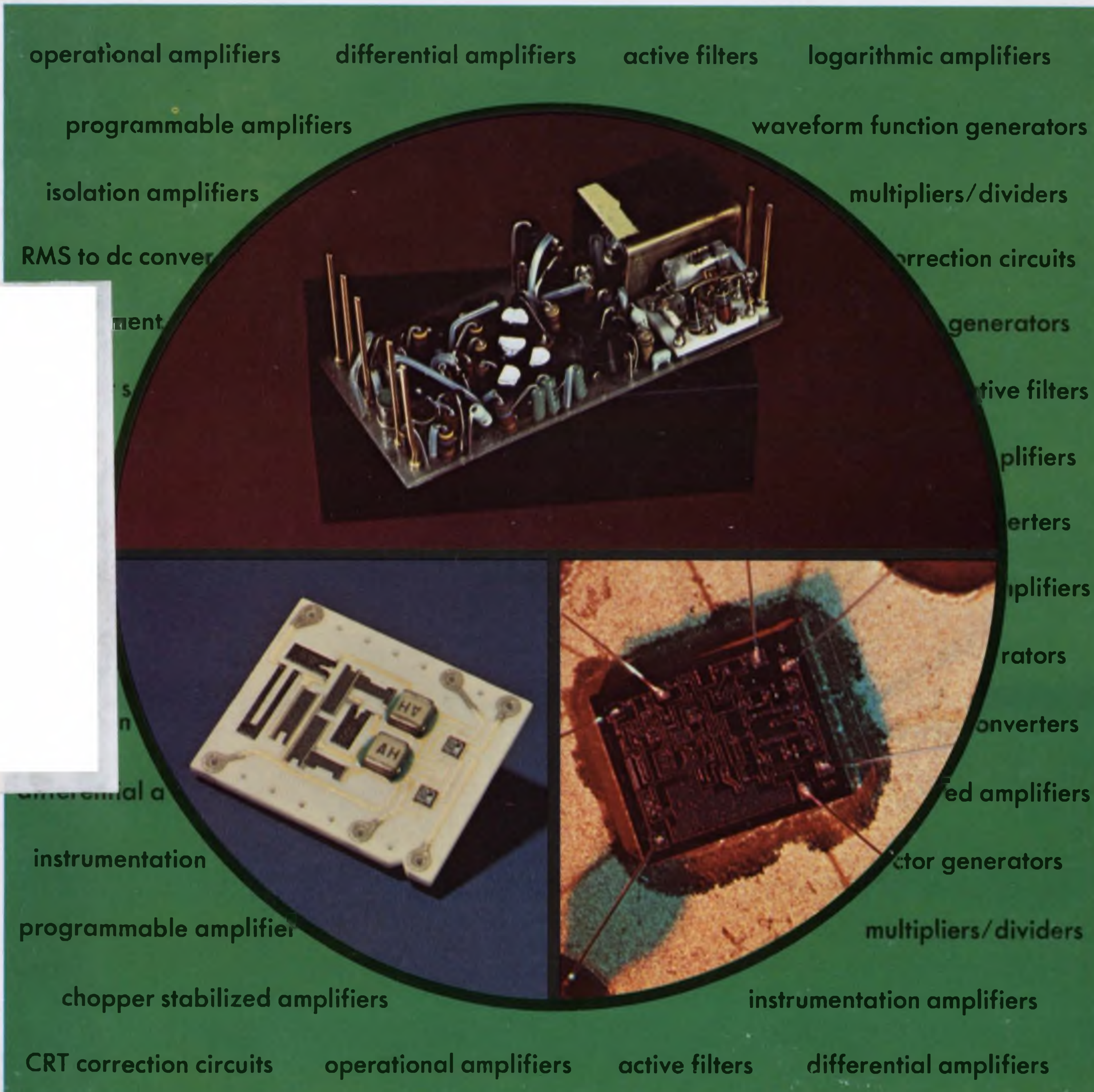
VOL. 21 NO.

# Electronic Design 21

FOR ENGINEERS AND ENGINEERING MANAGERS

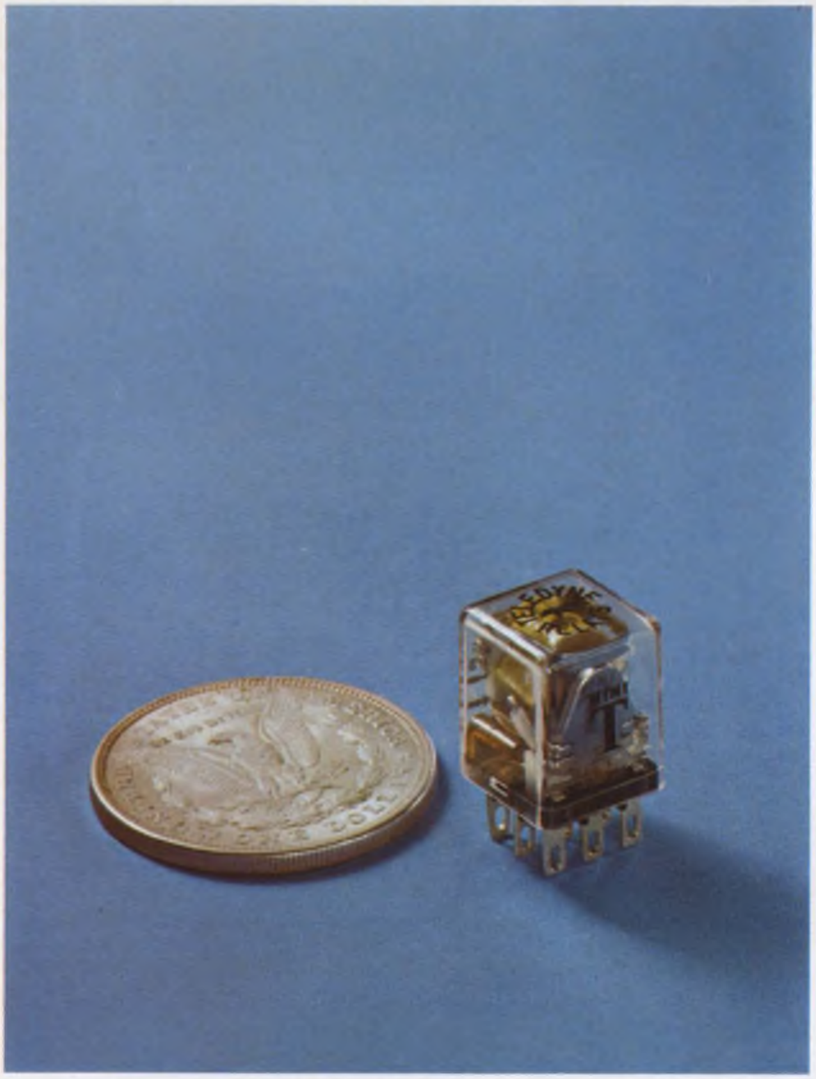
OCT. 11, 1973

**Process any signal you want** with analog-function modules. But be careful: You must spec them correctly or circuit malfunctions may creep in. Special parameters are measured in different ways by competing module houses. Sidestepping the troubles these differences cause is a tedious task. For help, see page 64.



# The smallest 5 amp general purpose relay

## MINI-T AND THE MINTED DOLLAR... SMALL IN SIZE BUT SOLID IN VALUE



Teledyne's new, heavy-duty 120 volt 5 amp relay is in stock at your local distributor. The space-saving (.4 cu. in.) 2PDT Mini-T is furnished with sockets and hold down clips for P.C. board or chassis mounting. This Teledyne relay employs an unusual shaded pole design that permits direct AC operation without the need for rectifying diodes. Available with either AC or DC coils and demonstrating cost effectiveness that's hard to beat, the United States-manufactured Mini-T is truly worth its one-half ounce weight in silver. The Mini-T . . . another finely-crafted relay from Teledyne. Call our nearest distributor today.

**TELEDYNE RELAYS**

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Telephone (213) 679-2205

INFORMATION RETRIEVAL NUMBER 2

# Electronic Design 21

VOL. 21 NO.

FOR ENGINEERS AND ENGINEERING MANAGERS

OCT. 11, 1973


## NEWS



## TECHNOLOGY



## PRODUCTS



### Departments



**Cover:** Photos courtesy of Analog Devices (top) taken by Paul Wagner, Beckman (left bottom) taken by Joe Hess of Hess Photographic, Anaheim, Calif. and Motorola (right bottom) taken by Lennie Ziegien.


ELECTRONIC DESIGN is published biweekly by Hayden Publishing Company, Inc., 50 Essex St., Rochelle Park, N. J. 07662. James S. Mulholland, Jr., President. Printed at Brown Printing Co., Inc., Waseca, Minn. Controlled circulation postage paid at Waseca, Minn., and New York, N. Y., postage pending Rochelle Park, N. J.

# The most powerful argument for buying a Nova 840 is what you don't pay for.

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# across the desk

## Nuclear waste a worry to some atomic experts

In a box accompanying John F. Mason's article *"Nuclear Power Electronics: Industry With a Long Future"* (ED No. 15, July 19, 1973, pp. 26-32), the statement appears: "Today's reactors also produce toxic waste, but the amount is small, and since it is packed and buried, nuclear specialists say it is no problem."

Alvin Weinberg, Oak Ridge director and a mighty advocate of nuclear power, seems to believe the toxic wastes pose quite a problem. In a recent issue of *Science*, he suggests that widespread use of fission energy may necessitate creation of a cult of guardians over the cooling nuclear ashes.

Ralph Lapp, who started his career as a pioneer nuclear physicist and who has written extensively on nuclear safety, considers nuclear waste disposal one of the prime problems of nuclear energy generation. Hannes Alfuén, Nobel Laureate in physics, is also seriously concerned about accumulating fission wastes. About a year ago he wrote a commentary on the extensive use of nuclear fission reactors for power generation in the *Bulletin of the Atomic Scientists*.

To my knowledge, there has been no commercially successful nuclear waste-disposal procedure that will isolate, with high probability, the toxic nuclear wastes from the biosphere over the lifetime toxicity of the wastes.

Who are the nuclear specialists who say that nuclear waste disposal is no problem, and what evidence do they offer to support their proposition?

*Emanuel Baskir*
5711 Warm Springs Rd.
Houston, Tex. 77035

*Ed. Note: We concede the subject is controversial. The nuclear scientists and engineers in nuclear plants who were interviewed feel that nuclear waste is more a public-acceptance problem today than one of disposal. "We have until 1982 to decide on a solution," an industry spokesman notes. That year is the one set by the Atomic Energy Commission for providing a permanent national disposal system for nonreclaimable waste from commercial reactors. So far there hasn't been much waste. To begin with, the nuclear fuel lasts three years. It is then shipped to a reprocessing center, where 85% is revitalized and returned and 15% is buried underground in cement. According to the AEC, it stays there in liquid form for five years, when it is converted into solid form to remain buried five more years. By 1982, many nuclear engineers believe, the AEC will probably go to a buried system for the final disposition of the waste, perhaps in a salt mine or between natural rock strata.*

## How are you doing?

If you think your company is doing just dandy, you might want to see how right you are (or how wrong) in a new book, the "Handbook of Corporate Performance Criteria for Electronic Companies." It costs $25.50 and is avail-

*(continued on page 11)*

**Electronic Design welcomes the opinions of its readers on the issues raised in the magazine's editorial columns. Address letters to Managing Editor, Electronic Design, 50 Essex St. Rochelle Park, N.J. 07662. Try to keep letters under 200 words. Letters must be signed. Names will be withheld on request.**

# Look what 5 volts can get you.

These five DPMs use the same 5VDC supply that powers the digital logic in your system.

This simplifies your design and improves reliability. It saves space, saves money, and reduces the amount of heat that's generated. And, because there's no line-power voltage near the DPM, internally generated noise is virtually eliminated.

So you get more reliable readings.

And here's what else you can get for 5 volts. BCD outputs. Overvoltage, polarity, and status indication. Automatic zero correction and programmable decimal points. Aluminum cases that install in a snap.

Each meter is given a seven-day burn-in before shipping. And we're shipping right now.

Our 5 volt DPMs are a whole new class of digital panel meters—a whole new way of thinking. Because now you can think of the DPM as a component, just like any other component in your system.

Take a look below. You'll find a meter that solves your particular problem. Then give us a call. Order a sample.

**A low-cost 3½ digit DPM for OEM applications.** An advance in price/performance capabilities for 3½ digit DPMs. LED display. Bipolar, single-ended input. Full scale range of 0 to ±199.9mV. 0.05% ±1 digit accuracy. Automatic zero and polarity. Normal mode rejection of 40dB at 60Hz or 50Hz. Common mode rejection of 60dB at ±200mV. Fully-latched DTL/TTL compatible outputs and control interface signals. Optional ratiometric input. Only ¾" deep. **$89 in 100's. AD2010.**

**A high-performance 4½ digit DPM for systems applications.** Capable of performing precision measurements of floating differential voltages in noisy environments. LED display. Full scale range of 0 to ±1.9999V. 0.01% ±1 digit accuracy. Automatic zero and polarity. Normal mode rejection of 60dB at 60Hz or 50Hz. Common mode rejection of 120dB at ±300V. Optically-isolated analog section. Fully-latched DTL/TTL compatible BCD outputs and control interface signals. **$199 in 100's. AD2004.**

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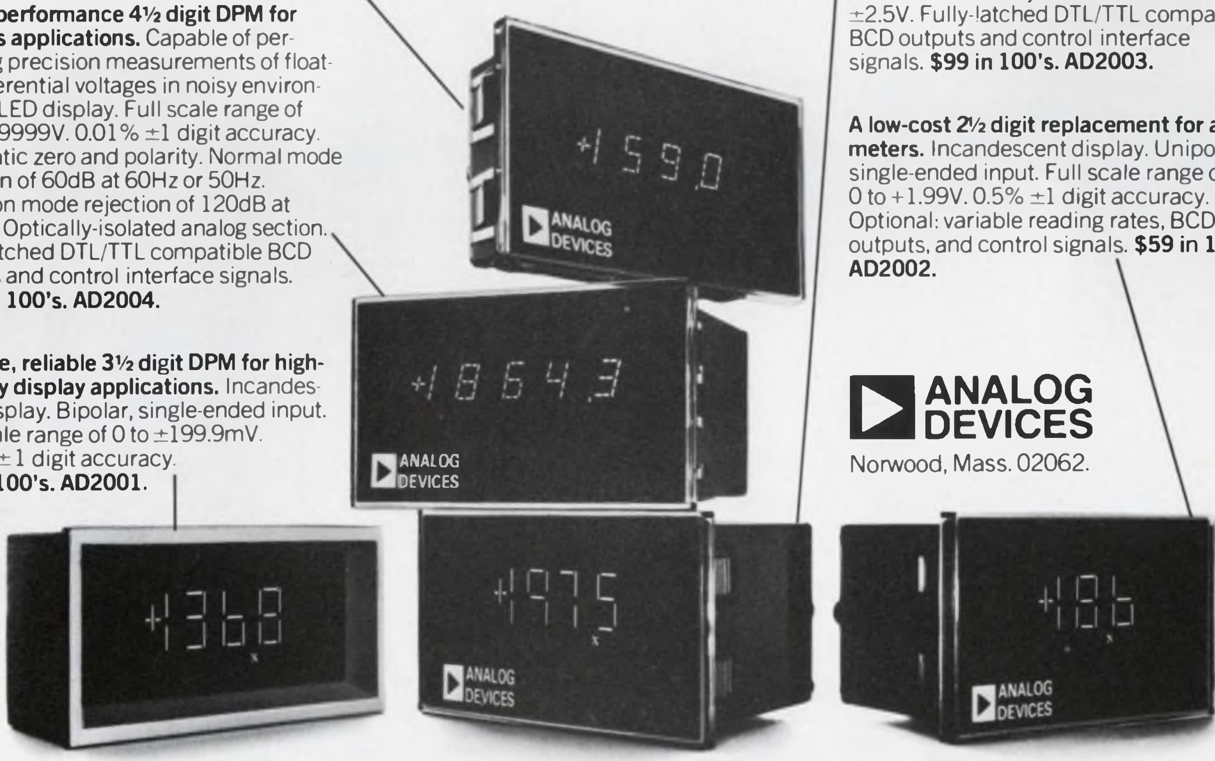


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## Call 617-329-4700

**for everything you need to know about 5 volt DC-powered DPMs.**

INFORMATION RETRIEVAL NUMBER 7


To surround her with safety,
at no extra cost...

*(continued from page 7)*

able from Schoonmaker Associates, P.O. Box 339, Coram, N.Y. 11727. Its more than 75 pages include tables, charts, scattergrams and checklists of 13 fiscal and 10 marketing parameters by which you can rate yourself against other companies in the electronics industry.

*Circle No. 570*

## 'Laundry' editorial brings a load of wash

For years I've been reading the editorials carried in high-class magazines such as the one you run, sometimes delighted, sometimes disgusted and sometimes just plain puzzled. Your latest open letter to the world left me puzzled. (See "Let's go beyond taking in each other's laundry," ED No. 13, June 21, 1973, p. 87).

On the one hand, I have no difficulty seeing what you wanted me to see. On the other hand, try as I might, I cannot see what your comments will change. Marketing departments are under the impression that they are using every last erg of "hustle" at their command to sell their black boxes wherever black boxes are purchased, and product engineering departments are rock-solid in their opinion that they have their fingers on the pulse of the nation's buyers. So what if you take pen in hand (or typewriter in finger) and voice the opinion that everybody is locked in a super-cooperative round-robin? Nobody drawing a salary from Charlie Sporck's Thing Factory is going to do anything different just because you have correctly analyzed at least one successful economic loop in the big picture of world input/output. If the days of growing by selling to one another are numbered, then I estimate that the number has at least five digits.

I'll tell you what the world thinks of our industry. The world thinks it turns on little tubes of Chapstik with wires coming out the bottom. The world thinks it consists largely of people making smaller and smaller clandestine transmitters to pick up telephone and face-to-face talk. The world thinks it consists of tape-recorded transcripts of presidential conversations with staffmen who are under a cloud of suspicion.

Don't misinterpret me. You didn't commit any particular error in parsing out your thoughts. It's just that I don't see where your comments are instructive to change. I might as well shoot water up a rope as suggest that Fairchild deemphasize its efforts to sell faster diode arrays to HP while HP tries to sell more effective curve tracers to Fairchild. It is going on now, and it will continue unabated in spite of contrary comments.

Here at the south end of the Santa Clara Valley, a bunch of guys in several smaller companies have been busted for stealing trade secrets, plus actual hardware, from IBM. That's a fit subject for an editorial.

Is it fair to have a beginning debriefing for a new engineer while a super sleuth goes down a checklist and tries to get an update on every project in the works at the guy's last employer? That is common practice and bears some small relationship to the current Senate hearings, in that at least a few witnesses have testified that everybody is a spy to the limit of his own resources. Should the "code of ethics" cover keeping your mouth shut after you leave a company?

How about "last look" as a matter for your fertile pen? Every major purchase is sold on the basis of multiple bids, and every supplier compels his salesmen to win "last look." Now you and I and everybody else knows that a last look is a sure antidote to the concept of bidding. It is OK in an auction but not in a bid. How about a few comments?

I see in the paper that gallium is getting hard to get. Who has the raw material? What kind of trading relationships does the U.S. have with the suppliers? If we run out of gallium, we might be in trouble. Perhaps a small bit of staff work could arm you with enough facts to make a fine set of comments on the situation.

*Name withheld*

*(continued on page 14)*

# Finally
# Monolithic True Log IF/RF Amplifiers

## Another First from PLESSEY

Specify Plessey's new SL530 series . . . the first monolithic true log IF/RF amplifiers in the world. You may do things you never considered before.

Like designing your own multi-channel radar IF strips in-house. Simply, quickly and economically. Yet your system will have more reliability and accuracy than before . . . at a much lower cost.

**Monopulse radar systems or ECM?**

Wherever phase information must be retained, the SL530 series is ideal. Throughout the entire strip, input signal phase information is retained. And retained.

Just think of the new SL530 series as building blocks. Cascade them for true logarithmic response at frequencies up to 80 MHz.

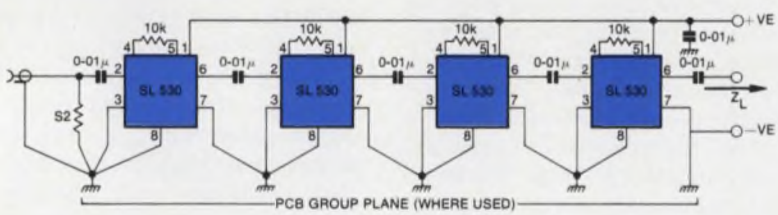
The SL530 may be the first device of its kind in the world. But state-of-the-art is a habit with Plessey.

**Successive Detection Log Amplifiers**

Another log amp original, the SL521, has been used by designers in successive detection log amplifiers. For over five years Plessey has consistently delivered SL521 devices for critical programs like the TPX-42 and APX-76.

Temperature range is full MIL-spec for both the SL521 and SL530. Screening to MIL STD 883 or 38510 available upon request.

### Typical 4-stage strip using SL 530 series

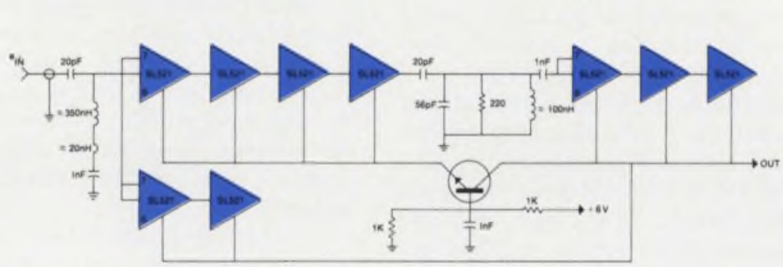



**SL530 True Logarithmic Limiting Amplifiers**

VOLTAGE GAIN @ 60MHz
14db typical
FREQUENCY RANGE
4-85MHz
MAXIMUM RECTIFIED OUTPUT
1.0V peak
PROPAGATION DELAY
7.0ns typical*
PACKAGE CODE
TO5/F.P.

*Group delay match over input range = 0.6ns

### 60 MHz wide-range logarithmic amplifier using SL521 series




**SL521 Limiting Wideband Amplifiers**

VOLTAGE GAIN @ 60MHz
11.3 min.
12.7 max.
FREQUENCY RANGE
7-150MHz
MAXIMUM RECTIFIED OUTPUT
1.0mA min.
1.1mA max.
PROPAGATION DELAY
2.0ns typical
PACKAGE CODE
TO5/F.P.

The next time you require radar IF strips, make things easy for yourself. If you need phase retention, specify Plessey's SL530. Or use the SL521 for successive detection systems.

Now, while you're thinking of it, call or write for more information. **It pays to specify Plessey.**

**PLESSEY SEMICONDUCTORS**
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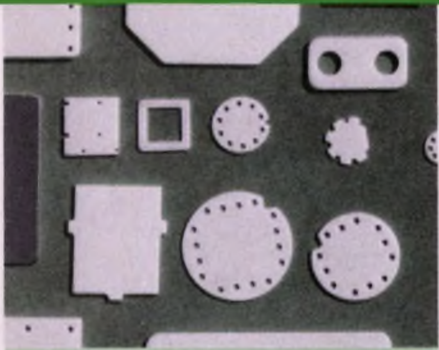
INFORMATION RETRIEVAL NUMBER 9

# INCREASE CIRCUIT DENSITY WITH

# AlSiMag® BRAND HYBRID COMPONENTS



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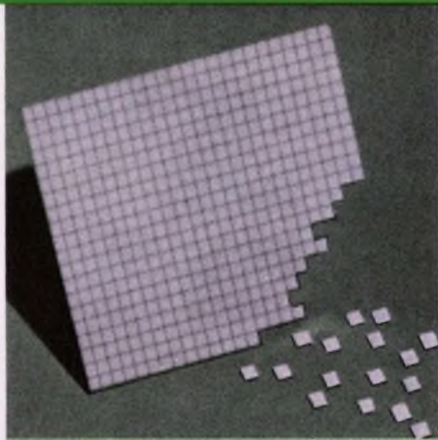

## SNAP-STRATES

From tooling for economy or from laser for accuracy, Snap-Strates are a proven cost reducer. Have you considered how much Snap-Strates and multiple processing can save you? Bulletin 712 on request. Phone 803/682-3215. Telex 570449.

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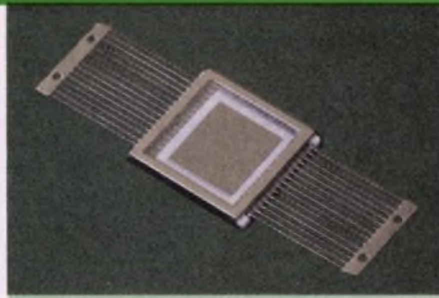

## HYBRID PACKAGES

All ceramic construction plus brazed-on leads for maximum reliability. Co-fired monolithic ceramic structure eliminates hermeticity problems, greatly increases thermal conductivity and structural strength. Ceramic construction permits mounting the package over conductors on circuit board. Custom made or write for current list of standard packages. Phone 615/265-3411. Telex 558432.

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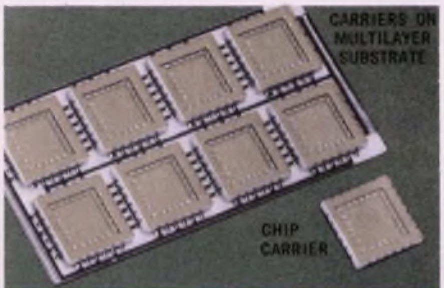


## CHIP CARRIERS

These small hermetic chip carriers allow far greater circuit density. Electrical testing after hermetic sealing allows storage of good devices in a less expensive package before committing to the circuit. The design permits conventional die attach, wire bonding and lid sealing operations . . . and re-flow solder attachment to a multilayer ceramic substrate, hybrid substrate or phenolic circuit board. Phone 615/265-3411. Telex 558432.

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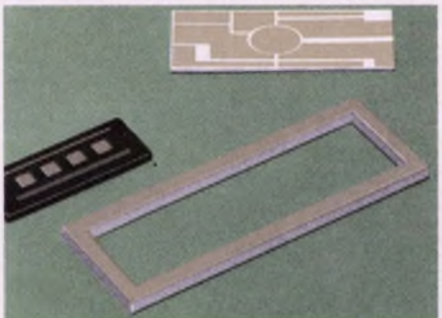

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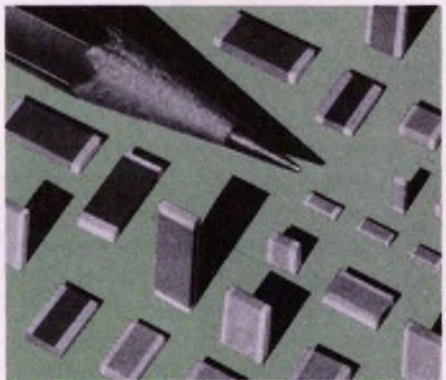

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CIRCLE NO. 226

**AMERICAN LAVA CORPORATION**
Chattanooga, Tennessee 37405  Laurens, South Carolina 29360

SUBSIDIARY OF 3M COMPANY

ACROSS THE DESK
*(continued from page 11)*

## 'Thou shalt not steal' backed as sound ethics

You were shocked—but only briefly—to learn that your old buddy was a thief (see editorial "My Friend's a Thief," ED No. 18, Sept. 1, 1973, p. 59) Why "only briefly"? Certainly you did not mean to infer that since "his crime was not unique" and since "upright officials condone stealing, justify it and even cover it up," stealing could be right and acceptable. However, you had some doubt: "Maybe he is not guilty." And you asked, "Why shouldn't my friend steal a bit"? The answer is simple: "Thou shalt not steal."

No one would advocate overtly the repeal of laws that forbid stealing because some or even the majority of people steal. Nevertheless we see such a trend today. Laws are decreed anachronous because they fail to alleviate crime. In some instances laws are repealed because someone may be hurt or even die in the process of breaking them. An ethic rooted in what is right is being replaced by an ethic founded on what is convenient and utilitarian.

What is legal is not necessarily moral. Moral clauses had to be appended to some of our recent legislation. But are we not heading for an era when what is moral will no longer be legal?

*Charles A. Benet*
5516 Del Oro Dr.
San Jose, Calif. 95124

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Your editorial "My Friend's a Thief" is another example of the growing trend to justify all immorality because of the Watergate incident.

If your friend is a thief he would have committed a theft in any age, any culture, any part of the world or in any standard of morality that considers theft a crime.

You make Watergate sound like the second eating of the apple. What conceit! What naiveté! If he were not your friend, would he not have been guilty? And if it had not been for Watergate, would he never have stolen the ICs?

*Michael N. Ingrisano*
1839 Rupert St.
McLean, Va. 22101

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POWER: ½ WATT (OR BETTER) AT 70°C

TEMPCO: CERMET— AS LOW AS 100 PPM/°C
WIREWOUND — AS LOW AS 70 PPM/°C

TEMPERATURE RANGE: –55° UP TO +150°C

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Bourns LOW-COST FAMILY of industrial TRIMPOT® potentiometers was designed specifically to give cost-conscious industrial electronics equipment manufacturers superior product quality and performance . . . AT LOWER PRICES.

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Complete data, price and delivery details on all LOW-COST FAMILY models is available upon request. Just write, or call, your local Bourns Sales Office, representative, or distributor.

FOR INSTANT INFORMATION DIAL EEM 800-645-9200 TOLL FREE

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INFORMATION RETRIEVAL NUMBER 12

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(SPECIAL LOW PRICE!!)

## NEW! .100" CENTER PC CONNECTOR

**COMPLETELY INTERCHANGEABLE WITH ALL MAJOR SUPPLIERS**

SERIES 7000

FEATURING: WIRE-WRAP OR DIP-SOLDER TERMINATION ☐ BIFURCATED BELLOWS CONTACTS ☐ UL-APPROVED INSULATOR MATERIAL ☐ GOLD OVER NICKEL PLATING, AND ALL THIS . . .

**FOR LESS THAN 2¢ PER CONTACT POSITION!!**

## WIN A HONDA!!

HONDA SUPER SPORT 350
(CB-350 K4)

To qualify, just fill out the attached reply card requesting quotation, or submit your own RFQ. Three-hundred (300) names will be randomly selected from all qualifying respondents and the winning name will be drawn on December 14, 1973. This special introductory offer expires Dec. 31, 1973. Void where prohibited by law.

**Stanford Applied Engineering, Inc.**

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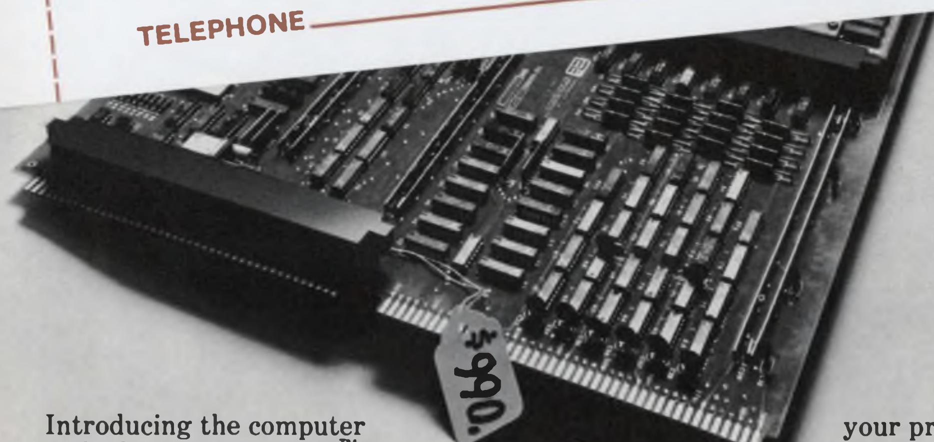
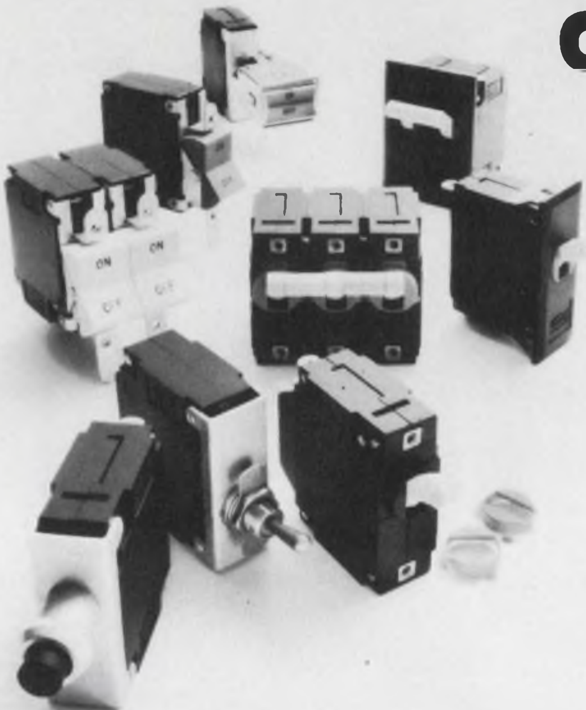


$990.

# Heinemann Type J. Outside, something for your customers.



A word to those of you who've been considering our hydraulic-magnetic breakers only in terms of reduced component and service costs—your customers may like the way they look on your equipment.

Heinemann Type J, for instance. This uncommonly versatile design is based not only on the tasteful use of form and color, but on some down-to-earth human engineering criteria as well.

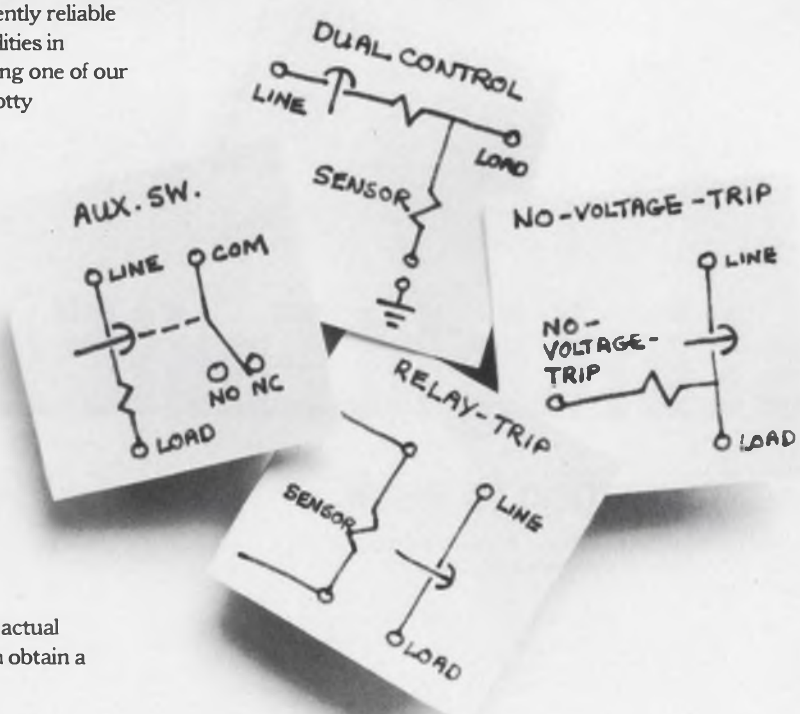
We offer a choice of packaging that includes two types of toggle actuator, a rocker handle, and both lighted and unlighted pushbuttons. There's also a snap-in model that installs without hardware to reduce your assembly costs.

# Inside, something for you.

Inside, our handsome, economical, and inherently reliable Type J breakers offer some intriguing possibilities in switching, protection, and control. (By applying one of our eight special-function internal circuits to a knotty design problem, you could become a hero in your company.)

Consider what you could do with a breaker that trips on current or voltage changes *in another circuit*... a breaker whose trip point is adjustable... another that controls not one, but two loads per pole... a single-pole breaker with two coils: one for overload protection, one for a separate control circuit. New this year is trip-alarm—built-in SPDT or DPDT contacts that actuate when the breaker trips electrically, but not when it's manually switched.

Our new Bulletin J-3333 gives a thorough airing to many such ideas based on actual applications of these internal circuits. You can obtain a copy by writing to Heinemann Electric Co., 2626 Brunswick Pike, Trenton, N.J. 08602.

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INFORMATION RETRIEVAL NUMBER 16

# Interdata, trying harder, offers 2 new mini systems

In an announced effort to become No. 1 in the minicomputer system market by 1976, Interdata Inc., has scheduled two new systems for introduction early next year. The company places itself No. 3 in today's market.

The first is the Model 7/16, a microprogrammed, 16-bit machine that includes an 8-kilobyte, directly addressable core memory unit. The mini is microprogrammed around an 80-ns LSI-bipolar ROM. Features include 16 hardware general registers, of which 15 can be used for indexing; up to 64 kilobytes of directly addressable main memory; 255 input/output interrupts with automatic vectoring to service routines; and a set of more than 100 instructions. Data word length is 8, 16 or 32 bits, and instruction word length is 16 or 32 bits. Typical execution time is 1.5 $\mu$sec for a 16-bit register-to-register add operation. Single unit price of the Model 7/16 will be $3200.

The second new minicomputer system is the Model 7/32, a machine that the company describes as "the world's first 32-bit minicomputer to be priced under $10,000" ($9950 in unit quantities). The 32-kilobyte core memory has an access time of 750 ns.

The 7/32 is a three-board processor packaged in a 16-slot chassis with hardware multiply/divide, and a new 32-kilobyte core memory module on a single 15-inch PC board. The processor is designed to directly address up to 1 megabyte of main memory as well as to perform 32-bit arithmetic and logical manipulations.

The machine has two sets of 32-bit registers, with 16 registers in each set. One set of 32-bit registers is for user programs; the other is for operating system and input/output use. There are more than 200 instructions. Typical execution time is 1 $\mu$sec for a 32-bit register-to-register add operation.

## Bubble memory planned for recording in space

In a major effort to improve the reliability of data recorders used in space, NASA is developing a bubble memory to replace mechanically driven tape recorders.

Dr. Robert L. Stermer, scientist at the NASA Langley Research Center in Hampton, Va., notes that while the mean time to failure of the current flight tape recorder is about 10,000 hours, bubble-memory recorders should last at least twice as long.

"We are looking towards a flight status recorder by early 1978," he reports. "The main applications will be in scientific weather satellites."

A 14-month $139,000 contract has been let to the Electronics Group of Rockwell International Corp. in Anaheim, Calif., for the initial feasibility study and production of a small engineering model of the data recorder. William C. Mavity, program development manager for domain memory products at Rockwell, says the recorder will have a capacity of between $10^7$ and $10^8$ bits. The design calls for dissipation of only 5 to 10 W of power and a read-data rate of about 150 kB/s. Writing is to be done at a slower 15 kB/s. Stermer says that eventually writing will be just as fast as reading.

Gadolinium gallium garnet substrates will be used with a bubble size of 4 to 6 $\mu$. This yields a bit density of about 2.5 million bubbles/in$^2$.

The recorder may be divided up into several 10,000-bit sections, so that if one section fails, the others will operate. Stermer notes that the present flight tape recorder fails catastrophically when it goes; no partial memory saving is possible.

Another advantage of the new recorder says Mavity, is that it will be able to stop and start on a bit without having to overcome the inertia of a mechanical recorder.

## New material spurs superconductor hopes

Borrowing from thin-film semiconductor technology, a researcher at the Westinghouse Research Laboratories in Pittsburgh has developed a new superconducting material that has a higher critical temperature than any material used so far.

Many applications for superconductors are being developed in laboratories throughout the world. These include superconducting generators, power-transmission lines, high-speed trains, ship-propulsion systems and microwave and magnetic field detectors. The major stumbling block to success has been the lack of superconductors with high critical temperatures.

The critical temperature, according to John Gavaler, developer of the new material, is the temperature at which a material first begins to exhibit superconductivity.

In his work, Gavaler used a modified sputtering process to produce a compound of niobium and germanium that has a critical temperature of 22.3 K (−419.5 F). Although this is only a 1.5-K increase over the previous record, Gavaler notes that advances in this area are generally measured in fractions of a degree.

In modifying the sputtering process, Gavaler used only 750 V instead of the usual 2 to 4 kV. In addition, instead of using a low argon gas pressure of 0.1 mm of mercury, he used 0.3 mm. The result of these changes is that low-energy particles of niobium and germanium can combine to form the desired compound.

According to Gavaler, the discovery of the new material demonstrates that superconductors can operate at temperatures well above the normal boiling point of hydrogen (20.5 K). This means that liquid hydrogen, which is cheaper than the presently favored liquid helium, could be used as a cooling agent. Ideally scientists would like to achieve superconductivity at room temperatures.

## Flammability ratings are revised by UL

The flammability ratings of plastics used in electrical and electronic equipment have been revised by Underwriters' Laboratories to make the designations more clearly reflect the manner in which the tests were conducted. Formerly the ratings emphasied the "self-extinguishing," or SE, feature.

A UL spokesman in Chicago says that the revisions were spurred in part by recent complaints by the Federal Trade Commission against 26 plastics manufacturers, calling on them to stop citing and using flammability standards of the American Society for Testing and Materials. The FTC indicated that because tests made by the society used relatively small pieces of matrials in a small, controlled area, they were meaningless in predicting the flammability of these materials in large-scale fires, such as in buildings.

While the Underwriters' Laboratories tests of electrical and electronic plastics are similar in nature, the materials are used essentially in small enclosures, like appliances, radios and television sets. As a result, the UL spokesman says, the tests are valid for the manner in which the material is used.

## Beam switching cuts landing-system costs

The use of antenna beam-switching instead of the more complex, phased-array system can substantially reduce the cost of microwave landing systems for small airports and general-aviation aircraft, according to Bendix Corp. spokesmen.

As a result, Bendix—one of four industry teams competing in the prototype phase of a Federal Aviation Administration program to develop a National Microwave Landing System—has added the beam-switching feature to its proposed system. Simplified ground-station equipment can result with costs reduced to one-third to one-fourth that of a full-blown phased-array system, the company says.

General-aviation receiver costs would also be cut, according to Edward D. Hart, director of engineering for the Bendix Avionics Div., Ft. Lauderdale, Fla.

Beam switching, says Charles W. McWilliams, Bendix director for air traffic control activities, is a relatively simple technique to move the antenna's beam electronically from one discrete position, to another. However, much of the circuitry associated with a full phased-array system is not needed. A new antenna model that corporates beam switching is being fabricated.

The simplified beam-switching system would give the pilot straight-on elevation and azimuth information like that of the localizer and glide slope of present vhf instrument landing systems. For the large jet airports, Bendix would use the full phased-array systems.

## Ultrasonic probe sought to show heart damage

An ultrasonic system that may enable physicians to measure precisely how much of a patient's heart tissue has been damaged by a heart attack is under development by the Massachusetts Institute of Technology in Cambridge.

Physicians who use the system would place a tiny, ultrasound, emitting-and-detecting probe into a patient's body to examine the heart. A high-speed computer would analyze and plot the results to indicate the extent of dead muscle tissue.

Dr. Padmakar Lele, professor of experimental medicine in the MIT Dept. of Mechanical Engineering, and other researchers discovered a couple of years ago that dead heart tissue differs consistently from normal in the way it absorbs ultrasound at various frequencies. Dr. Lele found, however, that early ultrasonic measurements were dependent on the angle at which ultrasonic pulses impinged on the tissue.

Such use of ultrasound to find dead tissue was thus not useful, because an ultrasound probe applied to the chest wall or inside a beating heart undergoes constant changes with respect to the heart muscle.

Dr. Lele subsequently discovered that by using a broadband ultrasonic pulse—containing a wide frequency range—he could obtain a curve representing how a piece of tissue reflected ultrasound through those frequencies. The shape of this curve would be the same regardless of the angle of the target. It could then be compared with the shape of the curve for normal tissue. Since the heart is in constant motion, only a few ultrasonic echoes of a heart wall from a probe would be clear enough for analysis. Hence the researchers have developed a prototype computer program that is presently capable of analyzing pulses at a speed of about seven echoes per second. A medically useful system would have to be capable of examining up to 100 echoes per second, Dr. Lele notes.

## Monsanto cuts price of non-red LEDs

In a surprise move that which may be the first indication of a trend in the light-emitting-diode indusry, the Monsanto Electronic Special Products Div., Cupertino, Calif., has reduced the price of its MAN 5, 8 and 7 green and yellow 0.27-inch, seven-segment displays to that of the company's equivalent red display.

The move, according to Monsanto, is intended to test the reaction of designers to a choice of display colors. Some designers of consumer electronics have been holding back in their use of red LED readouts. Because they are more difficult to read than green and yellow and the public tends to regard red as an indication of danger.

The new price of the MAN 5, 7 and 8 is now $2.70 in 1000 lots $5 in single units.

# Fluke counterattack


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**A seven function do-all 80 MHz instrument for $695.**

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### Model 1941A Digital Frequency Counter

Here's an outstanding low priced performer. It's unique among low frequency counters with unmatched features and capabilities. Frequency, rpm and totalize modes let you use it as a frequency monitor, precision tachometer or flow meter calibrator. The 6 digit display is clearly readable at 20 feet (7 meters). All functions are controlled by clearly marked pushbuttons.

A switchable low pass filter and attenuator simplifies operation in electrically noisy environments.

BCD output, a field installable option, interfaces easily with digital printers and automated test equipment providing 4-line 8-4-2-1 TTL compatible logic. A connector cable is all that is required to interface with Fluke's 2010A Digital Printer. No external circuitry is needed.

A programmable offset input option eliminates the need for manual calculations in measuring frequency offsets in receivers, as well as crystal oscillator and filter production.

### Model 1952A Universal Counter

The versatile one from Fluke. Counting from DC to 80 MHz in the standard version, this precision counter can be expanded in the field to cover telecommunications applications to 515 MHz.

Capabilities include frequency, frequency ratio, single period, period averaging, time interval measurement, totalizing and gateable totalizing. Matched input channels feature full control of coupling slope and trigger level. The standard display is 7 LED digits. 8 and 9 digits are available. Status lamps indicate units annunciation, overflow, gate and trigger level.

Ready to use when turned on, a standard 1952A performs to specifications that meet or exceed FCC requirements. An optional computer designed TCXO improves stability, reduces the aging rate and operates from −20° C to +60° C!

For data an optional BCD 8-4-2-1 parallel TTL compatible output is offered.

### Model 1950A Multi-Function Counter

The economical one from Fluke. The 1950A, a full five-function counter, outperforms counters costing much more. Measure frequency, single period, multiple period averages, ratios or totals. Features include a 6 digit LED display with automatic annunciation, variable trigger level control with status lamps and a switch selectable attenuator for operation in electrically noisy environments.

An ideal field instrument, the 1950A weighs only 5 pounds and operates from 12 Vdc.

Available with optional TCXO's, that meet or exceed FCC requirements, the 1950A will operate in the lab or in the field as soon as it is turned on. Fluke's -04 TCXO gives you an operating range from −20° C to +60° C!

Other low cost counters use preset trigger levels subject to noise spikes and ringing, which causes false readings. The 1950A uses a variable trigger level control which can be quickly set to the correct level by looking at the LED trigger status lamps. Testing high speed digital circuitry is no problem.

Record data easily with an optional BCD output. Fluke's Model 2010A Digital Printer cables directly to the 1950A. No external decoding and encoding circuitry is needed.

### Model 1980A VHF, UHF, Telecommunications Frequency Counter

The portable one from Fluke. The 1980A is a precision telecommunications counter designed to service mobile land, sea and air communications systems quickly, accurately and dependably. Ready to use instantly, this performance engineered counter operates under conditions that leave other counters out in the cold. With an optional TCXO the 1980A can be van or field operated, to specifications that meet or exceed FCC requirements, from −20° C to +60° C!

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INFORMATION RETRIEVAL NUMBER 21

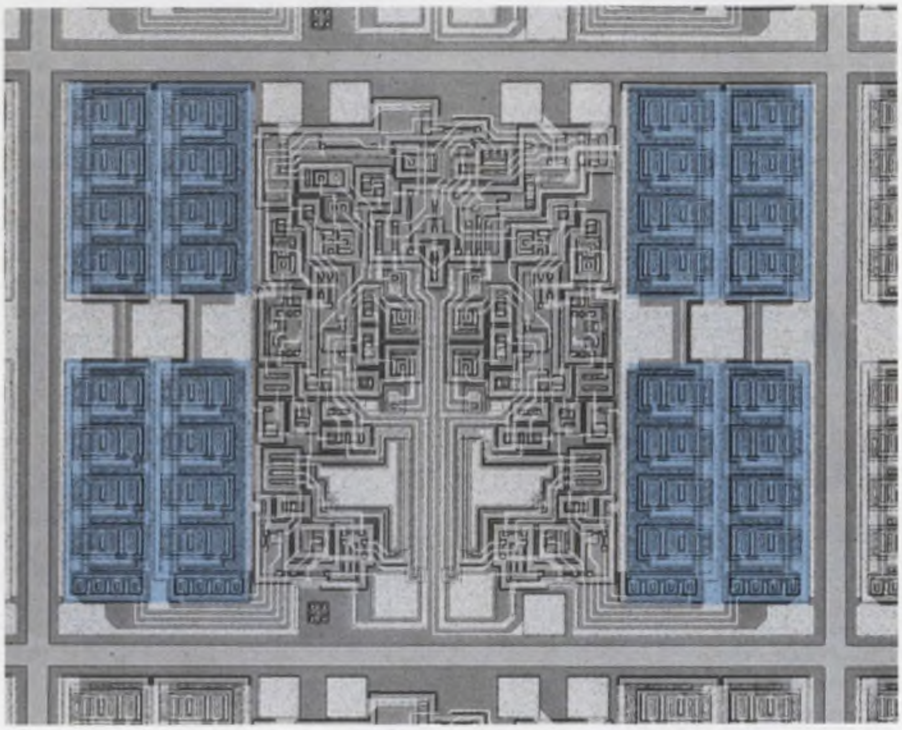
news

# Quad-linear ICs racing up the pike, paced by automotive applications

Quad-linear ICs, spawned by the special needs of the automotive industry for low-cost, highly reliable electronic devices, are rapidly becoming popular not only among linear-circuit designers but among digital as well.

These four-in-one circuits—be they op amps, comparators or Norton amplifiers—are being used in increasing quantities in antiskid, fuel-injection and emission-control circuits, all of which require low-power, dependable ICs. One industry source has estimated that the automotive market for quads will reach 10-million a month after next March.

The first quad-linear circuits appeared on the market about a year and a half ago. In May of 1972 both Motorola Semiconductor in Phoenix, Ariz., and National Semiconductor, Santa Clara, Calif., introduced quad-current amplifier circuits—the MC3401 and LM-3900, respectively.



**The National Semiconductor LM3900 quad amplifier** which can operate off a single-power supply of 4 to 36 VDC, features four independent internally compensated amplifiers.

### Benefits to the designer

Quad-linear devices offer a number of benefits to the circuit designer. First, the tendency is for the quad circuit to be cheaper than a combination of single or dual circuits. One quad takes less PC-board space than two duals or four singles—and a reduction in board size means easier mounting, lighter mounting structure and an overall reduction in the weight of a product. In addition, for many linear-circuit applications, quads allow the use of shorter signal leads—thereby reducing stray capacitance, excessive capacitance or inductive coupling and propagation delays.

An important cost saving over duals and singles comes from a reduction in the number of IC insertions in a board. The cost of inserting and connecting any package into a board varies from company to company; often the cost of a part is overshadowed by the labor cost of installation.

A less obvious cost saving comes from the reduced repair, rework and revision needed on boards designed intelligently with quad-linear circuits. A linear circuit is more likely to fail in service than a digital circuit. It must amplify analog signals over a variety of operating conditions, temperatures and signal situations, and any aberation can be disastrous to circuit operation. If the technician can replace the active circuitry of a whole section of a board with a single package, it can mean a very real saving in maintenance cost.

Some design engineers say they are seriously considering using three of four amplifiers in a quad package and leaving one as an installed spare. Their reasoning is that in a monolithic quad circuit the unused spare will be subjected to the same temperatures and stresses as the three active circuits—so the repair technician has a pre-aged replacement already on the circuit board. After switching in the good amplifier, the circuit should require a minimum of

**Northe K. Osbrink**
Western Editor

tweaking to perform properly, these designers say.

Today the circuit designer has a reasonable selection of quad-linear circuits to choose from. The initial offering of the MC3401 and LM3900 is still available and either has or is about to be second-sourced by RCA, Fairchild Semiconductor, Raytheon and Signetics. Today there is a further op-amp choice—the 4136 from Raytheon Semiconductor of Mountain View, Calif. It is a monolithic quad 741 high-gain voltage amplifier requiring a plus and minus power supply. Texas Instruments also has a quad 741, a two-chip version operating from a plus and minus supply.

Another unit available is the National Semiconductor LM324. It operates from one power supply of from 3 to 30 V dc, or can be operated on dual supplies.

A designer requiring a quad comparator is limited to the LM-3901, introduced by National Semiconductor and now second-sourced by Motorola. Additional components in the quad configuration include the quad opto-isolator, introduced in August by Litronix of Cupertino, Calif.; a number of quad epitaxial planar silicon transistors available from Texas Instruments, Dallas, and such devices as quad line driver-receivers from Signetics, Sunnyvale, Calif.

National Semiconductor's marketing manager for linear products, Art Fury, sees a strong future for the quad industry.

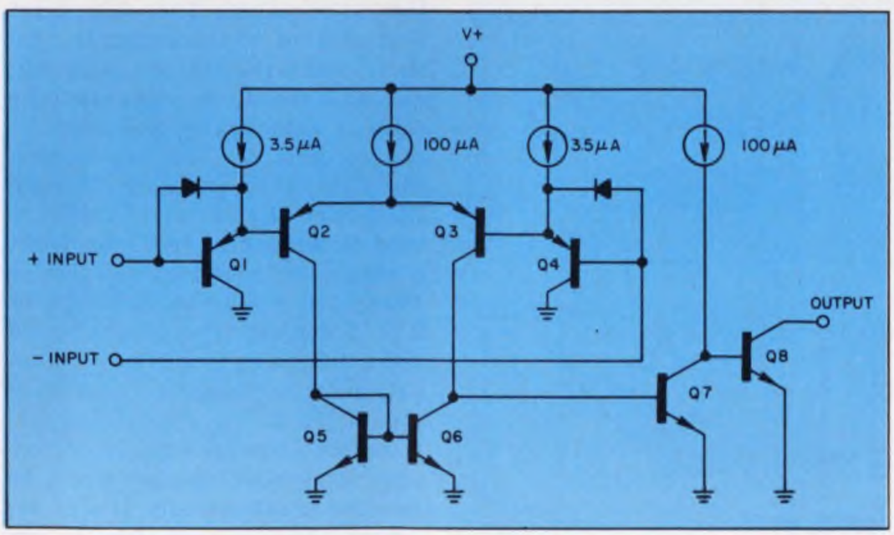
"Engineers are beginning to realize that quad-linear circuits can be building blocks," he says. "By adding a few external components, the quads can become function generators, active filters or signal-processing circuits."

These building-block circuits can be cheap and easy to design. As an example, Fury says, "a quad op amp can be made into a very nice, inexpensive function generator—not a Wavetek lab-quality unit but good enough to build into a piece of equipment for self-testing."

National will introduce about six new quad-linear circuits by the end of the year, and both Raytheon and Motorola have circuits in the works. Quad is a magic number for the linear manufacturer since four op amps, comparators or other linear circuits fit nicely into a 14 to 20-pin DIP.

Most manufacturers agree that the quad costs about the same per package as single or dual circuits. Orlando Gallegos, operations manager for Raytheon Semiconductor, says:

"Our monolithic quad op-amp chips have a rejection rate only about 10% higher than a single amplifier chip. When our lines are all handling three-inch wafers, we will be able to build any quad circuits for less than two duals." ■■




**Unlike most comparators, the LM 139 can operate from a single power supply** and still have an input common mode voltage range that includes ground. It is compatible with all forms of logic and has a power dissipation ranging from 570 mW to 900 mW, depending on the package.

# Wide-angle laser receiver has low noise and high sensitivity

The feasibility of a new wide-angle, low-noise laser receiver that can provide error-free detection for laser pulses of greater than 100 photons has been demonstrated.

