EDN

exclusively for designers and design managers in electronics

EEE

Op Amp Handles Multichannel Chores

A CAHNERS PUBLICATION

NOVEMBER 15, 1971

Now, there's a digital voltmeter that offers a combination of capabilities never before available. The new Hewlett-Packard 3403A.

Outstanding features of the 3403A are its eight-decade bandwidth, its six-decade ac voltage range (10 mV to 1000 V full-scale), its ability to measure both simple and complex signals with great accuracy (±0.2% reading ±0.2% range), and its advanced, solid-state 3-digit display.

With the 3403A, you can measure ac, dc, or ac + dc, with **true-RMS accuracy**—and get your readout in either volts or dB. Its wide voltage range, and **extraordinarily wide frequency range** give it unprecedented versatility. Its **direct readout in dB** makes it a "natural" for all kinds of communications work. And its ability to measure complex signals with crest factors as high as 10:1 makes it especially useful for noise measurement.

The 3403A is available with a wide variety of options and accessories, including dB display, autoranging, isolated or nonisolated digital output, isolated remote control, printer cables, active probes, and a rack adapter frame... making it ideal for systems applications, as well as lab and production work.

The 3403A's price ranges from $1400 to $2100, depending on options. An ac-only version, the 3403B, is also available, starting at $1150. For further information on the versatile new 3403A, contact your local HP field engineer. Or write Hewlett-Packard, Palo Alto, California 94304. In Europe: 1217 Meyrin-Geneva, Switzerland.

091/19

HEWLETT *hp* PACKARD

DIGITAL VOLTMETERS

HP's new 3403A voltmeter puts it all together... at an amazingly low price

- ☐ **True-RMS accuracy**
- ☐ **AC from 2 Hz to 100 MHz, plus DC**
- ☐ **Digital readout, in volts or dB**

CIRCLE NO. 2

At $49.00 this 12-bit DAC will convert you, too.

Ready? 12-bit resolution, speed 5μsec, linearity ±½LSB, and temperature coefficient ±30ppm/°C, plus the extras you expect in converters made by Analog Devices – like TTL/DTL-compatible inputs and monotonicity. All for $49 in 100's.

The DAC-12QZ inherits its performance from our top-of-the-line converters, and it owes its low price to new production techniques we've developed. Result: there is nothing like it for the money.

There *is* a less expensive converter in our line – the $29, 10-bit DAC-10Z we introduced last month. And there are some other nasty surprises for our competition coming up. For example, the ADC-8S to be announced next month. Its low price will doubtless change your buying habits – like using one ADC-8S per channel instead of multiplexing an expensive ADC.

Meanwhile send for detailed information. And if you want an evaluation sample of the DAC-12QZ or the DAC-10Z just call, or write us on your letterhead. Both are in full production and we have lots in stock. Analog Devices, Inc., Norwood, Mass. 02062, (617) 329-4700.

ANALOG DEVICES

Ever been away from home and missed your storage scope?

NEXT TRIP take one *with* you

- *SPLIT-SCREEN STORAGE*
- *25 MHz DUAL TRACE*
- *1 mV/DIV AT 16 MHz*
- *20-3/4 LB*

Storage isn't new. Portables aren't either. But storage in a portable oscilloscope certainly is. Now, they're together for the first time in the new TEKTRONIX portable 434 Storage Oscilloscope. It's virtually two instruments in one, offering you all the advantages of bistable split-screen storage, plus those of a portable oscilloscope with a conventional CRT.

How often have you had difficulty making measurements in applications where signals are single event or low rep rate, aperiodic or random? Storage provides you with an easy solution to many of these measurements. And, the portable 434 solves the problem of getting storage to the application.

To save your time, operating the 434 in a storage mode is as simple as pushing a front panel control. You just set the 434 to store a single sweep. When the event occurs, it's stored at writing rates up to 400 cm/ms and retained in a continuous view mode for as long as four hours. The bright, high-contrast display is clearly discernible even when you make the measurement in high ambient light. Another 434 feature you'll like is the CRT's high resistance to burns. It requires no more care than you give a conventional CRT.

The companion model 432 is a nonstorage model of the 434. Otherwise they're identical. Cabinet height is only 5-3/4 inches and rack height is 5-1/4 inches. Even so, there's room for a big 8 x 10-cm CRT. Bandwidth to 25 MHz, and sweep rates to 20 ns/div cover a wide spectrum of measurement needs. Deflection factors extend to 1 mV/div dual trace and are read out by lighted knob skirts even when you use the included 10X probes. Carrying weight is a very reasonable 20-3/4 pounds.

Before selecting your next portable, you'll want to see what's really new. Your field engineer will arrange a demo of the 432 and 434 at your convenience. Prices are: 432 Oscilloscope, \$1585. 434 Storage Oscilloscope, \$2150. U.S. Sales Prices FOB Beaverton, Oregon.

TEKTRONIX®
committed to technical excellence

Ask your field engineer about the 434 with 5000 cm/ms stored writing speed (option 1).

S-D puts the accuracy back into high speed DVMs

Make 30 accurate readings a second... even with noisy inputs

Most "high speed" digital voltmeters come to a screeching halt when they have to measure noisy signals. That's because most DVM's offer absolutely no noise rejection without using input filters—and even the best designed filter will limit a DVM to two or three readings a second.

Now Systron-Donner has done something to put the accuracy back into the high speed DVM. We designed our new fully-guarded 5-digit Model 7110 around Dual Slope Integration, the only reliable measuring technique that provides built-in noise rejection without the need for filters. As a result the 7110 will make 30 readings a second and give the right answer every time, even in the presence of unwanted noise and ripple. Yes, there's a filter, too, but you'll only need it for extremely noisy signals.

Built-in noise rejection is only one feature that makes the 7110 an outstanding lab or system meter. Five dc voltage and five dc ratio ranges are standard with all-range autoranging from ±1 microvolt to ±1100 volts. Both ac voltage and 4-wire resistance measurements can be added and, for system use, a variety of fully isolated digital output and remote programming options are available.

We also added some little things, like a light that tells if you've selected an optional function that isn't installed. (There's also circuitry that withstands overloads up to 1000 volts even if you mis-program all controls and inputs.) And to protect your investment we designed the 7110 so that every option can be installed at any time by simply adding plug-in cards.

Model 7110 is priced from $1,695 including 100 mV full scale and ratio ranges. Ask your local Scientific Devices office for technical data or contact: Concord Instruments Division, 888 Galindo St., Concord, CA 94520. Phone (415) 682-6161.

SYSTRON DONNER

Another S-D instrument first! Electronic counters/ Digital voltmeters/ Pulse generators/ Data generators/ Time code generators/ Sweep generators/ Spectrum analyzers/ Digital panel meters/ Digital clocks/ Signal generators/ Oscillators/ Laboratory magnets/ Precision power supplies/Analog & analog-hybrid computers/ Data acquisition systems.

CIRCLE NO. 6

NOVEMBER 15, 1971
VOLUME 16, NUMBER 22

EDN/EEE

EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

Cover

Cover photo, furnished by Harris Semiconductor, shows PRAMs emerging from their production facilities. See Progress in Op Amps, p. 57, for the inside story on this new programmable op amp.

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ibpa International Business Press Associates
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Everybody wants your components business.

But we're doing 6 things to earn it.

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3 Faster delivery. Our distributors can give you off-the-shelf delivery from an inventory of over 50,000,000 components. And our "ball parks" are firm, real and reliable. This lets you keep expediting and inventory levels to a minimum.

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We too want your business. But we're doing 6 extra things to earn it.

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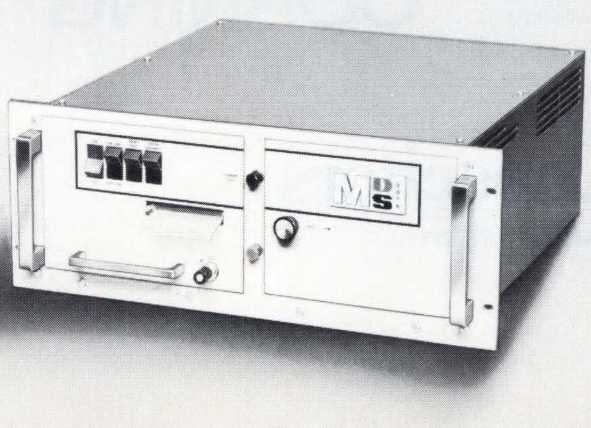
CIRCLE NO. 7



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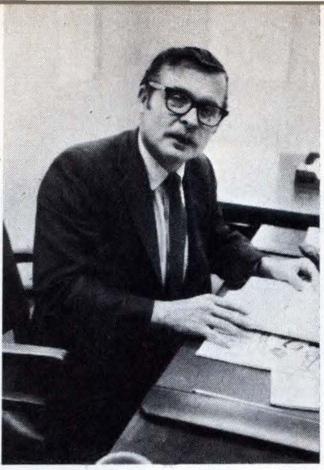
Editorial



Attitude may not be everything . . . but!

We were taken to task recently for implying that our troubled economy might benefit from a little more positive thinking and considerably less accentuating of the negative.

Our point was that the U.S. economy is still the strongest in the world, and despite its problems it contains most of the elements needed to right itself. What these elements need is a catalyst to activate them and get them going once again—and positive thinking and talk could be just such a catalyst.

A great design, production and distribution capability is worth nothing if it is merely a capability. It must be used to amount to anything. It won't be used, though, if everyone waits for everyone else to buy, or produce, or expand. And positive thinking can eliminate, or at least soften, this wait-and-see attitude.

This is especially true now that the President has established Wage and Price Boards to exercise a degree of control over these two vital ingredients of the economy. If these work as envisioned, to keep inflation under control, then peoples' and companies' attitudes could be the single most important factor in getting the economy going full steam again.

This doesn't mean, though, that positive thinking is going to solve all the problems besetting the electronics industry or the design engineer. Not at all. Foreign imports, particularly from Japan, are still going to cost American companies markets and American engineers jobs, and President Nixon's surcharge on imports isn't going to change this very much.

Also, a booming economy won't mean a booming military/aerospace electronics business, which in the past was so profitable for both companies and engineers.

These are knotty problems that arise from the increasing worldwide nature of the electronics industry, and the rather dramatic shifts in our national priorities here at home. They represent situations where decisions vitally affecting the electronics industry are made at the upper reaches of Government—where electronics is just another industry, along with steel, automobiles and textiles.

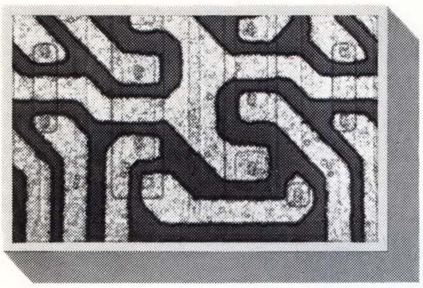
Nevertheless, the resolution of our industry's problems will be easier to bring about as well as more palatable to those involved if accomplished within the framework of a healthy economy. And positive attitudes, we feel, are significant steps in this direction.

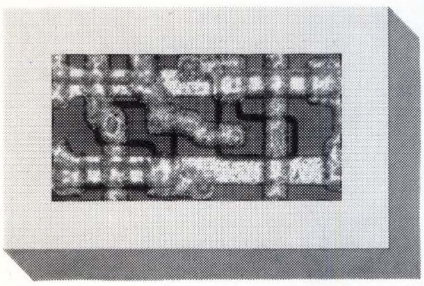
Frank Egan

EDITOR

"ISOPLANAR IS HERE, AND IT WORKS"

For openers, a 256-bit TTL RAM that's dense as MOS but fast as bipolar. Debugged and deliverable now.





Comparison of one bit of memory in conventional bi-polar design (top) and new isoplanar technique (bottom).

There Were Times We Had Doubts.

In March, when we announced the isoplanar process, we also announced that we weren't really sure it was commercially feasible.

We had had a lot of experience in production LSI bipolar memory components and systems (last year we shipped more than 8 million bits to Illiac IV alone). So we went ahead—antsy but optimistic.

We selected a fully-decoded 256-bit RAM to prove we could produce a device of that complexity quickly, efficiently, and profitably, using the isoplanar process.

We could. And did.

Presenting—debugged and deliverable—our new isoplanar 93410 256-bit RAM. Fast, small, dense.

As Les Hogan, our President, said: "Isoplanar is here, and it works." Beyond our expectations.

And, looking ahead, isoplanar is where it is going to happen.

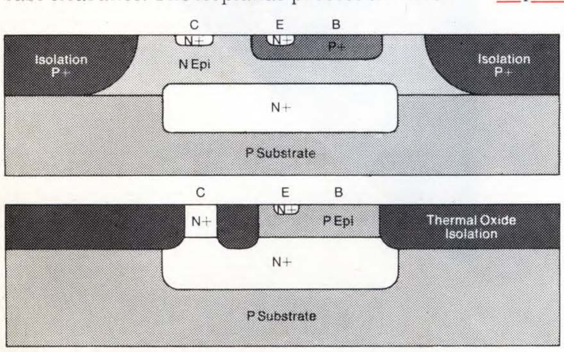
Isoplanar Technology. Briefly.

The old-fashioned planar process required a large region for p+ isolation and isolation-to-base clearance. The isoplanar process shrinks this region and fills it with thick insulating silicon oxide that needs no separation from base and collector regions.

Selective etching of silicon nitride, without harming the oxide, provides simpler masking rules and a self-aligning base. Transistor geometries are smaller and parasitic capacitance is reduced. The structures are less sensitive to defects in manufacturing (reduction of the active isolation area, for example, eliminates failures due to oxide pinholes). The surface of the chip is flat, so the traditional metal-over-oxide step problems are eliminated; metallization is simpler and more reliable.

We got smaller, denser, more reliable products with higher yield. At a low cost to our customers. Plus a reasonable profit for us.

What we hoped for, we got.



No space is required between base and collector regions and isolation in isoplanar bi-polar (bottom) compared to conventional planar bi-polar (top).

Isoplanar Is Good for You.

What do you get?

- More electronics for your dollar.
- MOS density.
- Speed of bipolar.
- Higher reliability from an essentially co-planar structure.
- Devices that are compatible with voltage and logic levels of standard ECL and TTL families.
- Wider choice of speed/power trade-offs—isoplanar design uses energy more efficiently.
- Smaller chip real estate, which reduces costs no matter how you look at it.
- Low-cost advantages from our higher yields.
- Devices that are available now.

The First Isoplanar Production IC in the World.

The 93410 high-speed TTL RAM is designed for scratchpad memory, buffer, and distributed main memory application.

- Operates from 0 to 75°C.
- Three chip select lines.
- Uncommitted collector outputs.
- Chip select access time: 20 Nsec.
- Read access time: 50 Nsec.
- Power dissipation: 2 mW/bit.

The 93410 is built on a 96 x 126 mil chip. It uses conventional, high-volume, reproducible metal widths and clearances. (For comparison, our own 256-bit 93400 bipolar memory for Illiac IV occupies a 110 x 140 mil chip, has only partial decoding, and typical access time of 50 Nsec.) It is available now in sample quantities (100-up) at $21.50 each in 16-pin ceramic DIP.

The 93410 is a superior product, per se. More important, it proves the economic feasibility of the isoplanar process. Today, for production of low cost TTL or ECL read/write memories. Soon, hopefully, for a host of other semiconductor devices.

Tomorrow's Memories.

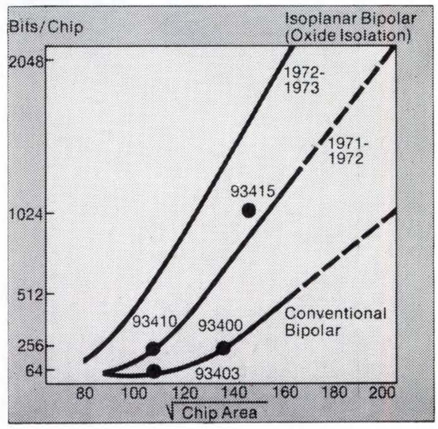
With the 256-bit isoplanar RAM a current reality, let's look at what isoplanar holds for tomorrow's memories.

We have in the works a temperature-compensated 9500 Series ECL-compatible 256-bit RAM.

We are in the development cycle of a 1024-bit fully-decoded TTL bipolar memory chip (93415) that's only slightly larger than our 256-bit isoplanar chip. The great potential in the isoplanar process will begin to be realized in this device. The 93415 is designed for high-speed buffer and main frame applications.

- Address access time: less than 100 Nsec.
- Chip select access time: less than 50 Nsec.
- Uncommitted collector outputs.
- Power dissipation: 0.5 mW/bit.
- 16-pin hermetic ceramic DIP package.

Both the ECL 256-bit RAM and the 1024-bit RAM will be available early in 1972.



The graph gives you some idea of where we've been and where we're going with bipolar memories and isoplanar. It indicates the feasibility of 2048 and 4096-bit read/write memories for 1973. By then we fully expect isoplanar to dominate memories in high-performance and small systems. Memory designers please note that our estimates of packing density and time scale are at least as conservative as our original announcement of the process.

Beyond Memory.

But isoplanar doesn't stop with memories.

The process, we feel, will profoundly effect the architecture of future generations of computers. Ultimately isoplanar technology will be used to fabricate together, on the same chip, combinations of logic and memory of much greater complexity than have been considered to date. Examples are content-addressable memories and multi-port registers. What we have learned thus far indicates that, in the long run, isoplanar will prove valuable in *all* complex bipolar circuits.

The process will also bring about significant improvements in high-frequency low-noise transistors, diodes, linear devices, in low-cost realization of monolithic complementary MOS devices, in radiation-resistant circuits —in the universe of semiconductor devices.

For More Information.

We've put together a package of information about the isoplanar process, products and prognosis. It's available for the asking.

Fairchild makes advanced products to uniform standards throughout the world.

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It's economical. Low per-line cost due to simplicity of design. To the front-end saving, add AMPECONOMATION—our cost-saving automatic application technique—for staking male contacts at speeds to 4,000 per hour. No tools needed to mount female housings.

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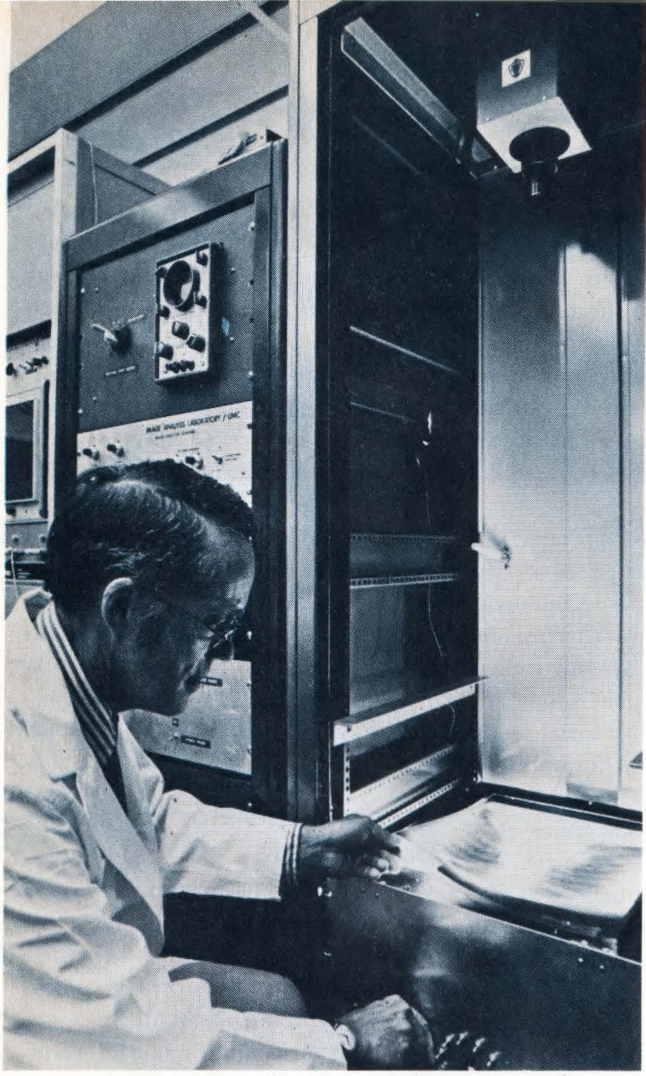


Dr. Gwilym Lodwick, of the University of Missouri Medical Center mounts an X-ray in an automated device for analyzing X-ray films.

Computer-Based Radiological Diagnosis System Outscores Physicians

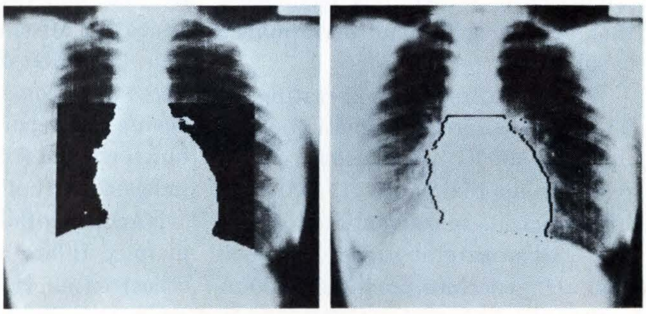
Advances continue to be made in the use of electronic equipment for improving the quality of medical diagnosis and treatment. One recent development was reported in a technical paper by researchers at the University of Missouri Medical Center and College of Engineering. Under federal grants a fully automated radiological diagnosis system was developed that utilizes an electronic scanner, an IBM computer and a series of complex computer programs. It is used to analyze chest X-rays and to prepare printed statements of heart abnormalities and their probable causes. A comparison of diagnoses performed by the automated system and those done by a panel of 10 experienced radiologists revealed a significant dfference in diagnostic accuracy.

In diagnosing heart abnormalities, the automated system and the panel fared equally well with correct assessments 94% of the time. The difference came in diagnosing normal hearts. Here the panel was correct 83% of the time while the computer scored diagnostic accuracy of 89%. Overall accuracy in 135 cases was 73% for the automated system and 62% for the panel. An additional factor to consider is that the scanner had only the frontal view in each case whereas the panelists had the advantage of both front and side views.

Conventional X-ray films are used by the system which compares the image on the film with known standards to determine the presence or absence of heart abnormalities. If abnormalities exist, it then prepares a list of possible causes in order of probability. Films placed in the scanner are examined in a 1024 by 1024 point matrix. Readings are recorded on magnetic tape that is fed into the College of Engineering's IBM computer where the data is processed into a mathematical 2-D array. The computer enhances areas for further examination and ignores areas found to be normal or irrelevant to the inquiry being made. Key features found in the enhanced areas are extracted and processed. The findings are compared with a decision-making format and the results are printed out for evaluation by a physician.

In addition to the benefits realized by the medical center, researchers recognize the possibility of utilizing the system to provide improved diagnostic services to remote areas. This could be done by spotting systems in rural areas for use by general practitioners.

This system not only provides more accurate diagnoses, but it also speeds the process and relieves radiologists of routine duties. Work is now going on to advance this technique beyond heart ailment diagnosis to include respiratory, digestive and bone tumor routines.



In these photos made from a special display device, an area is defined for enhancement (left) and the heart outline is precisely traced (right). Analyzing the slope and length of the lines mathematically, gives the computer data for determining the presence or absence of rheumatic heart disease.

Modern Technology "Shrinks" Generator Size

Superconductivity of conductors at cryogenic temperatures, a laboratory research phenomenon only a few years ago, is emerging as a practical technique to increase the efficiency of power generators. This 20th century technology has been combined with a dc generator principle over 100 years old by engineers at General Electric's Research and Development Center and the Large D-C Motor Business Section, Schenectady, N.Y. The result is a 150 kw (200hp) generator with size and weight about half that of conventional generators of comparable output.

The basic generator is similar in design to the homopolar machine demonstrated in 1831 by Michael Faraday – a simple rotating disc and horseshoe magnet.

Superconductive windings and liquid-metal electrical contacts are contributions of present-day technology that provide additional performance capabilties.

With the field coil operating at 450°F below zero a magnetic field of up to 60,000G is developed – compared to approximately 15,000G for iron core coils in conventional generators. Operating at a speed of 3600 rpm, the generator produces 17,000A at 9V.

One of the problems encountered in earlier designs of this type was the limitation of current output imposed by conventional carbon-based brushes. This problem has been solved by the use of an alloy of sodium and potassium – a liquid at room temperature – as the current collectors. Filling the narrow gap between rotor and stator, the liquid metal provides a collector with current carrying capacity of more than 3000A/sq. in. of surface. This is compared to 100A/sq. in. for carbon brushes.

Development of the generator is a result of a project sponsored by the Naval Ship Systems Command, Washington, D C. Similar techniques applied to dc motors are envisioned, with the resulting generators and motors providing a substantial reduction in size and weight for ship propulsion applications. In addition to saving weight and space, this system would provide easier control and greater flexibility than present propulsion systems afford. For example, speed and direction of a ship could be changed with this system merely by varying or reversing the field current of the generator. Mechanical alignment requirements also would be greatly simplified.

Other applications for machines of this type include those requiring high torques at variable speeds, or very large dc currents at low voltages. Designs are now on the drawing board for motors and generators with ratings up to 30,000 hp.

Spaceborne Computer To Relieve Ground Systems

By the mid-1970s, the Air Force Space and Missile Systems Organization (SAMSO) hopes to build and flight test a computer capable of diagnosing and repairing spacecraft malfunctions and fixing its own failures, independently of the ground.

NASA has flown computers in its manned flights, but there has been no concerted effort to develop reliable, nuclear survivable, on-board computers for unmanned flights.

By developing on-board systems, SAMSO engineers hope to lighten the workload of ground control systems and reduce future development costs.

Duties of the computer, which is to have a 5-year lifetime and nuclear survivability, will include station keeping, attitude control, vehicle housekeeping, sensing spacecraft parameters and making appropriate adjustments.

Systems definition contracts have been awarded to Raytheon of Boston, Mass., and to Ultra Systems of Newport Beach, Calif. These contractors will determine what type of computer is needed for on-board spacecraft computations and also identify technologies that must be developed before the computer becomes a reality.

Remote Operator Directs SAM

One of these days a man may sit in front of a console in Houston, Tex. and direct the movements of a vehicle similar to SAM while it travels across the surface of the planet Mars.

SAM is the popular name for a Self-propelled Anthropomorphic Manipulator, developed by the AEC/NASA Space Nuclear Systems Office (SNSO). SAM – equipped with manipulators that duplicate the movements of the human arm, and television cameras that see and transmit the movements – can be directed by a man a mile or millions of miles away.

SAM's operator will wear a "harness" over his head and arms (in fact, an "external skeleton") so that whenever or however he moves the movements will be duplicated by SAM wherever he may be.

The part of the communication system between SAM and his operator – known as the "data link" – is made by Phoenix Data, Inc., Phoenix, Ariz. It takes analog signals as they are generated by the operator's movements and changes them to digital information in PCM (pulse code modulation) format. In that form they are transmitted to SAM. After they are received, they are changed from their PCM state back to analog signals that direct SAM to duplicate the operator's movements.

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

New Celanex-917 is the first thermoplastic polyester to combine dimensional advantages of thermosets with processing advantages of thermoplastics. It's the most processable polyester on the market. By far.

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

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

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

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

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

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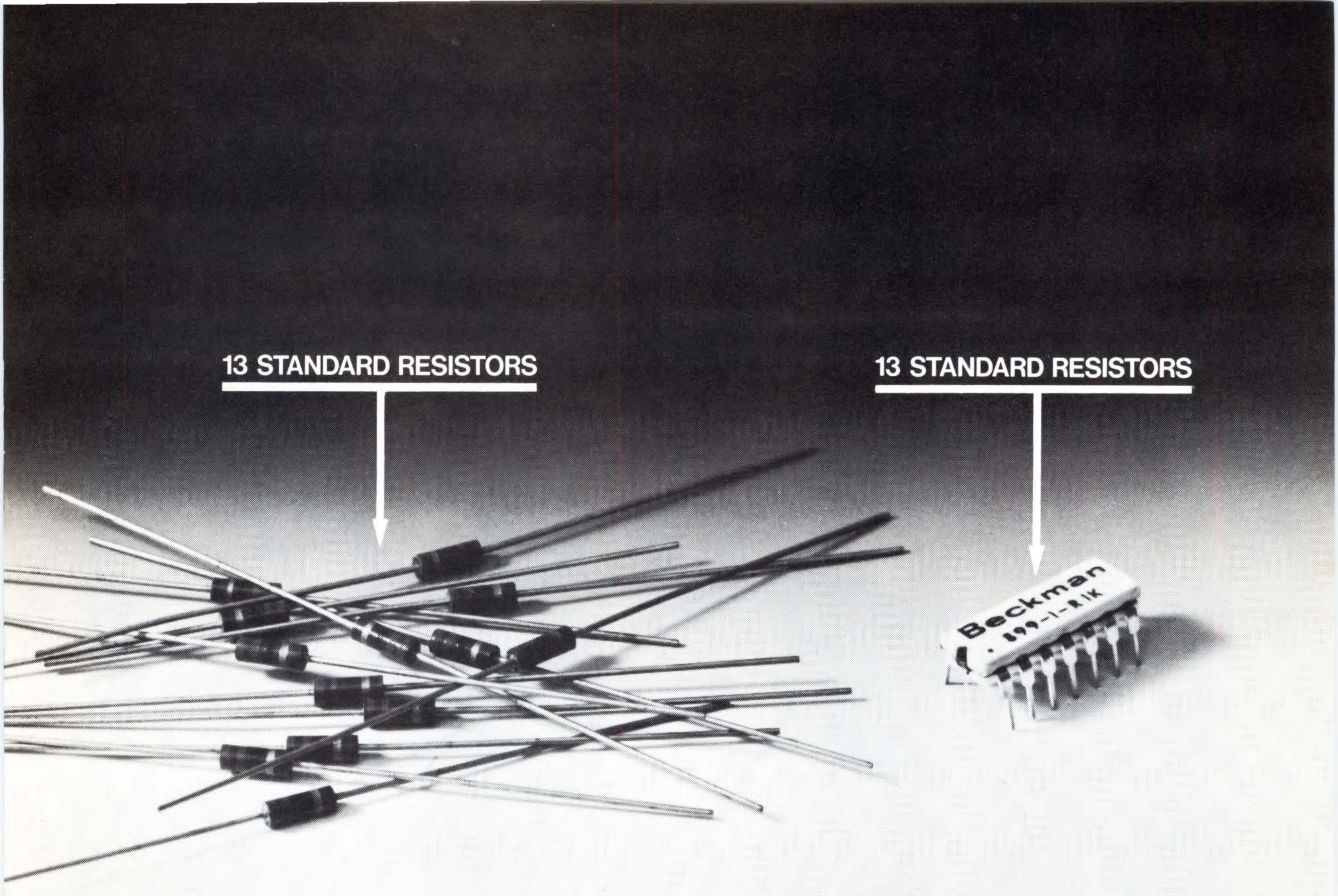

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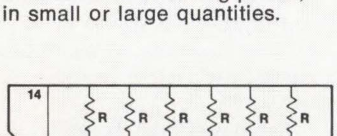

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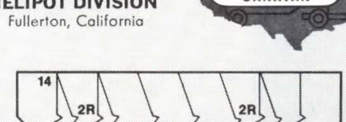

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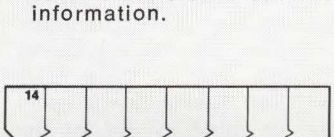

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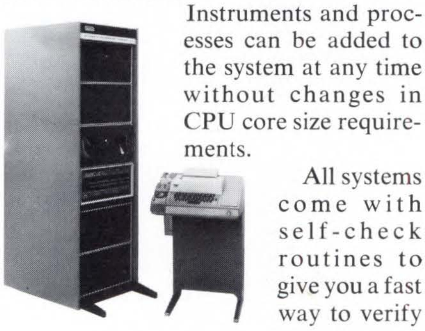

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OVERCOMING STABILITY PROBLEMS IN APPLYING FET-INPUT OP AMPS

Methods to reduce input and stray capacitance effects vary according to the amount of clôsed-loop gain.

