as compared to the first condition (top trace). For maximum speed, it is desirable to have more cell power during selection than during standby—contrary to the way most multiple-emitter cells operate. A negative resistance region occurs as $V_{cc}$ is varied near 2.5V. This occurs as the cell current stops flowing into the word line and starts flowing into the data line but at a reduced value. Operation in the negative resistance region should be avoided because of the possibility of oscillations that could destroy stored data. Two operating points shown on the scope traces indicate that about 75 mW of power is conserved simply by selecting all word lines during standby.

In reducing the power supply voltage, both the OFF state of the output circuit and the nondestruction of data have to be considered. The OFF state of the output data transistor limits the supply voltage to a lower limit of about 3V, whereas the lower limit of data destruction is about 2V. Thus the data destruction limit (3V) establishes the lowest standby voltage. A reduction from 5 to 3V represents a 50% saving in power supply current. If a single supply is used, then only a 50% power saving occurs because of regulator power dissipation.

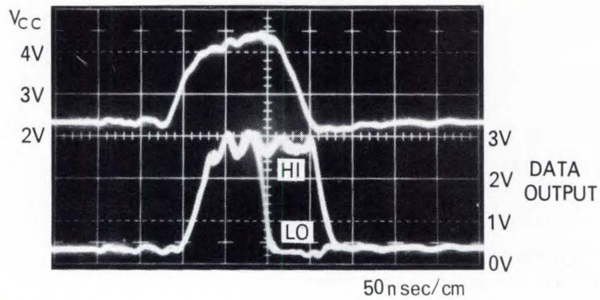



Fig. 8—**Top trace** is $V_{cc}$ pin at the 93400 with a 2V standby, and the bottom trace is the input/output data line reading out a checkerboard pattern. A tester verified the checkerboard pattern accuracy. Note that the unselected state of the data line is low because $V_{cc}$ falls below 3V in standby. Because of the power switch circuit delay and the reduced operating value of $V_{cc}$ due to $V_{sat}$ of Q1, the 93400 read data access time is increased by approximately 70 nsec.

estimate the system operation, a small (1024 × 8) buffer was designed with the power switching circuits to get a realistic indication of the actual power saved, and the results were as follows:

| Mode | Standby power | | Operating power | | Max access equals cycle time |
|---|---|---|---|---|---|
| | Total | Per Bit | Total | Per Bit | |
| Without power switching | 24W | 3.0 mW | 24W | 3.0 mW | 180 nsec |
| With power switching | 16W | 2.0 mW | 21W | 2.6 mW | 280 nsec |
| With power switching and low-power TTL | 10W | 1.2 mW | 13W | 1.6 mW | 365 nsec |

Cycle and access times include the time from the address driver input to the data register output. The power levels were obtained by switching only that part of the memory stack (substack) being accessed. Note that a more significant power reduction is obtained by using both power switching and low power TTL circuits. However, the access and cycle times increase to approximately twice those achieved without power switching.

## Author's biography

**Frank S. Greene,** president of Technology Learning Corp., performed the work described in this article while at Fairchild Systems Technology, Sunnyvale, Calif. There he also designed the semiconductor memory system for the ILLIAC IV computer. Frank received his Ph.D in E.E. from Santa Clara University and an M.S.E.E. from Purdue University. He has one patent pending and is a member of IEEE.

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# Computer graphics — who needs it? A lot more people than you think.

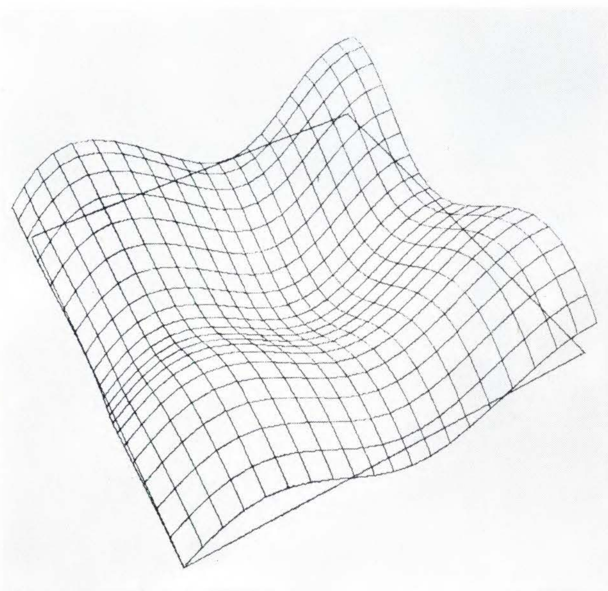
*Adding a graphical device may seem frivolous but the return on investment can be great.*

Computer graphics is a difficult topic to discuss because it means different things to different people. In part this attitude is caused by the looseness of the term "graphics". Are we talking about a little gadget that draws pictures or patterns? Are we referring to a line printer that generates reams of data printout pages? Are we referring to a newspaper whose copy is typeset by or through the assistance of a computer? Each of these illustrations could be put in the "graphics" pigeonhole.

The addition of a graphical device to a computer system seems frivolous to many people because there seems to be no immediate benefit to such an arrangement. However, upon examining the term "graphics" a little more closely in some areas, the question "who needs it?" answers itself. The case of the newspaper publisher is an example if we consider his job "graphics". Nevertheless, there are areas that remain vague and a few ground rules must be defined before describing how graphic systems are effectively employed.

## What is computer graphics?

Computer graphics spans a wide range. Graphic peripheral devices range from simple point plotting to video devices and microfilmers. Also, these tools vary in complexity and cost as well as use.



**Three-dimensional surface plot** is an example of hardcopy computer graphics. Using a FOCAL-based plotting program, this was generated with a PDP-8/L computer. Because of the program elements, this sort of plot is usually not performed in softcopy. If it is, then it is generally generated on a storage tube.

An obvious distinction between a permanent and a temporary graphical output is that the permanent unit generates a plot onto a sheet of paper or a trace onto a microfilm. The paper plot, though destructable, is unalterable and the microfilm, once developed, is equally a finished product. Peripherals producing this type of output are referred to as "hardcopy devices" and generally their outputs are the last step of the computer's process.

By contrast, the temporary graphical displays are almost invariably designed to include a cathode-ray tube (CRT). Such a peripheral presents the image in the form of lines or points of light on a display screen. Unlike a hardcopy graphical image, the light image can be altered if desired because of its temporary nature. A peripheral generating such an image is known as a "softcopy device". Perhaps it is worth noting that those wishing to preserve a softcopy image, can often convert the softcopy to hardcopy through photographic techniques.

Because of the transitory nature of a softcopy display, it is seldom that the initial image is in its final form — softcopy images lend themselves to manipulation. So it might be better to consider graphical outputs mainly in terms of their significance to the computer problem.

## Hardcopy versus softcopy

Hardcopy devices, by their very nature, seem easier to understand in terms of 'who needs graphics?'. Obviously the answer is anyone who has some form of processed data that he desires a finished graphical interpretation or version. This includes scientists who need graphical plots of finished data; cartographers who want computer-generated maps; and all individuals with similar needs for finished (and usually non-real-time) graphics.

Softcopy graphical devices are more difficult to talk about because less people are familiar with them. They are highly useful, but frequently ignored because those who can use them are relatively unaware of their existence. Consequently, this discussion will emphasize the less well known softcopy devices.

As previously mentioned, softcopy devices employ some form of video display — that is a CRT with a screen face on which a light image is activated through the use of directed electrons. There are two basic types — refresh and storage.

A refresh tube requires the image to be continuously updated if it is to be viewed by human eyes. This is equivalent to a television receiver and most oscilloscopes. Once the electron beam generates a picture, it will vanish immediately unless it is redrawn — actual time depends upon the phosphor used but the decay period is still in terms of seconds or fractions of seconds.

By contrast, storage tubes need only to have the picture drawn once with the electron beam and the image is retained for a long period of time—usually in minutes. Pictures may be created over a longer period of time because the user has no worrry about the initial image fading away while the later parts are being generated.

The characteristics of the tube displays lend themselves to various applications. Refresh tubes lend themselves to environments and situations where the image is in a state of flux. Storage tubes are employed in static applications. There are tradeoffs but the above statements provide a fairly reliable guideline to follow.

## Point plotters offer simplicity

A point plotter represents the simplest form of softcopy devices. As the name implies, it is a device controlled by the user's system that generates points of light on a display screen. Scientists, technicians and other professionals in fields as varied as clinical medicine and nuclear physics have need for point-plotted data. Whether the user is a chemist watching the output of his chromatograph or an engineer examining the result of a mathematical simulation, effectively he is looking at some form of a graph. It does not matter why he requires the points plotted into graphical form, but what is important is that he needs the data immediately and with precision.

The degree of speed and precision required in a graphical terminal determines the design and ultimately the price. Where ordinary point-plotting equipment is priced in the \$1000 to \$3000 range, those satisfying the high speed and very high precision requirements cost \$10,000 to \$12,000.

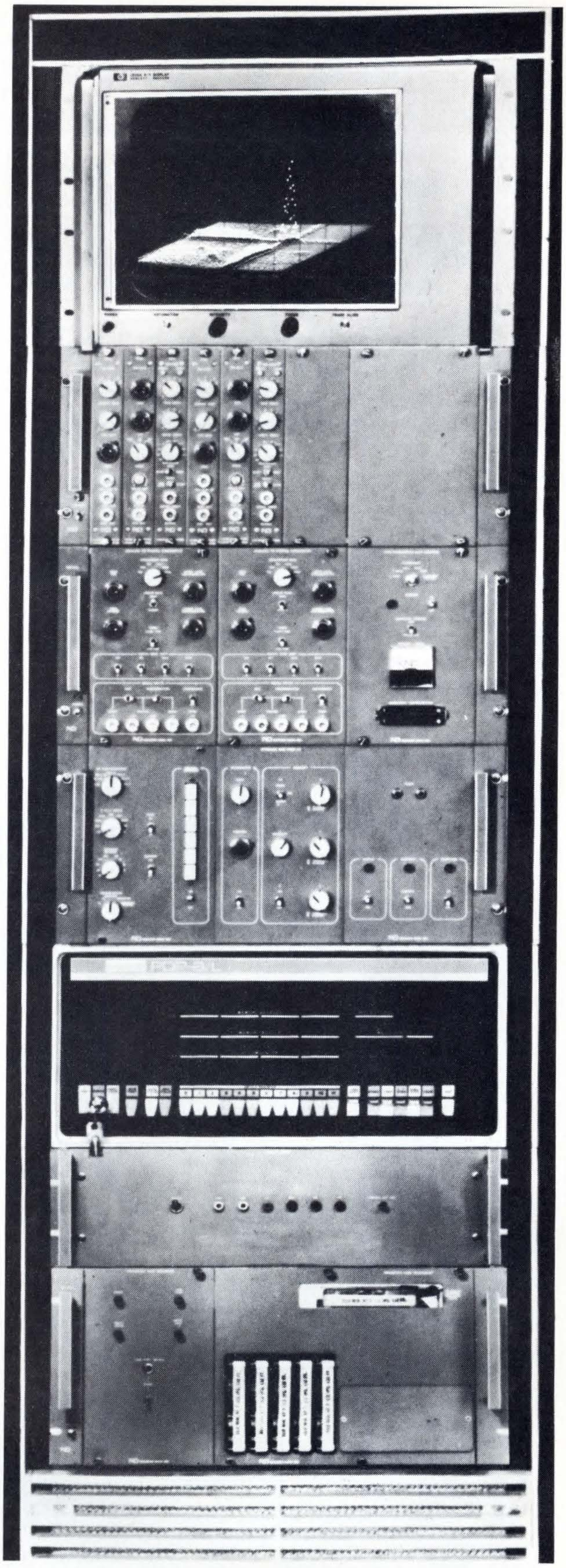
Point plotters are, in one sense, the *ultimate* graphical devices, because a succession of points can generate any line, figure, character or combination. In order to achieve this, considerable time and programming must be spent, particularly for the complex images. In this respect, the point plotter becomes far from an ultimate device because it can do virtually anything graphical but only with great loss in efficiency.

To increase the efficiency of the graphical presentations, other complex devices have been created. Each one, in essence, relieves the computer from some of the work involved in creating a display. In turn, the computer can devote more of its resources to the data rather than the display.

One such device is the alphanumeric terminal. On the screen, characters, numbers and punctuation marks are generated with internal logic rather than by computer. These units are popular in a variety of fields, generally where textual information is needed immediately and where the terminal must operate reliably and silently.

## Alphanumeric terminals have many uses

Recent studies indicate that there are more than 100,000 alphanumeric terminals in use and that this number is increasing by about 20 to 25 percent annually. Stock brokers use specialized versions for the latest market quotations, issue orders, etc. Major airlines use alphanumeric displays on-line with their reservation systems to verify airline capacities, for reservations, and to display other passenger information. Hospitals are beginning to employ these sys-



**Nuclear Data, Inc. 50/50 system** demonstrates one of the most fundamental forms of softcopy computer graphics—point plot in three dimensions. This type of system usually employs a small computer, in this case a PDP-8/L.

tems at their nursing stations for access to the hospital information system and to quickly and silently retrieve patient data and dietary information—silence is especially important in a hospital.