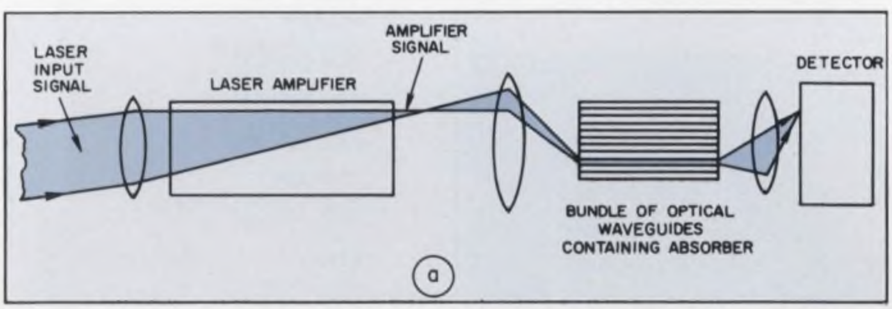
Called the bleachable absorber laser amplifier and detector (Balad), it is reported to give better field of view, sensitivity and bandwidth than present optical heterodyne or direct-detection receivers.

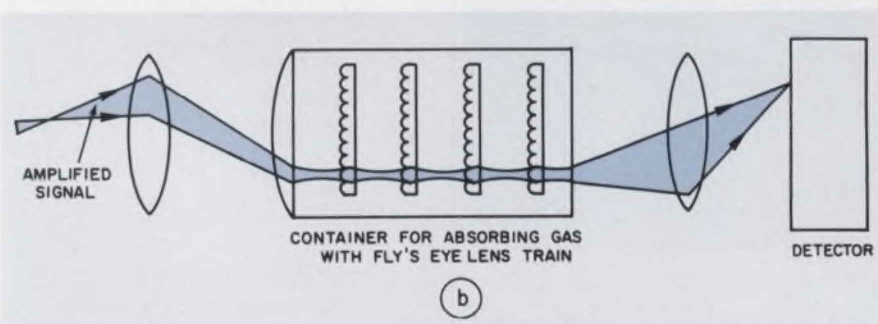
Balad is being investigated by Prof. Gordon Bould and Prof. James T. LaTourette at the Polytechnic Institute of Brooklyn in Farmingdale, N.Y. According to Professor LaTourette, the most important advantage of the receiver is that it can detect—with maximum sensitivity—a signal from any direction in a sizable field of view without need to narrow the field of view to a single diffraction-limited cone or resolution element, as present systems do.

The investigators say that the principal applications for the Balad system are in optical-radar and optical-communications systems where the incoming signal direction is uncertain or where a relatively broad area is monitored for radar or other signals. This contrasts with very narrow-beam systems in which the return signal may be easily missed because pinpoint aiming is required to acquire it.

LaTourette sees the Balad useful for hand-held optical communication receivers, where pointing accuracy is unstable and limited.

As Professor LaTourette explains it, the Balad receiver comprises a laser amplifier, a bleachable absorber and a detector, as well as necessary optical elements for signal-beam focusing (Fig. 1). The received signal (such as one from a radar return), is amplified, along with spontaneous emission from excited molecules in the laser amplifier.




**Wide-angle laser receivers with low noise and high sensitivity** are seen as feasible with arrangements like those shown above. The absorbing element in both systems allows the signal to pass, yet blocks the noise.

The output of the laser amplifier is applied to the gaseous absorber, which can be optical-absorber cells that are filled with an absorbing gas or a bundle of optical waveguides that contain the absorber (Fig. 1a). The gaseous absorber is designed to saturate at an average intensity above the spontaneous emission from the laser amplifier.

Upon saturation the spontaneous emission and other extraneous light are absorbed. The bleachable, absorbing gas acts like an optical squelch, and suppresses the background radiation that does not coincide with the signal beam in direction, in polarization, in frequency and in time.

But, La Tourette points out, the signal, which is higher than the background radiation is focussed onto the absorber. The signal essentially burns a hole in the absorber and passes through with low attenuation. The only light that reaches the detector is spatially coherent with the laser signal. As a result, the signal-to-noise ratio is considerably improved.

According to the researchers, the field of view for a 10.6-$\mu$m $CO_2$ laser Balad that could be used in an optical radar to detect a target of uncertain position is 100-by-100 resolution elements, or $2 \times 2$ degrees. The system would use a $CO_2$ laser amplifier with an $SF_6$ molecular absorber that operates at 130 K. The researchers conclude that several signals or possibly an entire image could be received simultaneously, if a photosensor array is used for the detector.

A Balad receiver that uses Xenon gas could function in a shorter range, but with higher resolution than the $CO_2$ system. ■■

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INFORMATION RETRIEVAL NUMBER 28

# Electron microscope method promises 10-Å resolution

A new technique for improving the resolution of surface-scanning electron microscopes, and thus allowing more detailed study of microelectronic devices, has been developed by scientists at IBM's Thomas J. Watson Research Center, Yorktown Heights, N.Y.

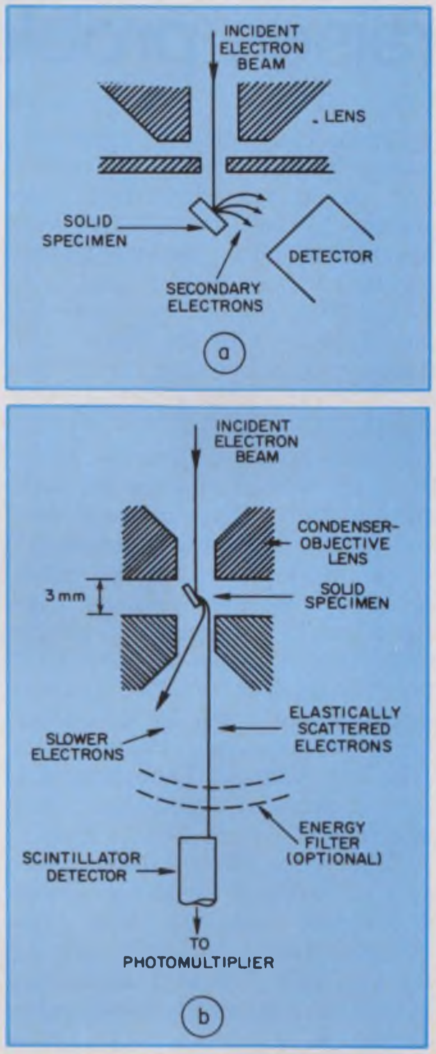
According to its discoverer, Dr. Oliver C. Wells, the technique will ultimately permit resolution of about 10 Å. While resolutions of this order and even greater have been achieved by transmission microscopes, surface-scanning devices have been able to resolve only 50 Å, and then only rarely.

With the new technique, Wells notes, the sample to be examined is placed inside the objective lens of the microscope, where the diameter of the scanning electron beam can be made much smaller—5 to 10 Å—than the 20 Å in conventional surface-scanning instruments. The lens itself is a short focal-length electron type and contrasts with the long focal-length lenses generally used in surface-scanning instruments.

In comparing the new technique with the old, Wells points out that in a conventional surface-scanning microscope a beam of electrons is accelerated to a high energy level and focused on the sample surface by a magnetic lens. The high-energy electrons cause lower-energy secondary electrons to be emitted from the surface of the sample. The number of secondary electrons emitted from each point as the beam is scanned back and forth across the sample gives a picture of the surface, which is displayed on a cathode ray tube.

Since the secondary electrons have a low energy level, they must be positioned far away from the strong magnetic field of the lens. Thus a long focal-length lens with its subsequent limited resolution is necessary.

In this new technique, the condenser part of the lens focuses a beam of electrons on the sample. The electrons are elastically scattered (deflected with little loss of energy) by the sample and are bent back toward the axis of the microscope by the objective part of the lens. These electrons, which have penetrated the surface of the specimen only slightly, are collected to provide the output signal.




**Conventional electron microscopes** (a) use a long focal-length lens while IBM's new technique (b) allows the use of shorter lenses for higher resolution.

Electrons that have penetrated the sample more deeply suffer a greater energy loss and are deflected by the lens out of the field of view of the collector. The property of discriminating between electrons that penetrate deeply and those that don't produces a very high contrast image, which also aids resolution. ■■

# Approaching Intelsat traffic jam raises problem in satellite design

Commercial satellite communications traffic over the Atlantic will exceed the capacity of the present Intelsat IV satellite system by 1975. By 1985 the traffic will be 10 times greater than it is today. Such projections, made by the Hughes Aircraft Space and Communications Group in El Segundo, Calif., raise a fundamental question:

Should a new-generation satellite with higher capacity be built and put into orbit, or should several interim satellites be launched?

An interim satellite, the Intelsat IV-A, is already under construction. It is expected to handle 8600 circuits, compared with 5000 for the Intelsat IV. Two interim satellites are scheduled to be orbited synchronously 22,300 miles over the Atlantic. Launching has been scheduled tentatively for mid-1975.

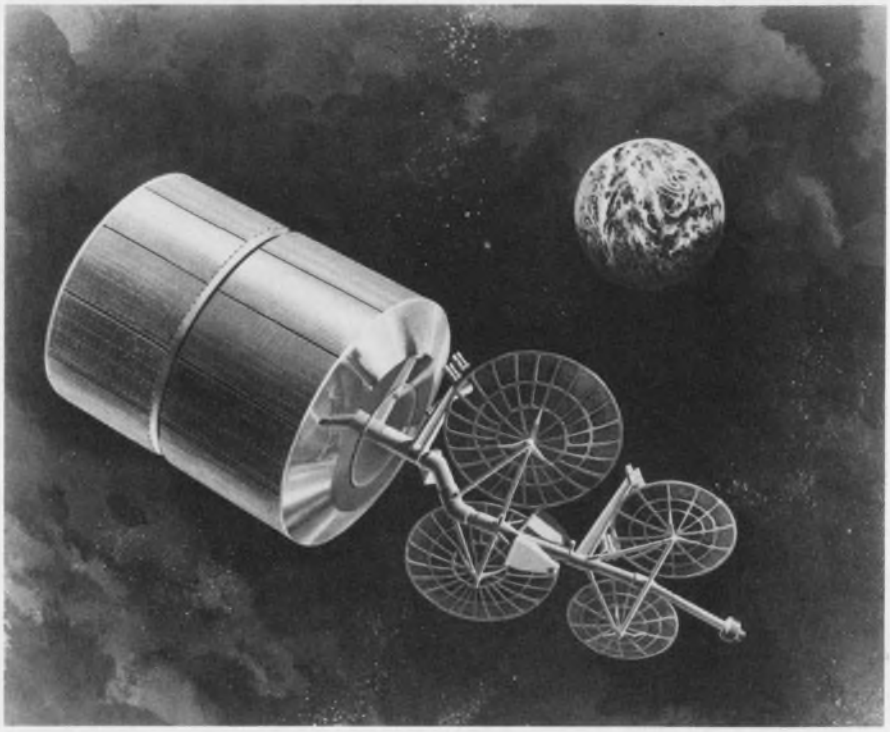
"But," says Steve Pilcher, manager of advanced Intelsat programs at Hughes, "even the IV-A birds will only handle projected capacity through 1978. The next generation is now a subject of considerable discussion."

Ralph Mitchell, commercial systems marketing manager at Hughes, notes that five or six IV-A satellites over the Atlantic would increase system capacity tenfold.

"If the multiple-satellite approach is used over the Atlantic," Pilcher notes, "and the satellites are spaced at least three degrees of orbit apart, about 10 satellites could be used simultaneously."

In agreeing that this approach has advantages, Mitchell says: "You can have up to 10 times the capacity of a single IV-A satellite over the Atlantic. You are dealing with a known, reliable satellite rather than with an experimental one. And those in orbit can spare each other if a satellite goes out."

**David N. Kaye**
Senior Western Editor



**Intelsat IV-A,** which is expected to be launched in mid-1975 to a station over the Atlantic, will handle 8600 circuits and output 500 W of power. The satellite will weigh 1700 pounds and has been designed with a seven-year life expectancy by Hughes Aircraft Co.

Mitchell also points to this disadvantage with a single, new-generation satellite: "The more capacity an individual satellite has, the less reliable the total communication system is. Large nodes of communication traffic are hard to relocate in case of a failure. It is better to have several satellites."

But the multiple-satellite approach is not without some shortcomings. "You need an additional antenna at the ground station for each additional satellite that you must communicate with," Pilcher says. The added expense would place a strain on some of the smaller countries in the Intelsat network.

At present the Intelsat system uses a 3.95-GHz down link and a 6.15-GHz up link, with 500 MHz of bandwidth. Proposals have been made within Intelsat to go to a new-generation satellite that would operate at higher frequencies, with a different polarization on the beam to add capacity. One proposal is for an 11-GHz down link and a 14-GHz up link, with 500-MHz of bandwidth. This would be used with linear polarization. The satellite would accept a pair of independent beams, polarized orthogonally to each other for maximum isolation. Since the same 500-MHz bandwidth could be used twice, the capacity could be doubled.

A second proposal calls for a 20-GHz down link and a 30-GHz up link with 2500-MHz of bandwidth. Since capacity is proportional to bandwidth, this would give a fivefold increase in capacity. When coupled with the orthogonal polarization scheme, an effective tenfold increase in capacity would result.

No other frequencies below 30 GHz are allowed under Federal Communications Commission regulations.

The main limitation to use of these higher frequencies is attenuation because of rain. At 20 or 30 GHz the rain problem is significantly worse than at 11 and 14 GHz. The problem, Pilcher notes, is so bad that extra ground stations would be needed at various sites to handle the traffic meant for a "rained-in" ground station. Even at 11 and 14 GHz, extra stations would be needed. In addition rain might cause such a disturbance in the polarization of the beam that reception would be marginal.

Some of these problems will be studied in future satellite launchings. The ATS-F satellite will carry 20 and 30-GHz beacons to check on rain effects when it is sent aloft in April, 1974. Canadian and European communication satellites will carry 11 and 14-GHz hardware when they are launched in 1975.

### Point-to-point links foreseen

Higher frequencies would also allow implementation of narrow-beam, point-to-point links. At 20 GHz, Pilcher notes, it's practical to use beams as small as 1 degree or less, with attendant efficiency of transmission. These point-to-point links could be used for dedicated, high-traffic nodes in the over-all network.

"Of course," says Mitchell, "a move to higher frequencies also requires a considerable investment on the part of the network members in new ground-station equipment."

Meanwhile changes are being considered in the modulation scheme of the current Intelsat satellite to double its capacity. At present frequency-division multiplexing (FM/FDM) is used. In 1975 an experimental time-division multiplexing scheme will be tried. It may expand system capacity ultimately through use of digital-gigabit, data-communications technology. ■■

# 'Interference-proof' portable radio is easy on the draw: only 50 mW

A unique approach to battery-operated, portable vhf receiver design, developed recently by the military, gives a sensitive receiver that can reject powerful, spurious signals from transmitters operating close to the receiver's frequency. The receiver draws only 50 mW.

Key elements in the new approach are:

- Elimination of the rf input amplifier/preselector stage.
- Use of a special passive FET mixer with substantially greater dynamic range than that of conventional mixers—in the order of 30 dB.
- Use of a highly selective, unusually low-loss (0.5 dB) crystal filter between the mixer and the first i-f stage to provide selectivity against the spurious signals.
- Use of a very-low-noise (1 dB) FET i-f input amplifier stage.

Other techniques for eliminating strong, adjacent-channel interference have been developed, notes John Slechta, electronic engineer at the Army Electronics Command, Fort Monmouth, N.J., and one of the developers of the new approach. Available techniques include the use of parametric up-converters and diode passive mixers pumped with a high-power local oscillator.

But none of these has been effective with portable equipment, Slechta points out, because these systems require 5, 10, or 20 W, which would run down the battery rapidly, or require increased receiver size.

## High dynamic range needed

Slechta explains the philosophy behind the new approach. The object, he says, was to have a front end with a very high dynamic range—140 dB—because military net radios may be placed close together.

Because the gain of an rf stage—as well as that in an active mixer—would increase undesired signal levels and drive the mixer into high distortion levels, both the rf stage and the active mixer were discarded.

The use of the FET mixer was decided upon because of its high signal-handling capability without distortion. The passive mixer has piecewise linear characteristics, Slechta notes, unlike the curved characteristics of other mixers, which generate the harmonics and intermodulation products that appear as unwanted signals at the receiver output.

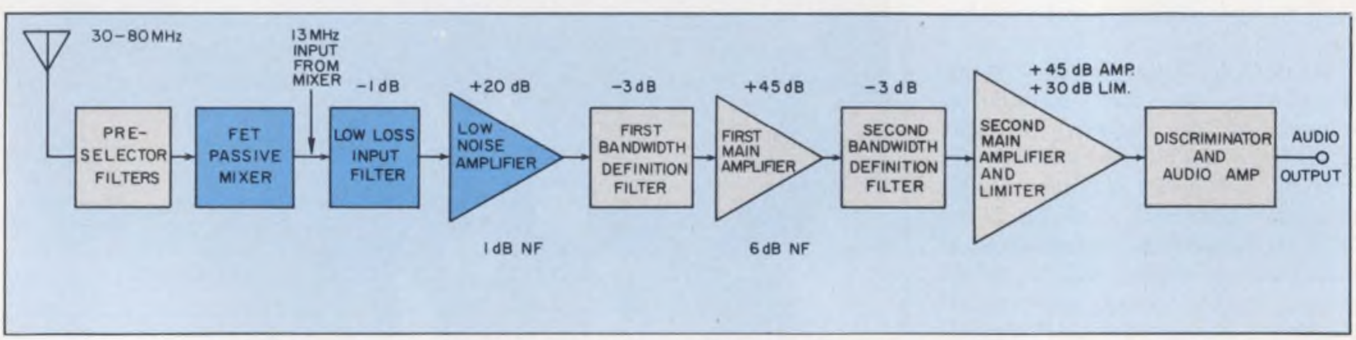
A penalty for using the passive mixer and front end is an increase in the signal-to-noise ratio.

For active-front-end receivers, Slechta says, a noise figure of 10 dB did not seriously degrade the over-all noise figure of the receiver. But with the passive front end, an unusually low noise figure of 1.5 dB was required for the first two elements following the mixer: a low-loss i-f crystal filter and the first low-noise i-f amplifier.

The crystal filter was necessary to reject large, unwanted adjacent-channel signals and prevent them from overloading the first i-f amplifier stage.

The input crystal filter requirements were out-of-the-ordinary, according to Wim van Dem Akker, chief engineer of passive networks, Damon Electronics, Needham, Mass., the filter designer.

First of all, the loss through the filter had to be very low—about 0.5 dB. Although the output impedance was 3 kΩ, the filter was loaded with a very high impedance—the input to the following i-f FET amplifier—of 50 kΩ. This was necessary because the i-f amplifier had to be operated at the high input impedance to preserve its 1 dB noise figure. ■■

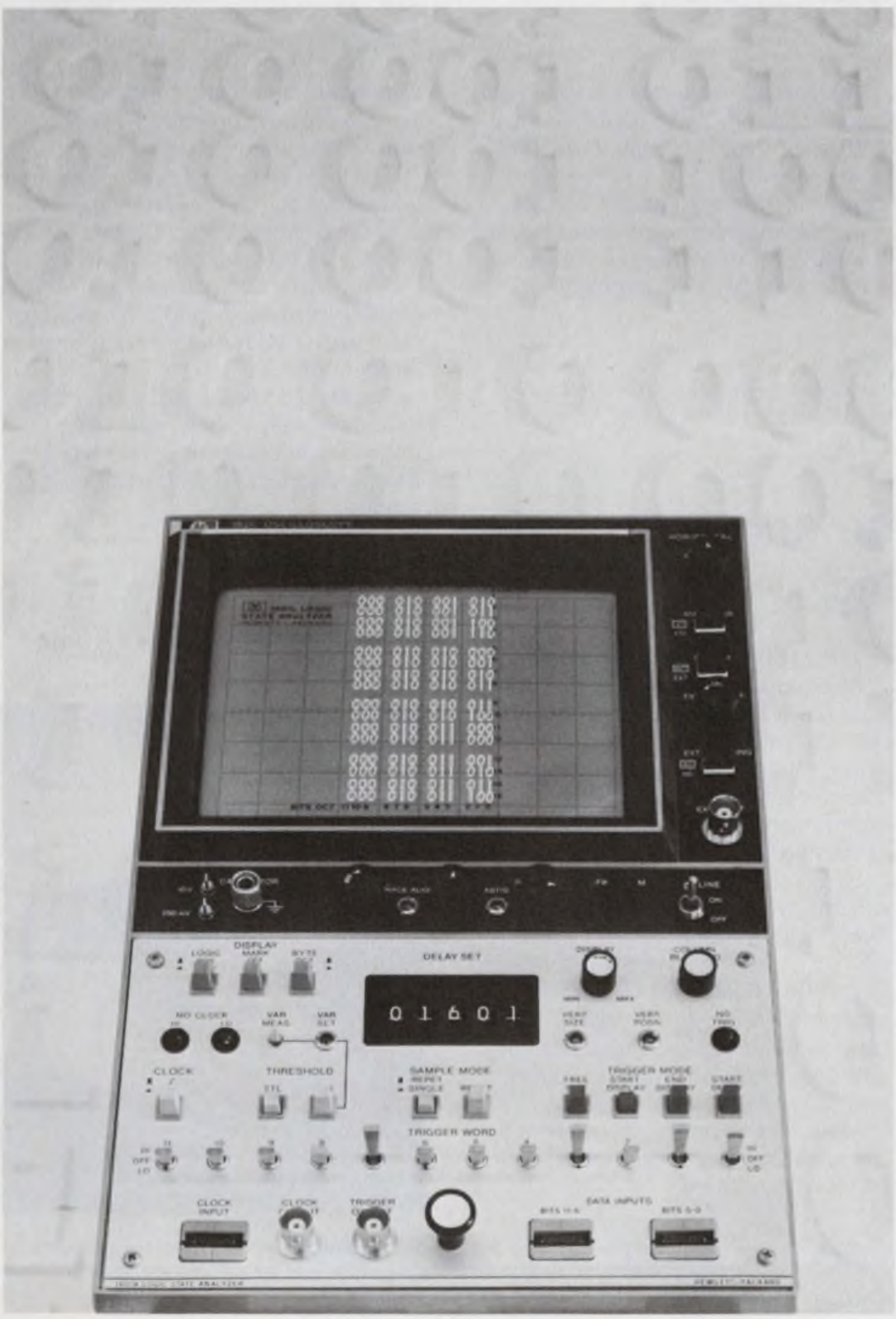



**High-level rejection of nearby, strong adjacent channel signals** was provided in the receiver, above, by use of new design techniques. The rf input stage was eliminated and only the passive mixer stage, preceded by preselective filters was used for the front end. The system selectivity was due to the first crystal filter.

# MEASUREMENT COMPUTATION NEWS

innovations from Hewlett-Packard

**OCTOBER, 1973**

## in this issue



## Now, view 12 data channels in binary

**HP's new logic analyzer displays 15 consecutive 12-bit words before or after the trigger event.**

HP's new high-speed logic state analyzer displays data directly on a CRT in system format—ones and zeros in octal, BCD or hexadecimal—giving you truth tables at a glance. With this new analyzer, you can design, test and service digital equipment faster and more efficiently.

The 1601L analyzer captures data, at rates up to 10 megabits/second, from as many as 12 channels. Data is displayed as 16 consecutive 12-bit words, in 1's and 0's format. The information is stored in shift registers and can be displayed indefinitely. Four trigger modes let you move the display window anywhere in the data stream, from 15 states before the trigger to 99,999 states after the trigger.

*(Continued on page 3)*

# Six HP counters fit most bench or system needs

If you're looking for a single electronic counter that satisfies almost any need up to 550 MHz, try HP's 5326/5327 universal counters/timers. All are excellent bench instruments that interface simply and inexpensively with automatic systems.

There are six models from which to choose. The simplest counter is the seven-digit 5326C that measures frequency to 50 MHz. Top of the line, model 5327B measures frequency up to 550 MHz, has a built-in digital voltmeter, includes time interval, and uses HP's unique time interval averaging to measure down to 150 ps. The 5327B also measures frequency ratio, period and period average.

With a minimum gate time of 0.1 $\mu$s, an HP universal counter can make nearly 10,000 measurements per second.

After selecting the basic counter, you can add options like 8-digit readout, a high-stability crystal time base with aging rate of only $5 \times 10^{-10}$ per day, complete programmability, and digital output. Every front panel control, even the analog control trigger level settings, can be programmed remotely.

*For details, check I on the HP Reply Card.*

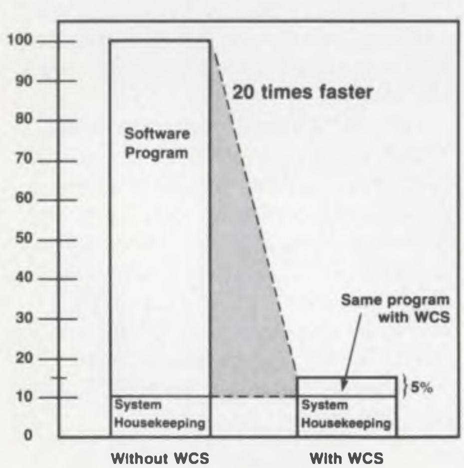
# HP computers cut time and cost with microprogramming

A single IC board lets you execute programs 2 to 20 times faster, quickly debug your programs, dynamically enhance your instruction set, and save valuable memory space. Called "Writeable Control Store," WCS allows you to implement microprograms in HP 2100A and 2100S computers.

Microinstructions stored on WCS work with FORTRAN II and IV, ALGOL, and Assembly language. These microprograms execute at 196-ns cycle time, so you can run programs up to 20 times faster than using conventional software.

Each WCS board stores 256, 24-bit microinstructions—enough to effectively double your machine's instruction set. Up to three WCS boards plug into the I/O slots of your CPU. When you order WCS, you receive a complete software package including core and disc based assemblers, editors, and utility routines.

Now, for half price, you can benefit from microprogramming. WCS is field or factory installed.




*For details, check Q on the HP Reply Card.*

# Solid-state plug-ins aid VHF/UHF swept testing

Besides microwave frequency coverage to 18 GHz, the HP 8620 solid-state sweeper line includes two versions for VHF and UHF applications. Each offers the performance needed for stringent swept tests yet these sweepers are economically priced. For the 3-350 MHz range, insert the 86210A module into the 8620B mainframe. The 86220A plug-in covers 10-1300 MHz. Both versions have 1% sweep linearity, low spurious signals, high stability, and fully-calibrated Start/Stop and ΔF sweeps plus CW operation. A 70 dB output attenuator is optional.

The 86210A has +13 dBm maximum calibrated output power levelled to ±0.25 dB. Accuracy is ±7 MHz in CW mode and ±10 MHz in all sweep modes. A special frequency adjustment control lets you maintain frequency calibrations with changing ambient temperatures.

The 86220A has +10 dB maximum calibrated output power levelled to ±0.5 dB. Accuracy is ±10 MHz in CW mode and ±15 MHz in all sweep modes.

*For more information, check N on the HP Reply Card.*

Easy to operate, HP's solid-state sweepers stress high performance from 3 MHz to 18 GHz.

# New automatic system for fast digital assembly testing

You don't need reference units because the 9560 system uses stored test patterns (truth tables). You can test at rates up to 22,000 patterns/second.

Manufacturing and maintenance costs of digital equipment can be sharply reduced with HP's new digital test system. The 9560 is fast because it tests all pins of a unit under test simultaneously. It's flexible, too: different units can be tested without interface rewiring because pins are set up as inputs by the test program. And you buy only the capability you need, expanding from 60-pin capability up to 360 pins simply by adding 12-pin digital test modules.

Logic reference levels are programmable, absolute, and independent for inputs and outputs, so your assemblies can be checked reliably at marginal conditions. Test programs and fault diagnostics are written in easy-to-use ATS BASIC. Computer-aided generation of test programs is available as a service or as a software package.

Choose either the 9560B paper tape system or the 9560D dual replaceable disc system. The disc memory offers virtually unlimited storage of test programs, diagnostics and test data.

*To learn more about automatic digital assembly testing, check 0 on the HP Reply Card.*

# Tiny quartz oscillators: lab quality components

HP's miniature quartz oscillators offer laboratory quality with component convenience. Aging rate is $< 5 \times 10^{-10}$/day; yet these accurate frequency sources are small enough to mount readily on PC boards for use in instruments, communications, and navigation equipment.

The 10544A oscillator is an economical 10-MHz unit with phase noise 125 dB below carrier frequency. Output is 1 V into 1000Ω.

The 5-MHz 10543A oscillator is better suited for mobile, portable and airborne uses. It has its own built-in voltage regulator, so it needs only a single 15 V to 30 V source. Phase noise is down 145 dB, and the model 10543A is better insulated so it's less affected by ambient temperature changes. (Shift is $<5$ parts in $10^9$ over a range of -28° to ±65°C.) The 10543A also delivers more output, 1 V into 50Ω.

HP quartz oscillators can be obtained in the range 5 to 15 MHz. Quantity discounts are available.

*For more information on crystal oscillators, check B on the HP Reply Card.*


Good things come in small packages, like these quality crystal oscillators in small board-mounting units.

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*(Continued from page 1)*

Included with the 1601L is a new probe system for single- and multiple-point probing of TTL, ECL and MOS logic families. It distinguishes high, low and floating levels with respect to a TTL or variable (± 10V) threshold. And the new probe system simplifies connections to ICs: you can connect it directly to back-plane test points without any test clips or extender boards.

Also available is the HP 5000A that displays two channels of data 32 bits long. Instead of a CRT, 32 LEDs display 32 successive clock cycles. The LEDs turn on for a logic "high" and turn off for a logic "low."

*For more information on HP logic analyzers, check A or F on the HP Reply Card.*

## Now, get 4-in-1 meter calibrator

The new 6920B ac/dc meter calibrator combines in one package all the outputs needed to test panel meters, multimeters, and other meters having an accuracy in the order of 1% or higher. You can use the 6920B to calibrate:

- dc voltmeters from 10mV to 1000 V
- dc ammeters from 1 $\mu$A to 5A
- ac voltmeters (average reading) from 1 mV to 1000V
- ac ammeters (average reading) from 1 $\mu$A to 5 A.

Output is constant voltage for voltmeters, constant current for ammeters. DC accuracy is 0.2% plus one digit; ac accuracy is 0.4% plus one digit. AC output is rms-calibrated and has the same frequency as the input line power (except when an external ac input is used).

Ten-turn digital potentiometer readout control (to three significant digits) determines output value within the limit of the range switch setting. You can set the output to normal "On-Hold" or spring-loaded "On-Test" positions.

*For details, check J on the HP Reply Card.*

One instrument—HP's new 6920B meter calibrator—can calibrate all your general-purpose meters.

## New pulse generator for MOS testing

The new 8015A has an option called "counted burst" that produces a precise number of pulses regardless of rep rate.

When you need to test MOS logic, try HP's new 8015A pulse generator with dual output. Each output can produce pulses as much as 16 V, or you can combine outputs for a 30 V range, from +15 to -15 V. Each output has a separate normal/complementary switch and separate selectable source impedance, 50Ω or 1 kΩ, for reflections and varying loads. Graduated level controls adjust the top and baseline of the pulse. And if you don't need dual output, a lower-priced single-output pulse generator is available.

With such versatility, you can test CMOS, low-threshold MOS and most high-threshold MOS logic, as well as TTL, HTL and discrete circuits. Repetition rates range from 1 Hz to 50 MHz. To step through logic states one at a time, you can generate single pulses or set it to a very low rep rate.

Transition time varies from 6 ns to 0.5 sec. Use the faster time for the different IC families and the slower time for trigger level detection and process control.

*For details, check L on the HP Reply Card.*

## New data generator for digital circuit tests

Need to evaluate digital circuits or systems at high bit rates? The new 3760A high-speed data generator supplies psuedo random binary sequences (PRBS) in nine different lengths ($2^3$-1 to $2^{15}$-1 bits) at rates from 1.5 to 150 megabits/sec. Or you can have the output in word form, with word lengths from 3 to 10 bits selected at the front panel. Data is available in normal or complemented form with either RZ or NRZ coding. For clock extraction tests in PCM digital communication work, you can periodically insert a block of 1 to 99 zeros.

The generator can be triggered either manually or automatically from an external clock, or an optional internal clock can be used. Clock output can be normal or complemented.

Both the clock and data are continuously adjustable in amplitude from 0.1 to 3.2 V p-p and in offset from 0 to ±3 Vdc. Data (and sync) can be delayed up to 100 ns with respect to the clock for easy equalization of cable lengths. For digital communications systems testing, the 3760A data generator combined with the HP 3761A error detector becomes a versatile bit error rate test set.

*Check E on the HP Reply Card for details.*

Test such digital circuitry as high-speed logic, computer memories, disc stores and digital tape recorders with this versatile data generator.

# HP data acquisition systems sport new software packages

HP's new 9601B real-time BASIC data acquisition system includes 12K memory, system teleprinter, punched tape reader, A/D interface subsystem, and operating software.

Now you can have real-time data acquisition with all the convenience of ATS BASIC programming. The new 9601B core-based Real-Time Executive (RTE) system with built-in data acquisition capability measures up to 64 single-ended or 32 differential analog inputs at sample rates to 45 kHz. This is expandable to 1056 single-ended or 528 differential inputs; and you can add digital input/output and analog output capabilities.

The 9601B relates system operations to external processes and external events occurring in real time. A single teleprinter handles system control and data logging; this is augmented by additional data logging devices to which output can be directed. Since output is buffered, system operations aren't delayed waiting for the completion of printouts.

The 9601B is upward-compatible to the core-based 9601C RTE-C system which is programmable in FORTRAN or assembly language, offers faster response, and has a wider choice of system control functions. Or, upgrade the 9601B further to an HP 9601E disc-based RTE system that combines mass storage and on-line program development with real-time operations.

HP also offers a modular library of **FORTRAN subroutines** for sensor-based data acquisition and control applications. These ready-to-use subroutines handle several tedious conversion and statistical processing tasks, so you are free to concentrate on the unique aspects of your application. Programs include thermocouple linearization, statistical analysis, curve fitting, determining humidity, interpolation, integration, and code conversion. Except for curve fitting and code conversion, these subroutines can be used in BASIC in the HP 9601B system.

*For more information, check O on the HP Reply Card.*

# New low-cost low-frequency automatic network analyzer

Ideal for low-frequency analysis, HP's new calculator-based network analyzer system measures amplitude and phase in the frequency range of 1 Hz to 13 MHz. A designer can use calculator programs to create and analyze a circuit; then use the system to compare a physical circuit to the theoretical one.

The HP 3043A low-frequency network analyzer consists of a 3320C frequency synthesizer, a 3575A gain-phase meter, and a 9820A desktop calculator. The calculator controls the instruments and processes data. Results can be displayed, printed or plotted. HP also provides an electrical engineering software package, at minimal cost, with programs on attenuator design, transfer functions, component design, and logic circuits.

The input signal range is 0.2 mV to 20 V rms. For amplitude measurements, display resolution is 0.1 dB. Display resolution for phase measurements is 0.1°.

*Calculate how to save time and money testing circuits and components. Check C on the HP Reply Card for more information.*

HP's low-cost, low-frequency network analyzer system runs under calculator control.

# Two-channel recorder ran 2K miles without a trace of failure

A choice of input plug-ins means versatility for HP's two-channel 7402A oscillographic recorder.

Start with 50 mm chart width and durable stainless steel pens with carbide tips. Then select a preamplifier plug-in for the sensitivity you need: 1 $\mu$V/division with differential, floated and guarded input; 1 mV/div. with a differential, balanced to ground input; and 20 mV/div. with a single-ended input. Chart speeds are 1 to 25mm/second. Frequency response is $\pm 2\%$ of full-scale from dc to 40 Hz, and overshoot is $<2\%$. Rise time is 7.0 to 7.5 ms.

And you don't have to worry about pen fatigue or failure. We ran a stainless steel pen continuously for two months (about 2000 miles or 3200 kilometers), and there was no apparent change in the trace.

*For more information, check K on the HP Reply Card.*

Because the 50 mm chart width is 25% wider than other comparably priced recorders, the writing resolution is 25% better.

# New card reader enhances HP calculators

Now, you can input data on punched or marked cards to your HP 9810, 9820, or 9830 programmable calculator. The new 9869A companion card reader reads 128-character Hollerith code and converts it to 7-bit ASCII for the calculator. And the new card reader won't slow you down—it reads a fast 300 cards/minute.

Use either 40- or 80-column format. You can even design your own card, thanks to a special command that transmits all the marks on the card without regard to coding. Data is stored in intermediate buffers for optimum transmission, which means you operate on blocks of data rather than stacks of cards.

With the new card reader, users can program a 9800 series calculator at their desks or at home. Applications include payroll, quality control, inventory control, education, medical records, and consumer surveys.

*For more information, check P on the HP Reply Card.*

Increase your calculator mileage—the 9869A card reader lets several people program simultaneously on cards.

# Let us give you our new dc power supply catalog

Choosing the right power supply for your application is easy with HP's new *DC Power Supply Catalog.* This 120-page catalog contains product descriptions, photographs, outline drawings (with U.S. and metric dimensions), terminal strip details, specifications, and prices for HP's complete line of power supplies.


Products covered are:

- General-purpose lab and system power supplies
- OEM modular supplies
- Precision voltage and current sources
- Digitally programmable power sources
- Multiprogrammer systems

*For your free copy, check S on the HP Reply Card.*

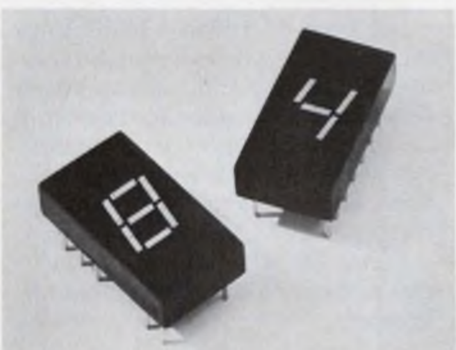
# HEWLETT-PACKARD COMPONENT NEWS

## New optoelectronics devices catalog now available


HP's new 100-page *Optoelectronic Designer's Catalog* is filled with detailed specifications and application notes on our broad line of optoelectronic products, including LED displays, LED lamps, high-speed optically-coupled isolators, and PIN photodetectors.

*For your free copy, check R on the HP Reply Card.*

## Send for your free LED display



The 7700 series LED displays are available in common cathode and common anode configurations.

That's right—check the reply card and we'll send you a free 5082-7730 LED display. These single-digit seven segment indicators feature a large (0.3 in. or 0.8 cm) red numeric plus right or left-hand decimal point. High contrast, continuous uniform segments, and wide viewing angle ensure readability. These low-cost LEDs are IC-compatible, too.

Also available is the new 5082-7740, the common cathode version. This choice of common anode or common cathode lets the designer minimize his display system cost by using the LED that complements his drive electronics.

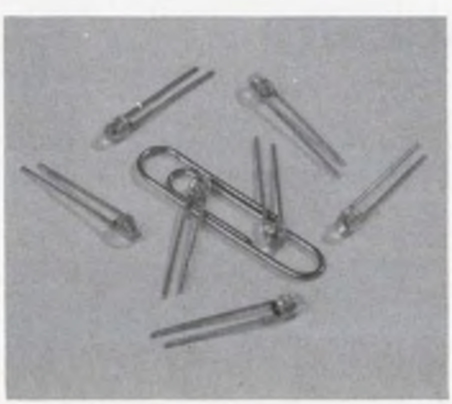
*For your free sample, check G on the HP Reply Card*

## New low-cost commercial LED lamp

HP's latest lamp is our lowest-priced gallium arsenide phosphide LED for high-volume applications. Use it in calculators, cameras, appliances, or automobile instrument panels. Power requirement is low, only 20 mA at 1.6 V. Model 5082-4487 has a typical light output of 0.8 mcd while model 5082-4488 has a guaranteed minimum output of 0.3 mcd.

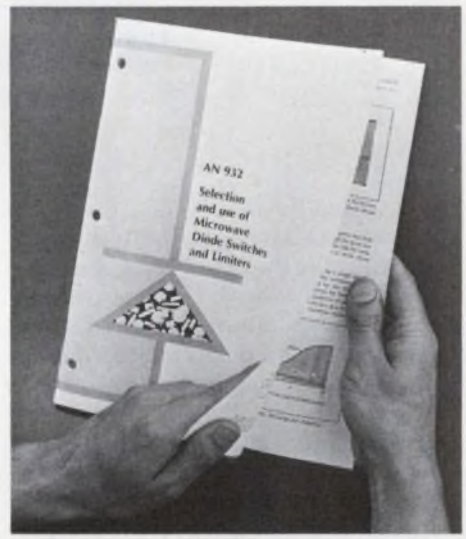
*For specifications, check H on the HP Reply Card.*

100 Clear lens and low profile make these new LEDs ideal for high-density applications.



## New application note on microwave diode switches

If you are using or considering diode switches and limiters for your system, this application note is a must.

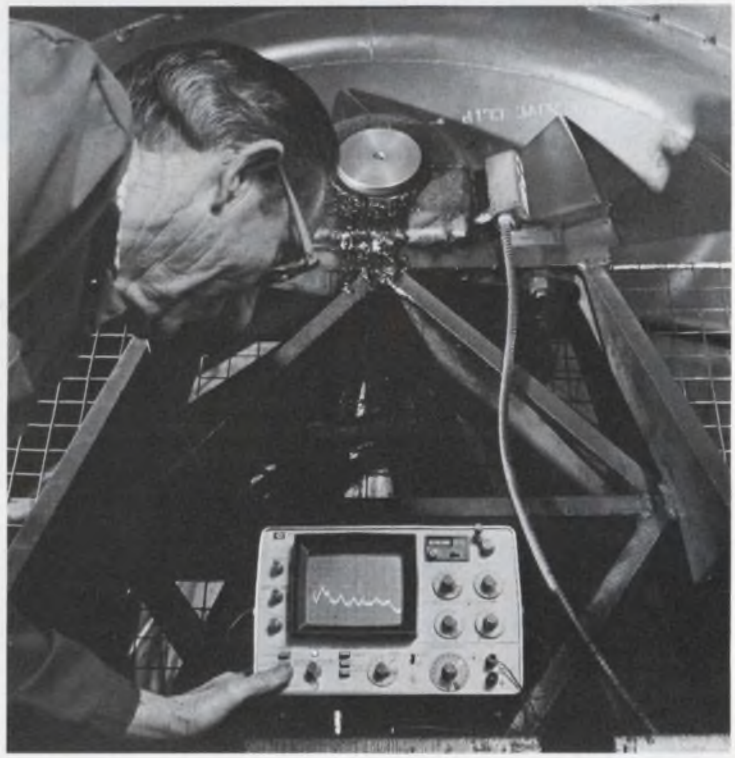



A new application note explains how to select and use microwave diode switches and limiters. In a practical tutorial style, this book covers:

- The effects of system mismatches and how to minimize these effects.
- How to select the proper switch for switching, attenuating, or modulating.
- How to change the threshold and slope of a limiter.
- The trade-offs in selecting coaxial modules, stripline modules, or complete switches.
- How to design bias networks.
- Multi-throw circuits and driver circuits.
- How to test switches and limiters.
- How to construct module test fixtures.

*For your free copy of AN 932, check T on the HP Reply Card.*

# New low-frequency spectrum analyzer has digital storage, adaptive sweep, and portability



Here, the 3580A checks mechanical vibrations of the bearing on a 200-hp fan. You can also use the spectrum analyzer to characterize audio filters, analyze voice and data communication channels, and evaluate underwater acoustical signals.

It's portable (only 35 lbs/16 kg.) and operates on batteries or line power, so you can take the new 3580A spectrum analyzer anywhere. This unique low-frequency spectrum analyzer has digital storage, CRT display, 80 dB dynamic range, "adaptive" sweep, and -150 dB sensitivity.

The 3580A analyzes signals from 5 Hz to 50 Hz, with a minimum bandwidth of 1 Hz for closely-spaced signals. Digital storage recalls the display at high speed from a digital memory, while adaptive sweep speeds up your measurements. Sweep times can be set from 0.1 to 200 seconds. When no signals are encountered, the sweep speeds up to 20 times faster. When signals are encountered, the sweep slows down to reproduce the full response. You don't have to readjust the intensity and focus controls—it's done automatically. Looking at two signals in a 10-kHz sweep, HP's adaptive sweep reduced analysis time from 200 seconds to only 14 seconds.

Amplitude range in the linear mode is 100nV to 20 V full scale; in the log mode, from -150 dB to +30 dB. With digital storage, you can store a trace, then later recall and superimpose it on a subsequent trace for comparison. We even connected the discrete dots so the display is a sharp continuous line that looks like an analog display.

Portability added to capability makes the 3580A an ideal field instrument.

*To learn more, check D on the HP Reply Card.*

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00344

# P&B low-profile R50 Relays let you tee off on critical printed circuit board spacing problems.

New low profile R50 relays with 0.1″ grid spacing are designed for switching currents where larger relays are usually required. Up to 2 amps @ 26 VDC or 1 amp @ 115 VAC, resistive.

While retaining a small package size—0.415″ height—some R50 operating parameters exceed those of reeds. Special 1 Form C contacts, for example, will switch capacitive or lamp loads that normally would weld reed relay contacts.

Additional features include contact resistance of less than 50 milliohms, sensitivity to 125 mw, and standard coil voltages from 6 to 115 VDC with operate and release times of less than 6 ms.

Enclosures are ultrasonically welded to their base making them ideal for use with production techniques requiring flow soldering and spray cleaning.

R50 relays can be used in most applications demanding high density packaging such as 0.6″ center to center spacing of printed circuit cards. Other applications include: Annunciator circuits that only require a single contact and limited mounting space for switching device . . . communication systems such as intercoms, modems, auxiliary tape devices, interfacing systems and read out devices . . . machine tool control circuits.

For complete information, contact your local P&B representative or call Potter & Brumfield Division of AMF Incorporated, Princeton, Indiana 47670. Telephone: 812 385 5251.

AMF
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**Solving switching problems is what we're all about.**

INFORMATION RETRIEVAL NUMBER 32

# washington report

Heather M. David
Washington Bureau

## Defense bill under heavy attack

Congressional liberals are mounting one of the heaviest assaults ever on the Defense Dept's budget, provoking a threat by President Nixon to veto the bill if reductions "imperil national security." Although House and Senate Armed Services Committees treated the authorization bill fairly gently, the Appropriations Committees are considering major surgery—reportedly as much as \$4-billion or \$5-billion in the \$85.2-billion request. The Senate Appropriations Committee has been getting advice from some of the Senate's most outspoken members on how the slashes should be made. Sen. Hubert Humphrey (D-Minn.) suggests a \$7-billion slice across the board. A group led by Sen. Stuart Symington (D-Mo.) and Sen. Thomas McIntyre (D-N.H.) want the Trident submarine construction program slowed. Sen. Birch Bayh (D-Ind.) and Sen. William Saxbe (R-Ohio) want to cancel the SAM-D antiaircraft missile system. Such amendments are counted as having a good chance for passage in the Senate, though there is less chance in the more conservative House. But if House Appropriations Committee chairman, Rep. George Mahon (D-Tex.), and his committee inflict heavy damage, it will be hard for the Administration to get funds reinstated on the House floor. A Presidential veto would mean a new round of deliberations, and the defense bill could be delayed until December.

## New transportation-system contracts let

Three companies have been selected by the Urban Mass Transportation Administration to do competitive work on a new transportation system, partly electronically controlled, that could be introduced into the nation's cities by 1980. Called the Dual Mode Transit System, it would employ vehicles that would be operated by drivers in suburban areas and electronically controlled on automatic guideways in heavier traveled areas. The Rohr Corp., General Motors and Transportation Technology, Inc., have received contracts for \$500,000 each for systems design using different propulsion methods.

## More domestic comsats approved

Hughes Aircraft Co., prime maker of spin-stabilized communications satellites, appears to be the big winner in the recent Federal Communications Commission decision to approve five more applications for domestic satellite operations.

The five new entries—some of them joint entries—are: American Satellite Corp., jointly owned by Fairchild Industries, Inc., and Western Union International, Inc.; RCA Global Communications, Inc., and RCA Alaska Communications, Inc.; General Telephone and Electronics Satellite Corp. and National Satellite Services, Inc., a Hughes Aircraft Co. subsidiary; AT&T; and Communications Satellite Corp.

Immediately after the FCC announcement, Comsat Corp., awarded a $65.9-million contract to Hughes for construction of high-capacity satellites for lease to AT&T.

## Industry council offering metric-conversion aid

The American National Metric Council, a nonprofit industry advisory organization, has opened a headquarters here and will start disseminating information and performing detailed studies to help industry convert to the metric system. The council, sponsored by the American Standards Institute, is headed by an executive board chaired by Adrian Weaver, director of standards practices for IBM. Advisers include Dr. Lee Davenport, president of GTE Laboratories, and Dr. Seymour Jerwald, vice president of the Westinghouse Electric Corp. The metric council's offices are at 1625 Massachusetts Ave., N.W. Washington, D.C. 20036.

At present there are 12 bills before Congress providing for conversion to the metric system.

## D-layer ionospheric communications explored

Air Force scientists believe they have opened a new avenue for military communication and detection systems by proving that medium-range frequencies can be extended beyond line-of-sight. Dr. Gary Sales, Cambridge Research Laboratory Scientist, has told Electronic Design that advances in developing high-altitude platforms make it possible to duct medium-frequency communications waves along the underside of the D-layer of the ionosphere (about 46 miles up).

The Air Force experimenters, using a 50-W transmitter carried on a high-altitude balloon, have transmitted at 220 and 440 kHz to a balloon-borne receiver 1000 miles away.

## Capital Capsules:

**The Senate has passed a pension-reform bill,** including provisions that would give workers vested rights after a minimum number of years, even if they change jobs—something engineers in the electronics industry have wanted for years. The House has not yet acted, but the bill is expected to be cleared by Congress this year. . . . **The Air Force will spend about $6-million on technology work,** with emphasis on an inertial guidance, for its proposed advanced ICBM. . . . Requests for proposals have been sent by the Navy to industry for **a new high-speed anti-radar missile** that will home on enemy radar signals. . . . The Air Force Avionics Laboratory plans to contract for **studies of high-data-rate laser communications systems** for use with satellites, remotely piloted vehicles and drone systems. . . . **Philco Ford Corp. and General Dynamics Corp. have won contracts from the Air Force** Space and Missile Systems Organization for design and definition on a defense navigation satellite. The efforts will deal with ground-station and user equipment.

# 3 excellent reasons for you to investigate the new TEKTRONIX® 60MHz Oscilloscope

### It's flexible

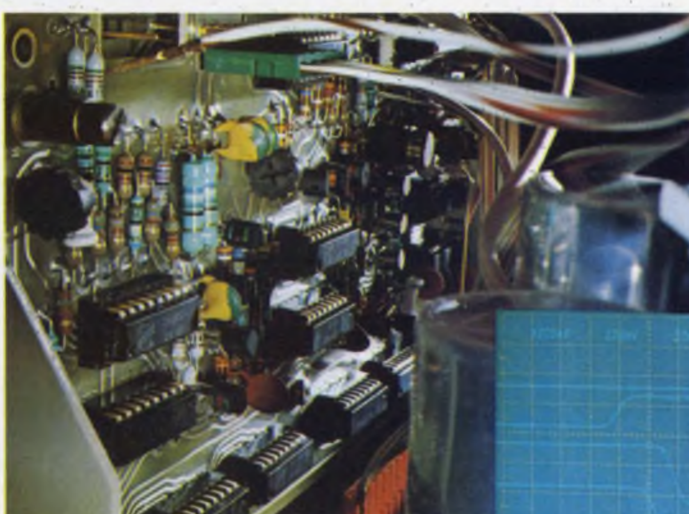
Basic units are the 5403 three-plug-in Mainframe, D40 Display Module, 5A48 Dual-Trace Amplifier and 5B42 Delayed Sweep Time Base. The 5403/D40/5A48/5B42 gives you 60 MHz bandwidth at 5mV/div sensitivity (1 mV/div at 25 MHz) and magnified sweeps to 10 ns/div. Two 60 MHz 5A48s may be paired for four-trace displays. The 5A48 has 5 display modes (Channel 1, Channel 2, Added, Alternate, and Chopped). This performance is offered in an easy to move or carry 29 lb. package. Fifteen other plug-ins (w/o CRT READOUT) give outstanding versatility, including: simple to use, dual-trace DC to 1 GHz bandwidth, delayed sweep sampler and sweeps to 1ns/div; high-gain differential amplifier with 10 $\mu$ V/div sensitivity and 100k:1 CMRR for low-amplitude, low-frequency applications; differential comparator amplifier (accuracy to 0.20%) and CMRR of 10k:1; four-trace 1 MHz amplifiers offering up to eight traces; curve tracer for displaying semi-conductor characteristic curves.

### Easy to operate

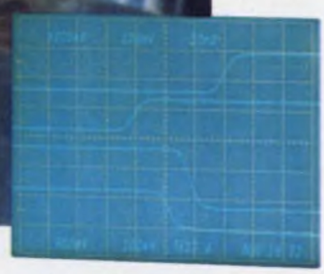
The 5400 has it with a large (6½") bright CRT, pushbutton functions, beam finder, and color coded control panels making the operator's job straightforward. Optional CRT READOUT further enhances ease of operation. Added operator speed, perception and convenience advantages are realized with the CRT READOUT as it actively displays measurement parameters. Plus, a unique, programmable CRT READOUT offers the ability to identify tests and note conditions on the display. Easy determination of control display has been brought together in one highly visible area.

### Low cost

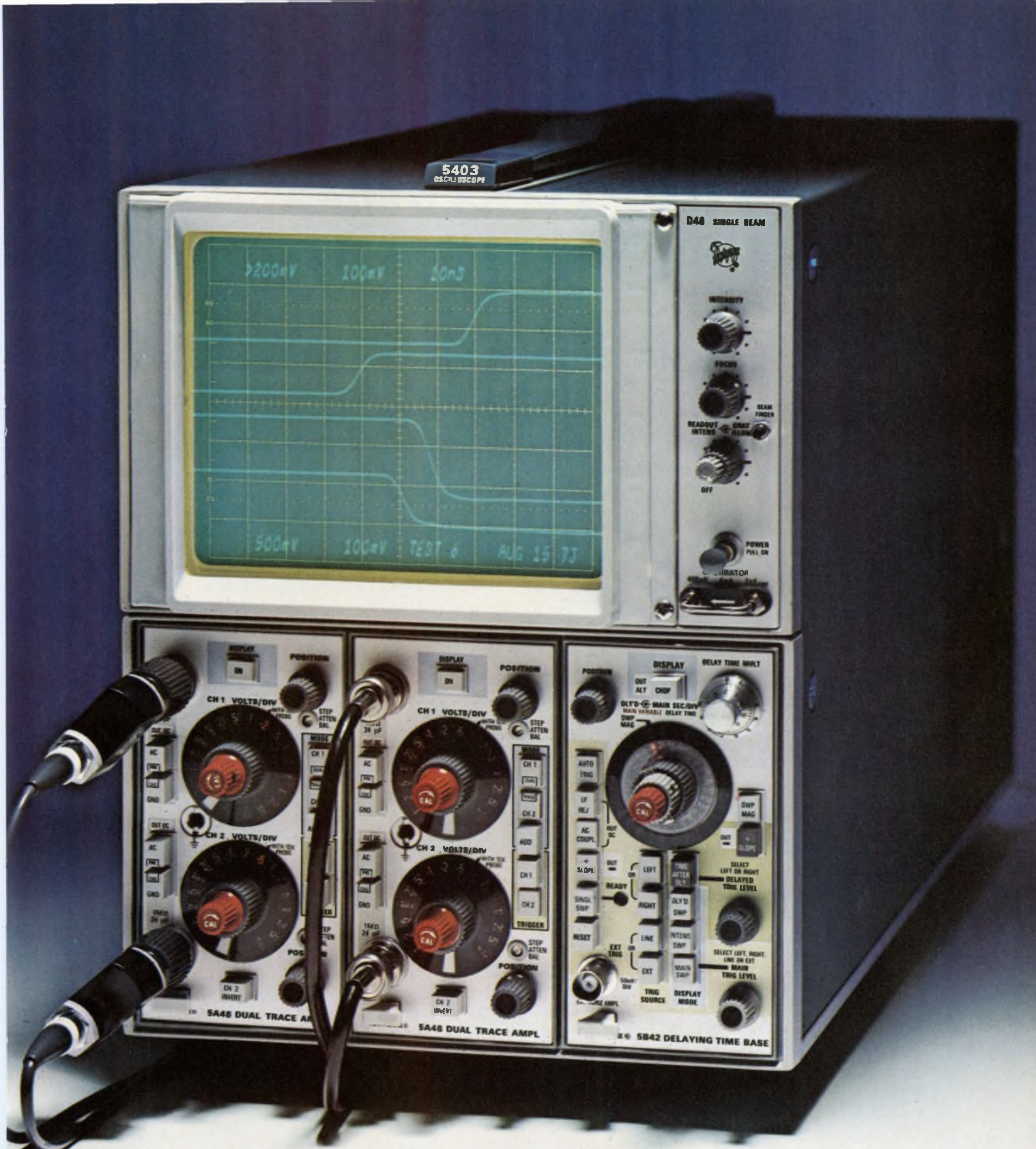
At $2200 ($1850 w/o CRT READOUT) the 5403/D40/5A48/5B42 is a very low priced 60 MHz, dual-trace, delayed sweep oscilloscope. Integrated circuits used wherever practical help keep reliability up and costs down. Maintenance costs are also low with Tektronix modular construction, fewer calibration points and ready access to circuits. CRT READOUT of plug-in parameters has never before been available at this price. The 5400 oscilloscope series provides versatility and excellent measurement value, with more on the way.