GARY LABELLE, Teledyne Semiconductor

FET-input operational amplifiers have become popular in applications such as active filters and integrators, where loading effects must be minimal. However, the high impedance levels associated with these applications can create stability problems because of amplifier input capacitance and stray capacitance from output to input. Methods to reduce these problems for applications with various closed-loop gains will be covered in this article.

Unity-Gain Compensation

Let's start off by looking at FET-input op-amp ICs with unity gain compensation, such as 741-type ICs (with built-in 30-pF compensating capacitance). The closed-loop and open-loop equivalent circuits for this type of amplifier are shown in **Figs. 1a** and **1b**. The open-loop response A_{OL} can be written as:

$$A_{OL} = \frac{e_o}{e_i} = \frac{R_i}{R_i + R_f}\left[\frac{[SR_fC_f + 1}{S\left(\frac{R_iR_f]}{R_i + R_f}\right)(C_f + C_i) + 1}\right]\frac{A_o}{S + \tau} \quad (1)$$

where A_o is the amplifier open-loop gain, τ is the pole frequency of the internal unity-gain compensation, C_f and C_i are design or stray feedback and input capacitance, $S = j\omega$ and R_f and R_i are the external design resistors.

The expression for A_{OL} indicates that the open-loop response, with $C_f \neq 0$, can have either a lead-lag or a lag-lead relationship with the compensated rolloff. Also, if $\omega_{lead} = \omega_{lag}$, the response resulting will be that of the compensation only.

The response resulting from the external components only is shown in **Fig. 2**. With $\omega_{lag} > \omega_{lead}$, the following equations can be used to obtain $R_fC_f > R_iC_i$ for the lead-lag condition or $R_fC_f < R_iC_i$ for the lag-lead condition:

$$\omega_{lag} = \frac{1}{R_p\,(C_f + C_i)} \quad (2)$$

$$\omega_{lead} = \frac{1}{R_fC_f} \quad (3)$$

$$R_p = \frac{R_iR_f}{R_i + R_f} \quad (4)$$

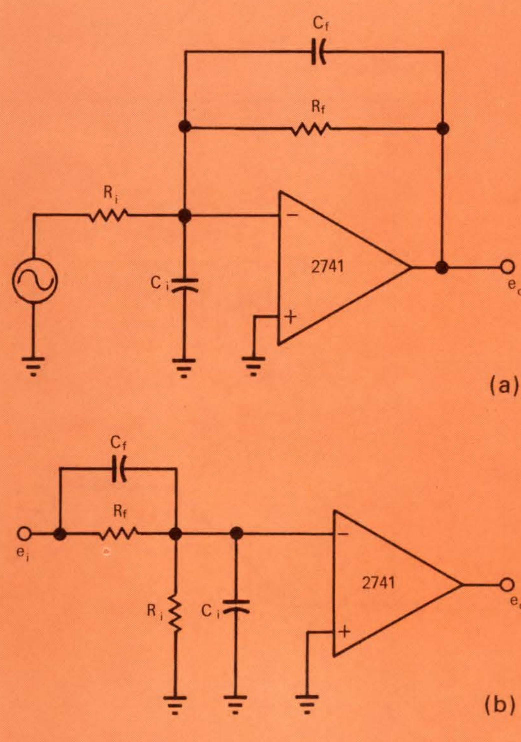

Fig. 1 – **Closed-loop** (a) and open-loop (b) equivalent circuits for FET-input op-amp IC.

(Continued)

FET Input Op Amps (Cont'd)

For the lag-lead condition, α can be expressed as:

$$\alpha = \frac{R_i\ (C_f + C_i)}{C_f\ (R_i + R_f)} \tag{5}$$

For the lead-lag condition, α is given by:

$$\alpha' = \frac{1}{\alpha} = \frac{C_f\ (R_f + R_i)}{R_i\ (C_f + C_i)} \tag{6}$$

The lag-lead response characteristic exhibits an attenuation $1/\alpha$ and a negative phase shift reaching a maximum at ω_ϕ. The response obtained when ω_ϕ is close to the open-loop unity-gain crossover frequency is undesirable because of the additional phase shift.

For the condition $\omega_{lead} = 10\ \omega_{lag}$, the additional phase shift at ω_ϕ is approximately 55°. For a factor **m** of 2 away (either double ω_{lead} or one-half ω_{lag}) from ω_{lead} or ω_{lag}, the phase shift is 25°, and for a factor of 5 away it is 10°. For most systems, the addition of 55° phase shift would reduce the closed-loop phase margin to an unacceptable value. For example, if 10° can be allowed, then the unity gain crossover frequency should be $m = 5\omega_{lead}$ or $\omega_{lag}/5$.

The overall loop response of **Eq. 1** caused by the op-amp compensation and the external components is shown in **Fig. 3**. If $R_iC_i = R_fC_f$ (**Fig. 3a**), the pole and zero in **Eq. 1** cancel, and both A_o and ω_{co} have a common "attenuation" factor $\beta = R_i/(R_i + R_f)$. Expressions for A_o' and ω_{co}' are defined by letting $A_o' = \beta A_o$ and $\omega_{co}' = \beta\omega_{co}$. For this case ω_{co}' is the open-loop unity-gain crossover frequency. With $R_iC_i > R_fC_f$ (**Fig. 3b**), the open-loop unity-gain crossover frequency is ω_{co}'', where ω_{co}'' is ω_{co} times the lag-lead attenuation factor $1/\alpha$ shown in **Fig. 2a**, or:

$$\omega_{co}'' = \frac{1}{\alpha}\beta\omega_{co} = \frac{C_f\ (R_f + R_i)}{R_i\ (C_f + C_i)}\ \frac{R_i}{(R_f + R_i)}\ \omega_{co} \tag{7}$$

$$= \frac{C_f}{C_f + C_i}\ \omega_{co}$$

The crossover frequency for the lead-lag response condition of **Fig. 3c** is $\alpha'\omega_{co}'$. Substituting $\beta\omega_{co}$ for ω_{co}' we obtain:

$$\omega_{co}'' = \alpha'\beta\omega_{co} = \frac{C_f\ (R_f + R_i)}{R_i\ (C_f + C_i)} \left[\frac{R_i}{(R_f + R_i)}\right] \omega_{co} \text{ and} \tag{8}$$

$$\omega_{co}'' = \frac{C_f}{C_f + C_i}\ \omega_{co}$$

If open-loop unity-gain crossover frequencies ω_{co}'' and ω_{co}' are known, one of the following conditions can be set to keep the lag-lead response from occurring close to the crossover point:

$$\omega_{lead} < m\omega_{co}'' \tag{9}$$

$$\omega_{lag} > m\omega_{co}' \tag{10}$$

$$\omega_{lag} = \omega_{lead} \tag{11}$$

The factor **m** was mentioned earlier and was 2 or 5 for the example given. **Eq. 9** requires that the lead condition occur before crossover—hence maximum phase shift (ϕm) must also occur before crossover. **Eq. 10** requires that the lag frequency occur after $m\omega_{co}'$. (Note: ω_{co}'' is not used in **Eq. 10** because the attenuation $1/\alpha$ does not occur until after crossover.) Using **Eqs. 9-11** and substituting for ω_{lead}, ω_{lag}, ω_{co}', and ω_{co}'', we can solve for the

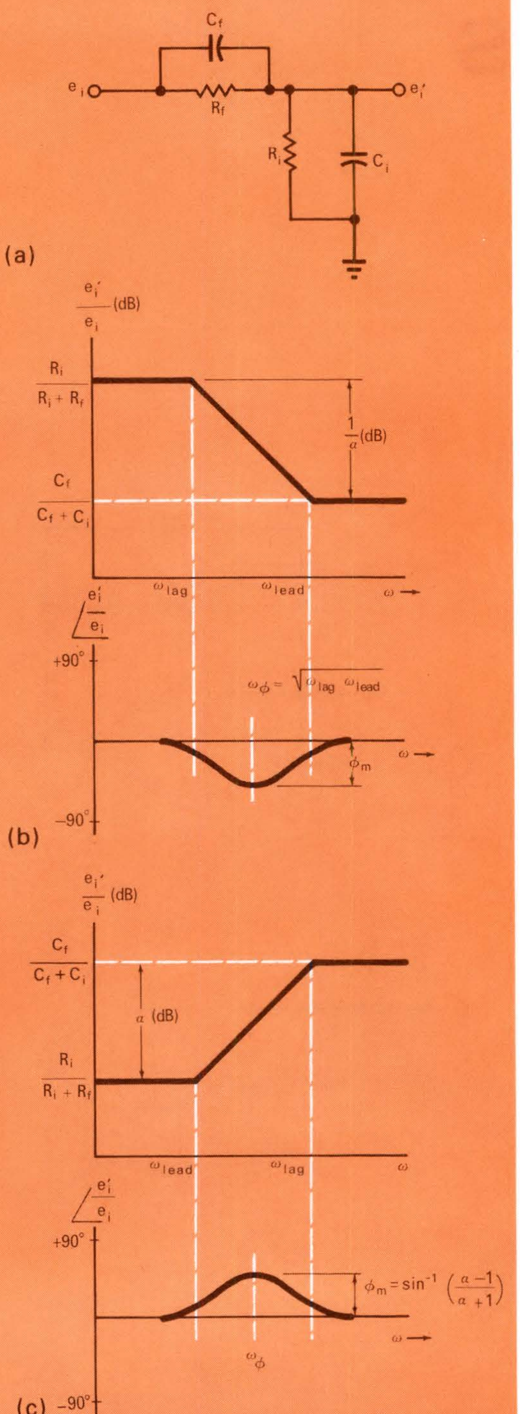

Fig. 2—**The gain and response** caused by the external components in the circuit only (a) is shown for the lag-lead condition (b) and the lead-lag condition (c).

external components R_f, R_i, C_f and C_i to be used with an amplifier having crossover frequency ω_{co} where ω_{co} is the open-loop unity-gain crossover frequency with unity feedback.

For **Eq. 9** ($\omega_{lead} < m\omega''_{co}$):

$$\frac{1}{R_fC_f} < \frac{C_f}{C_f + C_i}\omega_{co} \text{ or } \omega_{co} > \frac{C_f + C_i}{m\, R_fC_f^2} \tag{12}$$

For **Eq. 10** ($\omega_{lag} > m\omega'_{co}$):

$$\frac{1}{R_p\ (C_f + C_i)} > m\frac{R_i}{R_i + R_f}\omega_{co}$$

$$\text{or } \omega_{co} < \frac{R_f}{R_p^2}\frac{1}{C_f + C_i} \tag{13}$$

For **Eq. 11** ($\omega_{lag} = \omega_{lead}$)

$$\frac{1}{R_o\ (C_f + C_i)} = \frac{1}{R_fC_f} \text{ or } R_fC_f = R_iC_i \tag{14}$$

Typical Example

For a typical FET-input op amp (such as the Teledyne 2740 or 2741), $\omega_{co} = 2\pi$ (300 kHz), $C_i = 8$ pF and $C_f = 1$ pF. If we let m = 5 and set $R_f = R_i$, then **Eqs. 12-14** yield the following results:

(1) $2\pi\ (300\ \text{kHz}) > \frac{9\ \text{pF}}{5\ R_f\ (1\ \text{pF})^2}$

$$R_f > \frac{9}{2\ (3 \times 10^{-7})\ 5}$$

$R_f > 955$ kΩ (using **Eq. 12**)

(2) $2\pi\ (300\ \text{kHz}) < \frac{R_f}{m\ (R_f/2)^2}\frac{1}{9\ \text{pF}}$

$$R_f < \frac{4 \times 10^7}{9\ (2\pi)\ (3)\ (5)}$$

$R_f < 47$ kΩ (using **Eq. 13**)

(3) Since $R_f = R_i$, $R_fC_f \neq R_iC_i$. We can add 7 pF from input to output to make $C_f = 8$ pF. Then $R_fC_f = R_iC_i$ (using **Eq. 14**).

For the unity gain case $R_f = R_i$, the above three equations are sufficient to determine whether or not feedback capacitance C_f must be added.

For $R_f < 47$ kΩ, $R_f > 955$ kΩ and $R_f = R_i$, no changes need be made. However, for values of R_f between 47 and 955 kΩ (with unity gain), the stability of the op amp can be maintained by adding 7 pF across C_f (stray) so that the $R_fC_f = R_iC_i$ condition is achieved. Another way to insure stability is to measure the overshoot for a step input and adjust C_f for the desired stability. This method may also be used to check the calculated value of C_f. cause of the positive phase added. One drawback of this type of response,

The lead-lag response shown in **Fig. 2b** improves the phase margin because of the positive phase added. One drawback of this type of responce, however, is that the closed-loop, 3-dB bandwidth corresponds to the $\omega_{lead} = 1/R_fC_f$ frequency. Also, the crossover frequency is increased by the factor α' over the case when $R_iC_i = R_fC_f$.

Gain of 10 (20-dB) Compensation

For compensations other than unity gain, such as 20 dB or higher, **Eq. 1**

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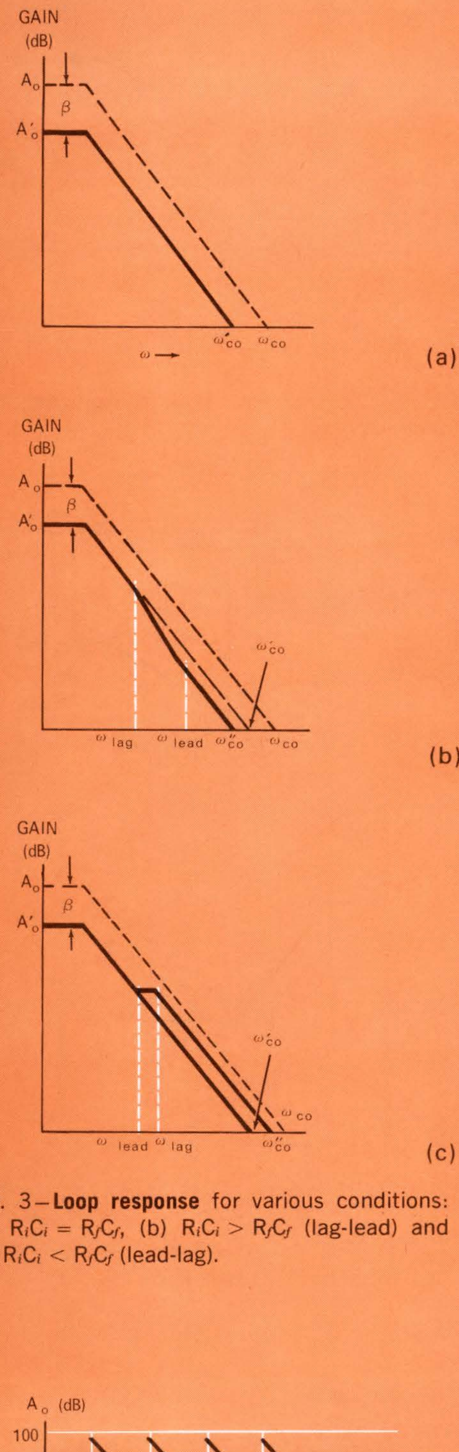

Fig. 3—**Loop response** for various conditions: (a) $R_iC_i = R_fC_f$, (b) $R_iC_i > R_fC_f$ (lag-lead) and (c) $R_iC_i < R_fC_f$ (lead-lag).

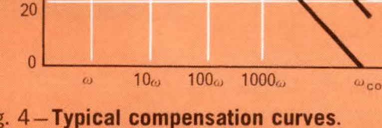

Fig. 4—**Typical compensation curves.**

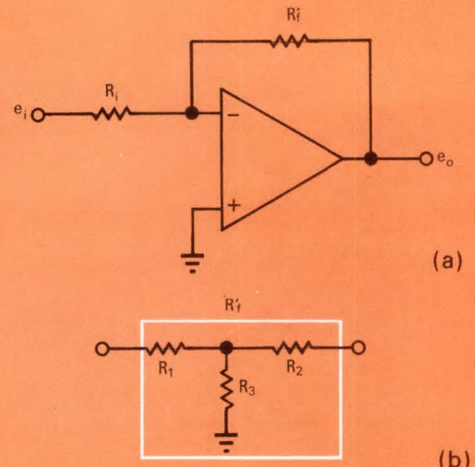

Fig. 5—**"T" feedback-circuit configuration** (b) for circuit in (a).

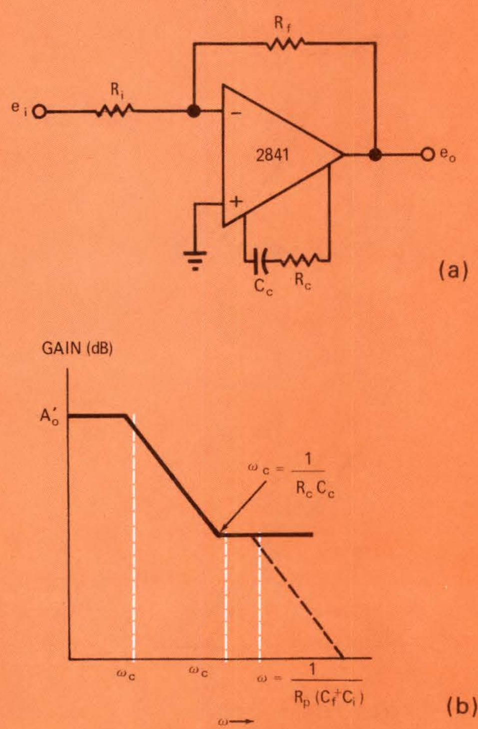

Fig. 6—**Type 2841 IC circuit** (a) with compensation. Response is shown in (b).

Gary LaBelle has been with Teledyne Semiconductor, Mountain View, Calif., for 3-1/2 years, and is presently product marketing manager, Hybrid Microcircuits. A member of ISHM, he received a B.E.E. from the University of Minnesota and an M.S. E.E. from the University of Santa Clara.

FET Input Op Amps (Cont'd)

can be reduced to:

$$A_o \simeq \frac{R_i}{R_f}\left[\frac{S\,R_f C_f + 1}{S\,R_i\,(C_i + C_f) + 1}\right]\frac{A_o}{S + \tau} \qquad (15)$$

Since $R_f \geqslant 10\ R_i$, we are interested primarily in the frequency response and the 10% gain error for a gain of 10 can be neglected. As shown in **Fig. 4**, ω_{co} now occurs at 20 dB of amplifier gain. When the total open-loop response is considered, the attenuation β should cancel the 20-dB gain and allow crossover at loop unity gain to occur at ω_{co} or below. This compensation in combination with the gain of 10 ($R_f/R_i = 10$) results in a stable system because C_i is typically 10 C_f (8-pF input capacitance compared to 0.5 to 1 pF stray capacitance). Hence $R_iC_i \simeq R_fC_f$, as seen in **Fig. 3c**. If C_f is large—say equal to C_i—then the relation $\omega''_{co}\ C_f/(C_f + C_i)\ \omega_{co}$ shows that $\omega''_{co} \simeq 1/2\ \omega_{co}$. This could cause stability problems because the attenuation β is offset by α' effectively extending crossover past ω_{co}. For the case above, β is 10. If $C_f = C_i\ \omega''_{co} = 1/2\ \omega_{co}$, the net loop attenuation will change from 20 dB at low frequency to 6 dB around crossover—this means the loop has 14 dB of gain left at ω_{co}. Extending crossover like this may allow the net unity gain to occur at an uncontrolled high phase region—resulting in poor stability. In general, if $(\beta - \alpha')$ is less than the gain being compensated for, this problem can occur.

The previous discussion covered the case when the closed-loop gain was 10. For a higher closed-loop gain with this compensation, the same lag-lead condition encountered in unity-gain compensation can occur—$R_iC_i \neq R_fC_f$.

Gain of 100 (40-dB) Compensation

For higher gains such as occur when $R_f/R_i \geqslant 100$ (and no added C_f), the open-loop response will always be lead-lag as shown in **Fig. 3c** with $\beta - \alpha' \simeq 10$ ($C_i = 10\ C_f$). For this case, the open-loop response could extend a factor of 10 past the recommended crossover frequency. Also, $1/R_fC_f$ is the closed-loop 3-dB point. Since R_f is very large, it can create problems. For these reasons, C_f should be kept as small as possible by using careful wiring techniques. To insure stability, the amplifier should be overcompensated so that $\beta - \alpha' \simeq K$, where K is the amount of gain you are compensating for. One way to keep the closed-loop bandwidth higher ($1/R_fC_f$) is to make R_f in the form of a "T" circuit (see **Fig. 5**). The closed-loop pole for this case can be made to occur at a much higher frequency.

In **Fig. 5a**, $G = -(R'_f/R_i)$ and in **Fig. 5b**, G can be expressed as:

$$G = -\left(\frac{R_1R_2 + R_2R_3 + R_3R_1}{R_iR_3}\right) = -\left(\frac{R'_f}{R_i}\right) \qquad (16)$$

Special Compensations

For an amplifier with external compensation (such as the 2841), the effects of input capacitance at unity gain can be minimized by leaving out the external 30-pF compensation capacitor when the pole caused by R_p and $(C_f + C_i)$ starts. For example, with $C_i = 8$ pF, $R_i = R_f = 1\ M\Omega$ and $C_f = 1$ pF, let

$$\frac{1}{R_p\ (C_f + C_i)} = \frac{1}{R_cC_c}$$

Then,

$$R_c = \frac{0.5\ M\Omega\ (9\ pF)}{30\ pF} = 150\ k\Omega$$

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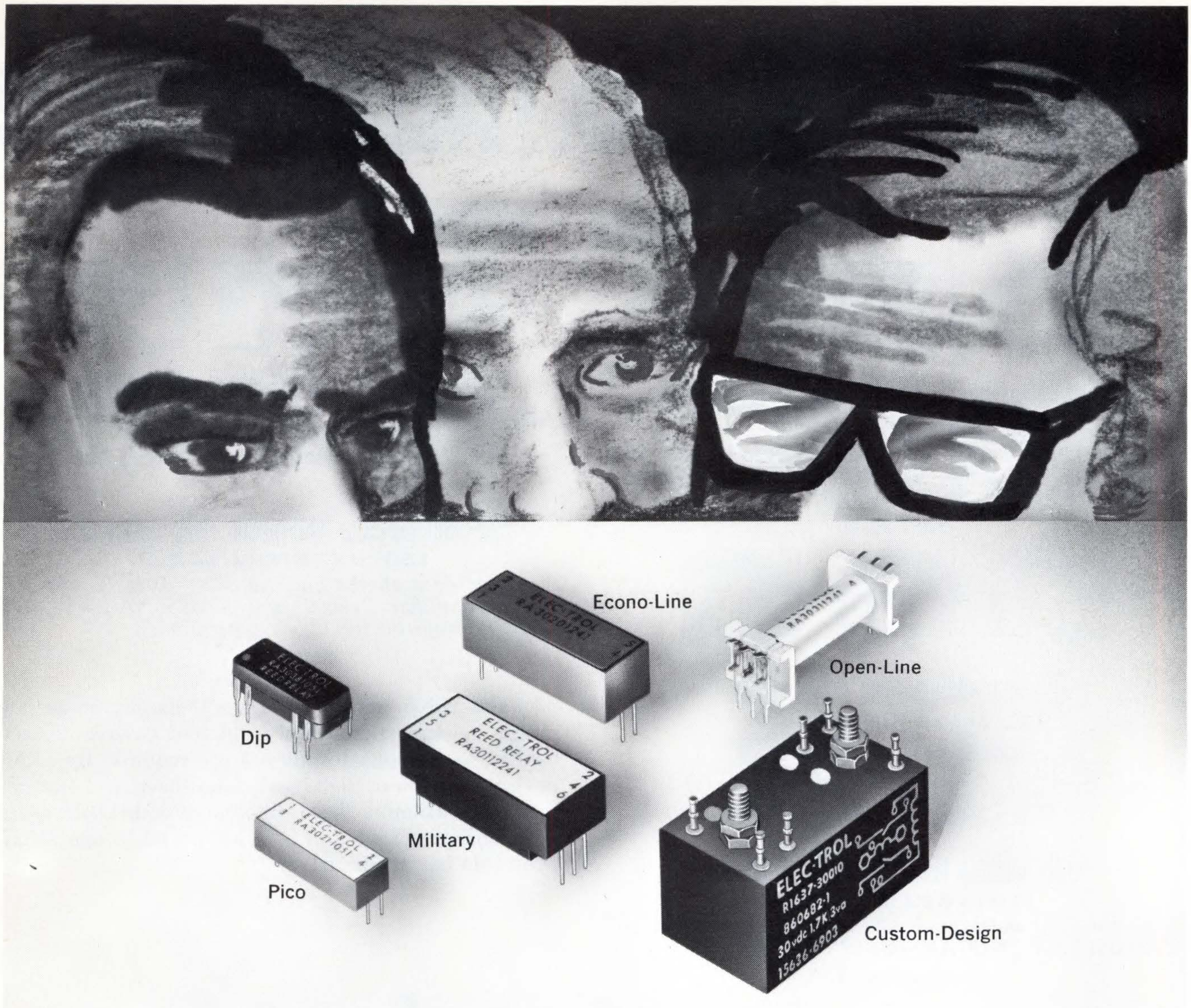

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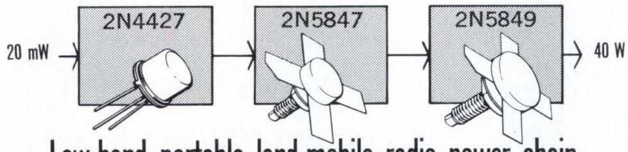

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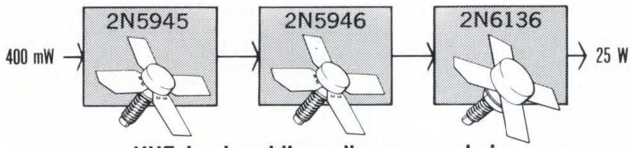

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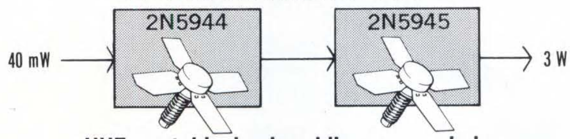

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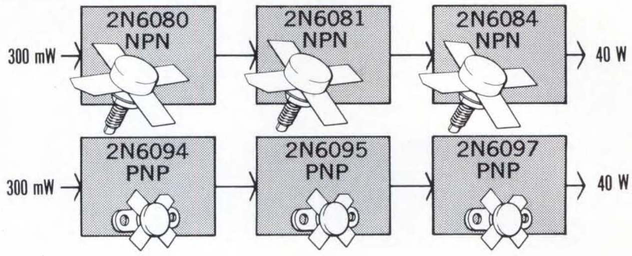

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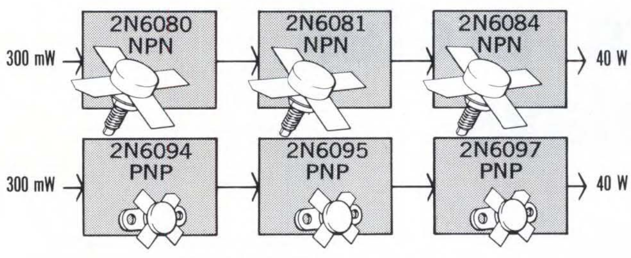

Marine radio power chain.
152 to 162 MHz, 12.5 V.

Send for data sheets and AN282: "Systemizing RF Power Amplifier Design" and AN495: "A 25 W, 175 MHz Transmitter for 12.5 V Operation."

CIRCLE NO. 24

Marine radio falls into the same frequency range as high-band land-mobile with the same type of modulation and voltage required. Both PNP and NPN chains are available from Motorola for your designs!

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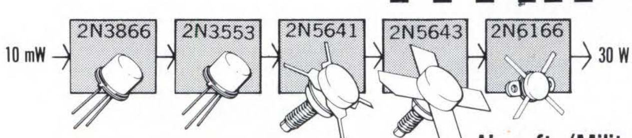
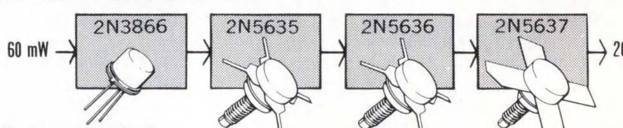




108 to 136 MHz, 13.5 V. **Aircraft/Military radio power chain.** **225 to 400 MHz, 28 V.**

Send for data sheets and AN481: "A broadband 4 W Aircraft Transmitter;" AN503: "A 25 W Broadband Aircraft Transmitter" and AN507: "A 13 W Broadband AM Aircraft Transmitter."

CIRCLE NO. 22

CIRCLE NO. 25

Typical AM systems are shown. Devices capable of 25 W and 50 W output for 225 to 400 MHz range are available on special request. And they're Isothermal-rugged!

With You At Once

. . . by cable TV!

CATV Device	Gain (dB)	Cross Modulation Distortion	Noise Figure (dB)	Case
2N5109	11 Typ	−70 dB Typ(1)	3.0 Typ	
2N5943	11.4 Typ	−67 db Typ(2)	3.4 Typ	
2N5947	11	−60 dB Typ(3)	3.8 Typ	
2N6135	11	−62 dB Typ(3)	4.8 Typ	

(1) 2 channel with +54 dBmV output level
(2) 12 channel with +40 dBmV output level
(3) 12 channel with +50 dBmV output level

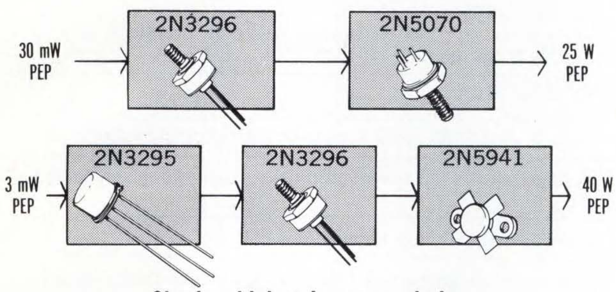
CATV. **5 to 300 MHz**

Send for data sheets with complete characterization for broadband CATV operation including distortion specs, noise figures and Y & S parameters . . . they're unique with Motorola!

CIRCLE NO. 26

Hybrid circuits offer important performance, reliability and space advantages. Both upstream and downstream hybrid designs are available from the factory.

. . . on single sideband!



Single sideband power chain.
2 to 30 MHz, 28 V.

Send for data sheets and AN546: "Solid-State Linear Power Amplifier Design."

CIRCLE NO. 27

The problem of linear amplifier design, including a technique for temperature compensation utilizing only passive devices can be solved. The block diagrams show output capability at two of the most popular power levels with 150 W PEP outputs easily obtainable with multiple devices.

. . . without noise!

Low-Noise Device	Noise Figure (max)	Frequency	Case
2N5179	4.5 dB	200 MHz	
2N5031	2.5 dB	450 MHz	
2N2857	4.5 dB	450 MHz	
2N5829 (PNP)	2.5 dB	450 MHz	
2N4957 (PNP)	3.0 dB	450 MHz	

Low Noise Designs.

Send for data sheets and AN215: "RF Small Signal Design Using Admittance Parameters;" AN419: "UHF Amplifier Design Using Data Sheet Design Curves" and AN421: "Semiconductor Noise Figure Considerations."

CIRCLE NO. 28

These low-noise devices excel in receiver front-end designs and have excellent noise figures at frequencies other than those listed. Design in Motorola quietness!

. . . and a word about ruggedness in RF.