Schools and universities are considering alphanumeric terminals as an instructional device. Computer-aided instruction is becoming increasingly important in education, for it yields a teaching system that can cope with the problem of devoting sufficient time and attention to each student while being faced with a student population that is expanding at a faster rate than that of the teacher population.

Management information is another activity that is beginning to use alphanumeric displays. Displays connected to management information systems provide the manager with information or actual decision guidance in a pleasant-looking and silent form. Such systems are popular in finance and industry.

### Users demands increase

When people begin demanding more characters on a screen display, their needs introduce many variables that have to be considered. A softcopy display, as noted earlier, usually is a presentation of some intermediate step in the activities of a computer. Usually this implies that a certain degree of interaction between the user and the process is desirable. This might be as simple as merely altering the operation of an analytical instrument while an experiment is taking place, or it may be as complex as carrying on a dialogue with a computer, either by words or in constructing an image by parts. In any case, interactive abilities lend themselves to establishing the parameters of a desired system.


**Engineer uses a light pen for interactive design** with a softcopy display device. For this application, a refresh display is required. The system, Graphic 15, is built around the PDP-15 computer.

Whenever a graphic system is contemplated, beyond the point plotter of alphanumeric stage, certain questions become apparent. First, is the system to be independent (local) or is it to be connected to a remote computer through some form of communication lines? Added to that, other considerations such as the size of the establishment it is to service, whether the display is part of an overall configuration or whether it is merely a subsystem or something far different must be taken into account.

### Remote operation develops peculiar situations

Because of the economics of the equipment involved, storage tubes usually are used for remote interactive work. This is because it is usually highly impractical—and sometimes completely impossible—for a remotely located computer to refresh a terminal display. Thus, the user has the choice of either purchasing a display with its own refreshing capability (for something in the neighborhood of $35,000 or more) or sacrificing some of the actual interactive capabilities of the computer by using a storage tube to eliminate the image refresh requirement. Since a storage tube terminal costs some $25,000 less than a terminal with its own refresh capabilities, some users gladly accept a reduction of interactive capabilities for the more economical approach.

Interactive displays have a variety of applications, but some of them can tolerate the use of storage tubes where others cannot. For example, Computer Aided Instruction (CAI) can afford to use the storage tube approach. This is because CAI is usually conducted in a dialog between computer and student. However, the dialog, whether alphanumeric or otherwise, is usually static and requires a specific decision from the user. Even in the university environment, where the student may want a pictorial representation of his performance, this approach remains valid if the results are treated as static images.

### Image for your needs

If a dynamic image is required, a refresh display becomes the obvious choice. Computer-Aided Design (CAD), in ways similar to CAI, can tolerate the use of a storage tube only in the simpler analytical situation. Usually, CAD requires the length of a line to be altered or an image element to be reoriented or relocated on the screen face—almost invariably impractical on anything but a refresh display.

A designer using a CAD system alters his image pictorially while the computer performs the equivalent mathematical operations and displays the results. This permits analysis of any design alteration to determine whether it is feasible and in many cases, it allows the system to optimize the initial design.

As a result, CAD is useful to communication system designers in establishing the most efficient way to run lines between terminals. Civil engineers use interactive graphics for road designs and calculate the stresses that a bridge would be subjected to. Architects use CAD for designing buildings and determining the optimum number of rooms, their size and distribution within the building. Electronic firms develop circuits, determine the system specifications and use CAD to assist in parts layout.

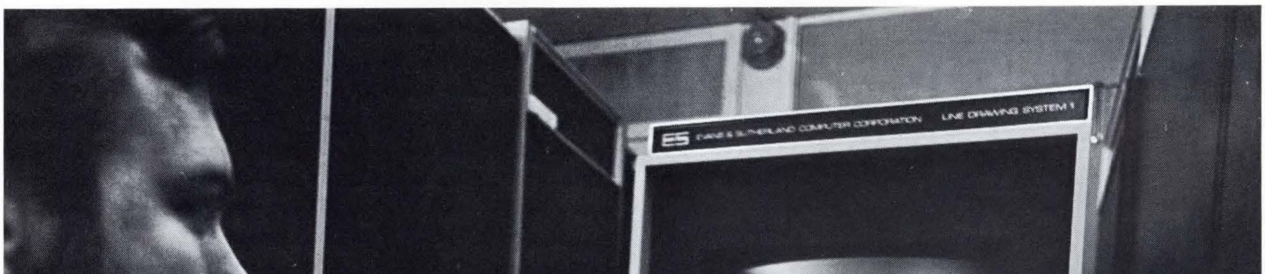
Besides CAI and CAD, interactive displays are applicable in many other areas. One of the most dynamic is simulation. A typical application of interactive graphical displays is flight simulation. In some cases, the display is used for pilot training, since the student's actions are reflected in the display and if he should 'crash', the only bad mark will be from the instructor.

Aeronautical engineers wishing to determine if a proposed design really works perform flight simulations of a different type. During a 'test flight', the engineers introduce stresses to the aircraft design and observe the resultant behavior. Not only can they test a design's airworthiness, but with interactive graphics, they obtain an idea of what limits to assign to such a design. Also the test pilot is provided with a better idea of what flight restrictions apply to a new model.

## Computer graphics bestows many benefits

Reflecting back upon the varied uses of interactive softcopy computer graphics, it is evident that there are a great many fields that benefit from what is referred to as "computer graphics". Until recently, many people who could benefit from computer graphics were stymied by the operational costs of a system. Large organizations like NASA,


**Interactive softcopy display** run on a PDP-12 computer is used in medical waiting rooms to interview patients. Such a dialog ensures that the patient's history is complete and accurate. Using a visual display permits maximum dialog to take place rapidly and at relatively low cost.



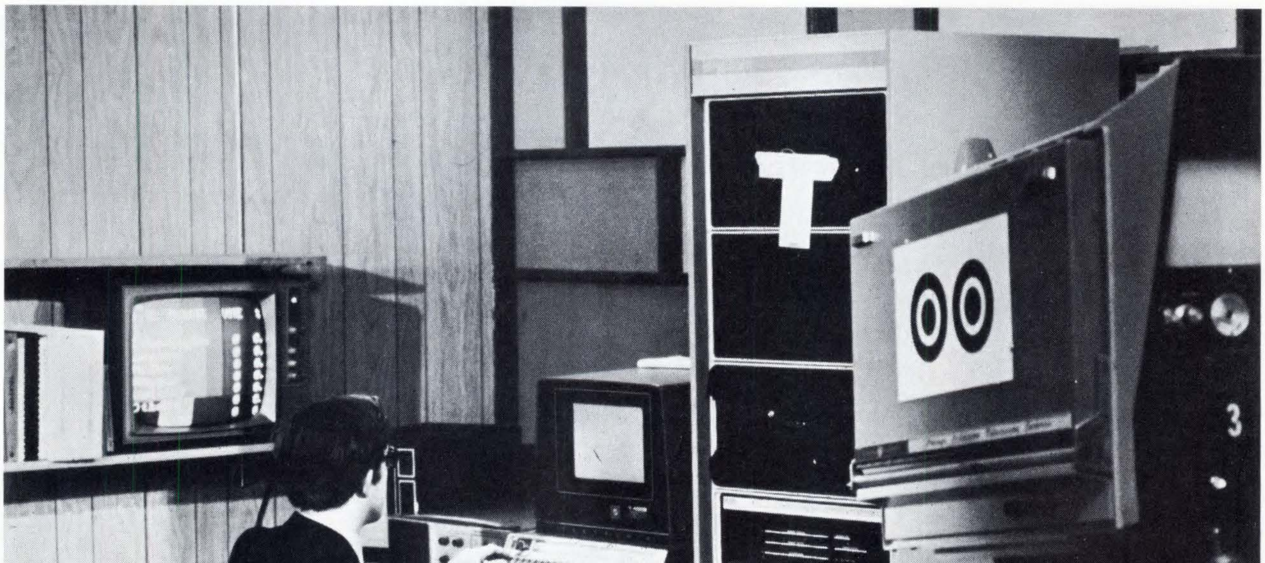

**Large computer systems** such as the PDP-10 find use with softcopy display applications. Frequently, larger computers are used for complex simulation displays, network design and similar applications requiring high computational power.

General Motors, Boeing or the National Institute of Health could afford these systems, but the user with a small budget could not.

Now the picture is changing. A revolution in the application of computer graphics has been initiated with the introduction of inexpensive computer graphic systems. Those who previously could not afford a system are beginning to get access to their own systems. From simple point plotters, remote graphics devices or inexpensive interactive graphic systems (i.e. a price of under $10,000 for a terminal) have created a new era of computer graphic applications. With the new inexpensive systems, the graphic needs of students, scientists, engineers and many other professional personnel are easily satisfied. □

### Author's biography

**Robert L. Katz** is responsible for display graphics marketing development at Digital Equipment Corp., Maynard, Mass. Mr. Katz is a graduate from Massachusetts Institute of Technology with a B.S. and he received his M.S. from the Sloan School of Management. He is a member of the Institute of Management Sciences and of the Society for Information Display.




**Data to an on-screen visual display** (left) informs the Public Television Network audience of the latest voting developments. As each delegate votes, PTV personnel located near the convention floor transmit this data to an operator who updates the computer.

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# One-Chip CPU available for low-cost dedicated computers

"Announcing a new era of integrated electronics."

This introduction for a new IC may seem immodest but Intel Corp. might just be correct. The IC is a single-chip CPU designed for low-speed microprogrammable applications such as terminals, peripherals, test systems and process control. The one-chip CPU was described at the EDN/EEE seminars in August.

The CPU, Type 4004, is designed to work with other members of Intel's MCS-4 microcomputer set. The other ICs in this kit of standard building blocks are the 4001 ROM, 4002 RAM and the 4003 shift register (SR).

The minimum system configuration consists of one CPU and one 256 × 8 bit ROM. For one-of-a-kind applications, an electrically-programmable ROM can be used in place of the mask-programmable 4001. The MCS-4 microcomputer is fabricated with silicon gate, low-threshold MOS technology.

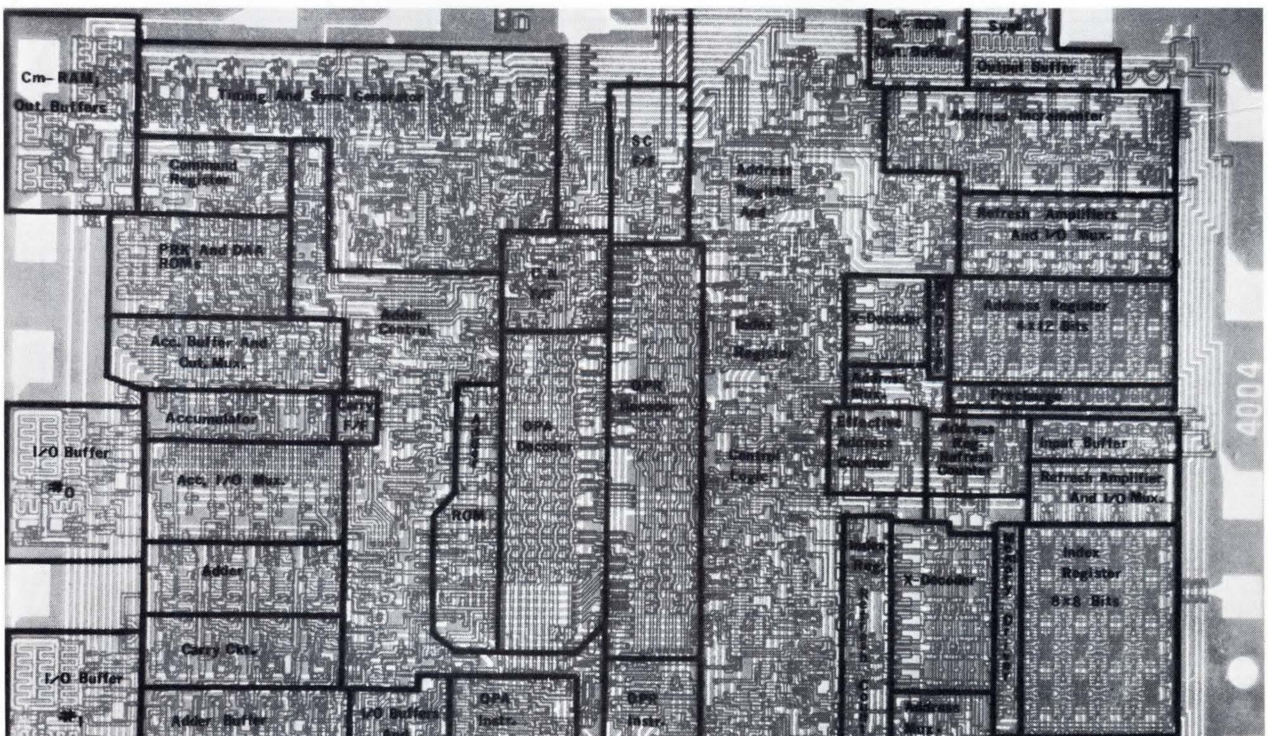
Packaged in a 16-pin ceramic DIP, the CPU chip consists of a 4-bit adder, a 64-bit (16 × 4) index register, a 48-bit (4 × 12) program counter and stack, an address incrementer, an 8 bit instruction register and decoder, and control logic.

Forty five instructions are included in the 4004's repertory. All timing, control and arithmetic operations are implemented internally.