CRT READOUT circuit board



Quick, non-ambiguous measurement information at a glance.


5403
OSCILLOSCOPE
100mV
20nS
500mV
100mV
TEST 6
AUG 15 73
SINGLE BEAM
INTENSITY
FOCUS
POWER
PULL ON
DISPLAY
POSITION
CH 1 VOLTS/DIV
CH 2 VOLTS/DIV
5A48 DUAL TRACE AMPL
DELAY TIME MULT
DISPLAY MODE
TRIG SOURCE
5B42 DELAYING TIME BASE

editorial

# Let's have more disclosure

After reading thousands of press releases, spec sheets and advertisements, I have to conclude that our industry churns out one heck of a lot of nifty products. None has any flaws. None has a drawback, weakness or limitation. But when I talk to engineers, I suspect they're not buying the same products. I learn that capacitors leak, resistors fry, amplifiers oscillate, voltmeters measure signals that aren't there, power supplies blast external components and burn up, fans and blowers bind and cook.

In some cases the faults are statistically unavoidable. We can't expect every item in a production run to be perfect. In other cases we become so enamored with one spec that we overlook another. We fall in love with bandwidth and forget noise sensitivity. We assume that a relay contact that's good at 5 A ought to be terrific at 40 mA. Or we forget that a "typical" spec may not describe the products we bought.

Sometimes the problem stems from the fact that the vendor doesn't tell us everything. In his exuberance for slew rate, he forgets to discuss drift. Or he forgets that "independent" controls interact, or that two specs are not concurrent; the supply will deliver 5 V and 30 A, but not at the same time. Vendors who want to stick around generally don't try to deceive. But they're not always overly ambitious in providing all the information we need for a prudent purchase and a good design.

Every engineer knows that all products have limitations. But almost no one has the time to investigate thoroughly every product he uses. So it would be useful—and mighty refreshing—if vendors began alerting us to the pitfalls and shortcomings of their products as well as their strengths. No engineer would be turned off by a spec that said: "Our Model Q is a super-speed amp, but if you can't stand some noise, try our Model T. It's not so quick, but it's quiet." After he recovered, an engineer who read that would feel that the vendor merited confidence—and business.

If he offered comparable products, prices and delivery, such a vendor would quickly gain a competitive edge. In time competing vendors would be forced to disclose more about their products. We might find ourselves in a new kind of horsepower race in which victory would go to the vendor with the fullest and most honest disclosure. That wouldn't be bad.

George Rostky

GEORGE ROSTKY
Editor-in-Chief

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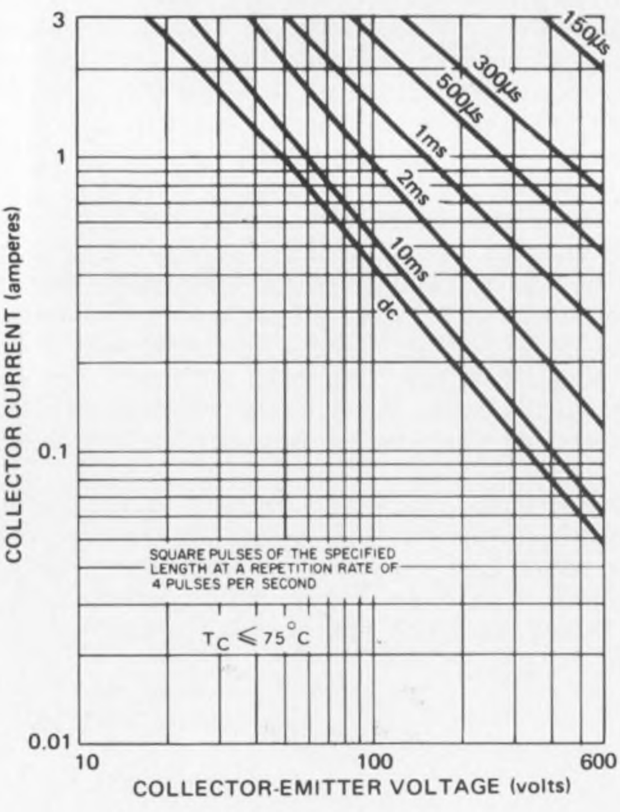


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INFORMATION RETRIEVAL NUMBER 36

# FOCUS on Analog-function modules

For most types of analog-function circuits, the specs don't tell the story. When they do, they don't tell it well. Compounding the problem is the fact that the same analog function may be available as a monolithic or hybrid IC or as a discrete component module. And the same specs—the very same words—don't necessarily mean the same thing for each circuit type.

The granddaddy of all function modules, of course, is the operational amplifier. But the specification problems aren't restricted to op amps. They extend as well to circuits like logarithmic amplifiers, active filters, multipliers, dividers, rms computing circuits, CRT pincushion correction circuits, vector generators and CRT waveform manipulation circuits. While many spec problems are peculiar to individual functions, just as many are universal.

The question of "typical" vs "guaranteed" specs often confuses the engineer. The typical numbers on the data sheet are not guaranteed in any way. If a circuit design leans on them, disaster can result. As one marketing manager puts it: "There are 17-million ways we can screw a customer, if we want to, and 16,999,990 of them will never be found." Typical values can differ from the specified limits by a factor of two to 10 times for many of the units in a large batch; there simply is no universal way of determining a typical value.

### Drifting along in a maze

Even when parameters are guaranteed, that doesn't mean they will stay constant. They will almost certainly drift, and the amount of drift is usually specified elsewhere on the data sheet.

**Dave Bursky**
Associate Editor


**Construction of this multiplier** from Function Modules, Inc., typifies the usual packaging approach for modules. Combined on one potted printed circuit board are resistors, capacitors, transistors and "discrete" ICs.

Time and temperature both take their toll, and vendors often don't make clear the nature of the total drift they specify. They may not tell you how—or if—the temperature drift must be added to the drift with time to get the over-all drift. Some of the more common parameters that are specified for drift are the various offset voltages and input currents.

Drift can be specified for long or short periods—by the hour, day, month or year. When a device is turned on, it may drift a lot at first and then settle to a low rate. Since time represents money, manufacturers usually don't test drift for months or years. Rather they test for a day or several hours and then extrapolate. This often works—but not always. A simple way that manufacturers determine the long-term stability is to multiply the drift per day by the square root of the number of days in the desired time period.

When manufacturers specify aging on data sheets, they usually assume that the temperature remains constant. Of course, it never does.

Neither time nor temperature drift is linear. Temperature-drift magnitude can vary widely for different temperature ranges. The published numbers on the data sheets are usually end-point averages—the voltage is measured at two different temperatures, and the voltage difference of the two measurements is then divided by the temperature span. But the number will probably never be valid for the conditions the device will actually encounter, since end points are usually extreme temperatures, like −25 and +75 C.

Real temperature-drift plots are far from linear. They belly and flatten in different temperature regions. For many circuits the average drift spec is fairly accurate for small deviations in the region of 25 C (usually the area of lowest drift). For large deviations, the average coefficient can produce large errors.

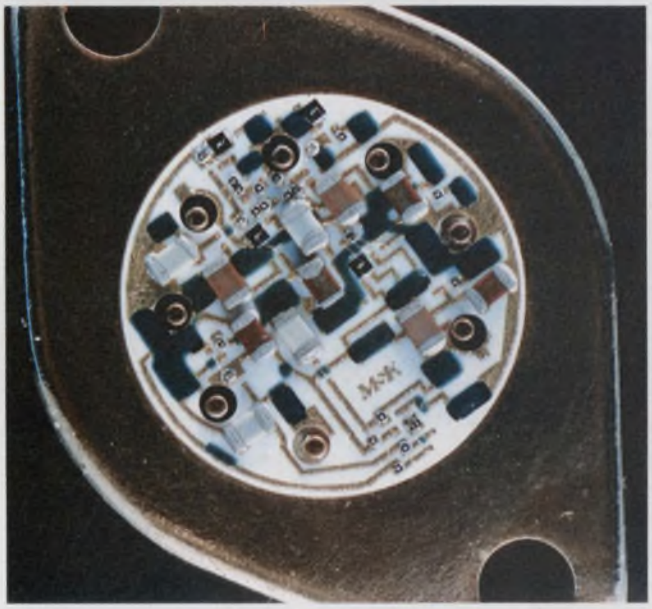
### The sneaky drift error

Most analog-function modules allow for external trimming of voltage and current offsets. But the external potentiometers have their own temperature coefficients and introduce a new drift error term that vendors don't always specify. For every millivolt of offset nulled out, an extra drift of several microvolts per degree C can creep in. Also the trimmer changes the current balance in several components, which causes other second-order drifts.

Voltage offset ($V_{os}$), input bias current ($I_b$) and input difference currents ($I_d$) occur in the input stages of op amps and related function modules. For instance, field-effect transistors have input bias currents that change exponentially—they double for every 10 C rise in temperature—while bipolar transistors change linearly. The basic bias current, before addition of the temperature drift, is measured at 25 C. Hence, if the operating temperature increases from 25 to 85 C, the bias current of a FET-input circuit increases by a factor of 64, while for a bipolar transistor circuit, the current merely doubles.

In addition to bias current drift, the bias currents cause problems due to the way they are measured. Module manufacturers use the higher of the two input currents while, for the most part, IC houses use the average of the two. Thus you can't directly compare bias current specs of modules and ICs.


**Modules made by Total Technology** include function generators, noise generators, voltage controlled amplifiers, antilog amps, bandpass filters, multipliers, and summing amplifiers.



**Model 780 high-slew-rate** hybrid op amp, from M.S. Kennedy, offers a 2000 V/$\mu$s slew rate with an output drive of 80 mA. It also has a 120-MHz bandwidth and is spec'd over the Mil temp range of −55 to +125 C.

### Noise: It's hard to measure

Signal sources, input resistors, internal components and power supplies—all introduce forms

## Table 1. Representative high speed linear circuits

| Company and model | Minimum slew rate | Settling time to 0.1% | Gain | Unity-gain bandwidth (min) | Cost 1 to 9 | Circuit type |
|---|---|---|---|---|---|---|
| Zeltex ZA910 M1 | 2000 V/$\mu$s | 200 ns | 120 dB | 70 MHz | $89 | Module |
| Optical Electronics 9826 | 1000 V/$\mu$s | 12 ns | 60 dB | 1 GHz | $42 | Module |
| Computer Labs FS125 | 250 V/$\mu$s | 80 ns | 100 dB | 30 MHz | $97 | Module |
| Dynamic Measurements 120 | 750 V/$\mu$s | 30 ns | 60 dB | 750 MHz | $95 | Hybrid |
| National Semi. LH0063 | 2000 V/$\mu$s | 15 ns | 0 dB | 70 MHz | $46 | Hybrid |
| Halex HX610 | * | * | 20 dB @ 100 MHz | 100 MHz | $30 | Hybrid |
| Analog Devices 505K | 120 V/$\mu$s | 800 ns | 100 dB | 10 MHz | $12 | IC |
| RCA CA3100H | 50 V/$\mu$s | 600 ns | 56 dB | 38 MHz ** | $4.25 | IC |

* - not listed on data sheet
** - typical values

of noise that affect a signal. Noise is easier to quantify if it can be separated into several adjacent or overlapping frequency bands. Since there is no industry standard for the bands, it's often difficult to compare noise specs from different vendors. Also manufacturers rarely use identical tests, measurement units and equipment for noise measurements.

Noise generated by the input stage, or input noise, is usually characterized in volts/$Hz^{1/2}$. Output noise is usually expressed in volts rms for frequencies above about 5 Hz, since it can easily be measured by rms-reading voltmeters. Below about 5 Hz, voltmeters are inaccurate, and scopes must be used. Thus peak-to-peak readings are used. To translate from input noise to rms output noise, multiply the input-noise spec by the square root of the bandwidth (closed loop) and then multiply by the closed loop gain. As a rule of thumb, you can then convert from volts rms to volts peak-to-peak by multiplying the rms output noise by six.

But rms doesn't always tell everything. For example, circuits like chopper-stabilized amplifiers, produce small spikes at the output. Vendors usually include the spikes in the rms noise figure. But the peak values of the spikes can be more than six times larger than the other noise components. Thus the noise spec would be much worse if expressed as peak to peak.

### Two kinds of power-supply rejection

Power-supply rejection has two forms: ac and dc rejection. Manufacturers rarely separate these on the data sheet.

Most vendors claim that all modules reject the ac noise that rides on top of the power lines since internal or external bypass capacitors act as a low-pass filter. But as frequency increases, rejection capability decreases due to internal stray capacitances.

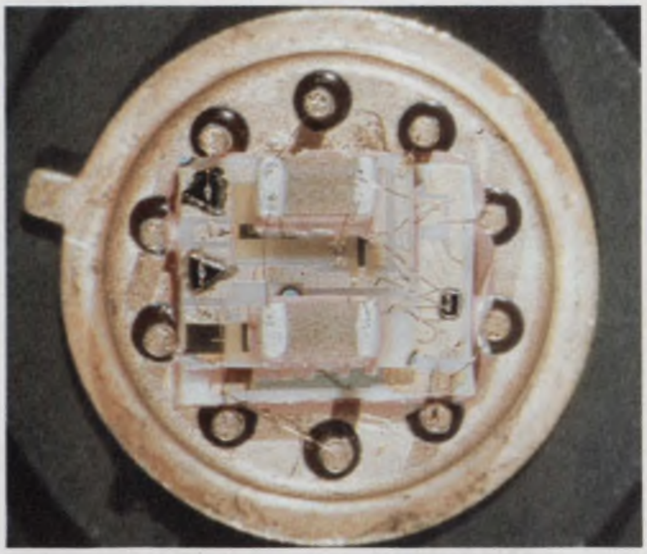
Changes in the dc supply voltage can cause errors in trimming voltages that are derived directly from the supply. Vendors seldom spell out the amount of such drift. When they do, various terms like $\mu$V/V change, %/% or decibels are used. The need for conversion from one to another just compounds the confusion.

### Open season for frequency response

Slew rate, frequency for full output and unity-gain bandwidth are just a few ways frequency response is specified. Slew rates vary with temperature, power-supply voltage, gain and other parameters. Most module vendors specify the slew rate at unity gain, as this is said to show the worst case performance for amplifiers with fixed compensation capacitors. But this doesn't tell how the amplifier will perform at gains higher than one.

Most vendors use a "fast rise-time" (how fast is fast?) pulse generator to provide a pulse the input can't follow. They then measure the output change and call it slew rate. Briefly defined, slew rate is the maximum rate of change of the output voltage for linear operation. Using the pulsed method, the vendor actually drives the unit into the nonlinear operating region, and the resulting "slew rate" is not really valid.

A simple formula, $S = 2\pi fE_p$, gives a simple way to approximate the slew rate of any circuit —providing you know the frequency for full out-



**Halex's Model HX610 hybrid** wideband amplifier delivers gain at frequencies beyond 100 MHz. When connected to a 100-Ω load the maximum output voltage at 100 MHz is 1.2 V pk-pk.

put (f) and the maximum voltage swing in one direction ($E_p$).

Full-power bandwidth or frequency for full-output—is often misspecified. It is probably best defined as the maximum frequency at which the unit can deliver rated output with minimal distortion. But this usually isn't done. Some companies test their units for full bandwidth and don't check the distortion at the output. Or, if they do, it is usually to an arbitrarily set percentage.

Some circuits can deliver usable power outputs at frequencies well beyond those specified for linear operation. Don't forget though, if you operate in the nonlinear regions, that offset voltages can be generated and must be compensated.

Since frequency response is gain dependent, vendors usually give the unity-gain bandwidth for "small signals" (how small is small?). Again, they assume that temperature remains constant. Usually they don't specify how gain varies as a function of temp, time, voltage, etc.

When bandwidth is measured, what is the gain of the amplifier at the beginning of the test? Some companies set the circuit so that they obtain a gain of 10 or so before the frequency is increased.

### The muddy waters of accuracy

If something is "accurate to 0.1%," does that mean percent of full-scale or of reading? And, is it referred to input or output? Vendors prefer to use percent of full-scale, since this enhances the apparent performance.

In many cases, accuracy is given for operation of units over their full-scale range. Once the range becomes restricted to, say, one-tenth of full-scale (by adjusting the scale factors or restricting the input signals), does the accuracy stay the same? Or is it still referred back to the maximum full-scale setting—thus becoming 10 times the original error?

Some modules are spec'd as having an error of so many millivolts plus a percent of full-scale. Others are just marked as a percent of reading or of full-scale, and still others are specified as a percent of reading plus a percent of full-scale. What does it all mean?

Settling time is associated with the frequency response of a circuit. Make sure you know which way it is defined, since there are no standard tests.

Is settling time measured from the time a step function is applied at the input? Or when the circuit output starts moving? The latter method ignores the signal propagation delay and shortens the apparent settling time considerably. Does the clock stop when the output stays within a percentage of its final value? Or when it first reaches the edge of the tolerance band? And for those devices that are spec'd at 0.01%, do you believe the vendor's equipment is accurate to 0.001%?

Other points to check are the gain for settling measurements, and the possible error on the output caused by a gain error. The output voltage is proportional to the input voltage times one minus the reciprocal of the closed-loop gain. The result times 100 gives the output error. For a gain of $10^5$, the percent error approaches 0.001%. As the gain decreases to $10^2$, the error increases to 1%. Now the output can't even get within 0.1% of the input. The gain would have to be at least $10^3$ to get an error approaching 0.01%.

### Op amp specs are fairly consistent

Of the many different types of functional modules, op amps are the oldest and therefore have the most standardized specifications. But there are still some areas—such as bias current and slew rate—where modular and IC op amps are specified differently.

Sometimes manufacturers spec a device using the noninverting inputs. The result is a set of useless parameters, unless you need a buffer. The use of an amplifier in the inverting, as opposed to the noninverting mode, has arguments on both sides. Some circuits can't use the positive input, since jobs like summing or integrating are ruled out. If signals are input to the noninverting terminal and the output is fed back to the input, positive feedback results and the amplifier saturates. The inverting inputs offer more versatility in circuit design.

Common-mode rejection (CMR) of an amplifier is a nonlinear function of the applied common-mode voltage. Also, it varies with temp and frequency and rejection deteriorates as frequency increases.

When vendors specify the common-mode range of an amplifier, they usually don't tell how the CMRR deteriorates as the limits are exceeded. The common-mode voltage ($E_{cm}$), sometimes called CMV, is the maximum voltage that can be applied simultaneously to both inputs while the output error is maintained to within a predetermined tolerance band.

Op amps fill many sockets, and there is no single type that's good for all applications. Table I lists some amplifiers that are noted for high speed and wide bandwidths. As can be seen in the table, modules with high slew rates and fast settling times are now starting to lose ground to some of the newer ICs and hybrids. Other vendors include Intronics, Teledyne Philbrick, Burr-Brown, ILC Data Device Corp., Intech, Function Modules, Hybrid Systems, M. S. Kennedy, Avantek.

One area in which modules are unlikely to be challenged by ICs is in handling large voltage swings. Dynamic Measurements Corp. probably has the best high-voltage unit on the market. Its Model 181 accepts a maximum differential voltage swing of 300 V, with a minimum slew rate of 100 V/μs. The common-mode voltage is ±135 V max, while the CMRR is 100 dB min. The amplifier can handle a capacitive load of 500 pF and delivers an output swing of ±140 V when the power supply is ±150 V. The gain at rated load is 110 dB min, and the unity gain bandwidth is 150 kHz.

Many other companies manufacture high-voltage op amps. They include Zeltex, Analog Devices, Teledyne Philbrick, Burr-Brown, Optical Electronics and others.

### Low power op amps available

At the other end of the op-amp power spectrum there are micropower op amps. These are finding growing use in battery operated instruments. Typical of the micropower modular op amps is the Teledyne Philbrick 140411. This draws only ±75 μA of quiescent current but delivers a respectable slew rate of 0.3 V/μs and an open-loop gain of 90 dB. Zeltex and several other companies also offer low power devices.

For low-power applications, ICs seem to have the edge. For example, Siliconix offers a triple micropower op amp—the L144. This circuit can be operated over supply voltages from ±1.5 to ±15 V simply by changing an external programming resistor. The external resistor sets the internal bias current of the op amps, thus controlling slew rate, gain, frequency response, and, of course, power consumption. The supply current for the three-amplifier chip reaches a maximum value of 400 μA. At the same time slew rates are 0.4 V/μs, while the gain is a modest 60-dB minimum.

Several other companies—National, Raytheon and Fairchild have micropower op amps with similar characteristics except that they are single rather than multiple amplifiers. These units are the LM4250, RM4132 and μA776, respectively.

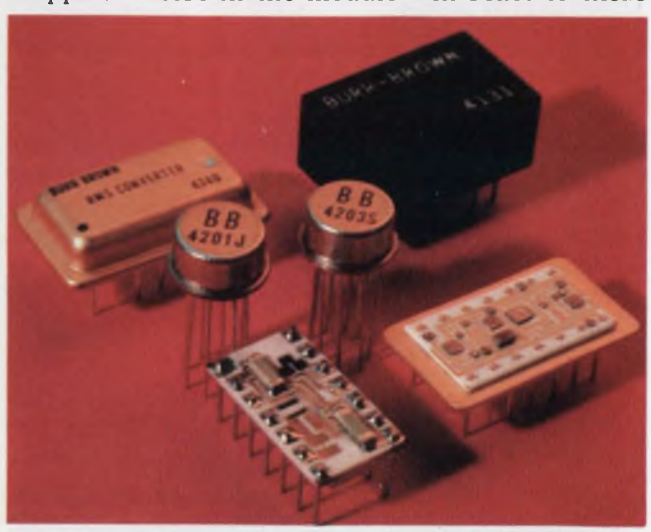
Also included in the price/performance race are quad op amps in a single IC package. National appears to be leading the quad race with the LM3900 and the LM324. While the 3900 doesn't have a true differential input, it can be operated from a low (5-V) single-ended supply. The newer unit, the 324, has true differential inputs and can also operate from single-ended supplies. Motorola, Raytheon and Texas Instruments will have quad devices on the market by the end of 1973.

### Choppers offer the lowest drift

Some amplifiers are designed to deliver extremely low drifts, usually less than 1 μV/°C and 2 μV/month. These are usually chopper-stabilized.

As an example of a chopper-stabilized amplifier, let's look at the Intech A-241. This unit has $V_{os}$ drifts of 0.05 μV/°C and typically 1 μV/month. Full-power bandwidth, though, is only 7.5 kHz, and the noise over a dc-to-10-Hz bandwidth is 2 μV pk-pk. Some of the other companies that offer chopper stabilized amplifiers are Analog Devices, Burr-Brown, Function Modules and Teledyne Philbrick.

Chopping frequency is one commonly omitted term. This becomes critical when the frequency of the measured signal is a subharmonic of the chopper. Filters in the module will react to these



**Burr-Brown makes these rms converter** modules that contain thermally coupled transistor pairs that accurately perform rms calculations without regard to waveshape.

# Table 2. Typical instrumentation amplifiers

| Company and model | Gain nonlinearity A=100 | Input impedence | CMRR A=100 | Frequency response (small sig.) | $V_{os}$ vs time | $V_{os}$ vs temp | Cost 1 to 9 |
|---|---|---|---|---|---|---|---|
| Function Modules 310 L | 0.02% | 500 MΩ | 100 dB | 10 kHz | 25 μV/month | 0.5 μV/°C | $75 |
| Burr-Brown 3625 C | 0.02%** | 300 MΩ | 80 dB | 50 kHz | 20 μV/month | 0.5 μV/°C | $59 |
| Analog Devices 605 L | 0.005% | 1000 MΩ | 94 dB | 300 kHz | * | 0.5 μV/°C | $80 |
| Datel AM-200 C | 0.1% | 10,000 MΩ | 100 dB | 25 kHz | * | 1 μV/°C | $49 |
| Zeltex 702M1 | 0.05% | 10,000 MΩ | 80 dB | 12 kHz | 15 μV/month | 20 μV/°C | $19 |
| Cycon CY1011A | 0.05% | 100 MΩ | 120 dB | 20 kHz | * | 1 μV/°C | $49 |

* - not listed on data sheet
** - typical

subharmonics and produce erroneous results.

A more unusual type of chopper amplifier is the MP221 produced by Analogic. Because the input signal is chopped at the input instead of later in the signal chain, $V_{os}$ drift is held to 0.05 μV/°C and 1 μV/month. As a result of the input-signal chopping, the full-power bandwidth is limited to 100 Hz, but over a dc-to-10-Hz bandwidth, noise stays below 0.3 μV pk-pk. Analog Devices also has this type of amplifier. A disadvantage of these chopper amplifiers is that they have limited bandwidths and are restricted to inverting inputs.

Until this year, chopper-stabilized amplifiers were available only as modules. Now, two companies have introduced chopper-stabilized circuits in monolithic and hybrid form. Texas Instruments came out first with its two-chip circuit, the SN72088, and close on its heels was the Harris Semiconductor HA2900—a truly monolithic circuit.

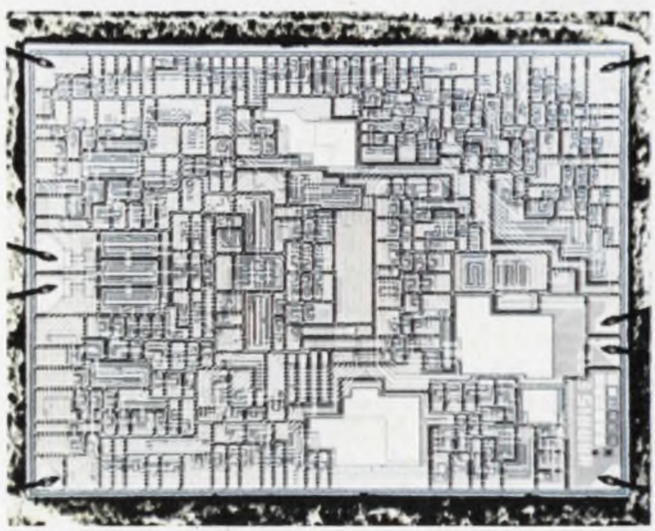
Another category of amplifier—the instrumentation amplifier also offers low drift. But these are primarily characterized by their constant CMRR during gain adjustments. Usually they need only one external resistor to set the gain, and the accuracy of gain tracking can be 0.1% or better while gain can be adjusted over a 1000-to-1 range.

Good instrumentation amplifiers offer the user CMRRs of over 100 dB combined with low drifts and input bias currents. For example, Zeltex's Model 770-440 keeps drift down to 2 μV/°C while the CMRR is a comfortable 110 dB. It uses a dynamic-bridge measuring technique that permits a gain nonlinearity of less than 0.01%, with six standard gain ranges from 20 to 1000 V/V. Output noise is only 4 μV rms, and the input bias current is 4 nA. Of the many companies that offer modular instrumentation amplifiers, Teledyne Philbrick, Analog Devices, Intech, Function Modules, Cycon, Datel, Burr-Brown and Optical Electronics are just a few. Some typical devices are listed in Table 2.

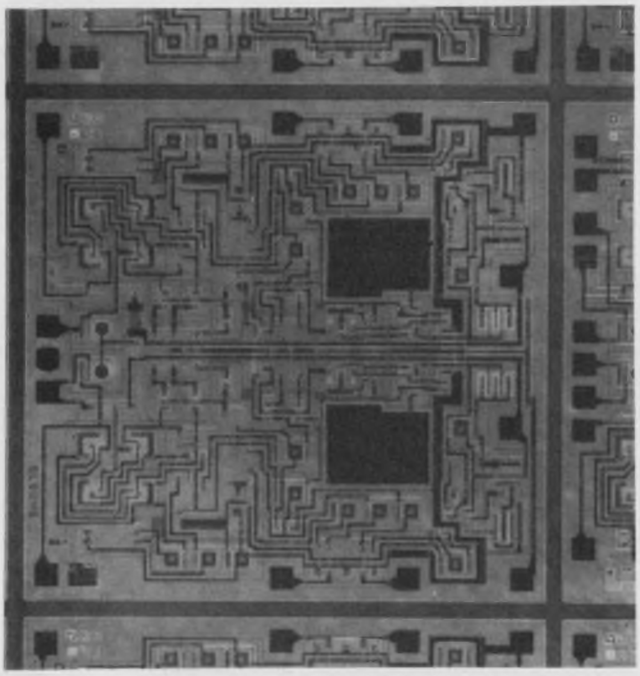
### Chips for instrumentation circuits

ICs are now finding their way into instrumentation systems. Analog Devices developed the first single chip instrumentation amplifier—the AD520, which needs only a few passive external components and has the constant CMRR and other features associated with true instrumentation amplifiers.

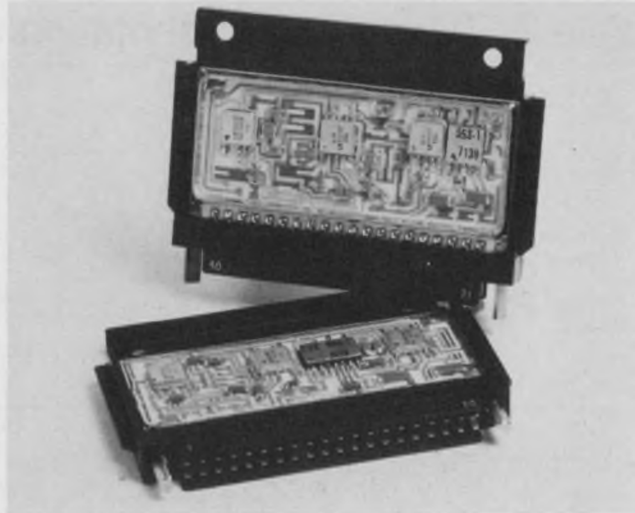
Some "premium" IC op amps exhibit many instrumentation qualities. For example, Precision Monolithics has developed the OP-05A—a high-quality op amp with an offset voltage of 150 μV maximum and a drift of 0.9 μV/°C. Input bias currents are only 2 nA maximum, while the open-

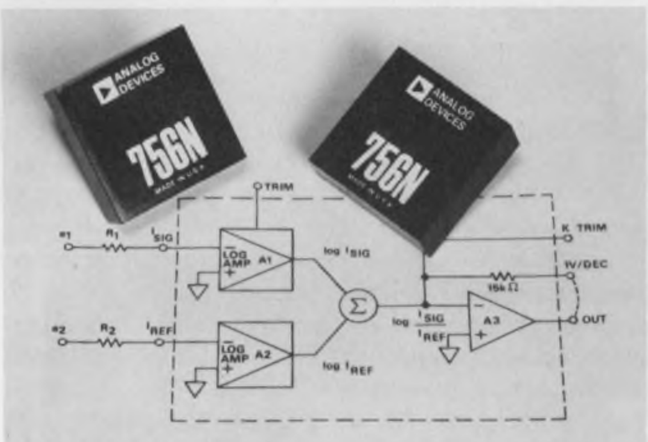


**By combining bipolar and MOS** technologies, Harris Semiconductor has developed the first truly monolithic chopper-stabilized op amp with differential inputs.



**Intersil's new log and antilog amplifiers** are the IC industry's latest thrust into the traditional module market.






**A log-ratio module, the 756,** introduced by Analog Devices can convert either current or voltage ratios into log terms. It uses a unique internal summing mode.

loop gain is well over 100 dB and the CMRR is 110 dB min. Other companies have units in this class—Fairchild, for instance, introduced the $\mu$A725, which others have second-sourced.

Parametric amplifiers using varactors offer lower input currents than other types of amplifiers. In other respects they are comparable to instrumentation amplifiers. Paramps offer input currents of a few femtoamperes (fA). For example, Teledyne Philbrick has Model 1702, its input bias current is so small—only 5 fA—that there is more leakage through the insulating plastic around the power-supply leads than the input current. Special guards and Teflon insulators and sockets must be used to keep this leakage to a minimum. Because of the low input currents, these amplifiers tend to have very limited bandwidths—typically 1 kHz for unity gain and less than 50 Hz for full power.

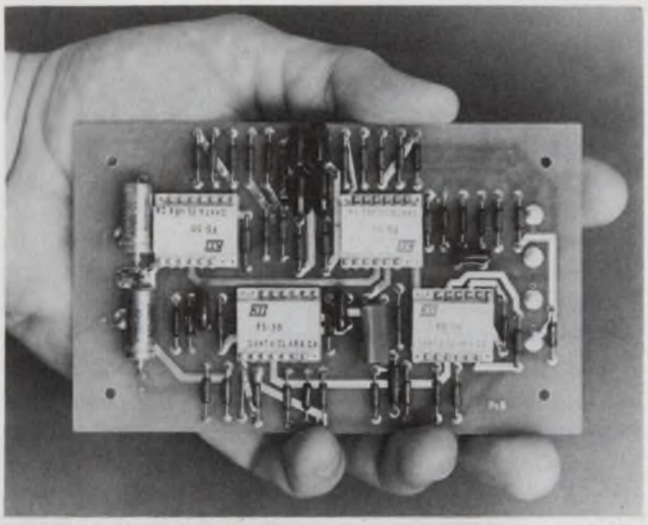
Function Modules and Analog Devices also have varactor-input amplifiers with input bias currents from 10 to 50 fA. Some types have asymmetrical input characteristics and are intended for inverting or noninverting operation only, but they also offer wider bandwidths than the Teledyne Philbrick differential-input types.

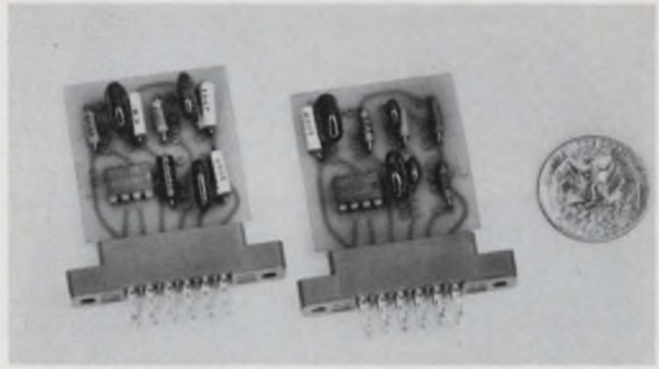
In terms of performance, isolation amplifiers are closely related to both instrumentation and parametric amplifiers. Situations that require high isolation, in the presence of high common-mode voltages, call for devices like the Analog Devices Series 272 or the Burr-Brown Model 3450/51. These isolation amplifiers can withstand common-mode voltages as high as 5000-V pulsed or 1000-V continuous. Thanks to internal dc-to-dc converters and transformer coupling, there is no connection between input, output and power supply. The input impedances of these units run as high as $10^{12}$ Ω, and the CMRRs can reach 115 or 120 dB.

One important category that merits mention is modular rack-mounting instruments. These units offer the ultimate in low drift, bias currents, high accuracy, stability and noise. Some of the many companies in this precision field are Preston Scientific, with its Series 8300; Newport Labs, with its Series 60/70A; Dynamics Electronic Products and Nanodyne.

### Special cases: log amps

Since logarithmic amplifiers are basically current-operated circuits, their range is specified over decades of input current, usually from 10 nA to 1 mA—a range of five decades. Log conformity specs tell you how well the amplifier will conform to its log curve and how far it will deviate. The specs are broken into several range spans—usually over two decades at a time. This





**Active filters come in all shapes** and sizes as demonstrated by the NAFI module made by Circuit Technology Corp. (left), the hand-held circuit card made by KTI (center) and the small plug-in circuit cards made by DeCoursey Engineering Labs (right).

lets the conformity spec appear very accurate, since it can appear as 0.1% over two decades but only 1% over the entire range.

As the input current of a log amp varies, so does the bandwidth and slew rate. The typical bandwidths of log amps range from hertz in the nanoamp regions to well into the kilohertz range for milliampere-sized currents.

Scale factors of log amps are set in much the same way as with op amps. A resistor in series with an antilog element generates the scale factor K. This varies with time, temperature, and, of course, component tolerance. Note that log amps are unidirectional devices—since the log of zero is asymptotic, modules must be specified with respect to the voltage polarity—0 to 10 V or 0 to −10 V. In antilog modules the scale factor is even more important, since it appears in the exponential term instead of as a constant multiplier.

There are now several modules than can take the log ratio of two currents or voltages. These units suffer from the same ills previously discussed for log amps, but they double the trouble, since they include the equivalent of at least two log amps and an antilog amp.

Five log modules on the market are unusual. The Analog Devices Model 756 log-ratio unit can take the ratio of either currents or voltages by using an internal summing node most other units don't have. Intech's multifunction log module, the A-733, can do $Y(Z/X)^m$ functions with accuracies as high as 0.5%, while Analog Devices' Model 433B claims 0.25% accuracy for the same job. The Teledyne Philbrick 4356 ac log amp can deliver the $\sinh^{-b}$ function and is linear through zero. The Burr-Brown 4116 log amp offers a 120-dB dynamic range with over-all 1% accuracy and 0.2% accuracy for a three-decade span.

Until recently you could buy a log amp only in modular form. Companies like Burr-Brown, with its 4116, Analog Devices with its 750 series, Teledyne Philbrick with its 4350 series and Function Modules with its 530 series more or less dominated the market. ICs are now starting to invade the marketplace. Intersil has two circuits available—the 8048, a log amp and the 8049, an antilog amp and Texas Instruments has the 76502, a log amp with four 30 dB-V log stages. Compared to modules their performance leaves something to be desired, but they are the smallest log circuits available.

### Filtering out filter spec problems

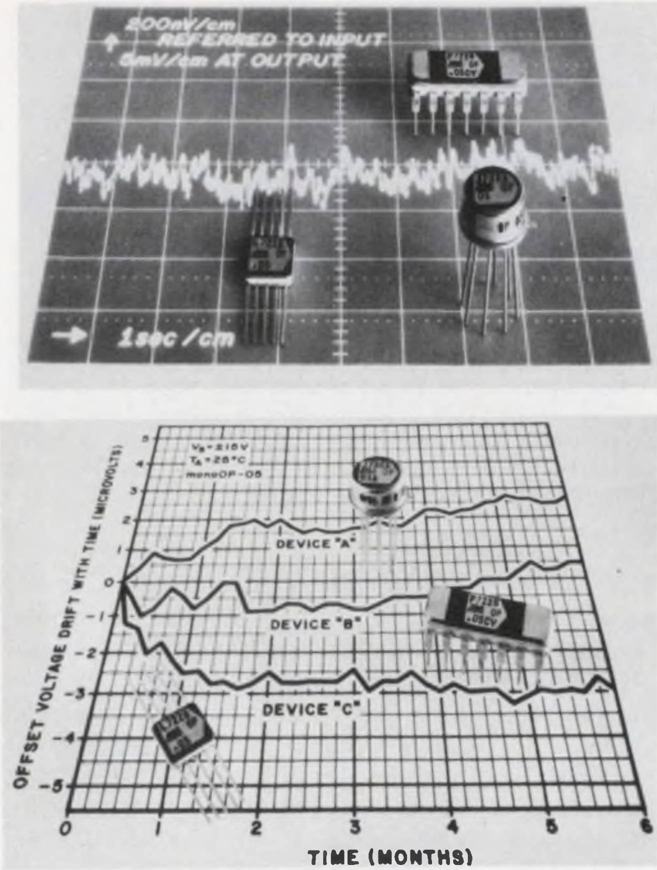
Active filters use many op amps and are subject to many of the same ills. In addition, several specifications are peculiar to filters.

If there is gain in a filter, how does it change due to amplifier variations? Also, if the filter acts as a bandpass device, how is the center frequency affected by drift in the amplifiers caused by temperature, time and voltage?

As an example of the specification problems, consider a case presented by Ferritronics of Canada: A bandpass active filter has a specified frequency range, temperature range and Q. If the bandwidth of the filter (-3 dB points) is of the order of 1% of the filter center frequency and the filter stability is about 200 ppm/°C, there is a shift of 2% over a 100-C temp range. But this shift takes the filter out its band, so of what use is the filter's excellent selectivity.

You can get many different filter responses—Butterworth, Cauer, elliptic or Chebychev—and each has different specs for you to worry about. The Butterworth response is the smoothest, with no ripple in the passbands or stopbands. Cauer, elliptic and Chebychev filters have ripple in either the passband, stopband or both. Therefore the designer should always specify ripple and cutoff steepness, keeping in mind the allowable tolerances of the components that are available to build the actual filter.

Zero phase shift and sharp cutoff tend to be




**Precision Monolithics' OP-05A** offers the best low noise (upper) and low drift (lower) specs for monolithic ICs.

mutually exclusive. A more practical approach is to settle for a linear phase shift if you need sharp cutoff.

Many companies are now using computer-aided design techniques to shorten design time and determine the stability of the final design. For example, Kinetic Technology has several computer terminals and uses a very easy-to-follow program that can determine all filter parameters. Use of a universal building-block approach by KTI allows the filter to be mass-produced and results in lower cost to the user. Only a minor job is left for the user: He must leave room and lay out his circuit for two or three external frequency-determining components.

Companies that manufacture complete filter modules contend that engineers don't want to spend time designing circuit boards for filters; they want something they can plug right in. And they point out that if an engineer does his own tuning, he is forced to stock a large number of precision resistors and to perform tedious and costly tuning procedures.

R. H. Simmons, sales vp of Polyphase Instrument Co., feels that LC and active filters should be used side-by-side—each where it is most cost effective. Below 100 Hz (down to 0.001 Hz) the actives usually have the edge; from 100 Hz to about 20 kHz the decision depends on the sophistication of the circuit goals. For even higher frequencies, active filters lose ground to the passive types, since high-frequency op amps are expensive. Though passive filters must be matched at the input and output to prevent losses, actives needn't be carefully matched, since they provide up to 60 dB of signal gain. One disadvantage of active filters, however, is that they're limited to relatively low signal voltages—lower than the supply voltages.

The information engineers give to filter manufacturers usually isn't sufficient to fully specify a module. The filter user should give complete response data for the magnitude curves, phase and delay characteristics (the filter's response in the time domain) and special operating conditions (low power, noise, stability, temperature, etc.). All manufacturers recommend that filter users work with applications engineers to separate the characteristics they need from the chaff.

The universal-active-filter approach taken by companies like KTI, Beckman and Burr-Brown uses the state-variable technique. Small modules —discretes and hybrids—generate both second-order numerator and denominator terms (biquadratic) and can be cascaded to realize higher order functions.

KTI has recently developed and patented a new filter synthesis technique called the primary resonator block. This allows the design of multiple pole-pair bandpass filters with sensitivities equal to those of their passive counterparts. Stability of the filter Q, is also improved.

Other, more exotic types of filters exist. Non Linear Filters, Inc., has its Model 1P1, which can eliminate noise. It is equivalent to a slew-limited amplifier that introduces negligible phase lag either inside or outside the passband, as required.

Aside from universal filter blocks, many companies have full product lines of pretuned filters or offer custom designs for all applications. They include companies like KTI, Frequency Devices, A. P. Circuit Corp., DeCoursey Engineering, Burr-Brown, Micropac Industries, Circuit Technology, Sprague, Ferritronics and Optical Electronics.

### Multiplying the problem

Analog multiplier specs depend on two or three input variables. Also various methods are used to do the multiplication—from Hall-effect devices and variable-transconductance circuits all the way to log-summing schemes. Each type has its merits, but to keep the discussion simple, let's concentrate on the popular variable-transconductance multiplier.

Basically multipliers accept two input signals —say, X and Y—and produce their product divided by a scale factor (usually 10). A "four-quadrant" circuit can handle input voltages of either polarity while a one or two-quadrant unit has a restricted input-polarity range.

Output accuracy is a function of both inputs and a scale factor. The output of the basic variable-transconductance multiplier contains an offset voltage that must be trimmed out.

But trimming introduces new drift terms because of the trimmer pots added to the circuit. Also the nulling is frequency-dependent, so that as frequency increases, ac error also increases. Data sheets should specify the frequency at which null measurements were made.

Most transconductance multipliers fall into the 2, 1 or 0.5% accuracy-tolerance groups after they are trimmed. With inputs X and Y limited to ±10 V in most cases, the multiplier outputs are usually 10 V max. For a 1% tolerance on the accuracy, the error for the max output is 100 mV. If input signals drop to only 1 V each, the output voltage would be 100 mV ±100 mV—a 100% error. Actually this much error never occurs. As a rule of thumb, when the output voltage drops below two-thirds of the maximum rated level, the output error tracks the output voltage. Therefore when the inputs are 1 V, the output error would be only 1 mV.

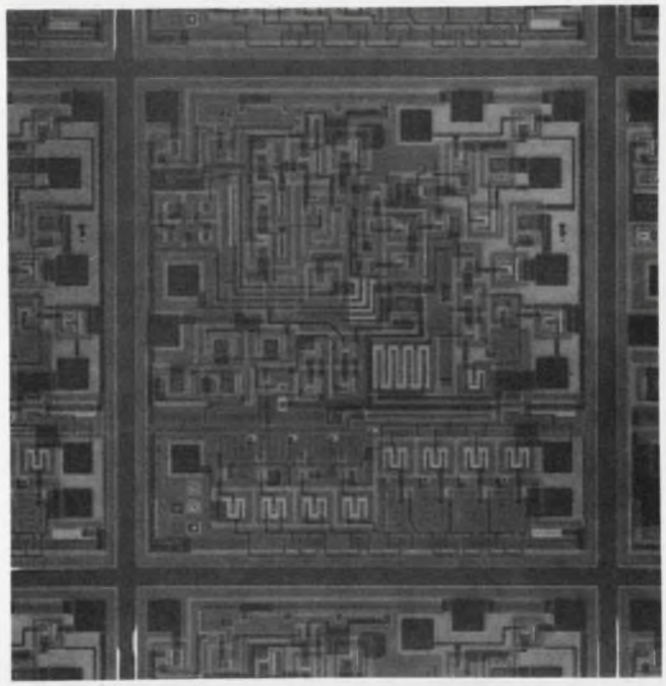
Feedthrough occurs when one input voltage is zero, the other input has a signal and an output voltage exists. The worst-case value of feedthrough is for a 20-V pk-pk signal on one input and 0 V on the other—most of the time measured at a frequency of 50 Hz. Without external trimming, this value can run as high as 50 mV pk-pk; when trimmed, it can be reduced to about 10 mV.

Linearity is defined as the maximum deviation from the best straight line at rated load, voltage and temperature. It can be measured by application of a full-scale dc input to one line and an ac voltage to the other. By nulling the output ac voltage against the input ac, you can see the nonlinearity. Another method involves measuring the output's harmonic distortion, which is usually caused by second and third-order harmonics.

As frequency increases, so does phase shift. The vector errors resulting from the shift can cause worse problems than gain error. Phase shift usually stays below 1 degree, and will then cause a vector error of less than 2%. Thus the response of a multiplier to high frequencies is phase-limited. Companies sometimes specify response for a small-signal vector error of 1%. This is the same as a phase shift of 0.57 degree.

### The hush-hush divide mode

Manufacturers rarely specify how well their multiplier/dividers will work in the divide mode. The denominator range is very important. A four-quadrant device is good only for two quadrants if used as a divider, because if the divisor value is negative, the feedback is positive and the multiplier saturates. To eliminate the positive feedback condition that occurs when the inputs to a divider go through zero an absolute-value amplifier can precede the input signal. The frequency response for the divider is then proportional to the magnitude of the divisor voltage. Even worse, the divider accuracy depends directly on the divider voltage.

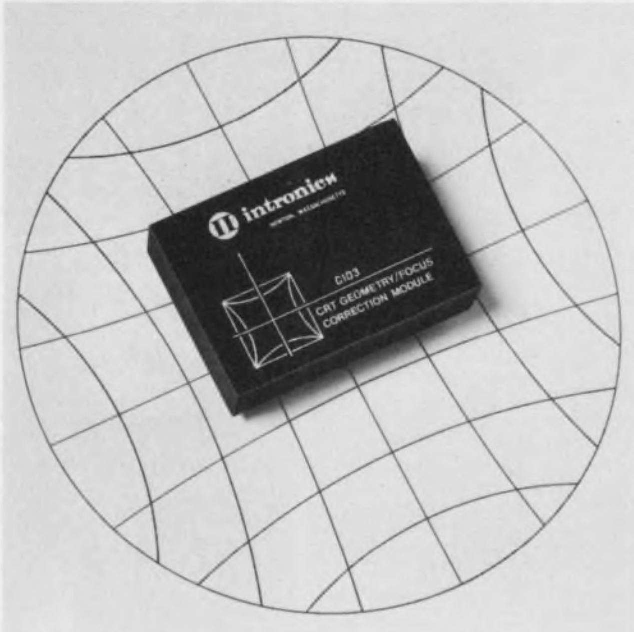


**Waveform generators are fast shrinking** in size but growing in performance. The example shown is the Intersil 8038—a monolithic multiple waveform generator.

Offset errors in the divide mode produce a fixed output error independent of both the numerator (Z) and the divisor (Y) and another error that is inversely proportional to the divisor magnitude. The end points of the divisor limits should be specified to aid the designer.

Multipliers are available in many accuracy levels, either trimmed or untrimmed and with or without output op amps. Among the better variable-transconductance units are the 550 series from Function Modules, which offer total error from 0.5 to 0.1%. This is without external adjustments and includes all offset, gain and nonlinearity error. Frequency response, though, is a low 150 kHz max at the −3 dB points for the 0.5% unit, and this drops to 25 kHz for the 0.1% unit.

Zeltex also has a high accuracy transconductance unit. Its ZM 606 is guaranteed to 0.5% total error with no external trimming, and it has a 3-dB bandwidth of 100 kHz. Most other module houses have units that can be externally trimmed to these tolerances, but then the additional drift factors come into play.




**CRT pincushioning** can be corrected by use of circuits like the Intronics C103 CRT geometry/focus correction module.

Companies like Intech, Analog Devices, Burr-Brown, Teledyne Philbrick, Intronics, Hybrid Systems and Optical Electronics have units that are externally trimmable. Motorola pioneered the development of the monolithic multiplier with the MC1495 and now offers several different types. Analog Devices has recently introduced a "monolithic," differential input multiplier, the AD 532, which has several thin-film, laser-trimmed resistors on the same chip and an accuracy of 1%. Burr-Brown also offers one of the laser-trimmed types with very similar specs, but at a higher price. Intersil has a monolithic multiplier, the 8013, which requires external trimming to attain accuracy of 0.5%.

Vector generators and pincushion-correction modules use multipliers to calculate the square root of the sum of the squares in two or three dimensions. All of the usual multiplier/divider errors apply, but they are tripled, since there are many more components. Companies like Intronics, Intech and Optical Electronics are some of the suppliers.

Some rms conversion circuits use the multiplier technique to get the rms value of an input signal. Some of the newer units from Burr-Brown use a thermal technique to obtain extremely high accuracies at reasonable costs. Errors for rms modules are usually specified as several millivolts plus a percent of reading. All rms converters tend to be slow but the thermal rms units usually react slower than computing types.

Burr-Brown's Model 4130K rms module uses a thermally coupled monolithic transistor pair. When trimmed, the accuracy of the unit is specified as 0.025% of input signal plus 0.025% of full scale. The bandwidth is 40 Hz to 100 kHz for rated accuracy, but settling time for large input changes runs anywhere from 2 to 10 sec.

Typical of the calculating rms modules is the Intronics R101, which can handle all types of waveforms from dc to 500 kHz. Accuracy is 10 mV + 0.1% of reading when the offset and scale factor are trimmed. The bandwidth spec is based on a 20-V pk-pk input signal and allows for a 1% output error. Most calculating units on the market include a filter for averaging, and in the Intronics unit the time constant is set for 2 ms. Higher accuracy computing units are available from Intronics and many other companies, including Analog Devices, Burr-Brown, Optical Electronics, Teledyne Philbrick and Intech.

Another type of circuit that uses multiplier techniques is the CRT waveform manipulator manufactured by Optical Electronics. The 6100 series of modules generates aerial and geometric perspective, interposition, parallax movement (rotation), depth of focus and binocular (stereo) depth cues.

### Circuits that can do even more

Modular circuits are continuing to advance with the development of variable transfer-function generators that can output any desired arbitrary function. Built-in pots adjust the curve breakpoints; the larger the number, the smoother and more arbitrary the desired function. Teledyne Philbrick is one of the companies that offers these diode-function generators.

Fixed waveform generators up until the last few years have been available only as instruments. Cal Tek Engineering has just introduced a modular waveform function generator that outputs sine, square and triangle waves simultaneously. The module contains oscillators, waveshapers and all the other circuitry needed to deliver all three signals. And, it operates over a frequency range of 0.1 Hz to 1 MHz. Total Technology also has a similar unit but it's limited to about 50 kHz.

Specs for this type of waveform generator need clarification. Linearity for triangular waves can be measured in different ways. Does the maximum deviation from the best straight line tell the story or is it the differential straight line approximation? The differential approximation method has the edge by a 4-to-1 margin.

When it changes direction, does the triangle wave have a switching offset? This occurs with some IC waveform generators. Or does the slope want to continue to integrate instead of switch? This is due to the finite settling time of the amplifier, and is more visible at high frequencies.

Also the integrator should have a slew-rate capability of about five times the maximum required to avoid rate limiting.

Challenging modular function generators are some of the new ICs from Intersil and Exar—the 8038 and 2207, respectively. The 8038 delivers sine, square and triangle waves at frequencies up to 1 MHz. The XR-2207 gives only triangle and square waves, also at frequencies up to 1 MHz. The stability of the Intersil unit can be chosen by the user from 100 ppm/°C to 10 ppm/°C, depending on cost and temperature. Both units offer linearity errors of less than 1% and 1000-to-1 swept-frequency ranges.

### Things to come

Circuits being readied for release next year include a programmable three-function waveform generator on a chip—four user-selectable frequencies can be set by external resistors, and digitally programmed by a binary input.

There is a growing need for programmable amplifiers in data-acquisition systems. Burr-Brown already has a modular programmable-gain amplifier, and Harris Semiconductor sells an unusual quad amplifier in which a two-bit binary input selects any one of the four possible outputs. Other companies are expected to emphasize digital control in new amplifier designs. Look, too, for more companies to introduce micropower op amps to meet the requirements of portable instruments.