Few semiconductors are subject to as severe treatment as RF devices. Load mismatching — by far the largest single cause of transistor failure — has largely been curtailed with the introduction of Motorola balanced emitter technology . . . BET* . . . and most recently, Isothermal* fabrication techniques. The latter has furnished an important new level in RF device ruggedness on many Motorola types with heat buildup reduced 50% through use of an asymmetrical emitter-resistor path design which apportions heat evenly over the entire chip surface.

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Call on the power of the Kokomoans for your systems of the 70's.

The tough breed of High Voltage Silicon Power Transistors.

Transistor	V_{CEX} Voltage	Continuous I_C	V_{CEO} (sus)	Maximum Power Dissipation	Typical Applications
DTS 401	400V	2A*	300V		*I_C Peak=5A Vertical magnetic CRT deflection, has good gain linearity.
DTS 402	700V	3.5A*	325V		*I_C Peak=10A Horizontal magnetic CRT deflection, features fast switching time, high reliability under horizontal sweep fault condition.
DTS 410	200V	3.5A	200V	80W	
DTS 411	300V	3.5A	300V	100W	Voltage regulator, switching regulator, DC to DC converter, class A audio amplifiers.
DTS 413	400V	2.0A	325V	75W	
DTS 423	400V	3.5A*	325V	100W	*I_C Peak=10A High V_{CBO} and V_{CEO} ratings make it practical to operate directly from rectifier 117V or 220V AC line.
DTS 424	700V	3.5A*	350V	100W	*I_C Peak=10A High V_{CBO}, V_{CEO}(sus) ratings make them ideal for use in deflection circuits, switching regulators and line operating amplifiers.
DTS 425	700V	3.5A	400V	100W	
DTS 430	400V	5A	300V	125W	Voltage regulators, power amplifiers, high voltage switching.
DTS 431	400V	5A	325V	125W	
DTS 701	800V	1A	600V	50W	Vertical magnetic CRT deflection circuits.
DTS 702	1200V	3A	750V	50W	Horizontal magnetic CRT deflection circuits operating off-line.
DTS 704	1400V	3A	800V	50W	
DTS 721	1000V	3A	800V	50W	High voltage DC regulators.
DTS 723	1200V	3A	750V	50W	Very high voltage industrial and commercial switching.
DTS 801	1000V	2A	700V	100W	Color vertical magnetic CRT deflection circuits.
DTS 802	1200V	5A	750V	100W	Color horizontal magnetic CRT deflection circuits.
DTS 804	1400V	5A	800V	100W	
2N3902†	700V	3.5A*	325V	100W	*I_C Peak=10A Ideal for switching applications. Can be operated from rectified 117 or 220 volt AC line.
2N5157	700V	3.5A*	400V	100W	
2N5241	400V	5A	325V	125W	For general use in electrical and electronic circuits such as converters, inverters, regulators, etc.
2N2580	400V	10A	325V	150W	
2N2581	400V	10A	325V	150W	
2N2582	500V	10A	325V	150W	
2N2583	500V	10A	325V	150W	
2N3079	200V	10A	200V		
2N3080	300V	10A	300V		

†Mil. qualified units available.

Transistors are NPN triple diffused.

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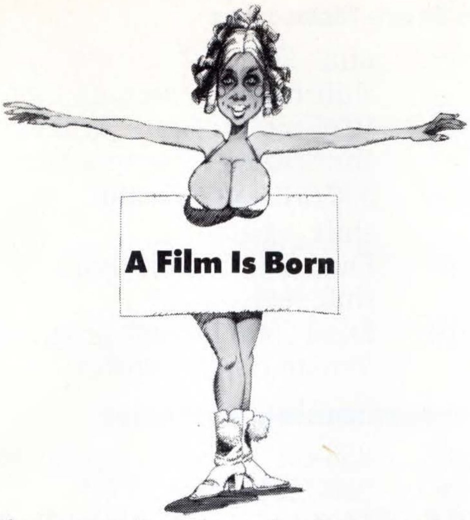
GM
MARK OF EXCELLENCE

CIRCLE NO. 19



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

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

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

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

Free crackerjacks.

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

Five-Part Flick

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

Part One: Mainframe Memories

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

Part Two: Scratchpad/Cache Memories

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

Part Three: Silicon Store Memories

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

Part Four: Buffer Memories

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

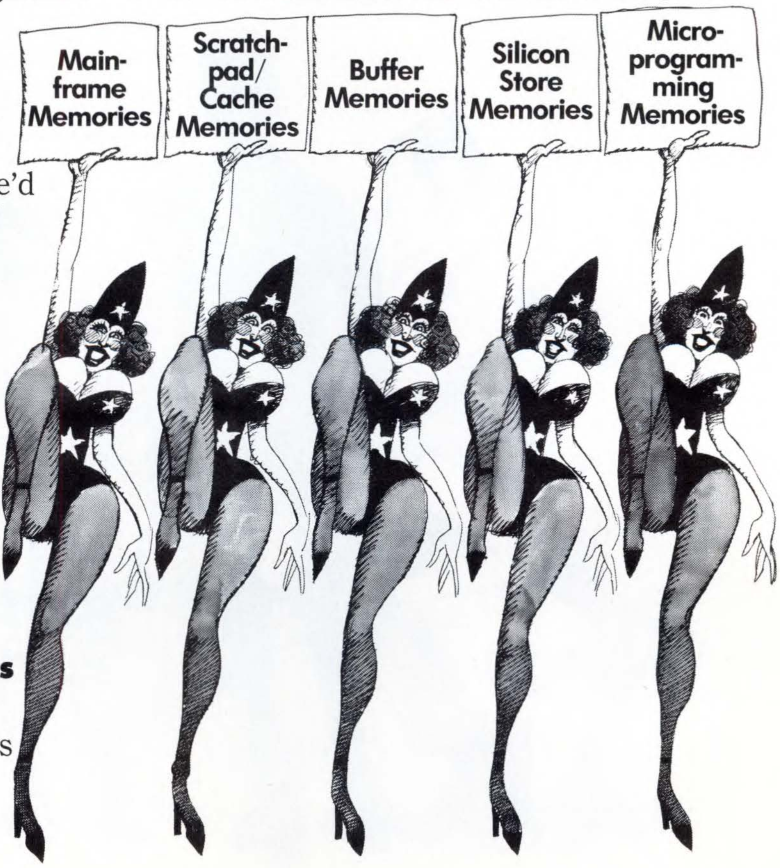
Part Five: Microprogramming Memories

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

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

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

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



Mainframe Memories

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

Scratchpad / Cache Memories

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

Buffer Memories

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

Silicon Store Memories

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

Microprogramming Memories

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

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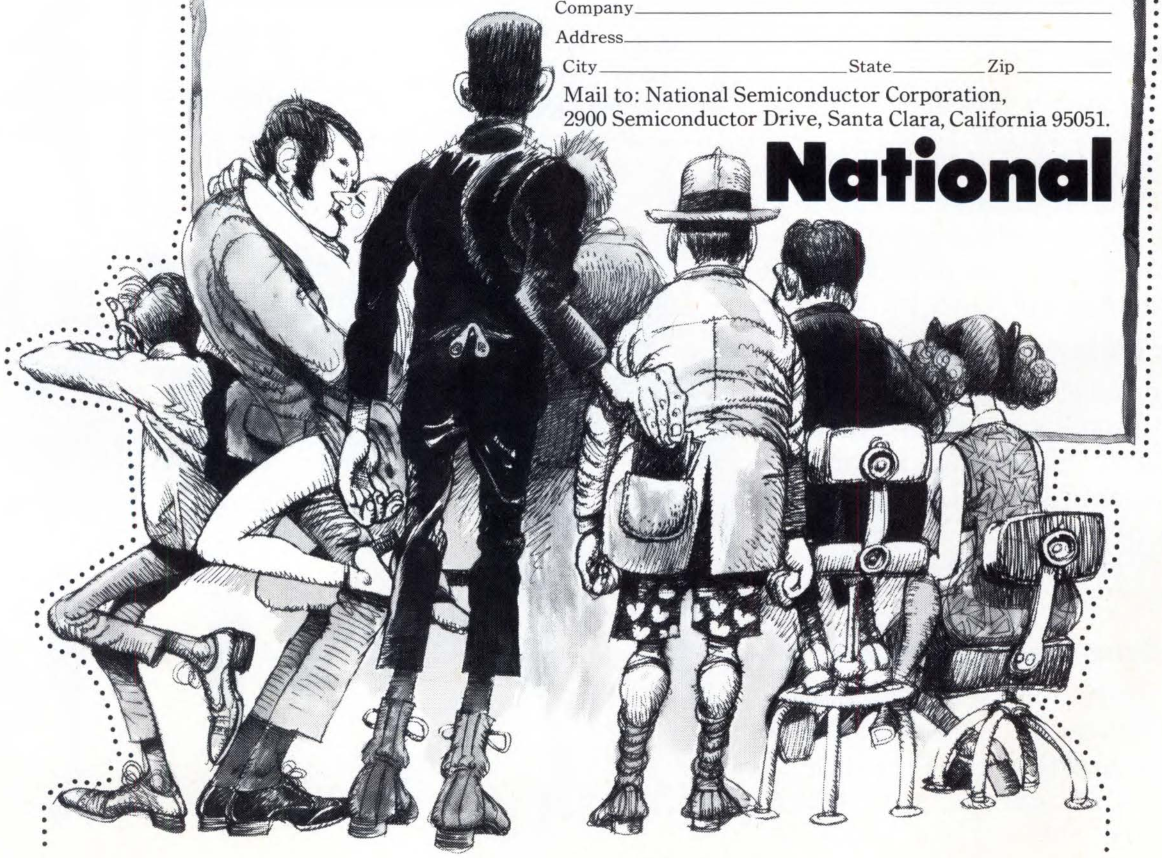


CIRCLE NO. 18

DON'T LET THE WRONG INPUT Q WRECK YOUR RF POWER AMPLIFIER

The very low impedances required in RF power amplifiers can cause high currents and excessive I^2R losses in passive matching components. Here is how to calculate what can be tolerated.

VINCENT F. PERNA, American Technical Ceramics

An RF power amplifier's input matching network must trade voltage for current as it lowers the signal impedance from the normal 50Ω line down to the 1 or 2Ω of the transistor input. This trade-off causes very large RF circulating currents to flow in the passive matching components. For example, capacitor C_3, in the widely used RF circuit of **Fig. 1**, can easily have a current of 1A or more flowing through it for 3W of input power. This, in turn, can cause I^2R losses in C_3 that can seriously degrade the amplifier gain and can even melt the solder that holds C_3 to the circuit. The problem is aggravated at frequencies over 100 MHz by the small physical size of the capacitor and the fact that the dissipation factors of most dielectrics increase with heat and frequency.

The designer, intent upon achieving optimum impedance matching between the 50Ω line and the transistor, often tends to overlook these large circulating currents and their heating effect. He may unintentionally have too high a loaded Q (Q_L) at the transistor input, which will increase the magnitude of this circulating current and the heating in the capacitor. Even if he does keep his Q within reason, he may unwittingly select a capacitor that has too high a series resistance.

What the designer needs is a quick method for looking at his circuit from this standpoint, and seeing quantitatively whether or not his design is within realistic limits—limits that are consistent with obtainable components, and which do not penalize the performance or the reliability of the stage.

Step-by-Step Procedure Simplifies Process

Here is a seven-step method for properly selecting the critical input capacitor, C_3, of the popular circuit configuration of **Fig. 1**.

(Continued)

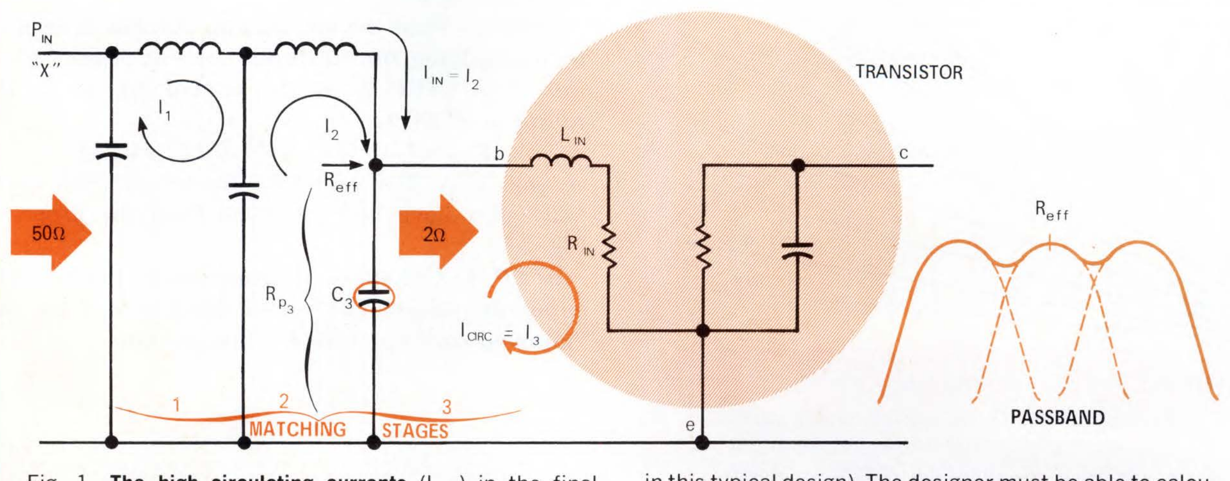


Fig. 1—**The high circulating currents** (I_{circ}) in the final matching stage of an RF amplifier can generate prohibitive I^2R losses in the passive components (particularly C_3 in this typical design). The designer must be able to calculate this current if he is to properly specify the critical components (C_3 in this example).

(Continued)

Wrong Q (Cont'd)

The following circuit and device parameters are known at the start:

1. Circuit configuration . . . . as shown in **Fig. 1**.
2. Power in 3W
3. Allowable capacitor loss . . . . . . 0.05 dB (1.1%)
4. Operating center frequency, f_0 . . 300 MHz
5. Transistor input characteristics (at operating frequency) . . . . 2 + j5

$$R_{in} = 2\Omega$$

$$X_{L(in)} = 5\Omega$$

These values were picked to represent common practice.

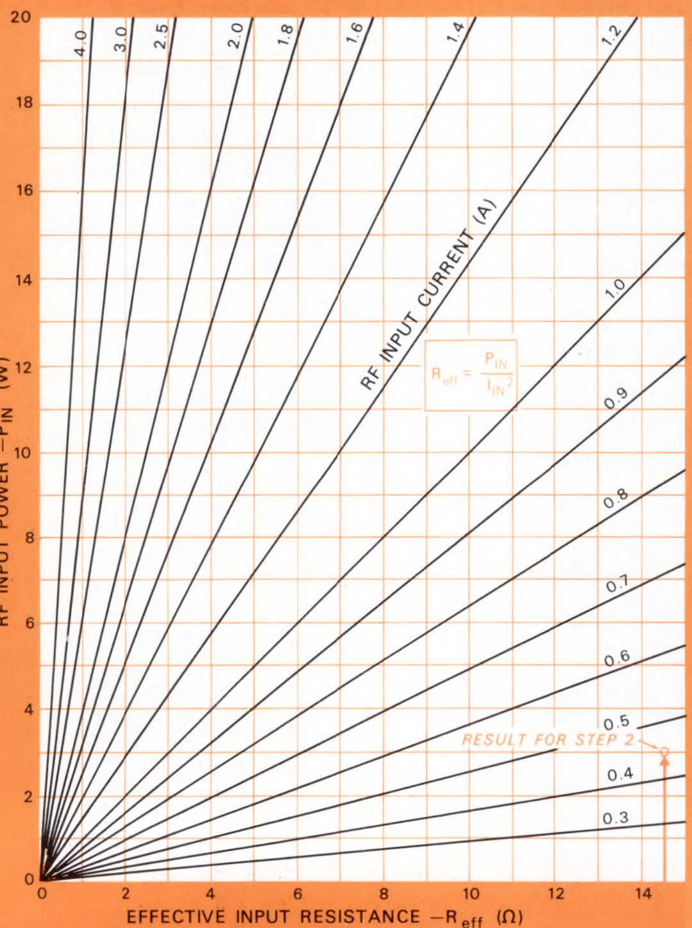


Fig. 2—**Input current (I_{in})** is plotted as a function of input power (P_{in}) and effective parallel input resistance (R_{eff}) on the final matching stage.

STEP 1—Calculate R_{eff}, the effective parallel input resistance of the parallel-tuned network containing capacitor C_3 at the given center frequency.

The equation is:

$$R_{eff} = (Q^2 + 1)\ R_{in}$$

R_{in} is known because it is given for the transistor at the 300 MHz operating frequency and the circuit's bias conditions (not shown in **Fig. 1**). This R_{in}, of course, must be for the actual large-signal RF input with the device biased for handling the 3W signal. It is obtained from measurements, as any transistor would have to be operating in a highly nonlinear mode at this power level. Nowadays most RF transistor manufacturers supply this data on their device specification sheets.

The circuit load Q (Q_L) can be obtained from the relationship:

$$Q_L = \frac{X_L}{R_{in}} = \frac{5}{2} = 2.5$$

More will be said about the practical considerations for this parameter later.

Putting these values into the equation for R_{eff}:

$$R_{eff} = (2.5^2 + 1)\ 2 = (6.25 + 1)\ 2 = 14.5\Omega$$

STEP 2—Find the input current, I_{in}, as defined in Fig. 1. This is known also as the line, or sustaining, current in RF circuits. Use the graph of **Fig. 2** for this. This graph solves the equation:

$$R_{eff} = \frac{P}{I_{in}^2}$$

where P, of course, is the signal power which has been given as 3W. Entering the graphs with these known values (as shown in **Fig. 2**), the RF input current, I_{in}, is found to be 0.46A.

STEP 3—Find the circulating current in stage 3 by multiplying the RF input current found in the last step, STEP 2, by the loaded circuit Q (Q_L) found in STEP 1.

$$I_{circ} = I_{in} \times Q_L = 0.46 \times 2.5 = 1.12A$$

or, say, 1.2A. The values for these first three steps could also have been obtained from the graph of **Fig. 3**.

STEP 4—Calculate the maximum permissible capacitor equivalent series resistance from the "allowed" or hoped-for I^2R dissipation:

$$R_s = \frac{P_{diss}}{I_{circ}^2}$$

The allowed I^2R dissipation, or P_{diss}, was given as 0.05 dB or 1.1%. This means the capacitor can dissipate only 33 mW. Therefore,

$$R_s = \frac{0.033}{(1.2)^2} = 0.023\Omega$$

STEP 5 – Calculate the capacitor's required minimum unloaded Q, Q_u.

$$Q_u = \frac{X_c}{R_s}$$

The capacitive reactance, X_c, required for C_3 at 300 MHz is given by:

$$X_c = \frac{R_{eff}}{Q_L} = \frac{14.5}{2.5} = 5.8\Omega$$

Therefore,

$$Q_u = \frac{5.8}{0.023} = 252$$

or, for a round figure, 300.

STEP 6 – Select a capacitor. Now that the allowable Q_u is known, the designer can search for the component. The capacitance value would be found in the customary two steps:

$$X_c = \frac{R_{eff}}{Q_L} = \frac{14.5}{2.5} = 5.8\Omega = \frac{1}{2\pi fC}$$

$$C = \frac{1}{(6.28)\ (3\times10^8)\ (5.8)} = 91.5 \text{ pF}$$

Since present-day microwave power transistors often have dual emitter leads to minimize lead inductance, a sensible choice for C_3 would be to use two separate capacitors, one on each lead. This helps to achieve balanced currents on the two emitter leads and relaxes the specifications for the capacitors. Two 47-pF capacitors could then provide the 91.5 pF.

The designer must now have information on actual capacitors. He must either obtain this from the manufacturer or make his own tests of likely devices. **Fig. 3** represents the type of information available on one brand of microwave capacitors (devices in this example, made by American Technical Ceramics). Entering the graph at the 300-MHz center frequency, it is seen that this particular type of capacitor has a Q_u for a 47-pF unit of about 300, or just about the value needed.

Having the capacitor's measured Q_u and R_s values plotted on the same graph against frequency helps the designer quickly evaluate the candidate and make trade-offs. For example, the benefit of using two paralleled capacitors for C_3 is readily evaluated. Recall that the computed allowable R_s from STEP 4 was 0.023Ω. Looking at **Fig. 4**, it can be seen that it is unlikely that this specification could be met with a single 91.5-pF capacitor. The 90-pF line is off the graph, but since R_s is seen to go up with higher capacitance values, even a 15-pF unit would not meet the specs and it is obvious that obtaining a 90-pF capacitor with just 0.023Ω series resistance is impossible.

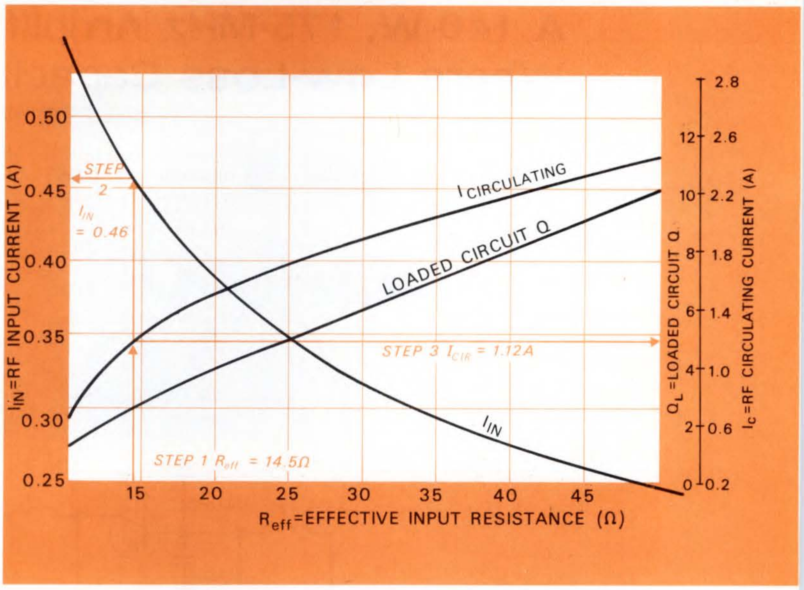


Fig. 3 – **Composite graph shows interrelationships between the parameters obtained in STEPS 1 through 3.** To obtain these plots, the transistor's lead inductance was held fixed and the base-emitter diode resistance was varied (see **Fig. 1** for model of transistor). Similar results can be obtained by holding the transistor resistance fixed and varying the base-emitter inductance of the base lead. These curves show very clearly how the "dangerous" circulating current goes up as Q_L goes up, substantiating the advice given in the text that Q_L should not be made too high.

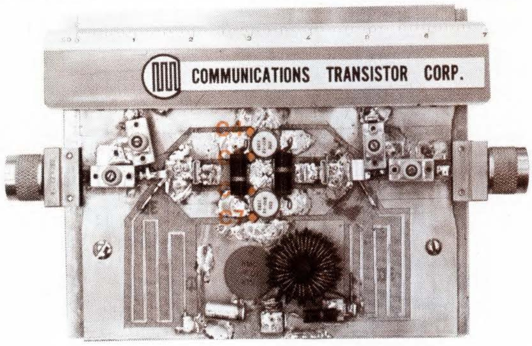
However, when the 0.023Ω specification is shared by two paralleled capacitors, each of these units can have an R_s as large as 0.046Ω, and each needs to have only half the capacitance to boot. **Fig. 4** indicates that a 47-pF capacitor can be obtained with a R_s of 0.035Ω, which provides a 30% safety margin.

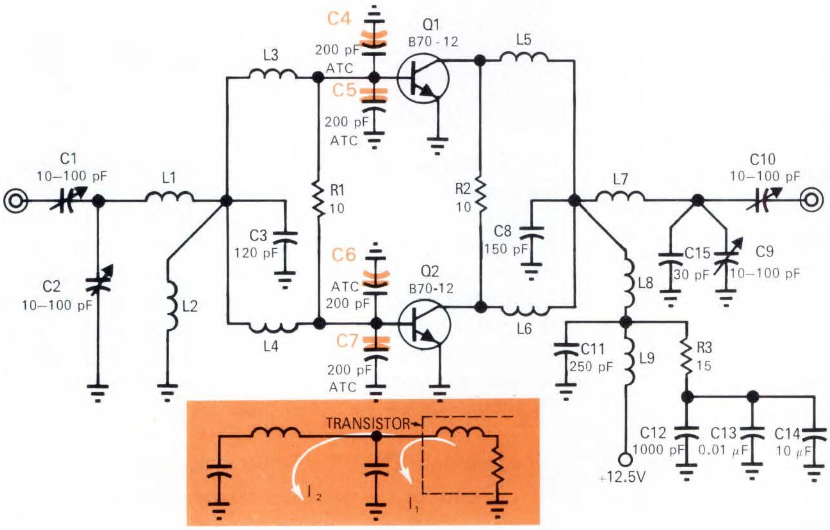
STEP 7 – Check temperature effects. The values for Q_u and R_s obtained from measurements – such as those plotted in **Fig. 4** – will only apply to a single temperature, which is most likely room temperature. But RF power amplifiers will rarely run at room temperature. They must be compact units able to operate within the restrictions of short wavelengths, and they must be shielded to prevent their RF from getting out and moisture from getting in; so it can be expected that they will run at some higher temperature – say, 125°C.

The temperature in the vicinity of the transistor will be even higher – perhaps 200°C. This heat will directly affect the tiny capacitors, which in typical RF designs will be placed snugly against the transistor.

Continued

A 140-W, 175-MHz Amplifier: Where Low-Loss Capacitors Are a Must





1/8''
L1 – 1/8'' WIDE COPPER STRAP 3/4'' HIGH
L2, L8 – λ/4 - 100Ω STRIP LINES
L3, L4 – 20Ω 1.5'' LONG STRIP LINES
L5, L6 – 20Ω 1.0'' LONG STRIP LINES
L7 – SAME AS L1 EXCEPT 1/4'' WIDE
L9 – 10 μh

This land-mobile communications amplifier by Communications Transistor Corp., San Carlos, Calif., must use low-loss, low-parasitic inductance capacitors at the inputs to the two paralleled RF power transistors. The impedance going into the transistor is less than an ohm, so the circulating currents are several amperes, according to Joe Johnson, the CTC application engineer who designed the circuit.

For the first impedance matching step to be effective, the two shunt capacitors must present a capacitive reactance of 1Ω. If the capacitors used cannot present this low reactance, most of the current will flow in the shunt capacitors of other matching steps (i_2 instead of i_1). This causes the Q of the first effective matching step to double or triple, with a similar increase in circulating currents. Therefore, the loss will not only occur in the ineffective capacitor but in other matching components as well, because of the higher circulating currents. Losses caused by an ineffective first match may cause 3-dB loss in gain as well as saturated power output. Gain is too hard to come by at 140W and 175 MHz to throw it away in a passive component.

Johnson said that he used the low-loss "porcelain" types of chip capacitors made by author Perna's company. These he has found have better RF dissipations (higher Q_u's) and lower parasitic inductance than the more common barium titanate NPO types often used. (Vitramon and American Lava are said also to make low-loss porcelain units). Though these porcelain capacitors are about three times as expensive as the NPO types, their cost is still small compared to the expensive transistors needed to produce large powers at these frequencies. The chips cost about a dollar apiece in single quantities, while the transistors cost over $50 each in single quantities.

Incidentally, note the straightforward circuitry for paralleling the two power transistors. Johnson said that this eliminates the more exotic combiners, etc. often used to insure load-sharing at these frequencies. See Ref. 5 for more information.

The heat will work against the designer, for the Q_u will go down with increased temperature. This in turn will mean that the R_s will go up, and this regenerative action could lead to disasterous thermal runaway.

To appreciate the touchiness of the situation, consider that these tiny microwave capacitors have volumes on the order of one-thousandth of a cubic inch. Therefore, even though their dissipation might only be 30 mW or so, the power density could be as high as:

$$(30\ \text{mW})\,(1000) = 30\ \text{W/in}^3$$

This is close to the 40 W/in^3 found at the tip of a soldering iron like an Ungar.

The only thing that may keep the capacitor's solder from melting may be the heat sinking provided by the typically flat-strip microwave conductors. The author recently heard of an engineer who thought he saw his capacitor chip moving, and indeed it was; the solder had melted and the device was being blown about in the solder puddle by the cooling fan! Obviously, an overheated input capacitor is not the nicest neighbor for an expensive RF transistor.

The objective of this final step, then, will be to estimate or make measurements that will forecast the deterioration of capacitor Q_u and R_s with temperature. □

Databank

1. "The Radio Engineering Handbook," By Keith Henny, McGraw-Hill, 3rd edition, 1941, p. 140.
2. "Communication Engineering," by William L. Everitt, Ph. D., McGraw-Hill, 2nd edition, 1937, p. 575.
3. "Electronic Engineers Handbook," by R. W. Landee, D. C. Davis, and A. P. Albrecht, McGraw-Hill, 1957, pp. 4-30.
4. "Evaluate Transistor Bandwidths the Easy Way," by V. F. Perna, Electronic Design Magazine 26, Dec. 20, 1970, pp. 40-42.
5. "175 MHz, 12V, 140W Amplifier," Application Note 2.1.8.4C, Communication Transistor Corp., San Carlos, Calif.
6. "Radiotron Designer's Handbook," edited by F. Langford-Smith, published by Radio Corp. of America, 4th edition, 1953, p. 410.

Vince Perna is a RF engineer who got so involved in helping one of his component suppliers that he ended up as vice president for applications with that company—American Technical Ceramics. Vince is impressed by the thirst for RF know-how that exists among today's engineers. He finds that his basic half-hour application lectures at RF houses often wind up with 2-hr question-and-answer sessions.

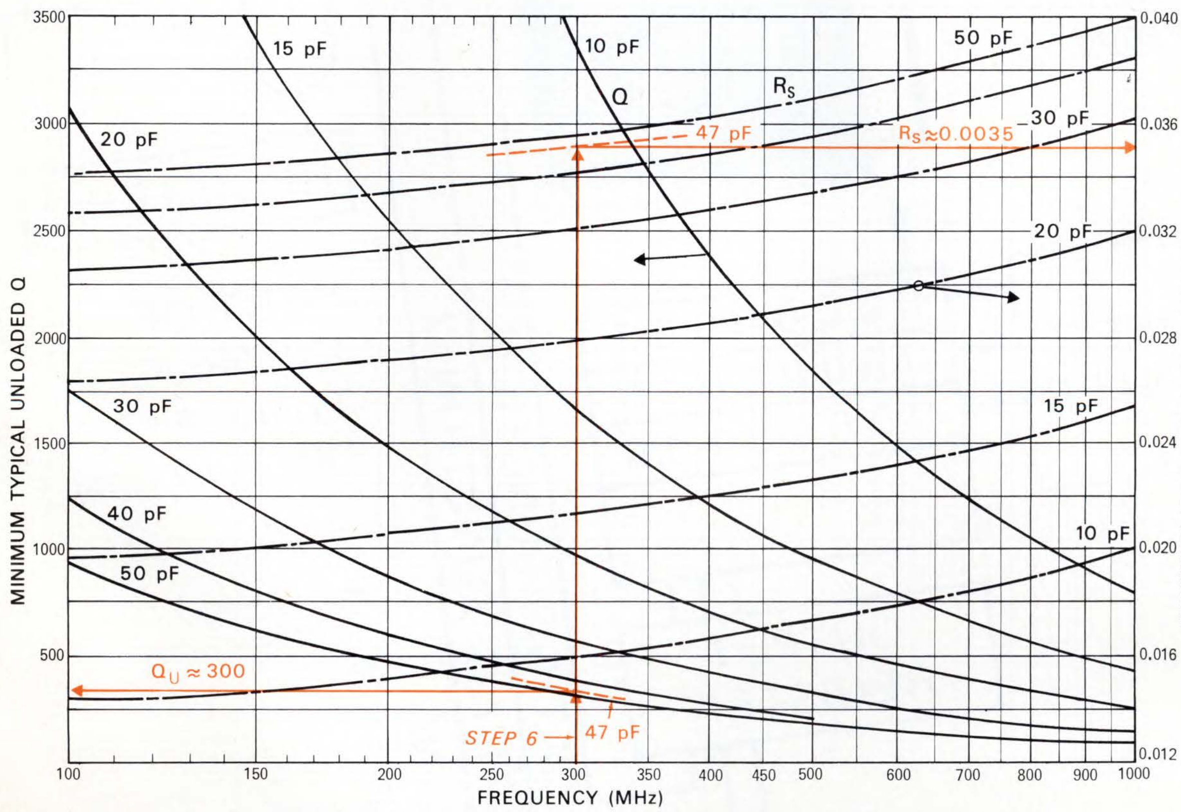


Fig. 4—**Appropriate data on available chip capacitors** is required if the designer is to select an RF unit that will have sufficiently low series resistance at the operating frequency. The data shown is for American Technical Ceramics ATC100-B chip capacitors.