Information flows between the 4004 and the other chips through a 4-line data bus. A system built with the MCS-4 set can have up to 4k × 8-bit ROM words, 1280 × 4 bit RAM characters and 128 I/O lines without requiring any interface logic. With the use of external gates the computer size can be increased even further.

The MCS-4 uses a 10.8 μsec instruction cycle. The basic instruction execution requires 8 or 16 cycles of a 750-kHz clock. Addition of two 8-digit numbers requires 850 μsec.

Custom systems using this 4004 chip are implemented by microprograms stored in a ROM. The idea of microprogramming a processor to imple-



ment a special controller is not new. IBM's system 360 computer and HP's 2100A desk calculator are two examples of both large and small systems that have exploited the inherent design and production advantages of microprogramming. In desktop calculators about 35% of the logic is associated with doing arithmetic. The other tasks are keyboard encoding, printing results, displaying status and general control. These functions can be done by microprogramming rather than by additional random logic. Microprogramming can even be used for keyboard switch de-bouncing and for converting 4-bit BCD code to 7-segment lamp code. Many features may be added to systems using this chip by providing additional ROMs.

This approach provides a flexible and modular technique for system design in which memory devices are used instead of logic devices. The major limitation to its application is speed. While an IC logic can make a decision in about 5 nsec, and combinatorial networks allow many decisions to take place in parallel, this computer chip performs decisions sequentially at 10.8 $\mu$sec per instruction.

The instruction repertoire of the 4004 consists of 16 machine instructions, 14 accumulator group instructions and 15 I/O and RAM instructions. A partial listing of the instruction set includes:

**DATA MOVES**
- Register to register
- Register to memory
- Memory to register

**ARITHMETIC & LOGICAL**
- Add
- Subtract
- Encode
- Complement
- Shift
- Rotate
- Increment
- Decrement

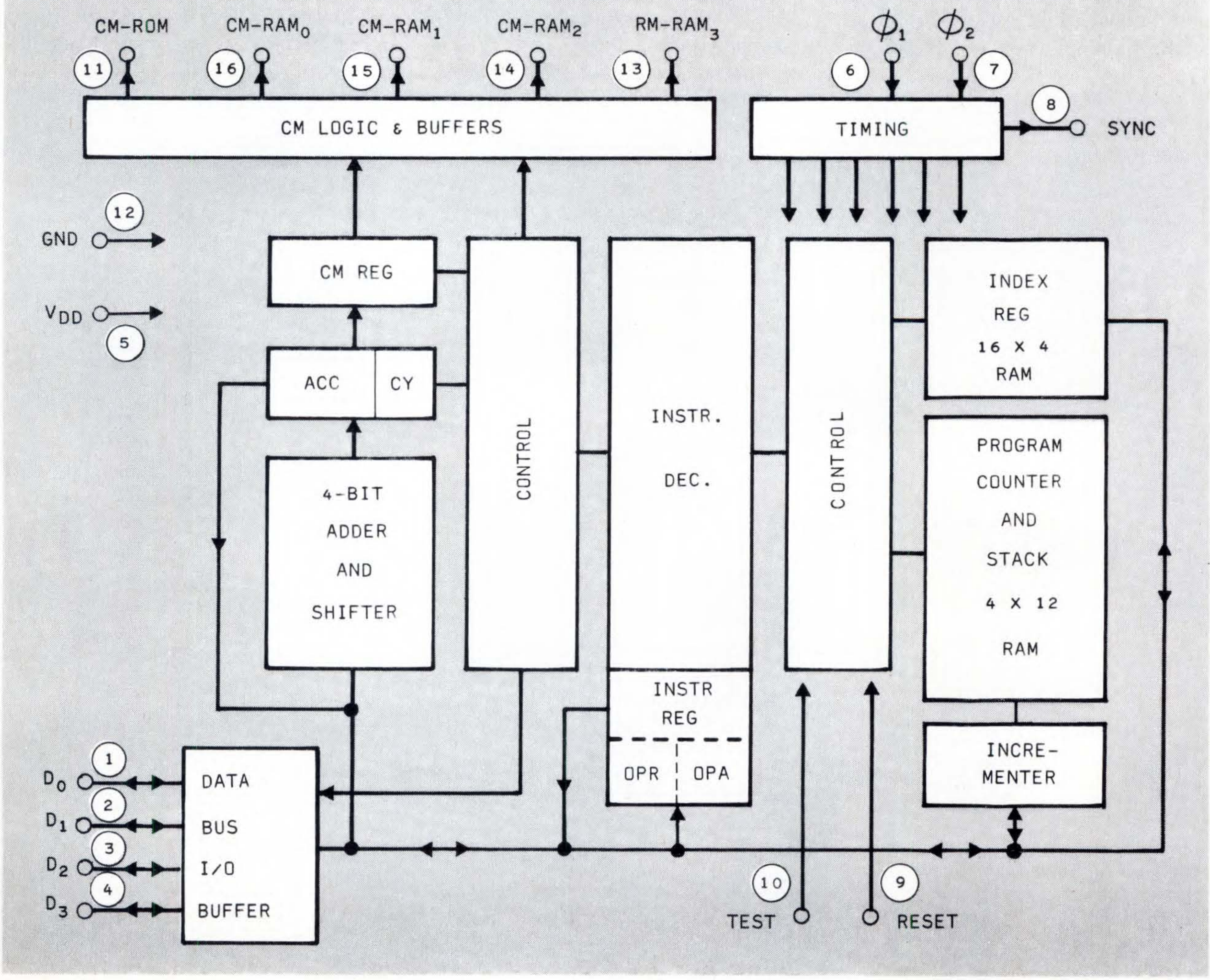
**CONTROL**
- Conditional jump
- Call
- Return
- I/O

The MCS-4 microcomputer set is available from Intel Corp. 3065 Bowers Ave., Santa Clara, CA 95051. Prices for the individual members of the set are:

**479**

| Part No. | Quantity | |
|---|---|---|
| | **1-24** | **100-999** |
| 4001* | $60.00 | $18.00 |
| 4002 | 50.00 | 15.00 |
| 4003 | 10.00 | 3.00 |
| 4004 | 100.00 | 30.00 |
| *(excluding mask charges) | | |

**4 BIT CENTRAL PROCESSOR UNIT (CPU) WITH 45 INSTRUCTIONS**



# Now JAN high voltage power switching transistors...

## it's a point worth repeating.

And they're available from Unitrode — optimized for the best combination of switching speed, saturation voltage and second breakdown to help you design more efficient power switching circuits. The result is performance features like these . . .

| Series | $I_C$ (max) | $V_{CE}$ (sus) (min) | $V_{CE}$ (sat) (max) | $E_{SB}$ (min) | $t_{ON}$ (max) | $t_{OFF}$ (max) |
|---|---|---|---|---|---|---|
| 2N5660 | 2A | to 400V | 0.8V @ 2A | 1.00mj | 0.25$\mu$s | 0.85$\mu$s |
| 2N5664 | 5A | to 400V | 1.0V @ 5A | 1.25mj | 0.25$\mu$s | 1.50$\mu$s |

The 2N5660 — 2N5667 series is available in TO-5 and TO-66 packages as JAN and JANTX power switching transistors to MIL-S-19500/454 and /455. Now that the best has been officially accepted, all that's needed is your approval. For fast action, call Sales Engineering collect at (617) 926-0404, Unitrode Corporation, Dept. 1 Z, 580 Pleasant Street, Watertown, Mass. 02172.

UNITRODE


CIRCLE NO. 12

# Digital-readout gain-phase meter spans 1 Hz to 13 MHz

*PROGRESS IN GAIN-PHASE METERS*

Basically this new instrument provides a better way to make simultaneous gain and phase measurements at audio and low RF frequencies. It does so without frequency tuning *or* amplitude setting—and covers a wider frequency range than its competitors.

Several features of the 3575A are of considerable importance to a user. One such is its unique correction scheme to reduce noise-caused errors. This eliminates errors caused by noise in some situations. In other cases, it both makes the errors smaller and causes them to increase less abruptly with an increase in the noise level.

**Effects of noise.** Most phase meters are subject to three types of noise-caused problems: Ambiguity, jitter and offset.

Ambiguity is the condition where readings are impossible because the input to the readout fluctuates wildly. This results in a bouncing analog meter reading, or a digital one in which all digits are constantly changing. It is the type of error that has been eliminated in the 3575A for any level. (Some competitive units require that noise be from 50 to 70 dB below the signal if they are to read correctly, and with greater noise input they can—and do—read 180° in error.)

Jitter caused by noise is handled in the usual way by filtering. Of course, the sample rate decreases as the amount of filtering is increased.

Offset effects from noise are a result of prefiring in the zero-crossing circuits. Band-limiting filtering will reduce offset errors, but the H-P scheme for minimizing the ambiguity problem is also quite effective against the offset error.

A direct comparison of measuring ability will show that both the 3575A and competitive units usually are free of noise-caused reading errors if the noise level is 60 dB down. At 40 dB down, some competitive units are already in trouble, but the 3575A will have only about 1° error.

### Key specs of the 3575A

—Its 1 Hz to 13 MHz range is considerably greater than that covered by other similar instruments. Phase accuracy is specified as ±0.5° from 1 Hz to 20kHz and phase resolution is 0.1°.

—Its dynamic amplitude span is 80 dB, permitting ranges of 200 $\mu$V to 2V, 2 mV to 20V and (with divider probe) 20 mV to 200V. Amplitude accuracy is ±1 dB from 1 Hz to 1 MHz, with 0.1 dB resolution.

—Its digital readout uses light-emitting diodes for a crisp, compact display.

—It provides Log A/B, or dBV A or dBV B (reference 1 volt).

—It has automatic internal ranging about 0°.

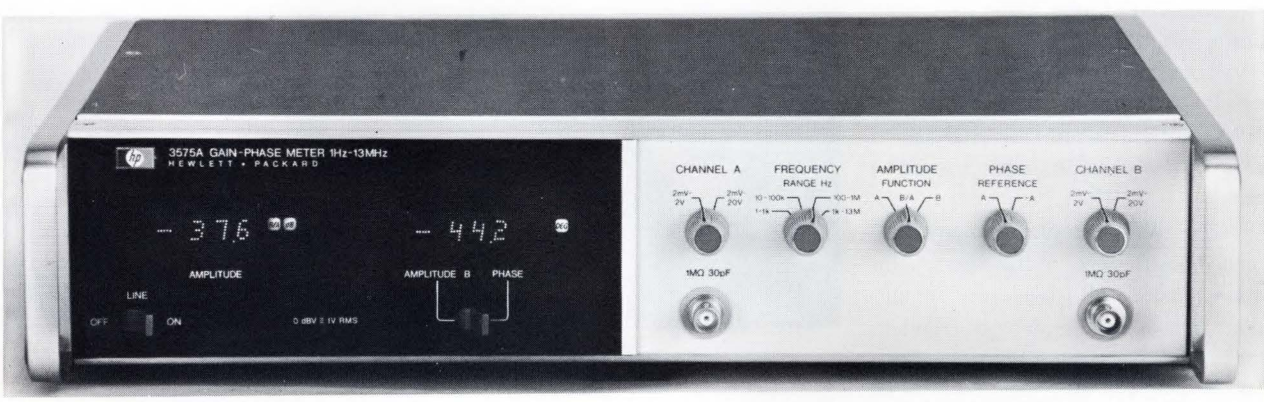
—Overload indication is included.

—The option choice is wide, and includes either one- or two-DPM units; the same plus programming; or units without DPM.

—Prices range from $2100 for the basic one-DPM version without programming to $2820 for the two-DPM version with programming.

### Some applications

Because a gain-phase meter is such a versatile instrument it can be used advantageously in a multitude of situations. For looking at transfer functions, for example, it offers a very use-




**Hewlett-Packard Model 3575A Gain-Phase Meter** is the first such unit with LED digital display to operate without requiring user tuning. Its operating frequency range is from 1 Hz to 13 MHz, and the dynamic amplitude span covered is 80 dB.

ful intermediate choice that avoids many of the problems inherent in using the oscillator-voltmeter method—and that costs a lot less than going to a network analyzer.

Phase lock loops, predicted to have such a bright future, are readily checked with a gain-phase meter. It lets the user determine the effects of adjusting controls such as those for filter response, phase offset and center frequency. After all, phase determines flatness in PLLs.

Group delay situations are often readily assessed by phase comparison techniques—so the 3575A offers an attractive tool here, too.

Both complex admittance measurements (even in active circuits without regard to excitation) and return loss measurements are relatively easy to make with a gain-phase meter.