Modules are becoming more complex as ICs and hybrids peck away at the lower-performance end of the market. Systems of today are becoming tomorrow's modules or hybrids and next year's monolithic ICs. ■■

## Need more information?

The companies and products cited in this report have, of necessity, received only brief mention. They've been selected for their illustrative or unique qualities. Other companies may offer similar products. Readers may wish to consult these manufacturers for further details:

A D C Products, 4900 W. 78th St., Minneapolis, Minn. 55435. (612) 835-6800. **Circle No. 365**

A P Circuit Corp., 865 West End Ave., New York, N.Y. 10025. (212) 222-0876. **Circle No. 366**

Adaptive Systems, P.O. Box 1481, Pompano Beach, Fla. 33061. (305) 974-8354. (W. Vlasak). **Circle No. 367**

Aerojet General, P.O. Box 460, Frederick, Md. 21701. (301) 662-4181. **Circle No. 368**

Allen-Bradley Co., 1201 S. Second St., Milwaukee, Wis. 53204. (414) 671-2000. (H. Rosenkranz). **Circle No. 369**

Altec Div., Altec Corp., 1515 S. Manchester Ave., Anaheim, Calif. 92803. (714) 774-2900. **Circle No. 370**

American Aerospace Controls, 131 Verdi St., Farmingdale, N.Y. 11735. (516) 694-5100. **Circle No. 371**

Amperex Electronic, Providence Pike, Slatersville, R.I. 02876. (401) 762-3800. **Circle No. 372**

Analog Devices, Inc., Route 1 Industrial Park, Norwood, Mass. 02062. (617) 329-4700. (F. Pouliot) **Circle No. 373**

Analogic Corp., Audubon Rd., Wakefield, Mass. 01880. (617) 246-0300. **Circle No. 374**

Aritech Corp., 130 Lincoln St., Brighton, Mass. 02135. (617) 254-2990. **Circle No. 375**

Astrodata Inc., 240 E. Palais Rd., Anaheim, Calif. 92803. (714) 772-1000. **Circle No. 376**

Astrosystems, Inc., 6 Nevada Dr., Lake Success, N.Y. 11040. (516) 328-1600. **Circle No. 377**

Avantek, Inc., 3175 Bowers Ave., Santa Clara, Calif. 95051. (408) 739-6170. (Stephen B. Witmer) **Circle No. 378**

B F Electronics, 415 S. Nardo Ave., Solana Beach, Calif. 92075. (714) 755-1881. **Circle No. 379**

Beckman Instruments, Inc., Helipot Div., 2500 Harbor Blvd., Fullerton, Calif. 92634. (714) 871-4848. (L. Pittroff) **Circle No. 380**

Bell, F. W. Inc., 4949 Freeway Dr., East Columbus, Ohio. 43216. (614) 888-7501. **Circle No. 381**

Bell & Howell, 706 Bostwick Ave., Bridgeport, Conn. 06605. (203) 368-6751. **Circle No. 382**

Betatronics Inc., 9440 Lincolnwood, Evanston, Ill. 60203. (312) 676-1747. (H. Allen). **Circle No. 383**

Bourns, 1200 Columbia Ave., Riverside, Calif. 92505. (714) 684-1700. **Circle No. 384**

Bulova Watch Co., Frequency Control Products, Electronics Div., 61-20 Woodside Ave., Woodside, N.Y. 11377. (212) 335-6000. **Circle No. 385**

Bunker-Ramo, 900 Commerce Dr., Oak Brook, Ill. 60521. (312) 654-3100. **Circle No. 386**

Burr-Brown Research Corp., International Airport Industrial Park, Tucson, Ariz. 85706. (602) 294-1431. (D. Haynes). **Circle No. 387**

CTS Corp., 905 N. West Blvd., Elkhart, Ind. 46514. (219) 293-7511. (R.A. Stackhouse). **Circle No. 388**

Cal Tek Engineering, 29 Pemberton Rd., Wayland, Mass. 01778. (617) 653-0355. (D. Sheehan). **Circle No. 389**

Calex, P.O. Box 555, Alamo, Calif. 94507. (415) 932-3911. (J. M. Francis). **Circle No. 390**

Centralab, Electronic Div. Globe Union, 5757 N. Greenbay Ave., Milwaukee, Wis. 53201. (414) 228-1200. (A. J. Koschnick). **Circle No. 391**

Cermetek Inc., 660 National Ave., Mountain View, Calif. 94040. (415) 969-9433. (W. Curtice). **Circle No. 392**

Circuit Technology, 160 Smith St., Farmingdale, N.Y. 11735. (516) 293-8686. (M. Spitz). **Circle No. 393**

Columbia Components, 60 Madison Ave., Hempstead, N.Y. 11550. (516) 483-8200. (L. Eagle). **Circle No. 394**

Computer Labs, 1109 S. Chapman, Greensboro, N.C. 27403. (919) 292-6427. (D. W. Brockman). **Circle No. 395**

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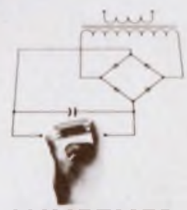

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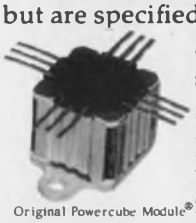

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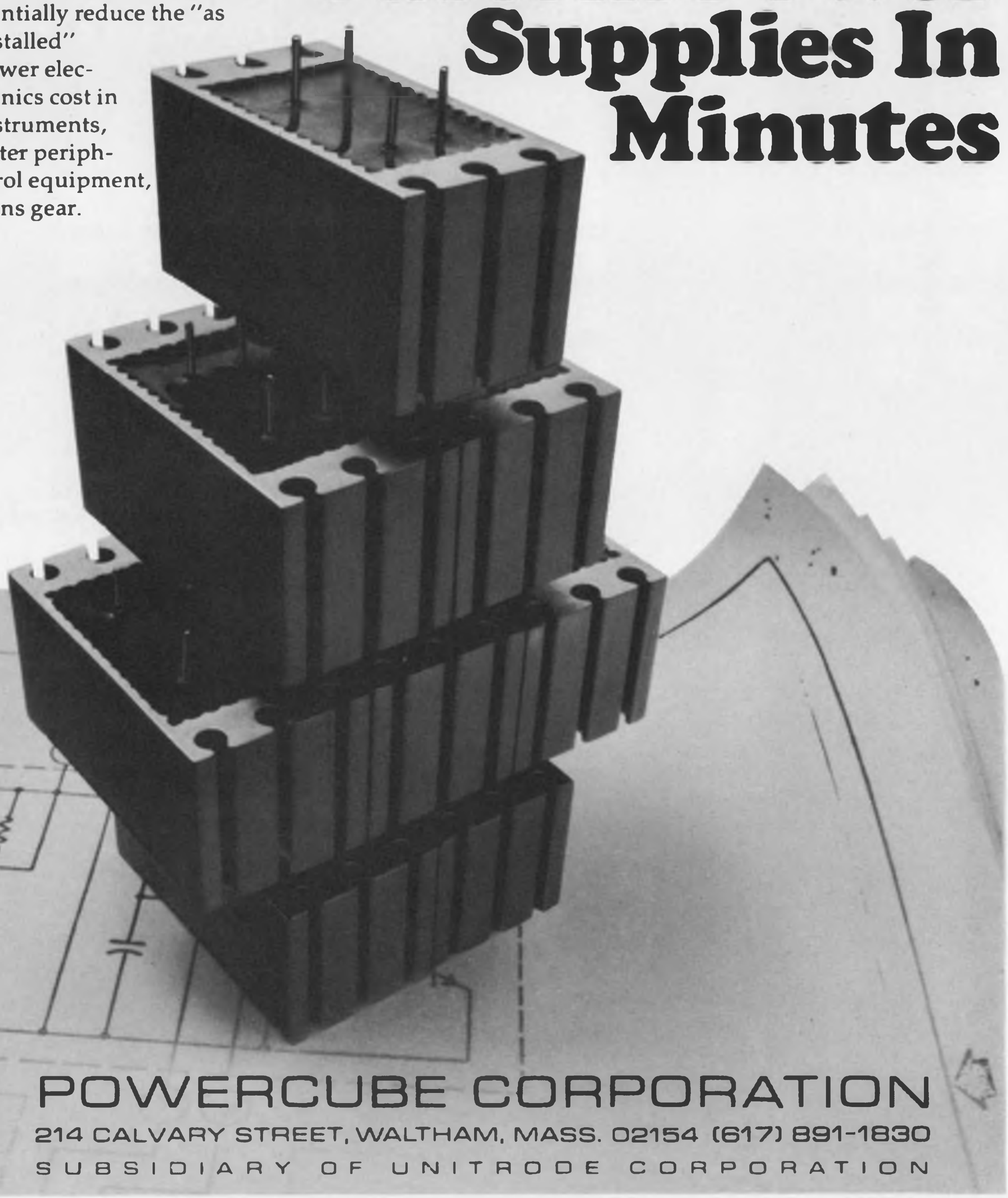

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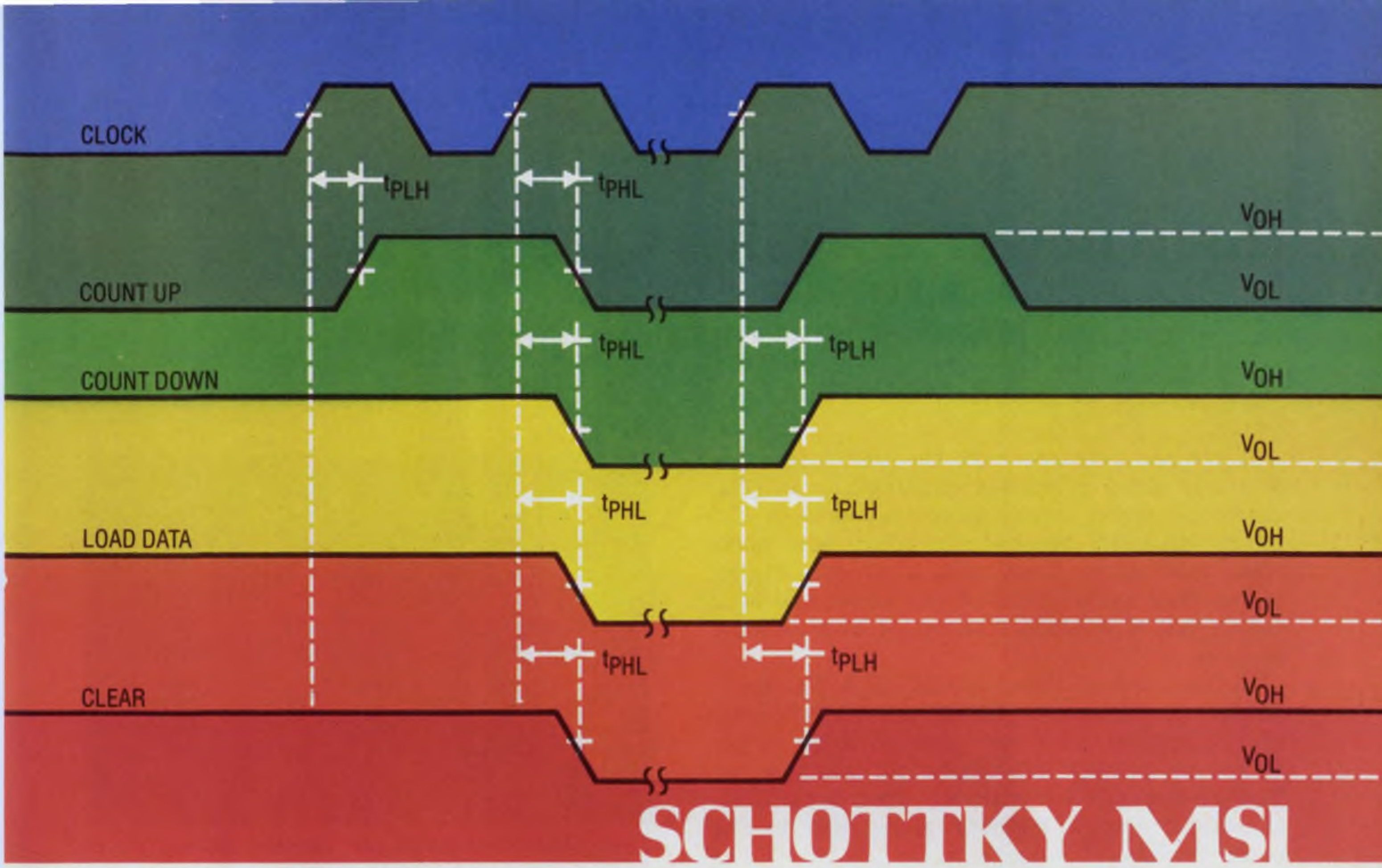


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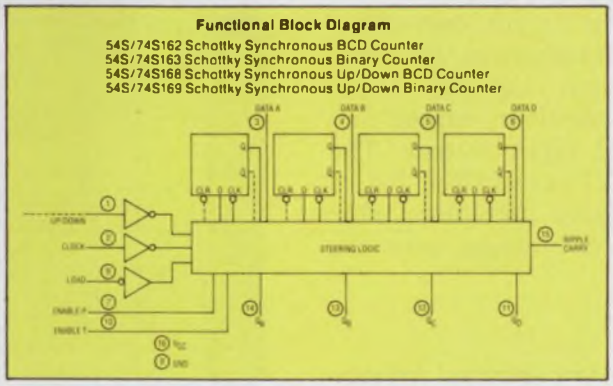


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# Build power amplifiers with IC drivers

that act as 'transconductance amplifiers.' The circuitry is simple and few external components are needed.

If you are a designer who has limited your use of IC op amps to voltage amplification at relatively low power levels, enter the world of "IC power drivers." Several manufacturers make them today at moderate cost. They offer higher power than conventional IC op amps, and they enable you to minimize the use of discrete components.

Devices such as Motorola's 2870MR, National's LH0041 and Signetics' SE540 are transconductance amplifiers that can directly drive power stages to provide an output of, say, 90 W. They're easy to work with, too. Most conventional op-amp design methods apply also to the power drivers.

To appreciate the usefulness of the new ICs, we'll examine some practical circuit designs. But, first, let's briefly consider the advantages of transconductance amplifiers.

## Op amp as a transconductance amplifier

The term "transconductance amplifier" is familiar to most vacuum-tube designers (if there are still any around). It is defined as

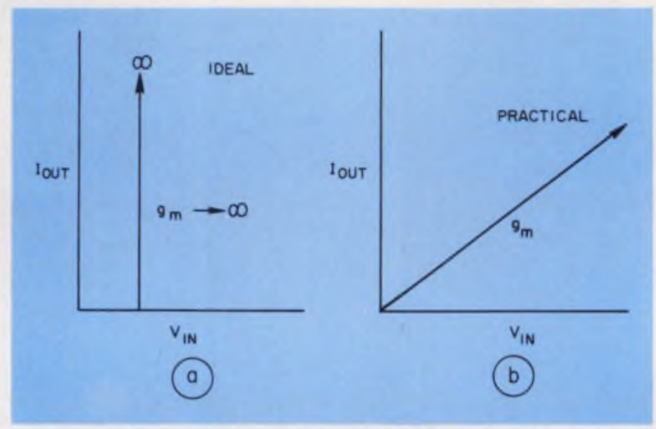
$$g_m = (dI_b/dE_c) \mid e_b = \text{constant},$$

where $I_b$ is total current through the tube, $E_c$ is grid voltage, and $e_b$ is plate voltage.

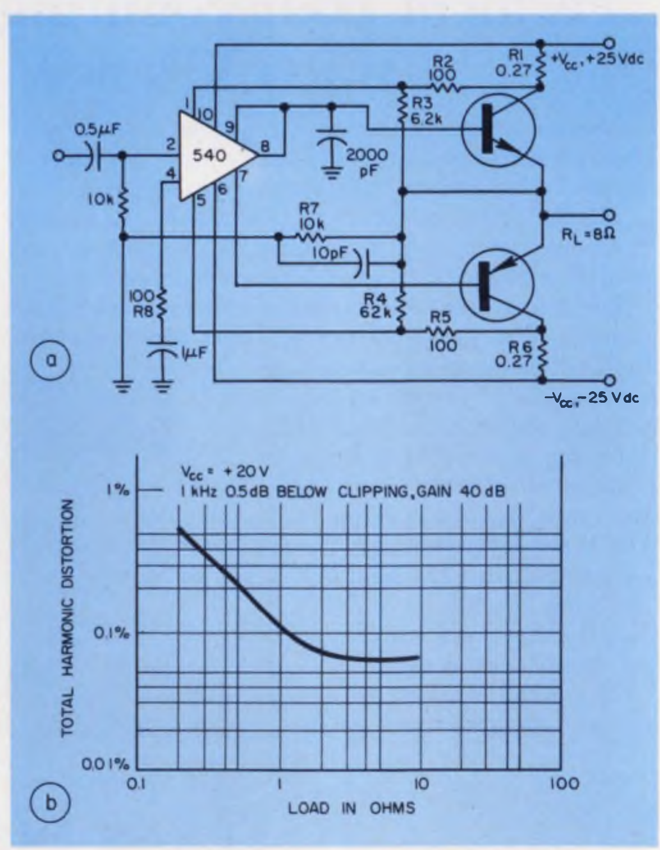
In general, a transconductance amplifier, for some input voltages, produces a proportional output current. As shown in Fig. 1a, an ideal transconductance amplifier has an infinite $g_m$ and, consequently, an infinite output current. In a practical transconductance amplifier, output current is a linear function of input voltage. The $g_m$ is then the slope of the VI curve (Fig. 1b).

In general, transconductance amplifiers offer the following performance advantages over the standard op amps:

- Simple compensation.
- High input impedance.
- Reduced noise (due to low internal voltage swing).

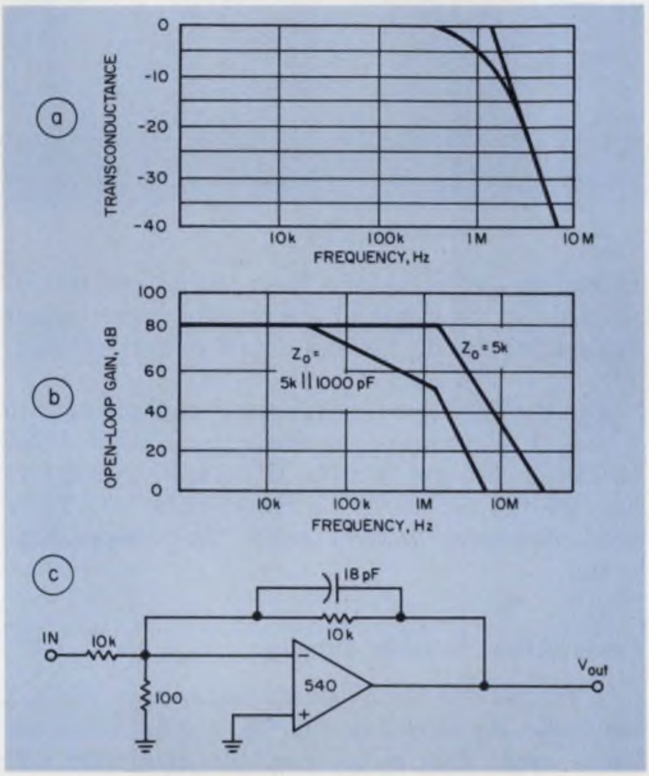



1. **An ideal transconductance amplifier** (a) has an infinite $g_m$ and, consequently, current. In practice, however, the current-vs-voltage curve is a linear function, with $g_m$ being the curve's slope (b).

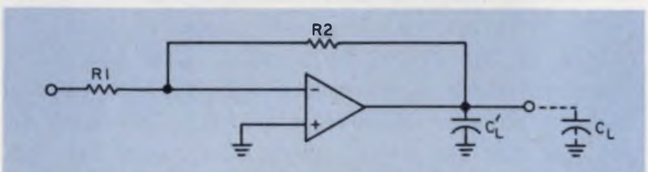



2. **Amplifier with 35-W output** (a) has a relatively low total harmonic distortion (b).

**George Opalinsky,** Linear Applications Engineer, and **Werner Hoeft,** Linear Design Engineer, Signetics, Sunnyvale, Calif. 94086.




3. **Constant transconductance over a wide frequency range** is obtained when the load is resistive (a). Open-loop voltage gain falls off faster when the load is capacitive (b). One way to compensate a power driver is to insert a lead network into the feedback loop (c).




| $A_{CL}$ | G.B.P. (MHz) | SLEW RATE (V/µs) | POWER BANDWIDTH (kHz) | $C_L'$ (µF) | $C_L$ (pF) |
|---|---|---|---|---|---|
| 2 | 1 | 0.3 | 4.8 | 0.5 | 50000 |
| 5 | 2.5 | 0.75 | 12 | 0.2 | 20000 |
| 10 | 5 | 15 | 24 | 0.1 | 10000 |
| 50 | 25 | 75 | 120 | 0.02 | 2000 |
| 100 | 50 | 15 | 240 | 0.01 | 1000 |
| 200 | 100 | 30 | 480 | 0.005 | 500 |

4. **A capacitor across the output** frequency-compensates a power driver. The required capacitor value depends on the closed-loop gain, $A_{CL}$, as shown in the table.

- High output current.
- Simple compensation.

Transconductance amplifiers, by their very nature, perform well in higher-power applications. These include audio amplifiers, transmission line drivers and servo and inductive-load drivers. In most of these applications a power driver drives a complementary pair of output transistors.

### Power driver as a general amplifier

Fig. 2a depicts a typical power amplifier with 35-W output. The driver has a linear current range of ±100 mA and a transconductance of 3.3 A/V. Power limiting in this circuit is provided by resistors $R_1$ and $R_6$; current limiting occurs at a level defined by $R_1 = R_6 =$ (750 mV/peak current). The voltage across $R_2$ or $R_5$ is 400 mV, and the circuit's ac gain is equal to $(R_7 + R_8)/R_8$. Total harmonic distortion of the circuit is less than 1% (Fig. 2b).

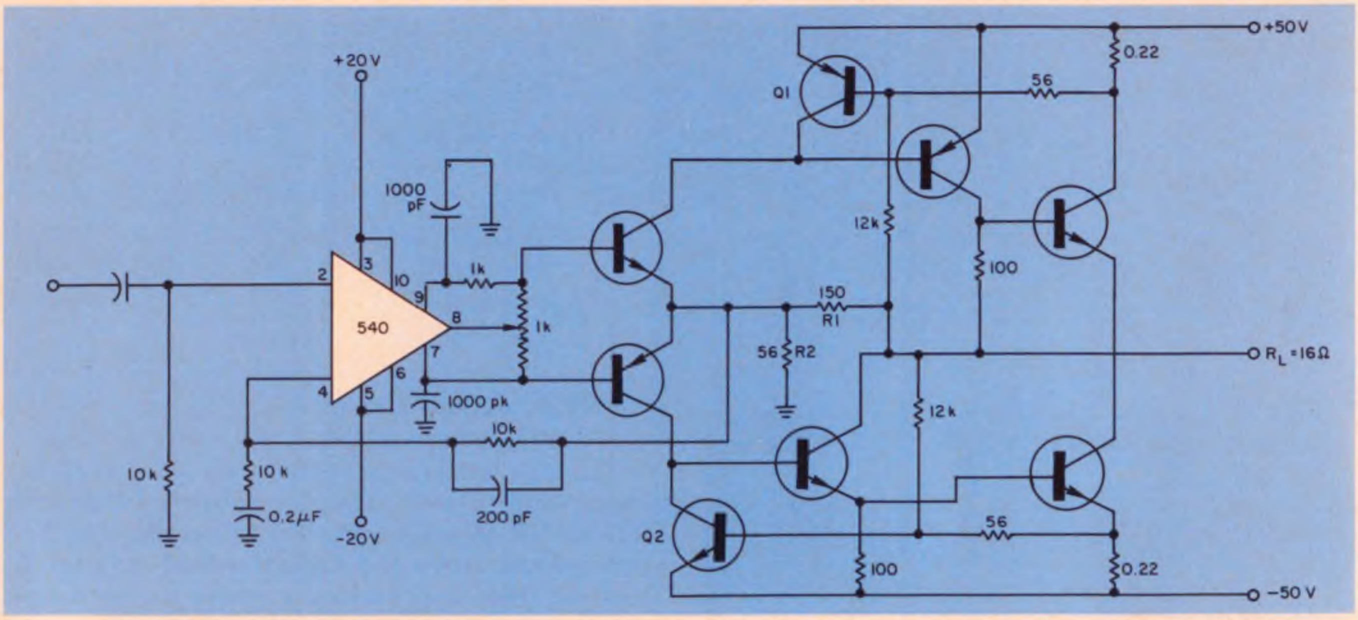
Fig. 3a shows the transconductance of a power driver (SE540) vs frequency. The output impedance is 5 kΩ in parallel with 1000 pF. Thus the equivalent open-loop voltage gain is

$$A_o = g_m \times R_L = 3.3 \times 5 \times 10^3 = 16.5 \times 10^3.$$

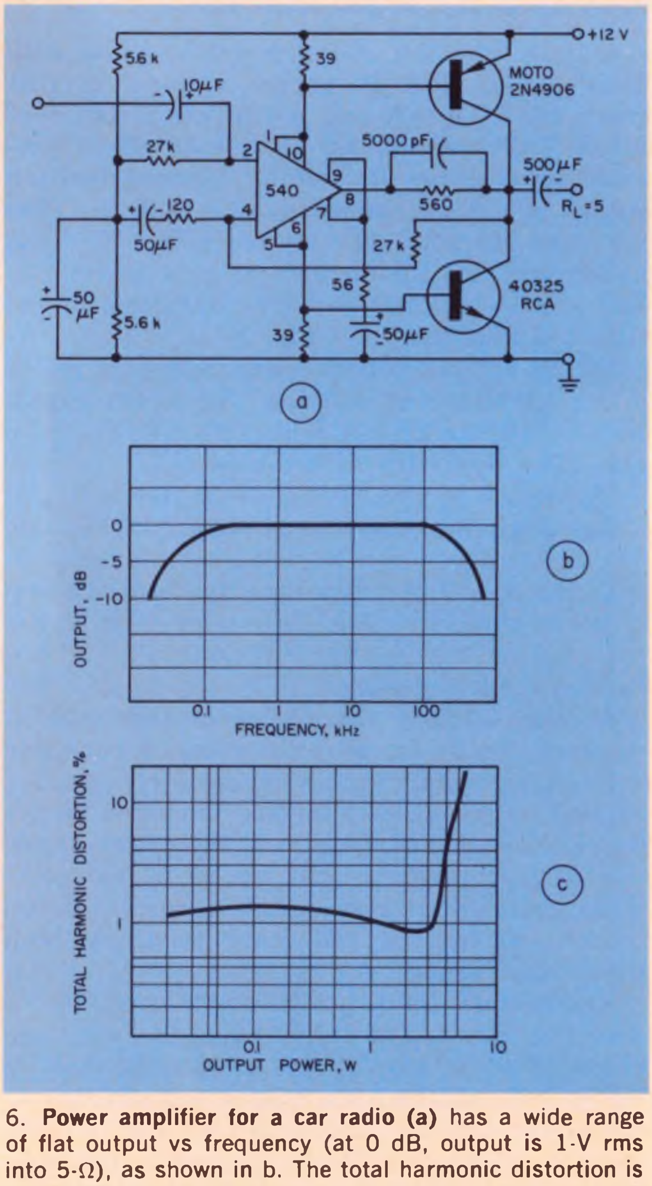
The frequency response is shown in Fig. 3b. The power driver can be frequency-compensated with use of a lead network in the feedback loop of the op amp (for closed loops with gains higher than 100 or 40 dB). The circuit in Fig. 3c can be used for lower gains.

Another method for frequency-compensation involves "brute force"—connecting a capacitor across the output (Fig. 4). Capacitor values for various values of ac gain are tabulated in the figure. Note that for $A_{CL} = 2$, the power driver can drive capacitive loads up to 50,000 pF—which corresponds to such loads as coaxial cables, capacitance bridges and other relatively high capacitance loads.

Another generalized high-power amplifier is shown in Fig. 5. The output stage has a voltage swing of 95 V pk-pk. This is accomplished by use of two amplification stages (in addition to the power driver). Transistors $Q_1$ and $Q_2$ limit current and power for the output stage. The feedback and load resistors, $R_1$ and $R_2$, determine the




5. **75-W, 95-V-swing power amplifier** uses two stages.




6. **Power amplifier for a car radio (a)** has a wide range of flat output vs frequency (at 0 dB, output is 1-V rms into 5-Ω), as shown in b. The total harmonic distortion is relatively low over the range of useful power output (c).

maximum output swing. Their values can be calculated on the basis of maximum rated output voltage for the device and actual output voltage:

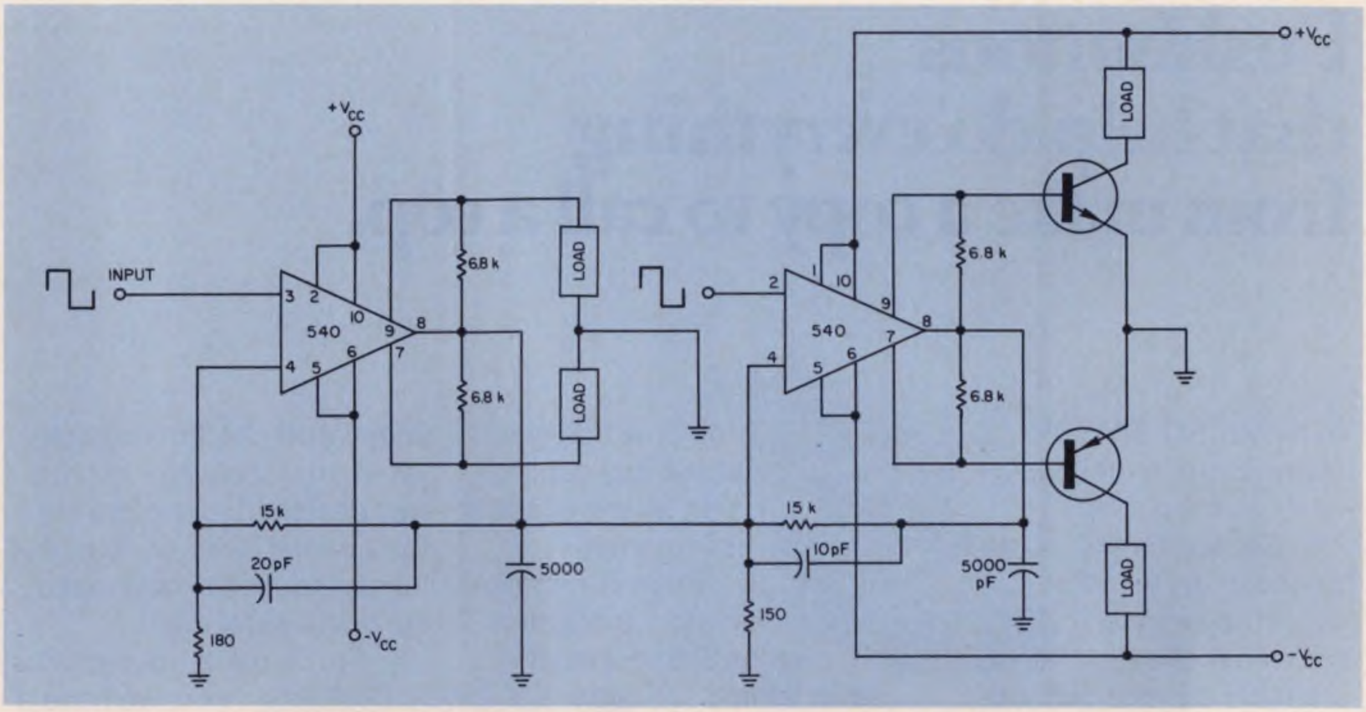
$$V_{out(max)}/V_{out} = R_1/R_2.$$

For low distortion, a quiescent current of 2 to 5 mA is maintained in the output stage. Low thermal resistance between the output transistors and the driver has to be maintained to achieve good quiescent control over the temperature range.

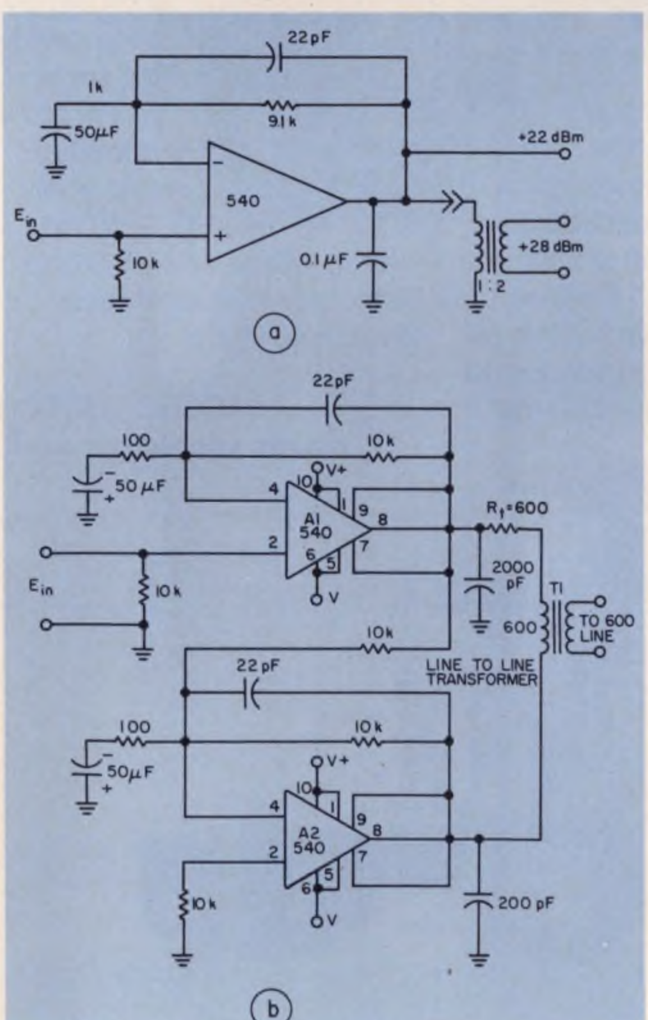
### Power drivers in audio circuits

A typical use for a power driver may be in a car radio. As shown in Fig. 6a, a different hook-up is used. This is because, for maximum efficiency, a voltage swing equal to the supply voltage is necessary. To this end, the supply current of the driver is sensed with a 39-Ω resistor, and the base of the output transistor is driven from these resistors. The maximum drive current for the output stage is determined by the 56-Ω resistor in series with a 50-μF capacitor from the output of the driver to ground. The 560-Ω resistor provides a reference for the output and high-frequency stabilization. Figs. 6b and 6c demonstrate the driver performance in this application. The input sensitivity for 1-W output into a 5-Ω load is 7 mV rms. The maximum short-circuit current is 1 to 2 A.

Fig. 7 shows how a power driver can be used to drive relays, solenoids or other electromechanical devices. The load can be either push-pull or single-ended (as in conventional hook-ups). In the push-pull circuit, the load is driven in either the positive or negative output arms—or in both. Depending on the input polarity, either output can be selected. In addition the output can be gated off by application of a voltage, via a cur-




7. **Relays, solenoids and small motors** can be driven by the power driver, as shown.




8. **Single-ended (a) or balanced line driver (b)** can be built with the power driver, simply and inexpensively.

rent-limiting resistor, to either pin 5 and 6, or between pins 1 and 2. The current required to do the limiting is approximately 1 mA for pin 1 and 0.1 mA for pin 5. Calculate the input signal required for maximum load current by dividing the peak load voltage by the closed-loop gain.

### Power drivers as line amplifiers

In audio applications, an IC power driver—such as the Signetics 540—can deliver very respectable unbuffered power levels, since it is rated for ±100-mA current output and can deliver 1 W of power. The 540 features a wide frequency response and power bandwidth, low input noise and internal current limiting. Thus it makes a simple line-driver stage with a minimum of components (Fig. 8a), and with a step-up transformer of 1:2 ratio, it will deliver up to +28 dBm.

Fig. 8b shows a power driver connected as a 600-Ω balanced-line driver. $A_1$ is a 40-dB noninverting stage, as before, driving one end of the transformer primary with an in-phase signal. At the same time $A_2$ inverts this signal and supplies a mirror image of it to the opposite end of the transformer. Thus the drive to the transformer is doubled prior to the source termination resistor, $R_t$.

The circuit has a reasonably clean total harmonic distortion of 0.1% up to +10 dB and reaches a maximum of 0.17% at +20 dB. The +20 dB is the maximum that can be achieved with ±15-V supplies, but a few more dB can be squeezed out with higher supply voltages. ■■

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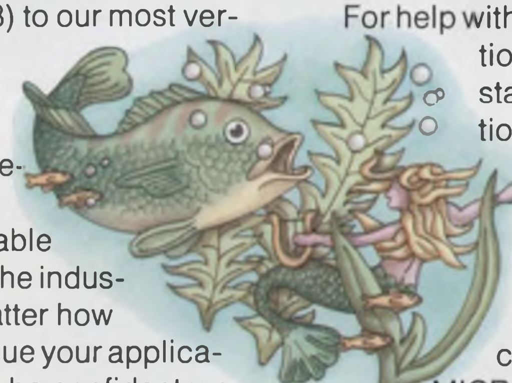

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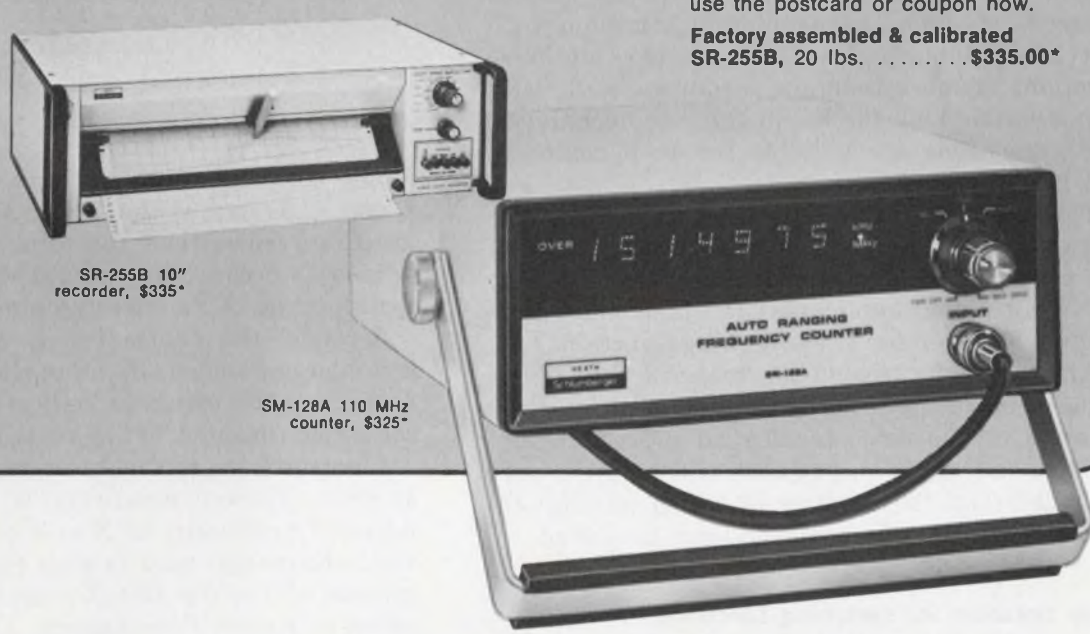


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INFORMATION RETRIEVAL NUMBER 40

# Trade your Karnaugh maps

## for topological procedures that easily reduce switching functions that have many variables.

Current memory devices, made possible by rapidly advancing technology, permit low-cost logic design flexibility. Instead of implementing the truth table of a switching function with logic gates, the designer can store it in a ROM or programmable logic array (PLA). Moreover, since the memory content can be changed, a single device can implement different switching functions at different times.

There is a disadvantage in using the storage technique. The amount of memory used depends on the size of the truth table—a quantity that increases rapidly with the number of variables.

The answer is minimization of the switching function before storage. And topological techniques are ideally suited for the task. These algorithms can handle many variables without the need to express the given function as the sum of minterms (which can amount to a million with just 20 variables). The designer can minimize functions of more than six variables—a difficult or impossible task for Karnaugh map techniques. The algorithms are suitable for both computer and hand execution.

The topological technique uses a series of operations on a compact matrix representation of the truth table. These operations first find the list of all prime implicants, and then find an irredundant cover for the switching function.

Although it is beyond the scope of this article to describe all the techniques[1] used, an exposition of some of the basic topological procedures applied to the single-output case will help the user to understand the manner in which multiple-input, multiple-output problems can be solved.

### Array notation for switching functions

A special notation, called "cubic notation," is used to represent the given switching function as an array in the computer. The Boolean function is expressed as a sum of products. Each product term is translated into a single row of the array, called a cube. Each column of the array corresponds to one of the input variables. For a given product (row) and variable (column) the symbols "1" and "0" represent the variable and its complement, respectively. The symbol "X" is used if the literal does not appear in the product term. Thus, the array for the switching function

$$f = A\,\overline{B} + \overline{A}\,B\,C$$

is

$$\begin{bmatrix} 1\,0\,X \\ 0\,1\,1 \end{bmatrix}.$$

The three columns correspond to each of the three variables A, B and C. The first row represents the product $A\overline{B}$; the second, the product $\overline{A}BC$. The cubic notation for two functions like

$$f_1 = A\,B\,C + \overline{A}\,\overline{B}\,\overline{C} + (A\,B\,\overline{C} + A\,\overline{B}\,C)_{\text{DON'T CARE}}$$

$$f_2 = \overline{A}\,\overline{B}\,C + A\,B\,\overline{C} + (A\,B\,C)_{\text{DON'T CARE}}$$

is

$$\begin{array}{ccc} ABC & f_1 & f_2 \\ \end{array}$$
$$\left[\begin{array}{ccc} 000 & 1 & 0 \\ 001 & 0 & 1 \\ 101 & d & 0 \\ 110 & d & 1 \\ 111 & 1 & d \end{array}\right].$$

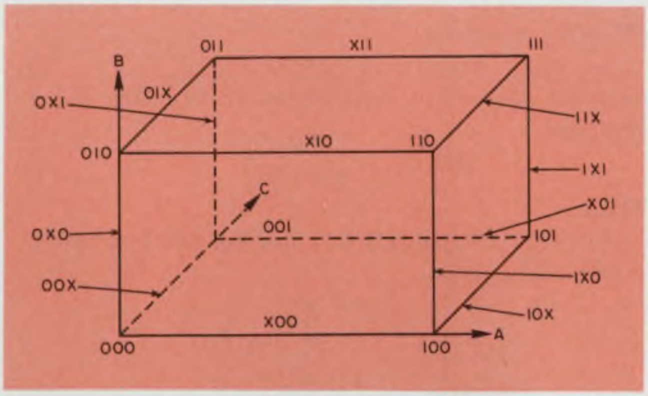
The array contains columns corresponding to $f_1$ and $f_2$, as well as the input variables, but there are fewer rows than the total number of products. This occurs first because identical rows in the variables A,B,C are combined.

Secondly the values for $f_1$ and $f_2$ are made zero and not shown, if the particular row (product) does not result in either the "don't care" condition (denoted by d) or the ONE condition.

Literature on this subject refers to the rows as cubes. The universal cube $U_n$ is defined as an n-tuple (n columns) of X's; it corresponds to the whole Karnaugh map in map representation. An n-tuple of 1's, 0's and X's containing r X's, is called an r-cube. For example, 1X0X1 is a 2-cube which represents the product term $A\overline{C}E$; 11011 is a 0-cube which corresponds to the minterm $AB\overline{C}DE$. The 2-cube, XX, has four 1-cubes 1X, 0X, X1 and X0. Topologically, XX is a square with four edges. Similarly, the 3-cube has six planes (2-cubes) and twelve edges (1-cubes)—as shown in Fig. 1.

Cubic notation provides an efficient method for processing functions of a large number of

**Stephen Y.H. Su.,** Associate Professor, Department of Electrical Engineering, City College of the City University of New York, New York, N. Y. 10031.




1. **The universal cube** for a three-variable Boolean function has 6 planes (2-cubes) and 12 edges (1-cube). In this topographical interpretation, vertices represent minterms; X's signify absence of a literal; and 1 denotes the variable and 0, its complement. The literals in the are A, B, and C—in that order.

| $\sqcap$ | 0 | 1 | X,d |
|---|---|---|---|
| 0 | 0 | $\phi$ | 0 |
| 1 | $\phi$ | 1 | 1 |
| X,d | 0 | 1 | X |

| | CASE 1 | CASE 2 |
|---|---|---|
| $c^i$ | X1X | 1XX |
| $c^j$ | 1X0 | 0X0 |
| | 110 | $\phi$XX |
| RESULT | 110 | $\phi$ |

3. **Row intersection** determines the minterms common to $c^i$ and $c^j$. The appearance of $\phi$, when the columns are compared according to the table, gives a vacuous response (case 2).

| $c_k^i$ \ $c_k^j$: $\subseteq$ | 0 | 1 | X,d |
|---|---|---|---|
| 0 | Y | N | Y |
| 1 | N | Y | Y |
| X,d | N | N | Y |

| | CASE 1 | CASE 2 | CASE 3a | CASE 3b |
|---|---|---|---|---|
| $c^i$ | X00 | 110 | X11 | 011 |
| $c^j$ | X0X | X10 | 111 | 11X |
| | YYY | YYY | NYY | NYY |
| RESULT | $c^i \subseteq c^j$ | $c^i \subseteq c^j$ | $c^i \subseteq c^j$ | |

2. **Boolean product** $c^i$ **subsumes** (is a subset of) $c^j$ if it contains nothing but a subset of minterms of $c^j$. An all-Y result, based on a column-by-column comparison according to the table, is needed to affirm that $c^i$ subsumes $c^j$.

| $c_k^i$ \ $c_k^j$: # | 0 | 1 | X,d |
|---|---|---|---|
| 0 | Z | Y | Z |
| 1 | Y | Z | Z |
| X,d | 1 | 0 | Z |

| | CASE 1 | CASE 2 | CASE 3 |
|---|---|---|---|
| $c^i$ | X0X | 1X0 | 1XX |
| $c^j$ | 01X | 1XX | 110 |
| | 1YZ | ZZZ | Z01 |
| RESULT | X0X | $\phi$ | 10X<br>1X1 |

4. **The sharp operation** deletes all minterms from c that are common to $c^i$ and $c^j$. Use the table for column-by-column comparison. Three courses of action are available; (1) copy $c^i$ if one or more Y's occur; (2) declare the result vacuous if all columns are Z; (3) copy $c^i$ for each occurrence of 1(0) and place the 1(0) in that column's position.

variables by hand or computer. Only four symbols need be recognized: 0, 1, X and d; and these can be represented with only two bits in the computer. For example, the two-function array requires only 50 bits of packed storage.

In the case of multiple-output functions, all that's required is one additional column per output variable. New equations need not be written for each one. The translation from algebraic-to-cubic notation—or the reverse—is straightforward, regardless of the number of variables.

### Five key operations

Five operations—Subsuming, Union, Intersection, Sharping and Consensus—will be used extensively on the input arrays to find the prime implicants or irredundant covers. All apply to arrays that have an equal number of columns, n. For the scope of this paper, we will restrict these operations to single-output functions.

A subsumed array is generated from a given array by deleting all rows that contain nothing but the minterms (0-cubes) of other rows. Subsuming occurs with pairs of rows $c^i$ and $c^j$ as follows: if at every column position k where element $c_k^j$ is a 1 (or 0), element $c_k^i$ is also 1(0); then, $c^i$ is said to subsume $c^j$; and $c^i$ is to be deleted. The normal procedure for subsuming is given in Fig. 2 and requires element-by-element comparison according to the chart. The outcome must be all Y for an affirmative result. The union [ U ] of two arrays [A] and [B] is obtained by first combining all rows into a single array [F], then performing the subsume operation on [F].

The array [F], resulting from the intersection of two arrays [C] and [D], covers all minterms common to both [C] and [D]. Array [F] is generated by finding the row intersections as defined in Fig. 3 and taking the union of the result.

As a result of the sharp product (#), the array

$$[F] = [A] \# [B]$$

covers all minterms (elements) of [A], which are not contained in [B]. To obtain the sharp product [A] # [B], perform the sharp operation for each $a^i$ in [A] with all rows of [B]; that is,

$$f^i = a^i \# b^1 \# b^2 \# b^3 \text{----} \# b^m,$$

where m is the number of rows in [B]. Then perform the union operations on the $f^i$'s. The sharp product for any two rows is obtained from the table shown in Fig. 4.

The four array operators possess important properties with respect to cover equivalence—the case when two arrays cover the same minterms or 0-cubes. In terms of cover-equivalence both cube union and cube intersection are commutative, associative and distributive over each other; thus,

$$\begin{aligned}
&[A] \cup [B] = [B] \cup [A] \\
&[A] \cap [B] = [B] \cap [A] \\
&[A] \cup [B \cup C] = [A \cup B] \cup [C] \\
&[A] \cap [B \cap C] = [A \cap B] \cap [C] \\
&[A] \cup [B \cap C] = [A \cup B] \cap [A \cup C] \\
&[A] \cap [B \cup C] = [A \cap B] \cup [A \cap C].
\end{aligned}$$

Additionally:

- The intersection of cubes $c^1$, $c^2$ ---$c^q$ is not empty if $c^i \cap c^j \neq \phi$ for all i, j contained in (1, 2, ---q).
- If [A]#[B] = [B]#[A], then [A]#[B] = [B] # [A] = $\phi$ and [A] and [B] are cover equivalent.

### Sharp algorithm for prime implicants

Minimizing Boolean functions by the Karnaugh map gives two-level AND-OR realizations corresponding to the sum of products. To obtain a minimum sum of products, we assign the "don't cares" to 1's and 0's in an attempt to minimize the number of product terms (cubes) and the number of literals for each term (maximum cube sizes). A prime implicant is the largest cube obtainable by assigning don't cares to 1's and 0's and by combining the adjacent implicants. Note that one can never obtain a simpler result by not using prime implicants than by using them. Thus, the first step of minimization is to find the set of all prime implicants.

Consider the switching function f and the three specifications, f=1; f=0 and f=d or don't care. Let arrays [ON], [OFF] and [DC] be the sets of n-tuples corresponding to the three conditions. Then:

$$U_n = [ON] \cup [OFF] \cup [DC], \qquad (1)$$

and by use of the sharp operator, we can compute the third array from any two; that is,

$$\begin{aligned}
ON &= U_n \# [OFF \cup DC], &(2)\\
\text{and} \quad OFF &= U_n \# [ON \cup DC], &(3)\\
DC &= U_n \# [ON \cup OFF]. &(4)
\end{aligned}$$

The sharp operator also gives a collection of the largest available cubes. For example, the result of [A]#[B] is a collection of the largest cubes containing those minterms that are in [A] but not in [B]. It can be proven[1] that the array [PI(f)] given by

$$PI(f) = U_n \# [OFF(f)] \qquad (5)$$

contains all prime implicants of function f. Suppose

$$[OFF] = \begin{bmatrix} 0\,0\,1 \\ 1\,1\,0 \end{bmatrix}.$$

Then

$$[PI(f)] = U_n \# [OFF] = [XXX\#001]\#110,$$

which expands to

$$[PI(f)] = \begin{bmatrix} 1\,X\,X \\ X\,1\,X \\ X\,X\,0 \end{bmatrix} \# 110,$$

gives the matrix of prime implicants

$$[PI(f)] = \begin{bmatrix} 1\,0\,X \\ 1\,X\,1 \\ 0\,1\,X \\ X\,1\,1 \\ 0\,X\,0 \\ X\,0\,0 \end{bmatrix}.$$

The translation to a Boolean equation is simply

$$f = A\,\overline{B} + A\,C + \overline{A}\,B + B\,C + \overline{A}\,\overline{C} + \overline{B}\,\overline{C}.$$

Equation 5 offers a very convenient way to find all prime implicants by a computer. The sharp subroutine has already been written[1,2] and all one need do is input the OFF array and call the subroutine once. The array [OFF] can be computed from Eqs. 2 to 4 if not known explicitly.

### Consensus algorithms for prime implicants

The iterative consensus algorithm or the more efficient generalized consensus algorithm[3] permits operation on a single array

$$[C] = [ON] \cup [DC]$$

to obtain the prime implicants.

The star product (Fig. 5) is applied in an iterative fashion to [C]; that is,

$$[C] = [C] \cup (c^i * c^j)$$

for all rows i, j in [C], provided $c^i * c^j \neq \phi$. Replacement of [C] continues until

1. No consensus terms can be found, or
2. All new consensus terms found are immediately deleted in the subsumed union.

Take as an example

$$[C] = \begin{bmatrix} 0\,1\,0 \\ 0\,0\,0 \\ 1\,0\,1 \\ 1\,0\,0 \\ X\,1\,1 \end{bmatrix}.$$

Then $c^1 * c^2$ gives 0 X 0. But rows 0 1 0 and 0 0 0 subsume 0 X 0 and are deleted from [C] before 0 X 0 is added. So the first iteration gives

$$[C] = \begin{bmatrix} 1\,0\,1 \\ 1\,0\,0 \\ X\,1\,1 \\ 0\,X\,0 \end{bmatrix}.$$

Similarly 1 0 1 * 1 0 0 = 1 0 X, so 1 0 1 and 1 0 0 are deleted and

$$[C] = \begin{bmatrix} X\,1\,1 \\ 0\,X\,0 \\ 1\,0\,X \end{bmatrix}.$$

Continuing the process with

$$X\,1\,1 * 0\,X\,0 = 0\,1\,X$$
$$X\,1\,1 * 1\,0\,X = 1\,X\,1$$
$$0\,X\,0 * 1\,0\,X = X\,0\,0$$

gives the prime implicants

$$[C] = \begin{bmatrix} X\,0\,0 \\ X\,1\,1 \\ 0\,X\,0 \\ 1\,X\,1 \\ 0\,1\,X \\ 1\,0\,X \end{bmatrix}.$$

### Generalized consensus algorithm

A generalization of the star product forms the basis of the more efficient consensus algorithm. If there are any two rows c and d in which the first columns are either (0,1) or (1,0), then

$$c * d = X \circ [(c_2 \text{---} c_n) \cap (d_2 \text{---} d_n)],$$

where the concatenation operation, ($\circ$) means tacking on an X to the sequence produced by intersection with the remaining columns. For example, if c = 01X1 and d = 1X01, delete the first column and perform the intersection

$$1X1 \cap X01 = 101.$$

Then place the X before the first position, which gives $c * d = X101.$

The above operation generalizes to handle consensus between two n-column arrays [C] and [D]:

$$[C] = C_1\,C_2 \text{--} C_n$$
$$[D] = D_1\,D_2 \text{--} D_n,$$

where $c_i$ and $D_i$ denote the ith column of [C] and [D], respectively.

Suppose column $C_i$ contains all zeros and column $D_i$ contain all 1's; then the consensus of [C] and [D], with respect to column 1 is an n-column array with X's in column one and the array $[P] = [c_2 \text{--} c_n] \cap [D_1 \text{--} D_n]$ for columns 2 to n.

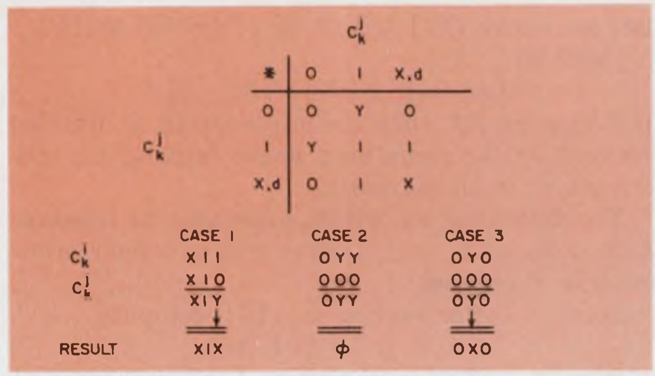
Continue to use the same switching function

$$C = \begin{bmatrix} 0\,1\,0 \\ 0\,0\,0 \\ 1\,0\,1 \\ 1\,0\,0 \\ X\,1\,1 \end{bmatrix}.$$

Let [C(1,0)], [C(1,1)] and [C(1,X)] denote subarrays of [C] with the same number of columns, containing 0's, 1's and X's in column 1, respectively; that is,

$$[C(1,0)] = \begin{bmatrix} 0\,1\,0 \\ 0\,0\,0 \end{bmatrix}$$
$$[C(1,1)] = \begin{bmatrix} 1\,0\,1 \\ 1\,0\,0 \end{bmatrix}$$
$$[C(1,X)] = [X\,1\,1] \quad .$$

Define [D(1,0)] and [D(1,1)] as the arrays [C




5. **Star product gives** the consensus of two Boolean products. A vacuous result occurs if any column-by-column comparisons, as specified in the table, result in more than one Y. (case 2). Otherwise, the symbol is copied, except than an X replaces the Y.

(1,0)] and [C(1,1)] with column 1 deleted. Then

$$[D = (1,0)] \cap [D = (1,1)] = [00],$$

and let $G_1 = X00$

be the generalized consensus with respect to column 1.