FOR A FREE REPRINT OF THIS ARTICLE, **CIRCLE NO. L62**

...for *fast* system microprogramming

When your system needs the advantages of custom microprogramming, code conversion, or look-up table functions and you are fighting time plus development cost, Motorola's MCM4004 or MCM4006 1024-Bit ROMs can solve your problem. Just supply your truth table/output option requirement and the final processing steps are completed — the net result, a custom function without the cost and time required for a developmental program.

The basic organization of both memories is 256 four-bit words. By removing appropriate emitter connections on the pre-ohmic mask, each bit can be programmed to meet your specific logic requirement. Both devices offer optional 2.0 kilohm pullup resistors on the four collector outputs. The open collector output option is obtained by removing pre-ohmic connections to the 2.0 kilohm resistors. Utilizing the open collector option at the buffered output bit lines allows many memories to be wire-ORed to form large arrays.

The MCM4006 features a typical address time of 40 ns and chip select time of 20 ns (typ) with standard TTL input loading of 1.6 mA. The MCM4004 offers reduced input loading (0.1 mA typical) and is recommended for large systems. Typical MCM4004 address time is 50 ns and typical chip select time is 25 ns.

Systematic application

Use the MCM4004/4006 wherever there is a need to store information for repetitive use in a system. Typical applications would include look-up tables, character generation, and random logic. The devices are ideal for microprogramming where complex arithmetic subroutines are performed. As illustrated, the ROM generates basic gating functions in a computer. The address counter selects the instructions from the ROM in a fixed sequence to perform the designated subroutine. The resultant advantage is faster processing of information compared to a subroutine contained in the main memory.

Contact your local Motorola representative for ordering information. 100-up price for either ROM is $17.50 and the programming mask set-up charge is a low $600 per program with reduced costs for additional masks. For detailed specifications write Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, Arizona 85036.

Evaluate the MCM4004 and 4006 . . .
The option and savings are yours.
Look to Motorola for your memory requirements. Our capabilities in bipolar and MOS provide a comprehensive selection to meet your specific requirement.

MEMORIES TO REMEMBER

DEVICE	FUNCTION	TECHNOLOGY	ORGANIZATION	ACCESS TIME
RAMs				
MC1680/81	4 Bit RAM	ECL - BiPolar	2 x 2	< 4 ns
MC1682/83	4 Bit RAM	ECL - BiPolar	2 x 2	< 4 ns
MC1684/85	4 Bit CARAM	ECL - BiPolar	2 x 2	< 4 ns
MC1036/37	16 Bit RAM	ECL - BiPolar	16 x 1	< 20 ns
MC4004/5	16 Bit RAM	TTL - BiPolar	16 x 1	< 25 ns
MCM4064	64 Bit RAM	TTL - BiPolar	16 x 4	< 60 ns
MCM1170	64 Bit Static RAM	Metal Gate P-MOS	16 x 4	500 ns
MCM14505	64 Bit Static RAM	Metal Gate CMOS	64 x 1	200 ns (typ)
MCM1173/72	1024 Bit Dynamic RAM (6001 Equiv.)	Metal Gate P-MOS	1024 x 1	350 ns
MCM2372	1024 Bit RAM (1103 Equiv.)	Si-Gate P-MOS	1024 x 1	300 ns
ROMs				
MCM4001	128 Bit ROM	TTL - BiPolar	16 x 8	< 45 ns
MCM4002	256 Bit ROM	TTL - BiPolar	32 x 8	< 50 ns
MCM4004	1024 Bit ROM	TTL - BiPolar	256 x 4	< 60 ns
MCM4006	1024 Bit ROM	TTL - BiPolar	256 x 4	< 50 ns
MCM5003A/4A	512 Bit PROM	TTL - BiPolar	64 x 8	< 75 ns
MCM1130	2240 Bit Static ROM	Metal Gate P-MOS	Programmable	500 ns
MCM1131/32	2240 Bit Char. Gen.	Metal Gate P-MOS	Col. Sel. 64 x 35 (5 x 7)	500 ns
MCM1120	2240 Bit ROM	Metal Gate P-MOS	Programmable	700 ns
MCM1121/22	2240 Bit Char. Gen.	Metal Gate P-MOS	Row Sel. 64 x 35 (5 x 7)	700 ns

MEMORIES TO COME

DEVICE	FUNCTION	TECHNOLOGY	ORGANIZATION	ACCESS TIME
RAMs				
MC10140	64 Bit RAM	ECL - BiPolar	64 x 1	< 15 ns
MCM4256/7	256 Bit RAM	TTL - BiPolar	256 x 1/ 128 x 2	< 60 ns
MCM1175	1024 Bit Dynamic RAM (6002 Equiv.)	Metal Gate P-MOS	1024 x 1	110 ns (typ)
MCM2377	2048 Bit RAM	Si-Gate P-MOS	2048 x 1	360 ns
ROMs				
MCM4003	512 Bit ROM	TTL - BiPolar	64 x 8	< 75 ns
MCM4005	1024 Bit ROM	TTL - BiPolar	1024 x 1	< 50 ns
MCM4007	1024 Bit ROM	TTL - BiPolar	512 x 2	< 50 ns
MC10139	256 Bit PROM	ECL - BiPolar	32 x 8	< 17 ns
MCM5005	1024 Bit PROM	TTL - BiPolar	256 x 4	< 60 ns
MCM1110	2048 Bit ROM	Metal Gate P-MOS	256 x 8	600 ns
MCM1140	4096 Bit ROM	Metal Gate P-MOS	512 x 8	700 ns
MCM1150	2560 Bit ROM	Metal Gate P-MOS	256 x 10	600 ns
MCM2340	4096 Bit ROM	Si-Gate P-MOS	512 x 8	500 ns

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CIRCLE NO. 30

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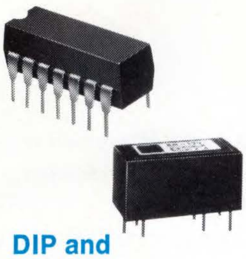


DIP and Subminiature Relays

Dual-inline, 8 and 14-pin packages are offered in Forms A, B and C and 2 Form A, with ratings 3 to 10 watts, for switching 3, 5, 10, 12, 24 and 28 VDC. They interface directly with TTL, RTL, DTL and HTL logic.

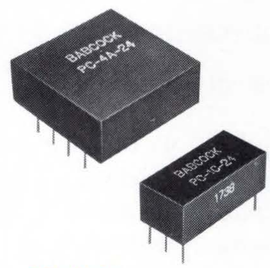
The new sub-miniature Series R is a heavy duty, SPDT, PC board, glassless polar reed relay. Rated to 20 watts at 1 amp., latching and non-latching, open coil and encapsulated versions will switch 1.5, 3, 6, 12, 24, 28, 35, 42 and 60 VDC.

For more information, circle No. 31.

Miniature, Open Frame Relays

Low cost, faster switching speeds, high-density packaging, rugged reliability and long life (to 100,000,000 cycles) are features of these axial-lead and plug-in units. Offered in Forms A, B and C — and combinations — they are rated at 3 to 10 watts, for switching 5, 6, 12 and 24 VDC. Axial-lead relays may be ordered with from 1 to 6 contacts.

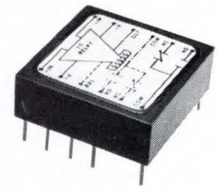
For more information, circle No. 32.



Miniature, PC Board Relays

From 1 to 12 reeds, selectable in combinations from a large assortment of options, may be specified in Series PC relays. Rated at 4 and 10 watts, for switching 28 to 250 VDC, these encapsulated units will operate over 100,000,000 cycles at low levels.

For more information, circle No. 33.



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This extremely sensitive relay will operate on as little as 1.0 mv . . . ideal for many *transducer and thermocouple applications.* It is available in any 1 or 2 reed combinations, rated at 3 to 10 watts DC. This unit comprises an IC op-amp precisely matched to a reed relay; an integral programmable hysteresis option eliminates problems due to input signal variations or noise.

For more information, circle No. 34.

Detail technical data on the complete line of Babcock relays is available by writing or calling Babcock Control Products, Babcock Electronics Corp., Subs. of Esterline Corp., 3501 No. Harbor Blvd., Costa Mesa, Calif. 92626; Tel: (714) 540-1234

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ESTERLINE

Voltage-Controlled Attenuator Has Minimum Phase Shift

A FET in a pi network mades a good attenuator at a specific radio frequency, but gives variable phase shift with changing attenuation. A tank circuit across source-drain leads solves the problem.

*E. E. BALDWIN, National Bureau of Standards**

A pi configuration resistive attenuator using a FET as the varying element provides a convenient way to vary gain and is particularly desirable when automatic control is required. Since a changing voltage level is all that is needed to change signal attenuation, it appeared to be a desirable approach for a radiometer (operating at 30 MHz) requiring controlled gain changes in two channels.

Tests of a low-priced commercial FET as the series element in a pi configuration resistive attenuator (**Fig. 1**) revealed that gate voltages near pinch-off permitted attenuation over 40 dB. With improved shielding to reduce leakage paths, greater attenuation was obtained.

Unfortunately, changes in junction capacitance with voltage changes resulted in phase shifts up to 40° near pinch-off. This application required that relative phase remain constant with changing attenuation.

A resistor in series with the gate instead of the RF choke reduced effects of gate capacitance changes, and phase shift was cut to about 20°. To reduce the effect of source-drain capacitance changes, it seemed reasonable to swamp it with additional capacitance. The addition of a variable inductor in parallel with the capacitor (**Fig. 2**) provided the ability to tune for a high impedance at the frequency of interest.

With this configuration, gate voltage was set to provide 55 dB attenuation and the phase angle was corrected by adjusting the inductor. Phase shifts were thus held to less than 2.0° for attenuation up to 50 dB. In this version, residual insertion loss was 15 dB.

An integrated circuit amplifier set for constant gain was added to the circuit giving the system a 9 dB gain at minimum attenuation.

In the final version of the circuit (**Fig. 3**), the gate is grounded to an interstage shield. Voltage is fed to source and drain through small RF chokes allowing inverted operation. **Fig. 4** shows a plot of phase shift as a function of attenuation.

This circuit has also been used in a 30-MHz level controlled signal source with the gate voltage obtained from a diode voltage detector at the output terminal of the source. □

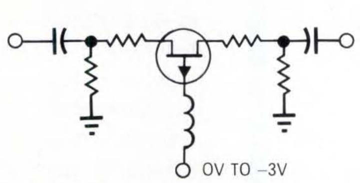


Fig. 1—**Pi attenuator** with FET gives 40 dB attenuation.

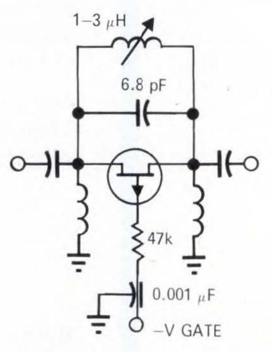


Fig. 2—**Variable inductor** allows tuning for high impedance.

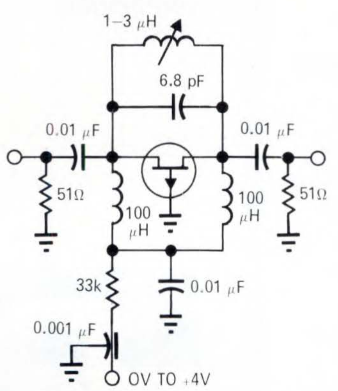


Fig. 3—**Final circuit** has small RF chokes for inverted operation.

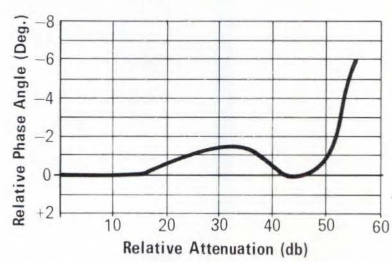
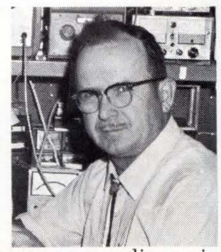


Fig. 4—**Phase shift** is <2.0° for 50 dB attenuation.



Eugene Baldwin is an electronic technician at the National Bureau of Standards, Boulder, Colo., where he has been employed for 10 years. Prior to that he had 15 years experience as a radio engineer and in customer service. In addition to his work, he pursues electronic interests as an amateur radio operator (WØ-RUG) and as an IEEE member.

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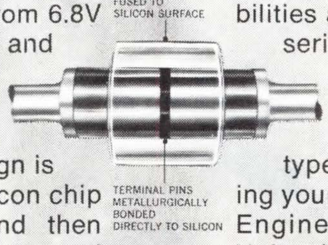
The 1N4461-89 series from Unitrode is available off-the-shelf as JAN and JANTX zeners to MIL-S-19500/406 in most voltages from 6.8V to 100V. They offer greater reliability and improved electrical characteristics at no more cost than conventional 1 watt whisker-type metal can zeners. The reliability of the double pin design is further increased by bonding the silicon chip directly between terminal pins and then fusing a hard glass sleeve to the exposed silicon surface and pins.



This results in a voidless, monolithic structure with exceptional zener stability. Surge capabilities are 5 times greater than the 1N3016B series. Zener impedances are improved and reverse currents are two orders of magnitude lower. The point is, now you can switch from whisker-type to double slug design without shaving your standards. For fast action, call Sales Engineering collect at (617) 926-0404, Unitrode Corporation, Dept.11A, 580 Pleasant Street, Watertown, Mass. 02172.

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CIRCLE NO. 49

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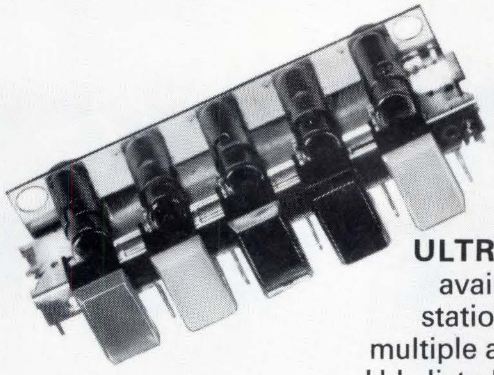
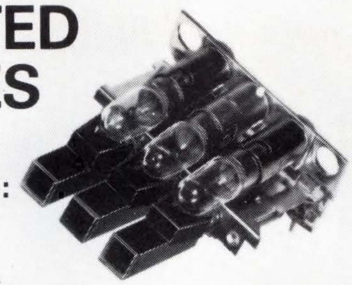
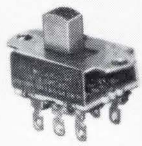
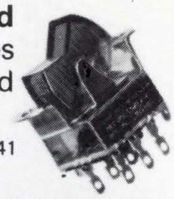




ULTRA-GLOW® pushbutton: available with 1 to 15 stations, 1 to 3 poles and multiple actuations. Basic switch is U.L. listed at 3 or 6 amps at 125v.

CIRCLE NO. 40





ULTRA-GLOW® slide and rocker: Select from 1 to 3 poles and a variety of colors. U.L. listed from 1 to 10 amps at 125v.

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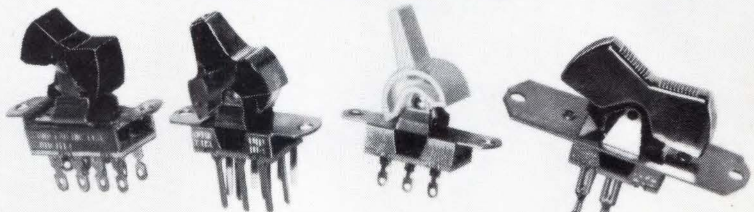

Pushbutton: you can order from 1 to 15 stations with 1 to 6 poles and multiple actuations. U.L. listed at 3 or 6 amps at 125v.

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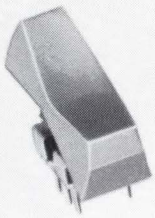
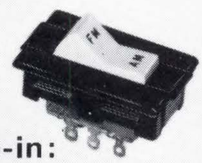


Rocker and slide: available with 1 to 3 positions and 1 to 6 poles. U.L. listed from 1 to 10 amps at 125v. Custom designs available.

Rocker— CIRCLE NO. 43
Slide— CIRCLE NO. 44



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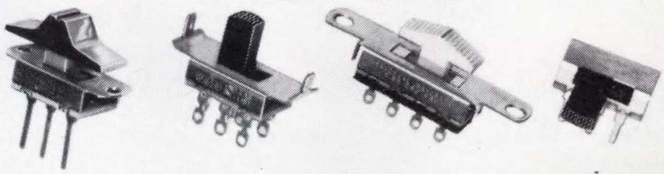

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① The MR-11 miniature type is a glass tube DPST relay with 20 ampere switching capability. CSA listed. Also available SPST and 3PST. **CIRCLE NO. 35**

② The EM-1 standard type is a glass tube SPST relay with 35 ampere switching capability. UL and CSA listed. Also available DPST and 3PST. **CIRCLE NO. 36**

The HD heavy duty type is a glass tube relay similar to the EM type but features 60 ampere switching capability. UL and CSA listed.

③ The "100" relay is an encapsulated glass tube relay with 100 ampere switching capability. CSA listed. **CIRCLE NO. 37**

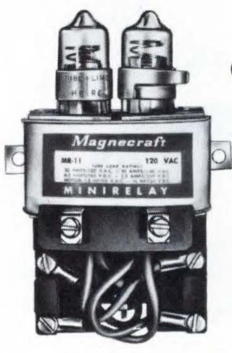
④ The A-11 HI-POWER is an armored steel-encapsulated DPST relay with 25 ampere switching capability. Also available SPST and 3PST. **CIRCLE NO. 38**

The "B" series HI-POWER relays are similar to "A" type but feature 50 ampere switching capability.

⑤ The H-1 HI-POWER is an armored steel-encapsulated SPST relay with 100 ampere switching capability. Also available in DPST and 3PST. **CIRCLE NO. 39**

⑤

①



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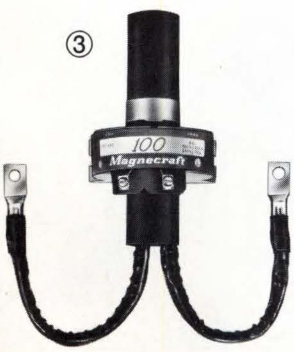

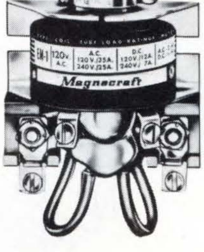

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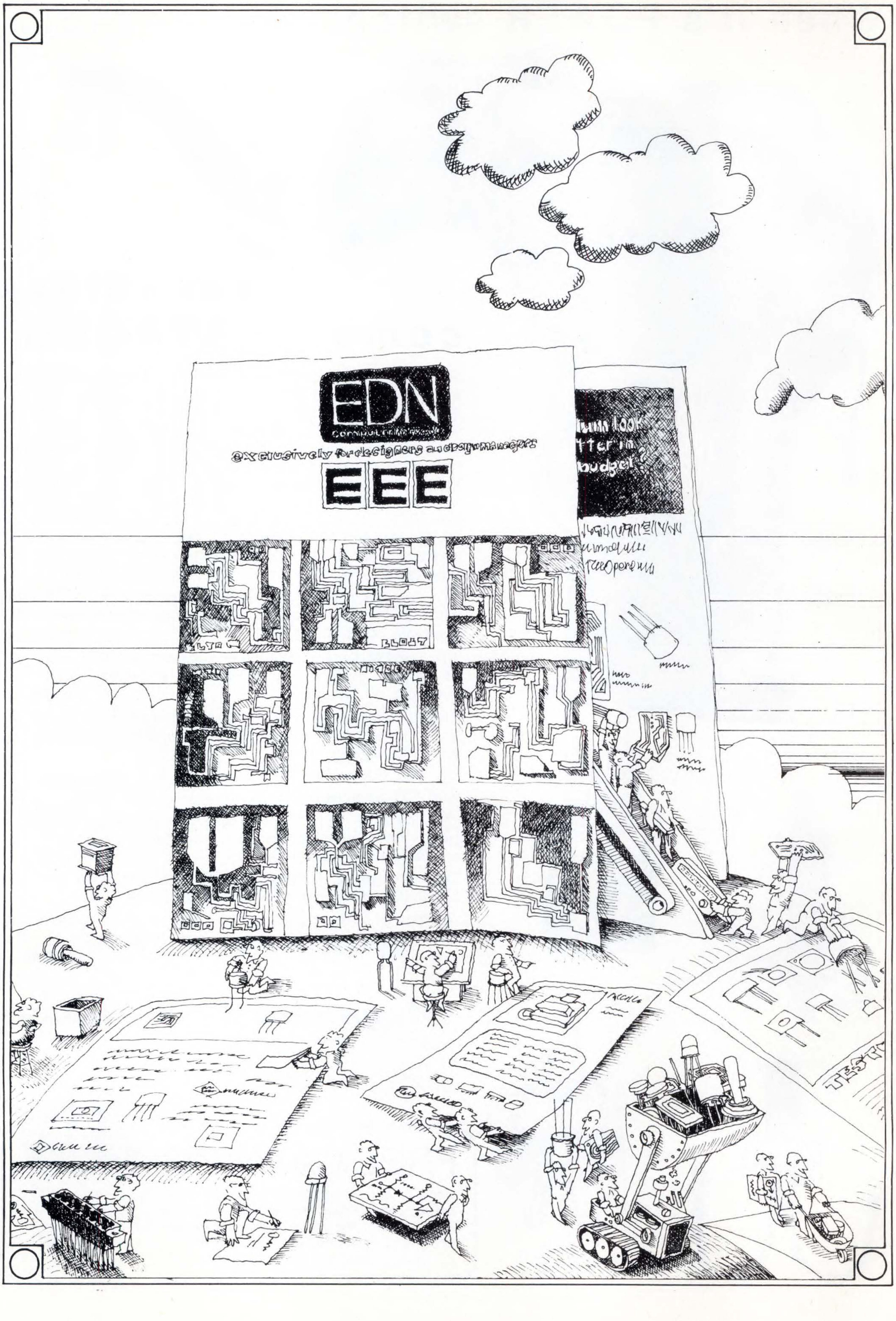

EDN
EEE

announcing the 1st annual EDN/EEE creative design contest

How to enter

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

1st Annual EDN/EEE
Creative Design Contest
221 Columbus Avenue
Boston, Mass. 02116

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

How your entry will be judged

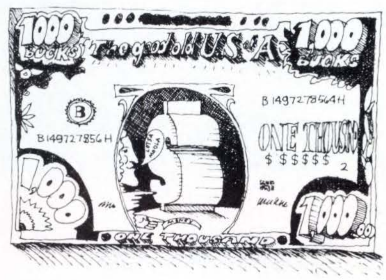
All entries will be judged by the Publisher and editors of EDN/EEE on the basis of 3 criteria:

1. Technical competence and utility
Is the design real . . . will it work?

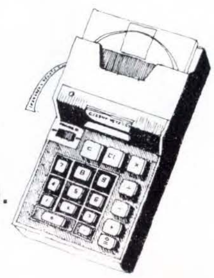
2. Creative imagination
How unique and original is your idea? Does it perform a much needed function? Is it a source of fun! Will other designers get a real charge out of it?

3. Number of different advertised products
Have you really studied the January 1st 1972 issue of EDN/EEE. Have you imaginatively used components throughout the design? Include a list of advertised products with your entry—or just tear out the ads describing them and staple to your entry.

Here are the prizes



1st prize:
$1,000 cash money



10 2nd prizes:
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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. Winning entries will be displayed at the 1972 IEEE show.

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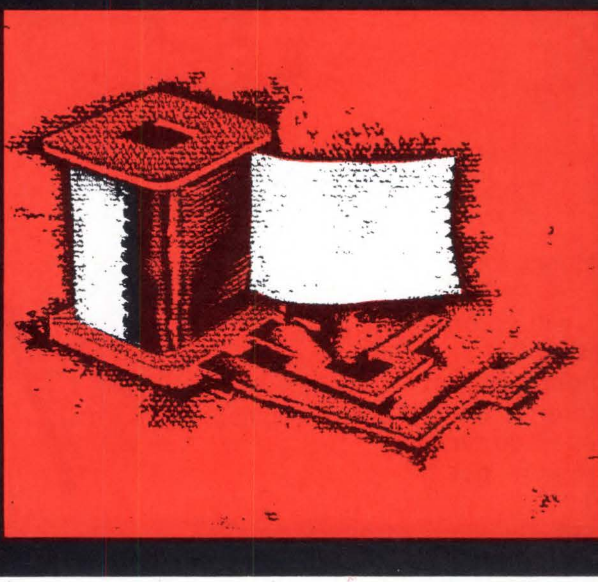

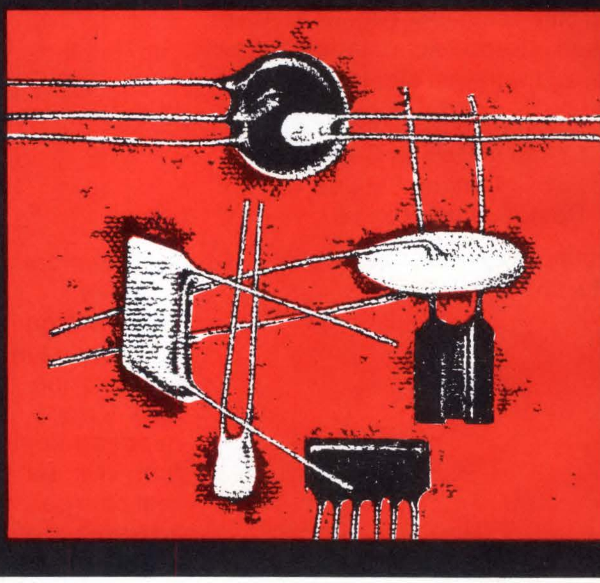

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Dielectric Materials & Systems Division 3M COMPANY

CIRCLE NO. 50

Three-Element Neon Indicator Detects Positive and Negative Overloads

Inexpensive technique provides bipolar sensing and visual indication in one very-high-input-impedance device.

ALEXANDER E. KONCSOL, Sierra Research Corp.

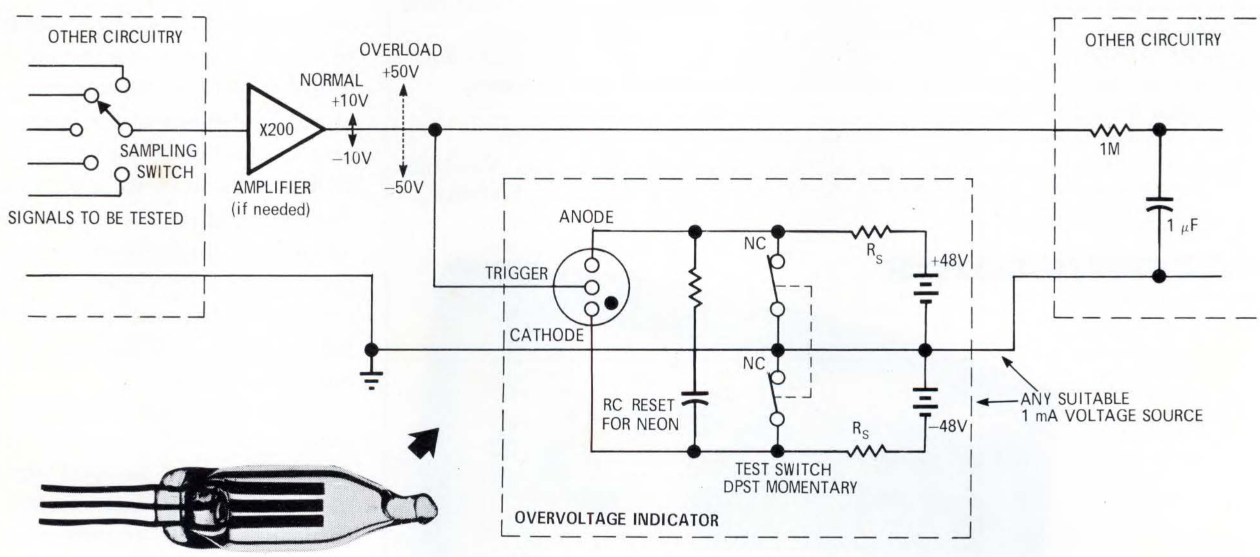
Malfunction indicators are always a bit of a nuisance. The challenge is to get a reliable check on the circuit operation without having the indicating device introduce more unreliability and cost than it is worth. These requirements are met simply and directly by a technique that uses a three-element neon tube for indicating both positive and negative overvoltages on a signal line. The neon device has very high input impedance when it is off—over 5000 MΩ—so is normally "invisible" to the main circuit.

Bias voltages for the anode and cathode of the three-element neon are set just under the level that will cause firing, but above the level at which a glow will be maintained once the neon is fired. The signal to be tested is connected to the middle (trigger) electrode.

Normal signal swing on the trigger electrode is less than ±10V, a range over which the neon won't fire (it is assumed that the test switch has been pushed to activate the biases). If the swings grow to ±50V, however, the neon triggers. In this event there will be enough voltage difference between the center electrode and one of the outer electrodes to break down the neon gas. For the particular three-element neon used in the circuit shown, this voltage is between 65 and 82V.

Once the trigger initiates the breakdown the neon glow spreads

(Continued)



CHARACTERISTICS		
THREE-ELEMENT NEON	SIGNALITE 120TG-27-2	
VOLTAGES	TRIGGER TO ANODE OR CATHODE	ANODE TO CATHODE
FIRE	65-82V	96–120V
HOLD	60-72V	65–77V

Overvoltage indication circuit has a high degree of isolation from the main signal path, thanks to the high input impedance of the three-terminal neon. Its main disadvantages are that the signal must be raised or lowered to the neon's operating range, and that additional bias supplies must be provided.

(Continued)

Indicator (Cont'd)

across all three electrodes, giving a bright display.

A positive and negative bias supply is needed for the neon, but it can be small, since it only is called on to supply a milliampere or so.

In many solid-state circuits the signal being monitored must be amplified to make it fall within the range of the neon. This is the function of the X200 amplifier shown on the diagram.

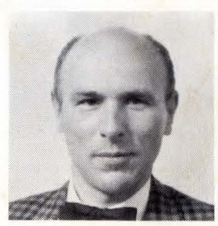
Indicator Can Be Time Shared

The application of the circuit, as shown, is to check any of 12 op amps in a radar subsystem for overload. This is done by looking for an overvoltage on the summing points.

All of the op amps are chopper stabilized by one time-shared correction loop, so just one of these indicators can be used on the correction loop to monitor all 12 amplifiers. If the summing-point voltages rise toward 250 mV it is assumed that the op amps are overloaded. An amplifier with gain of 200 is used to convert the millivolt levels at the summing point to the 50V range of the neon. Overload is checked by pushing the test switch and looking for neon flashes as the stabilization loop cycles past the op amps at the loop's 5-Hz rate. The test switch is incorporated to make certain that the neon test circuit does not interfere with the main circuit's normal operation.