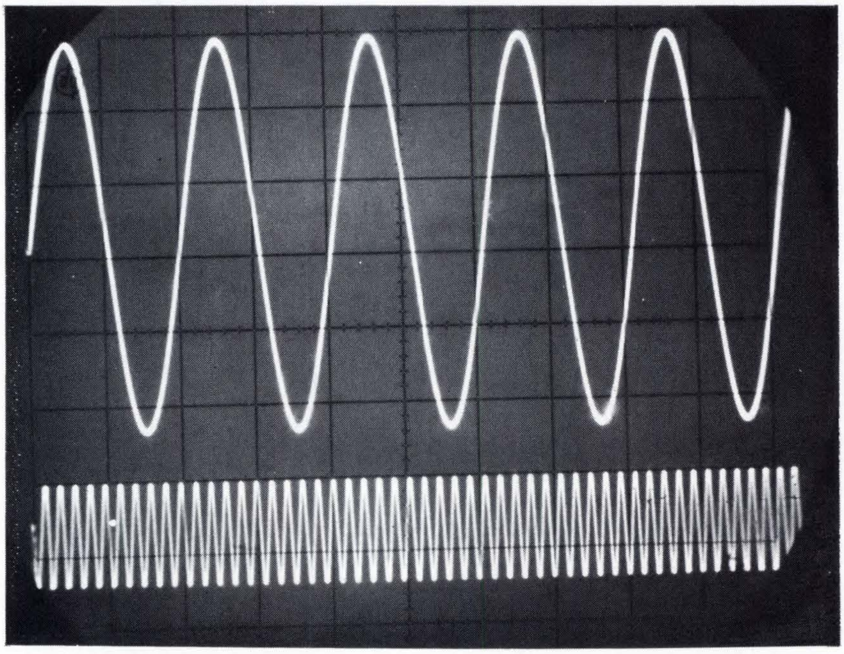
### Summing up

The new 1 Hz to 13 MHz Model 3575A Gain-Phase Meter provides, at these frequencies, much the same capability as the analog-readout Model 8405A Vector voltmeter did from 1 to 1000 MHz.

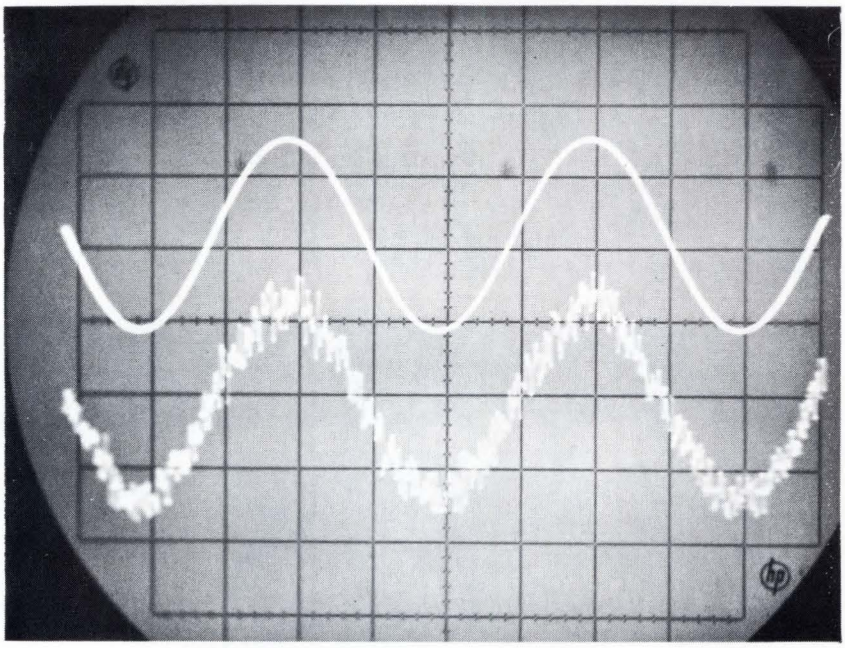
It has an 80 dB dynamic range, measures Log A/B or dBV A or dBV B, was designed for unusual noise-immunity and does not require either frequency tuning or amplitude setting.

Various versions are offered, at prices ranging from $2100 for a one-DPM unit without programmability to $2820 for a programmable two-DPM unit.

It is a new basic tool with many uses, for it measures two of the three major characteristics of waveforms (amplitude, phase and frequency). Hewlett-Packard Co., 1601 California Ave., Palo Alto, CA 94304. **151**



**Versatility of the gain-phase meter** is well-illustrated by its ratio-measuring capabilities. It can measure, in dB, the log ratio of two signals. Further, these signals need not be of the same frequency, which increases the instrument's usefulness.



**Phase measurements of noisy signals** are readily made with the new 3575A gain-phase meter. Even the high-frequency noise present on the lower trace does not preclude a useful phase measurement, for it only results in a phase offset of 2.5°—and the measurement is free of jitter or bobble in the readout.

# Norden Encoders perform for you!

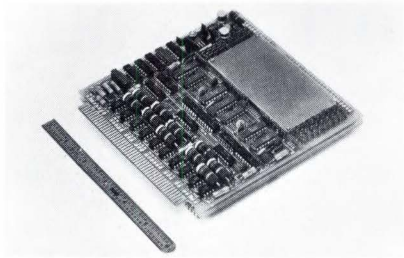
## Look at these new 1971 additions to Norden's line. More are on the way.

| | Total Count | Revolutions for Full Count | Diameter" | Model Number |
|---|---|---|---|---|
| **NEW! Optical Absolute** | 10,000 | 50 | 2.25 | OADC-23/4/BCDQ-200L |
| **NEW! Optical Absolute** | 1,000 | 1 | 2.25 | OADC-23/3/BCD-1000L |
| **NEW! Optical Incremental:** Series now available with shaft seal—permits drenched operation. | | | | |
| **NEW! Contact Size 11** | 8,192 | 32 or 64 | 1.06 | ADC-11/13/BNRY-256L |
| **NEW! Contact Size 11** Altitude Reporting Encoder | 1,280 | 16 | 1.06 | ADC-11-ALT-1280 |
| **NEW! Contact Size 11** | 10,000 | 100 | 1.06 | ADC-11/4/BCDX-100 |
| **NEW! Contact Size 11** | 3,600 | 36 | 1.06 | ADC-11/4-36/BCDX-100 |
| **NEW! Rugged Industrial Grade Optical Incremental Encoders** | | | | |
| All available with quadrature and internal squaring circuit options | 2,000 Pulses | 1 | 3.500 | OADC-35/2000/INC |
| | 1,500 Pulses | 1 | 3.500 | OADC-35/1500/INC |
| | 1,250 Pulses | 1 | 3.500 | OADC-35/1250/INC |
| | 1,000 Pulses | 1 | 3.500 | OADC-35/1000/INC |
| | 600 Pulses | 1 | 3.500 | OADC-35/600/INC |
| | 500 Pulses | 1 | 3.500 | OADC-35/500/INC |
| | 300 Pulses | 1 | 3.500 | OADC-35/300/INC |
| | 200 Pulses | 1 | 3.500 | OADC-35/200/INC |
| | 100 Pulses | 1 | 3.500 | OADC-35/100/INC |
| **Optical Incremental Encoders** | | | | |
| All available with index marker, quadrature outputs and internal squaring circuit options. Other counts on special order | 100 Pulses | 1 | 2.250 | OADC-23/100/INC |
| | 250 Pulses | 1 | 2.250 | OADC-23/250/INC |
| | 256 Pulses | 1 | 2.250 | OADC-23/256/INC |
| | 336 Pulses | 1 | 2.250 | OADC-23/336/INC |
| | 500 Pulses | 1 | 2.250 | OADC-23/500/INC |
| | 512 Pulses | 1 | 2.250 | OADC-23/512/INC |
| | 1,000 Pulses | 1 | 2.250 | OADC-23/1,000/INC |
| | 1,024 Pulses | 1 | 2.250 | OADC-23/1,024/INC |
| **IC-Compatible Encoders. For direct interface with TTL & DTL circuits** | | | | |
| Binary | 128 | 1 | 1.750 | ADC-ST7-BNRY-E/L |
| | 8,192 | 64 | 1.750 | ADC-13-BNRY-E/L |
| | 524,288 | 4,096 | 1.750 | ADC-19-BNRY-E/L |
| Binary-Decimal Code | 100 | 1 | 2.250 | ADC-ST2-BCD/L |
| | 1,000 | 10 | 2.250 | ADC-3-BCD/L |
| | 10,000 | 100 | 2.250 | ADC-4-BCD/L |
| | 100,000 | 1,000 | 2.250 | ADC-5-BCD/L |
| | 1,000,000 | 10,000 | 2.250 | ADC-6-BCD/L |
| | 360 | 1 | 2.250 | ADC-3-36BCD-E-360L |
| | 3,600 | 10 | 2.250 | ADC-4-36BCD-E-360L |
| | 36,000 | 100 | 2.250 | ADC-5-36BCD-E-360L |
| | 360 | 1 | 3.250 | ADC-ST3-36-BCD/L |
| | 3,600 | 36 | 2.250 | ADC-4-36-BCD/L |
| | 36,000 | 360 | 2.250 | ADC-5-36-BCD/L |
| | 360,000 | 3,600 | 2.250 | ADC-6-36-BCD/L |
| **External Logic V-Scan Binary Encoders** | | | | |
| | 128 or 256 | 1 | 1.750 | ADC-7/8-BNRY-XB |
| | 8,192 or 16,384 | 64 | 1.750 | ADC-13/14-BNRY-XB |
| | 524,288 or 1,048,576 | 4,096 | 1.750 | ADC-19/20-BNRY-XB |
| **Single Turn Gray Code Encoders** | | | | |
| Available with various levels of RFI suppression | 256 | 1 | 1.066 | ADC/11/8/GRAY |
| | 256 | 1 | 1.750 | ADC-ST8-GRAY |
| | 512 | 1 | 2.250 | ADC-ST9-GRAY |
| | 1,024 | 1 | 3.062 | ADC-ST10-GRAY |
| **Multiturn Gray Code Encoders** | | | | |
| Available with various levels of RFI suppression | 1,024 | 4 | 1.062 | ADC-11/10GRAY256 |
| | 1,024 | 16 | 1.062 | ADC-11/10GRAY 64 |
| **Low Cost Magnetic Noncontacting Encoders** | | | | |
| Incremental | 128 | 1 | 1.750 | MADC-18/128/INC |
| Binary | 128(V scan) | 1 | 1.750 | MADC-18/7/BV |
| Binary | 8,192(V scan) | 64 | 1.750 | MADC-18/13/BV |
| Binary | 524,288(V scan) | 4,096 | 1.750 | MADC-18/19/BV |

For more information and detailed specs, write Norden, Att: Components Dept., 100 Helen Street, Norwalk, Conn. 06856. Phone (203) 838-4471. TWX: 710-468-0788.

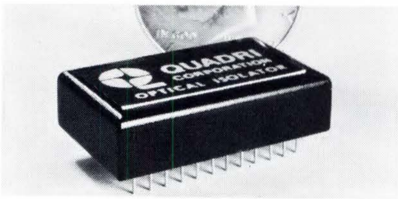
**Norden** DIVISION OF UNITED AIRCRAFT CORPORATION

CIRCLE NO. 22

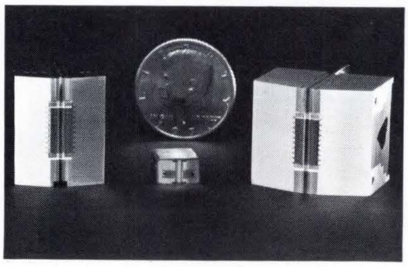


**CORE MEMORY MODULE,** Model 620, is a 1024-word by 10-bit configuration that fulfills desk-top computer and similar small-memory requirements. Operational modes are full-, half- and split-cycle. Access time is 350 nsec and the cycle time is 1 $\mu$sec. The unit operates over the 0 to 60°C temperature range and is nonvolatile. Fabri-Tek, Inc., 5901 S. County Rd. 18, Minneapolis, MN 55436. **154**

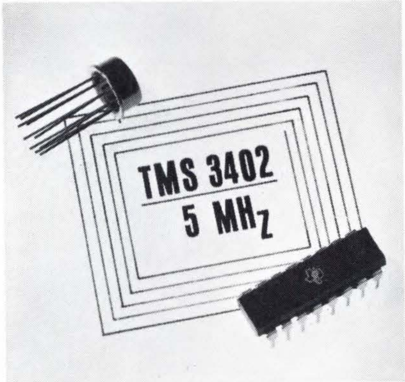

**VIDEO-DISPLAY TERMINAL,** Model 401, features a 132-character display consisting of four lines of 33 characters each. A 5 × 7 dot matrix forms a 63-character USASCII code. There are indicators for operator control and six special functions. The basic unit is adaptable to a variety of off-line and on-line configurations. Single unit prices begin at $1495. Centronics Data Computer Corp., 1 Wall St., Hudson, N H 03051. **155**



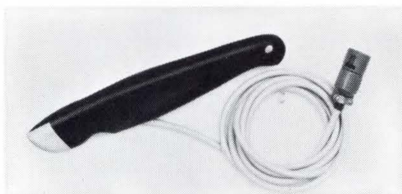

**DUAL-CHANNEL OPTICAL ISOLATOR** Model 814 has 20 to 30 nsec rise time and provides total system isolation by eliminating potential differences and ground loop currents. This 2-channel system comes in a 24-pin DIP and both input and output are TTL compatible. Each channel consists of a gallium arsenide emitter, PIN diode, high-gain amplifier and an output driver. Quadri Corp., 2950 W. Fairmont, Phoenix, AZ 85017. **156**