Similarly,

$$[D(2,0)] \cap [D(2,1)] = \begin{bmatrix} 0\,0 \\ 1\,1 \\ 1\,0 \end{bmatrix} \cap \begin{bmatrix} X\,1 \\ 0\,0 \end{bmatrix}$$
$$= \begin{bmatrix} 1\,1 \\ 0\,0 \end{bmatrix},$$

which gives the generalized consensus for column 2 as

$$G_2 = \begin{bmatrix} 1\,X\,1 \\ 0\,X\,0 \end{bmatrix}.$$

Similarly, $$G_3 = \begin{bmatrix} 1\,0\,X \\ 0\,1\,X \end{bmatrix}.$$

It can be shown that the matrix of prime implicants is found from

$$[C] \cup [G_c],$$

where

$$[G_c] = [G_1] \cup [G_2] \cup [G_3] \text{---} \cup [G_n],$$

which in this case gives us the prime implicants

$$[PI(f)] = \begin{bmatrix} X\,1\,1 \\ X\,0\,0 \\ 1\,X\,1 \\ 0\,X\,0 \\ 1\,0\,X \\ 0\,1\,X \end{bmatrix}$$

Note that this result is the same as that found with the basic consensus procedure.

### Finding an irredundant cover

To reduce the expression further, note that a prime implicant of f is an extremal (essential prime implicant) if it contains at least one minterm of the ON array which is not covered by any other prime implicants. Let [PI(f)] denote the array of prime implicants of f, written as

$$[PI] = p^1, p^2, p^3 \text{--} p^h,$$

where $p^i$ is a prime implicant contained in [PI].

Denote array [PI] with row $p^i$ deleted as $[PI-p^i]$ and let

$$[A]=[p^i \cap ON]\#[PI-p^i].$$

If [A] is empty, then the minterms in $p^i$ are also covered by the remaining prime implicants; otherwise, $p^i$ is an extremal.

The following algorithm generates an irredundant cover of f; such a cover will be a near minimum or minimum:

Step 1. —For each $p^i$ in [PI], compute

$$A = p^i \ \# \ [PI-p^i].$$

Step 2. —If $A = \phi$, throw $p^i$ away; increment i by one; and go to the first step. Otherwise, (if $A \neq \phi$), add $p^i$ back to [PI]; and increment i by 1. Then go back to the first step.

In general, there will be more than one irredundant cover. The matrix [C] of the previous example has five irredundant covers, of which only $[C_1]$ and $[C_2]$ are minimal. They are:

$$[C_1] = \begin{bmatrix} 0\,1\,X \\ 1\,X\,1 \\ X\,0\,0 \end{bmatrix}, [C_2] = \begin{bmatrix} X\,1\,1 \\ 1\,0\,X \\ 0\,X\,0 \end{bmatrix}, [C_3] = \begin{bmatrix} 0\,1\,X \\ 0\,X\,0 \\ 1\,X\,1 \\ 1\,0\,X \end{bmatrix},$$

$$[C_4] = \begin{bmatrix} 0\,1\,X \\ X\,1\,1 \\ 1\,0\,X \\ X\,0\,0 \end{bmatrix}, [C_5] = \begin{bmatrix} X\,1\,1 \\ 1\,X\,1 \\ X\,0\,0 \\ 0\,X\,0 \end{bmatrix}.$$

Every minimum cover is an irredundant cover, but the reverse is not always true.

For computer minimization of an n-input, m-output function by Bartee's method[4], you must generate all multiple-output prime implicants of n+m variables, then execute a covering problem. Su[5,6] and Dietmeyer developed a computer algorithm for simplification of multiple-output functions which deals with several functions of n variables. The algorithm maximizes the sharing of AND gates among the output variables. Length limitation of this article does not allow us to treat these two algorithms; interested readers should consult references 1, 4 and 5. Fortran programs can be found in Appendices G, H and J of reference 1. ■■

**References**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6. Su, S.Y.H., and Dietmeyer, D.L., "Computer Reduction of Two-Level Multiple-Output Switching Circuits," *IEEE Trans. on Computers*, Vol. C-18, Jan., 1969, pp. 58-63.




INFORMATION RETRIEVAL NUMBER 41

# HOW TO SELECT THE PROPER DRIVER FOR YOUR DISPLAY.

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- Displays
- Decoder/driver truth tables
- Decoder and display selection guide
- 7 segment decoder/driver format
- Ripple blanking capabilities
- 7 segment incandescent displays
- 7 segment fluorescent displays
- 7 segment cold cathode or neon displays
- Light emitting diode displays
- Basic multiplexing systems
- Multiplexing systems

Precise information to make it easy for you to select the most cost-effective driver for your display system.

### DIRECT DRIVE DISPLAYS

| Display | Driver | Output Drive mA | Output Drive Volts | Input Compat. | Remarks |
|---|---|---|---|---|---|
| **LED Common Cathode** | | | | | |
| | 7-Segment Decoder/Driver | | | | |
| | 9660 ** Constant Current Source Outputs | 5 to 50 | | MOS | Output Current programmable with a single resistor |
| FND 500*, 70<br>DL 704 | 7-Segment Decoder/Driver/Latch | | | | |
| | 9368 Constant Current Source Outputs | 19 @ 1.7 Constant Current | | TTL | Direct Drive. No resistors or transistors |
| DL 4, 402<br>MAN 3, 4 | 7-Segment Decoder/Driver/Latch | | | | |
| | 9368 Constant Current Source Outputs | 19 @ 1.7 Constant Current | | TTL | Requires either resistor current limiting or pulse width modulation to reduce current output |
| **LED Common Anode** | | | | | |
| FND 507*,<br>DL 1A, 6, 8, 10, 707<br>MAN 1, 6, 10,<br>H.P. 5082-7730<br>SLA 1, 3, 7,<br>T.I.L. 302 | 7-Segment Decoder/Driver | | | | Requires 7 current limiting resistors per display |
| | 9317B | 40 | 20 | TTL | |
| | 9317C | 20 | 30 | TTL | |
| | 9357A (7446A) | 40 | 30 | TTL | |
| | 9357B (7447A) | 40 | 15 | TTL | |
| | 7-Segment Decoder/Driver/Latch | | | | |
| | 9370 | 25 | 7 | TTL | |
| **Incandescent** | | | | | |
| "Alco Inc."<br>"Appollo" Diametrics Inc.<br>Dialight Corp.<br>EDP Corp.<br>Pinlights<br>Mesa<br>"Minitron"* Readouts Inc.<br>"Minitron"* Luminetics Inc.<br>"Numitron"* RCA Corp. | 7-Segment Decoder/Drivers | | | | No additional components required |
| | 9317B | 40 | 20 | TTL | |
| | 9317C | 20 | 30 | TTL | |
| | 9357A (7446A) | 40 | 30 | TTL | |
| | 9357B (7447A) | 40 | 15 | TTL | |
| | 7-Segment Decoder/Driver/Latch | | | | |
| | 9370 | 25 | 7 | TTL | |
| **Gas Discharge** | | | | | |
| 1-of-10 Type<br>Nixie*<br>Most Types | 1-of-10 Decoder/Drivers | | | | No additional components required |
| | 9315 (7441) | 7 | 65 | TTL | |
| | 93141 (74141) | 7 | 55 | TTL | |
| 7-Segment Type<br>Panaplex*<br>Sperry SP Series<br>Alco Elfin | 7-Segment Decoders | | | | Requires 7-NPN Transistor interface devices |
| | 9307<br>9358 (7448) | 2mA @ 0.85V To Drive NPN Transistors | | TTL<br>TTL | |

## MULTIPLEXED LED DISPLAYS

### Common Cathode

Display: FNA 30, 35, 37; FND, 500*, 70; MAN 3, 4; DL 4, 33, 34, 704; H.P. 5082-7400 Series

| Segment Drivers (Current Source) | Output Drive mA | Output Drive Volts | Input Compat. | Remarks |
|---|---|---|---|---|
| **7-Segment Decoders** | | | | |
| 9307 | | | TTL | Requires interface units such as 9661 |
| **7-Segment Decoder/Drivers** | | | | |
| 9660 ** | 50 @ 3.0 | | MOS | Output Current programmable with one resistor |
| **7-Segment Decoder/ Driver/Latch** | | | | |
| 9368 | 16mA @ 2.1V | | TTL | |
| **Segment Drivers** | | | | |
| 9661** Quad Segment Driver | 5-75 @ 3.0 Constant Current | | MOS | Output Current programmable with one resistor |
| 75491 Quad Segment Driver | 50 | | MOS | Requires current limiting resistors |

| Strobe Drivers (Current Sink) | Output Drive mA | Input Compat. | Remarks |
|---|---|---|---|
| **Decoder Drivers** | | | |
| 9345 1-of-10 Decoder<br>93145 1-of-10 Decoder | 80<br>80 | TTL<br>TTL | |
| **Strobe Drivers** | | | |
| 75492 Hex LED/ Lamp Driver | 250 | MOS | Inverting (sink only) |
| 75491 Quad Segment Driver | 50 | MOS | Inverting (sink only) |
| 9662 ** Quad LED Digit/Lamp Driver | 600 | MOS | Inverting or non-inverting selection pin |
| 9663 ** Hex LED Digit/Lamp Driver | 600 | MOS | Inverting or non-inverting selection pin |

### Common Anode

Display: FND 507*; MAN 1, 6A, 10; DL, 6, 10, 707; H.P. 5082-7730 Series; T.I.L. 302; SLA 1, 3, 7,

| Segment Drivers (Current Sink) | Output Drive mA | Output Drive Volts | Input Compat. | Remarks |
|---|---|---|---|---|
| **7-Segment Decoder/Drivers** | | | | |
| 9317B | 40 | | TTL | Require current limiting resistors |
| 9357B (7447) or (7446) | 40 | | TTL | Require current limiting resistors |
| **7-Segment Decoder/ Driver/Latch** | | | | |
| 9370 | 25 | | TTL | Require current limiting resistors |

| Strobe Drivers (Current Source) | Output Drive mA | Input Compat. | Remarks |
|---|---|---|---|
| **Strobe Drivers** | | | |
| 9661**Quad Segment Driver | 75 | MOS | Non-inverting |
| 75491 Quad Segment Driver Transistors | 50 | MOS | Non-inverting |

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INFORMATION RETRIEVAL NUMBER 43

# Solve LC network transfer functions

## the easy way. Synthesize the circuit elements with an iterative technique that permits the use of a simple calculator.

LC network transfer functions can be so complicated—as when dealing with large-signal rf power amplifiers—that designers often use trial-and-error methods to build their circuits. Smith Chart techniques help, but the values obtained are limited in accuracy and resolution. With an iterative approach to the problem, however, designers equipped with only a desk-top calculator can obtain precise network-component values, as well as network efficiencies, both directly and easily.

Unlike many network-analysis programs available for use with a computer, the proposed technique avoids matrices and imaginary numbers. Only real numbers are used. And since simple four-function and square-root operations are the only ones required, a simple calculator can do the job.

### Basic conversions are simple

The conversions for parallel-to-series R, L or C equivalents—an essential part of the technique—are shown in Fig. 1 for an RL circuit. The two formulas, however, are general, and in Fig. 2 they are presented in a circular chart for each of four possible cases. Also shown are some useful inverse relationships.

The equations in the outer ring relate dependent variables at the chart's center to independent variables in the middle ring. For example, to find $R_s$ as a function of $R_p$ and $X_p$, follow the wedge from $R_s$ through $f(R_p, X_p)$ to

$$R_s = \frac{R_p X_p^2}{R_p^2 + X_p^2}.$$

To illustrate the design technique and the use of the formulas, let's consider the general network of Fig. 3. Assume that the following are given: output impedance, $R_3$; input impedance, $R_4$; input capacitance, $C_1$; output capacitance, $C_2$; component Q of $L_1$, $Q_1$; component Q of $L_2$, $Q_2$; and network insertion loss, I. With these parameters specified, the remaining three elements—$L_1$, $L_2$ and $C_3$—can be determined.

In Fig. 4a the network components are labeled with superscripts in addition to subscripts. This notation allows us to relate a change in the superscript to a conversion of the type shown in Fig. 2. The subscripts on equivalent elements remain the same, so the effect of an element in Fig. 4a can be determined at any point in the sequence "a" through "i."

Follow the indicated conversion through to Fig. 4h. Note that each time two resistances or reactances appear in series or parallel, they are combined into one element. The result in the figure permits the input impedance to be read directly. If $C_1^a$ and $L_1^h$ are resonant, $R^h_{123}$ forms the real input impedance. The goal, of course, is to make $R^h_{123} = R_4$.

### Technique yields I/O impedances

With the network reduced to equivalent components, the input impedance can be found. The output impedance can be found with the same technique, but by looking into the output port. With the right port terminations, the transfer function can then be determined by a simple division.

An iterative technique progressively simplifies the circuit in terms of the required components. As a result, no equation higher than first order need be encountered. One of the unknown elements will be arbitrarily selected, and a computer program will determine the remaining two elements and the insertion loss. The arbitrary element can then be varied until the insertion loss is within specification and/or all the elements are of practical values.

Let's choose $L_2$ to be the arbitrary element in this case, since this selection leads to an easy solution. $R_2^a$ is now chosen from the relation $R_2^a = (\omega \times L_2^a)Q_2$. An estimate of $L_1^a$ (from Fig. 5) determines $R_1^a$ from the formula $R_1^a = [\omega \times (L_1^a)_{est}]/Q_1$. Note that Fig. 5 does not include dissipative elements $R_1$ and $R_2$, and that source termination $R_4$ has been added. From the conversions of Fig. 5a through 5d, $(L_1^c)_{est}$ can be determined from the inverse relationship that

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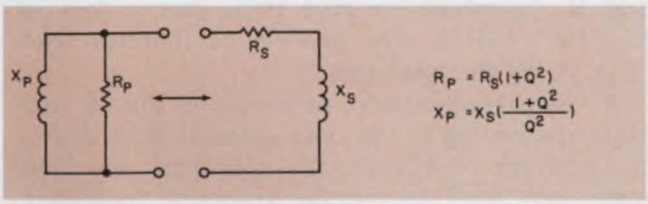
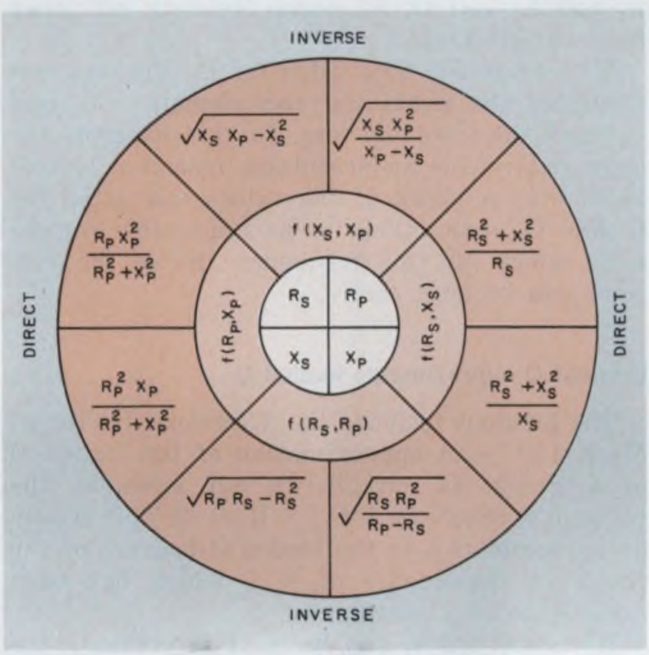
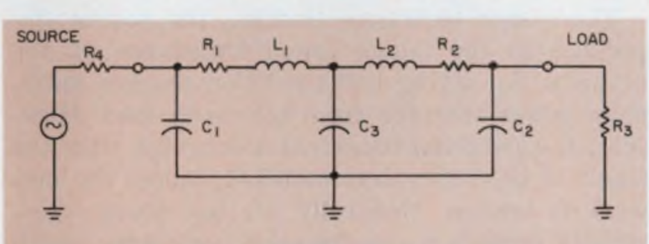


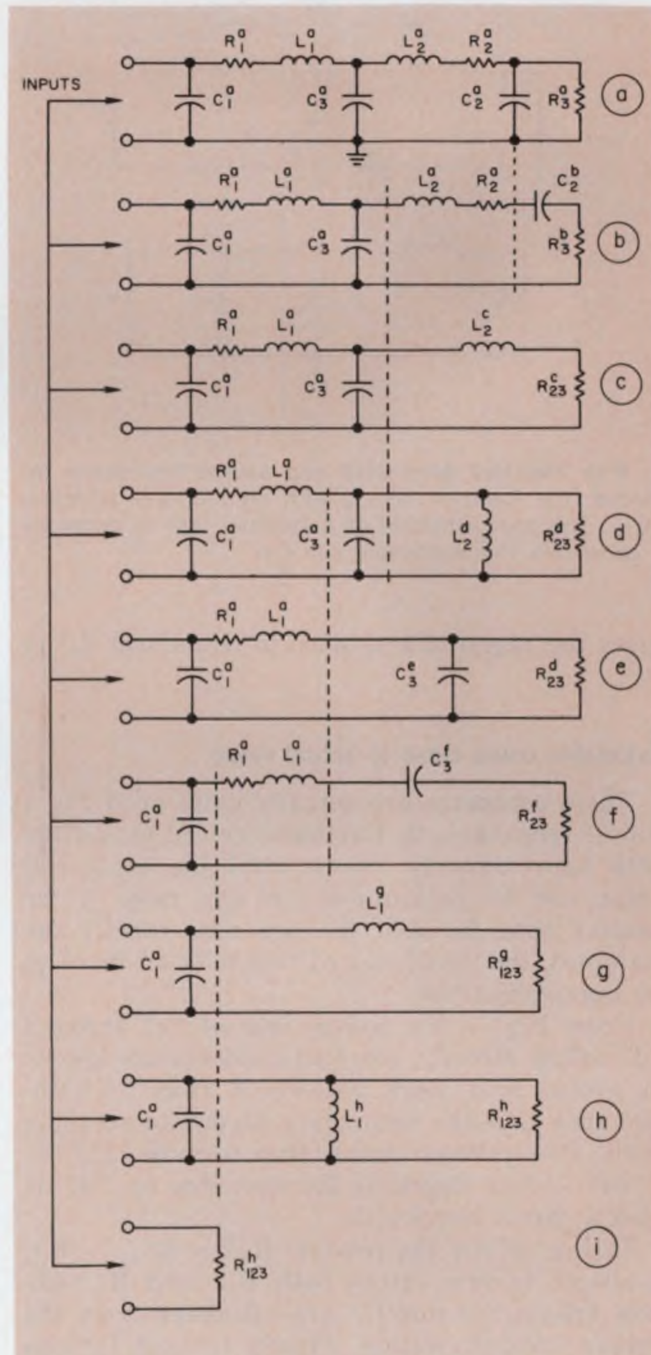

1. **Converting from parallel-to-series R, L or C** equivalent circuits involves simple relationships.



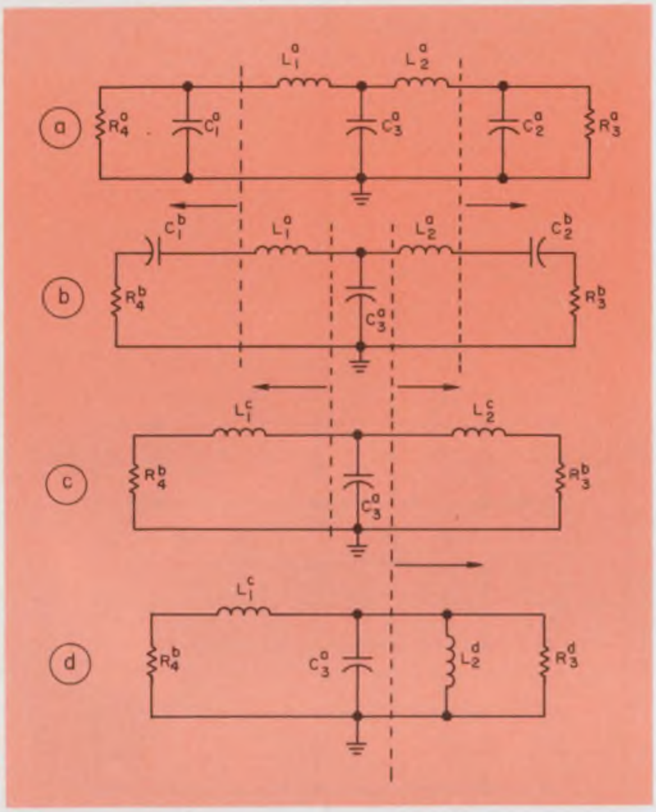

2. **All possible conversions are tabulated** in a circular chart. The formulas in the outer ring provide the RLC equivalents for series-to-parallel and parallel-to-series conversions.




3. **A general RLC network** covers a variety of transfer functions often encountered. These include circuits for large-signal rf amplifiers.




4. **The general network reduces to a single, equivalent component** by use of the relationships in the circular chart. For maximum power transfer, design the image input impedance—$R_{123}{}^h$—to equal the source impedance.




5. **With resistors eliminated and source impedance included,** the iteration begins with an arbitrary selection of $L_2$. The approximation of a lossless case is generally a close one for reasonable coil Qs.

gives the required reactance to transform $R_4^b$ to $R_3^d$.

### Estimates come close to actual value

These estimates are actually quite good for a coil of reasonable Q. Furthermore coil Q is often only approximately known until the exact coil value can be determined. In any case, if we assume that $R_1^a$ and $R_2^a$ are now exactly determined, the remainder of this solution involves no approximations.

From Fig. 4, the conversions of "a" through "d" follow directly, since all elements are known or given. Now work backwards from "h." Inductance $L_1^h$—the inductance needed to resonate with $C_1^a$—follows from the formula $L_1^h = 1/(\omega^2 \times C_1^a)$. Similarly the next step up, "g," is also a direct conversion.

In Fig. 4f use the relation $R_{23}^f = R^g_{123} - R_1^a$, a simple inverse. Since both $R_{23}^d$ and $R_{23}^f$ are now known, $C_3^e$ and $C_3^f$ are calculated from the proper inverse relation. Finally $L_1^a$ and $C_3^a$ can be determined, since

$$X_{L^g_1} = X_{L^a_1} - X_{C^f_3} \text{ and}$$
$$Y_{C^e_3} = Y_{C^a_3} - Y_{L^d_2}.$$

To complete the design, let's now compute the insertion loss corresponding to the three element values just determined. Again with reference to Fig. 4, follow the conversions "a" through "i." Note the steps where the dissipative elements $R_1$ and $R_2$ combine with other resistors, and compute the insertion loss at each of these points. Their product will then be the entire network loss.

In our example, from Fig. 4b to 4c, $R_2^a$ combines with $R_3^b$ to give $R_{23}^c$ and an insertion loss of $R_3^b/(R_2^a + R_3^b)$. Again from "f" to "g," $R_1^a$ and $R_{23}^f$ combine to give $R^g_{123}$ and a loss of $R_{23}^f/(R_1^c + R_2^f)$. The product of the two fractions yields the total loss.

A computer-program printout in Fig. 6 provides the results of the operations indicated. For the network of Fig. 3, the following specifications were used as inputs: resonant frequency, 165 MHz; input capacitance, 22 pF; output capacitance, 36 pF; input impedance, 9 Ω (resistive); output impedance, 50 Ω (resistive); and $L_1$ and $L_2$ coil Q, 85 each. Network efficiency must exceed 90%.

With an initial trial value for $L_2$, the program calculates the remaining two elements—$L_1$ and $C_3$—and the insertion loss. In this example the third trial yields an acceptable insertion loss of about 9%. A check of the values calculated for $L_1$ and $C_3$ shows them to be reasonable component values for this frequency; hence the network can be built easily.

### Printout Q approximates loaded Q

The printout includes the "Network Factor of Merit (Q)"—an approximation of the loaded Q of a simple LC circuit. In our example, the printout Q equals $(\omega \times C_3^a \times R_{23}^d)/2$. This is only an approximation to the loaded Q because of the frequency dependence of $R_{23}^d$, which has been assumed to be a constant.

However, this Q can be used to estimate the network bandwidth. The component selected for the estimate—in this case $C_3$—exhibits the greatest sensitivity to variation. Most commonly used network-analysis programs provide for an element sensitivity calculation.

The design technique matches the source impedance to the image input impedance of the network. Satisfying this condition ensures maximum power transfer from source to load. However, the condition does not guarantee that the load will be conjugately matched, unless the network is lossless. Generally it's not always possible to provide a simultaneous conjugate match at the input and output ports of a lossy two-port network. The output-port mismatch will, of course, be worse for a more lossy network. ■■

| PRINTOUT | COMMENTS |
|---|---|
| PGM TO DETERMINE ELEMENT VALUES OF FIVE WATT OUTPUT CKT VER 6/18/72<br>WHAT IS DESIRED RESONANT FREQUENCY? 165E6<br>WHAT IS THE DESIRED VALUE OF C1? 22E-12<br>WHAT IS THE DESIRED VALUE FOR C2? 36E-12<br>WHAT IS THE INPUT IMPEDANCE, REAL PART? 9<br>WHAT IS THE OUTPUT IMPEDANCE, REAL PART? 50<br>WHAT IS THE COIL Q OF L1? 85<br>WHAT IS THE COIL Q OF L2? 85 | Characterize network |
| WHAT IS A TRIAL VALUE FOR L2? 1E-6 | First trial value |
| FIVE WATT OUTPUT CIRCUIT SOLUTION F= 1.65E+08 HZ<br><br>INPUT Z= 9 OUTPUT Z= 50<br>C1= 2.2E-11 C2= 3.6E-11<br>Q OF L1= 85 Q OF L2= 85<br>R1= 7.29043 R2= 12.1968<br>NETWORK FACTOR OF MERIT (Q)= 90.6366<br>INSERTION LOSS =-11.2823 DB NETWORK EFFC.= 7.44339 %<br>VOLTAGE INSERTION LOSS =-3.83502 DB<br><br>L1 L2 C3<br>2.37004E-07 1E-06 4.90307E-12 | Solution for the value of L2 shows insertion loss much too high |
| ANOTHER EXECUTION? YES | Change value of L2 |
| WHAT IS A TRIAL VALUE FOR L2? .5E-6 | Second trial value |
| FIVE WATT OUTPUT CIRCUIT SOLUTION F= 1.65E+08 HZ<br><br>INPUT Z= 9 OUTPUT Z= 50<br>C1= 2.2E-11 C2= 3.6E-11<br>Q OF L1= 85 Q OF L2= 85<br>R1= 4.16342 R2= 6.09839<br>NETWORK FACTOR OF MERIT (Q)= 28.332<br>INSERTION LOSS =-4.75156 DB NETWORK EFFC.= 33.4845 %<br>VOLTAGE INSERTION LOSS = 2.69572 DB<br><br>L1 L2 C3<br>2.46172E-07 5E-07 5.74107E-12 | Insertion loss better, but still too high |
| ANOTHER EXECUTION? YES | Change L2 again |
| WHAT IS A TRIAL VALUE FOR L2? 50E-9 | Third trial value |
| FIVE WATT OUTPUT CIRCUIT SOLUTION F= 1.65E+08 HZ<br><br>INPUT Z= 9 OUTPUT Z= 50<br>C1= 2.2E-11 C2= 3.7E-11<br>Q OF L1= 85 Q OF L2= 85<br>R1= 0.33945 R2= 0.60984<br>NETWORK FACTOR OF MERIT (Q)= 1.60284<br>INSERTION LOSS =-0.40532 DB NETWORK EFFC.= 91.0895 %<br>VOLTAGE INSERTION LOSS = 7.04196 DB<br><br>L1 L2 C3<br>2.73641E-08 5E-08 6.02359E-11 | Insertion loss under 10%—meets specification |

6. **A printout of a program** shows a final design after only three iterations.

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INFORMATION RETRIEVAL NUMBER 44

# DVMs can do more than measure. By using the instrument's binary-coded data outputs and the internal clock, you can design a high-speed component tester.

If you've got a digital voltmeter with binary-coded data outputs, you can use it as part of a high-speed, go/no-go test system. The system is especially suited for testing resistor networks and other multiple devices mounted in a common package. Here's how it works:

Designed to replace a manual switch box, the tester uses the DVM's internal clock to control a sequencer and the BCD outputs to signal an out-of-spec condition and to halt the test (Fig. 1).

The sequencer—actually two J-K flip-flops hooked up to count to eight ($2^3$)—controls a bank of reed relays that switch the pins of the device under test (DUT). Actually it's the size of the counter and the relay bank that limits the number of devices that can be tested in any one sequence.

Outputs of the DUT are measured by the DVM, the BCD lines of which are monitored by a preset decoder. The decoder, in turn, controls a free-running clock, whose pulses are counted by the sequencer. If an in-spec value is indicated, the "normal" test sequence continues—that is, the clock keeps running and the tester will switch to the next pin of the DUT.

This sequence will run as long as no out-of-tolerance reading occurs or until the end of the test sequence is reached.

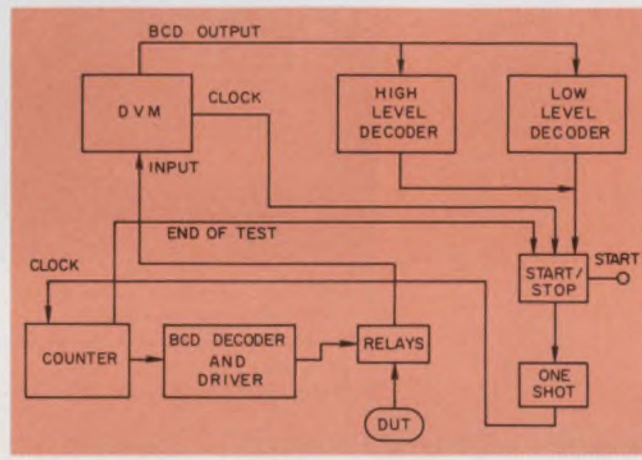
If the decoder reads an out-of-spec condition, it outputs a negative pulse that stops the clock, thus halting the test sequence.

The measured value is then displayed on the DVM, and the system remains in standby until the start button is depressed.

### Decoder spots limits

For illustration, assume that the DUT is a resistor pack, with values that are allowed to vary between 9.8 and 10.8 Ω. The BCD outputs are decoded for the minimum and maximum acceptable levels (Fig. 2) as follows:

**Carlos A. Pironio,** Associate in Applied Science, Microwave Semiconductor Corp., Somerset, N.J. 08873.



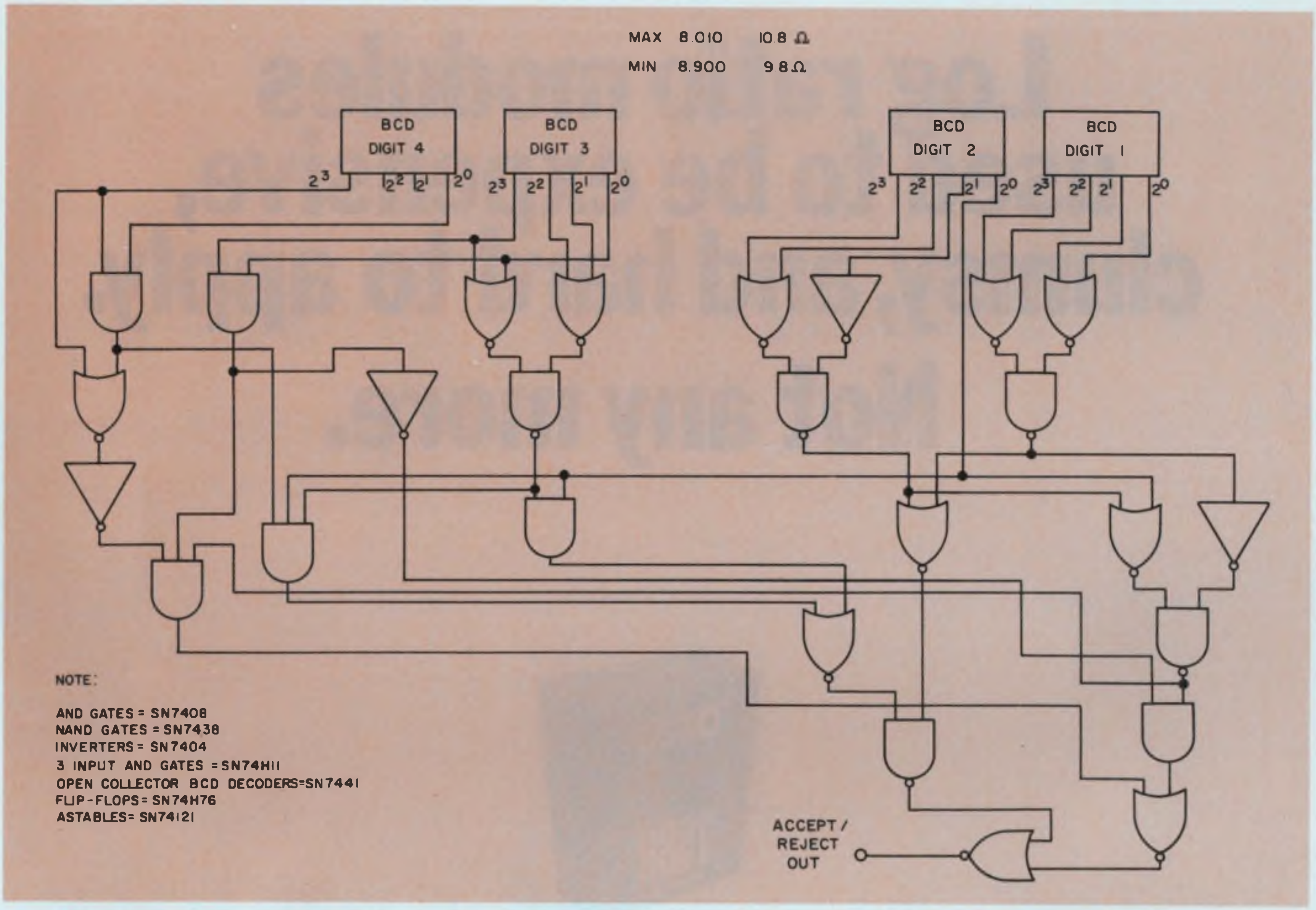

1. **Test-system block diagram** shows functional relationship between circuit elements. For N devices, N drivers are required; for n limits, n decoders are needed.

1. The first BCD digit is decoded for a zero level. The combination of NOR-NAND gates functions as an OR gate.
2. When a number other than zero appears on the first BCD digit, the output of the NAND gate is TRUE; the true level acts as a warning, since it implies that the device under test may be defective.
3. The warning output level is then compared with the levels of the second, third and fourth decoded BCD digits at the outputs of the NAND gates.
4. If the combination of decoded outputs is TRUE, the decoder output, called the accept/reject output, will be negative; this indicates that a defective resistor has been found.

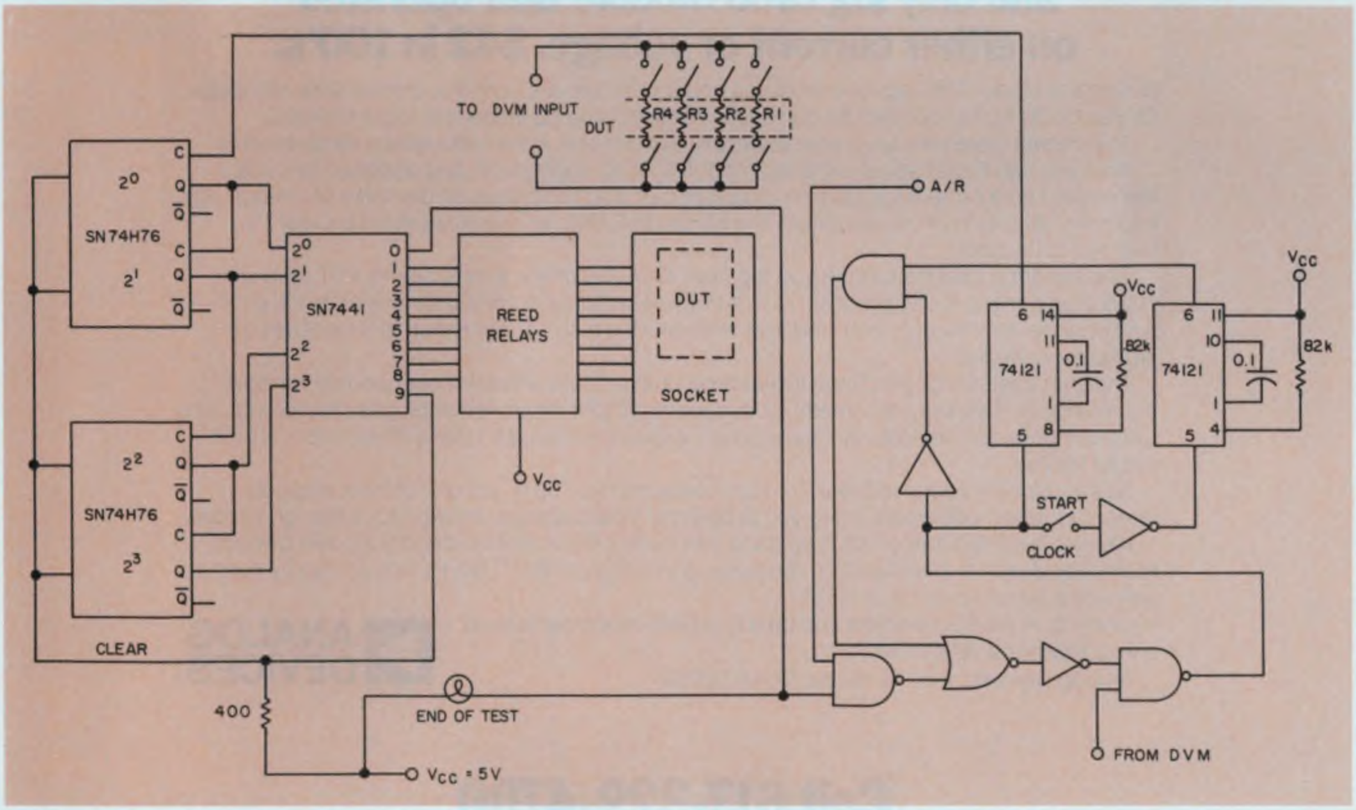
The accept/reject pulse serves as the input to the clock. A negative pulse stops the clock; a positive pulse keeps the clock running.

Clock pulses are totalized by the $2^3$ counter, the state of which is decoded by a BCD-to-decimal circuit (Fig. 3).

If the reading of a resistor is within limits, the decoder energizes the reed relay and the next resistor of the DUT is switched to the DVM input terminals. The sequence continues until the last resistor is measured. ■■




2. **DVM data outputs are decoded** for the device limits by NOR-NAND gates. Readings outside the limits are indicated by a negative accept/reject pulse that stops the free-running clock, thus halting the test.




3. **Details of counter, decoder-driver and clock:** Seven decoder outputs energize double-pole reed relays that switch each resistor of the pack to the DVM input terminals. Output 9 clears the counter and ends the test.

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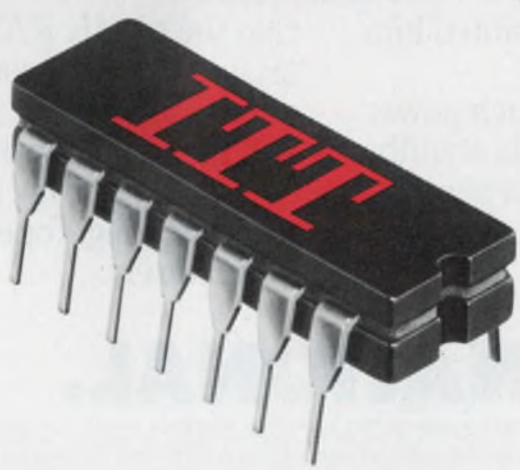


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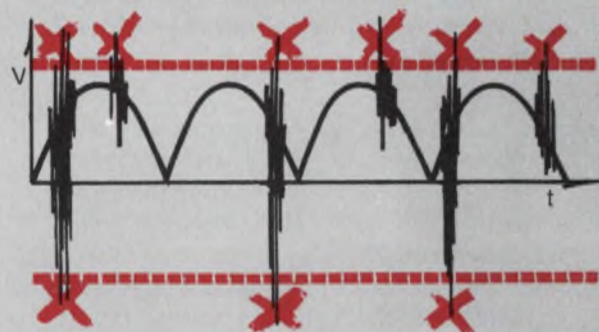


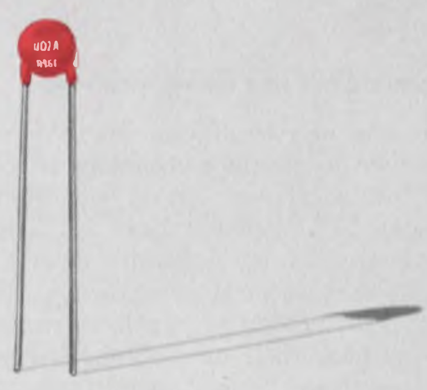

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# Don't spoon-feed your engineers! Put one man in charge of the design project wherever possible. He'll do the job faster and cheaper than a committee will, RCA manager says.

Some companies put great stress on the "team" approach to design—the more heads you can knock together, the more innovative the product is apt to be, they reason. I prefer the opposite tack: The most effective management technique that I've evolved to design and develop component products has been the one-man engineering project.

Seldom do I assign four or five engineers to design, say, a power transistor. I assign one engineer to work on it, and he's almost completely independent of anyone else. That's not to say that he doesn't need support people, but he usually will work smarter and harder on that project alone than if he were part of a larger team. Why? Because it's all his.

Sometimes the one-man design approach isn't entirely feasible. Sometimes it's necessary to draw on a variety of engineering disciplines to complete a project. So be it. But, wherever possible, I let a loner run the show.

Of course, the designer needs management guidance to complete the project; so we try to establish the boundary conditions for it.

### Measuring the yardstick

If, for example, the project is developing a 500-V power transistor for a switching operation, we first ask one of our applications engineers what kind of equipment this transistor would perform in. From our marketing people, we establish what the cost must be to compete in the market. Economics and what the customer's need is play a major role in any engineering task. It's important for the engineer to give the customer what he needs and not what the company thinks it might be able to sell him.

We try to make these guidelines as broad as possible. We don't pin the engineer down to what technology he must use. Obviously we'd like to guide him to a technology that we already have well-developed and in full production. But that may inhibit him too much in meeting the performance and cost goals. So we allow him to establish the specific tasks to meet the project goal.

We then ask him to come up with timing milestones and a final deadline for himself. My staff and I track the task and the dates; we only measure against a yardstick that he himself has defined.

After the engineer has picked the deadlines for his tasks, the dates are then reviewed with his supervisor, the marketing and applications departments and all the people that make up the product organization. Management decides whether or not it can afford the timing he has presented. We may decide that we'd finish the product too late, or we may decide that the timing is too early, which can be just as troublesome since excessive pioneering is necessary.

One of the tasks will be figuring costs—the startup costs and manufacturing costs. The designer introduces his design into manufacturing and for the first year of production, even though manufacturing is making the product, the designer really has to answer for whether the cost and the yields in production are achievable. He must also target, or forecast, a final cost on the product. He'll use the standard techniques that are available, such as the learning curve, as well as his own experience and the experience of the supervisor.

### Engineers don't like being spoon-fed

The one-man technique works in designing a component or simple equipment. If a complicated piece of equipment must be designed, the manager will probably have to assign three or four engineers of different disciplines to the project, because of their knowhow. But it's difficult to get a group of people to work in concert. They all have their own opinions about what the task is and how long it should take. The greater the mix of technology, the harder it is to use the one-man technique. If the project demands the development of a more difficult singular technology, the easier it is to use the one-man technique. If,

**Carl Turner,** Director of Power Transistor Operations, RCA Solid State Div., Somerville, N.J. 08876.

## Carl R. Turner

**Education:** BSEE, Rutgers University; MSEE, Stevens Institute.

**Experience:** Hughes R&D Labs from June, 1956, to June, 1957, as a circuit design engineer; from June, 1957, to November, 1957, U.S. Army Ordnance Officer concerned with ballistics electronic instrumentation; joined RCA in 1957 as a transistor applications engineer to develop a silicon power transistor including the design of all types of power amplifiers and switching circuits, high-frequency amplifiers and switching circuits, and control circuits.

He was promoted in 1961 to engineering group leader of applications and was responsible for developmental applications of new transistor types and customer application assistance.

He was promoted in 1963 to manager of power transistor applications and was responsible for all aspects of customer applications assistance, test equipment development, transistor specifications and new circuit development of RCA power transistors.

He assumed the position of manager of power devices in 1969. In this position, he was responsible for developing all RCA power devices, including power transistors, thyristors, rectifiers and circuit modules.

**Present Responsibilities:** Director, power transistor operations with responsibility for design, marketing, applications, planning and manufacturing of all power transistors for RCA.

**Publications:** Articles on various transistor application topics.

**Patents:** Several in the field of power transistor circuit design. Mr. Turner was a prime mover in the field of power transistor ratings and characteristics leading to industry standardization in such areas as second breakdown and safe area, thermal cycling, failure modes and temperature variations.

**Personal:** Married, two sons; hobby is boating.

for example, you're talking about developing a product with more gain, the one-man technique will work; if you're talking about developing more bandwidth, then many more engineering skills are needed to complete the job.

What I've defined is perhaps not unlike what other companies may do in our field. I do think, however, that there's one important difference: We attempt to get the individual to define the project tasks himself. This works for us. In many other companies the engineer is told when the product has to be finished, and that can be very unappetizing to him.

I find that asking the engineer to break down all the tasks and sub-tasks of the problem and put his own dates on them encourages him to do all the additional jobs that are required to meet those dates, simply because they're his.

Besides enriching the engineer's job, the one-man technique also gives the company a product faster than it could get it any other way. Why? Because a good engineer will tend to be somewhat optimistic about how fast he can do things. Engineers tend to be pessimistic when they estimate costs, but they're usually optimistic as to when they can accomplish a job. They assume that they can control everything with their own hands. It turns out, of course, that some aspects of their tasks involve people in other areas who aren't as well motivated in their specific tasks as the engineer is. But because the dates are the engineer's, he'll go the extra mile if he has to.

I call that persistence. There's nothing more important to success than persistence—in my experience anyway. There are many other ingredients in the success of an engineer, but there's nothing that can get you closer to a success pattern more consistently than persistence.

### Offsetting the drawbacks

Drawbacks to the one-man technique?

If the engineer is inexperienced, and if his direct, first-line supervisor is inexperienced, we must put safeguards and checkpoints on their dates and tasks to ensure the project's success. When you're dealing with a lot of new technology, the way we do in the solid-state business, you're not always following the straightest path to your goal. I've heard it said that if you find a path with no obstacles, it probably doesn't lead anywhere. So, even when you lose your way a bit, you can learn something new that you wouldn't have learned otherwise. Some of our most successful programs were ones on which we'd made nearly every mistake in the book.

Aside from inexperience, another drawback is people who don't like to accept the responsibility of a one-man project. They like to be the followers, often because they doubt their own ability to manage the task. But, as Moliere once said, "Doubts are more cruel than the worst of truths." In my experience there seems to be a greater distribution of leadership capability in the engineering profession than there seems to be in people in general. Not everyone, however, is capable of doing a job like this capably.

Because some people might even have an emotional trauma over setting dates, matching the engineer with the right project for him is the most important job the manager has. Not every engineer is a genius, and not every project requires a genius. A genius is difficult to manage; for every plus he offers, there's a minus that causes extra effort on the part of the manager to control and direct him.

There are also engineers whom I call utility infielders. These are guys who aren't really all-stars, but they can play many different bases and they're just as important as the genius. They may not be able to design a device that requires considerable innovation, but they can design the device that's an extension of the state of the art. In fact, for every new device that requires a lot of innovation and new technology, there are two or three devices that do not. But whatever project we assign our engineers, we always try to make them reach a bit—that's the responsibility of most managers.

Over-all, the flexibility of the one-man approach more than compensates for its drawbacks. In our business the timing of when to finish and when to introduce a product is extremely important. It's important, too, to build into the product a cost that will allow you to be competitive. The timing and the cost aspect of our business are enhanced by the single-engineer approach, because it gives him a little more flexibility. He may come up with some ingenious things that you wouldn't have thought of—if we had tied down the designer of our Darlington transistor, for example, he probably would have tended to copy the competition, and would have been wrong in that case. As it was, we came up with a superior device at lower cost, because the designer had room to move.

### Persistence and tempo—a 1-2 punch

I evolved the one-man technique over the last 13 or 14 years as a supervisor. I find that it works well for us, maybe because we have a mature group of engineers. Also, it doesn't hurt to get the new guy involved in a project as soon as possible and make him reach. Rather than have him function as a junior member of a rather complex project, we'd rather have him run his own show on a relatively simple problem.

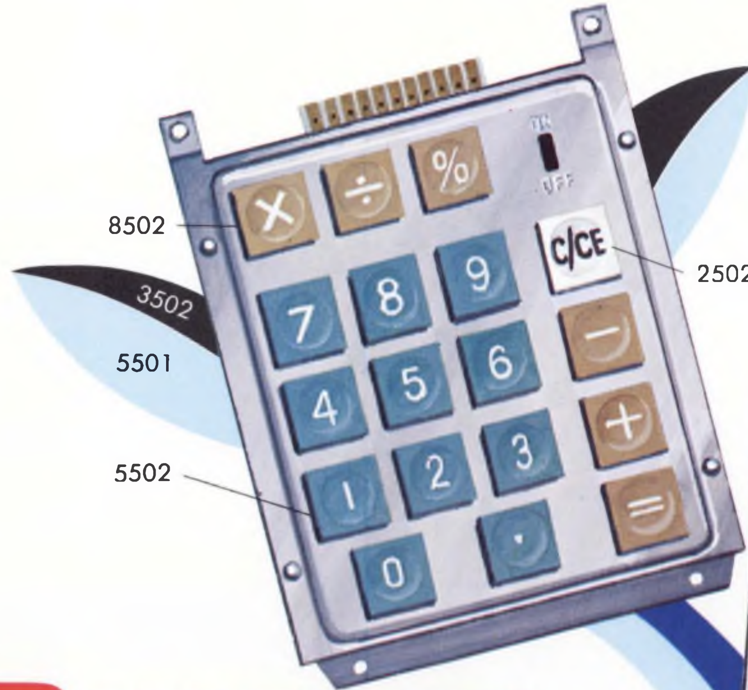
I like to think that we've improved our turnaround time, from inception of the product to production, by about 40% with the one-man approach over the way we did it six or eight years ago. But it's still not good enough. Time is the real enemy here; we have to experiment constantly with faster ways of turning around the product design. We believe strongly in persistence. The trick is to get the guy involved so he stays with the job until it's completed.

Another thing that I've been sensitive to is "tempo"—the beat at which everyone operates. In chess, tempo is your ability to think some moves ahead of your opponent. In our organization we define the ability as: "Let's think in terms of now rather than later."

Another thing that has helped me improve my operation here is cutting down on some of the red tape. Over the years I've cut as much of the "relative to approval" red tape as I can. I think a manager should keep the need for supervisory approval of work to a minimum.

When you do that, though, you must be willing to accept the fact that there are going to be mistakes. But there's a virtue in mistakes: If the same mistake keeps popping up, I've located a guy who tends to be incompetent in the tasks he's been assigned. That gives me a chance to weed him out and transfer him to another job.

Because we work in a big-company environment, I can usually match a guy to a task. He may not always be fitted to my type of operation, but I can find a job for him somewhere. These matchups are part of the "tempo" and "persistence" theme that I've used with my guys for the last four or five years. I've found that if I give an engineer a chance, he'll set a pretty good challenge for himself. ■■

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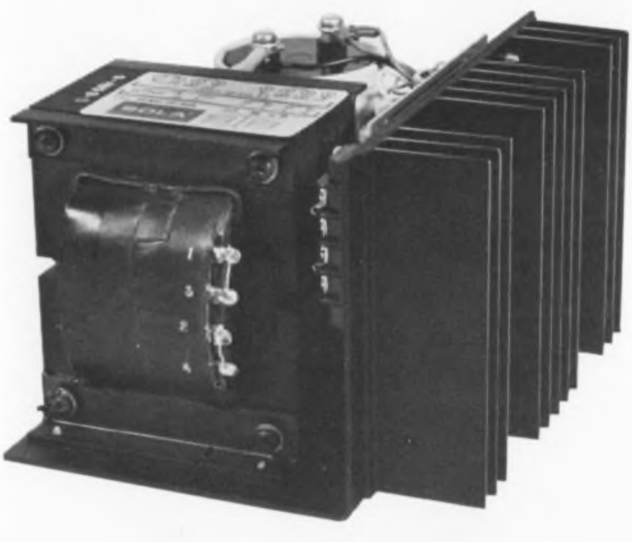

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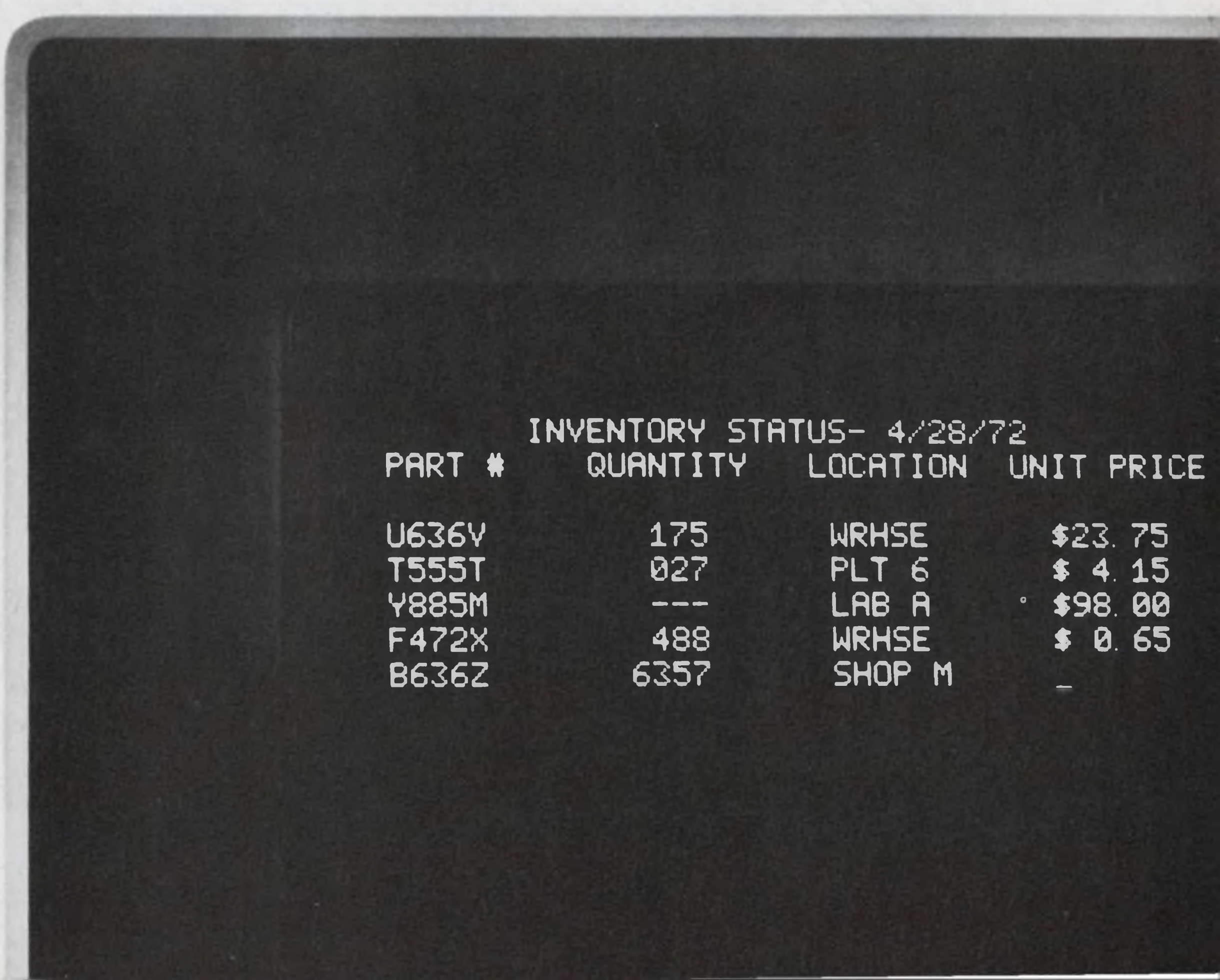

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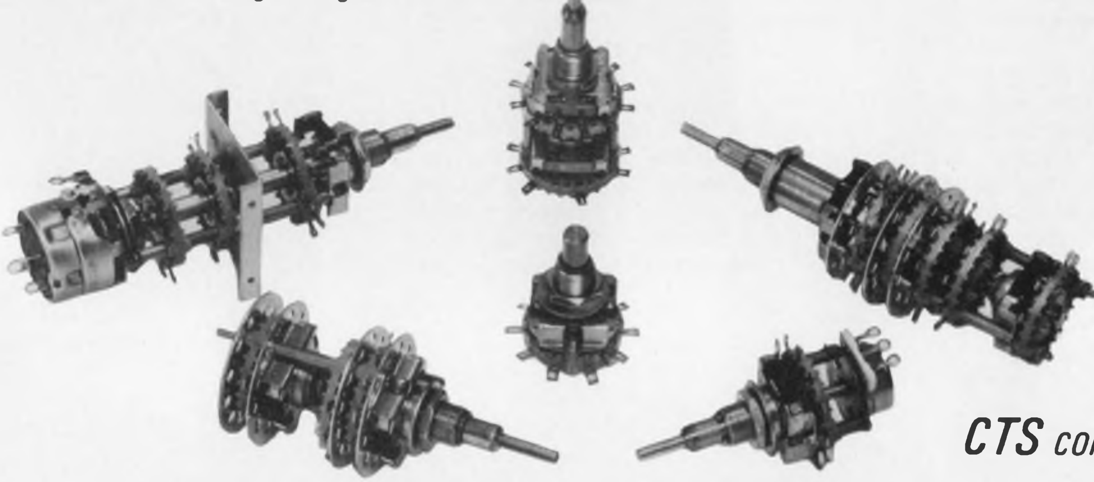

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| D-MOS FET Device | Freq. (GHz) | NF (dB) | Power Gain (dB) | $C_{iss}/C_{oss}/C_{rss}$ (pF) | 100-up price |
|---|---|---|---|---|---|
| SD200*/201 | 1.0 | 4.5 | 10.0 | 2.0/1.0/0.13 | $4.00 |
| SD202*/203 | 1.8 | 5.0 | 6.0 | 3.0/1.0/0.2 | $5.25 |
| SD300 | 1.0 | 8.0 | 13.0 | 2.0/1.0/0.02 | $3.00 |
| SD301 | 1.0 | 6.0 | 14.0 | 2.0/0.6/0.02 | $3.35 |
| SD304 | 0.5 | 5.0 | 16.0 | 2.0/1.0/0.03 | $1.00 |

**TO IMPROVE SWITCHING PERFORMANCE—Typical Values**

| D-MOS FET Device | $r_{DS}$ (On) Ω | $t_d$ (On) $t_r$ (ns) | Analog Swing | $C_{iss}/C_{oss}/C_{rss}$ (pF) | 100-up Price |
|---|---|---|---|---|---|
| SD210* | 30 | 0.6/0.7 | ±10V | 2.6/1.3/0.2 | $1.50 |
| SD211 | 30 | 0.7/0.8 | ± 5V | 2.6/1.3/0.2 | $1.50 |

*Unprotected inputs: all others diode-protected.