Effectively, this technique provides, at low cost, a reliable and rugged built-in go/no-go tester (the neons cost about $0.73 each in less than thousand lots). As an indication of its ruggedness, the circuit will operate over a −55 to 90°C temperature range. ☐

Alexander E. Koncsol received his B.S.E.E. from the Univ. of Buffalo in 1954. He is a senior circuit design engineer at Sierra Research Corp.



Honeywell Data Acquisition News

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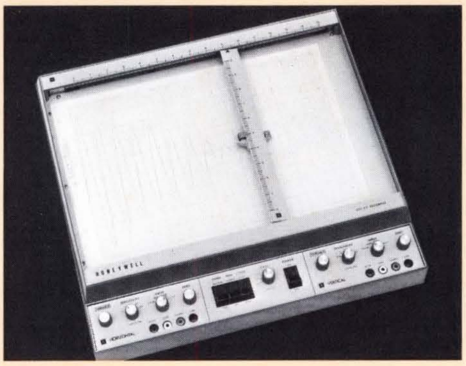

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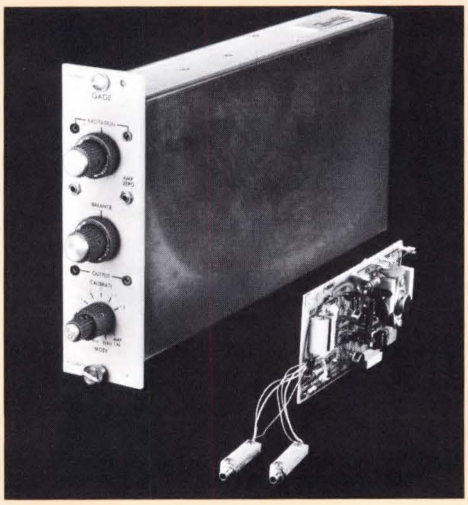

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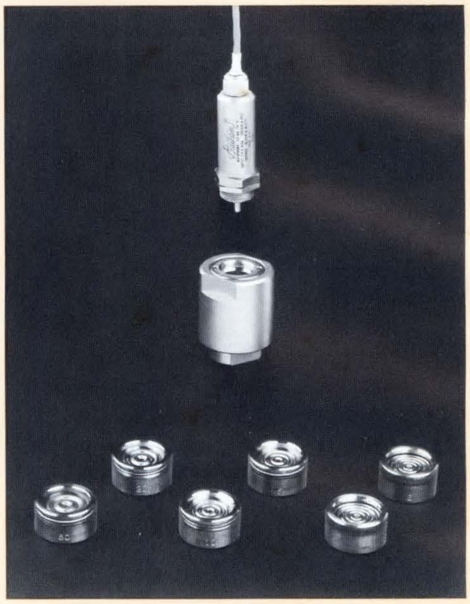

ranges we have available to the Universal Cell. For example, our load cells are available in a wide variety of ranges, from 0-0.5 pound, all the way up to 0-1,000 pounds. Which means you can choose the exact range you need for the job at hand. Other functions available include: tension, compression, displacement, pressure, force, even linear displacement. So what you end up with is goof-proof range selection, plus maximum flexibility, both at a fraction of the price you'd expect to pay for such a system.

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Readers have voted Peter T. Skelly winner of the August 1 Savings Bond Award. His winning circuit was called "Voltage-controlled current source." Mr. Skelly is with the University of Washington, Seattle, Wash.

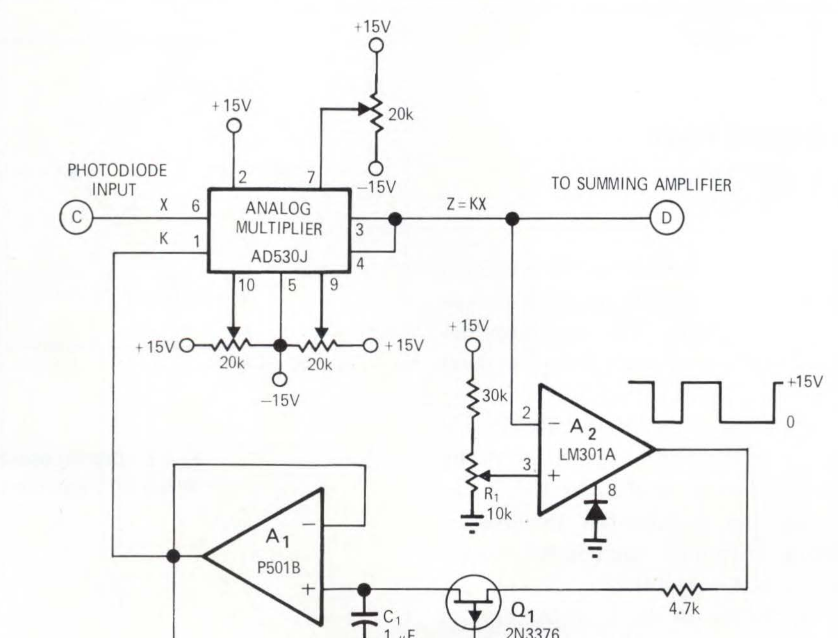
Automatic scaling circuit for optical measurements

To Vote For This Circuit Circle 161

by Robert E. Keil
Honeywell Inc.
Hopkins, Minn.

One problem that occurs with precision optical measurements is a possible drift in light intensity due to thermal cycling of the lamp filament, dirty optics and other causes. Another problem that occurs, even with differential measurements, is the gain variation between photodetectors and between amplifiers. Both of these problems can be minimized by using an automatic scaling circuit to allow frequent and swift recalibration.

This circuit automatically produces a scale factor (K) and then computes the desired product (Z = KX) for a particular input reference level (e. g., when a known portion of the photodiode's active area is illuminated). Thus the circuit is essentially a very



A reset pulse at point B commands this scaling circuit to automatically recalibrate itself. The circuit has important applications in optical measuring systems.

linear (1%) agc circuit that automatically corrects its scale factor on receiving a reset pulse at point B.

Comparator A_2 compares the output of the multiplier to a preset reference voltage on R_1. The output of A_2 switches from 15V (positive saturation voltage of A_2) to zero or vice versa, depending on the value of A_2's input voltage at pin 2.

If this input voltage is greater than the reference on pin 3, then the output will switch to zero and remain there until C_1 has discharged enough to lower the output of A_1, and, hence, the output of the multiplier, to a voltage less than the reference on pin 3 of A_2.

If on the other hand the input at pin 2 of A_2 is less than the reference on pin 3, then the output of A_2 will switch to 15V. The output of the multiplier will then be adjusted upwards until the voltage on pin 2 of A_2 again exceeds the reference on pin 3.

From the preceding explanation we can see that the output of A_2 is continually switching from 15V to zero during the entire reset or scaling period. This is the only time that Q_1 is turned on.

Capacitor C_1 and FET Q_1 together form a track-and-hold circuit. The voltage across C_1 is buffered and presented to the multiplier as the scale factor K. The scale factor is effectively the average value of the output from A_2.

After the reset pulse at point B has disappeared, the scale factor K remains constant during the measuring period.

Timing of the reset pulse depends on the actual system application. Normally one would initiate a reset pulse between each measurement. The circuit operates quite rapidly and a reset-pulse duration of around 20 msec should be adequate in most applications.

For a differential measuring system, one would, of course, include a scaling circuit in each leg to ensure a linear output over the entire measurement range. This technique allows accurate measurement of a part (i.e., photo-optical diameter or length measurement) even when it is not centered exactly on the two photodetectors. ▭

Stable low-distortion bridge oscillator

To Vote For This Circuit
Circle 162

by Klaus J. Peter
H. H. Scott, Inc.
Maynard, Mass.

The Meacham bridge circuit can form the basis for a stable transformerless crystal oscillator. The oscillator described here produces a low-distortion sinewave output.

This type of oscillator requires a quartz crystal cut for operation in the series-resonant mode. Oscillator frequency can be adjusted upwards by adding trimming capacitance in series with the crystal.

Depending on the *Q* of the crystal and on the degree of temperature stabilization, accuracies of one part in 10^8 are possible with this type of oscillator.

In the circuit of **Fig. 1**, the Meacham bridge is nearly balanced at resonance and all arms appear resis-

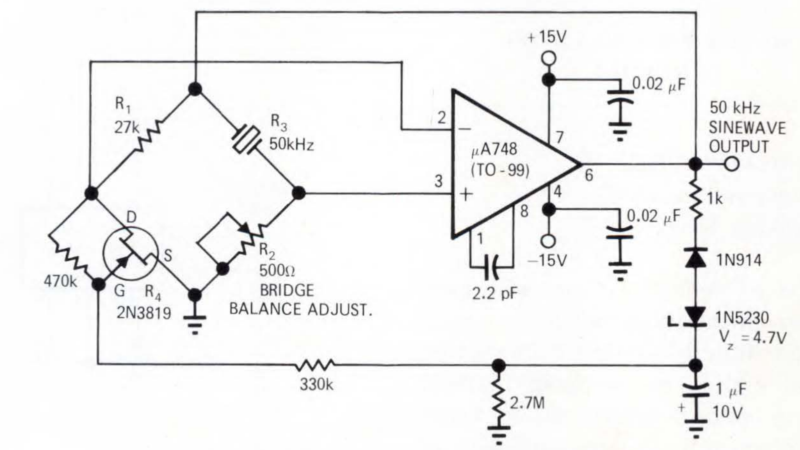


Fig. 1 – **Crystal oscillator** using a Meacham bridge needs no transformers.

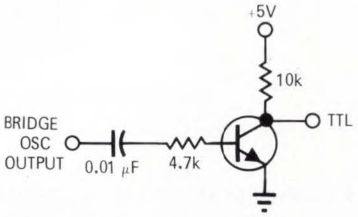


Fig. 2 – **Simple interface** circuit allows oscillator to be used as TTL clock generator.

tive. As can be seen, the bridge is coupled to the differential inputs of a high-gain amplifier. The ratio of R_3 (crystal resistance) and R_2 determines the degree of positive feedback around the amplifier. The ratio of R_1 and R_4 determines the negative feedback applied to the amplifier's inverting input.

When power is first applied, R_4 consists of the channel resistance of the FET with zero gate bias. This has a value of between 200 and 300Ω. In this condition, the loop gain is high and oscillations begin to build up. When the negative peaks of the oscillations reach about 5.3V, the FET gate starts to go negative. This increases the drain-source resistance and alters the R_1/R_4 ratio so that negative feedback increases. At some point, an equilibrium is reached and the amplitude of the oscillation remains constant.

The component values shown in **Fig. 1** are for a 50-kHz crystal (+5° X-cut). The same circuit has been used (with minor modifications) for 100- and 200-kHz crystals. For frequencies above 200kHz, an op amp capable of higher slew rates must be used.

For the circuit shown, measured harmonic distortion was about 0.5%. Distortion consists mainly of second-harmonic products. To achieve low-distortion, the operating point should be chosen so that the ratio R_1/R_4 is greater than 100, thus reducing the nonlinear-resistance effects of the FET.

Output amplitude can be raised or lowered by changing the zener-diode value. If a split supply is not available, a resistive divider can be used across a 30V supply. To use the oscillator as a clock generator for TTL circuitry, a simple output stage, as shown in **Fig. 2**, can be added. ▭

Logic-supply crowbar

To Vote For This Circuit
Circle 161

Lee Strahan
Exact Electronics, Inc.
Hillsboro, Ore.

Here is a simple circuit that can provide "crowbar" overvoltage protection for a 5V, 1A power supply. It can be adjusted to trigger at 10% overvoltage (5.5V). The circuit is fast-acting, temperature-stable, and requires no external power source.

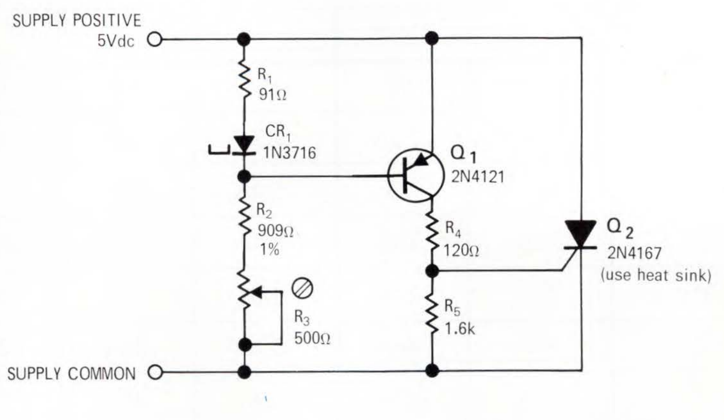
Tunnel-diode CR_1 is the level-sensing element. Resistors R_2 and R_3 bias the diode near its peak-point current. Trimming resistor R_3 adjusts the bias current so that at precisely 5.5V, the tunnel diode switches slightly past its valley point. The voltage across the diode then increases. This voltage, combined with the voltage drop across R_1, is sufficient to bias Q_1 into saturation.

When Q_1 turns on, it supplies gate current to the SCR which fires and continues to conduct until power-supply current is removed. The power supply that is being protected must include a fuse and current-limiting circuitry. Resistor R_5 prevents leakage current from activating the SCR.

Operating speed of the crowbar circuit depends almost entirely on the SCR. An overvoltage transient with a duration of under 0.5 μsec can trigger the crowbar, and the SCR can discharge a typical filter or line capacitance in less than 1 μsec.

Trip-point stability of the circuit depends on the peak-point current stability of the tunnel diode. Actual measurements have indicated that the trip-point voltage shifts by less than 2% over a temperature range from room ambient to an upper test limit of 150°F.

If desired, it is possible to remove CR_1 and R_1 and replace these components with a single 150-Ω resistor. This modification yields a less expensive circuit which can react at the same speeds but which does not have the trip-point stability of the circuit shown. ▭



Overvoltage-protection circuit using tunnel diode has excellent temperature stability. Resistor R_3 allows fine adjustment of the trip point.

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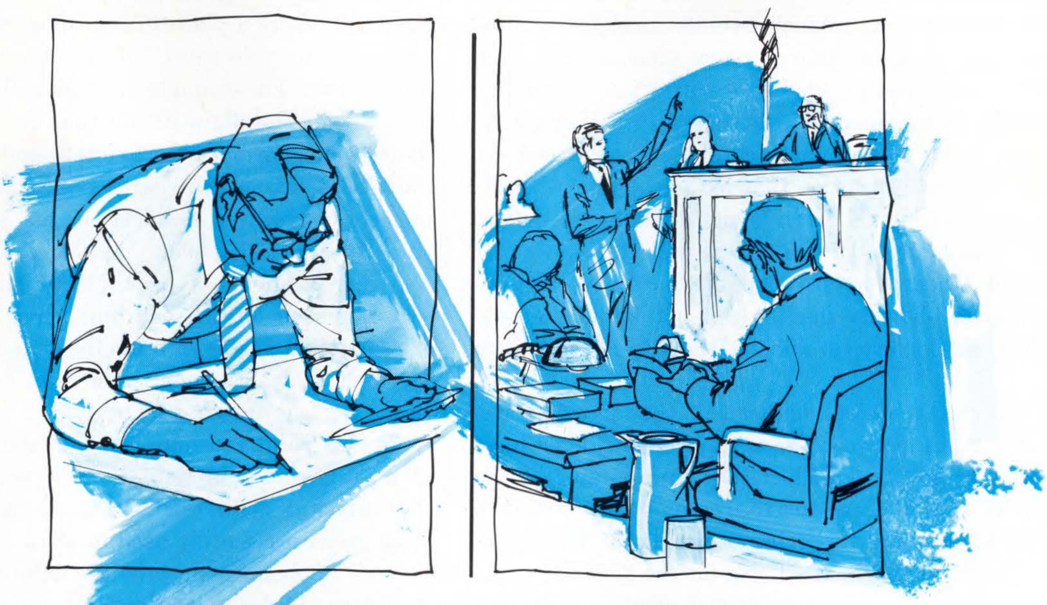

WHO'S RESPONSIBLE FOR PRODUCT SAFETY?

Product liability laws have changed to such an extent in the past couple of years that everyone from company president to designer should be aware of these changes and their consequences.

ROY W. FORSBERG, Boston Editor

"Don't worry about the minor defect in this design, if someone gets hurt it's the company's problem, not ours."—"No one in his right mind would operate our new product in that manner!"—"Our new product wasn't meant to do that, so we can't be held responsible for any injuries incurred!"

You have probably heard these and similar statements made at some time during a new product design or release. They sound like reasonable statements, right? Wrong, on all counts! Recent changes in product liability laws, both written and unwritten, have changed the entire complexion of product liability, and the effects will be felt all the way from company president to product designer. Because of this, it is necessary for every person, even those remotely associated with new products, to be acquainted with the laws, the consequences of their violation and what to do if they are overlooked.

Changes and trends in the law of strict liability in tort[1] for product defects make it much easier for the user of your product to sue you. Yes you, meaning that the retailer, company president, quality assurance manager and designer can be individually sued by a person injured by a product that passes through your jurisdiction as it wends its way from the drawing board to the user's hands.

Except for one, the changes assist the injured party if he sues you, and even the one change in your favor is of dubious value. This latter change states that if a period of 5 years or more passes between date of manufacture and date of injury, the product is presumed free from defect unless the injured party can prove otherwise. All this does is make the injured person's case more difficult. In a case where the injured party would get a recovery based on the proof he has put forth, the statute probably will not affect the trial outcome even though the judge must inform the jury of the above legal requirement. The remaining changes are all adverse to the interest of the manufacturer.

Reduction of "contributory negligence" as a factor is

[1]*If a product, through a defect, becomes unreasonably dangerous and causes an injury, it is defectively made. A person who makes and sells such a defective product has committed a fault (a tortious act). It is implied that he was negligent, and he is strictly liable to the injured person.*

(Continued)

the most important and far-reaching change. Prior to recent changes in product liability principles, most courts said that an injured party must be free from fault of contributory negligence in order to recover. This was determined by whether a jury *thought* he was acting as a reasonably careful person would act under the same situation that led to the injury. "Contributory negligence" is no longer available to the defense—"assumption of risk" is the principle now being followed. Under this provision, all that the plaintiff is required to show is that he did not know that the product was defective, and he will *always* testify to this.

If this change doesn't bother you, the following ones should hit you between the eyes. You don't even have to make or sell the product that causes injury to be liable for suit. You can get in trouble by just trying to be a good guy and rectifying a complaint. For example, a paint company was liable for the death of a customer's employee who complained about a paint finish. The paint company *gave* lacquer reducer to the customer so he could remove the paint, and subsequently the reducer caught fire causing his death.

You may not even work for a manufacturer and still be liable. A supplier, job shop, design consultant, subcontractor, blueprint shop, etc., involved with a defective product is just as liable as the final manufacturer. You may not only be sued by the injured party but also by the manufacturer, and you may end up paying the entire judgment. And don't kid yourself that good business relationships will keep the latter from happening. Such suits are usually ordered by attorneys working for your customer's insurance company and your customer must do what they say. The trend is for lawyers representing those charged with defective products to add additional parties as quickly as possible in an attempt to avoid a judgment against their client.

Even those who rent, or loan for free, property that causes injury can be liable under the last change. What counts is who put the product in the stream of commerce for use by others!

Now if the above changes don't shake you, maybe the latest trends will. These not only make it *possible* that you will make a defective product but they also make it *probable* that you can be sued.

Your product doesn't have to be made in the same state in which a person was injured. For example, you may make your product in New England, sell it in some other eastern state to a person who then moves to the West Coast and subsequently becomes injured. Consider the difficulties in defending yourself if you do no business, know no one and have no office out there.

Even more frightening is the "proximate cause" trend. Initially a plaintiff had to show that the product was the "sole cause" of his injury, but that is no longer true. For example, a truck collides with another vehicle. The plaintiff can take the course that the truck's age, normal wear and tear and maintenance or lack of it was a contributing proximate cause for a defect, and recover damages. If this isn't bad enough, the defect doesn't even have to cause the injuries. Another example, a person through his own fault drives his car off the road into a tree and becomes injured. He can recover from the manufacturer on the grounds that his injuries would not have been as bad if the car was designed properly.

At this point you may feel that the examples given don't relate to your field of work, so all this product liability stuff doesn't pertain to you. Not so! The examples given are merely used to show you the extent of what's happening in product liability, and a little objective thinking on your part should help you discover that you, too, can be affected.

What Can Be Done! Surely things can't be so gruesome that a prudent person cannot take precautionary measures to reduce the chance of being sued for a defective product. A manufacturer has at his disposal many tools to help ensure a safe, well-made product. These include a product design department, quality control, reliability testing, customer service and such. No matter what part of the team you belong to, you can play a big part in accomplishing the above objective. What's needed is for you to consider all the ramifications to overall product safety at every step you take in a product's design and manufacture.

One of the most important things you can do is to determine all possible uses of your product. All potential situations must be considered whereby the product or something it controls comes in contact with people who might be injured. Imagination must be used to better understand the product you are involved with. Obviously, without a crystal ball you can't anticipate everything—after all "Murphy's Law" exists everywhere—but you sure can help to change the odds in your favor. If your company can afford it, the services of an outside expert would be of significant assistance in this area. However, if you cannot afford an expert or if such a practice is against company policy, a team composed of the quality assurance manager, a design engineer, advertising manager and company attorney could call on some of your biggest customers to see just what is happening to your product. This team should look for a myriad of things, such as: How is the product handled and transported? Are instructions and labeling adequate? Who is the average user—his mentality, expertise, educational back-

ground and degree of responsibility? Who might be near the product when in use and who could be affected if it malfunctions, breaks, or explodes? If your product is simply a part of an assembly, the team should explore how it relates to the final product; what happens if it fails; whether your product becomes dangerous if another part fails, etc.

Such field trips can result in any or all of the following procedures:

1. Review of QC program to insure testing for uses and failures discovered in the field;

2. Design changes to eliminate, limit or improve product usage;

3. Clear and distinct marking and labeling to alert all persons subject to injury;

4. Notification *in writing* to any of your suppliers whose parts have been found defective either through use or design;

5. Notification of your customers by billing, mailing and contract documents that your product or part is per their order or spec if the design's origin is not your own.

Even advertising literature can cause loss of a liability suit so that, too, should be reviewed. Statements like "safe," "insures ease and safety of operation," "insures the safety of the operator," "adapts to many and varied purposes and uses" can be libelous if a person does become injured. Remember, while a product defect can be a design which permits a dangerous use, it also can be a failure of design suitability for uses clearly stated or implied in your advertising, sales literature or catalog.

Lack of labeling and marking of functions on the product itself can cause loss of liability suit even though all precautions appear to be taken. For example: a manufacturer of power tools was sued because a plaintiff lost a couple of fingers while operating a tool which had proper safety guards attached and complete instructions for use in literature provided. However, the plaintiff claimed he received the product from a trading stamp store without instructions, and even though he had used the tool for a couple of years, didn't know how its "built-in" devices for safety were supposed to be used.

What If You Are Involved in a Suit? In a lawsuit one important step that occurs before a trial is the "discovery" phase where the plaintiff can ask written questions that must be answered in writing under oath. He is entitled to obtain all corporate records that pertain to the defective product, including discarded designs, engineering or process changes, memos between company personnel regarding the product and its deficiency, test results, prior claims made against the product, documented customer complaints, any safety tests run by independent experts, sales literature and any other records. He can also take oral depositions from individuals within the defendant company—usually people involved with product design, quality control, sales and customer relations. These latter depositions don't always become part of the trial, but they do help establish the facts for both sides.

This discovery phase can pretty well establish the future course of the suit, so it becomes imperative that a prediscovery conference be held within the departments of the defendant company. Here all the facts of the product design and history are presented to, and reviewed by, your attorney. It is most important for everyone to be candid and truthful here and not to be defensive, because a popular tactic used in court is to "divide and conquer." That is, to get one department of a company on the defensive and have it blame another department for product defects. It is also very helpful to obtain opinions of an independent outside expert. The product designer should not feel that his professional expertise is being questioned if this happens. This is merely a legal tactic that will surely be employed by the plaintiff.

So you see it is vital for all those involved in a new product to be "safety conscious" at all times. The consequences of the loss of a lawsuit or even an outside settlement can be staggering, for it can open a "Pandora's Box." Word of such happenings travels fast among trial attorneys and a favorable (to the plaintiff) settlement can lead to many, many more suits of the same type that become increasingly difficult to defend. *Who's responsible for product safety?*—**You!**

This article is based on a series of articles that originally appeared in *Quality Management & Engineering*, a Hitchcock Publication, written by Wendell W. Clancy. Mr. Clancy is an attorney who has been engaged primarily in insurance defense litigation.

Digitally Controlled Power Sources Include Added Systems-Oriented Functions

Digitally Controlled Power Sources (DCPS's) are complete. digital-to-analog links between a computer (or other digital source) and any application requiring a fast, accurately settable source of dc or low frequency ac power. Such applications generally require more than a programmable power supply or D/A converter with a power amplifier — the DCPS's include these added functions in a single compact trouble-free package:

INTERFACE Customized plug-in interface cards match the Digitally Controlled Power Source to the computer (8421 BCD or Binary).

ISOLATION All digital inputs are floating and isolated from the floating analog output, thus avoiding troublesome loops between the output ground and computer ground.

STORAGE Inputs from all digital data lines are stored upon receipt of a gate signal from the computer. Output levels are maintained until a new gate signal is received — thus, the computer is free to perform other tasks in the interval between voltage level changes.

FUNCTION SELECTION Selects the output voltage range, and isolates the three input bits to the current limit D/A converter.

OUTPUT VOLTAGE D/A CONVERTER Converts one polarity bit plus 16 BCD voltage bits or 15 binary voltage bits to an analog voltage for input to the power amplifier. Thus, resolution is 0.5mV for straight binary and 1mV for BCD operation.

REFERENCES Provide voltage for the Output Voltage and Current D/A Converters.

CURRENT LIMIT D/A CONVERTER Sets current limit of power amplifier to one of eight values.

CIRCUIT POWER SUPPLIES Provide all the necessary dc power — no external power supplies are required.

FEEDBACK Informs the computer when each programming operation is completed and when the output current is overloaded.

BIPOLAR POWER AMPLIFIER Programs either side of zero or through zero without output polarity switches or "notch" effects, with an accuracy of 1mV, 5mV, or 10mV depending on range and model. Outputs now available include ±50V @ 1A, ±50V @ 5A, and ±100V @ 0.5A.

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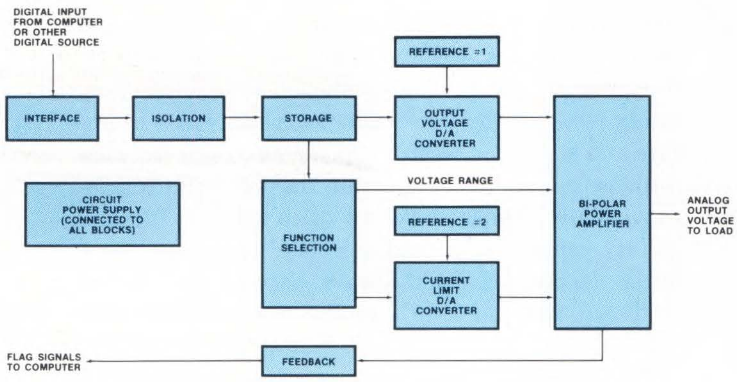

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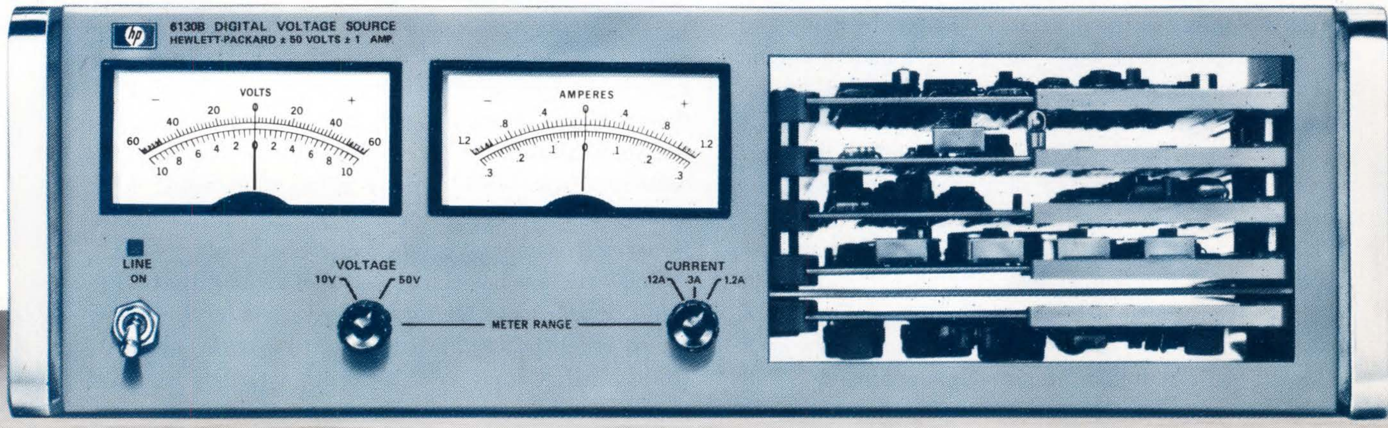

Four-Channel Op Amp—New Linear Building Block

PROGRESS IN OP AMPS

A new concept in operational amplifiers recently introduced by Harris Semiconductor of Melbourne, Fla. provides designers with a powerful new circuit building block.

Packaged in a 16-pin dual-in-line, this new device is called the HA-2400 PRAM (Programmable Analog Module).

Both digital and analog circuitry have been combined in this package to give an operational amplifier with four input channels and the capability of digitally selecting the desired channel. **Fig. 1** shows a functional block diagram of the circuit.

Four input preamps can be switched by the decode/control circuitry to effectively connect the desired input to the output amplifier. Feedback networks connected from the device output to the various inputs create, in effect, one op amp for conditioning up to four input signals—or four different op amps for conditioning a single input signal. It all depends on how you hook it up.

Obviously this is a device that a designer can use to solve a wide variety of problems. Programmability is the key feature that makes the PRAM stand out from other op amps and a number of suggested applications have been developed around this capability (**Table I**).

One of the most obvious applications is as an analog multiplexer with buffered input and output (**Fig. 2**). This circuit is used for analog signal selection or time-division multiplexing.

The feedback signal places the selected amplifier channel in a voltage follower (non-inverting unity gain) configuration, and provides very high input impedance and low output impedance. For low-level input signals, gain can be added to one or more channels by connecting the negative inputs to a voltage divider between output and ground.

Bandwidth is approximately 10 MHz. The output will slew from one level to another at about 15V/μsec.

Expansion to multiplex 5 to 12 channels can be done by connecting the compensation pins of two or three devices together and using the output of only one of the devices. The enable input on the unselected devices must be low. Sixteen or more channels can be multiplexed by connecting the outputs of four 4-channel multiplexers to the inputs of another 4-channel multiplexer. Differential signals can be handled by two identical multiplexers addressed in parallel. Of course, all four inputs do not have to be used if the application doesn't require them. For example, in the design of a phase selector (**Fig. 3**) only two inputs are used. This circuit passes the input signal at unity gain, either unchanged or inverted depending on the Digital Control input. A buffered input is shown because low source impedance is essential. Gain can be added by modifying the feedback networks. Signals up to 100 kHz can be handled with 20V peak-to-peak output.

This same circuit can be used as a phase detector by driving the Digital Control input with a reference phase at the same frequency as the input signal. Average dc output is then proportional to phase difference, with zero volts at ±90°.