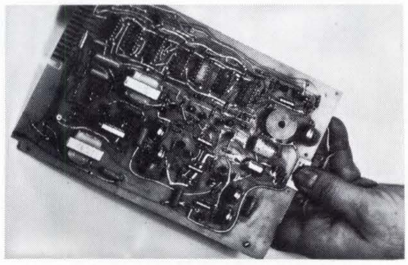
**MAGNETIC TAPE HEADS** are available for open reel or cassette drives. The need for flux gates has been eliminated yet there is <5% crossfeed through read amplifiers. Both NRZI and phase-encoded versions are available for 7- or 9-track read/write units. Quantity price is <$500 for open reel heads and <$50 for cassette heads. Ampex Corp., 13031 W. Jefferson Blvd., Marina del Rey, CA 90291. **157**



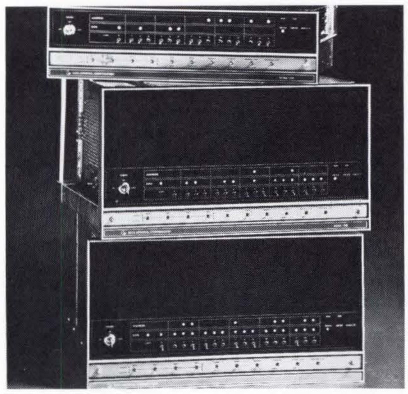

**DYNAMIC, 500-BIT MOS/LSI SHIFT REGISTER,** TMS3402, operates from 500 kHz to 5 MHz. At 1.0 MHz, power dissipation is 10 mW. The device can be directly interfaced with TTL/DTL logic and is designed for applications requiring storage lengths in 100-bit multiples. It is available in 16-pin plastic DIP or 10-lead TO-100 metal packages at $9.60 each. Texas Instruments Incorporated, Box 5012, MS/308, Dallas, TX 75222. **158**



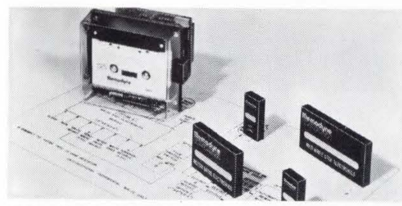
**HAND-OPERATED MAGNETIC TRANSDUCER** called Mag-Pen reads magnetically coded cards, tags and oxide-coated stripes. An unusual feature permits 45° tilt or azimuth misalignment without affecting reading ability. Data transfer rate is from 1200 to 12,000 flux reversals/sec. Available units are Model MP-200-A (includes interface electronics) and MP-200-X (less amplifier). Keonics Inc., 1600 Victory Blvd., Glendale, CA 91201. **159**



**COMMUNICATIONS CONTROL MODULES, LINE-CONTROL MODULE,** Model 906013, and "handshake" module, Model 906008, can be employed in either tone (DTMF) or rotary dial pulsing applications. Both modules are on a 5.5- by 8- by 1-inch card. For small quantity orders, unit prices are $155 and $112 respectively. G-V Controls, Div. of Sola Basic Industries, 101 Okner Parkway, Livingston, N J 07039. **160**



**THREE COMPUTERS,** 1210, 1220 and 820, are the latest members of the Nova family. The 1210 costs $4350 with 4k of core memory and $5750 with 8k words. The 1220 with low-cost expansion capability is priced at $5250 with 4k memory and $6650 with 8k. Both have cycle time of 1200 nsec. The 820 with an 800 nsec cycle time is priced at $6450 (8k memory) and $7850 (8k memory). Data General Corp., Southboro, MA 01772. **161**



**INCREMENTAL DIGITAL CASSETTE RECORDER** Model UIW-101 is a unidirectional, write only true bit-by-bit unit that has an unusual slip-clutch drive system (patent pending). The unit handles NRZI data at random rates from 0 to 300 bps. Packing density is 120 bpi, thus a standard Phillips cassette has 432k bit capacity. Single unit price is $189 (OEM quantity, $99). Memodyne Corp., 49 Pollard St., N. Billerica, MA 01862. **162**

**COMPUTER-BASED MULTICHANNEL ANALYZER** ND4420 is designed for single, dual and multiparameter analysis. Features include 32 software-controlled functions; facilities for generating alpha-numeric or graphic displays and a compiler. Nuclear Data, Inc., 100 W. Golf Rd., Palatine, IL 60067. **163**

**DISC FORMATTER** for the 5000-Series disc drives requires only 3.5-inches of rack space and has internal card space to accommodate the user's coupler interface. The unit provides comprehensive data and hardware error checking, and can be configured using a programmable ROM. The logic is made up of easily-interfaced DTL/TTL devices. Pertec, 10880 Wilshire Blvd., Los Angeles, CA 90024. **164**

**A BUMP STORAGE** feature has been added to the 360 CORE plug-compatible add-on main memories for IBM System/360, Models 30, 40 and 50. The BUMP capability is a standard feature available without cost on all 360/CORE units. Cambridge Memories, Inc., 285 Newtonville Ave., Newtonville, MA 02160. **165**

**MAGNETIC TAPE DEVICES** are 1600 bpi phase-encoded units that have reading speeds up to 200 ips, and IBM compatibility with error checking and correction. Construction uses all solid-state logic and a TTL/DTL-compatible control interface. Macro Products Corp., Box 2807, Culver City, CA 90230. **166**

**OPTICAL CABLE** (OPTICABLE), Model 15, represents a new concept in logic signal transmission. The cable, TTL compatible, requires 5V for operation and is a complete, self-contained system including connectors and drivers. Up to 48 channels come in a 0.35-inch diam bundle, and a variety of predetermined lengths are available. Quadri Corp., 2950 W. Fairmont, AZ 85017. **167**

**KEYBOARD ARRAY** designated EB sells for as little as \$0.40/switch in quantity. Specifications include key travel of 0.15 inch, 50-mA contact rating at 30V, 0.156-inch edge board pad termination and contact resistance of 0.1Ω (plus circuit board). Chomerics, 77 Dragon Ct., Woburn, MA 01801. **168**

**MAGNETIC TAPE SUBSYSTEM** ST3400/3800-III, is plug-to-plug attachable to the standard channel interface of either IBM system 360 or 370. Subsystem diagnosis is contained within the system and does not require the CPU for initiation or operation. Storage Technology Corp., 2270 S. 88th St., Louisville, CO 80027. **169**

**GRAPHIC SUBSYSTEM** Model 2020 provides the capability of entering data from maps, charts or even handwriting using a pen-like stylus. Available in either a desk-type console or as a desk blotter type, and in both 10- by 10-inch and 20- by 20-inch models, they exhibit resolution of 50 or 100 lines/inch. Compunetics, Inc., 1100 Eldo Rd., Monroeville Industrial Park, Monroeville, PA 15146. **170**

**LINE PRINTER,** Model 101A, prints a 9 ×7 dot matrix to form characters at speeds up to 165 cps. Standard features are paper runaway control, manual line spacing, full 64-character set, hardware code select and 50 or 60 Hz multivoltage. Centronics Data Computer Corp., 1 Wall St., Hudson, N H 03051. **171**



CIRCLE NO. 31



CIRCLE NO. 32

# keep working at it

## Now that you've seen the January 1 issue of EDN/EEE, you're probably working hard on your entry. Keep at it!

**How to enter**

Any reader of EDN/EEE may enter this contest. All you need do is study the January 1, 1972 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?

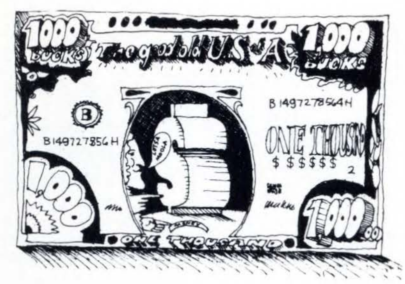
**2. Creative imagination**

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:
Portable electronic calculators worth $400 each.

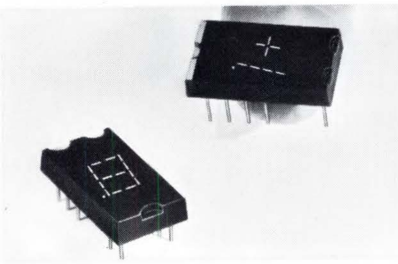
**Contest details**

Any reader of EDN/EEE may enter. Contest is not open to employees of Cahners Publishing Co. or their families. All entries become the property of EDN/EEE. YOUR ENTRY MUST BE POSTMARKED NO LATER THAN MIDNIGHT, MARCH 1, 1972. Results will be announced and winning entries described in a later issue of EDN/EEE.

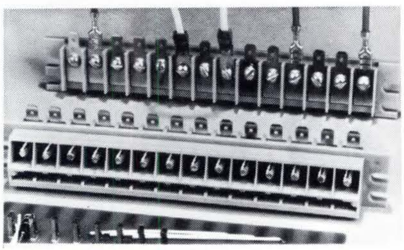
EDN/EEE

**Cahners Publishing Company, Inc.**
221 Columbus Avenue, Boston, Mass. 02116

# COMPONENTS/MATERIALS

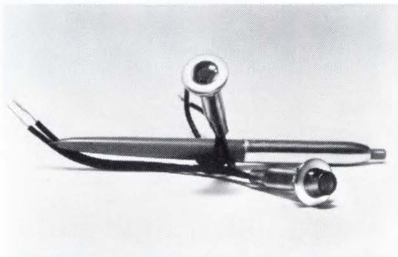


**GAASP LED READOUTS,** Types 745-0003, 0004 and 0006 have 0.270-inch characters. Each is available with a seven-segment digit or with a ±1 symbol. They are rated for 30 mA continuous forward current/segment. Maximum reverse voltage is 6V and peak light emission is at 650 nm. In orders of 1000 or more they are priced at $7.50 each. Dialight Corp., 60 Stewart Ave., Brooklyn, NY 11237. **172**

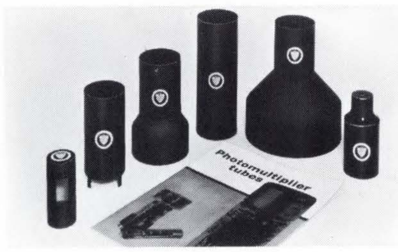


**TERMINAL BLOCK** accepts PC cards. Multi-tap printed circuit edge connector accepts 0.062-inch-thick single-side printed circuit cards at base and provides terminal block connections for wiring on top. It is available in 14 or 16 position sizes with conductors on 0.375-inch centers. AMP Inc., Harrisburg, PA 17105. **173**


**REAR PROJECTION READOUT** provides 48 discreet messages. The unit is about 3 inches long by 1-1/3 by 3/4 inches and weighs just over 3 oz. The readout, designated Series 1002, has resolution adequate to permit messages of up to four lines of eight characters each to be projected in seven point type size. Quantity pricing of the Series 1002 is $82 each. Industrial Electronic Engineers, Inc., 7720-40 Lemona Ave., Van Nuys, CA 91405. **174**



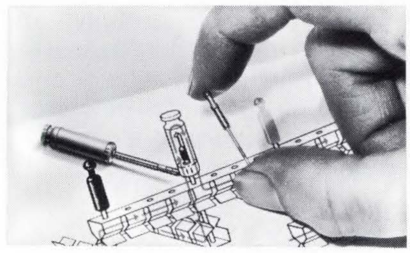
**ONE-PIECE INDICATOR LIGHTS,** Series 2900, are available in six standard lens shapes, four body sizes and various lens colors. The units come with bare leads, insulated leads, or solder lugs; and can be ordered with neon or incandescent lamps. One-piece design eliminates sockets and spring contacts, and speed-nut mounting reduces assembly time. Industrial Devices, Inc., Edgewater, N J 07020. **175**



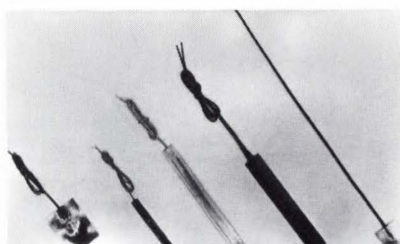

**PHOTOMULTIPLIER SHIELDS** assure optimum gain in magnetic environments. These standard shields cover over 90% of the photomultiplier tubes currently manufactured. Modifications of shield lengths are available on special order. Perfection Mica Co., 740 Thomas Dr., Bensenville, IL 60106. **176**


**DIGITAL DISPLAY** designed for direct connection to current and voltage transmitters is available in 3-1/2- or 4-digit versions. For applications where transmitter output is not linear with respect to the input, a nonlinear A/D converter is available. Standard TTL-compatible BCD output is accessible at the rear panel. Price is from $169 up, depending on configuration. Digilin Inc., 1007 Air Way, Glendale, CA 91201. **177**

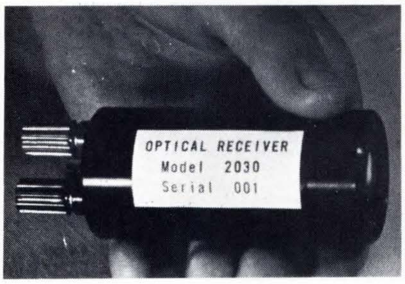

**SIX-DIGIT IMPULSE COUNTER** that features snap-in mounting, requires only 1.2 by 2 inches of panel space. Reliability is rated at up to 250 million counts. Standard options include manual or electrical reset, internal illumination and reverse-color wheels. Count speeds are up to 100/sec. Price is $21.30 each in lots of 100. Kessler-Ellis Products Co., Atlantic Highlands, N J 07716. **178**