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**INFORMATION RETRIEVAL NUMBER 55**

# ideas for design

# Make a true rms-to-dc converter, using only one IC multiplier and an op amp

An rms-to-dc converter circuit uses one IC multiplier and a dozen inexpensive components. It can compute, with less than 1% error, the rms value of a voltage over a dynamic range of 20:1. The circuit is less complex and has higher accuracy than two-multiplier explicit rms circuits, since it is based on an implicit solution of the rms equation.

A block diagram of the implicit solution is shown in Fig. 1a. The functions of squaring and square-rooting are performed simultaneously in the $V^2/Z$ block when the output is fed back to Z. This feedback increases the gain of the input as the signal level decreases, and thus increases the dynamic range of the circuit.

Fig. 1b shows a practical version of the implicit circuit. The AD531J IC multiplier provides the $V^2/Z$ transfer function with less than 1% error. The output signal from the AD531J is averaged by a low-pass RC filter and buffered by the 741 op amp connected as a follower. The output of the 741 is fed back to the Z input of the AD531J through $R_F$ and $Q_1$, which convert the output voltage to the required current, $I_Z$.

The circuit has an upper −3 dB bandwidth of 750 kHz, which is independent of signal level, and a lower limit, excluding the dc response, set by the RC time constant. The input dynamic range is from 0.2 V to 5 V rms, with a crest factor of 2. Table 1 lists the four steps needed to trim the circuit for errors of less than 1% of full scale (50 mV).

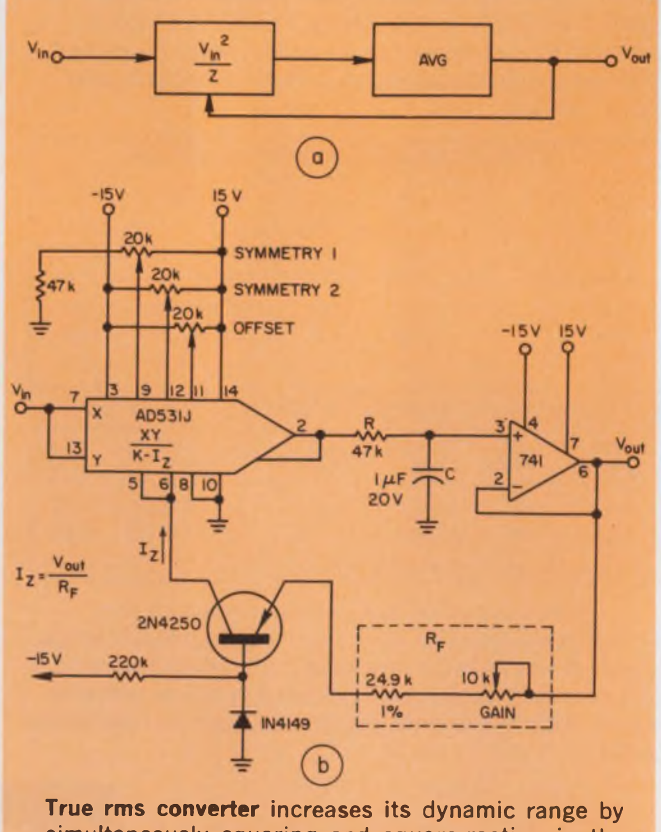
In contrast, the conventional explicit approach requires two multipliers—one to square the input signal, followed by a low-pass filter to average the signal, and a second multiplier connected as a square-rooter to compute the root of the mean-square. The limited dynamic range and accuracy of the two-multiplier rms circuts do not justify their complexity or high cost. Modular rms converters have good dynamic range and high accuracy, but they are expensive—usually three to five times the parts cost of the one-multiplier rms circuit.

*Lewis Counts, Manager, Analog Engineering, Analog Devices, Route 1 Industrial Park, P.O. Box 280, Norwood, Mass. 02062.* CIRCLE NO. 311

## Table 1. Trim procedure to minimize error

Starting with the trim pots centered, apply the specified dc input voltages, and adjust the trim pots for the specified output.

| STEP | $V_{in}$ | ADJUST | $V_{out}$ |
|---|---|---|---|
| 1 | +10.0V, −10.0V | SYMMETRY 1 | EQUAL OUTPUTS FOR +,−in |
| 2 | +1.00V, −1.00V | SYMMETRY 2 | EQUAL OUTPUTS FOR +,−in |
| 3 | +1.00V | OFFSET | +1.00V |
| 4 | +1.000V | GAIN | +10.00V |




**True rms converter** increases its dynamic range by simultaneously squaring and square-rooting in the $V^2_{in}/Z$ block (a). The actual circuit (b) requires only four trim adjustments and 13 components.

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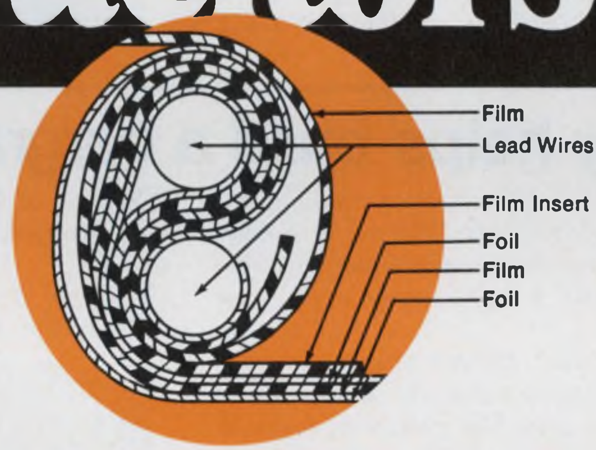


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INFORMATION RETRIEVAL NUMBER 56

# 2-component RC network initializes CMOS registers

CMOS storage elements are known for low power consumption and high storage density. They also have another advantage—ease of initialization or reinitialization to a predetermined bit pattern. A 1/8-W resistor and a 30-pF capacitor suffice for initialization because of the negligible input current drawn by the memory cell (Fig. 1a). A bounce-free switch is not required.

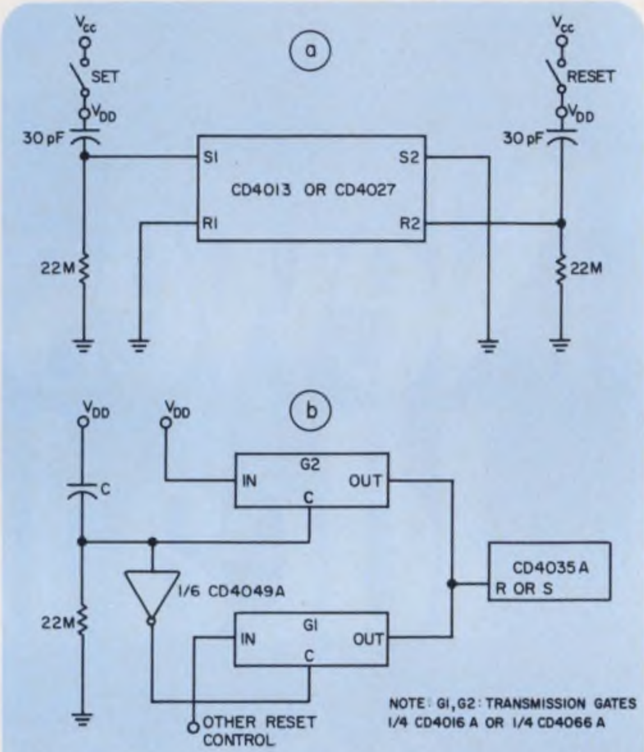
Increasing the capacitor to 1000 or 1500 pF permits initialization with power-supply turn-on—where the capacitor is connected directly to the power bus.

The circuit in Fig. 1b allows both initialization and reset to a ONE or ZERO. At power turn-on, transmission gate $G_1$ conducts and the set or reset line of the memory goes high. At this time $G_2$ is open and the reset control line is disconnected from the cell.

After the capacitor has charged, gate $G_2$ closes and $G_1$ opens. The control line can now reset (or set) the cell. The effective capacitance presented across the control line is 15 to 20 pF.

A capacitor on the order of 0.001 $\mu$F is needed if $V_{DD}$ is switched, and 0.005 to 0.01 $\mu$F if $V_{DD}$ is connected directly to the power supply.

*Otto Bismarck, Solid State Div., RCA, Route 202, Somerville, N.J. 08876.* CIRCLE No. 312




**Simple RC network** initializes CMOS memory element (a) because input-current requirements are low. The addition of a pair of transmission gates (b) provides turn-on initialization and system reset capability.

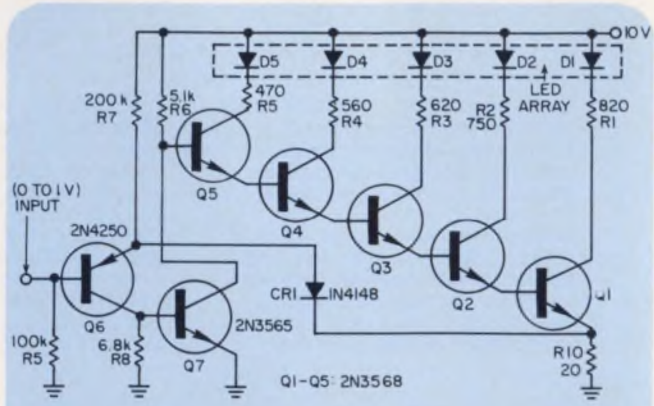
# LED array helps build a bargraph display

A bargraph display is an effective medium for viewing a monitored variable. Where low resolution (5 to 10 segments) is sufficient, the display can be built with a LED array and a few transistors.

With the five-segment system shown, transistors $Q_1$ to $Q_5$ saturate successively as the input signal increases from zero. The resulting currents drive LED diodes $D_1$ through $D_5$. As each transistor turns on, its emitter current flows through $R_{10}$. Transistors $Q_6$ and $Q_7$, as well as $CR_1$ and associated resistors, comprise a feedback amplifier that forces the voltage across $R_{10}$ to equal the input voltage. And this causes the display to "deflect" linearly.

For $R_{10} = 20\ \Omega$ and a current of 10 mA per LED, the resolution is 200 mV and the full-scale input equals 1 V (for five LEDs). Diode $CR_1$ cancels the $V_{BE}$ offset of $Q_6$. Resistors $R_1$ through $R_5$ control the LED currents. The voltage across $R_3$, for example, is 10 V minus 1.5 V (two transistor $V_{BE}$'s) minus 0.6 V (30 mA $\cdot$ $R_{10}$). Since $V_{CE(SAT)}$ of $Q_3$ is negligible at 10 mA, 6.4 V must be dropped. And 620 Ω is the nearest standard value.

*David Barton, Litronix, 19000 Homestead Rd., Cupertino, Calif. 95014.* CIRCLE No. 313




**Successive saturation** of transistors $Q_1$ through $Q_5$ give the LED display a bargraph appearance. Feedback through $CR_1$ helps linearize the apparent deflection as a function of input voltage.

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INFORMATION RETRIEVAL NUMBER 57

# Programmable current generator has linear response and ignores power variations

Changes in transistor $h_{FE}$ and $V_{BE}$ introduce nonlinearities or offsets in conventional current generators. The use of extra elements to cancel the $V_{BE}$ drop is not an effective solution. But varying the emitter current in accordance with the input control voltage is.

In Fig. 1 op amp $A_1$ transfers control voltage $V_{IN}$ to the emitter of $Q_1$ and also supplies the required base current. This eliminates the effects of $V_{BE}$ drop within the feedback loop. The current flowing through $Q_1$, which is equal to $V_{IN}/R_1$, produces a voltage drop of $V_{IN} \cdot R_2/R_1$ through collector resistor $R_2$.

Op amp $A_2$ transfers the voltage at point B to C. And the output current, $I_O$, from $Q_2$ is given by

$$I_O = \frac{V_{IN}/R_1}{R_2 R_3}.$$

To keep the operation of $Q_2$ in the linear region, the load resistance, $R_L$, is constrained according to the equation

$$\frac{R_1 R_3 \left[V_{CC} - 2 - V_{IN(max)} \cdot R_2/R_1\right]}{R_2 \cdot V_{IN(max)}} \geq R_L,$$

thereby keeping $V_{CE(Q2)}$ above 2 V. The exact expression for the output current is

$$I_O = \alpha_1 \alpha_2 \frac{V_{IN} R_2}{R_2 R_3} + \alpha_2 \frac{R_2}{R_3} \cdot I_{CBO(Q1)} + I_{CBO(Q2)}$$

The use of transistors with large beta and low leakage makes the second and third terms negligible compared with the first. The component values shown provide for 0-to-10-V input with a scale factor of 1 mA/V. As shown by the plot (Fig. 2), the actual constant is 0.96 mA/V. Since both $Q_1$ and $Q_2$ are tied to a common $V_{CC}$ bus, any changes in $V_{CC}$ cancel one another out. And the circuit-stability factor, $\frac{dI_C}{dI_{CBO}}$ for $Q_1$ an$Q_2$ is excellent, approaching the theoretical limit of unity.

*V. Ramamoorthy, Electronics Engineer, Indian Space Research Organization, A 3-6 Peenya Industrial Estate, Bangalore, India 560022.*

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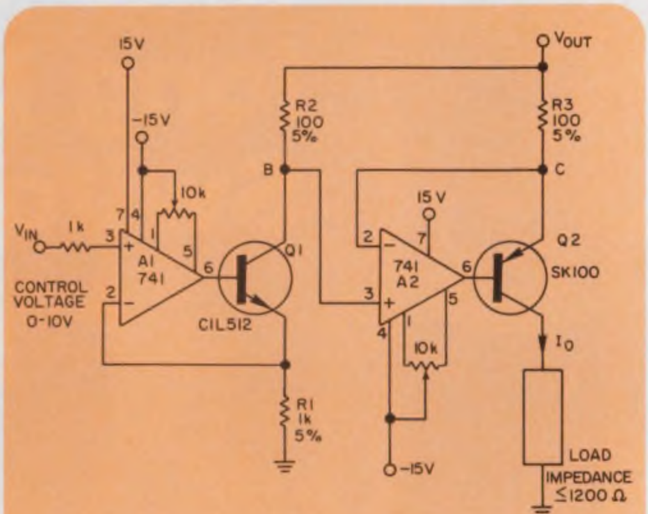
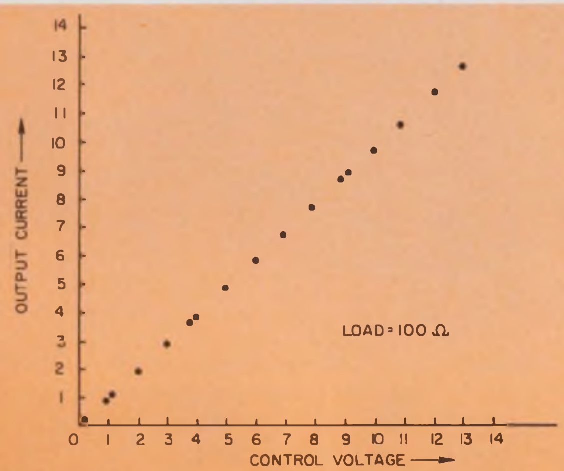



1. **Variable-current generator** operates by successively transferring input-voltage variations to the emitters of $Q_1$ and $Q_2$. Control of emitter current instead of base current minimizes errors caused by changes in $h_{FE}$ and $V_{BE}$.




2. **Output current is linear** with input voltage from 0 to 10 V. The circuit shown provides a scale factor of 0.96 mA/V.

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# Adaptive tester handles multi-family logic

PC boards containing a mix of logic families present a real headache to the designers of automatic test equipment. The acceptable signal levels at each pin vary according to the type of family—5 V for TTL, 10 V for MOS, and almost anything for discrete components. How do you cope with such a situation on a pin-for-pin basis?

Instrumentation Engineering, Inc., of Franklin Lakes, N. J., solved the problem with a programmable driver/receiver system that can treat any pin as either an input or output. The system—called ML$^2$M, for multi-level logic module—attaches to the company's System 390 logic tester. It handles up to 400 pins with no need to rewire different pin configurations.

As shown in the diagram one driver/receiver (d/r) is used for each active pin. The multiplexer joins a pin to the d/r. Two switching networks apply driving and receiving reference-voltage levels to the d/r. The driver reference section can switch two voltage pairs from four programmable supplies; the receiver reference section switches 12 supply levels.

One d/r can drive any of two logic families, since ZERO and ONE require two reference-level pairs. By contrast, a single d/r can serve as a receiver to any of six logic families. Each pair of reference voltages defines the upper and lower limits for an expected ZERO or ONE.

Two voltage comparators in each d/r permit programmed control of three tests: window, under-limit for logic ONE and over-limit for logic ZERO. The specifications are as follows:

For the driver:

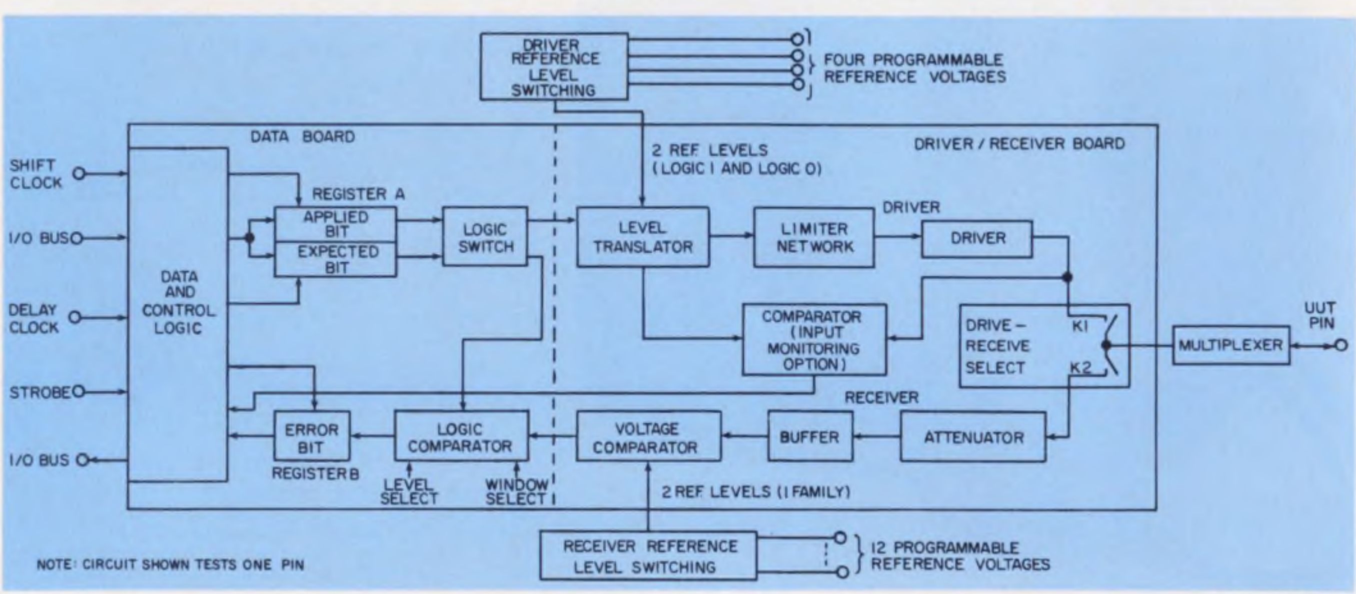
- Output voltage—±18 V (±1% or ±20 mV).
- Current source or sink—60 mA.
- Output impedance—less than 1.5 Ω at the UUT pin.

For the receiver:

- Operating range—±75 V.
- Input impedance—greater than 1 MΩ from −10 to 10 V and >10 MΩ outside this range.
- Voltage measurement accuracy—better than ±1.5% or ±50 mV.
- Speed—I/O bus rate.

Variable delays from the ML$^2$M permit time to elapse between the computer input word and the output interrogation. This allows measurement of or introduction of propagation delay through the unit under test. A hardware option permits continuous monitoring.

The decision to drive two families but check six was based on operating experience. Circuit boards to be tested usually contain a maximum of six logic types. However, system users often have suitable auxiliary programmable sources that can supply external test stimuli for the remaining four of the six logic types.




**Driver receiver module** handles a variety of logic levels. Each module can, on command, supply stimuli for any of two logic families or check responses for any of six families.

# Toohey Reports.

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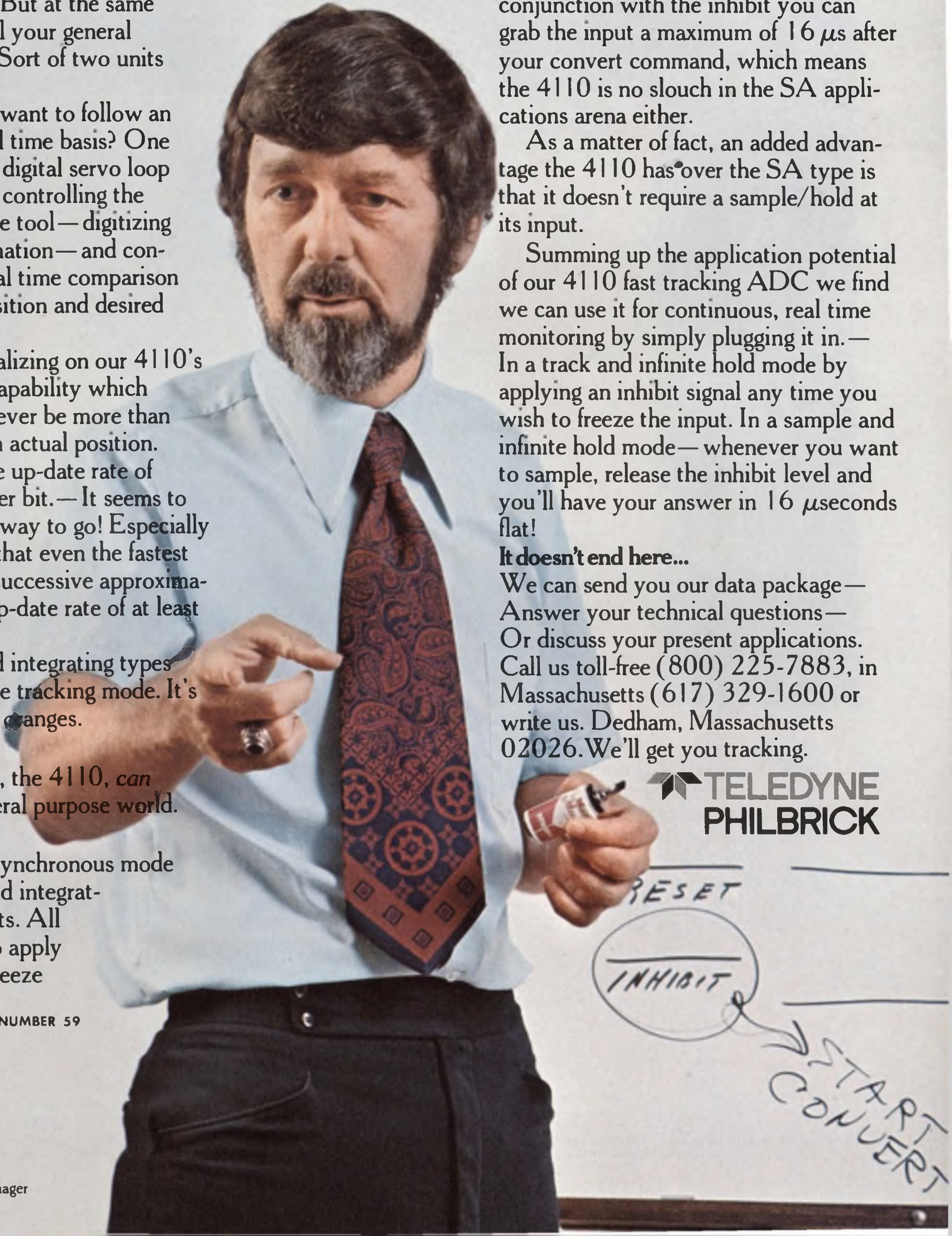


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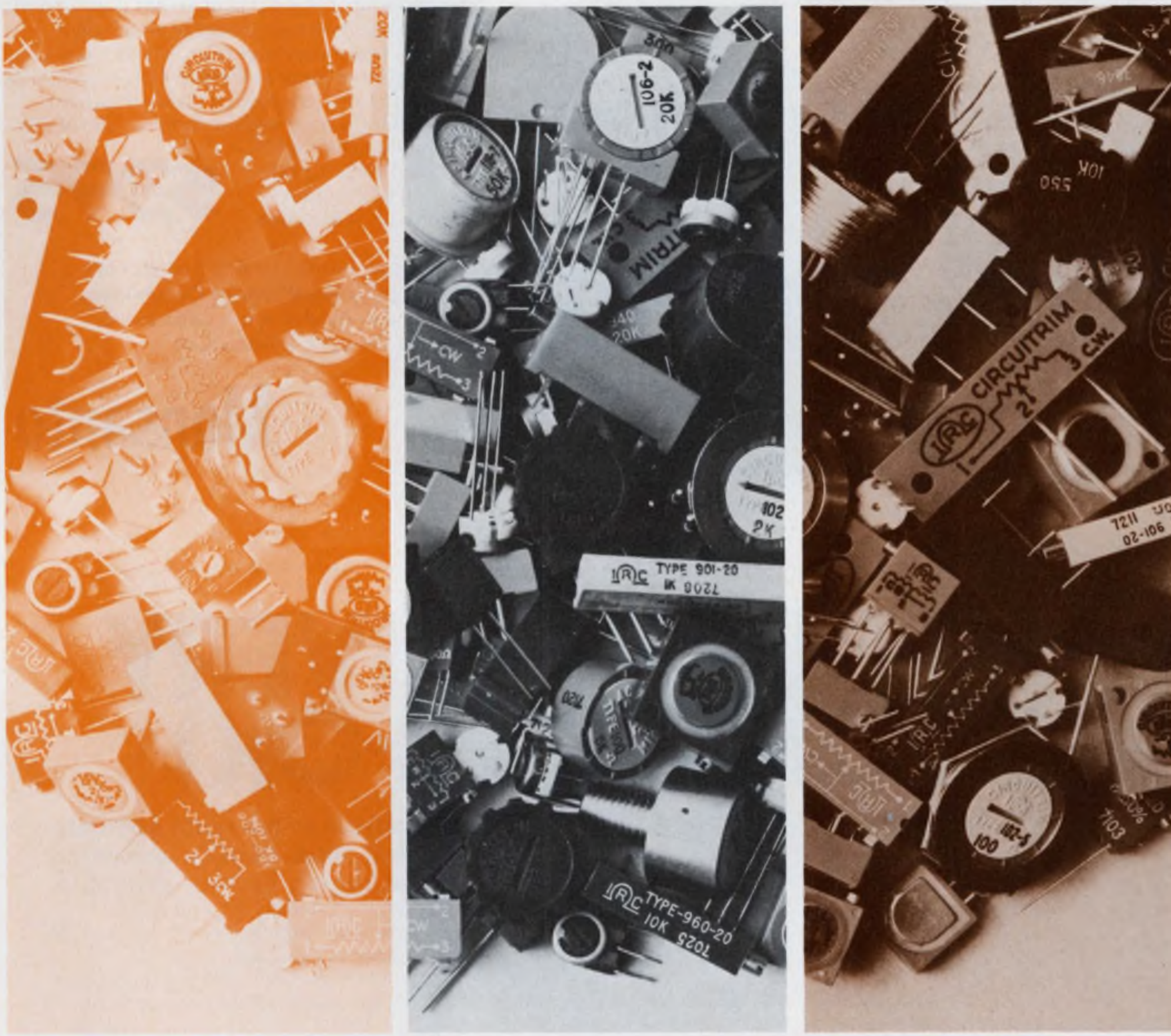


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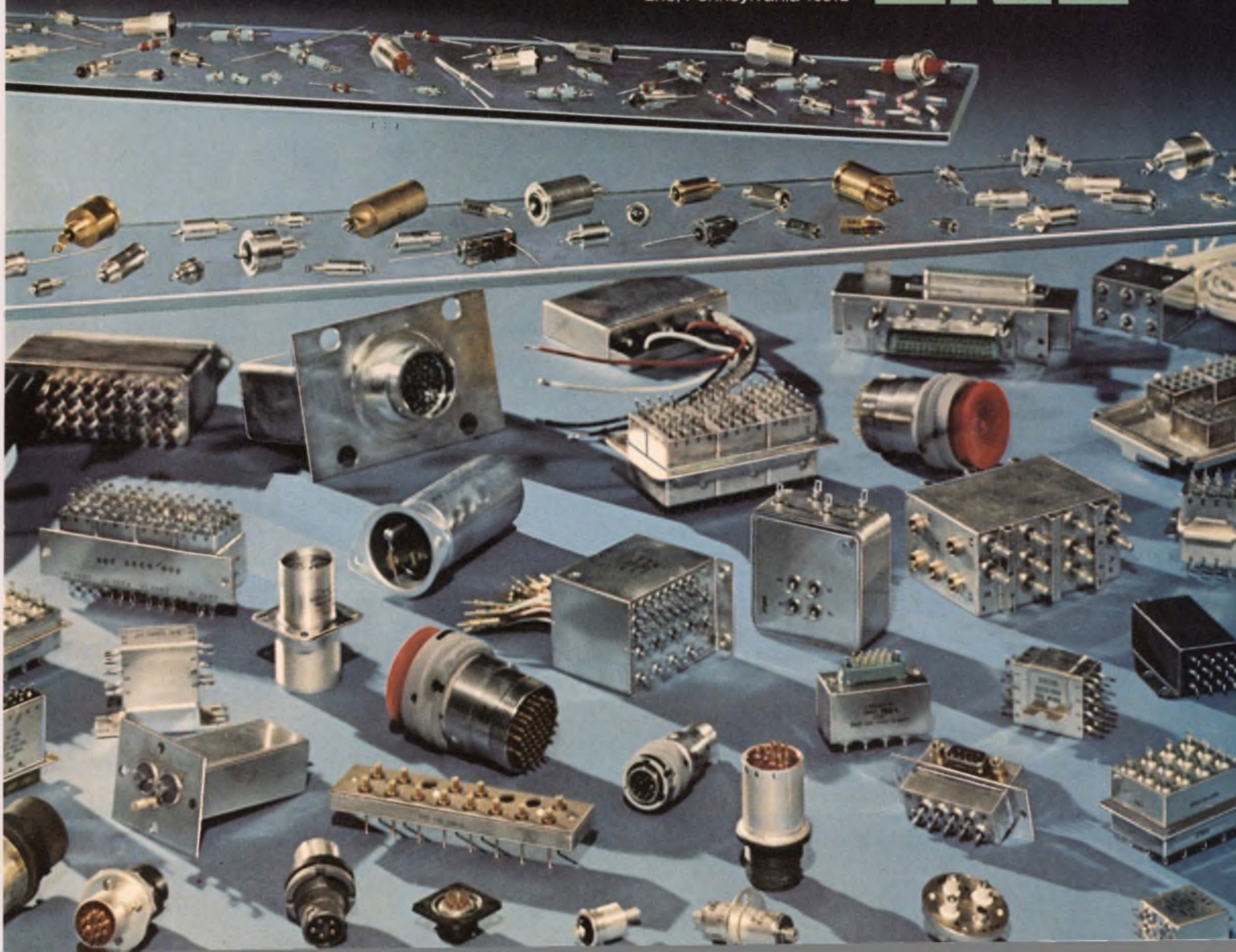


# international technology

# PCM range greatly boosted with variable coding signals

The dynamic range of a pulse-code-modulation system has been greatly increased by a technique in which the coding signals are not fixed but vary to follow the envelope variations of the input signal. Acceptable speech quality is reported at a transmission rate of 9600 b/s.

The adaptive pulse-code modulator (APCM) has been developed by the Signals Research and Development Establishment, Christchurch, Hampshire, England. At the transmission end (Fig. 1) the input speech signal passes through a bandpass filter, which removes frequencies above 2400 Hz and below 250 Hz. The removal of higher frequencies prevents aliasing—that is, distortion because of violation of the sampling theorem—with a rate of 4800 samples/s. Removal of frequencies below 250 Hz balances the loss of high frequencies.

The signal is applied next to three voltage comparators. The first (A) compares the signal with zero. If the signal is positive, it produces a logic ONE at its output. If negative, a ZERO is produced. The output is applied to a bistable circuit that is sampled at 4800 Hz, and this produces a time-quantized polarity signal in the form of a 4800 b/s data stream.

The two other comparators (B and C) compare the band-limited signal with voltages +V and −V. If the signal is more positive than +V, comparator B produces a ONE at its output. Comparator C produces a ONE if the signal is more negative than −V. The amplitude digits are produced by application of the outputs of both comparators to an OR gate, whose output is sampled in a second bistable circuit. Each digit is a ONE if the corresponding sample is more positive than +V or more negative than −V. Otherwise it is zero.

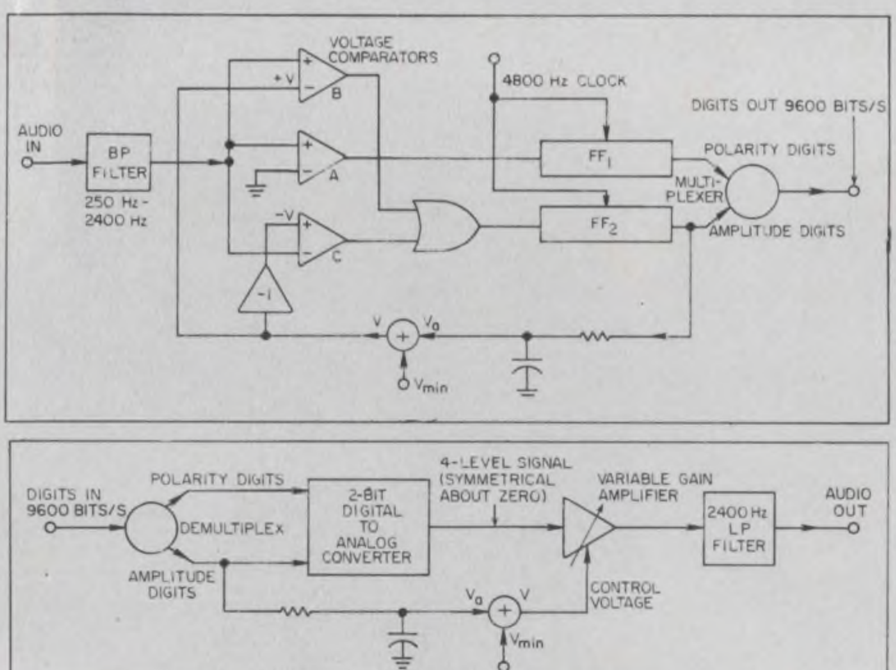
Feedback from the digital output is used to obtain the voltage (V). The amplitude digits—which switch between zero voltage for a logic ZERO and positive voltage for a logic ONE—are applied to an RC integrator with a 10-ms time constant. This produces a positive voltage ($V_a$), which has a small fixed voltage ($V_{min}$) added to it to obtain V. Adding $V_{min}$ ensures that V never falls to ZERO, and V is inverted to provide −V.

Multiplexing is achieved by transmitting digits alternately from the two channels, which produces an output of 9600 b/s.

At the receiving end the digits are demultiplexed by use of the decoder (Fig. 2). The channels are separated by switching the digits alternately to two outputs, and then by determining which channel contains the amplitude information and which has the polarity. The polarity and amplitude digits are applied to a two-bit digital-to-analog converter, which produces a four-level signal symmetrical about ZERO. A variable-gain amplifier introduces the amplitude variation. The voltage ($V_a$) is recovered from the amplitude channel by use of an RC integrator similar to the one in the coder. The fixed voltage ($V_{min}$) is added to $V_a$ to obtain V. This controls the amplifier gain, which is directly proportional to the value of V.

The output from the variable-gain amplifier is a four-level signal whose amplitude varies at a syllabic rate with the variations of the threshold V at the coder. The waveform passes through a 2400-Hz, low-pass filter to remove frequency components above the signal band, and forms the output from the decoder.

Quantization noise measurements show that the APCM coder is superior to an adaptive delta-signal modulator when both are operating at 9600 b/s.




**Two-bit adaptive pulse-code modulation coder** (above) produces an output of 9600 b/s. At the receiving end the digits are demultiplexed by the two-bit decoder shown below.

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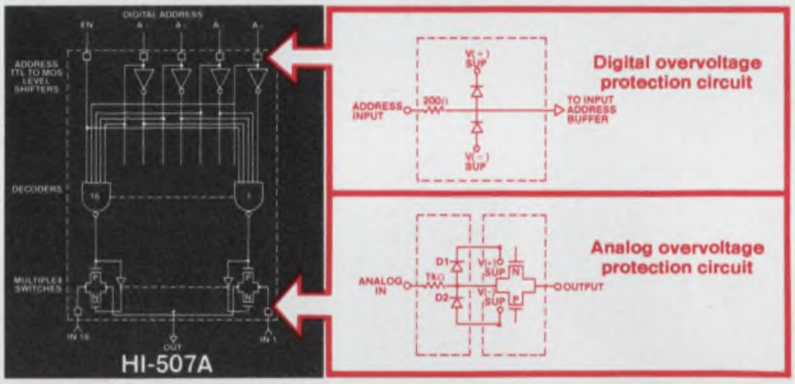


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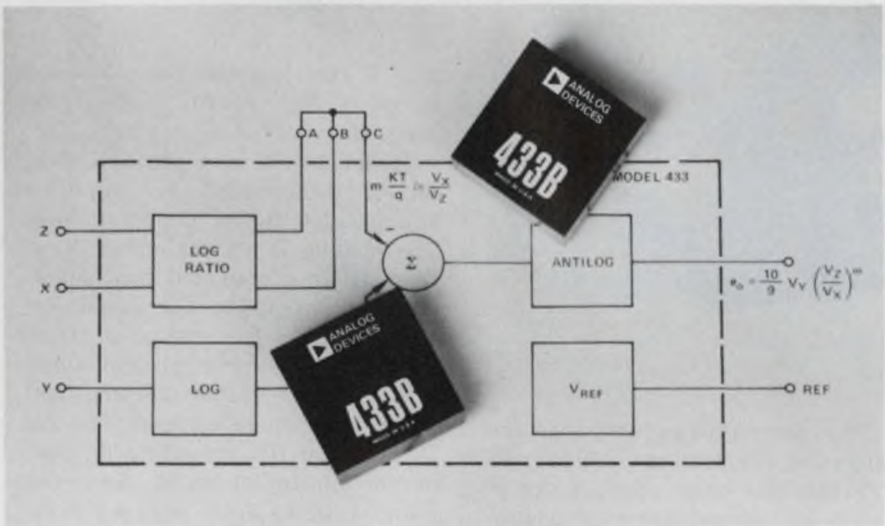
# new products

## Multifunction log module achieves 0.25% accuracy




*Analog Devices, Route 1 Industrial Park, P.O. Box 280, Norwood, Mass. 02062. (617) 329-4700. P&A: see text.*

Every circuit manufacturer's goal is improved performance with little or no increase in cost. Analog Devices has developed a programmable multifunction log module, the AD433B, which has a maximum error of 0.25% of full-scale. And it costs only $17 more than less accurate and less versatile units.

Either by connection of jumpers to the pins or selection of two external resistors, the user can program the unit to multiply, divide, square, square-root, square a ratio, square-root a ratio or raise a ratio to an arbitrary power, m, which can take on any value from 0.01 to 10. The basic functional equation for the circuit is $(10/9)Y(Z/X)^m$.

The input variables can span a voltage range of 0.01 to 10 V. In this range the error is only 1 mV ±0.15% of the theoretical output voltage. Thus the total error decreases with a decreasing output voltage.

Output offset voltage cannot be trimmed, but is guaranteed not to exceed 2 mV at 25 C. The output offset drift stays below 1 mV/°C over the entire operating temperature range of −25 to +85 C. Accuracy, offset drift and noise performance are practically independent of denominator level. This further minimizes the output error. In addition the output error over the entire operating temp range reaches a maximum of 1%.

The 433B includes a stable voltage reference that drifts only 0.005%/°C. This reference can be used to hold any of the input variables at a constant value. When the module is connected as a divider, it has almost 20 times better accuracy than that obtained with a conventional 0.1% multiplier/divider connected in a feedback loop.

The closest competing module is the Intech Model A-733. This offers accuracy within 0.5% maximum and an operating temperature range of 0 to 70 C. Furthermore the output error of the Intech unit remains constant as the output decreases. Prices for the A-733 start at $70 for 1 to 9 units.

The AD433B comes in a 1.5-by-1.5-by-0.62-in. modular package and is priced at $87 for 1 to 9 pieces. Delivery is from stock.

Analog Devices **CIRCLE NO. 251**
Intech **CIRCLE NO. 252**

## Tiny vibration amplifier boasts many features

*Validyne Engineering, 19414 Londelius St., Northridge, Calif. 91324. (213) 886-8488.*

The PA89 is a vibration monitoring amplifier plug-in module. A connector on the rear panel of the MC1 case provides a constant current source and input for operation with an external impedance converter. A switch on the front panel selects either internal or external impedance converter operation. This switch also disconnects both inputs so a test-point jack on the front panel becomes a calibration signal input. Two outputs are provided. One provides ±10 V peak at 100 mA, and is capable of sustaining a direct short indefinitely without damage to the amplifier. The second is attenuated to ±1 V, peak. The function switch allows for selection of nonintegrating and integrating amplifiers such that the output is proportional to acceleration (g's), velocity (in/sec) or displacement (in.). Internally selectable low-pass filters provide for the modification of the 20 kHz frequency response to 2 kHz, 600, 200 or 60 Hz.

**CIRCLE NO. 256**

## Constant gain preamp has 15-MHz bandwidth

*Trodyne Corp., 39 Industrial Ave., Teterboro, N.J. 07608. (201) 288-4400. $175.*

Type 7529 is a 40 dB fixed-gain preamplifier. The 3-dB bandwidth is 8 kHz to 15 MHz. Weight is 4.5 oz. The amplifier has dual BNC connector inputs to allow single ended or differential inputs.

**CIRCLE NO. 257**

# Isolation amplifier provides 160-dB isolation and gain, too


*Burr-Brown, International Airport Industrial Park, Tucson, Ariz. 85706. (602) 294-1431. P&A: See text.*

Now the isolation amplifier user has a choice. Burr-Brown has just introduced two units that it calls ISO-OP-AMPs—the 3450 and 3451. They offer full differential inputs and an isolation mode rejection of 160 dB. They compete with the Analog Devices 272 series which has dominated this important area.

The 3450 has a bipolar input stage with an input drift of 1 $\mu$V/°C, while the 3451 has a FET-input stage with an input-bias current of 25 pA. Both Burr-Brown units can be connected in all of the common op-amp feedback networks.

Open-loop gain of the 3450 is guaranteed at 94 dB minimum. For both ISO-OP-AMPs, the isolation mode rejection at dc is a resounding 160 dB minimum but drops off to 120 dB minimum at 60 Hz. And with a source unbalance of 1 k$\Omega$, rejection drops further still, to 105 dB. The isolation impedance stays at a high $10^{12}$ $\Omega$ with an input capacitance of 16 to 20 pF, over the 3-dB bandwidth. But this bandwidth is only 1 kHz typical.

The Burr-Brown units can handle voltages as high as 500 V (peak, continuous) and 2000 V (peak spike, nonrepetitive).

The operating temperature range for the 3450 is −25 to +85 C, while the gain nonlinearity is 0.01% maximum. Input impedance for the unit is a low $10^7$ $\Omega$ for differential-mode operation and $5 \times 10^9$ $\Omega$ for common-mode operation.

The 3451 has a more limited operating temp range of 0 to 70 C and the gain nonlinearity increases to 0.1%. But its input impedance stays at a comfortable $10^{11}$ $\Omega$ for differential or common-mode operation.

The competing Analog Devices series 272 isolation amplifiers offers other features. Models 272 and 273 are unity-gain amplifiers and offer a CMR at 60 Hz of 115 dB, when a 5 k$\Omega$ source unbalance exists. The 274 can deliver a gain of up to 40 dB and maintain the CMR 115 dB over the entire gain span. However, all three units can handle differential-input voltages of 5000 V peak and maintain a common-mode voltage isolation of 1000 V peak. Small-signal −3 dB response is at least 2 kHz, while the operating temperature range is 0 to 70 C. Prices start at $109 for a single unit.

Price in unit quantities for Burr-Brown's 3450 is $165, while it is $105 for the 3451. Both units are available from stock.

Burr-Brown **CIRCLE NO. 253**

Analog Devices **CIRCLE NO. 254**

## Signal conditioning amps offer mini-size

*B & F Instruments, Inc., Cornwell Heights, Pa. 19020. (215) 639-7100.*

Model 1-800 is a signal conditioner, differential dc amplifier and isolated power supply in one. The module is so small that 30 of them fit in a standard rack adapter, 3-1/2 in. high. The amplifiers are available for operation from 28 or 12 V dc. For ground applications, an optional "Scamp-pak" power unit operates from 110/220 V, 50 to 60 Hz, providing dc power for up to 60 units. Amplifier gain is 10 to 1000 with an accuracy of 0.1%. Common-mode rejection for balanced inputs is 126 dB at dc and 96 dB at 1000 Hz, both at gains of 1000. The operating temperature range is −20 to +55 C.

**CIRCLE NO. 258**

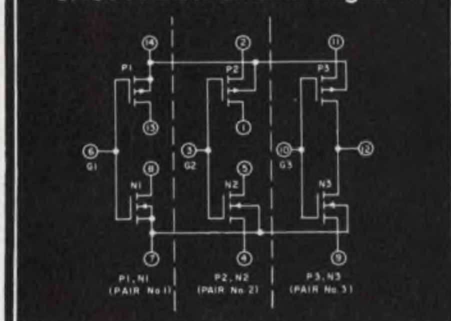
## CMOS logic modules offer many functions

*Control Logic, Inc., Nine Tech Circle, Natick, Mass. 01760. (617) 655-1170. From $20 to $60; 30 day.*

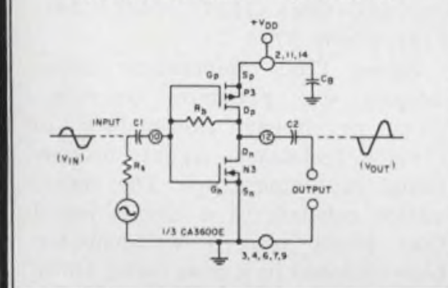
The I Series of CMOS high noise immunity modules use unregulated power supplies and have a high fan-out capability per function. Power consumption is lowest of all digital logic families. Logic levels are 0 to 15 V with spurious noise immunity of 45% of the supply voltage (6.5 V max). In severe electrically noisy environments performance is in excess of 1 MHz operating speeds. Operating temperature range is −40 to 85 C. The I Series includes gates, shift registers, timers, counters, comparators, optically coupled ac/dc inputs and outputs, light/relay drivers and photocell input modules.

**CIRCLE NO. 259**

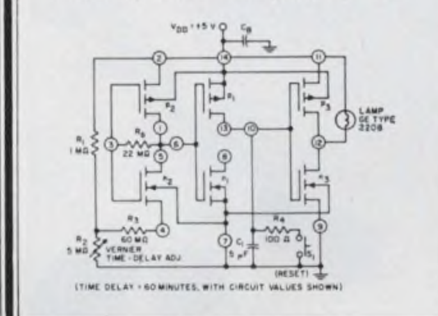
# Linear COS/MOS... RCA's CA3600E premieres



CA3600E schematic diagram



CA3600E transistor pair biased for linear-mode operation



Analog timer using CA3600E

Meet the linear IC with the advantages of COS/MOS. The new RCA CA3600E Transistor Array... three pairs of complementary enhancement-type MOS (p-channel/ n-channel) transistors on a single chip.

The CA3600E is designed for a great variety of applications requiring virtually infinite input impedance, wide bandwidth, matched characteristics, lower power consumption and general purpose circuitry.

And that's not all. With the new CA3600E you get performance advantages that include square-law characteristics, superior cross-modulation performance, and a greater dynamic range than bipolar transistors.

Whether you're working in timing, sensing and measuring or any other applications, or if you're tired of fighting beta variation in your bipolar circuit, let your "linear" imagination run wild. The features offered in the new CA3600E COS/MOS Linear IC are too good to pass up.

- ☐ Virtually infinite input resistance/ 100 gigohms
- ☐ Each transistor rated for operation up to 15V and 10 mA
- ☐ Low gate-terminal current/ 10 picoamps
- ☐ No "popcorn" (burst) noise
- ☐ Matched p-channel pair/gate-voltage differential ($I_D = -100uA$) ... ±20mV (max)
- ☐ Stable transfer characteristics over a temperature range of −55°C to +125°C
- ☐ High voltage gain/up to 53dB per COS/MOS pair.

Supplied in the 14-lead dual-in-line plastic package, the CA3600E is available in production quantities from your local distributor or direct from RCA.

For complete data sheet/ application note write: RCA Solid State, Section 57J11, Box 3200, Somerville, N.J. 08876. Or phone: (201) 722-3200.

RCA Solid State
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International: RCA, Sunbury on Thames, U.K., or Fuji Building, 7 4 Kasumigaseki, 3 Chome, Chiyoda Ku, Tokyo, Japan. In Canada: RCA Limited, Ste. Anne de Bellevue 810, Canada.

INFORMATION RETRIEVAL NUMBER 68

## Temperature transmitter linear over 600 C span

*Yellow Springs Instrument Co., Sostman Div., Box 279, Yellow Springs, Ohio 45387. (513) 767-7241. From $115.*

Series 1200 temperature transmitters use platinum thermometers or linear thermistors to provide resistance signals proportional to temperature. The transmitter consists of a circuit board that plugs into a wall-mounted base enclosed in a dust cover. Units can be operated on 117 or 230 V ac, 50/60 Hz. Model 1250 temperature transmitter uses platinum thermometers for temperature sensing. It can be ordered with a temperature span as narrow as 50 C and as broad as 600 C over a range of −50 to +600 C (−58 to +1112 F) with an absolute accuracy of ±0.1% full scale. Units are factory calibrated. Model 1252 transmitters use YSI linear thermistors as temperature sensors. They are limited to −30 to +100 C.

**CIRCLE NO. 260**

## P-i-n diode drivers switch in 10 ns or less

*Micro-Dynamics, Inc., 10 Sonar Dr., Woburn, Mass. 01801. (617) 729-9450. $65 ea. (1-9); 30 day.*

High speed digital drivers can drive p-i-n diodes in rf switch, attenuator, and modulator applications. The input is TTL/DTL compatible with the input impedance tailored for cable termination and voltage source impedance matching. All units are screened to MIL-STD-883, method 5004, level B. Bidirectional switching speeds are less than 10 ns over the temperature range of −55 to +125 C. Two basic package configurations are available, either 0.4 in. square by 0.1 in. thick or 0.75 in. square by 0.15 in. thick.

**CIRCLE NO. 261**

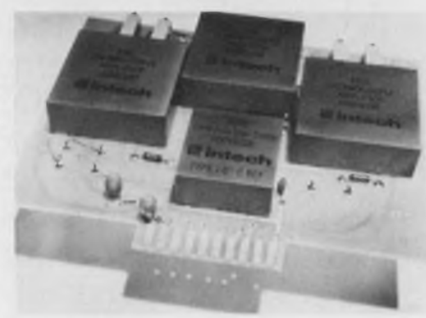
## Two-axis magnetometer designed for small size


*Develco, Inc., 530 Logue Ave., Mountain View, Calif. 94043. (415) 969-1600.*

Model 9100 is a two-axis miniature fluxgate magnetometer. It offers single-core, two-axis construction to provide good sensitivity, low noise and good linearity over a wide range of operating temperatures. The unit weighs 2.5 oz and measures 1-1/4 by 1-3/8 by 2-1/2 in.

**CIRCLE NO. 262**

## Thermocouple amplifiers need no reference source



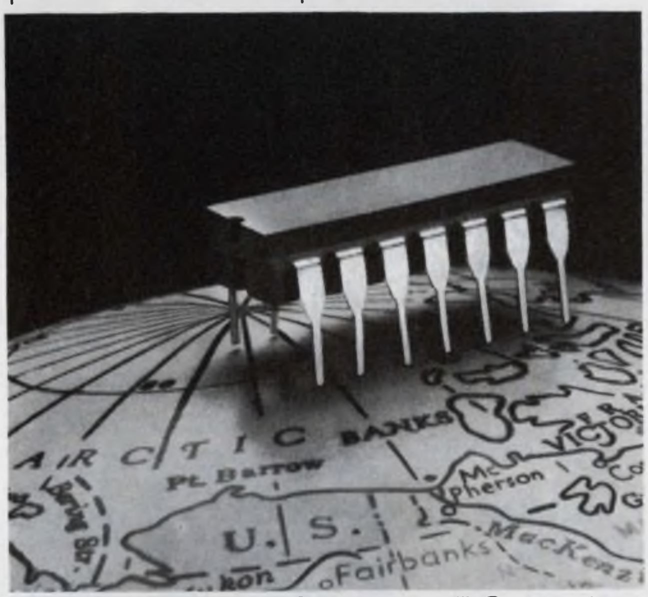
*Intech, 1220 Coleman Ave., Santa Clara, Calif. 95050. (408) 244-0500. $80 (601), $95 (602), $385 (600).*

The A-601 thermocouple amplifier and A-602 cold junction reference module, when used together, can accurately amplify a thermocouple signal with less than ±1 C error without the use of any cumbersome reference temperature baths. The gain of the amplifier is externally adjustable from 10 to 1000 with a single resistor. The module has a common-mode range of 20 V and a low input drift of 1 $\mu$V/°C. The output accuracy is held to better than ±1% over the entire operating temperature range. The A-601 provides precision amplification of the thermocouple signal, and the A-602 is a precision reference cold junction signal simulation.