By connecting the output to a comparator that drives the Digital Control, a synchronous full-wave rectifier is formed. And, with a low-frequency input signal and a high-frequency

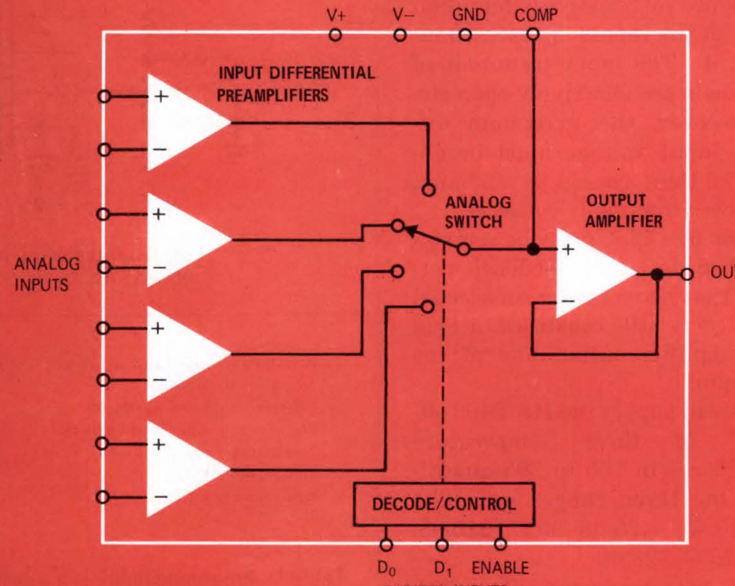

Fig. 1—**PRAM** functional block diagram.

(Continued)

digital control signal, a balanced (suppressed-carrier) modulator results.

As you can see from these few examples, this is a powerful device. Some of the details about the PRAM that a designer must be aware of in addition to its specifications (**Table II**) are compensation requirements, offset adjustments and input voltage limitations.

Offset voltage	----	2 mV
Bias current	----	50 nA
Offset current	----	5 nA
Input signal range	----	±10V
Voltage gain	----	150k
Slew rate	----	±15V/μ sec at Av = 1 ±50V/μ sec at Av = 10
Power dissipation	----	135 mW
Select delay	----	100 nS
Logic threshold	----	1.4V

Table II – **PRAM** specifications.

Frequency compensation is done by connecting an external capacitor from pin 12 to ac ground (V + supply), and is recommended for closed loop gains less than 10. If offset adjustment is required, it can generally be accomplished by resistive summation at either of the inputs for each channel (**Fig. 4**). The input terminals of OFF channels are effectively open circuits; however, the maximum differential input voltage must be observed and their voltage levels must never exceed the supply voltages.

Another fact that must be remembered when designing feedback networks is that networks for unselected channels may still constitute a load at the amplifier output and at the signal input.

Harris will supply the HA-2400 off-the-shelf in three temperature ranges. Prices in 100 to 999 quantities for the three ranges are: 0 to 75°C, \$10.45; −25 to 85°C, \$15.95; −55 to 125°C, \$23.65.

Harris Semiconductor, Box 883, Melbourne, Fla. 32901. **169**

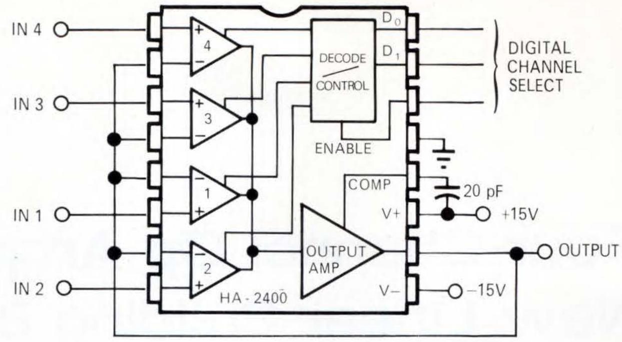

Fig. 2 – **Analog multiplexer** with buffered input and output.

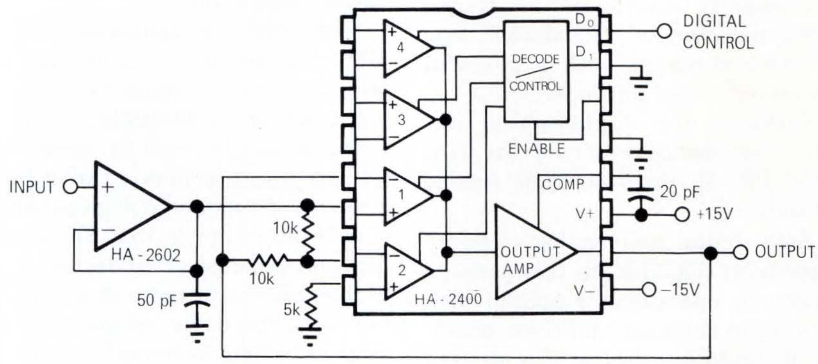

Fig. 3 – **Phase selector** with buffered input.

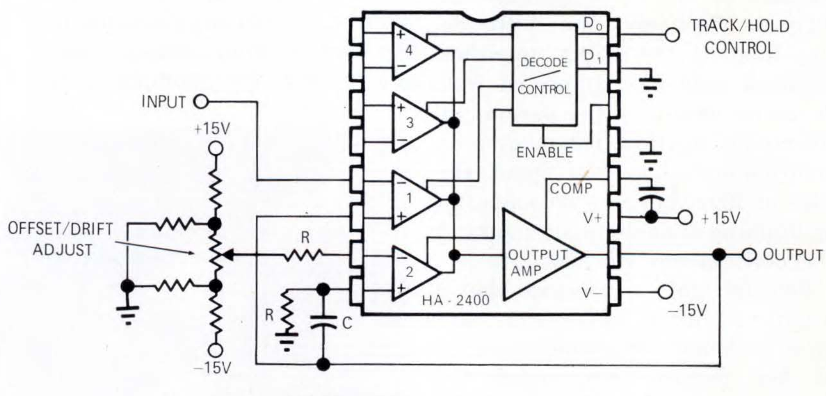

Fig. 4 – **Offset/drift adjustment** can normally be done as shown in this track and hold/sample and hold circuit.

Programmable gain amplifier (Inverting or noninverting)	Phase selector
Programmable attenuator	Phase detector
Programmable adder/subtractor	Synchronous rectifier
Programmable sine-wave oscillator	Integrator/ramp generator with initial condition reset
Programmable power supply	Track and hold/sample and hold
Programmable comparator	Multiplying D/A converter
Programmable active filter	

Table I – **Programmability is a key feature;** however the device may also be used when an application requires a single channel to be switched on and off.

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For samples of the X440 capacitor and applications assistance, write TRW Capacitor Division, Box 1000, Ogallala, Nebraska 69153. Phone (308) 284-3611. TWX 910-620-0321. X440's are available off the shelf at all TRW stocking distributors.

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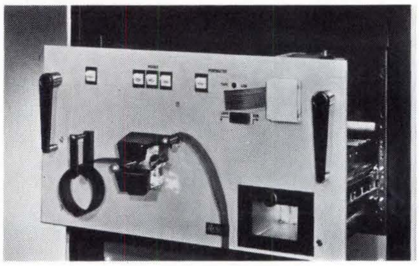
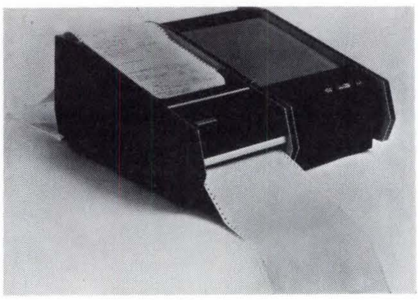
November 15 - December 13, 1971

DATE/DAY/TIME	AREA	SITE
Monday, Nov. 15		
9:00 - 11:30 a.m.	Boca Raton, Fla.	IBM
1:30 - 4:30 p.m.	Ft. Lauderdale, Fla.	Systems Engrg. Labs.
Tuesday, November 16		
9:30 - 12:00 noon	St. Petersburg, Fla.	Honeywell
Friday, November 19		
9:00 - 12:00 noon	Dallas, Texas	Texas Inst. Gov. Prod. Apparatus Div.
1:30 - 4:30 p.m.	Irving, Texas	Recognition Equipment
Monday, November 22		
9:00 - 12:00 noon	Phoenix, Ariz.	Honeywell Information Systems Inc.
1:30 - 4:30 p.m.	Scottsdale, Ariz.	Motorola
Tuesday, November 23		
1:30 - 4:30 p.m.	San Diego, Calif.	Stromberg Datagraphix Inc.
Wednesday, November 24		
9:00 - 12:00 noon	La Jolla, Calif.	Control Data Corp.
1:30 - 4:30 p.m.	San Diego, Calif.	NCR
Monday, November 29		
9:00 - 12:00 noon	Concord, Calif.	Systron Donner
1:30 - 4:30 p.m.	San Leandro, Calif.	Friden
Tuesday, November 30		
9:00 - 12:00 noon	Mountain View, Calif.	Sylvania
2:00 - 4:30 p.m.	Walnut Creek, Calif.	Varian Associates
Wednesday, December 1		
9:00 - 12:30 p.m.	Santa Clara, Calif.	Memorex
1:30 - 4:30 p.m.	Santa Clara, Calif.	Hewlett-Packard
Thursday, December 2		
9:00 - 1:00 p.m.	Palo Alto, Calif.	Philco-Ford
2:00 - 4:30 p.m.	Palo Alto, Calif.	Hewlett-Packard Microwave Div.
Friday, December 3		
9:00 - 12:00 noon	Sunnyvale, Calif.	Singer-Link
1:30 - 4:30 p.m.	San Jose, Calif.	IBM
Monday, December 6		
9:00 - 12:00 noon	Westlake Village, Calif.	Burroughs Corp.
1:30 - 4:30 p.m.	Woodland Hills, Calif.	Litton Systems
Tuesday, December 7		
9:00 - 12:00 noon	Van Nuys, Calif.	Litton Data
1:30 - 4:30 p.m.	Van Nuys, Calif.	RCA.
Wednesday, December 8		
9:00 - 11:30 a.m.	Woodland Hills, Calif.	Data Products
2:00 - 4:30 p.m.	City of Industry, Calif.	Burroughs Corp.
Thursday, December 9		
9:00 - 12:00 noon	Culver City, Calif.	Hughes Aircraft
1:30 - 4:30 p.m.	Marina Del Rey, Calif.	Ampex
Friday, December 10		
9:30 - 12:00 noon	El Segundo, Calif.	Xerox Data Systems
1:30 - 4:30 p.m.	Hawthorne, Calif.	NCR
Monday, December 13		
9:00 - 12:00 noon	Anaheim, Calif.	Calif. Computer Products Inc.



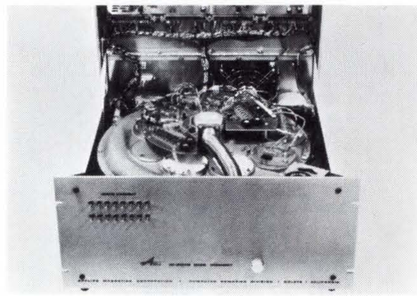
Punched-tape reader and perforator, 2075 Series, handles 1-inch, 8-channel paper and most mylar, paper mylar or aluminum mylar tapes between 0.003 and 0.0043 inch thick. Unit reads up to 200 cps in either synchronous or asynchronous drive. Perforator punches—either independent of, or with, the reader—5-, 6-, 7- or 8-track tapes at up to 75 cps. REMEX, A unit of Ex-Cell-O Corp., 1733 Alton St., Santa Ana, CA 92705. **170**



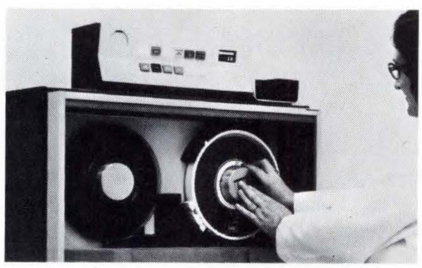
Data communications printer, a 100 line/min unit, is designed to replace the conventional teleprinters. Precise multiple copy printout can be delivered at 1200 baud over a dial-up or leased line network. Automatic error control routines assure accurate printout. Standard 80 or 132 column multi-copy continuous form paper is used for printout. Tally Corp., 8301 S. 180th St., Kent, WA 98031. **171**

Modem test set, Model 225, simplifies the testing of both synchronous (up to 0.5 MHz) and asynchronous (selectable from 75 to 9600 bps) digital data transmission systems. Features include capability of testing full duplex, half duplex and simplex; availability of six patterns and their inverse; and display of bit or block, error count and blocks transmitted. Systron-Donner Corp., Datapulse Div., 10150 W. Jefferson Blvd., Culver City, CA 90230. **172**

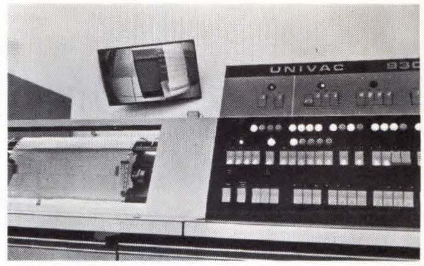
Direct dial, auto answer modem converts "Teletype" terminals into hardwired, online communication stations for attended or unattended operation. The coupler consists of two units—a "Teletype" cover plate, Model 4001, that mounts directly on the terminal surface, and the electronics required for interfacing with the Bell Telephone Data Coupler 100A (CBS) and 1001B (CBT). Omnitec, 903 N. 2nd St., Phoenix, AZ 85004. **173**



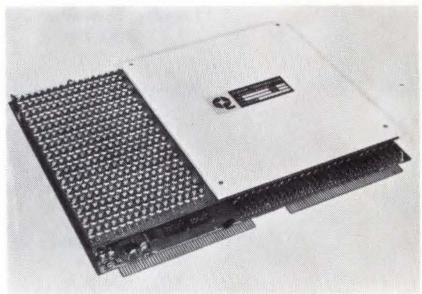
Disc memory M-200 Series is field expandable from 564 to 9024 kbit capacity. Complete system, requires only 8.75 inches of standard rack space. The head/track configuration achieves an average access time of 12.5 msec. Bit price ranges from $0.0008 (single unit) to $0.0005 (OEM quantities). Computer Memories Div., Applied Magnetics Corp., 75 Robin Hill Rd., Goleta, CA 93017. **174**



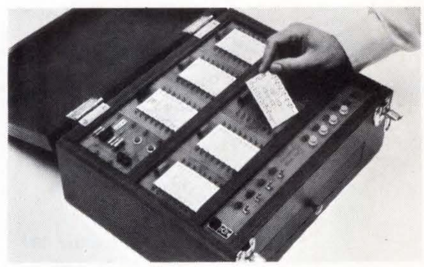
Self-threading computer-tape cartridge is fully compatible with all IBM 2420 and 3420 type automatic threading tape drives. Constructed of high-impact plastic, the cartridge wraps around the tape reel and snap-locks in place. As the cartridge need not be removed from the tape reel, it also serves as a dust protective collar. Cartridges come separately or mounted on loaded tape reels. 3M Co., Magnetic Products Div., Box 3686, St. Paul, MN 55101. **175**



Rectangular convex mirror permits any computer room operator to check at a glance the stacking formation of printout sheets from a high-speed printer. Printout "mis-stacks" can slow job progress down because printers have to be stopped to correct the collating problem. Mirror prices range from $35 to $65 depending upon size desired and quantity ordered. Norman Industries, Inc., 814 W. Diversey Parkway, Chicago, IL 60614. **176**



Electrically-alterable ROM offers capacities up to 100k bits per PC board, 150 nsec read-only cycle time and 90 nsec access time. The system, comprised of low-threshold, square-loop core array in a 2-core/bit mode, can be divided into a ROM and a read/write configuration. Without write electronics, the price is as low as $0.01/bit. Quadri Corp., 2950 W. Fairmont, Phoenix, AZ 85017. **177**



Breadboard kit, called Digi-Kit, offers a fast and easy way to breadboarding digital ICs through the use of an exclusive "Universal Integrated Circuit" (UNIC) card. Overlays show complete wiring diagrams for the common devices of the standard TTL 7400 line. The kit includes a pre-wired regulated power supply, switches, indicator lamps, 100 patching leads and dual clock card. General Electronics Associates, Inc., 9184 Coventry Dr., Northfield, OH 44067. **178**

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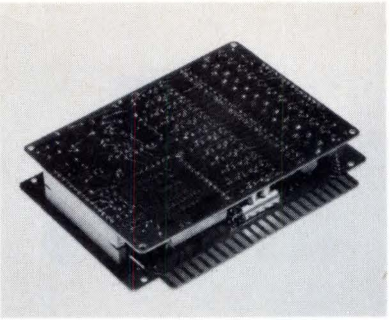
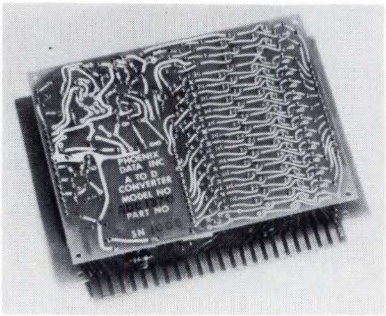
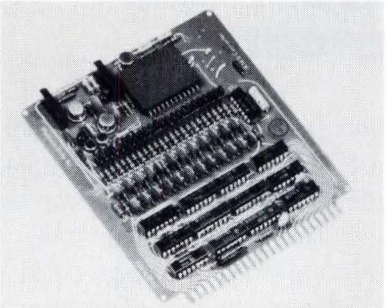


ADC 700 Series Converters. Convert 12 binary bits in 6.5 μsec and 8 binary bits in 3.5 μsec with up to 0.025% full range accuracy and ±10 ppm/°C stability. Voltage switching attains high conversion speed without sacrificing accuracy, while maintaining linearity. A reference generator circuit allows the units to meet their specified accuracy with ±5% regulation of the power supplies. Saturated bipolar switches help to provide low temperature coefficient. Series includes six fully-repairable models. Prices start at $375 each. Phoenix Data, Inc., 3384 W. Osborn Rd., Phoenix, AZ 85017. Phone 602/278-8528. TWX 910-951-1364.



ADC 1370 Series Converters. Capable of encoding ±10V full range inputs into 13 binary bits of data with a minimum thruput time of 14 μsec. Provides a resolution of 1 part in 8,191 with an accuracy of ±0.015% of full range. Features a low temperature coefficient of ±5 ppm/°C; full range input of ±10V, 0 to +10V, 0 to +5V, or ±5V standard; with optional 100 megohms input impedance amplifier; serial and parallel outputs; 71,428 conversions on command or continuous. Prices start at $875 in 1 to 5 quantities. Phoenix Data, Inc., 3384 W. Osborn Rd., Phoenix, AZ 85017. Phone 602/278-8528. TWX 910-951-1364.



ADC 300 Series Converters. Complete, fully-assembled, plug-in modules incorporate all of the functions necessary to perform conversions except for power supplies. Accurate to within ±0.025%. Single card open construction facilitates field repair and low profile permits units to mount on 0.5" centers. Price of the ADC 312 (12 bit) unit in 1 to 5 quantities is $300. Phoenix Data, Inc., 3384 W. Osborn Rd., Phoenix, AZ 85017. Phone 602/278-8528. TWX 910-951-1364.

ADC 700 Circle No. 12
ADC 1370 Circle No. 13
ADC 300 Circle No. 14.

Metallized cassette, the Capitol/Audev Datasette, was designed for digital applications and contains computer tape that is certified 100% at 3200 fci after assembly in the cassette. Characteristics permit operation at speeds up to 200 ips, and record speeds up to 30 ips. Audio Devices, Inc., 100 Research Dr., Glenbrook, CT 06906. **179**

General purpose 16-bit computer, PDP-11/45, handles up to 126,976 words of memory. Features include floating point, multiple unified buses, memory segmentation, 300 nsec inter-register instruction execution time and two software monitor systems—DOS for stand alone computation and RSTS for real-time application. Digital Equipment Corp., Maynard, MA 01754. **180**

Digital stack card for the ECOM F Series doubles the capacity from 4 to 8k on the same physical size card and the bit length remains from 9 to 18 bits. Cycle time is 750 nsec. Standard Memories, Inc., 15130 Ventura Blvd., Sherman Oaks, CA 91403. **181**

Desktop alphanumeric terminal, Model 80, functions as a peripheral device for the System 10 business computer. Features include, "fill-in-the-blanks" formatting, quick and easy editing, display of 1600 characters, 10-key numeric keyboard and 1500 character transfer rate. Singer Co., Friden Div., San Leandro, CA 94577. **182**

Semiconductor memory system, the in-10 system, has a maximum cycle time of 450 nsec and a 325 nsec access time maximum. Systems are assembled modularly from 8 by 10 inch cards, each storing 4k, 18-bit words or 8k, 9-bit words. One card controls up to eight memory cards. A 32k, 18-bit word or 64k, 9-bit word of storage occupies only 400 cubic inches. Price is approximately $0.015/bit. Intel Corp., 3065 Bowers Ave., Santa Clara, CA 95051. **183**

Coupler/recorder, Model 503, converts decimal or BCD information into terminal- or computer-compatible input data, and provides a punched paper tape record of that data. Both desk-top and rack-mount configurations are available. Ambient Systems, Inc., 3020 Scott Blvd., Santa Clara, CA 95050. **184**

MOS memory system consisting of an optional memory tester card, test panel and power supply provides up to 147,456 bits of storage. In lieu of the memory tester, the optional card converts the memory into a special purpose controller, minicomputer or similar memory-oriented system. Signal Galaxies, Inc., 6955 Hayvenhurst Ave., Van Nuys, CA 91406. **185**

Data cassette T300 complies with standards of ANSI and ECMA and is certified after assembly to assure zero dropouts. An off-center hole in the back edge of the cassette is for ANSI drives. A fiberglass-reinforced case made of a conductive molding compound dissipates static charges. Information Terminals Corp., 1160 Terra Bella Ave., Mountain View, CA 94040. **186**

Printer, Model 0768-02, adds full upper- and lower-case print capability to the 9000 computer series excepting the 9200. The unit has an ASCII 94 character subset and performs numeric printing at 2000 lines/min. Sperry Rand Corp., Univac Div., Box 500, Blue Bell, PA 19422. **187**

Head-per-track disc memory systems come in two configurations with 8.7 msec access time. Model 6100 has from 1 to 4 megabit capacities and from 16 to 64 tracks in increments of 16. Model 6200's capacities range from 1 to 8 megabits—also in increments of 16 from 16 to 128 tracks. Digital Development Corp., 5575 Kearny Villa Rd., San Diego, CA 92123. **188**

Modem DVM 1300 requires no external data access arrangement and is completely compatible with Bell System interface specifications for conditioned lines, dial-up lines, PBXs and PABXs. Data transmission rate is 1300 bps with 10^{-6} error rate. Operational modes (two modems required) are full and half duplex, switch selectable. Unit dimensions are 19 by 13 by 7 inches. Phonplex Corp., Sub. of Instrument Systems Corp., 410 Jericho Turnpike, Jericho, NY 11753. **189**

Cassette transport module, Model 171, provides block-synchronous write/read up to 15 ips, bi-directional high-speed search and fast rewind. Maximum data transfer rate is 1500, 8-bit bytes/sec. Price for OEM quantities is $150. Dicom Industries Inc., 715 N. Pastoria Ave., Sunnyvale, CA 94086. **190**

Cassette heads with built-in precision come in three versions—single-track, single-gap (A282A) and a pair of two-track, single-gap (A281A and A281H). Precision mount feature reduces assembly time, and precision guides insure proper tracking of the tape. Arvin Magnetics, 6950 Washington Ave., S. Eden Prairie, MN 55343. **191**

Multiplex Modem System Model 5150 permits up to 24 channels (depending on baud rates) over a standard Bell System Type 3002 nonconditioned line or equal facility. The desk-top cabinet or standard 19-inch rack mounted configuration accommodates up to eight individual PC card modems with one common plug-in power supply. Basic price per channel is $285. RFL Industries, Inc., Boonton, N J 07005. **192**

Programmable word generator Model 1602 is intended for memory testing and features 16 independent channels, each with a basic 16-bit word capacity. Selectable bit rates range from 1k to 5 MHz. E-H Research Laboratories, Inc., Box 1289, Oakland, CA 94604. **193**

Illuminated keyboard, Series 59C, features front-panel lamp replacement and a choice of 0.5 inch square or truncated keys. This switch matrix can be specified in a variety of configurations to meet any special data terminal keyboard applications. Total travel is 0.1 inch with actuation force of 6 oz. Oak Electro/Netics Corp., Crystal Lake, IL 60014. **194**

Plug-compatible, add-on core memory system, Expanda-Core 11 Series, enables PDP-11 users to expand their storage from 4k to 32k in 4 or 8k single card increments. The memory system can also be added to the PDP-11 processors that have no memory. It is designed for field installation. Price ranges from $5600 (basic 8k expansion module) to $15,000 (24k of add-on memory). Cambridge Memories, Inc., 285 Newtonville Ave., Newtonville, MA 02160. **195**

A 4-digit data logger, Model 8040LR, multiplexes up to 10 input channels at a stepping rate that is controlled externally or internally. A strip printout provides the channel identity, data and a sequence number for the run identification. Visual display and an electrical output are provided. Dytro Corp., 63 Tec St., Hicksville, NY 11801. **196**

A line of 2400 bps synchronous modems, Series 24S, is available in either single PC board or stand-alone modem pack versions. They come in full duplex configurations with 10 msec turn-around time for polling economy and 200 msec turn around for 2-wire half-duplex operation. Sanders Associates, Inc., Daniel Webster Highway, S., Nashua, N H 03060. **197**

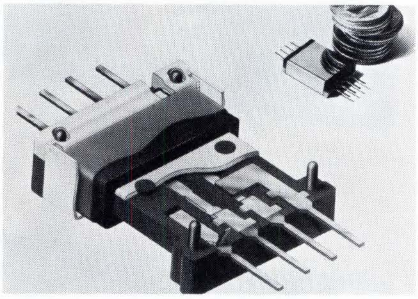
Remote batch-processing terminal CP-4B, directly compatible with the IBM 360 and 370, is specifically designed for operation by non-technical personnel. Operating in either the two or four wire half-duplex mode, it will interface with I/O units operating in EBCDIC code or the 7 or 8 level UASCII code sets. Data Computer Systems, Inc., 17131 Daimler St., Santa Ana, CA 92705. **198**

Disc memory, Model 6400, is a head-per-track unit that offers minicomputer designers 128 to 512k, 16-bit words of storage. Average access is 17.4 msec, and data rate is one word every 8 μsec. Magnafile Inc., 2602 E. Magnolia, Phoenix, AZ 85034. **199**

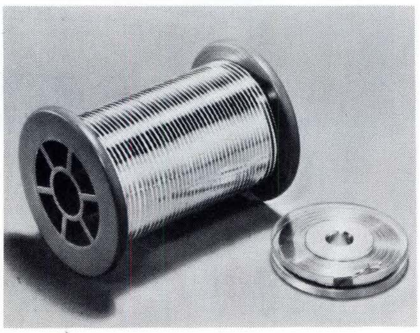
Disc system, an addition to the FASTRACK memory systems, features packing density of 6000 bpi. Eleven models span the range from 38.4 to 153.6 megabits with 16.7 msec average access time and 4.5-, 9-, 18- and 36-MHz data transfer rates. Data are recorded on one to four 16-inch discs. Pacific Micronetics Inc., 5037 Ruffner St., San Diego, CA 92111. **362**

Fast-switching cores MT-1401 have a typical peaking time of 50 nsec and a typical switching time of 100 nsec. These 14-mil lithium cores have a write/read current of 880 mA and a partial current of 440 mA. Distributed voltage is 40 mV for a "1" and 5mV for "0". With these cores, a 4k-word by 18-bit memory system with an access time of under 235 nsec and <50 nsec cycle time is possible. Data Products, 6219 DeSoto Ave., Woodland Hills, CA 91364. **363**

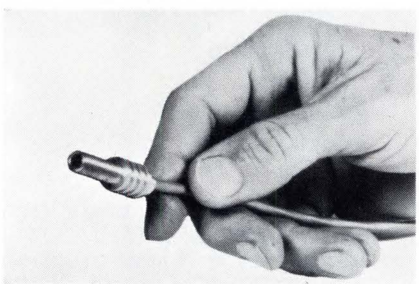
Disc storage unit for mini and midi computers comes in three versions. The rack mountable, fixed-head units offer a capacity range from 0.8 to 3.2 megabits. All models have 8.3 msec access time and 3 megabits/sec data transfer rate. Xerox Data Systems, 701 S. Aviation Blvd., El Segundo, CA 90245. **364**



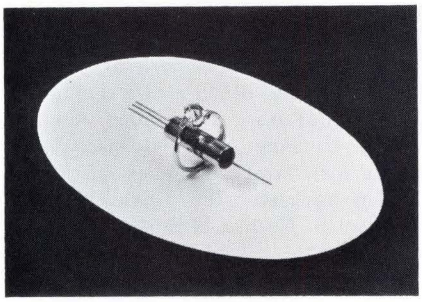
Integrated reed relays, Type IR², are designed to be totally compatible with TTL ICs. They require only 50 mW for operation at 5V dc. Optimum heat transfer is provided by an integral alumina substrate that permits low thermal offset. Kam Corp., 845 Commercial St., San Jose, CA 95112. **200**



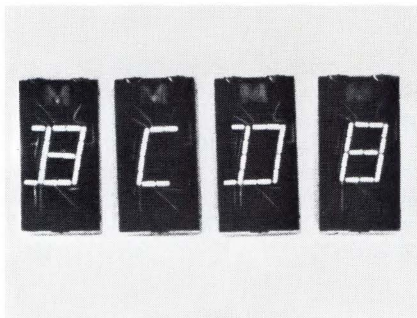
Metal ribbon is now offered in thicknesses from 0.010 inch to 1/8 inch. Among the compositions available are various types of gold: high purity, doped and alloyed; platinum- or palladium-clad on nickel; silver-clad "nickel silver"; and numerous eutectic bonding alloys such as gold-germanium and gold-silicon. Consolidated Reactive Metals, Div. of Consolidated Refining Co., Inc., 115 Hoyt Ave., Mamaroneck, NY 10543. **201**



Miniature phototransistor packaged with an incandescent light source can detect marks as small as 3 mils at 75 mils distance. The Model 502 Mini Scanner operates on 5.0V minimum V_{cc} and delivers 1.5V output signal when viewing high-contrast marks of 15 mils or larger. Accu-Sort Systems, Inc., 601 Lawn Ave., Sellersville, PA 18960. **202**

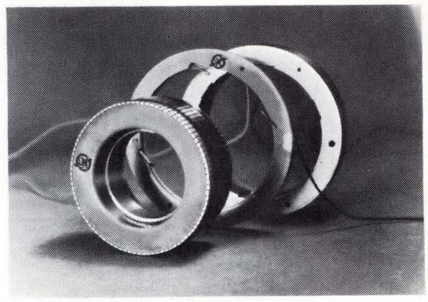


Reed relay meets MIL-Q-9858A specs at a price of $0.29 each in quantities of one million. Features include magnetic shielding, less than 100 mΩ contact resistance, contact rating of 1A or 250V switching at 20W and various coil ratings. Electronic Applications Co., 2213 Edwards Ave., South El Monte, CA 91733. **203**