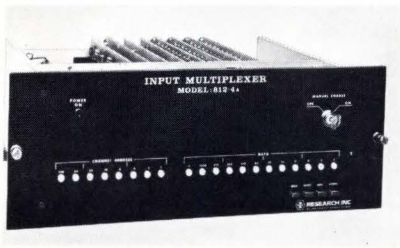
**COMPONENT HOLDING PIN** for matrix board programmers increases programming options and reduces expense of changing hardwired components. Replacing the shorting pin, the type 0762-516 pin electrically interposes a diode between the matrix's electrical cross points. Sealectro Corp., 225 Hoyt St., Mamaroneck, NY 10543. **179**



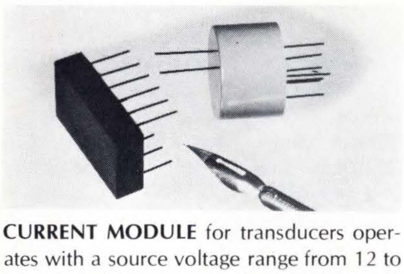
**THERMAL-RIBBON TEMPERATURE SENSORS** provide sensing of temperatures from −328 to +500°F. Two basic sensor types are available: Platinum or nickel-iron element resistance thermometers, or lower cost thermocouples. Suitable for sensing of air, gas, liquid or solid surface temperatures, they are available with or without a self-adhesive strip for press-on installation. Minco Products, Inc., 7300 Commerce Lane, Minneapolis, MN 55432. **180**



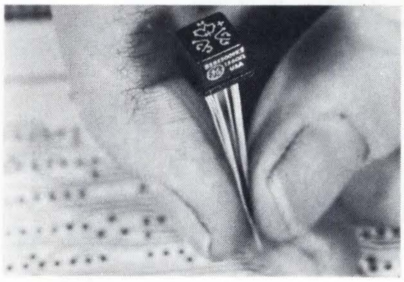

**OPTICAL RECEIVER,** Model 2030, is intended for wide-band communication links and instrumentation systems. It is an all-solid-state unit with a silicon PIN diode as the light-detector element and a 70 MHz band transimpedance amplifier as the gain stage. Spectral response range is 0.4 to 1.1 $\mu$m. Prices are from \$72 (1-9) to \$64.50 (10-29), with 2 weeks delivery. Optical Communications Technology, Box 262, Goodyear, AZ 85338. **181**



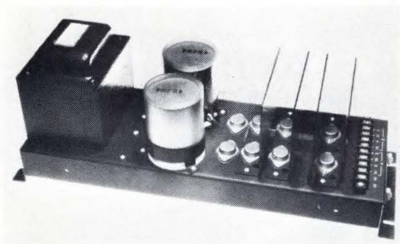

**MULTIPLEXER-A/D CONVERTER,** Model 812-4A, handles 12 differential analog input signals and is expandable in 32-channel increments to a maximum of 256 differential channels. Signal recognition and conversion occurs at rates up to 10,000 signals/sec in either the random access or sequential mode. Conversion resolution is 11-bits plus sign. Research, Inc., Box 24064, Minneapolis, MN 55424. **182**



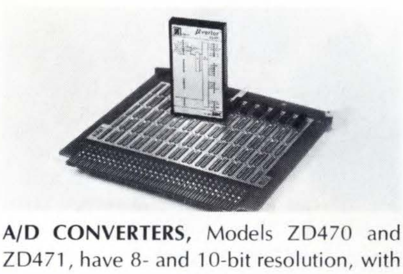
**CURRENT MODULE** for transducers operates with a source voltage range from 12 to 45V dc and has a standard 4 to 20 mA output range. This module functions with most standard bridge-type transducers. Transducer operation is not affected by input voltage changes or transmission line resistance variations. The unit sells for \$60 to \$95, depending on type and quantity, with 3 week delivery. Electronic Modules, Inc., 2500 E. Foothill Blvd., Pasadena, CA 91107. **183**



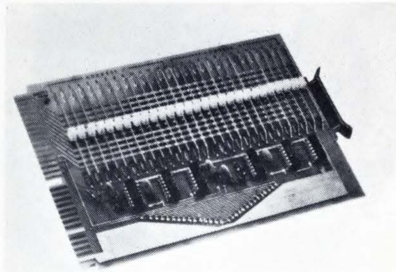
**TO-5$^2$ HYBRID RELAYS,** Type 3SBS, are available in single- or dual-diode versions. Both versions contain diode chips within the relay enclosure for coil suppression. In addition, the dual version protects against accidental application of reverse polarity. They may be ordered calibrated to either voltage or current standards, and with a choice in headers and coil resistance. General Electric, 777 14th St., N.W. Washington, D C 20005. **184**



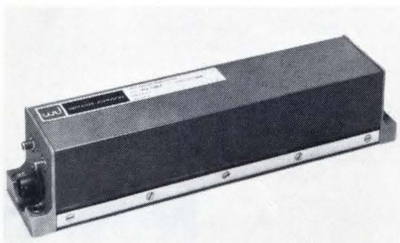
**DUAL-OUTPUT POWER SUPPLY,** Model DRD 15-5, provides $\pm$15V dv at 5A, each output. Input requirement is 105 to 125V ac at 60 Hz. Other specifications include 0.02% line or load regulation and 500 $\mu$V rms ripple. Price from 1 to 9 units is \$96 each. Kit forms are available at considerable saving. Universal Electronics Co., 17811 Sky Park Circle, Irvine, CA 92664. **185**



**A/D CONVERTERS,** Models ZD470 and ZD471, have 8- and 10-bit resolution, with conversion times of 15 and 30 $\mu$sec respectively. Linearity is $\pm$0.05% of full scale and quantizing error is $\pm$1/2 LSB. The 0.4-inch-high modules are DIP-compatible with most PC boards. Data coding is either binary or 2's complement with output data in either NRZ serial or parallel binary bits. Prices are \$79 (ZD470) and \$99 (ZD471). Zeltex, Inc., 1000 Chalomar Rd., Concord, CA 94520. **186**



**CONTROL MODULES** 906003 and 906004 make it possible to program additional telephone numbers in any of several combinations. They can be programmed to dial any telephone number up to 14 digits. Models are reprogrammable by means of an unusual slide-bar arrangement. Prices vary from \$60 to \$75 per module, depending on quantity and model desired. G-V Controls Div. of Sola Basic Industries, 101 Okner Parkway, Livingston, NJ 07039. **187**



**LOW-NOISE TRAVELING-WAVE AMPLIFIERS,** WJ-3066 Series, span the 4 to 18 GHz frequency range. Overdrive characteristics are 4 dBm output power at 4 dBm input for the full range. Normal power level is 10 dBm. Dimensions for the units are 2.375 by 2.375 by 10.375 inches and they weigh 5 lbs. Watkins-Johnson Co., 3333 Hillview Ave., Stanford Industrial Park, Palo Alto, CA 94304. **188**

**POWER SUPPLY MODULE** Model 2198 provides an isolated, regulated 5V dc output from a 115V ac, 400 Hz source with 1% regulation. Temperature coefficient is 0.025%/°C over the temperature range of −55 to 125°C. The Model 2198 is provided with 12-inch leads. Model 2199 is electrically identical, but supplied with solder-terminal header. Unit prices are \$75 (1-9) and \$40 (lots of 100). Melcor Electronics Corp., 1750 New Highway, Farmingdale, Long Island, NY 11735. **189**

## CIRCUITS

**ABSORPTIVE PIN DIODE ATTENUATOR,** Model M189, covers the 200 MHz to 18 GHz frequency range and provides up to 70 dB of attenuation. VSWR is $<2.0$ through 12.4 GHz and $<2.3$ through 18 GHz. General Microwave Corp., 155 Marine St., Farmingdale, NY 11735. **190**

**WIDEBAND DATA AMPLIFIERS** A-205, A-206 and A-207, offer eight internally-programmed gain ranges from $-10$ to 60 dB. Gain ranging is accomplished either automatically or manually. Input impedance is 100 M$\Omega$ and the passband is from dc to 10 kHz. Intech, Inc., 1220 Coleman Ave., Santa Clara, CA 95050. **191**

**OEM POWER SUPPLIES,** LS Series, feature high MTBF (to 173,000 hrs) and consist of four models: LS5-4 (5V), LS6-3.6 (6V), LS12-2.4 (12V) and LS15-2 (15V). All units are enclosed in anodized aluminum cases. In quantity of 1 to 9 pieces, the price is $82 each with delivery from stock. Dynage Inc., 1331 Blue Hills Ave., Bloomfield, CT 06002. **192**

**V-BAND DETECTOR** Model 4480H achieves a 15GHz bandwidth over the 50 to 75 GHz range through mechanical tuning. Unit price is $525, and the detector is available on a 45-day delivery. Hughes Electron Dynamics Div., 3100 Lomita Blvd., Torrance, CA 90509. **193**

**DIGITALLY PROGRAMMABLE ATTENUATOR** PA-53 spans the frequency range of dc to 500 Hz with a total attenuation of 1.5 dB in 0.1 dB steps. Available in 50$\Omega$, the unit comes with any of the following connectors: BNC, TNC, N and SMA. Price is $250. Texscan Corp., 2446 N. Shadeland Ave., Indianapolis, IN 46219. **194**

**TRANSDUCER AMPLIFIERS,** CY1011, 1010, 1020 and 1021, feature gain linearity of $\pm 0.05\%$ and adjustable gain from 0.1 to 10,000. Single unit, prices are $24 (CY1010), $39 (CY1011), $29 (CY1020) and $49 (CY1021). Cycon, Inc., 1080 E. Duane Ave., Sunnydale, CA 94086. **195**

**THREE- AND FOUR-PORT QUADRATURE DIRECTIONAL COUPLERS,** Models 1536, 1537, 1538 and 1539, are for 50$\Omega$ systems and span the 0.95 to 13.1 GHz range. All have either 10 or 20 dB coupling. Units will be available from stock in late January at prices ranging from $425 to $475. Weinschel Engineering, Box 577, Gaithersburg, MD 20760. **196**

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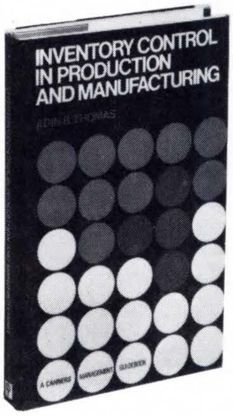


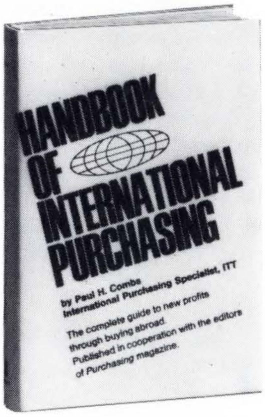


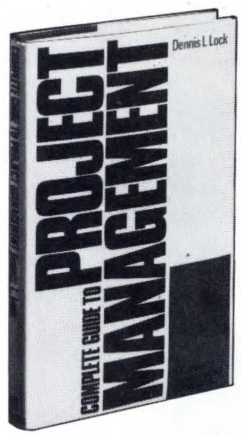


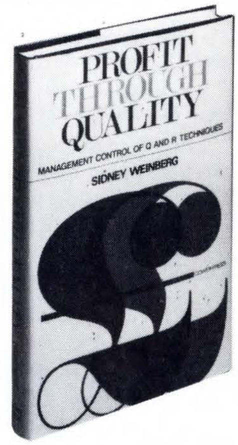


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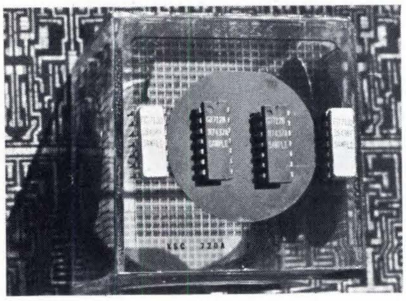
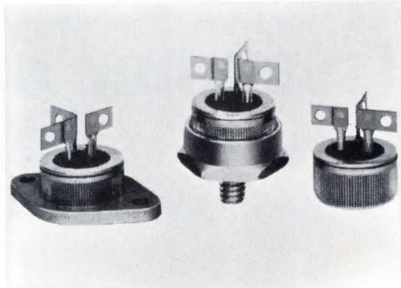
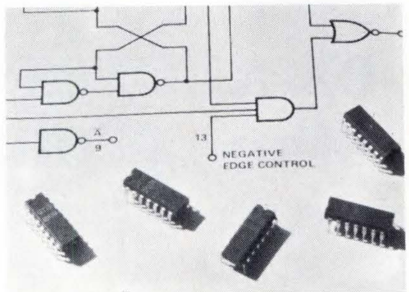


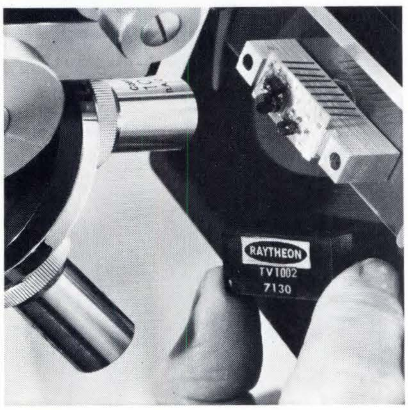
**TTL QUAD 2 NAND BUFFER ICs** drive highly capacitive loads. The "7437," can drive three times the load of a "7400." Similar to the "7403," the "7438" has open-collector outputs to permit "wired-AND" applications. Propagation delay time is less than 15 nsec low to high. The plastic N7437A costs \$0.78 each, and the S5438F (KOVAR DIP) \$5.04 each in 100 quantities. Signetics Corp., 811 E. Arques Ave., Sunnyvale, CA 94086. **197**