**CIRCLE NO. 263**

# RCA COS/MOS in low cost ceramic.

RCA now offers COS/MOS in a new low cost ceramic package. So you can select, from our complete line of COS/MOS circuits, an IC package to meet your exact needs for performance and price.




Our new CD4000AF Ceramic IC's feature electrical characteristics identical to the present AD and AK series weld seal ceramic COS/MOS circuits. You get a completely hermetic package designed to operate over the full military temperature range of −55°C to +125°C...at a commercial price.

Compare the prices of our new ceramic IC's. If you've needed the temperature range and hermetic features of ceramic, but couldn't afford

| TYPE NO. | FUNCTION | AF PRICE (1000+) |
|---|---|---|
| CD4001AF | Quad 2-input NOR gate | $ .98 |
| CD4011AF | Quad 2-input NAND gate | .98 |
| CD4013AF | Dual "D" master-slave Flip-Flop | 2.03 |
| CD4020AF | 14-stage binary/ripple counter | 5.90 |
| CD4027AF | Dual J-K master-slave Flip-Flop | 3.14 |
| CD4029AF | Presettable up/down counter | 7.94 |
| CD4042AF | Quad clocked "D" latch | 4.23 |
| CD4046AF | Micropower phase-locked loop | 5.63 |
| CD4047AF | Monostable/Astable multivibrator | 3.75 |

the price, now you can discover the digital world of COS/MOS in RCA's new low cost ceramic package.

Our complete line of COS/MOS CD4000AF Series Ceramic IC's, in 14-lead or 16-lead dual-in-line packages, are available at your local distributor. Or you can order them direct from RCA.

For complete pricing and data sheet write: RCA Solid State, Section 57J11 Box 3200, Somerville, N.J. 08876.Or phone: (201) 722-3200.

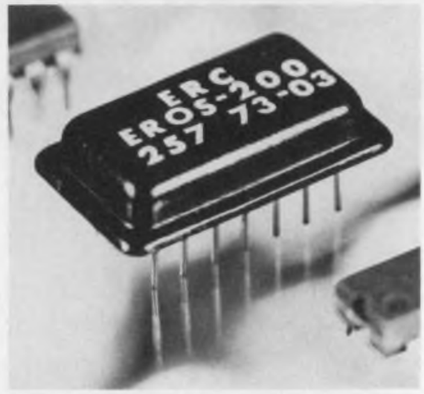
RCA Solid State
products that make products pay off

International: RCA, Sunbury-on-Thames, U.K., or Fuji Building, 7-4 Kasumigaseki, 3 Chome, Chiyoda-Ku, Tokyo, Japan. In Canada: RCA Limited, Ste. Anne de Bellevue 810, Canada.

INFORMATION RETRIEVAL NUMBER 70

MODULES & SUBASSEMBLIES

## Xtal oscillators span 30 kHz to 15 MHz




*Electronic Research, P.O. Box 913, Shawnee Mission, Kan. 66201. (913) 631-6700.*

EROS-200 Series of oscillators cover the frequency range of 30 kHz to 15 MHz. They have operating temperature ranges of 0 to 50, −20 to +70 or −55 to +105 C. Ambient stabilities are ±0.002%, ±0.003%, and ±0.005%, respectively. The oscillators will drive 10 TTL loads and will run off the TTL supply. They can withstand vibration of 35 g's peak to 2000 Hz and shock of 500 g's, 1 ms, half-sine. The 14-pin dual-in-line type hermetic package is 0.875 by 0.515 by 0.2 in.

**CIRCLE NO. 264**

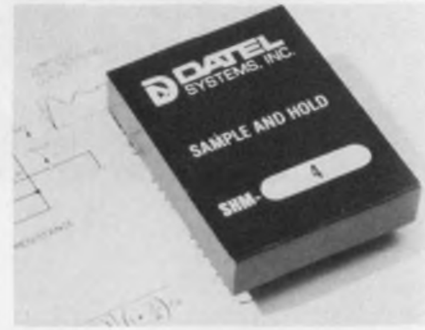
## Proportional controller is accurate to 0.05 C

*Oven Industries, Inc., P.O. Box 229, Mechanicsburg, Pa. 17055. (717) 766-0721.*

Model 5C1-110, a proportional ac zero crossing temperature controller, delivers control accuracies to ±0.05 C of set point stability at the probe. This unit minimizes the controller effect on set point stability to less than ±0.005 C/°C for ambient changes from −55 to +100 C and ±0.0025 C/V for line fluctuations from 105 to 135 V ac. It operates from a 120 V ac ±12%, 50 to 400 Hz power source and will withstand up to 30% input transients for one second. The output triac controls currents up to 4 A over a base plate temperature range of −55 to +85 C and up to 8 A from −55 to +60 C. TP Series thermistor sensor probes are used for control over a temperature range of −20 to +250 C.

**CIRCLE NO. 265**

## S/h amplifier settles to 0.005% of FS in 6 μs




*Datel Systems, Inc., 1020 Turnpike St., Canton, Mass. 02021. (617) 828-6395. $49; stock.*

The Model SHM-4 sample-and-hold amplifier reduces the aperture uncertainties of rate and error, switch transition time and jitter to less than 2 ns. The output decay rate of 20 μV/ms lets the outputs of several SHM-4s be sequentially processed. The unit will accept a ±10 V input signal with an input impedance of 100 MΩ. Settling time to ±0.005% is less than 6 μs and the slew rate is 5 V/μs while providing ±5 mA of output current.

**CIRCLE NO. 266**

## S/h amplifier delivers gain and settles fast


*Hybrid Systems Corp., 87 Second Ave., Burlington, Mass. 01803. (617) 272-1522. $89 (1-9); stock to 2 wk.*

Model SH730 sample/hold circuit has a total acquisition time of less than 1 μs to achieve a 0.01% accuracy for a full 20 V signal change. Its slew rate is 20 V/μs, and it has a total aperture time of under 50 ns. The aperture uncertainty or jitter time is 5 ns. It can also deliver 20 mA output at ±10 V. The small signal bandwidth of the SH730 is 5 MHz and its small signal settling time to 0.01% is 500 ns. Also, while its parameters have been optimized for an input/output gain of 1, it can be programmed for higher gains.

**CIRCLE NO. 267**

# relays rewarded


**Our congratulations, and TEN $50 U.S. Savings Bonds from the Struthers-Dunn 50th Anniversary Relay Contest are awarded to:**

**Alfred B. Stucki**
**Brigham City, Utah**

**for this solution to a relay problem, independently judged the second most imaginative entry of wide interest to users of relays:**

## CAPACITOR SEQUENCED COMMUTATOR IS CHEAPER AND SMALLER THAN SOLID STATE EQUIVALENTS

Relays K1, K2, K3 of Fig. 1 are energized in timed order to sequentially sample each of 8 data outputs from airborne telemetry. Fig. 2 shows identical timing circuits that operate the 28v coil of K1. With timers pulsing K1 at 3 second intervals the other relays operate in the sequence shown in Fig. 3.

To conserve power in this application, K2 and K3 are 6V bistable latching relays, operated by pulsed energy from capacitors C1 through C4. Not shown is a calibration timer that switches telemetry inputs from data signals to a calibration bus.

For the stresses of rocket-borne telemetry such as this, we'd recommend combinations of rather specialized S-D aerospace relays to accommodate the vast number of poles. K1 could be two FCM-410 types, K2 could be a specially modified FCL-406, K3 could be an FCL-1.

## RELAY SENSES TEMPERATURE, CONTROLS OR PROPORTIONS OUTPUT

The predictable +0.3%/°C temperature coefficient of copper lets the relay coil become the temperature sensing element in the unique circuit of Fig. 4. Accuracy and sensitivity are both better than 0.5°C according to the author.

K and $R_4$ are one arm of a bridge whose other arm is $R_1$, $R_3$ and temperature adjusting pot $R_2$. An IC comparator detects bridge output and operates the relay by switching from 3 to 24 volts on less than 0.5 mV signals.

"Offset adjustment" $R_6$ adds hysteresis so the circuit may function as an ON-OFF pulse proportional controller or as a sensitive, ON-OFF temperature switch.

A 4K ohm sensitive relay such as S-D type A112XAX will minimize self-heating. But for over-temperature protection, self-heating can be desirable. Try a 250-300 mW DIP reed relay such as S-D type MRR1CDL which will automatically latch since its temperature rises 20°-40°C when energized. Our thanks and $50. to R.C.D., Santa Clara, Ca.

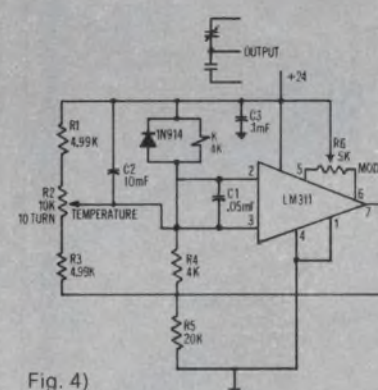
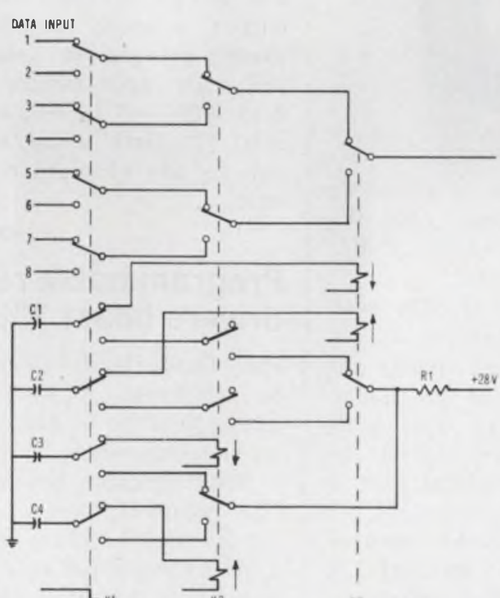
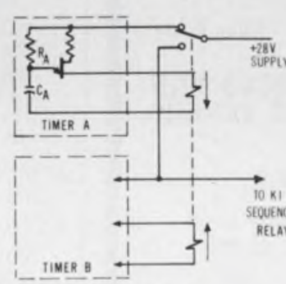


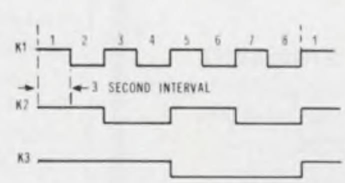

Fig. 4)




(Fig. 1)




(Fig. 2)



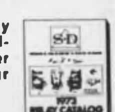

(Fig. 3)

**STRUTHERS-DUNN, INC.**

PITMAN, NEW JERSEY 08071

Canada: Struthers-Dunn Relay Div., Renfrew Electric Co., Ltd.

**Over 100 Basic Relay Types, even more modifications. Check reader service number for your catalog.**




INFORMATION RETRIEVAL NUMBER 72

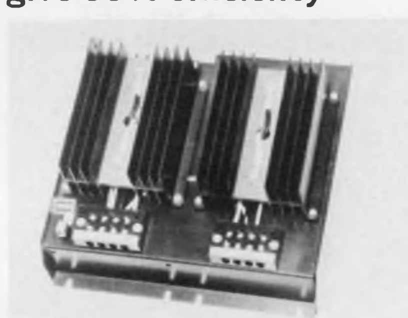
## Drive image intensifiers with gate generator

*Mercury Engineering, Inc., 765 Pinetree Dr., Indian Harbour Beach, Fla. 32937. (305) 773-3656. $45 (unit); 30 day.*

Model SP105C gate pulse generator can drive image intensifier and camera tubes. It offers rep rates to 30 kHz, pulse widths of 200 μs max and rise/fall times of less than 60 ns. Focus and holdoff voltages from +500 to −1800 V are remotely programmable and the generator is available for either passive or gated operation.

**CIRCLE NO. 268**

## Proportional controllers give 99% efficiency



*Loyola Industries, Inc., 1526 W. 240th St., Harbor City, Calif. 90710. (213) 534-4370.*

The BPAC series of SCR heat controllers are designed to deliver proportional electrical power to conventional electrical resistance heaters. They can be used with standard temperature control instruments or thermostats, with a low voltage, or current output, or slidewire controls. Some features include: automatic shut-off if command signal stops; efficiency over 99% and near zero maintenance. Models are available with power outputs from 1 to 350 kW, supply voltages from 120 to 600 V and single-phase or three-phase operation.

**CIRCLE NO. 269**

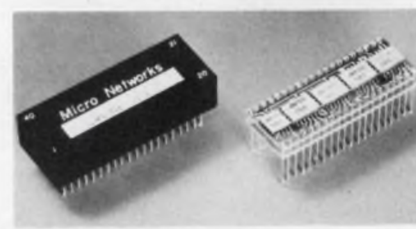
## Scanner head useful for close quarters

*Autotron, Inc., 3629 N. Vermilion, Danville, Ill. 61832. (217) 446-0650. $36.75.*

Model ELB5BH inch-wide retroreflective scanner head reads retroreflective code markings on 1 in. centers. Maximum distance obtained from a standard retroreflective disc is 5 ft. and with retro-reflective tape 6 in. Scanner lamp life is in excess of 20,000 hours.

**CIRCLE NO. 271**

## A/d converters give 12 bits over MIL temp




*Micro Networks Corp., 5 Barbara Lane, Worcester, Mass. 01604. (617) 756-4635. From $199 (1 to 24); stock to 3 wk.*

The MN515H and MN516H are miniature 12-bit a/d converters and guarantee ±1/2 LSB linearity from −55 to +125 C. The MN515 includes a 12-bit d/a converter and monolithic logic programmer. The MN516 provides the user with output storage registers. Both models provide for user selectable full scale input ranges (0 to +5, 0 to +20, −5 to +5, and −10 to +10 V). Both serial and parallel outputs are provided on the same unit.

**CIRCLE NO. 270**

## Programmable receivers, drivers boast 1% error

*ILC Data Device Corp., 100 Tec St., Hicksville, N.Y. 11801 (516) 433-5330. $100 to $250; depending on requirements.*

Programmable line drivers and line receivers have a channel accuracy of 1%. These units offer a 1 MHz throughput rate, driver outputs up to +30 V at 60 mA, transfer glitches of less than 3 V·ms, driver output impedance of 1.1 Ω and receiver input impedance of $10^{11}$ Ω. The driver package is 2 cu. in. and the receiver package is 1.5 cu. in.

**CIRCLE NO. 272**

# the standard power supply is a minor consideration... until it fails!

OEM's are getting a little tired of 'power failures'. And many have decided it's better to pay the difference to be sure their products are powered reliably. The cost isn't that much more -- and it may save some valuable reputations.

This concept puts North Electric squarely in the picture, because reliability is our stock in trade.

We've been the leading custom power producer for more than 40 years -- and our modular power supplies follow the same quality standards . . . including rugged Life Tests, EMI analysis, shock, vibration, humidity and temperature tests -- and most are UL recognized.

Another point - if you are presently making your own power, let us show you (through a make or buy analysis) why it might be to your advantage to have North handle this specialized area of production.

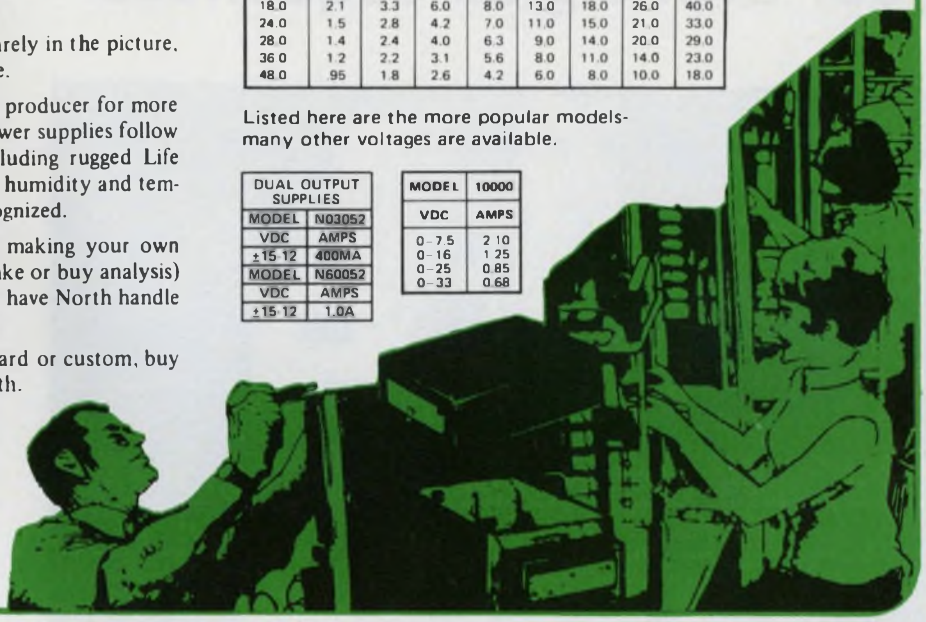
When you buy power supplies, standard or custom, buy from the one big name that makes both.

| MODEL | 11000 | 12000 | 13000 | 14000 | 15000 | 16000 | 17000 | 18000 |
|---|---|---|---|---|---|---|---|---|
| VDC | AMPERES | | | | | | | |
| 5.0 | 3.9 | 5.3 | 11.3 | 13.0 | 20.0 | 32.5 | 49.0 | 82.0 |
| 12.0 | 2.8 | 4.2 | 8.0 | 10.5 | 15.0 | 23.0 | 36.0 | 58.0 |
| 15.0 | 2.4 | 3.7 | 7.5 | 9.5 | 14.0 | 20.5 | 27.0 | 47.0 |
| 18.0 | 2.1 | 3.3 | 6.0 | 8.0 | 13.0 | 18.0 | 26.0 | 40.0 |
| 24.0 | 1.5 | 2.8 | 4.2 | 7.0 | 11.0 | 15.0 | 21.0 | 33.0 |
| 28.0 | 1.4 | 2.4 | 4.0 | 6.3 | 9.0 | 14.0 | 20.0 | 29.0 |
| 36.0 | 1.2 | 2.2 | 3.1 | 5.6 | 8.0 | 11.0 | 14.0 | 23.0 |
| 48.0 | .95 | 1.8 | 2.6 | 4.2 | 6.0 | 8.0 | 10.0 | 18.0 |

Listed here are the more popular models-many other voltages are available.

| DUAL OUTPUT SUPPLIES | |
|---|---|
| MODEL | N03052 |
| VDC | AMPS |
| ±15-12 | 400MA |
| MODEL | N60052 |
| VDC | AMPS |
| ±15-12 | 1.0A |

| MODEL | 10000 |
|---|---|
| VDC | AMPS |
| 0–7.5 | 2.10 |
| 0–16 | 1.25 |
| 0–25 | 0.85 |
| 0–33 | 0.68 |



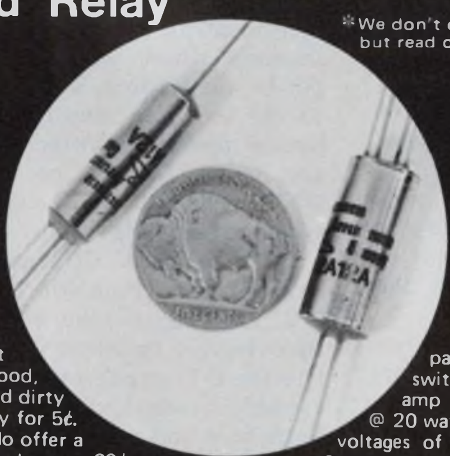
NORTH ELECTRIC COMPANY

Electronetics Division/Galion, Ohio 44833
A United Telecommunications Company
419/468-8874
Ask for Product Manager/Standard Power

INFORMATION RETRIEVAL NUMBER 74

# What This Country Needs is A Good 5¢* Cheap and Dirty Reed Relay

*We don't offer one, but read on:



We don't offer a good, cheap and dirty reed relay for 5¢. But we do offer a damn good one at 29¢ (1 million), 35¢ (500,000), 39¢ (100,000) — or how many do you need?

What do you get for these prices? Mil Q-9858-A specs: hermetically sealed coils—magnetic shielding for high density packing — switches 1 amp or 250V @ 20 watts — coil voltages of 1, 3, 5, 6, 10, 12, 15, & 24 volts — contact resistance less than 100 milliohms—micro size .275"OD x .950" long.

Available in 1, 2 & 3 Form A & 1, 2 Form C versions. How do we do it at these prices? Our secret is patent pending.

FREE SAMPLES
To phone or letterhead requests

ELECTRONIC APPLICATIONS CO.
2213 Edwards Ave • So. El Monte, Calif. 91733
(213) 442-3212

INFORMATION RETRIEVAL NUMBER 75

THE MINIATURE PC ROTARY SWITCH.

# Very big in communications circuits.

The screwdriver operated PC mount rotary is 0.6 inches in length. It's half that in diameter. (A shaft-actuated bushing-mounted version also available.)

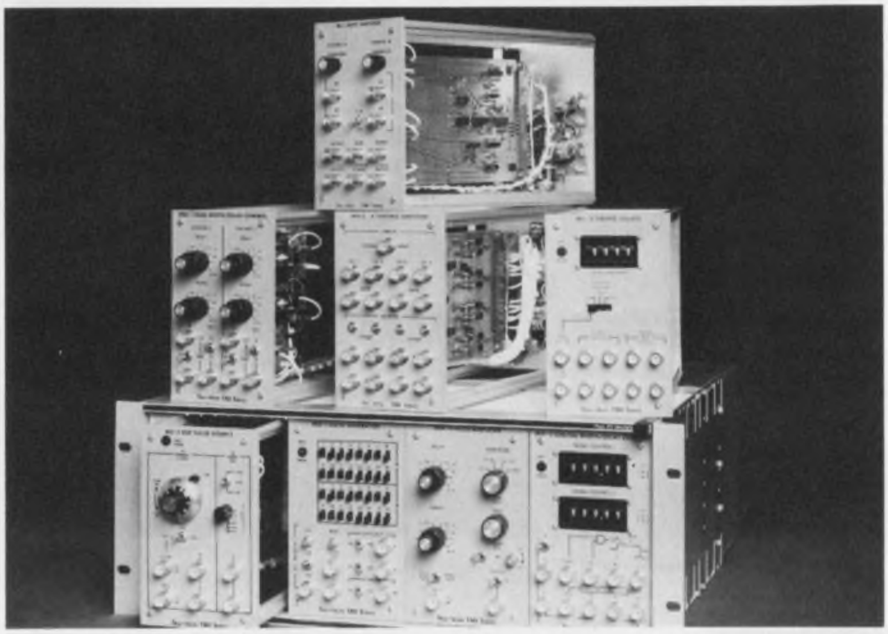
Both provide a 36° angle of throw with one or two pole circuitry. Rated make or break 200 milliamps at 115 VAC resistive load for 5,000 cycles. (Or 50 milliamps at 25,000 cycles.)

For more information on all Grayhill products, write today for our newest Engineering Catalog. Grayhill, Inc., 565 Hillgrove Avenue, La Grange, Illinois 60525. (312) 354-1040.

Grayhill INC

INFORMATION RETRIEVAL NUMBER 76

# Modular family lets you build your own digital sequences



Tau-Tron, Inc., 685 Lawrence St., Lowell, Mass. 01852. (617) 458-6871. See text; stock to 8 wk.

With over 20 plug-ins to choose from in Tau-Tron's new modular family of digital signal-processing equipment, you can probably put together the exact complex digital signals you need.

Tau-Tron's TMI Series includes digital pulse sources, data/word generators, width and delay units, conditioning and buffer amplifiers, bit-error-rate testers and a host of other modules—all operating from dc to a not-to-be-sniffed-at 100-MHz rate. Most units are available in programmable versions.

While the top rate doesn't quite touch the blazing 500-MHz top speed of some of the company's high-speed, stand-alone instruments, 100 MHz should be sufficient for most applications.

And you don't have to worry about deterioration of the pulse—or pulses—as each pulse zips in and out of the interconnected modules. Each module reconstitutes the waveform so that the typical transition time of 2 ns (3.5 ns, max.) is maintained right to the output BNC jack.

To further maintain pulse integrity, all signal connectors are BNC and a 50-Ω system is used throughout. Thus all input and output impedances are 50 Ω.

Setting up a system is almost as fast as the pulses themselves. Just select the right combination of quarter or half-rack-width modules, shove each module into the mainframe, join them up and hit the single power switch on the mainframe.

Each plug-in receives unregulated dc power at its rear connector. Regulation and distribution are then performed within the individual modules.

Each module's power requirement is specified in terms of unit loads: The standard mainframe can handle up to 12 unit loads.

Since the $700 mainframe fits a standard 19-inch rack, it will hold two half-size, or four quarter-size, or one half-size plus two quarter-size modules.

If your application is unique, Tau-Tron will supply specialized plug-ins to fit the bill. For example, special codes, formats, levels or functions can be accommodated. Or you can update your system by adding or rearranging modules to change just those pulse parameters that need changing. In short, the TMI Series offers versatility and expansion at competitive costs.

Representative plug-ins of the series include the MS-1 vhf pulse source, the MG-1 data/word generator, the MW-1 dual width/delay control, and the MA-2 four-channel amplifier.

The $500 MS-1 outputs 1 Hz to 100 MHz and—through a unique combination of a VCO and frequency divider—lets the user select his required frequency within the range. The fundamental VCO frequency—which can be precisely dialed anywhere between 30 and 100 MHz—and/or submultiples of the fundamental can be selected as the output. As an alternative, an external source or optional crystal oscillator can be used to provide the output frequency.

The MG-1 is a dual 16-bit data generator that provides two independent 16-bit serial streams plus a multiplexed 32-bit word. All outputs achieve clock rates of 100 MHz and can be selected in reset-to-zero (RZ) or NRZ format. The MG-1 sells for $1000.

By connecting one of the TMI's sources to the MW-1 dual width/delay control, you can obtain two channels whose width and delay can be varied from a low value to 10 ms in seven steps. A vernier control provides continuous coverage. Other features of the $800 MW-1 include RZ/NRZ outputs and synch/asynch triggering.

If you need TTL-compatible levels—rather than the standard 2-V TMI signal—the $350 MA-2 four-channel amplifier will translate the 2-V signal into 2.7 V with variable baseline offset of ±2 V. Both true and complement signals are simultaneously outputted.

As for jitter and stability, you can expect less than 0.1 and 0.5%, respectively, for the MS-1 clock-source VCO, and better than 0.01 and 0.05% for the MS-1 crystal oscillator. Amplitude jitter is less than ±0.5%, and the terminated waveshape distortion is ±7%, maximum.

**CIRCLE NO. 250**

## Tracking filters lock on to low-level signals

*Spectral Dynamics, P.O. Box 671, San Diego, Calif. 92114. (714) 565-8211. 140: $1350; 141: $2850; 142: $3350; 45 days.*

Signals below the level of background noise can be locked onto and tracked through a range of 3 Hz to 20 kHz with this family of Tracking Filters. The family includes the SD141Single-Channel Filter (containing its own carrier generator), the SD142 Two-Channel Tracking Filter Slave, and the SD140 Carrier Generator for providing both carrier tuning signal and 100-kHz reference signal for the two-channel unit. Input tuning signals can vary in amplitude from 30 mV to 30 V pk-pk.

**CIRCLE NO. 273**

## Logic probe checks ICs, costs just $59


*Digi-tronix, P.O. Box 1699-G, Los Gatos, Calif. 95030. (408) 356-2484. $59; stock.*

The Logic Probe Model HS 50A is for testing, fault analysis and R&D of digital ICs. The unit indicates logic ONE and ZERO; shows symmetry/nonsymmetry of pulse patterns; indicates presence of pulse trains to 25 MHz; detects and identifies polarity of pulses to 20 ns. The unit derives 5-V, 75-mA operating power from the unit under test via flexible, clip-terminated power leads. Probe housing is made of heavy-gauge, high-impact, scratch-resistant polypropylene.

**CIRCLE NO. 274**

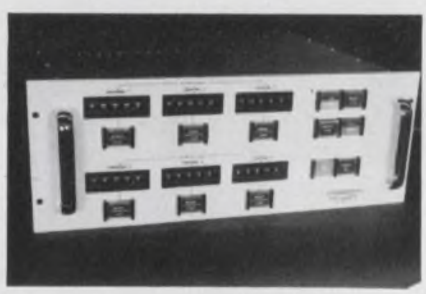
## Unit converts any meter to true rms reading

*Ufad Corp., P.O. Box 96, Ada, Mich. 49301. $249; stock to 30 days.*

Model 731A allows any dc meter to accurately measure true rms. It also increases the sensitivity, frequency response, and accuracy of any multimeter or DVM. The unit converts any wave shape to a dc output, has an accuracy of ±0.25%, a bandwidth to 1 MHz, and its own ranging amplifier of 10 mV to 300 V, with overrange capability greater than 40% on all ranges with full accuracy.

**CIRCLE NO. 275**

## Time-delay generators output 100 V



*Cordin, 2230 S. 3270 West, Salt Lake City, Utah 84119. (801) 487-1075. 453: $3200; 455: $5100; 90 days.*

These digital time-delay generators, Models 453 and 455, feature an output greater than 100 V into 50 Ω and 100-ns increments of time delay, which can be triggered independently, operated by a common trigger (parallel mode) or all channels may be triggered separately (independent mode). The independent mode allows the use of one channel's output to trigger the next channel and thereby extend the total delay range by as much as six times. Total delay range per channel is 1.0 to 9999.9 μs.

**CIRCLE NO. 276**

## Digital megohmmeter weighs just 4 lb


*ITT Jennings, 970 McLaughlin Ave., San Jose, Calif. 95116. (408) 292-4025. $495; stock.*

MINIMEG 15100 miniature digital megohmmeter measures 7 × 6 × 3 in. and weighs less than 4 lb. Its case is of high-impact plastic. Power is supplied by a self-contained rechargeable battery. Test voltage is fixed at 500 V dc, and there is a factory preset current limiter. There are three ranges: 0 to 20, 20 to 200 and 200 to 2000 MΩ. A 0 to 200 Ω range is provided for continuity testing. Measured values are shown on a 3-1/2-digit LED display with an accuracy of ±2% of reading ±1 digit.

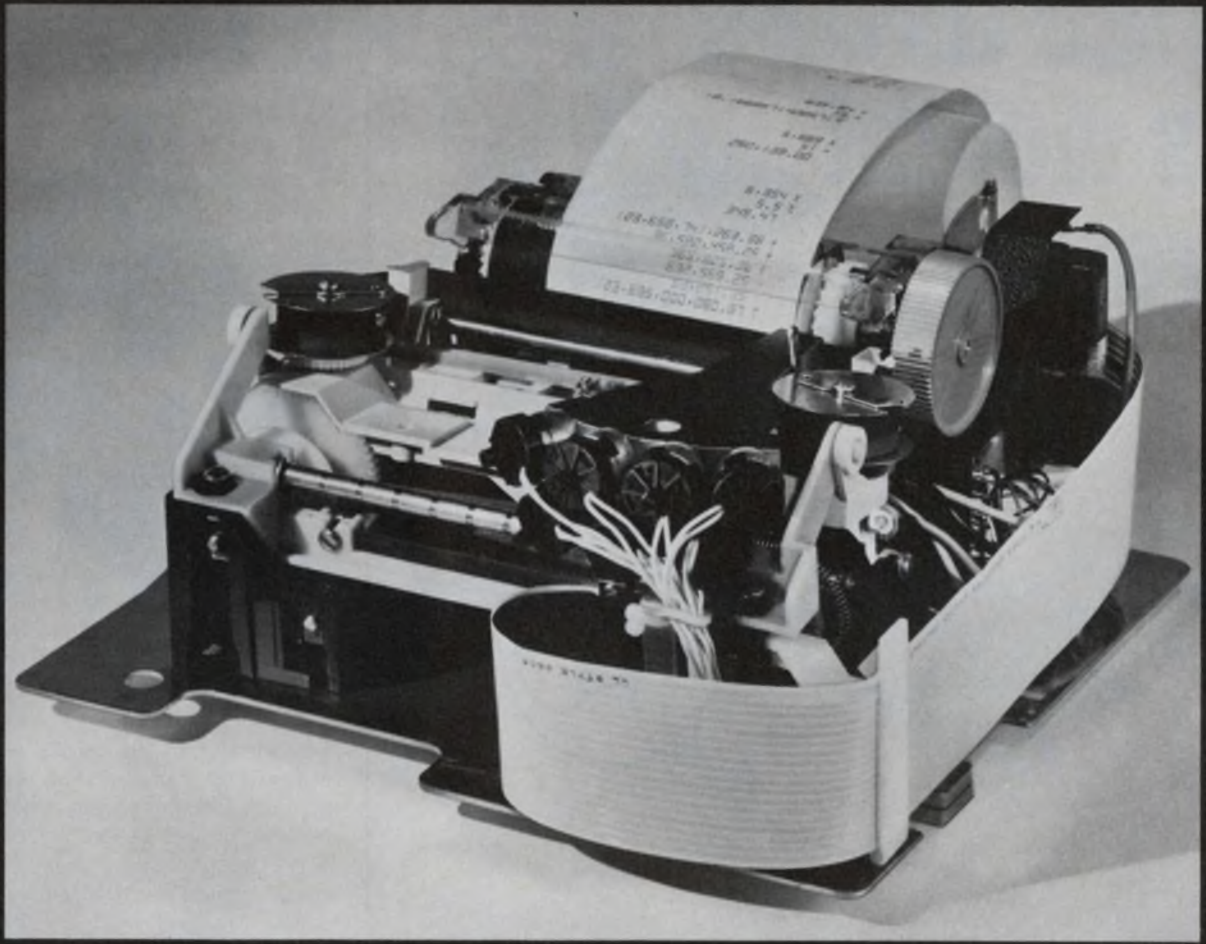
**CIRCLE NO. 277**

## Preset counter lets you dial any time base


*United Systems, 918 Woodley Rd., Dayton, Ohio 45403. (513) 254-6251. $815; stock to 2 wk.*

With a five-digit display, the Model 104B preset counter/timer features a variable time base that permits the operator to dial in any time base desired. Specs include a frequency range of 5 Hz to 32 MHz, a BCD output for systems compatibility, and scaling for direct readout in engineering units. The 104B can also generate crystal-controlled time interval signals, with 1-μs resolution, from 10 μs to 10 s.

**CIRCLE NO. 278**



# Our Supersonic Printer can speed up your next design.

If your next design requires a narrow print-out, consider Victor's high-speed matrix printer.

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Because it's outstandingly reliable. Reliable enough to print 35 million characters without periodic maintenance.

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INSTRUMENTATION

## Digital stopwatch offers ±0.0025% accuracy

*Intersil, Inc., 10900 N. Tantau Ave., Cupertino, Calif. 95014. (408) 257-5450. $195.*

The major feature of Cronus I battery-operated, electronic, split-second stopwatch is its accuracy. Measuring range is 23 hours, 59 minutes, 59.99 seconds, with an accuracy of ±0.0025%. Other features include: four distinct operational functions (Standard Start/Stop, Taylor/Sequential, Split, Event/Time-Out); large, bright numerical read-out for easy indoor and outdoor use; remote control capability; and a compact, water-resistant casing.

**CIRCLE NO. 279**

## Generator sweeps over 1000:1 range

*Vibration Instruments, 1614 Orangethorpe Way, Anaheim, Calif. 92803. (714) 879-6085. $1690; 30 days.*

Designated the VIC 965A, this sweep generator enables continuous frequency sweep over a 1000:1 range and also serves as a function generator. The 3-1/2-in.-high unit offers five frequency ranges from 0.035 Hz to 350 kHz. Sine, square and triangular outputs, with dc offset, may be obtained. The 10-V output can be attenuated 60 dB.

**CIRCLE NO. 280**

## Time-delay generators feature low jitter

*Cordin, 2230 South 3270 West, Salt Lake City, Utah 84119. (801) 487-1075. 436: $5600; 438: $8300; 90 days.*

Two new digital time-delay generators combine low jitter with high voltage output. Both the three-channel Model 436 and the six-channel Model 438 feature a jitter less than ±1 ns, referenced either from trigger input to $T_0$ or from $T_0$ to the delayed outputs. Output is 40 V into 50 Ω, with 3-ns rise time. Time delay increments can be selected with a range of .001 to 999.999 μs in 1-ns steps.

CIRCLE NO. 281

## Impedance bridge fits in palm of a hand

*Brown Electro-Measurement Corp., 11060-118th Pl. N.E., Kirkland, Wash. 98033. (206) 822-6092. $355; stock to 90 days.*

Model 303A is said to be the world's smallest Universal Impedance Bridge. It is completely self-contained and measures inductance to 1200 H, capacitance to 1200 μF and resistaice to 12 MΩ. Accuracy is 1% for L and C, and 0.25% for R. Resolution is 0.001%.

CIRCLE NO. 282

## Electronic filter sets precisely

*Ithaco Inc., 735 W. Clinton St., Ithaca, N.Y. 14850. (607) 272-7640. $649.*

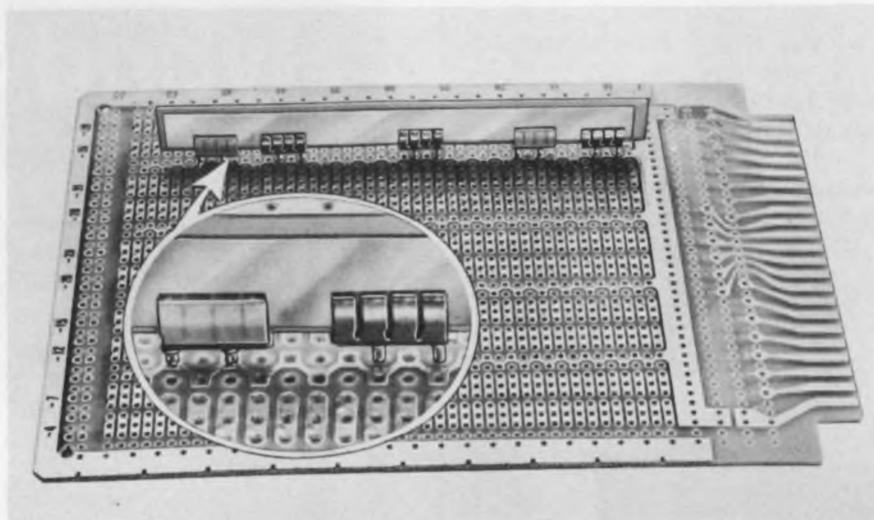
Model 4251 Variable Electronic filter operates either as a high or low-pass filter. Corner frequency may be set with 3-digit resolution and 1% accuracy from 0.01 Hz to 111 kHz. Phase and amplitude accuracy are 2° and 1%, respectively. Attenuation slope is 24 dB/octave. Total hum and noise is 50 μV, or less. Used as a low-pass filter, response can be set to be maximally flat (Butterworth) or linear phase (Bessel).

CIRCLE NO. 283



INFORMATION RETRIEVAL NUMBER 82

# Universal plug-in PC board eases component mixing



*Vector Electronic Co., 12460 Gladstone Ave., Sylmar, Calif. 91342. (213) 365-9661. $12.95 (1 to 19); stock.*

A unique combination of pads, busses and planes etched on a circuit board with 0.10-in. grid-hole patterns allows dense assemblies of intermixed DIPs, analog modules and discrete components. Called the Model 4112-4 by Vector Electronic Co., the "Universal Plugboard" is supported by an extensive line of sockets, terminals, capacitive bus strips and bus links.

The key to the board's versatility lies in rows of three-hole pads on the wiring side. Spaced on 0.1-in. centers, the pads accommodate DIPs with either 0.3-in. or 0.6-in. lead separation. The triple, closely spaced pads also match the lead patterns of TO-5 and TO-18 packages and analog modules with 0.1-in. spacing on two leads, but the others have wider spacing.

Power busses—also on the wiring side of the board—are located between pairs of triple pads to provide short interconnection paths. A zig-zag configuration allows use of Vector's laminated "trolley" bus strips to provide low shunt impedance at high frequencies. The strips, made of laminated solder-plated brass and Kaptron, fit between DIP rows. They are installed by use of miniature spring clips with offset pins that contact either the zig-zag power bus or the ground plane. The trolley strips come in 4.1 and 8.2-in. lengths and 0.3 and 0.5-in. widths. For a 4.1 by 0.5-in. strip, the total distributed capacitance is about 200 pF.

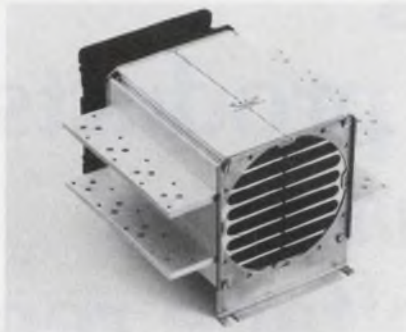
On the component side of the 4.5 by 6.5-in. board, a full ground-plane surrounds all holes, but, unless strapped, it remains isolated from them and from the grounded edge-strip on the plug-board. The strip provides a short ground connection to any device terminal and allows separate case and electrical grounds.

A standard double-row connector with 22/44 contacts spaced on 0.156-in. centers can be used. The board is intended for breadboard, prototype and low-volume production applications—using either soldered or wrapped-wire interconnections.

T113-series bus links are available in 0.2 and 0.3-in. lengths and also in 12-in. strips with speed-nut perforations on 0.3-in. centers. The links are merely pushed down onto pins and soldered.

**CIRCLE NO. 255**

## Fan keeps large heat sink area cool



*WEI Corp., 2140 S. Santa Fe St., P.O. Box 10577, Santa Ana, Calif. 92711. (714) 540-4688.*

Model 3750 forced-convection heat sink can cool components that are mounted on its four ledges and all flat surfaces. Circuits boards can be directly attached to the ends of the ledges. The heat sink uses a 4-1/8 in. (mounting centers) fan.

CIRCLE NO. 284

## Flat cable comes with 50 conductors

*Ansley Electronics Corp., Old Easton Rd., Doylestown, Pa. 18901. (215) 345-1800. From $0.01 per ft/conductor; stock.*

Blue Streak is a flame-retardant 105-C, PVC, flat cable with conductors of 28-AWG solid or stranded, and 30-AWG solid wire. The cable has a light-blue color, and a dark-blue streak down one edge identifies polarity. Also, a color streak between every fifth conductor helps identify individual conductors. The cable comes in 100-ft reels with 14, 16, 20, 26, 34, 40 and 50 conductors. A complementary line of insulation piercing connectors is also offered.

CIRCLE NO. 285

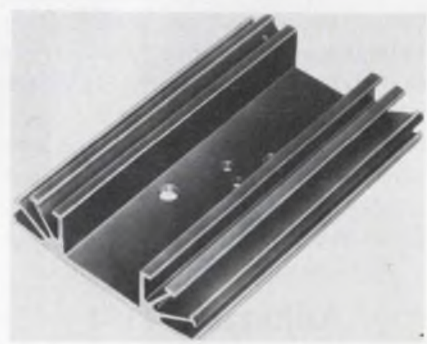
## DIP insertion tool handles staggered leads

*Micro Electronic Systems Inc., 8 Kevin Dr., Danbury, Conn. 06810. (203) 746-2525. $150 (unit qty) 60 days.*

A DIP-a-DIP insertion tool when outfitted with special left and right side plates allows easy insertion of any staggered-lead IC. Though 24 and 42-pin models are featured, any size can be supplied. You pick up an IC by simply pressing down on it with the tool's slots aligned to the IC leads. Insert the IC into a socket or PC board and then release it by a push on the plunger. The side plates of the DIP-a-DIP will plumb the leads perfectly.

CIRCLE NO. 286

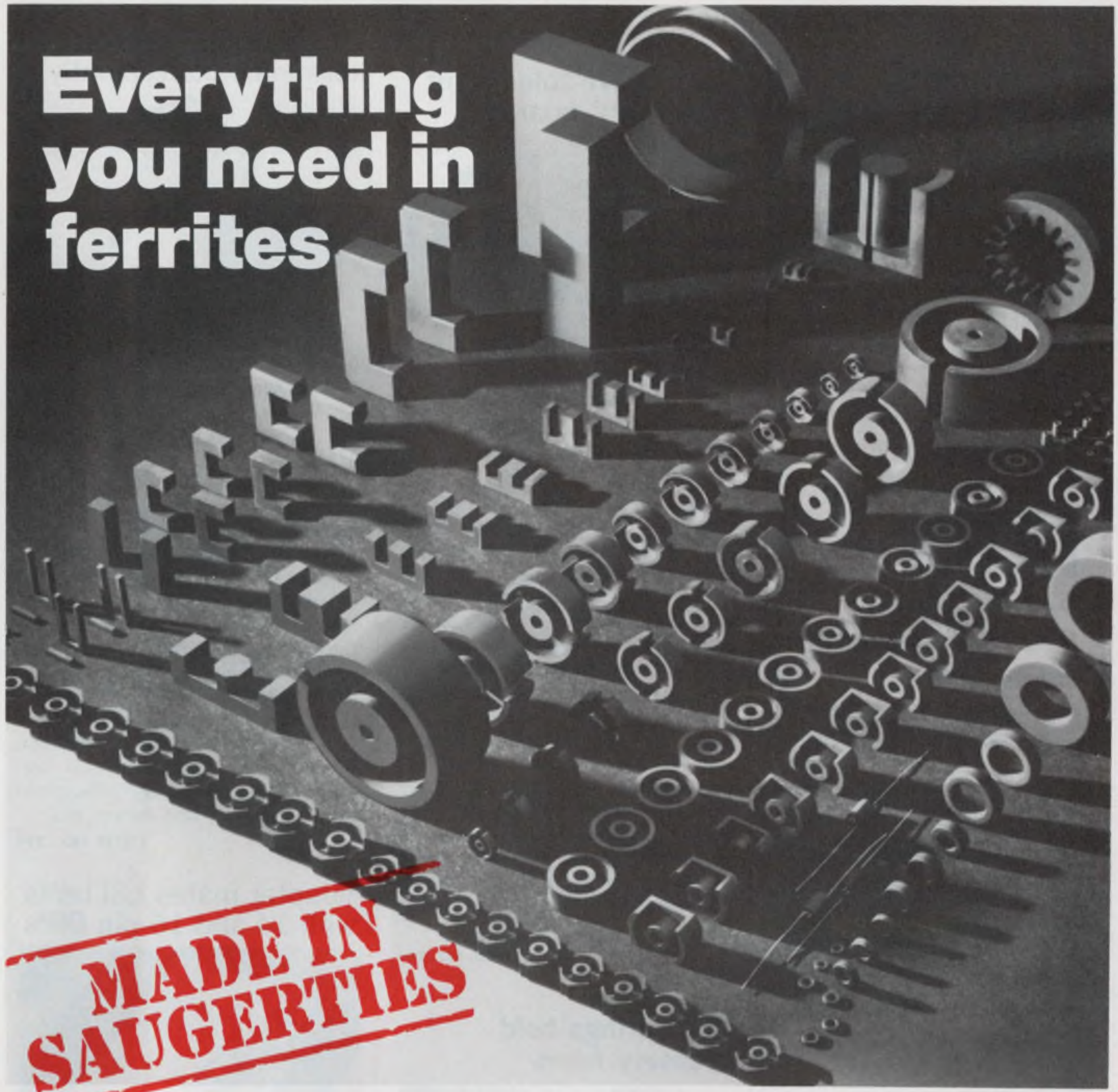
## Heat-sink extrusion mounts on PC boards



*Jermyn, 712 Montgomery St., San Francisco, Calif. 94111. (415) 362-7431. $0.37: 1.5 in. unfinished (250 up).*

The LC range of low-profile (0.562 in.) heat sinks mount on PC boards. They are made from a lightweight extrusion which weighs only 1.5 oz per 3 in. length. Typical thermal resistance is 10 C/W for a single TO-66 transistor mounted on a 3 in. length. Standard lengths of 1.5 and 3 in. are available and they are either blank or drilled for one or two transistors. The extrusion is also available in 36-in. lengths, unfinished.

CIRCLE NO. 287




**Broad Product Line:** Ferroxcube offers a complete array of sizes and shapes of ferrite cores. They're made in Saugerties, N.Y. and stocked throughout the U.S.A. Toroids for pulse transformers, pot cores or square cores for precision filters, transformer cores in all sizes and shapes— E, U, I, specials and read-only memory cores —you can trust Ferroxcube to provide the optimum core for your inductors.

**Unsurpassed Materials Technology:** Ferroxcube, the acknowledged U.S. leader in ferrite technology, offers a wide range of standard materials for your cores. Chances are that one of them has exactly the *right combination of characteristics* for your application. And, you can depend on Ferroxcube to deliver the same uniform, product characteristics year after year for consistent, optimum circuit performance in your designs.

**24-hour Availability:** Standard components are available for 24-hour delivery from any of seven warehouses conveniently located in Boston, New York, Saugerties, Philadelphia, Chicago, Santa Clara and San Diego.

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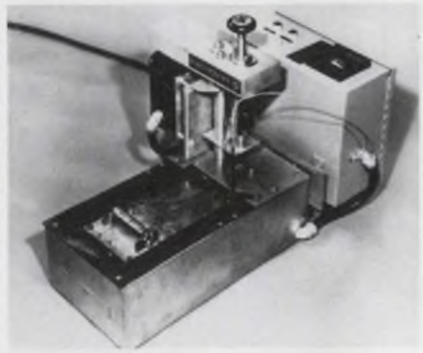
16402

INFORMATION RETRIEVAL NUMBER 87

PACKAGING & MATERIALS

## Small wave-solder unit repairs PC boards



*Electrovert, Inc., 86 Hartford Ave., Mount Vernon, N.Y. 10553. (914) MO4-6090.*

Minipot is a small wave soldering unit which incorporates most of the features available in the large solder-wave pumping machines. It has only a 115-lb reservoir pot capacity. A micrometer permits wave-height adjustment to 1/64 in., and interchangeable nozzles provide a choice of several different wave configurations. The pot's small capacity makes it ideal for experimental and low-production tinning, and PC-board repair work. It delivers a continuous high temperature to 850 F. Thus with polyurethane insulated wires, the insulation melts and the copper conductor is tinned in one operation.

CIRCLE NO. 288

## Coil springs hold ordinary fuses

*Oneida, 843 N. Cottage, Meadville, Pa. 16335. (814) 336-2125.*

Coil-spring fuse holders make it easier than ever to replace fuses. The new holder replaces more costly pig-tail fuses. Regular fuses snap into the holder in seconds.

CIRCLE NO. 289

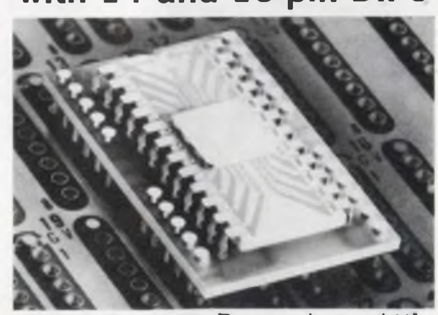
## Tray orients, serves terminals conveniently

*Vector Electronic Co., Inc., 12460 Gladstone Ave., Sylmar, Calif. 91342. (213) 365-9661. $8.95 (unit qty).*

A handy, slotted tray orients miniature terminals so that they may be easily selected prior to insertion into circuit boards. Terminals are simply dumped in small quantities into the tray, then shaken. Terminal tails fall through the slots, positioning the heads up, ready for use. Two versions are available. The P-164 pickup tray is designed for use with Vector R30, R31 and R32 socket pins, and with T49 and T46 wrap-post terminals. The P-165 tray is designed for the smaller R41 socket pin.

CIRCLE NO. 290

## Adapter mates LSI units with 14 and 16-pin DIPs

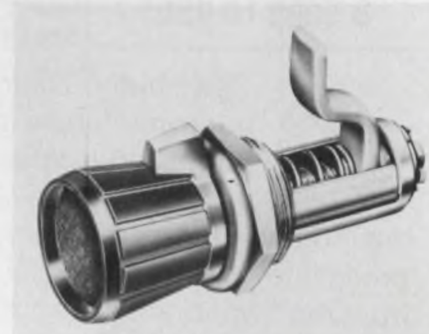


*Augat Inc., 33 Perry Ave., Attleboro, Mass. 02703. (617) 222-2202. $2.75 to $6.00 (unit qty); 6 wks.*

A new LSI adapter plug provides packaging flexibility by accepting 24, 28, 36 and 40-pin LSI devices and adapting them to 14 and 16-pin IC patterns for any of Augat's P, W and R packaging panels. The LSI DIPs are soldered to the adapter which plugs into the packaging panel. The glass-epoxy adapter is keyed at one end for identification of pin #1 and the pins are located to prevent improper installation.

CIRCLE NO. 291

## Latch holds cabinet doors tightly closed



*Southco, Inc., 200 Industrial Highway, Lester, Pa. 19113. (215) 521-0800.*

Keep doors dust-tight and rattle-free with Southco's No. 16 adjustable grip latches, now available with a stylized black thermoplastic knob. The latch is quickly installed. Insert it into a punched or drilled hole and tighten a retaining nut. The pawl is quickly adjusted to the frame thickness by simply turning the plastic knob. The door is then opened or closed with a quarter turn of the latch's actuator-indicator. An additional turn of the knob tightens the pawl against the frame to suppress vibration and seal gasketed closures.

CIRCLE NO. 292

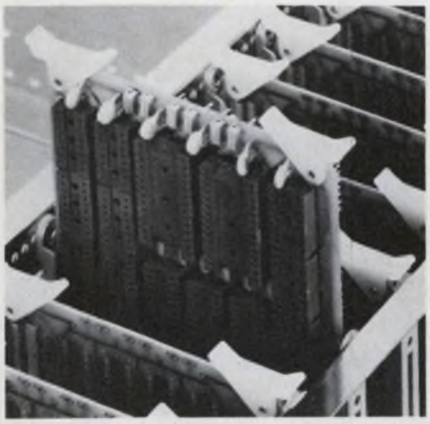
## Pellets provide metered epoxy resins

*Amicon Corp., 25 Hartwell Ave., Lexington, Mass. 02173. (617) 861-9600.*

Uniset pellets allow the use of automated assembly techniques without the need to meter and position small drops of liquid resins. Each preformed pellet has a precise volume and shows essentially no change in melting point or other characteristics after extended storage at room temperature. However the pellets melt and cure rapidly when heated above 200 F and yield durable cured epoxy resins. Uniset preforms have characteristics that range from low-flow grades, for sealing resistors and close tolerance seals, to high-flow grades, which soften and cure for embedment and impregnation applications.

CIRCLE NO. 293

## IC packaging system includes accessories

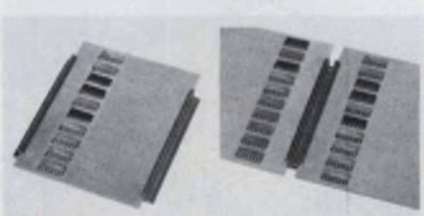


*Techmar Corp., 2232 S. Cotner Ave., Los Angeles, Calif. 90064. (213) 478-0046. $40: cards (unit qty); stock.*

This IC packaging system includes wire-wrap cards and a complete line of accessories and card cages. The card has a ground plane on the components side and $V_{cc}$ and ground circuitry on the wire-wrap side. It has a universal hole pattern that accommodates IC sockets with 0.300 or 0.600 in. spacing. Accessories include IC sockets, socket adapters, jumper clips, test jacks, by-pass capacitors and connectors.

**CIRCLE NO. 294**

## Plastic strips hold down PC boards



*Richco Plastic Co., 5825 N. Tripp Ave., Chicago, Ill. 60646. (312) 539-4060.*

Model BMS hold-down strip for firm positioning of printed circuit boards are made of rigid vinyl. Strips are cut to length and can be stapled or tacked to wooden surfaces or adhered to metal with their self-adhesive backing. Circuit boards simply snap into the channels formed by the strips. The strips are available with single channels, or with double channels for side-by-side mounting of boards. Base widths are 13/16 and 1-1/4 in., respectively. Free samples available.