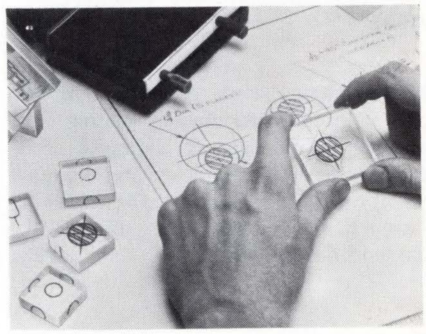


Solid state display, the MAN1002, is a hexidecimal LED array capable of displaying numbers 0-9 as well as 14 distinct letters. The unambiguous display features a 0.27-inch character using eight segments of GaAsP LEDs. The eighth segment is actually two half-segments that are lighted when letters are displayed. Prices begin at $16 each in unit quantities. Monsanto Commercial Products Co., 10131 Bubb Rd., Cupertino, CA 95014. **204**

High-power stepping motor, Model 110-J, provides up to 1/2 horsepower and has response speeds of up to 10,000 steps/sec. Icon's unique radial-land rotor design, high current capacity (13A/winding) and 10-state current-switching sequence made possible the power, speed and accuracy improvements. Icon Corp., 156 Sixth St., Cambridge, MA 02142. **205**



Compact dc tachometer has ripple voltage of 1% pk-pk deviation. The 24 oz. TG-2936 has voltage sensitivity of 1.75V/rad/sec and can be used for velocity damping in servo positioning mechanisms as well as rate reference applications. Maximum operating speed is 90 rad/sec. Inland Motor Corp., Radford, VA 24141. **206**



Transparent plastic symbol stamps are designed to allow perfect alignment on the drawing, and to speed drafting of repetitive symbols. Stock stamps are available for most industrial needs. Custom stamps can be made in sizes up to 36 inches² to reproduce fine lines, thick lines, fine detail or even half-tones with sharp clarity and the opaqueness of drafting ink. Symbo Corp., Box 558, Morton Grove, IL 60053. **207**

Electrically conductive conformal coating is flexible, consists of one component and is air drying. The coating is made of pure silver filler in a vinyl copolymer. Resistivity is <0.01Ω/square; tack free dry time is 3 min; cure time is 24 hrs. Cost is less than $0.15/in²/mil thickness. Tecknit, 129 Dermody St., Cranford, N J 07016. **208**

Components/Materials

Epoxy glass laminate, designated 205-NMX, is flame retardant and will not delaminate or measle when subjected to solder pot temperatures of 520°F for extended periods of time. Price is $2.25/ft^2 and quantity discounts are available. New England Laminates Co., Inc., 25 Crescent St., Glenbrook, CT 06906. **209**

High contrast filter (HCF) improves contrast of CRT displays. The new filter, that can be made in sizes up to 10 inches square, enhances the contrast of both alpha-numeric and gray-scale displays. Options are available for all commonly-used phosphors. Contrast ratios greater than four have been achieved. Optics Technology Inc., 901 California Ave., Palo Alto, CA 94304. **210**

Precision polystyrene film-foil capacitors, Type 54PX, feature tolerances to ±0.1% and stability or retrace of less than 0.05%. Operating temperature is −55 to +85°C with no de-rating. Units are available with capacitances from 0.001 through 0.022 μF at 100V dc. Wesco Electrical Co., Inc., 27 Olive St., Greenfield, MA 01301. **211**

Emitter diffusion source helps reduce crystal imperfections for improved yield and reliability. N-250 helps prevent crystal imperfections caused by diffusing a high concentration of phosphorus onto a wafer surface. The solution also helps eliminate "emitter dip effect" sometimes caused by strain induced by high-phosphorus doping. Emulsitone Co., 41 E. Willow St., Millburn, N J 07041. **212**

Glass-ceramic chip capacitors with range from 10 to 330,000 pF are intended for hybrid circuit applications. Available in four sizes and six stability characteristics, the chip capacitors are offered in tolerances of 5, 10 or 20%. Corning Glass Works, Corning, NY 14830. **213**

LED cartridge lamps offer direct plug-in replacement for incandescent cartridge lamps without circuit modification. The TEC-LITE L-1015 Cartridge Lite includes internal series resistors and is available in five models for 5.0, 6.3, 10.0, 14.0 or 24.0V operation. Flat or curved lenses are designed to increase side illumination. TEC, Inc., 9800 N. Oracle Rd., Tucson, AZ 85704. **214**

Film dielectric capacitors for 115V ac 400 Hz operation are specifically designed, manufactured and screened for ac operation. Standard capacitance values from 0.001 to 2 μF are available in six case styles. Electro Cube, Inc., 1710 S. Del Mar Ave., San Gabriel, CA 91776. **215**

Speed reducer uses ball bearings instead of gears to provide quiet rotation and zero backlash. The planetary reducer is stocked in two models, one with a 5:1 reduction ratio and the other with a ratio of 10:1. Torque ratings available are 5, 9 or 14 oz inches. Dimensions of both models are 2 inches long by 3/4 inch diam. Insco Corp., Main St., Groton, MA 01450. **216**

Adhesive tape combines optically clear FEP "Teflon" film backing and thermosetting acrylic adhesive. Series 2352 electrical insulating tape is available in 18- and 36-yd rolls slit 1/4, 1/2, 3/4, 1, 1-1/2 and 2 inches wide. Other widths can be custom slit in 1/16-inch increments up to 6 inches wide. Dodge Industries, Inc., Hoosick Falls, NY 12090. **217**

Nylon, self-retaining tinnerman mini-clamp C61332AA is designed to positively secure wiring on compact assemblies. It retains its holding power over a temperature range of −40 to 300°F. Corrosion-proof, nonconductive and nonabrasive, it will retain wire bundles up to 3/16 by 1/4 inch. Eaton Corp., Engineered Fasteners Div., Box 6688, Cleveland, OH 44101. **218**

Lighted pushbutton switches, the Tellite 800 Series, meet the requirements of MIL-S-22885/74A(EC). The miniature 4-lamp plug-in switches are available in 2PDT and 4PDT, as well as alternate and momentary versions. They can be obtained in a choice of full display vertical or horizontal split-legend configurations. Master Specialties Co., 1640 Monrovia, Costa Mesa, CA 92627. **219**

Fine angle stepping motors, Responsyn Series 100, offer resolution of up to 2000 steps per revolution. This produces step angles as low as 0.18 degrees. The motors are designed for 100V operation and provide high torque and high inertia-handling capability. USM Corp., Gear Systems Div., Rt. 128, Wakefield, MA 01880. **220**

Components/Materials

Superconducting magnets are made of stabilized Nb_3Sn coating bonded directly to a high-conductivity substrate of copper tape. The 3- to 7-inch bore standard magnets are available with field strengths up to 50 kG. Union Carbide Corp., 270 Park Ave., New York, NY 10017. **221**

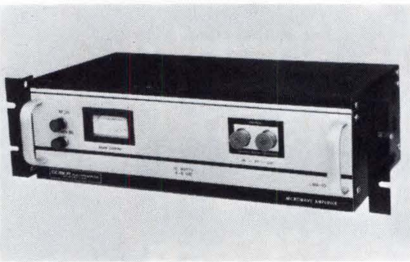
Electrically-conductive resin systems can be cured by electrical current. Cure time can be varied depending upon applied power, and cure times as short as 3 to 5 sec have been achieved. The use of electrical curing lends itself to automated production techniques by eliminating long cure cycles at high temperatures. Conshohocken Chemicals, Inc., 8 Rodney Rd., Rosemont, PA 19010. **222**

Cooling fan delivers 17-inch-wide airstream from a 19-inch-wide package. Called the "Sidewinder" because the flat blower wheels are mounted sideways, the unit is capable of delivering up to 515 CFM. Slow blower speed and high back pressure also result in quieter operation. McLean Engineering Labs., Princeton Junction, N J 08550. **223**

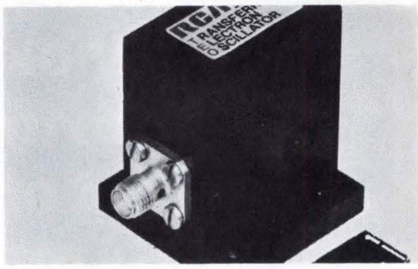
Transformer and inductor cores of "Feramic TC-12" are now available in IEC pot-core configurations. Initial permeability of 2500, maximum permeability of 3200 and hysteresis constant of ≤0.6 are claimed for the new material with loss factors of ≤1.2 at 4 kHZ and ≤5.0 at 100 kHz. Indiana General, 405 Elm St., Valparaiso, IN 46383. **224**

Transducers for measuring pressure, shock, vibration and displacement are capable of operating in nuclear reactors and other severe environments. Operating at temperatures up to 550°F and at ambient pressures up to 3600 PSI, they can withstand both complete submersion and high radiation levels. Columbia Research Labs., MacDade Blvd. and Bullens Lane, Woodlyn, PA 19094. **225**

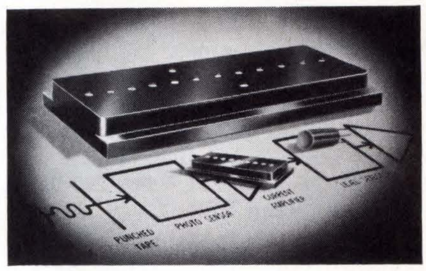
Magnetic proximity switches combine compact physical size with power rating of 120W. They are available in SPNO and SPNC. Models 5TA and 5TB-90-T are housed in a threaded brass case measuring 1/2 inch in diam and 1-1/2 inches long. Tann Controls Co., 20210 Sherwood, Detroit, MI 48234. **226**



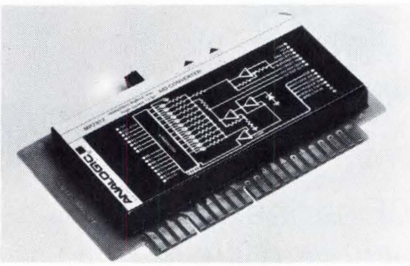
Two TWT amplifiers, 10 LMA and 20 LMA, have power outputs of 10 and 20W respectively over the frequency range from 1 to 12.4 GHz in four octave bandwidths. All units have minimum gain of 30 dB over each octave, and come in a 19-inch rack configuration. The noise figure is 30 dB, and spurious modulation is 35 dB below carrier. Cober Electronics, Inc., 7 Gleason Ave., Stamford, CT 06902. **227**



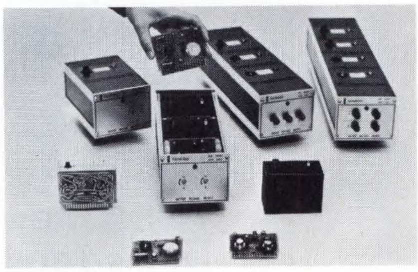
Transferred electron oscillator S262V2 is a fixed frequency device that provides a minimum of 25 mW power output at 9250 MHz. These 4 oz units operate over the −20 to 70°C temperature range with frequency stability of ±35 KHz/°C. In quantities of 100 or more the price is $300 each. RCA Microwave Applications Engineering, 415 S. Fifth St., Harrison, N J 07029. **230**



Light sensors, OH110 (one element), OH910/A (9 element) and OH1210/A (12 element) consist of a monolithic amplifier/digitizer chip with DTL/TTL-compatible output. Built-in light sensing permits the units to be used in applications requiring light sensing at a precise level. Rise and fall times are 40 nsec. Centralab Semiconductor, 4501 N. Arden Dr., El Monte, CA 91734. **233**

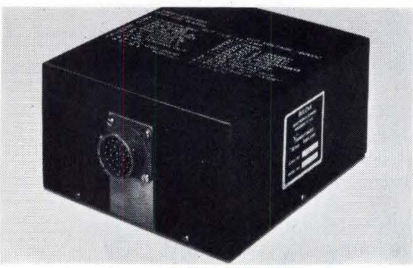


Twelve-bit A/D converter modules, Series 2812, feature 2 μsec/bit conversion time, accuracy to ±0.015% full scale response and stability to 6 ppm. Full-scale input options are 5, 10, ±5, ±10 and ±10.24V. Units come in a Modupac configuration (2 by 2 by 0.39 inches) or as a Modupac on a plug-in PC board for 0.5-inch center mounting. Power requirements are ±15 and 5 Vdc. Price is $250 each (OEM discounts are available). Analogic, Audubon Rd., Wakefield, MA 01880. **228**



High-voltage power supplies come in four standard frame lengths (HV01 to HV04) and nine standard modules that supply voltages ranging from −300V to 25 kV dc. A 6.3V ac-output module is available. Frames are either enclosed in blue vinyl finish or open. Each module can be purchased with either standard or precision regulation. Peak-to-peak ripple ranges from 0.2 to 0.3%, and temperature coefficient is 0.035%/°C. Tecnetics Inc., Boulder Industrial Park, Boulder, CO 80302. **231**

Modular power supply, Model MS-15/100, provides ±15V dc at 0 to 100 mA with only 1 mV ripple and noise. Designed for operational amplifiers and functional modules, the 15 oz module comes in a plug-in package measuring 3.5 by 2.5 by 1.25 inches. Other features include line and load regulation of 0.03% and temperature stability of 0.015%/°C. Price is $45 each (1 to 9 quantities). Pacific Instrument Co., 4926 E. 12th St., Oakland, CA 94601. **234**



Power amplifier, Model DCAM-300, consists of a preamp operational amplifier with adjustable gain, and a dc power amplifier with voltage gain of 10. A selected resistor limits the output current within the 1 to 15A (20V dc) range. The 3- by 6- by 5.5-inch unit weighs approximately 3.5 lbs and requires only 28V dc for operation. Bulova Watch Co., Inc., Electronics Div., 61-20 Woodside Ave., Woodside, L.I., NY 11377. **229**

Two-way portable FM radio, HANDIE-COM MH-70, is designed for VHF (150.8 to 174 MHz) operation. The unit is available in either a standard or universal configuration with 2W RF power output and up to four-frequency operation. The 8- by 3.1- by 1.6-inch radio may be ordered with carrier squelch or "Private-Line" tone-coded squelch. Motorola Inc., Communications Div., 1301 Algonquin Rd., Schaumburg, IL 60172. **232**

White (gaussian) noise modules come in three sizes: 2 by 2.5 by 1 inches, 2 by 4 by 1 inches and 2 by 6 by 1 inches. They also can be custom designed to any given specifications. These RFI-shielded modules also have filtered power lines to block noise from entering the power system. Stability is ±3 dB in the temperature range of −30 to 100°C. Solitron Devices, Inc. 256 Oak Tree Rd., Tappan, NY 10983. **235**

Solid-state flasher, Model FS 129, operates up to 100W loads with input of 115V ac ±15%, 50/60 Hz. Flashing rate is 90/min at 50% duty cycle. Prices range from $12.97 (small quantities) down to $5.76 (500-999). SSAC Precision Products, Box 395, Liverpool, NY 13088. **236**

Voltage-tunable Gunn flange oscillators, GFOV(X) 100, 110 and 120, offer output power of 10, 25 and 50 mW respectively. They can replace voltage-tuned klystrons with output power of 100 mW or less. Price is $130 each for 1-9 quantity. Fairchild Camera and Instrument Corp., 3500 Dear Creek Rd., Palo Alto, CA 94304. **237**

Voltage sensor, Model 585 MILLIVOLT-SENSOR, has better than 50 μV repeatability on any trip point between 0.5 and −0.5V. In operation, the sensor generates 12V dc, 50 mA (maximum) when the input voltage is below the set point. Price is $58 each ($40.60 at 100 pieces). California Electronic Mfg. Co., Box 555, Alamo, CA 94507. **238**

20W, CW TWT amplifiers of the 1277H Series span the 1 to 18 GHz frequency range in five models. They weigh only 20 lbs and unit dimensions are 3.5 by 16.75 by 13.75 inches. Hughes Electron Dynamics Div., 3100 W. Lomita Blvd., Torrance, CA 90509. **239**

FET-input instrumentation amplifiers, Models 300 A/B/C/D, can be programmed externally for gain ranging from unity to 2000. Stabilities are from 50 through 3 μV/°C. For quantities of 1-9, prices range from $35 to $59. Dynamic Measurements Corp., 6 Lowell Ave., Winchester, MA 01890. **240**

Frequency-to-voltage converter FC62 broadens the capabilities of the company's MC 1 multi-channel transducer. This module will generate 10V dc output for any frequency between 250 Hz to 25 KHz after adjustment of a 7-position switch and the range trim control. Validyne Engineering Corp., 18819 Napa St., Northridge, CA 91324. **241**

LC bandpass filters, Nos. 535-7134-(01/08) and 535-7135-(01/08), are high-order elliptic function and fourth-order Chebyshev respectively. Units come in an epoxy case with standard PC board spacing dimensions. Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, MA 02138. **242**

Solid-state stepper motor actuator on printed-circuit board features full- and half-index angle resolution in either direction under control of the external logic signal. Power capability is 30V, 5A maximum, and price is $100 each. Industrial Digital Control Ltd., 400 Quest Boul De Maisonneuve, Montreal 111, PQ. **243**

Double-balanced mixer, Model 767, operates in the dc to 300 MHz range with 6.5 dB (100 MHz) conversion loss and 40 dB (100 MHz) isolation. Computer-matched hot carrier diode quad is used to achieve uniformity from unit to unit. Price in 0.8 by 0.4 by 0.25 inch package is $40 (1-4 units). Summit Engineering Corp., 1820 S. 7th Ave., Box 938, Bozeman, MT 59715. **244**

Crystal oscillator/IC, Series 7400, is less than 0.18 cubic inches in volume and plugs into standard 14-pin TO-116 DIP socket. Frequency range is 3 to 20 MHz, with stability of ±0.005%. Operating temperature range is −55 to 105°C. Price is < $15 each in production quantities. Spectrum Technology, Inc., Box 948, Goleta, CA 93017. **245**

Modem bandpass filters will pass mark and space frequencies of one channel while rejecting adjacent channels. Filter responses are tailored to insure 40, 50 or 60 dB of adjacent channel separation depending on the type. Integrated Electronics Inc., 16845 Hicks Rd., Los Gatos, CA 95030. **246**

Analog divider AD-5020 is a 1.12- by 1.12- by 0.4-inch encapsulated module designed for PC-board mounting, and requires no external components for complete operation. Features include 2% of full scale accuracy, −3 dB small-signal bandwidth of 1 MHz, 50 mV/V offset, 3 mV/°C offset temperature coefficient and inputs of ±10V (X-input) and 0 to 10V (Y-input). For 1-9 quantity, price is $85 each. GPS Corp., 14 Burr St., Framingham, MA 01701. **247**

Frequency multiplier, Model FM-600, features 10 mV rms sensitivity, transformer coupled input and switch selectable multiplication factors of X10 and X100. The latest IC phase-lock and digital components are used to achieve a coherent and absolute multiplication of the input signal. A phase-locked digital system lessens the temperature drift effects between 0 to 50°C. Quantity price is $395 each. Anadex Instruments Inc., 7833 Haskell Ave., Van Nuys, CA 91406. **248**

Phase comparators, Models CP-410 and CP-411, are available with bandwidths up to 30% in the frequency range 200 kHz to 200 MHz. There are nine standard models with center frequencies ranging from 278 kHz to 160 MHz, and other center frequencies are available. Phase error at center frequency does not exceed ±1.5° for lower frequencies and ±3.0° for higher frequencies. Lorch Electronics Corp., 105 Cedar Lane, Englewood, N J 07631. **249**

Constant-current regulators, Models CCR and CCR-HS, provide output from as low as 10 μA up to 1A in either a pre-set module or as a remotely variable unit. Input voltage range is 10 to 35V. Prices begin at $40 each. Thunder Scientific Corp., 623 Wyoming, SE, Albuquerque, NM 87123. **250**

Dual-output power supplies, D Series, are for powering operational amplifiers and other loads requiring balanced voltages. Models with ±5, ±12 and ±15V outputs and current ratings from 400 mA to 2.4A are included in the series. Line and load regulation are ±0.1%. All models come in extruded aluminum cases having mounting provisions on three surfaces. Prices range from $85 to $160 each. Acopian Corp., Easton, PA 18042. **251**

Low-pass filter, Model 2632, passes 2 to 32 MHz with under 0.5 dB loss and 1.5 (maximum) VSWR. Rejection is 100 dB, 80 to 1000 MHz. Rated at 100W, the unit has Type C Jacks, connectors. Price is $110 each. Microwave Filter Co., 135 W. Manlium St., East Syracuse, NY 13057. **252**

D/A converters ZD429 and ZD433 accept 2- and 3-digit BCD with corresponding outputs of 0 to 9V and 0 to 9.99V. These self-contained units have 20 μsec settling time and ±1/2 LSB linearity. Additional features include pin-for-pin compatibility between modes, adjustable full-scale and zero offset and DIP socket compatibility. Prices are $19 (ZD429) and $39 (ZD433) in quantities of 1-9. Zeltex, 1000 Chalomar Rd., Concord, CA 94520. **253**

Time-delay unit, Model 70-BITD, is for use with the Series 70 solid-state annunciator systems. The plug-in module provides an adjustable delay for either normally-open or normally-closed field contacts. A single module accommodates two separate contact inputs, each individually adjustable. Four models span the 0 to 10 sec and 1 to 300 sec delay ranges, either 12 or 125V dc. SCAM Instrument Corp., 7405 N. Hamlin Ave., Skokie, IL 60076. **254**

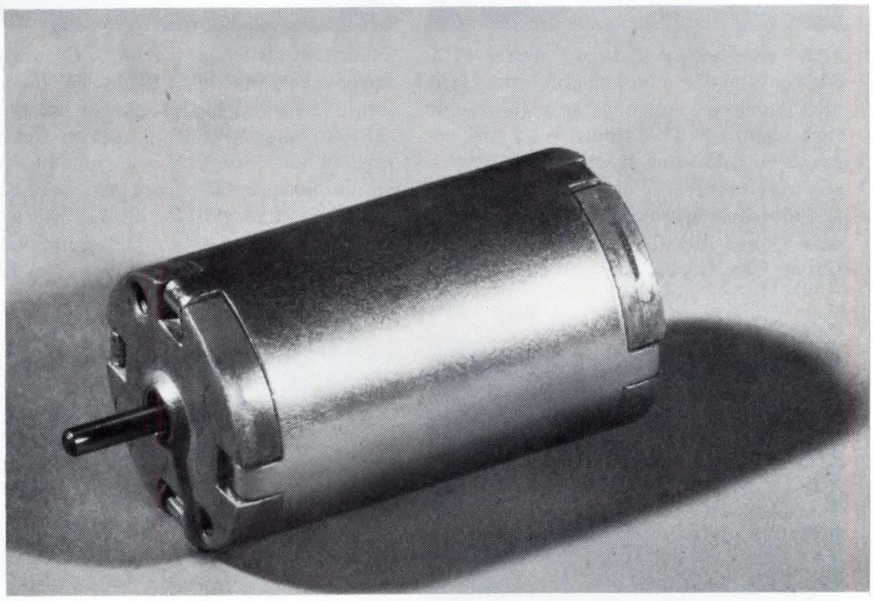
A/D converter, Model ADC-8S, comes in an op-amp-sized package measuring only 2 by 3 by 0.4 inches and has 8-bit resolution. The converter provides ±1/2 LSB linearity, 60 ppm/°C temperature coefficient and 1 msec conversion time. Four different input ranges are available: 0 to 5V, 0 to 10V, ±5 and ±10V. Prices for the TTL/DTL-compatible unit are $79 singly and $49 in 100 lots. Analog Devices, Inc., Box 280, Norwood, MA 02062. **255**

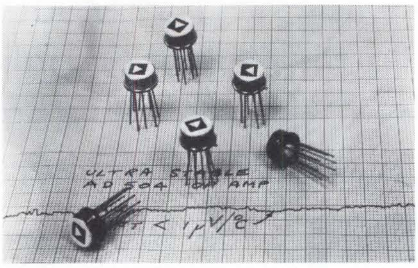
Stepper drive card D3/2 drives 4-phase stepper motors at up to 4A/phase (8A total). This 20 kHz unit will drive commercially available size 32 50 in oz rated 1.8° steppers at slew speeds up to 20,000 steps/sec. Dahmen Burnett Electronics, Grenier Industrial Village, Londonderry, N H 03053. **256**

Opto-isolator PT-001 grants 5000V isolation and 3.5 msec rise time. The device consists of a solid-state LED source and a spectrally-matched photoconductive cell assembled in a light-tight tubular package. The unit exhibits < 1 pF coupling capacitance and < 3 pF cell shunt capacitance. Case temperatures range is −40 to 75°C. Pricing in 1000 quantities is $2.80 each. Allen-Bradley Co., 1201 S. 2nd St., Milwaukee, WI 53204. **257**

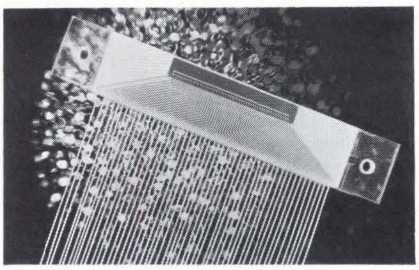
Temperature-compensated crystal oscillator JKTCXO-10 offers three or more binary-related outputs within the 200 Hz to 5 MHz frequency range. Power consumption for the 1 by 1.5 by 0.5 inch package is 12 mW or less. Price (1000 piece quantities) is $115 each. CTS Knights, Inc., Sandwich, IL 60548. **258**

AC line regulator, LR Series, features a (patent pending) zero-cross switching technique to achieve response time of < 1 cycle. Input, rather than output, sensing is employed, and there is no distortion of the input waveform. Regulation efficiency is approximately 90%. Voltage and load regulation remain unchanged whether the load power factor is unity, 90° leading or lagging. Topaz Electronics, 3855 Ruffin Rd., San Diego, CA 92123. **259**

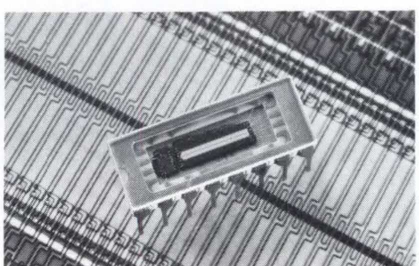




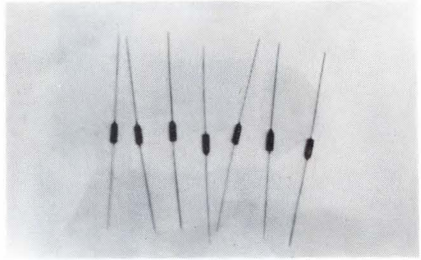
IC op amp combines thin-film resistor technology and new circuit concepts to provide drift specifications approaching those of chopper-stabilized op amps. The monolithic AD504 series features offset voltage drift ratings of less than 1 $\mu V/^{\circ}C$, dc gain in excess of 10^6 and 120 dB common-mode rejection. Analog Devices, Inc., 221 Fifth St., Cambridge, MA 02142. **275**



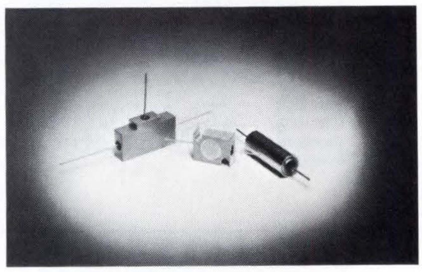
Photovoltage readout array, model EPX 34, contains 50 p/n junction integrated photosensitive elements for high resolution scanning. The silicon cells are arrayed on 0.125-inch centers and have a cell-to-cell clearance of 0.0865 inch. Price is $358 each. European Electronic Products Corp., 10150 W. Jefferson Blvd., Culver City, CA 90230. **276**



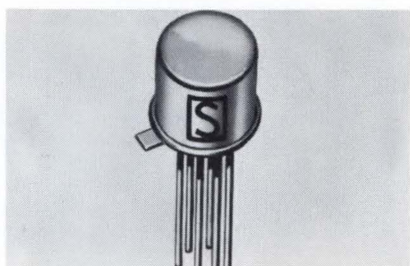
Self-scanning optical array contains 256 sensing elements. The RL-256, designed for facsimile, TV camera and other high resolution applications, has photodiodes spaced on 1-mil centers. On-chip scanning circuitry allows serial output on a single video line. TTL compatibility is provided by drive circuits contained in the same 16-lead DIP. Reticon Corp., 365 Middlefield Rd., Mountain View, CA 94040. **277**



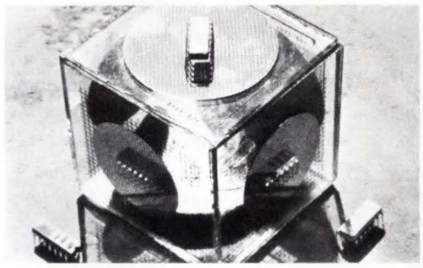
UHF tuning varactors, 1N5681 through 5695 and 1N5696 through 5710, offer high Q and high tuning range. These silicon Bi Taxial varactors are available with 10%, 5%, 2% and 1% tolerances, capacitance values from 6.8 to 100 pF and Q up to 600. Price is $5.50 each in lots of 100. CODI Semiconductor Div. of Computer Diode Corp., Pollitt Dr. S., Fair Lawn, N J 07410. **278**



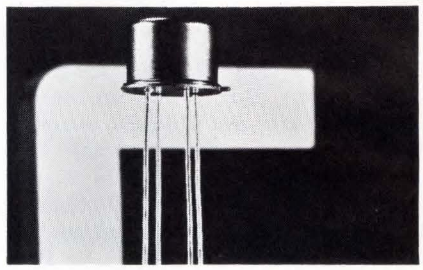
Solid-state switches utilizing PIN diodes are now available in SPST and SPDT versions. The SPST Model A9S111 has typical switching times of 10 nsec on and 16 nsec off. The SPDT A9S211 has 40 nsec on and 60 nsec off times. Prices are $55 for the 111 and $170 for the 211. Aertech Industries, 825 Stewart Dr., Sunnyvale, CA 94086. **279**



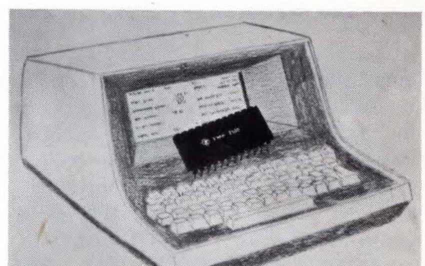
Dual FETs are low-noise matched pairs. SDF500 through SDF514 monolithic dual n-channel devices are matched to within 3 mV gate-source differential voltage for the 500, 505 and 510. Other devices in the series are matched to within 5, 10, 15 or 20 mV. The FETs are similar to the 2N5452 and 2N3954 and differ essentially only in noise, CMRR and capacitance. Solitron Devices, Inc., 8808 Balboa Ave., San Diego, CA 92123. **280**



Dual NAND Schmitt trigger ICs provide TTL system interface for slowly changing waveforms. Identical except for temperature range, the 5413 and 7413 feature built-in temperature compensation and typical hysteresis of 800 mV. Typical propagation delay times are 18 nsec for low-to-high and 15 nsec for high-to-low transitions. Signetics Corp., 811 E. Arques Ave., Sunnyvale, CA 94086. **281**



Darlington power transistors with 10A rating offer high voltage of 150V minV_{CER} and 1000 min current gain at 5A. Series U2T105/205 units available in TO-33 and TO-66 packages are planar and completely passivated. Prices, in quantities of 100, are $3.03 for the U2T105 and $3.25 for the U2T205. Unitrode Corp., 580 Pleasant St., Watertown, MA 02172. **282**



MOS/LSI static 2560-bit read-only memories feature 400-nsec access time. The fully DTL/TTL-compatible TMS 2500 series operate with +5 and −12V power supplies. TMS2501 is programmed as an ASCII row-output character generator for a 5 × 7 dot matrix, and custom programming is available in TMS 2500 to suit the user's need. Texas Instruments Incorporated, Inquiry Answering Service, Box 5012, MS/308, Dallas, TX 75222. **283**

Complimentary low-voltage MOS countdown circuit, type HCTR 1601, is a 16-stage unit designed for use in electronic watches. Ion-implantation techniques are used to obtain threshold voltages of 0.7 ±0.2V. Price is $20 each in lots of 100. Hughes Microelectronic Products Div., 500 Superior Ave., Newport Beach, CA 92663. **284**