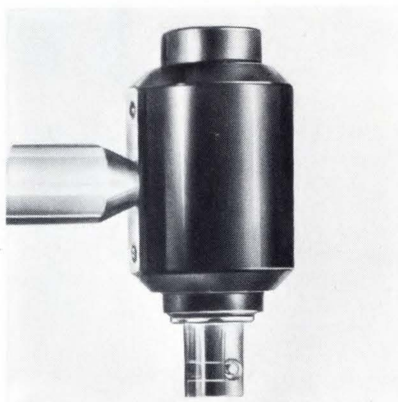
**CENTER-GATE, GLASS PASSIVATED TRIACS** are rated at 30 and 40A, and provide improved dv/dt and di/dt characteristics. Passivation is done with a very dense, void-free sodium-free glass that provides a hermetic seal and eliminates "punch-through". They are available with $V_{DROM}$ ratings from 50 to 600V, and in press-fit, stud-mount and TO-3 packages or chip form. Hutson Industries, 2019 W. Valley View Lane, Dallas, TX 75234. **200**



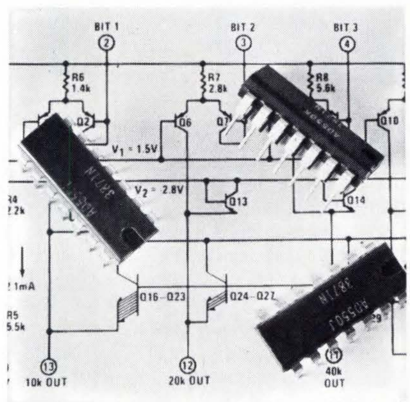

**BIDIRECTIONAL ONE-SHOT IC,** Type N8T20B, triggers on either positive or negative pulse edge, or both. Designed for processing of high-speed, low-level digital signals, it functions as a zero-crossing detector with thresholds of ±4 mV. Output pulse width can be set from 10 to 800 nsec, ±1.0%. Price is \$5 per unit in orders of more than 100. Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. **203**



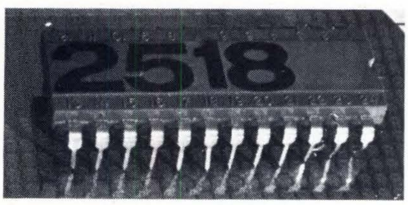

**HYBRID RF AMPLIFIERS,** TV1001 and TV1003, measure only 0.41 cubic inches, including heat sink. TV1001 has a frequency range of 40 to 300 MHz (±0.5 dB) and minimum gain of 29 dB. Price is \$100. TV1003 has a frequency range of 2 to 130 MHz (±0.5 dB) and gain of 17 dB. Price for the TV1003 is \$80. Raytheon Co., 350 Ellis St., Mountain View, CA 94040. **198**



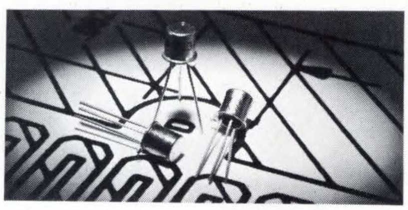
**INFRARED DETECTOR** features response time of <1 nsec. This 10.6 micron detector operates at room temperature and utilizes the photon drag principle. Radiation passing through a doped germanium crystal creates a longitudinal voltage differential which can be monitored by oscilloscope. Oriel Corp. of America, 1 Market St., Stamford, CT 06902. **201**



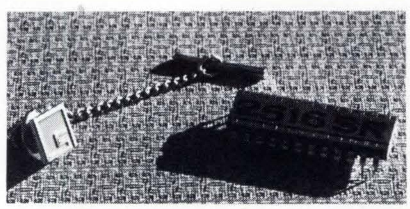

**IC QUAD CURRENT SWITCH,** Model AD550, is offered in sets of 2 or 3 switches designed for 8- or 12-bit D/A converters. Switching time is 500 nsec, and settling time (to ±1/2 LSB) is 1.8 μsec for 12-bit sets. Price is \$6.00 for the 8-bit set in quantities of 1000. Analog Devices, Inc., Route 1 Industrial Park, Box 280, Norwood, MA 02062. **204**




**MOS STATIC SHIFT REGISTERS** are organized hex-32 and hex-40 bits for EDP applications. The hex-32 "2518B" and hex-40 "2519B" are silicon p-channel enhancement-mode devices. Typical clock rate is 3MHz, and supply current is 16 mA. The units operate from sources of +5 and −12V. In quantities of over 250 pieces the price is \$6 each. Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. **199**

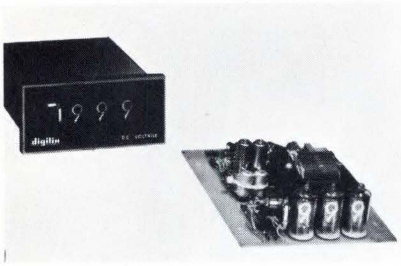


**P-CHANNEL FETs** models PF510 and PF511, feature reduced capacitance. $C_{ISS}$ of 12 pF is achieved by a new p-channel manufacturing process. The PF510 is a 30V, and the PF511 a 20V, device. Both have max. $V_{GS(OFF)}$ of 10V and $R_{DS}$ of 200 Ω. The PF510 is priced at \$1.50 each, the PF511 is \$1.00 each, in 100-up quantities. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clar, CA 95051. **202**



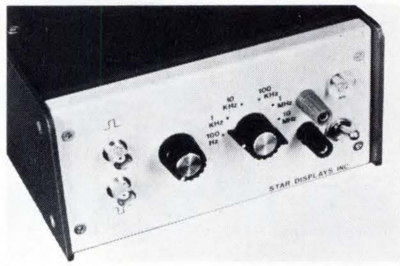
**MOS READ-ONLY MEMORY** Type 2516SR generates "ASCII" alphanumeric font. This high-speed, 3072-bit static IC is available for use in vertical-scan CRT displays, printer character generators and panel displays. Utilizing "Sanderson-Rabbett channel" technology, the 2516SR is suitable for code-conversion and microprogramming application. Signetics 811 E. Arques Ave., Sunnyvale, CA 94086. **205**

# EQUIPMENT



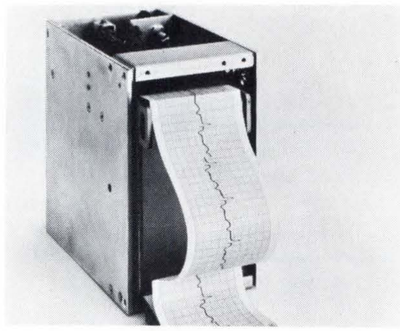

**DPMS FOR OEM USE** feature automatic polarity detection, 0.6-inch gas-discharge display tubes and standard TTL-compatible BCD output. Measuring range is 0 to ±1.999V including overrange. Model 1352 (without case) is priced at $125 and Model 2352 (with case) is $159. BCD option is $15 extra. Digilin, Inc., 1007 Air Way, Glendale, CA 91201. **206**


**DC VOM** has five ranges of dc volts with 100 $\mu$V resolution, and five ranges of ohms with resolution of 0.1$\Omega$. Basic accuracy is 0.1% of reading. Model 261 has both self-check zero and calibration front-panel controls. It is available with battery pack for complete portability. Price is $279 and availability is stock to eight weeks. United Systems Corp., 918 Woodley Rd., Dayton, OH 45403. **209**

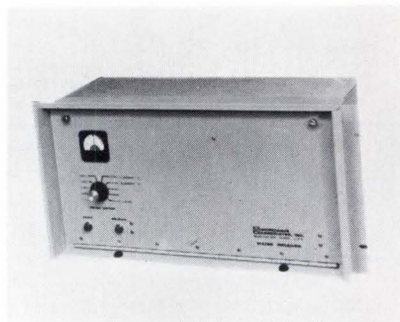



**PULSE GENERATOR/POWER SUPPLY** was expressly designed for display and TTL circuit checkout. Power output is 5V at 2.5A dc, regulated and short-circuit proof. Pulse output is either positive or negative pulse trains from 30 Hz to 10 MHz. Size of the unit is 3-1/2 by 7 by 7 inches. Star Displays, Inc., 1655 W. 11th Ave., Eugene, OR 97402. **212**


**FREQUENCY COUNTERS** with 10 Hz to 80 MHz range employ superspeed Schottky TTL and light emitting diodes. Model SM-104A provides a 1 MHz crystal time base with ±1 ppm/year stability. Model SM-105A is similar but with time-base accuracy of ±10 ppm. Both count to 80 MHz with only 0.25V input. Price, assembled and tested, is $350 for SM-105A and $500 for SM-104A. Heath/Schlumberger Scientific Instruments, Benton Harbor, MI 49022. **207**

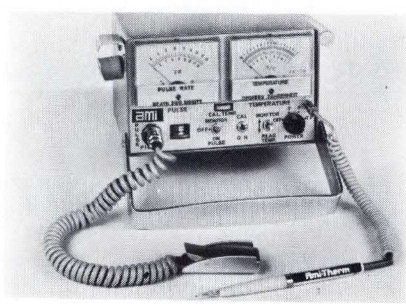


**STRIP CHART RECORDER** uses fan-fold paper. Model GRZ-70 features front paper loading, rectilinear hot-stylus recording and a choice of one to four speeds. Primarily intended for OEM use with electrocardiograph and fetal monitoring equipment, the unit is available with single and dual 50 mm channel configurations as well as a dual channel of 50 and 80 mm. General Scanning Inc., 80 Coolidge Hill Rd., Watertown, MA 02172. **210**



**ONE WATT, 12 GHZ MICROWAVE RADIO** for CATV CAR band distant signal relay use, Model MA-12G, is entirely solid-state. The unit is intended for wideband video use in the 12.7 to 12.95 GHz band. Transmitter section features a 2 GHz crystal oscillator with 0.005% stability, while the receiver is a super-heterodyne with 70 MHz IF and a GUNN-diode local oscillator. Microwave Associates, Inc., Burlington, MA 01803. **213**

**MICROWAVE COUNTER** with single input measures from dc to 18 GHz with −35 dBm sensitivity. Operation of Model 5340A is entirely automatic. Display is eight digit, and resolution is switchable from 1 Hz to 1 MHz. Price is $5300, with delivery in May 1972. Hewlett-Packard Co., 1601 California Ave., Palo Alto, CA 94304. **208**




**PULSE AND TEMPERATURE MEASURING DEVICE** completes both counts in about 20 sec/patient. The Model TP-102 is available with either disposable or rechargeable batteries and with several plug-in interchangeable temperature probes. AMI Medical Equipment, Div. LMC Data, Inc., 116 E. 27th St., New York, NY 10016. **211**


**PULSE GENERATOR** features ±15V output, 4 nsec rise time, dc-to-50 MHz operation and a price of $395. Model PG-11A measures 4 by 8-1/2 by 9-1/2 inches and rack adapters are available as an option. Availability is 30 days ARO. Chronetics, Inc., 500 Nuber Ave., Mt. Vernon, NY 10550. **214**

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**TWT MICROWAVE AMPLIFIER,** Model 1177H03F-005, covers all common carrier bands in the 3.7 to 11.7 GHz range. Mid-band gain and power output exceed 50 dB and 10W respectively. Weight is 24 lbs, price is $6200 and delivery is 60 to 90 days. Hughes Electron Dynamics Div., 3100 W. Lomita Blvd., Torrance, CA 90509. **215**

**TEMPERATURE MEASURING BRIDGES** of the 2105 Series provide accuracy of ±0.2% or ±0.25 to ±0.5°C, depending on model and range. Values are read from an 11-inch circular scale. Both single and dual temperature range models are available with prices starting at $398. Special Instruments and Machinery Co., 6 Lamesa Ave., Eastchester, NY 10707. **216**

**BOAT COMPASS** with digital readout, Series 1290, comes complete with compass head, readout module and a variable control unit to permit operation on 12, 24 or 32V battery. Availability is end of 1971 and estimated price is $455. Arc Industries Inc., Box 3498, Indialantic, FL 32903. **217**

**LOCK-IN AMPLIFIER** with completely automatic reference tracking and 1 $\mu$V sensitivity is available at $1295. Model 128 requires only signal connection and phase-shifter adjustment before use. Signal channel response is flat from 0.5 to 100 Hz. Princeton Applied Research Corp., Box 565, Princeton, NJ 08540. **218**

**POWER SIGNAL GENERATOR,** Model SLRD, covers from 6.7 to 12.7 GHz with output power between 0.25 and 3W, depending on frequency. Features include single tuning range, linear frequency tuning, internal 1 kHz squarewave modulation or external pulse modulation. Price is $8725. Rohde & Schwarz Sales Co. (USA) Inc., 111 Lexington Ave., Passaic, NJ 07055. **219**

**HIGH VOLTAGE SUPPLY** operates from 50 to 400 Hz lines and provides 0 to 5000V dc at 0 to 15 mA. Line or load regulation is better than 0.01%. Model SV615 weighs 27 lbs. Prices range from $615 to $525 depending on quantity. Delivery is 30 days ARO. ERA Transpac Corp., 67 Sand Park Rd., Cedar Grove, NJ 07009. **220**

**RANDOM-ACCESS AUTOMATIC CIRCUIT ANALYZERS** of the 700 Series that now includes Models 701 through 704 offer a wide selection of switching and a range of test speeds up to 5000 tests/min at prices starting under $20,000. Dit-Mco International, 5612 Brighton Terrace, Kansas City, MO 64130. **270**

**AUTOMATIC TESTER,** the TESTPAC II, is a second-generation testing and checkout system. It can simultaneously control and interface up to 20 or more programmable test instruments. A computing analyzer performs arithmetic operations and includes multiple data storage registers. Base price is $21,500. Zehntel, Inc., 1450 Sixth St., Berkeley, CA 94710. **271**

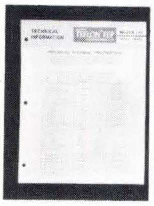
**INTEGRATING DIGITAL VOLTMETER,** Model 521C, measures from 10 mV to 1000V full scale while integrating 92 readings/sec. Accuracy is better than 0.01% of full scale. Guarding and bipolar averaging reduce common-mode noise more than 150 dB. VIDAR Corp., 77 Ortega Ave., Mountain View, CA 94040. **272**

**RESISTIVITY MEASURING INSTRUMENT** operates by the dc 4-point method and displays results directly in Ω-cm. Model VR-4 is useful for measuring the resistivity of bulk slices, thin wafers, epitaxial layers and diffused layers of all semiconductor materials. Features include both 0.25 and 1 mm point spacing probes. Measurement range is from 0.001 to 1000 Ω-cm. Price is $2925. Siltec Corp., 3717 Haven Ave., Menlo Park, CA 94025. **273**

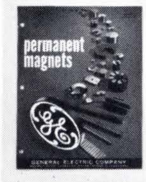
**EMERGENCY AC POWER SOURCE,** Model EP100, has an average power rating of 100 VA square wave output. Capacity is 4 hrs at 100 VA. Recharge time is less than 8 hrs. Size is approximately 1 ft$^3$; weight is 30 lbs, excluding battery; and price, without battery, is $215. ERA Transpac Corp., 67 Sand Park Rd., Cedar Grove, NJ 07009. **274**

**GRAPHIC RECORDER,** Model 7754A, is a compact 4-channel unit that uses hot-tip stylii to make high-contrast traces on Z-fold paper. Response time is as short as 5 msec, and plug-in preamplifiers permit recording a wide range of physiological data. Z-fold paper is used. Price is $4500, with signal conditioners at extra cost of $125 for a signal coupler to $700 for a bioelectrical preamplifier. Hewlett-Packard, Medical Electronics Div., 175 Wyman St., Waltham, MA 02154. **275**

## LITERATURE



**"TEFLON"** and its physical, thermal and chemical properties is the subject of two bulletins, T-2D and T-3D. Included in the 14 pages are details on the unique properties of FEP fluorocarbon film and its bondability. DuPont Company, 1542 Farmers Bank Building, Wilmington, DE 19898. **227**




**PERMANENT MAGNET** catalog contains 20 pages listing all standard items including cast and sintered Alnico, "Lodex" and "Gecor". Information is also included on a self-contained magnetizer and a portable demagnetizer. General Electric Co., 99 Neff Rd., Edmore, MI 48229. **228**

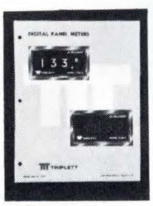
**LOCK-IN AMPLIFIER,** Model 126, is described in the four-page specification sheet T-291. Three charts and eight graphs describe the instrument's operation. Also discussed are five plug-in preamplifiers that provide sensitivity to 1 nV. Princeton Applied Research Corp., Box 565, Princeton, N J 08540. **229**

**DESIGNING SC MEMORY SYSTEMS** with the Intel 1103 MOS RAMs is made easy by this 28-page handbook of instructions. Pictured and described are three completed systems that illustrate the design techniques. "1103 Handbook" is available without charge. Intel Corp., 3065 Bowers Ave., Santa Clara, CA 95051. **230**


**HEATHKIT'S 1972 CATALOG** contains more than 350 do-it-yourself electronic projects. Some of the new items included are a waste compactor for the kitchen, the AR-1500 AM/FM/FM-Stereo receiver, a table-top road racing layout and modular electronic workshops for youngsters. Heath Co., Benton Harbor, MI 49022. **231**

**REAL-TIME SPECTRUM ANALYZERS** that require only 7 inches of panel height are the subject of a 12-page brochure tha describes their features, specifications and applications. Federal Scientific Corp., 615 West 131st St., New York, NY 10027. **232**

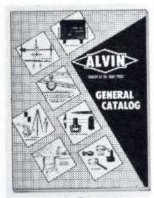
**DIGITAL MULTIMETERS** of the Series 5300 are described in a four-page data sheet that lists the major features of two models, and includes instrument photos and descriptions of the instruments' basic operating capabilities. Dana Laboratories, Inc., 2401 Campus Dr., Irvine, CA 92664. **233**



**DIGITAL PANEL METER** brochure describes a line of small dc meters in 2-, 2-1/2-, 2-3/4-, 3-, and 3-1/2-digit units. A 3-1/2-digit ac model is also described. Complete descriptions, specifications, dimensional information and prices are included. Triplett Corp., DPM-PR Dept, Bluffton, OH 45817. **234**

**SUBMINIATURE COAXIAL CONNECTORS** are described in a 24-page catalog. Line drawings for the SMA Series are included, and a section both explains various cabling procedures and illustrates an assortment of crimping assembly tools. Kings Electronics Co., Inc., 40 Marbledale Rd., Tuckahoe, NY 10707. **235**

**PRECISION INSTRUMENTS AND BRIDGES,** including both a new portable bridge and a new self-balancing bridge for capacitance/dissipation factor are the subject of a six-page short form catalog. Special Instruments & Machinery Co., 6 Lamesa Ave., Eastchester, NY 10707 **236**




**DRAFTING SUPPLIES AND EQUIPMENT,** plus those for artists, engineers and technical illustrators, make up the content of a 212-page general catalog. Such features as graphic illustrations and a quick-reference index make it a useful reference. Alvin & Co., Inc., 615 Palisado Ave., Windsor, CT 06095. **237**


**CONNECTORS AND SWITCHES** are covered in a 28-page catalog. It describes standard and miniature-pin connectors, relay and switch connectors, PC connectors and terminals and lighted push-button switches. Information on crimping tooling is included. Molex Inc., 5224 Katrine Ave., Downers Grove, IL 60515. **238**

## LITERATURE

**"POWER TRANSISTOR DIRECTORY"**, publication PTD-187C, contains information on new product programs as well as new product data. Epitaxial-base power transistors and monolithic Darlington types are included. RCA Solid State Div., Box 3200, Somerville, N J 08876. **239**

**PLOTTING TECHNIQUES** are studied and compared in "Reprint A/1" that is intended to help decision-makers utilize computer data in a selective, speedy and more meaningful manner. The specialized capabilities of some key inventor/manufacturers are detailed and relatively compared to competing processes. Data via graphs, pictures, maps and 3-D models are explored. Request a copy by writing directly to Spatial Data Systems, Inc., 132 Aero Camino, Goleta, CA 93017.

**"PURE BINARY SWITCH"** bulletin describes the Series B29 thumbwheel switch that converts any decimal input from zero to 99,999 to its binary equivalent. The brochure includes specifications, photos and installation data. The Digitran Co., 855 S. Arroyo Prkway, Pasadena, CA 91105. **240**

**SOLID-STATE CATALOG** describes several relays, controls and assemblies including tubular time-delay relays, hybrid time-delay modules and "zero crossover" switches. Guardian Electric Manufacturing Co., 1550 W. Carroll Ave., Chicago, IL 60607. **241**

**NOMOGRAPH** that provides a fast means of calibrating a real-time power spectral density system in terms of PSD level using a sine-wave calibration signal is offered free. The 8-1/2- by 11-inch nomograph is useful to those analyzing random data such as noise, vibration or underwater acoustic signals. It applies expressly to the company's "Ubiquitous" Series of real-time spectrum analyzers with 200- to 2000-line resolution. Write directly to Federal Scientific Corp., 615 West 131st St., New York NY 10027.

**TABLETOP ELECTRON MICROSCOPE** is described in Bulletin 2400. Photos, an operating diagram and basic specifications of the instrument are given along with representative photomicrographs. Ultrascan Co., 18530 S. Miles Parkway, Cleveland, OH 44128. **242**

**SYNCHRONOUS DC MOTORS** of the Series 3000 are covered in a two-page product sheet. It lists applications and features of the motors which operate over a range of 30 to 3000 rpm with direct-drive torques up to 128 oz-in. Sequential Information Systems, Inc., 249 N. Saw Mill River Rd., Elmsford, NY 10523. **243**

**MODULAR COMPONENT ENCLOSURES** that permit customized enclosing at production prices are described in a brochure "IF Can Enclose Your Hardware in a Custom Case at a Standard Price!". The brochure explains how components can be modularized, and features a multipurpose specification chart to enable quick, easy ordering. Industrial Fabricating Div. of Axel Electronics, Inc., 820 Woodend Rd., Stratford, CT 06497. **244**

**EPOXIES AND REACTIVE RESINS** are conveniently tabulated in a four-page brochure that lists electrically-conductive and quick-cure epoxies, and materials for potting, encapsulating, bonding, casting and sealing. Kenics Corp., One Southside Rd., Danvers, MA 01923. **245**

**ELECTRONIC ENCLOSURES** are featured in a 12-page catalog that contains photographs, exploded views, dimension tables, and prices. The items included are available for immediate shipping. Techmar Corp., 2232 S. Cotner Ave., Los Angeles, CA 90064. **246**

**FET-INPUT OP AMP** that is laser trimmed for offset voltages less than 1 mV is described in two data sheets. One covers the AD506 with CMRR of 90 dB and the other covers the AD516 which slews at 50 volt/$\mu$sec, with gain-bandwidth of 30 MHz. Analog Devices, Inc., Rte. 1 Industrial Park, Box 280, Norwood, MA 02062. **247**

**OFF-LINE PRINTING** with the company's off-line print station that features data compression is described and illustrated in a 4-page brochure. Tally Corp., 8301 South 180th St., Kent, WA 98031. **248**

**RELAYS AND TIMERS** are the subject of a 24-page catalog that provides information and application data on industrial, mercury-wetted, electronic time-delay, RF coaxial, magnetic latching and power relays. Synchronous motor timers are also included. Midtex, Inc., 10 State St., Mankato, MN 56001. **249**

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## ADVERTISERS INDEX

## EDN/EEE INDEX, JANUARY 15, 1972 ISSUE

# Application notes

**SCR MOTOR CONTROL** is the topic of the second article in a two-part series dealing with the control of shunt motors. It is included in Motorgram (Vol. 51, No. 5). Bodine Electric Co., 2500 W. Bradley Pl., Chicago, IL 60618. **250**

**DC SECONDARY VOLTAGE STANDARD USE** is the topic of a six-page note that gives illustrations of 31 ways to use the AN3100 secondary voltage standard. Analogic Corp., Audubon Rd., Wakefield, MA 01880. **253**

**MOS COUNTER DECODER APPLICATIONS** note contains eight pages with illustrations, performance graphs and ways of using the MK 5002 four-digit decoder with numeric displays. Mostek Corp., 1400 Upfield Dr., Carrollton, TX 75006. **256**

**"THE ADVANTAGES OF DIRECT DIGITAL FREQUENCY SYNTHESIS"** is the title of Application Note AN-14. This two-page note compares the various approaches to synthesis and describes the advantages of using direct digital methods over direct and indirect analog techniques. Rockland Systems Corp., 131 Erie St. East, Blauvelt, NY 10913. **251**

**ANALOG MULTIPLIER PRINCIPLES,** along with 14 application circuits, is the subject of Technical Bulletin AD530 that also details the circuit operation of the monolithic AD530. Included are operation, error analysis and applications as well as a comprehensive bibliography. Analog Devices, Inc., Rte. 1 Industrial Park, Box 280, Norwood, MA 02062. **254**

**ELECTRICAL TAPES** for transformer and coil applications are the subject of an eight-page guide that defines electrical, thermal and mechanical characteristics of specialty electrical tapes. Included are charts that cover major coil applications and indicate the tape best suited for each application. Permacel, Box 671, New Brunswick, N J 08903. **257**

**DIGITAL 300 SERIES OF APPLICATION BRIEFS** contains seven notes on the use of high-noise-immunity logic. Topics include: eliminating internally generated noise, second level gating, BCD-to-decade decoder, master-slave flip-flop and others. Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94040. **252**

**"BIBLIOGRAPHY ON TRACKING CONTROLS"** is a 24-page booklet that lists 668 books, reports and articles on such human-engineering problems as continuous tracking, contouring and discrete positioning by the human operator. Measurement Systems, Inc., 523 West Ave., Norwalk, CT 06850. **255**

**MINIATURE FEED-THRU FILTERS** are covered by Data Sheets 730-1 and 731-1 that describe the available units and thoroughly discuss their performance. In addition, several typical applications are described and illustrated. CAPITRON Div. of AMP Inc., 1595 S. Mt. Joy St., Elizabethtown, PA 17022. **258**

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