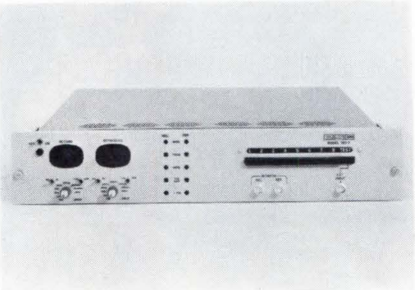
CMOS synchronous counter (SCL54004) is functionally in-socket interchangeable with CD4004 and equivalent type counters, but features an accessible eighth stage, higher speed and synchronous (rather than ripple-carry) counting. It is available in all package types and in a low voltage "A" series. Price is $5.75 in quantities of 100. Solid State Scientific Inc., Montgomeryville, PA 18936. **285**

Complete chroma system for color TV receivers is provided by three ICs. The N5070B is a complete subcarrier regeneration system. The N5071A is a chroma amplifier system and the N5072A performs the demodulation function. Price is approximately $1 each in quantity. Signetics Corp., 811 E. Arques Ave., Sunnyvale, CA 94086. **286**

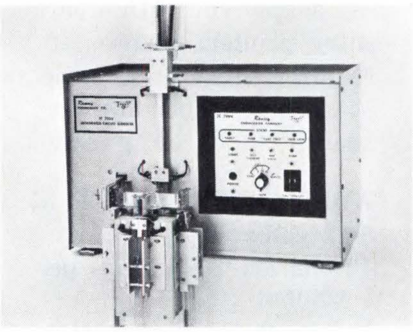
Gallium-arsenide (GaAs) tuning varactor diodes are suitable for use with tunable IMPATT and Gunn sources. They feature liquid-phase, epitaxially-grown abrupt pn junctions, and are available with minimum breakdown voltages of 15, 30, 45 and 60V. Varian, Solid State Div., Salem Rd., Beverly, MA 01915. **287**

A complete sound channel for FM receivers in a single IC package, the ULN2129 consists of a multistage IF amplifier-limiter section, a power supply zener regulator, an FM detector, a buffer amplifier and an audio preamp. A unique feature of the device is that only one single-winding coil is required for tuning the IF section. Sprague Electric Co., North Adams, MA 01247. **288**

Silicon planar fast-recovery diodes, type 1N5766, feature high-current and high-temperature capabilities. Operating from −65 to 200°C, they have a 30A continuous current rating. Surge current rating is 250A for 8 msec. Price is $30 each in quantities of 100. Solitron Devices, Inc., 1177 Blue Heron Blvd., Riviera Beach, FL 33404. **289**

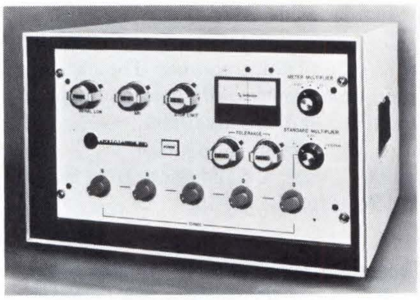


Monitor oscilloscope to display information recorded on 7-track magnetic tape, Model 280B, enables observation of the signal both as it is entered and after it is recorded on the tape. Horizontal sweep rates range from 0.3 Hz to 1 MHz. Frequency range is dc to 5 MHz, vertical sensitivity is between 0.7 and 2V pk-pk (calibrated at 2V pk-pk). Prices start at $1790 each. Precision Standards Corp., 1701 Reynolds, Santa Ana, CA 92705. **290**

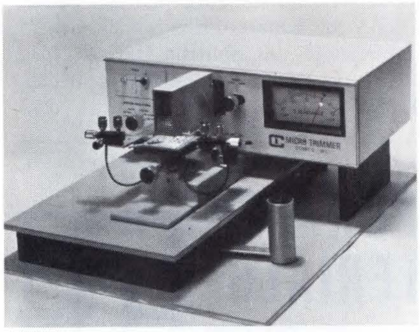


Integrated circuit handler accepts 8-, 14- and 16-pin DIPs directly from shipping magazines and sorts in two grades of accept and one of reject. Model 7000 can handle and sort up to 7000 DIP packages/hr. Ramsey Engineering Co., 1853 W. Country Road C, St. Paul, MN 55113. **291**

Panel frequency counter has 100 mV RMS sensitivity, trigger level adjustments and 999,999 count capacity. Model 6100 counts frequencies from dc to 50 MHz for a selected time base interval from 1 msec to 10 sec in decade steps. Price each is $350. Newport Labs., Inc., 630 E. Young St., Santa Ana, CA 92705. **292**

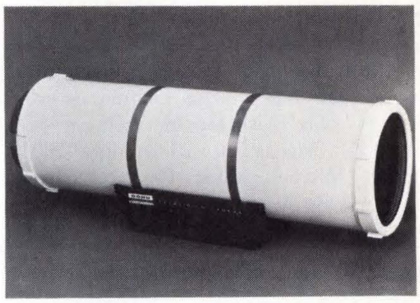


Resistance trimming bridge with linear deviation output incorporates logic circuitry that permits accurate resistance adjustment with straight or L cuts using a laser or air abrasive cutting tool. Model 400 is operable from 1Ω to 11.1 MΩ with accuracies to ±0.05%. Featured are high resistance to electrical noise and a 0 to +12V output. Apollo Lasers, Inc., 6365 Arizona Circle, Los Angeles, CA 90045. **293**



Automatic ratio trimmer, Model MT-100AR, produces a specific ratio of resistance between two resistors on a substrate by trimming just one. Substrates up to 2 by 2 inches can be handled by the standard unit priced at $3690. Comco Inc., 1222 W. Olive Ave., Burbank, CA 91506. **294**

Transistor noise test set, Model 512B, measures the noise figures of transistors over the frequency ranges of 10 HZ to 10 kHz or 10 Hz to 50 Hz. Noise figure is read directly in dB for the most popular values of base resistance. Quan-Tech, Div. of KMS Industries, Inc., 43 S. Jefferson Rd., Whippany, N J 07981. **295**



Vidicon camera that provides a usable picture with only 0.0005 fc illumination features both automatic and remote control capabilities as standard. Resolution is 700 lines horizontal center and 400 lines in each corner. The 2840 Series unit will function in temperature ranges of −40 to +140°F without auxiliary heating or cooling and in humidity up to 100%. Cohu Electronics, Inc., Box 623 San Diego, CA 92112. **296**

Accurate Pyrometer measures from −50 to 1500°F without user calibration. Model 825 has an 8-inch meter and its overall accuracy is better than ±2% of full scale. Price, including 10-ft-long probe type sensor and instruction manual, is $95. Triplett Corp., Bluffton, OH 45817. **297**

Frequency synthesizer with low spurious and phase noise, Model 6160A, is priced at $4995. Frequency coverage is 1 to 160 MHz, typical phase noise is lower than −62 dB and ALC provides better than ±1 dB flatness. The unit is BCD-programmable with TTL positive logic. John Fluke Mfg. Co., Box 7428, Seattle, WA 98133. **298**

Equipment

Breadboarding and debugging device called Micropatch I contains built-in power supply and readily interfaces with all external devices. Micropatch, 9201 Gazette Ave., Chatsworth, CA 91311. **299**

Two-channel potentiometric recorder weighs less than 7 lbs, has basic sensitivity of 100 mV and accuracy of ±0.5% of full scale and provides response time of less than 1 sec to full scale. Model 3400 has 2-5/16 inch chart width/channel. Recording is inkless and rectilinear, and chart speeds from 1/2 to 240 iph can be provided. Price is $543. Rustrak Instrument Div., Gulton Industries, Inc., Municipal Airport, Manchester, N H 03103. **300**

Power laser diode pulser provides 100A 100V pulses and has adjustable repetition frequency from 1 to 10,000 Hz. Pulse width is 50 to 200 nsec and rise time is typically less than 15 nsec. Model LDP-4 is priced at $2,395. Savant Engineering, Inc., Indian Head Industrial Blvd. and Warson Rd., St. Louis, MO 63132. **301**

Radiometer features combination of a lock-in amplifier with a vibrating-capacitor electrometer. In ac mode it operates as a lock-in amplifier and will resolve up to 5×10^{-14}A rms. In dc mode it operates as a vibrating capacitor electrometer with resolution to 1×10^{-13}A. Both analog recorder output and a 3-1/2-digit BCD output are provided. Unit price is $3865. International Light, Inc., Dexter Industrial Green Newburyport, MA 01950. **302**

Temperature controller maintains a drift stability of better than ±0.0002°C/hr. Sensitivity is 0.00005°C. and various probes cover the useful range from −20 to 140°C. Sanda, Inc., 130 N. Presidential Blvd., Bala Cynwyd, PA 19004. **303**

Data-transmission test set, Model 220, is a self-contained, portable unit designed to isolate problems in all types of data communication systems. An audible line monitor allows the user to hear normal and changing line or data conditions, and readout is by LEDs. Model 220 is usable in data systems that operate at rates to 330,000 bits/sec with either synchronous or asynchronous modems. International Communications Corp., 7620 N.W. 36th Ave., Miami, FL 33147. **304**

DVM with 5-digit resolution, Model MX-1, features auto ranging and a fast active filter. It measures dc voltages from 100 μV to 1000V in three ranges and is priced at $1000 including the fast active filter and manual/automatic ranging. AC volts, ratio, printer outputs, input cable and rack mount are available options. Non-Linear Systems, Inc., Box N, Del Mar, CA 92014. **305**

Digitally-controlled voltage source provides 250W output of dc or low-frequency ac power. Output voltage can be swung from −50 to +50V or vice versa in less than 300 μsec while supplying any current between 0 and 5A. Model 6129B features internal storage of all digital input data to eliminate the need for refreshment. Price is $2700. Hewlett-Packard Co., 1601 California Ave., Palo Alto, CA 94304. **306**

Video motion detector, Model 304, accepts signals from standard TV cameras and produces an alarm indication whenever a change in brightness occurs at any of four preselected locations in the camera field of view. Price is $1250 each. Colorado Video, Inc., Box 928, Boulder, CO 80302. **307**

Stable temperature source for calibrating thermocouples, Model CSD-938, holds a constant temperature with accurate control between 110 and 300°F. There are three working temperature holes with an ID of approximately 0.2 inch and a larger (0.3 inch) hole for a thermometer. Stabilization within 0.2°F requires less than 1 hr for set point change. Hy-Cal Engineering, 12105 Los Nietos Rd., Santa Fe Springs, CA 90670. **308**

Quality laboratory portable recorder offers silent operation and has eight channels on 1/4-inch magnetic tape. Model P1-6200 also features 1, 10, 100 speed ranges for time expansion or contraction studies in direct and FM. Its dc closed-loop servo capstan drive and reel motors use battery or ac power without special inverters. Precision Instrument Co., 3170 Porter Dr., Palo Alto, CA 94304. **309**

Oscilloscope with 1500 cm/μsec writing speed is priced at $950 (Model 180C) and $1050 (Rack Model 180D). Like other 180 series models, these scopes accept all existing plug-ins for the 180 series, so can achieve frequency response to 100 MHz and sampling response to 12.4 GHz with a 35 psec TDR. Hewlett-Packard Co., 1601 California Ave., Palo Alto, CA 94304. **310**

Chart recorder provides full-scale response on its 10-inch chart in less than 0.3 sec. It uses a moving-element linear servo motor and disposable unitized pen system. There are 240 different models of the Speed Servo II recorder. All provide ±0.25% of full scale or 3.5 μV accuracy which ever is greater. Prices start below $1000. Esterline Angus, Box 24000, Indianapolis, IN 46224. **311**

Network test system for backplane and harness testing can also be used to test bare PC boards, multilayer chips and other multiple-connection devices. Although a computer-operated system, the N131 requires absolutely no programming. Configurations are available to handle networks of up to 1152, 2304 and 3456 pins with prices ranging from $38,500 to $57,100. Teradyne, Inc., 183 Essex St., Boston, MA 02111. **312**

Data amplifier, Model 122, has gain range of 0.02 to 5000 for inputs of ±2 mV to ±300V for full scale output. Available options include filter, dual outputs and input suppression. Price of the standard version is $495. Honeywell Test Instruments Div., Box 5227, Denver, CO 80217. **313**

Laser tooling/alignment system uses a single mode helium-neon gas laser to project an optically straight beam of light at the detector target. When the beam strikes the target, it generates two signals accurately proportional to displacement of the beam on the target in two orthogonal directions with respect to the beam. Price of the complete Model 3000 tooling system is $4990. ATI, Inc., 2205 Stoner Ave., Los Angeles, CA 90064. **314**

Differential microvoltmeter features (±0.01% + 1/2 μV) accuracy, and has five ranges from 0.11 to 1100V full scale. Model A-75B incorporates a floating recorder output that is totally isolated from both input and case. Operation may be either from power lines or internal rechargeable batteries. Price including battery pack is $845. Medistor Instrument Co., 4503 8th Ave., N.W., Seattle, WA 98107. **315**

250 MHz pulse generator, Model 122A, provides PRF from 3 kHz to 250 MHz, pulse amplitudes from ±250 mV to 5V into 50Ω, transition times of less than 1 nsec and an unattenuated baseline offset of 0 to ±2.5V (unaffected by attenuator or amplitude controls). Price is $2875. E-H Research Labs, Inc., Box 1289, Oakland, CA 94604. **316**

Radiation survey meter measures exact dose rates of scatter radiation emitted from any direction within a 180° arc about the instrument. Model 470 can detect radiation at levels from 1 mR/hr to 300R/hr in ten full-scale linear ranges. The unit is light weight and is powered by two 9V transistor batteries. Victoreen Instrument Div., VLN Corp., 10101 Woodland Ave., Cleveland, OH 44104. **317**

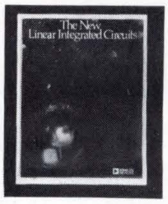
Octave converter supplies averaged sound-level data in real time simultaneous with narrowband peak-by-peak analysis of noise. Model SD305 converts narrowband data obtained through the SD301 Series analyzers and SD302 ensemble averagers to octave displays. It also can provide 1/6, 1/3 or 1/2 octave displays. Frequency range is 0.1 Hz to 16 kHz. Spectral Dynamics Corp., Box 671, San Diego, CA 92112. **318**

Automatic continuity verifier handles up to 128 points at a time and displays results on a screen. Model ACV is set to reduce time by as much as 80%. It can indicate extra wires and is usable with cable length up to 18,000 ft of 24 gauge. Price is $1500. SCI Electronics, Inc., 8330 Broadway, Houston, TX 77017. **319**

Digital panel meter offers a ±3999 count and provides display blanking, autopolarity, BCD outputs, remote hold command, read rate control, overload and plus-minus indicators and true differential inputs. The Model 400A combines accuracy of 0.05% with digitizing rates of 0 to 60 readings/sec. Its BCD is buffered, isolated and gated. Price is $189. Newport Labs., Inc., 630 E. Young St., Santa Ana, CA 92705. **320**

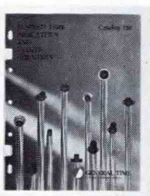
Varactor test set, Model 891, tests for opens or shorts and measures the 1 MHz capacitance and capacitance ratio values, displaying them on a digital panel meter. It also sorts to preset limits, and provides BCD outputs to operate handlers and other auxiliary equipment. Sorting speed is up to 10,000 diodes/hr. Price is $3995. MSI Electronics Inc., 34-32 57th St., Woodside, NY 11377. **321**

Digital tachometer that can monitor speeds up to 40,000 rpm has accuracy of ±0.02% and never needs recalibration. Series 10 units are available with 3-, 4- or 5-digit readout and with or without set points for alarm. Operation is from an input signal from a magnetic pick-up or shaft encoder. Optron, Inc., 1201 Tappan Circle, Carrollton, TX 75006. **322**



Linear ICs are featured in a 20-page catalog that includes FET-input op amps, ultrastable, high-speed and popular general-purpose op amps, instrumentation amplifiers and others. A general description and electrical characteristics are provided for each item. Analog Devices, Rte. 1 Industrial Park, Box 280, Norwood, MA 02062. **323**

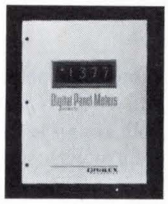
Instrumentation tape recorders are pictured in short-form catalog D165, a six-page brochure that has a convenient table with specifications for portable, airborne and ground-based recorders. Ampex Corp., 401 Broadway, Redwood City, CA 94063. **324**



Elapsed-time indicators and event counters are featured in Catalog 136. Mil-specs and data are given for each model. This 20-page catalog also lists special designs, modifications, mounting configurations and dimensions. General Time Corp., Industrial Controls Div., Thomaston, CT 06787. **325**

Minicomputer Model 80 with 16,000 bits directly addressable solid-state memory, built-in "Teletype" interface and direct-memory access port is described in an eight-page bulletin. Interdata, 2 Crescent Pl., Oceanport, N J 07757. **326**

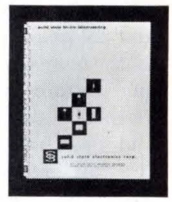
"Temperature Measurement Handbook and Catalog" is a 144-page booklet that contains the complete edition of the latest NBS calibration tables for thermocouples; temperature measurement data pertinent to thermocouples, thermistors and RTDs; and descriptions of a variety of temperature measurement devices. Omega Engrg. Inc., Box 4047, Stamford, CT 06907. **327**



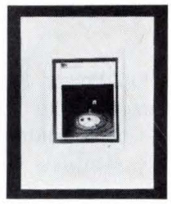
Digital panel meters, Series 35, are described in a four-page brochure that gives features, specifications, mounting and ordering information and prices. Gralex Industries, Div. of General Microwave Corp., 155 Marine St., Farmingdale, NY 11735. **328**

Glide test system is described in a brochure that outlines the benefits of using the GT-200 system in detecting and removing surface protrusions on coated or plated discs. The general problem of testing and burnishing discs is also described. Three Sigma Inc., Three Computer Dr., Cherry Hill, N J 08034. **329**

Precision power resistors are covered in a 16-page catalog that includes complete specifications, performance and derating curves for a line of wirewound resistors. Tepro of Florida, Inc., Box 1260, Clearwater, FL 33517. **330**



FM-FM solid-state telemetering modules including voltage controlled oscillators, dc amplifiers, dc signal isolators, frequency-to-dc converters, tone oscillators, pressure transducers and laboratory telemetering systems are described in a 40-page catalog. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, CA 91343. **331**



Transistor catalog contains 130 pages with complete data on an entire transistor line including npn and pnp small-signal transistors, FETs and proelectron types. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. **332**

Digital counters, printers, voltage-to-frequency converters, frequency-to-dc converters, frequency meters and frequency deviation meters are described in a 16-page catalog that contains complete specifications, prices and a list of representatives. Anadex Instruments Inc., 7833 Haskell Ave., Van Nuys, CA 91406. **333**

Data Module, a miniature coding device that is equivalent to a 1 by 4 matrix board or a hexidecimal thumbwheel switch, is described in an eight-page brochure. Interswitch, 770 Airport Blvd., Burlingame, CA 94010. **334**

Thermal data including a temperature conversion scale, thermal conductivity and thermal resistivity table, coefficient of thermal expansion and other conversion factors are listed on a wall chart. Graphs of viscosity-temperature profiles and peak exotherm profiles of various "Castall" resins are also included. Castall, Inc., Weymouth Industrial Park, East Weymouth, MA 02189. **335**

Microelectronics microscope for semiconductor and metallographic research is described in a 12-page brochure that lists features, shows sample photomicrographs and describes accessory equipment. Hacker Instruments Inc., Box 646, West Caldwell, N J 07006. **336**

"DC Power System Handbook" is a 28-page manual that covers the application of nickel-cadmium systems for stationary applications such as emergency lighting and power systems. Dual-Lite Co., Simm Lane, Newtown, CT 06470. **337**

Trimmer and precision multiturn potentiometers are described in a 12-page catalog that covers both wirewound and cermet trimmers in round, square, cube, rectangular and dual in-line configurations. IRC Div. of TRW Inc., 2801 72nd St. N., St. Petersburg, FL 33733. **338**

Read/Write amplifier for computer tape transports is described in data sheet 1-409. It provides a description, block diagrams and complete specifications of the MA 751 which is capable of reading and writing 1600 bpi phase-encoded magnetic tapes. Potter Instrument Co., Inc., 532 Broad Hollow Rd., Melville, NY 11746. **339**

Connectors, sockets and lighted pushbutton switches are featured in catalog 7FOM. It contains 24 pages of products listed in tabular form. Prices are included for each item in various quantities. Waldom Electronics Inc., 4625 W. 53rd St., Chicago, IL 60632. **340**

Vacuum motor/blowers for electronic equipment cooling, air sampling devices and other products utilizing vacuum or air pressure are described in Bulletin 2-VT572-001. The brochure includes design features, specifications and application considerations for both single- and two-speed motors. AMETEK/Lamb Electric, 627 Lake St., Kent, OH 44240. **341**

Automatic terminal-crimping machine for insulated and non-insulated solderless terminals and butt connectors from #26 to 8 AWG is described in a four-page data sheet. It covers the capacity, speed and range of applicability of the machine. Operation, setting up and maintainance are illustrated. Hollingsworth Solderless Terminal Co., Nutt & French Creek Roads, Phoenixville, PA 19460. **342**

Micro 1600/21 minicomputer is described in a four-page bulletin that covers organization, standard features, special CPU features, instruction repertoire, input/output operations and system elements and options. Microdata Corp., 644 E. Young St., Santa Ana, CA 92705. **343**

Low-cost potentiometer pressure transducer for a wide variety of industrial applications is described in a two-page brochure with specifications, dimensions and prices. Robinson-Halpern Co., One Apollo Rd., Plymouth Meeting, PA 19462. **344**

Tubular solenoids with pulling forces ranging from 1-3/8 oz to 12 lbs are described in a series of nine data sheets. Curves, specifications and dimensional information are provided. Hart-Advance Relay Div., Oak Electro/Netics Corp., Crystal Lake, IL 60014. **345**

Control knobs made of machined aluminum or plastic are described in an eight-page catalog. A complete series of aluminum knobs and five families of plastic knobs with spun aluminum inlay tops are covered. Alcoknob Div., Alco Electronic Products, Inc., Box 1348, Lawrence, MA 01842. **346**

Solid-state relay Series NR1D is described in catalog 1201. Information on static and operating parameters, physical data and schematics are provided for this relay designed for high-inrush inductive ac loads. C. P. Clare & Co., 3101 W. Pratt Blvd., Chicago, IL 60645. **347**

Dynamic mimic displays in mosaic patterns for controls, switches, lights, signaling devices and other items necessary in assembling modular switchboard controls and displays are described in a catalog that provides specifications, illustrations and prices. Hathaway Instruments, Inc., 5250 E. Evans Ave., Denver, CO 80222. **348**

Programmable oscillator that provides the interface between a digital computer and an ac power source is discussed in a four-page brochure. The 830T unit described provides the ability to independently program system frequency, phase B angle, phase C angle and three independent amplitudes. Behlman Div. of California Instruments Co., 5150 Convoy St., San Diego, CA 92111. **349**

Transistor and IC sockets and mounting devices are described in a 12-page catalog that provides outline drawings and dimensions of the Supercon one-quarter turn and "Press-Fit" mounting sockets. Sealectro Corp., 225 Hoyt St., Mamaroneck, NY 10543. **350**

Solid-state sweep oscillator and accessory units for multiband operation are described in an eight-page data sheet. Features and complete specifications of the Model 230A are provided. Weinschel Engrg., Gaithersburg, MD 20760. **351**

Active filters designed to replace crystal-lattice filters in the audio frequency range are described in bulletin AF-7000. Specifications, curves and physical dimensions are given in the brochure. Polyphase Instrument Co., E. Fourth St., Bridgeport, PA 19405. **352**

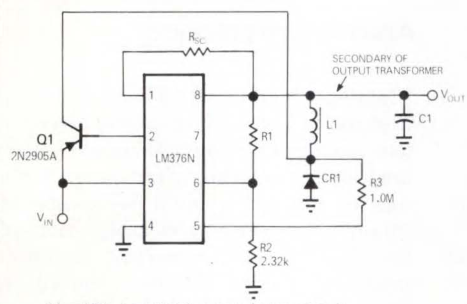
Design chart shows the relative amplitude of mixer-generated intermodulation harmonics for three types of frequency mixers. It enables an engineer to properly select the best LO frequency, the optimum f_R level and the correct type of mixer for each application. Relcom, 2329 Charleston, Rd., Mountain View, CA 94040. **353**

Industrial minicomputers of the SPC-16 family are covered in a six-page brochure that describes the SPC-16/30 with a cycle time of 1440 nsec, the SPC-16/50 at 960 nsec and the SPC-16/70 at 800 nsec. General Automation, Inc., 1055 S. East St., Anaheim, CA 92805. **354**

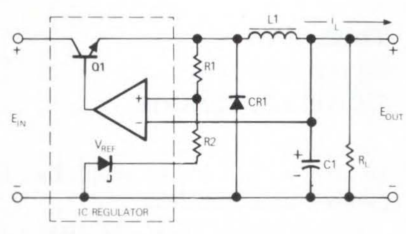
Plastic instrument tubing that withstands flash fires is described in Bulletin 1211-B-1. Communication wires and polyethylene tubes make up the inner core of this multisheathed bundle. A physical properties chart and a diagram showing time-to-failure under fire conditions are included. Dekoron Div., Samuel Moore & Co., Mantua, OH 44255. **355**

Don't Plug that Regulator in Yet!

Our switching regulator article that appeared in the Sept. 15 EDN/EEE, pp. 39-41, had errors in both the simplified switching regulator circuit (Fig. 2) and in the "Switching Regulators Reviewed" diagram. The corrected circuits are shown below. Those regulators should work now.

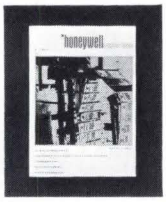


Simplified switching regulator circuit



Switching regulators reviewed diagram

The Honeywell Computer Journal



Vol. 5, No. 2, 1971; 96 pages; $3.00 per copy, subscription $10.00 per year. Honeywell Information Systems, Inc., Advanced Systems & Technology, Box 6000, Phoenix, AZ 85005.

This issue of the journal (which is published four times a year) is devoted to computer memories. Five articles discuss the following aspects of memories: 1. A survey of the development of main memory systems including recent semiconductor versions. 2. A case for increased modularity in main memories. 3. A detailed description of a MOS memory, objectives of the design and considerations leading to the design decisions taken. 4. Examples of ROM applications and technologies in a look at the evolution of ROMs. 5. A discussion of emerging technologies that promise a hundredfold increase over the capabilities of present-day multiple-spindle magnetic disc systems.

Revised Semiconductor Guide

Gives replacement information for more than 41,000 solid-state devices.

This 73-page illustrated catalog provides characteristics and outline drawings of the 124 components in the GTE Sylvania ECG semiconductor line; including transistors, ICs, diodes and rectifiers. A complete alphanumeric cross reference—by type number—is contained in the guide. Catalog ECG 212D can be obtained from any franchised GTE Sylvania distributor for $1 per copy.

Theory of Synchronous Communications

Dr. J. J. Stiffler; Prentice-Hall, Inc., Englewood Cliffs, N J 07632.

Part of Prentice-Hall's information and system science series, this book deals with communication systems in which the existence of a time reference common to both the transmitter and receiver is a necessary condition for operation. Systems of this kind are used in many modern applications including TV and data communications.

The book covers both coded and uncoded pulse modulation techniques, and presents methods for providing and maintaining synchronization. It also provides a thorough coverage of decodable and synchronizable codes, and applies the theory of maximum-likelihood detection and estimation to the synchronization problem.

Also Worth Noting

"Catalog of Marketing Publications for the Electronics Industry" (8 pages) describes four handbooks on methods of marketing products in the technical industries. For a copy of the catalog and a free sample of "Mainly Marketing", a monthly report on the electronic and associated technical industries, write: Mainly Marketing, Schoonmaker Associates, Box 35, Larchmont, NY 10538.

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Advertiser's Index

Index to Ads, Products and Literature

Application Notes

"Commercial Uses and Evaluation of Non-Flammable Elastomer Materials" is a reprint of a technical paper that summarizes the latest developments in non-flammable elastomers. Topics discussed include: developments resulting from NASA's Apollo program and their potential commercial uses; a test for rating flammability of materials in air; and a look at things to come. Industrial Rubber & Packing Div., Raybestos-Manhattan, Inc., Box 9140, Bridgeport, CT 06603. **356**

Traveling-wave-tube history, technology and applications are presented in a 22-page brochure that discusses how the TWT works, electrical and mechanical construction techniques, different types of tubes and possible future developments and trends. Hughes Electron Dynamics Div., 3100 W. Lomita Blvd., Torrance, CA 90509. **357**

Cyclic Redundancy Check (CRC) character generation is the subject of an application note that discusses the CRC error correction technique. This technique employs a modified cyclic code in conjunction with the character parity to correct error bursts of unlimited length in any one of the nine tracks of an IBM-compatible formatted magnetic tape. Error detection is also discussed. Pertec Peripheral Equipment, 9600 Irondale Ave., Chatsworth, CA 91311. **358**

"The Shunt-Wound dc Motor and Control" is a two-part application note. Part I is a brief review of the shunt-wound dc motor and the evolution of speed-control techniques. It is published in Motorgram (Vol. 51, No. 4). Part II, to be published in the next edition, will discuss control usage. Bodine Electric Co., 2500 W. Bradley Pl., Chicago, IL 60618. **359**

"Microprogramming Implementation Guide" outlines third-generation computer architecture and the advantages and method of implementing microprogramming. A detailed description of microprogrammed-system data flow is explained. The use and advantages of alterable core ROMs is described with a detailed cost/performance curve analysis. Computer software aids for microprogramming are also outlined. Datapac Inc., 18872 Redhill Ave., Santa Ana, CA 92707. **360**

Standby power using an energy storage device Power-Pack is described in application note 71923. Five circuit diagrams show the device used for standby power with regulated and unregulated power supplies, used as an energy accumulator and as a nonvolatile sample-and-hold system. Gould Ionics Inc., Box 1377, Canoga Park, CA 91304. **361**

Reprints Available in this issue are offered as follows:

R.S. No.	Title	Page No.
L61	Overcoming Stability Problems in Applying FET-Input Op Amps	19
L62	Don't Let the Wrong Input Q Wreck Your RF Power Amplifier	31
L63	Voltage-Controlled Attenuator Has Minimum Phase Shift	40
L64	Three-Element Neon Indicator Detects Positive and Negative Overloads	47

You can't blame engineers or purchasing agents for trying to save every last penny on resistors these days. But lowest price doesn't necessarily mean lowest cost. For example, most manufacturer's color bands won't stand up to the cleaning methods used to remove excess flux. Or they darken and become illegible from the heat produced in normal usage. This can mean costly identification errors on your production line. The unnecessary expense of rework. Our solution? A-B quality. Bright, crisp identification of Allen-Bradley's specially formulated paints. Baked on to stay on. Designed to resist aging. Discover the other ways to save money. Ask your nearest A-B distributor for our free booklet "7 ways to tell the difference in fixed resistors." Or write Allen-Bradley Electronics Division, 1201 South Second Street, Milwaukee, Wisconsin 53204. Export: Bloomfield, New Jersey 07003. Canada: Galt, Ontario. United Kingdom: Bletchley, Bucks.

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Temp. Coefficient: ±150 PPM/° C standard
Operating Temp.: −55° C to +125° C
Resolution: Essentially infinite
Adjustment: 87 = 1 turn; 85 = 12 turns nominal
Construction: Sealed case permits cleaning in common solvents. Standoffs permit board washing.
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