**CIRCLE NO. 295**

## FR-4 PC board laminate can be punched

*Westinghouse Electric Corp., Industrial Material Div., Hampton, S. C. 29924. (803) 943-2311.*

Unlike conventional epoxy-glass laminates, FR-4 PC-board laminates, designated Super Punch, can be punched instead of drilled. Punching holes instead of drilling can reduce manufacturing costs as much as 30%, according to Westinghouse. Even with drilling, Super Punch produces cost savings through reduced tool wear. Drill bits typically last as much as three-times longer. Other manufacturing processes including routing, shearing, blanking and slotting will also show increased tool lifetimes. In addition, as many as six boards can be stacked and drilled simultaneously on numerically controlled machines.

**CIRCLE NO. 296**

## C-band driver/output amps produce 1 MW

*Varian Eastern Tube Div., Salem Rd., Beverly, Mass. 01915. (617) 922-6000.*

Two crossed-field amplifiers operate as C-band driver and output amplifiers with up to 1 MW output power. The SFD-244A driver amp delivers 65 kW of peak output over the 5.4-to-5.9-GHz range. It is designed for cathode-modulated operation and features a 40% dc-to-rf efficiency. Duty cycles reach 0.0012 with a pulse width of 5 $\mu$s. The SFD-257 output amp provides at least 1 MW over the same frequency range. It operates with a 50% efficiency and at a 30-kV level. Maximum duty cyle is 0.001.

CIRCLE NO. 297

## Video detectors handle up to 100 W

*American Electronic Laboratories, P.O. Box 552, Lansdale, Pa. 19446. (215) 822-2929.*

The Models LD 3384 thru 3388 octave-band video detectors cover the 1-to-18-GHz frequency range and provide burnout protection up to 100 W peak power in crystal video systems. The units have a flatness of response of ±0.75 to ±1.5 dB. The tracking specs for pairs of units are ±0.5 to ±0.75 dB.

CIRCLE NO. 298

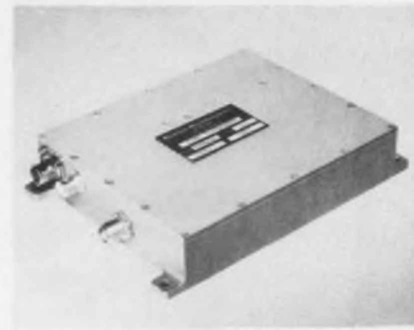
## Optical sig gen stabilizes power

*Hughes Electron Dynamics Div., 3100 W. Lomita Blvd., Torrance, Calif. 90509. (213) 534-2121. $1500.*

An optical signal generator provides a laser signal that is variable from 0 to 1 mW. The signal mode can be either digital with on/off keying up to 100 kHz, or cw with stabilized output. The power stabilization circuitry offers a short-term stability of better than 2% over the entire range from 0 to 1 mW. Called the Model 3071H, the new instrument includes a polarized He-Ne laser with an internal power supply. The 3071H operates directly from a 115/220-V-ac line.

CIRCLE NO. 299

## L-band transmitters halve dissipation



*Emhiser Rand Industries, 7721 Convoy Ct., San Diego, Calif. 92111. (714) 278-5080. 8 wk.*

The Series VT-4900L L-band airborne TV transmitters provide efficiencies of about 25% with outputs of 10 to 20 W minimum. And dissipated power is reportedly less than half that in previous models. Standard transmitters have peak deviations of +6 MHz; deviations up to ±16 MHz are available as options. The transmitters come with frequencies set in the range 1435-to-1540 or 1710-to-1850 MHz, and with a frequency stability of ±0.03% under all combinations of input voltage variations and environmental conditions.

CIRCLE NO. 300

## X8 multiplier spans 24% bandwidth

*Zeta Laboratories, 616 National Ave., Mountain View, Calif. 94040. (415) 961-9050.*

The Model 512 X8 frequency multiplier offers a 24% bandwidth for the 960-to-1220-MHz Tacan band. The multiplier accepts an input signal of +10 dBm and provides 20 mW of output power. Spurious outputs are maintained at least 65 to 70 dB below the required output. The 5120 operates over the −55-to-+83-C temperature range and draws less than 160 mA from a 15-V supply.

CIRCLE NO. 301

# 1,500,000

## KNOBS TO CHOOSE FROM...

and they're "Warranted for Life"

Kurz-Kasch has over 1½ million low cost, high quality knobs in inventory, ready to ship to you. (You save . . . no tooling cost on stock knobs, specials 4 to 6 weeks delivery.) Your local distributor's stock is available at factory prices. Select instrument and control knobs from 24 families with 367 basic sizes and shapes in general purpose phenolics, melamines and ureas. All Kurz-Kasch knobs are warranted for the life of the product on which they're used. Send now for free 20 page catalog. (Also found in THOMAS REGISTER "THOMCAT."®)

**Kurz-Kasch, Inc.**
2876 Culver Avenue
Dayton, Ohio 45429
(513) 296-0330

INFORMATION RETRIEVAL NUMBER 96

# LOW-COST NAKED ENCODERS

The Decitrak® naked encoder is specially designed for OEM applications . . . a stripped-down, low-cost incremental encoder easily integrated into systems designs. One part of the unit is a code disc easily mounted to your shaft; the other is an LED light source/photocell assembly ready for installation into your equipment. An economical, flexible solution to your systems design problems! Contact us today for a low, low quote and your **free** copy of our new applications brochure.

*Theta* **INSTRUMENT CORP.**
Specialists in Digital Automation
Fairfield, New Jersey 07006
Phone: 201 - 227-1700

INFORMATION RETRIEVAL NUMBER 97

# KEPCO TALKS POWER SUPPLY TECHNOLOGY:

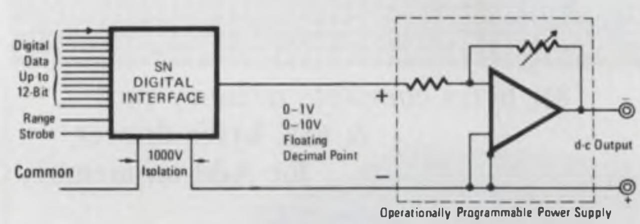
## DIGITAL CONTROL FOR ANALOG VOLTAGE

The interface between things analog and things digital is a fascinating subject that preoccupies a significant part of the electronics business. Products abound for converting digital control signals into analog ones and for digitizing the smoothly varying flow of ordinary things. Why then should we at Kepco feel a great need to introduce a new digital programming interface?

Because the things we control—power supplies—have some special requirements not otherwise satisfied by the available hardware.

1. Isolation . . . When you're controlling a 500-volt d-c power supply and want to be able to ground plus, minus or neither, you will appreciate an absolute separation of the digital and the analog circuits.
2. De-glitching . . . This rather amusing expression describes the process of getting rid of the switching transients in the D/A conversion process. Such transients, however, aren't very amusing when they're driving your kilowatt power supply into saturation!
3. Data Storage . . . If you're controlling lots of analog things (hopefully our power supplies among them), it's nice to have a little memory in each digital interface, so your expensive computer—or whatever—can go on and do other things.
4. Power . . . When you're worrying about system things, who wants to spend time fooling with ±15V and 5V supplies and their stabilizers, grounding, etc.?
5. Mounting . . . A monolithic or discrete modular plug-in DAC requires that you have something to plug them into—a printed circuit card. . . .

   Designing and debugging the card is a lot of work.




THE "SN" COUPLES TO A PROGRAMMABLE POWER SUPPLY IN PLACE OF ITS NORMALLY FIXED REFERENCE.

To help you solve these problems Kepco has designed the SN Digital Interface for our power supplies (and other analog-controlled devices) incorporating:

1. Optical isolation that can support up to 1000 volts.
2. A 6 microsecond, built-in delay-storage system to completely eliminate "glitches" (total settling time: 26 microseconds).
3. A latching memory, addressed by a separate strobe—so you can control what is placed in storage.
4. A self-powered system with built-in regulated power supplies including their transformer. . . just add 115/230V a-c.
5. All this is on a printed circuit card that can plug-in to a variety of bench, chassis and rack hardware. Additionally, all the I-C's, opto-couplers and the DAC plug into the SN's board, so you can maintain it yourself.

Five SN programming cards are offered—2-digit and 3-digit BCD and 8-, 10- or 12-bit binary.

We've published a nice brochure describing our SN programmers and would be delighted to have the opportunity to send it to you.

*with* **KEPCO** *you're in control!*

Write Dept. EL—05
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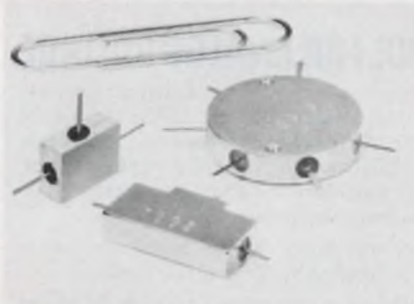
INFORMATION RETRIEVAL NUMBER 98

## Fast SPMT diode switches have low loss



*Alpha Industries, Inc., 20 Sylvan Rd., Woburn, Mass. 01801. (617) 935-5150. $85 to $400 (1-9); stock to 4 wk.*

A series of single pole, multi-throw solid-state switch modules have low insertion loss of 0.5 to 3.5 dB from 0.5 to 18 GHz, respectively, and fast switching speeds of 10 to 30 ns (for SPDT modules). Units in the MO1700 and MO1800 series have a minimum isolation of 35 to 55 dB, maximum VSWR of 1.5 to 2.5:1 and are available with up to six outputs.

**CIRCLE NO. 302**

## Light modulator has 94% transmittance

*Lasermetrics, Inc., 19 Legion Pl., Rochelle Park, N.J. 07662. (201) 843-5780. $1495; 2-4 wk.*

An electro-optic light modulator can operate with unpolarized as well as polarized light. Since the modulator doesn't use polarizers, it has an over-all transmittance of 94%. Called the EOM-3100, its optical losses result only from reflection and absorption. Half-wave retardation voltages from 488 to 632 nm range, respectively, from 195 to 250 V. The linear aperture has a diameter of 2.5 nm, and the useful optical bandwidth is listed at 450 to 1100 nm.

**CIRCLE NO. 303**

## Uhf TV triodes rated up to 250 W


*Amperex Electronic Corp., 230 Duffy Ave., Hicksville, N.Y. 11802. (516) 931-6200.*

A family of broadband, forced-air-cooled coaxial ceramic triodes are available for uhf TV translator and driver applications. Seven triodes—the YD1300 through YD-1331—are offered with either planar structures for outputs up to 50 W or cylindrical structures for outputs to 250 W. Drive powers range from 0.25 W (YD1300) to 8 W (YD1331 and YD1332). Intermodulation products are −56 dB.

**CIRCLE NO. 304**

## Data normalizer handles swept VSWRs

*Kruse Electronics Div., 735 Palomar Ave., Sunnyvale, Calif. 94086. (408) 735-9660. $2500; under 4 wk.*

The Model 7100 data normalizer can store and compare swept parameters such as VSWR, gain and loss. It stores input analog data vs any desired variable voltage in a digital memory. Reference sweeps, raw test traces, and normalized (differential) sweep outputs are available on demand at any selected sweep rate for as long as required. A sweep-refresh option permits the 7100 to convert CRT display into a single-function selective erase storage oscilloscope.

**CIRCLE NO. 305**

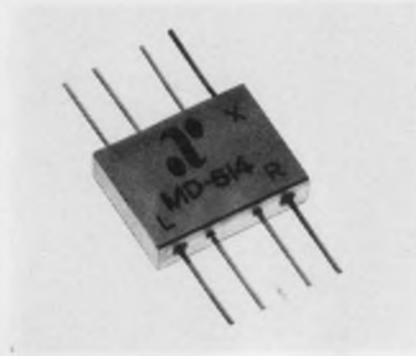
## Quad horn antennas cover 8-16-GHz range

*Sanders Associates, Grenier Field, Manchester, N.H. 03103. (603) 669-4615.*

Operating over the 8-to-16-GHz frequency range, quadrature horn antennas can receive vertical and horizontal polarization. When fed with a 90-degree quadrature hybrid, they radiate in a circularly polarized mode. Called the CA-116 series, their typical power handling capabilities are 2 kW peak power and 80 W average power. They feature a nominal 60° 3-dB beamwidth with an axial ratio or boresight of 2.0 dB.

**CIRCLE NO. 306**

## Small flatpack holds double-balanced mixer

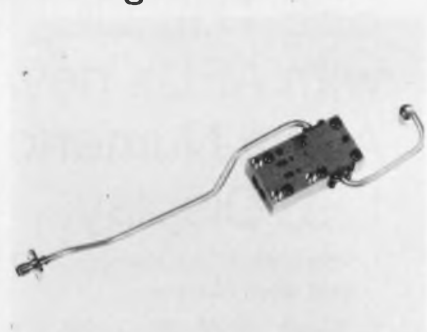



*Anzac Electronics, 39 Green St., Waltham, Mass. 02154. (617) 899-1900. $75 (1-5); stock.*

The double-balanced mixer comes in a miniature flatpack and operates over the dc-to-2-GHz frequency band. Called the MD-614, the new mixer offers a conversion loss less than 8 dB, typical isolation greater than 20 dB and frequency response of 600 MHz to 2 GHz at the LO and rf ports. At the i-f port, the response is dc to 1 GHz. The mixer measures only 0.500 $\times$ 0.375 inch with a 0.125-inch profile.

**CIRCLE NO. 307**

## Gain equalizers use semi-rigid cables

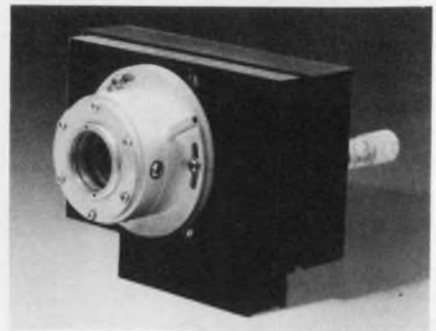


*Frequency Contours, 3140 Alfred St., Santa Clara, Calif. 95050. (408) 984-7820.*

A gain equalizer operating from X to $K_u$ band incorporates a 0.141-inch diameter semi-rigid cable instead of conventional rf connectors for lower insertion loss and VSWR values. The equalizer covers the frequency range of 8.8 to 17.0 GHz and provides a nominal midband attenuation of 13 dB. Maximum insertion loss, including cable loss, is 1.4 dB and VSWR is 1.75:1 maximum.

**CIRCLE NO. 308**

## Frequency doubler uses crystal-in-liquid



*Korad, Div. of Hadron, 2520 Colorado Ave., Santa Monica, Calif. 90406. (213) 829-3377.*

The KM2 temperature-controlled frequency doubler, for solid-state lasers, features a liquid-immersed crystal for higher beam intensities and pulse repetition rates. It can be used with either horizontally or vertically polarized oscillator-amplifier industrial laser systems. Nominal operating temperature for the KM2 is 70 F. Conversion efficiencies of 3 to 15% can be obtained, depending on fundamental beam radiance. The KM2 is available in three models for conversion of the following wavelengths: Model KM2-901—10,600 to 5300Å; Model KM2-902—5300 to 2650Å; and Model KM2-903—6943 to 3472Å.

**CIRCLE NO. 309**

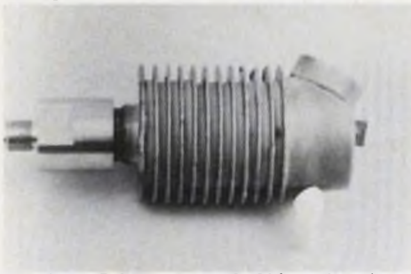
## Gunn diodes deliver up to 500 mW cw

*GHz Devices, 16 Maple Rd., Chelmsford, Mass. 01863. (617) 256-8101. 1-4 wk.*

Gunn diodes are now available from the company for narrowband applications in the 4-to-12.5-GHz frequency range. Output power levels up to 500 mW cw are offered with typical efficiencies of 4% and typical thermal resistance of 20 C/W. Called the GC-5620 through 5650 series, the units have output power levels starting at 200 mW.

**CIRCLE NO. 310**

## Photomultiplier tube response reaches 1 GHz



*Varian LSE, 601 California Ave., Palo Alto, Calif. 94304. (415) 493-4000. $3500 (CsNaKSb cathode): 60 days.*

The VPM-152 photomultiplier tube features a response of dc to 1 GHz and over-all rise time of 0.32 ns. The photomultiplier comes with a photocathode material of InGaAsP (suffix A), GaAs (suffix M) and CsNaKSb (suffix D). For the VPM-152M, typical quantum efficiences reach 18% at 530 nm, while its cathode luminous sensitivity is 750 $\mu$A/lumen. The 152M covers the 145-to-900-nm spectral range.

CIRCLE NO. 572

## Digital power meter costs $750

*General Microwave, 155 Marine St., Farmingdale, N.Y. 11735. (516) 694-3600. P: See below.*

The Model 467A digital power meter can be used with the GMC 420 series thermoelectric power heads to measure modulated, pulsed, and cw signals from 10 MHz to 40 GHz. Power levels range from 10 nW to 3 W and the unit costs only $750. The digital readout has an accuracy of ±0.5% of reading ±1 count. Short-term noise and drift is limited to less than ±1.5 nW.

CIRCLE NO. 315

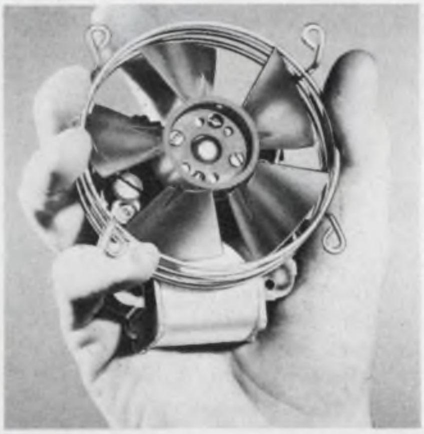
## Reflection bridge for precision tests

*Wiltron Co., 930 E. Meadow Dr., Palo Alto, Calif. 94303. (415) 321-7428.*

The Model 66G reflection bridge provides 70-dB directivity and 1.02 test-port match over any octave band within the 1-to-400-MHz frequency range. The bridge permits measurements of reflection coefficients to 0.032 with an accuracy of 1% or better. If more than a one-octave band is required, a directivity of 66 dB and a test-port match of 1.05 can be provided over approximately two decades of frequency.

CIRCLE NO. 316

## Fan priced $2 less than competition's

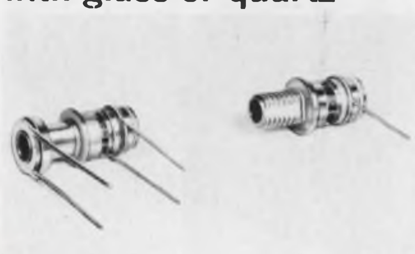


*Howard Industries, One North Dixie Hwy., Milford, Ill. 60953. (815) 889-4105. $5.25 (1000 up); 6 wks.*

Howard's new 3-90-8177 low-cost miniature fan delivers up to 34% (47 vs 36 $ft^3/min$) more air with a 17% (30 vs 36 dB) lower noise level than competitive fans. And it is available on a six-week delivery basis, rather than the usual months other vendors require. The fan is powered by a UL-approved unit-bearing motor and it fits the same 2.81 in. mounting centers as other leading units.

**CIRCLE NO. 317**

## Tubular trimmers made with glass or quartz



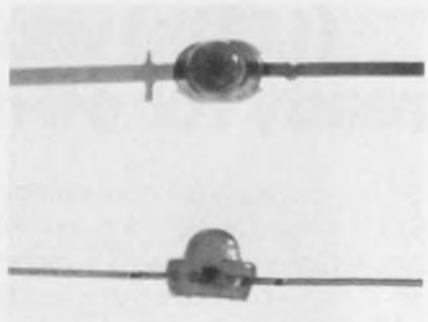
*Sprague-Goodman Electronics Inc., 371 Willis Ave., Mineola, N.Y. 11501. (516) 746-1385.*

The new trimmer Pistoncap capacitors are available for both panel and PC mounting. The use of low-loss glass or quartz dielectric materials results in high stability under conditions of changing frequency, voltage and temperature (TC ±50 to ±100 ppm/°C). Capacitors will meet or exceed the requirements of MIL-C-14409C for PC38, PC42, PC48 and PC52 units.

**CIRCLE NO. 318**

COMPONENTS

## LED for 10¢ allows high-volume use



*Litronix, Inc., 19000 Homestead Rd., Cupertino, Calif. 95014. (408) 257-7910. $0.10 (100k up); $0.17 (1000 up); stock.*

The low-cost GaAsP LED, RL-54, equivalent to Monsanto's MV-54, has a typical brightness of 0.8 mcd at 20 mA. It has a red-diffused lens, and it operates from a 5-V supply, which makes it TTL compatible. The low cost allows high volume use in array applications.

**CIRCLE NO. 319**

## Pushbutton switches use magnet as return spring

*Alco Electronic Products, Inc., 1551 Osgood St., North Andover, Mass. 01845. (617) 685-4371. $2.75: NC, $2.54: NO (500 up); stock.*

Four new types of magnetic-repulsion pushbutton switches have been added to the Alcoswitch MSPM series. They are available NO or NC with pin or flat terminals and in single pole only. Conventional spring returns have been replaced with ceramic magnets, which provide the required repulsion. Pressure change is minimal over long periods of service. Contacts are glass-encapsulated reeds. They are rated 100 mA at 50 V dc with a life expectancy of over 10,000,000 operations.

**CIRCLE NO. 320**

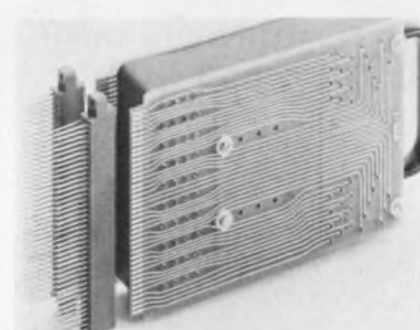
## Xenon point source draws only 5 W

*ILC Technology, 164 Commercial St., Sunnyvale, Calif. 94086. (408) 738-2944.*

A short-arc point-source lamp, the SA-5X-2R1, draws only 5 W and provides a continuous white-light output that closely simulates solar spectral radiation. The arc is only 0.25 mm long. Formerly, such a lamp required 35 W to produce such a stable arc. The lamp envelope is 4 mm in diameter by 40 mm long. The point source is almost distortion free because of the tubular, clear, fused-quartz envelope. Rated life is over 1000 hours. The lamp operates on 12 V dc and 400 mA.

**CIRCLE NO. 321**

## Card-file mounted relay eases automatic wiring



*T-Bar Inc., 141 Danbury Rd., Wilton, Conn. 06897. (203) 762-8351.*

T-bar relays, popular in data handling circuits, are now available for plug-in, card-file mounting which lends itself to automatic wiring. Eight units mount in 5-1/4 high by 19-in. wide rack-size cages. Standard units come in prepackaged modules with 14 circuit arrangements, from 36 to 52 DPDT. These packages contain T-Bar's 900 series switches that claim high transfer reliability even after long periods of inactivity.

**CIRCLE NO. 322**

# COMING NOV. 22

## A MAJOR, IN-DEPTH ISSUE OF YEAR-LONG REFERENCE VALUE

# INSTRUMENTATION '73

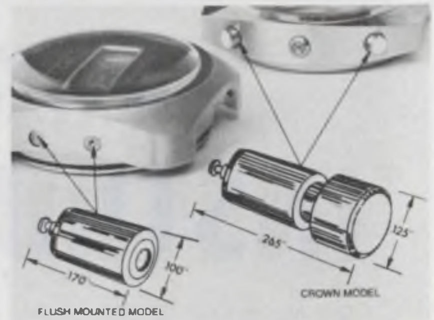
On November 22, **Electronic Design's** editors will go all out to provide readers with an exceptional issue: INSTRUMENTATION '73. Emphasis will be both on the **design** and **use** of test and measuring instruments. The report covers both **conventional instruments**—oscilloscopes, spectrum analyzers, voltage-current-resistance measuring instruments, time and frequency measuring instruments, signal sources, recording instruments, and circuit testers, and **newer unconventional instruments**—such as logic analyzers, logic probes and clips, digital memory oscilloscopes, etc. You'll find latest state of the art information, latest advances in component and circuit design that have made new performance levels both possible and practical. New approaches to packaging are also covered.

The user will be given tips on the problems that surround buying and using test and measuring instruments. Special attention is given to systems and computer compatibility. Trade-offs, and details on manufacturers' specs are included. It's an issue that will be extremely valuable for months to come.

Note: If your company has made significant new developments in instrumentation, be sure our editors know about it. (You may also want to tip off your own ad department if you are involved in this field. It's going to be a red hot issue!)

**Electronic Design**

## Tiny switch activates wristwatch displays




*Digital Time Products Inc., 2700 Shames Dr., Westbury, N.Y. 11590. (516) 997-3480.*

Nanoswitch, Series NSPB-5000 pushbutton switches, are claimed to be the smallest known devices of their kind. The company says that variations of these switches have been incorporated into the designs of most of the solid-state liquid-crystal, and LED digital-display wristwatches now on the market. The basic switches have a static rating of 50 V at 100 mA with a maximum switching voltage rating of 25 V.

**CIRCLE NO. 323**

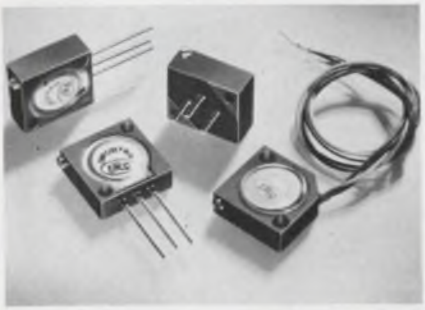
## Low-cost pressure switch handles 10 A

*Mobile Systems International, Inc., 395 N. Johnson Ave., El Cajon, Calif. 92020. (714) 442-2547. $9 (OEM qty); stock.*

A miniaturized, precision, pressure switch is offered in a broad selection of ranges from 1 to 75 lb/in$^2$. It is field-adjustable with a simple screwdriver/spring movement. With its PVC body and stainless-steel diaphragm, it will operate dependably at temperatures to 165 F and will withstand vibration to 10 g. A 10-A, over-center, electrical switch is easily wired for either NO or NC operation. Gold contacts assure dependable switching over many thousands of cycles.

**CIRCLE NO. 324**

## Cermet trimmers driven by worm-gear drive

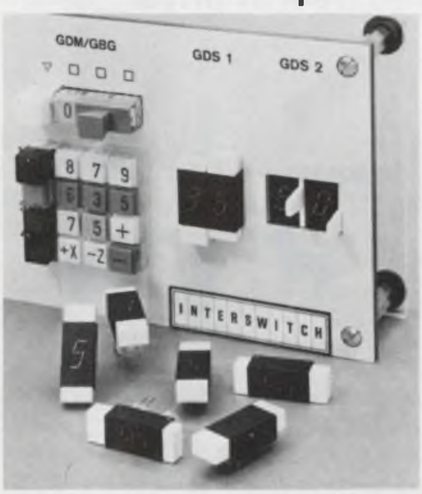


*TRW/IRC Potentiometers, 2801 72nd St. North, St. Petersburg, Fla. 33733. (813) 347-2181. $1.96 to $3.19 (distributor qty); stock.*

Half-inch square cermet trimmers for low-cost commercial applications provide essentially infinite resolution and operation up to 150 C. Called Type 25, they are available in 12 standard resistance values from 100 Ω to 1 MΩ and are rated 3/4 W at 70 C. A worm-gear drive allows the wiper contact to idle when it reaches either end of the resistance element.

**CIRCLE NO. 325**

## Slide-action switch suited for data input

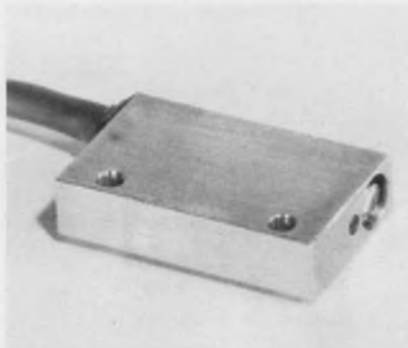



*Interswitch, 770 Airport Blvd., Burlingame, Calif. 94010. (415) 347-8217.*

A dual inline package, the GDS slide-action switch has 10 positions and only measures 1.34 × 0.39 × 0.47 in., not including the contacts. The switch has a 0.275 × 0.43 in. display, and it is designed to last for over 1,000,000 switching operations at 48 V ac. It is especially suited for direct input of digital numerical values in the standard BCD code.

**CIRCLE NO. 326**

## LED scanner detects objects by infrared



*Scanning Devices Co., 226 Broadway, Cambridge, Mass. 02139. (617) 354-7226.*

Model S-6 is a reflective photoelectric scanner which uses a LED for a light source and a phototransistor for a sensor. The LED can operate with up to 200-mA continuous current and the high-speed phototransistor (1.5 μs) handles to 30 V dc at 50 mW. The scanner, using conventional dc amplification, has an operating range of 1 ft when dependent upon the reflectivity of the object itself. A range of 10 ft is possible when a mirror is used. The unit operates in the infra-red region with peak response at about 9300 Å.

**CIRCLE NO. 327**

## Switch for PC boards sets with thumbwheel

*Electronic Engineering Company of California, 1441 E. Chestnut Ave., Santa Ana, Calif. 92701. (714) 835-6000. $1 per station (OEM qty); stock to 60 days.*

Series 21 Strip-Switch, a single-piece thumbwheel unit that mounts directly to a PC board without rivets or hardware, holds up to 11 stations. It can mount on either or both sides of a PC board.

**CIRCLE NO. 328**

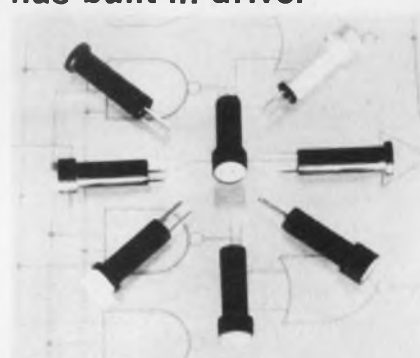
## Probe cools components for testing

*FTS Systems Inc., P.O. Box 158, Stone Ridge, N.Y. 12484. (914) 687-7664. $290 (unit qty).*

Compact cooling equipment is now available for on-the-spot cooling to −75 F. It permits the user to place refrigeration as easily as one now places heaters. The cooling probe is available with a threaded tip for attaching adapters to cool transistors, ICs or resistors for trouble-shooting or testing heat sensitive circuitry. A five-foot flexible line connects the probe to the refrigeration system.

**CIRCLE NO. 329**

## Incandescent display has built-in driver



*Data Display Products, 5428 W. 104th St., Los Angeles, Calif. 90045. (213) 641-1232. $1.87 (1000 up); stock to 3 wks.*

These panel display lights, with built-in driver and keep-alive bias, interface directly with MOS and TTL circuits for either positive or negative logic. A current of 20 mA provides a brightness of 0.035 MSCP, and units that operate on 5 to 28 V are available. An optional built-in lamp test can be provided. Sizes of 1/4 and 3/8 in. diameters and a variety of lens styles allow many selections of mounting methods and appearances.

**CIRCLE NO. 330**

## Dual JFETs combine low noise, low drift

*Intersil, 10900 N. Tantau Ave., Cupertino, Calif. 95014. (408) 257-5450. $2.95 to $19.95 (100 up).*

Monolithic dual n-channel junction FETs feature noise voltages less than 10 $nV/\sqrt{Hz}$ at 10 Hz, and less than 5 $nV/\sqrt{Hz}$ at 1 kHz. Called the 2N6483, 2N6484, 2N-6485 and IMF6485, the new devices also offer low drift. The 2N6483 has $5\mu V/°C$ voltage differential drift, 5mV differential gate-source voltage and 100 dB common-mode rejection. The 2N-6484 has 10 $\mu V/°C$ drift, 10 mV differential G-S voltage and 100 dB CMRR. The 2N6485 has 25 $\mu V/°C$ drift, 15 mV differential G-S voltage and 90 dB CMRR. The IMF6485 has 40 $\mu V/°C$ drift, 25 mV differential G-S voltage and 90 dB CMRR. All models come in TO-71 cans.

**CIRCLE NO. 331**



## High-speed op amp has 2.5-$\mu$s settling to 1.0%

*Analog Devices, Route 1 Industrial Park, Norwood, Mass. 02062. (617) 329-4700. AD509J: $11.50 (1-24); stock.*

The AD509 IC op amp combines a high slew rate of 100 $V/\mu s$ minimum with a guaranteed settling time to 0.01% of 2.5-$\mu$s maximum in a unity-gain configuration. Other features of the AD509 include a unity-gain small-signal bandwidth of 20 MHz and a 150-kHz minimum full power response. The new op amp can drive capacitive loads of 500 pF without deterioration in settling time and has internal compensation for all values of closed-loop gain greater than 3.

**CIRCLE NO. 332**

## Single package contains 16-k ROM

*American Microsystems, Inc., 3800 Homestead Rd., Santa Clara, Calif. 95051. (408) 246-0330. $22 (100-999).*

Within a 24 or 28-pin DIP, the S8996 contains 16 kbit of MOS read-only memory organized as a 4096 $\times$ 4-bit array. The choice of a 24 or 28-pin package permits the direct replacement of available 8-kbit ROMs. The S8996 features a maximum propagation delay of 700 ns and I/O TTL compatibility with three-state outputs. Also, the new ROM requires only a single TTL clock input. The S8996 operates from +5 and −12 V power supplies, and the total package dissipation is 350 mW.

**CIRCLE NO. 333**

## S-TTL multiplier speeds processing time

*Fairchild Semiconductor, 464 Ellis St., Mountain View, Calif. 94040. (415) 962-3816. $15.50 (100-999); 2-3 wk.*

A 4 $\times$ 2-bit Schottky-TTL multiplier, called the 93S43, can multiply two 12-bit numbers in a typical time of 125 ns using 2's complement multiplication and an iterative array of 32 devices. Even faster operation can be achieved by using 93S43 devices in combination with high-speed arithmetic logic units. The 93S43, a direct replacement for the AM2505 circuit, comes packaged in a 24-pin DIP.

**CIRCLE NO. 334**

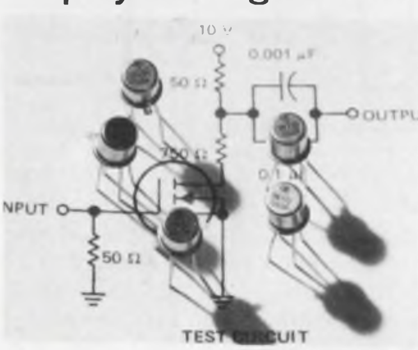
## 15-MHz FET op amp has 70-V/$\mu$s slew rate

*National Semiconductor, 2900 Semiconductor Dr., Santa Clara, Calif. 95051. (408) 732-5000. LH-0062C: $18 (100); stock.*

The LH0062 FET op amp combines a wide bandwidth of 15 MHz with a fast slew rate of 70 V/$\mu$s. Settling time is 1 $\mu$s to 0.1%. The circuit contains a monolithic dual JFET chip and a bipolar op amp similar to the LM118, and plugs directly into standard monolithic amplifier sockets. Typical offsets are 2 mV and 1 pA. Offset voltage temperature coefficient is 5 $\mu$V/°C and drifts are only 4 $\mu$V and 0.1 pA per week.

**INQUIRE DIRECT**

## N-channel MOSFETs simplify biasing



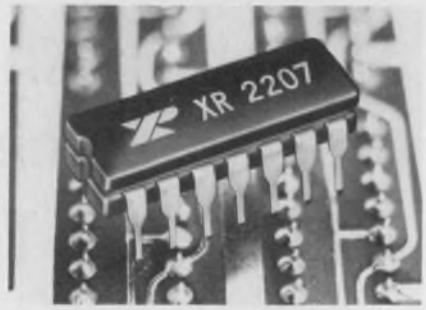

*Texas Instruments, P.O. Box 5012, M/S 308, Dallas, Tex. 75222. (214) 238-3741. 90¢ to $1.30 (100 up); 8 wk.*

Five new n-channel MOSFETs are offered in TO-72 metal cans with independent substrate connections for simplified biasing. Two devices—the 3N128 and 3N153—are depletion-type, while the other three—the 3N169 through 3N171—are enhancement-type. The 3N-128 is a vhf amplifier featuring frequency ranges up to 300 MHz. It has high minimum forward-transfer admittance of 5000 micromhos, low maximum feedback capacitance of 0.35 pF and guaranteed power insertion gain of 13.5 dB at 200 MHz. The 3N153 can be used as a high-impedance chopper or switch with a low on-state resistance of 300 Ω maximum. The 3N169 through 3N171 are choppers with low on-state resistance of 200 Ω maximum. Threshold voltages are available in three continuous ranges from 0.5 to 3 V.

**CIRCLE NO. 335**

ICs & SEMICONDUCTORS

## VCO IC drifts held to 30 ppm/°C

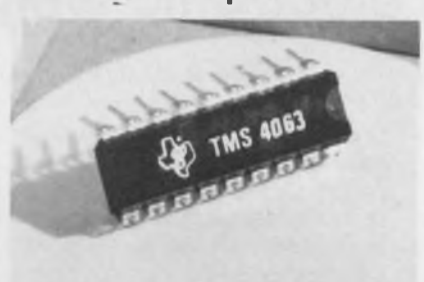



*Exar Integrated Systems, 750 Palomar Ave., Sunnyvale, Calif. 94086. (408) 732-7970. XR-2207-MN: $13.50 (100 up).*

The XR-2207 precision voltage-controlled oscillator boasts a frequency stability of 30 ppm/°C, a 1000:1 sweep range and simultaneous square and triangular outputs. The XR-2207 operates with either single or dual supplies from ±4 to ±13 V and with a frequency stability of 0.1%/V. The basic oscillator frequency is from 0.1 to 1 MHz. With an external capacitor, as many as four discrete frequencies can be generated by the choice of four external resistors.

**CIRCLE NO. 336**

## 130-ns 1024-bit RAM comes in 18-pin DIP




*Texas Instruments, P.O. Box 5012, M/S 308, Dallas, Tex. 75222. $6.60 (100 up); stock.*

The company's 1024-bit MOS RAM is now offered in an 18-pin (300-mils between centers) dual-in-line package. Called the TMSS-4063, the device features maximum access and cycle times of 130 and 200 ns, respectively, over the 0-to-70-C temperature range. Power dissipation is 120 mW in the operating mode and 2 mW in standby. The use of a 4-transistor-per-bit cell permits simple timing and the termination of the refresh operation to obtain data.

**CIRCLE NO. 337**

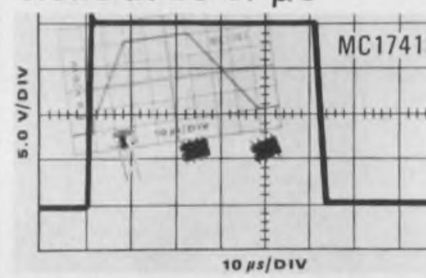
## Avalanche rectifiers peak at 20 kV

*AFI Industries, 400 Warburton Pl., Long Branch, N.J. 07740. (201) 229-8300. $1.50 to $20; stock.*

A line of high-voltage rectifiers called the 500A through 3000A Series offer a PIV voltage range of 5 to 20 kV. Current ratings are 500 mA to 3 A. The devices also feature low reverse leakage current of 1 μA. Mounting is reportedly simplified through a special flange molded as an integral part of the package.

**CIRCLE NO. 338**

## 150-kHz op amp IC slews at 10 V/μs




*Motorola, P.O. Box 20924, Phoenix, Ariz. 85036. (602) 244-3466. MC-1741SCP1: $1.25 (100 up); stock.*

A guaranteed minimum slew rate of 10 V/μsec and a minimum power bandwidth of 150 kHz are offered in the MC1741S op amp. An improved version of the company's MC1741 op amp, the new IC boasts a signal-transient improvement of 20 times that of the earlier device. All other dc and dynamic specifications for the MC1741S and the MC1741 are identical.

**CIRCLE NO. 339**

## Multiplier IC dissipates only 125 mW

*Advanced Micro Devices, 901 Thompson Pl., Sunnyvale, Calif. 94086. (408) 732-2400. Am25L05-PC: $10 (100 up).*

The Am25L05 low-power multiplier offers a typical power dissipation of 125 mW. It can multiply a four-bit number by a two-bit number and add a four-bit number to the product. All operations are performed in 2's complement arithmetic, giving a 2's complement double-length product. The high-speed device allows, for example, multiplication of two 8-bit numbers in only 275 ns.

**CIRCLE NO. 340**

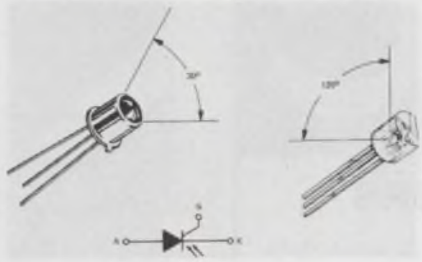
## Voltage comparators offer 20-ns response

*National Semiconductor, 2900 Semiconductor Dr., Santa Clara, Calif. 95051. (408) 732-5000. LM-360 (Epoxy B): $3; LM361 (Epoxy B): $1.75 (100 up); stock.*

Two high-speed differential voltage comparators feature guaranteed response times of 20 ns maximum. Called the LM160 and LM161 series, the new comparators are bipolar ICs with high speed differential inputs and complementary TTL outputs. Typical delays on either series varies only 3 ns for overdrive variations of 5 to 500 mV. The pinouts of the LM161 permit the front end to be run on ±15-V op-amp supplies, while the TTL output section is run on +5 V and ground. For both series, versions cover MIL-spec and commercial temperature ranges. Packaging includes TO-5 can, flatpack, standard DIP and Epoxy B DIP.

**INQUIRE DIRECT**

## Thyristors activated by light



*Motorola, P.O. Box 20924, Phoenix, Ariz. 85036. (602) 244-3466. 15-V MLS101: 84¢; 200-V MLS105: $2.10 (100-999); stock.*

A line of annular, light-activated thyristors are available in both plastic and metal packages. Part numbers MLS101 through MLS105 designate the plastic, TO-92 version and part numbers MLS201 through MLS205 are the metal case, TO-18 version. Both versions have peak reverse blocking voltages from 15 to 200 V and peak forward surge current of 5 A. Forward rms current for the MLS101 series is 250 mA, and for the MLS-201 series, it's 400 mA.

**CIRCLE NO. 341**

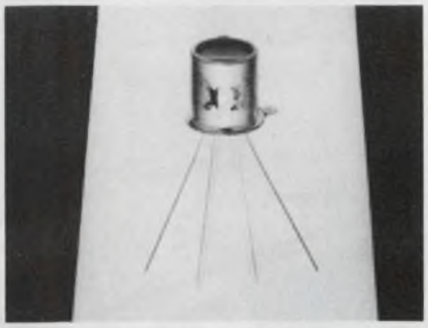
## Dual interface IC connects ECL to MOS


*Texas Instruments, P.O. Box 5012, M/S 308, Dallas, Tex. 75222. (214) 238-3741. SN75368N: $3.24 (100 up); 6 wk.*

A dual ECL-to-MOS level converter and interface IC—the SN-75368—is reportedly the first of its kind. The memory driver accepts standard SN10000 ECL output signals and creates high current, high voltage levels for driving MOS circuits. The SN75368 may be used to drive address, control and timing inputs for such MOS RAMs as the TMS4062, AMS7001, and the 1103. The SN75368 operates over the 0-to-70-C temperature range. It is offered in either a 14-pin plastic (N suffix) or ceramic DIP.

**CIRCLE NO. 342**

## Switch contains photodetector, amplifier

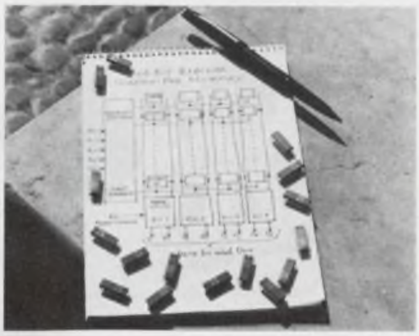


*Vactec, Inc., 2423 Northline Industrial Blvd., Maryland Heights, Mo. 63043. (314) 872-8300. $2.50.*

The VTX-1050 switch combines a photodetector and an amplifier to activate sensitive relays or CMOS logic circuits without interface elements. The new switch operates from any 11-to-20-V-dc supply, and requires only two external components to set the switching level. Sensitivity is adjustable from 5 $\mu W/cm^2$ to 10 $mW/cm^2$. The light source can be incandescent, neon, or LED. The unit is hermetically sealed in a TO-18 enclosure.

**CIRCLE NO. 343**

## 64-bit RAM can write while reading



*Signetics, 811 E. Arques Ave., Sunnyvale, Calif. 94086. (408) 739-7700. $7.05 (100); 4 wk. (large qty.).*

A high-speed bipolar RAM accepts data simultaneously while its contents are being read. Called the 82S21, the new "write-while-read" RAM is a 64-bit TTL device organized into 32 words of 2 bits each. Features include a 25-ns read access time, buffered address lines and latches and decoding circuits on the chip. Open-collector outputs can deliver 48 mA each. The new memory comes in a 24-pin DIP.

**INQUIRE DIRECT**

## 1-kbit RAM accesses in 80 ns


*Intel Corp., 3065 Bowers Ave., Santa Clara, Calif. 95051. (408) 246-7501. $40 (100-999).*

A 1024-bit n-channel silicon-gate RAM, the 2105, has an access time of 80 ns and a read-write cycle time of 180 ns. Standby power disipation is a low 80 $\mu W$/bit. The RAM costs 0.4 cents per bit in 100-999 quantities—reportedly one-half the cost of bipolar memories with equivalent speed. Organized as 1024 words by one-bit, the 2105 has all address decoding circuitry on the chip. Address, data, and write-enable inputs are low level for TTL compatibility. In addition, output OR-tie capability is provided for memory expansion.

**CIRCLE NO. 344**

DATA PROCESSING

## Optical mark reader buffers ASCII data

*Datum, Inc., 170 E. Liberty Ave., Anaheim, Calif. 92801. (714) 879-3070. $1995; 45 days.*

Model 5098 assembles pencil-marked data into ASCII characters. The unit reads documents up to 8.5 × 11 in. Each 12-bit document entry is translated into two 10-bit serial characters, then formatted and buffered for transmission. Model 5098 scans at 13 in/s and can transmit at rates up to 9600 baud. A reverse channel control permits retransmission of data in case of error.

**CIRCLE NO. 345**

## Tape readers operate at 1000 or 200 char/s

*Superior Electric Co., 1000 Middle St., Bristol, Conn. 06010. (203) 582-9561. See text; stock.*

Photoelectric tape readers TRP-1000R and TRP1000F read 200 to 1000 char/s synchronously or zero to 60 char/s asynchronously. The search/rewind speed is 1000 char/s. Both Slo-Syn units handle 1 in. eight-channel tape having a maximum light transmission of 40%. A LED light source eliminates aging effects. Model TRP1000F, selling for $980, holds 200 feet of fan-fold tape; model TRP1000R accommodates 750 feet of tape on reels and costs $1475.

**CIRCLE NO. 346**

## Sampling method boosts X-Y recorder speed

*General Radio, 300 Baker Ave., Concord, Mass. 01742. (617) 369-4400. $1500.*

A sampling feature permits the 1715 X-Y recorder to plot repetitive swept measurements that have sweep times ranging from 0.01 to 10 s. The recorder operates at speeds up to 20 in/s in the direct mode and 20 ms a point in the sampling mode. The input range is 0 to 4 V for the X-axis and −2 to 2 V for the Y-axis. Any paper size up to 11 by 17-in. can be used with the 1715.

**CIRCLE NO. 347**

## System automatically watches your clock

*ISM Corp., 20 Sylvan, Woburn, Mass. 01801. (617) 935-6370. $400.*

The Clockwatcher electronically totalizes the amount of time on a given project. Continuous monitoring of one to 15 stations is furnished via a visual digital display. Additional modules can increase capacity of the number of projects to be monitored. Operation of the Clockwatcher consists of pressing a button and setting the number of people working on a project. It even records overtime hours.

**CIRCLE NO. 348**

## ROM programmer is intelligent and portable

*Pro-Log Corp., 2826 Metropolitan Pl., Pomona, Calif. 91767. (714) 593-7408, $1900; 3 wk.*

Controlled by a microprocessor, these portable programmers list, program, duplicate and verify data on 1702A and 5203-type reprogrammable ROMs. Model 810 programs a 1702A ROM; 811 a 1702 ROM and 812 a 5203 ROM. Options include a TTY interface, paper-tape reader and a ROM erase light. Each unit comes in an attache case and weighs less than 14 pounds.

**CIRCLE NO. 349**

## Graphics system uses improved controller

*Adage, Inc., 1079 Commonwealth Ave., Boston, Mass. 02215. (617) 783-1100. $30k-50k; Mar., 74.*

The Adage/400 graphic display system provides an interactive graphics facility when attached to a host computer. A large CRT display forms part of each user work station. Each work station includes digital and analog accessories for interacting with displayed images. The display controller, a microprogrammed microprocessor, handles the key image manipulation routines with minimal host computer involvement. Options include depth cueing, two and three-dimensional windowing, a circle generator and a color CRT.

**CIRCLE NO. 350**






## Printers operate at 180 or 420 lines/min

*Potter Instrument Co., 532 Broad Hollow Rd., Melville, N.Y. 11746. (516) 694-9000. See text; 90 days.*

Two printers, models LP6150 and LP6350, offer a choice in speed of 180 or 420 lines/min. Both printers use a helical platen concept. Printing is accomplished with two moving parts—12 hammers and the spiralling platen. The printers produce up to six copies at a time with 132-column lines. The character set, which is ROM programmed, handles any foreign or custom font in 64 or 128-character sets. In 1000 quantities, model LP6150 which prints 180 lines/min. costs $2450 and model LP6350 which prints 420 lines/min. costs $3465.

**CIRCLE NO. 351**

## Electrostatic device prints or plots

*Versatec, Inc., 10100 Bubb Rd., Cupertino, Calif. 95014. (408) 257-9900. $9900; Aug.*

The Matrix 1600A, an electrostatic printer/plotter, combines the plotting capability of the Matrix 1600 plotter plus the printing capability of the Matrix LP-1616 printer. The unit prints one hundred 16-by-16 dot-matrix characters at 300 lines/min from ASCII input data. The stationary writing head contains a 1600-nib plotting array with a spacing density of 160 nibs/in. The Matrix 1600A plots across 10 inches of an 11-in. paper width; paper is fed at the rate of 0.75 in/s.

**CIRCLE NO. 352**

## Flexible disc software supports on-line system

*Xebec Systems, Inc., 566 San Xavier Ave., Sunnyvale, Calif. 94086. (408) 732-9444. $3350; 30 days.*

Users of Data General or Digital Computer Controls computers can operate in an on-line interactive mode with this flexible-disc operating system. The package includes flexible-disc drive, software operating system and all hardware interfaces. The system requires a minimum of 8 k words and 12 k if used for Fortran. The drive accommodates one or two discs each capable of storing up to 260 kbytes. Random storage access is 300 ms (average) with a transfer rate of 31 kbytes/s.

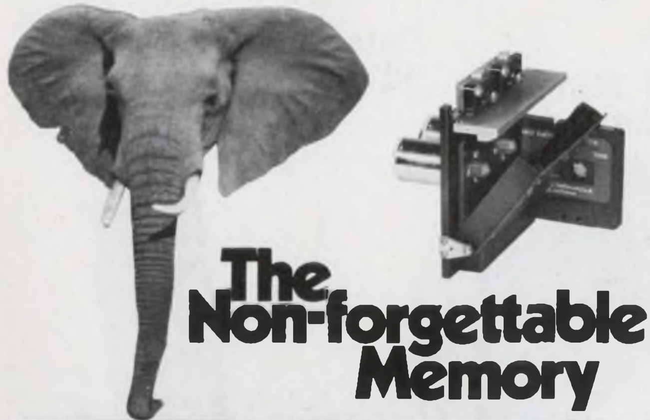
**CIRCLE NO. 353**

## Instrumentation recorder withstands 100 g shock

*Genisco Technology Corp., 18435 Susana Rd., Compton, Calif. 90221. (213) 537-4750. $10,000-$15,000 120 days.*

Compact size and rugged construction are key features of the model 10-236 instrumentation recorder. It is suited for use in torpedos and rockets where space is at a premium. The recorder weighs 6.75 pounds and measures 3-1/2 × 5-3/4 × 7-3/16-in. Salient design parameters include tape speeds of 7.5-in/s to 120-in/s in five standard increments, and a recording capacity of up to 14 tracks on 0.5-in. or 1-in. tape. A special drive mechanism provides the necessary force between tape and head without the use of pinch rollers. Flutter is less than one percent p-p. Model 10-236 draws 50 watts (with inverter) from 28 V dc when operating at 30-in/s. The unit withstands up to 100 g shock.

**CIRCLE NO. 354**



# The Non-forgettable Memory

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- Because it is the simplest ☐
- Because it is the most rugged ☐
- Because it is solidly built ☐
- Because the design is versatile ☐
- Because of patented constant speed drive ☐
- Because there are no moving parts except the motors ☐
- Because it is low cost ☐
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**1. TEMPILABELS°:** self-adhesive temperature monitors consisting of one or more heat-sensitive indicators sealed under transparent, heat resistant windows. The centers of the indicator circles turn from white to black irreversibly at the temperature ratings shown on the label. Tempilabels° are available in several sizes, and in single or multiple temperature ratings from 100° to 500°F. Accuracy is within ±1% of the stated rating. They are particularly useful for monitoring operating temperatures of equipment or processes; obtaining temperature data of components as a guide to design and material selection; safeguarding temperature-sensitive materials in storage or transit. To serve as a permanent record, Tempilabels° can be removed from the surface and attached to a report.

**2. TEMPILAQ°:** materials of calibrated melting points suspended in an inert, volatile non-flammable vehicle. Available in over 100 systematically spaced temperature ratings from 100° to 2500°F. Tempilaq° indicates its temperature rating by liquefying within ±1% of its rating. Available in bottles or spray cans.

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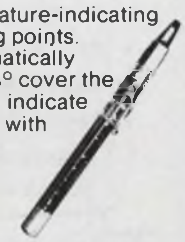


**Detailed data and price sheets as well as samples are available upon request.**

**Tempil° DIVISION, BIG THREE INDUSTRIES, INC.**
Hamilton Blvd., South Plainfield, N.J. 07080
Phone: 201 • 757-8300 • Telex: 138662

INFORMATION RETRIEVAL NUMBER 129

DATA PROCESSING

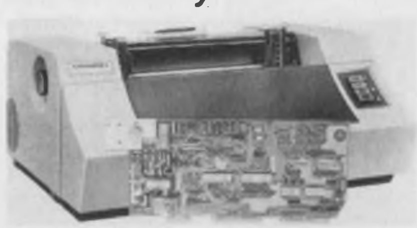
## Miniature CRT terminal designed for data entry

*Car-Mel Electronics, 2218 Cotner Ave., Los Angeles, Calif. 90064. (213) 477-4216. $1950; stock.*

A complete miniature CRT terminal, the D-301 Informer, works directly with a minicomputer or can be connected to phone lines for remote data entry. Each terminal includes a standard keyboard with separate number pad and special-function keys. Other features include dual-intensities and cursor addressing. And, the electrical interface is compatible with EIA standards.

**CIRCLE NO. 355**

## Impact printer uses LSI circuitry

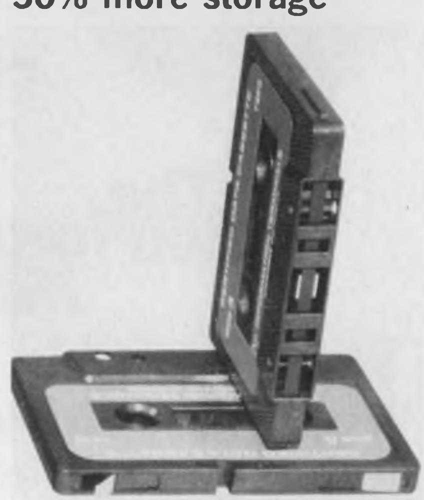


*Centronics Data Computer Corp., One Wall St., Hudson, N.H. 03051. (603) 885-0111. $4030 (unity qty.) 45 days.*

The 101AL is a 132-column, serial impact printer which uses LSI electronics. Printing speed is 165 char/s and 60 to 200 lines/min. The unit will produce an original plus at least four carbon copies. The last printed line is visible for immediate reading. The standard mode produces a line of elongated boldface characters on command. The printer employs a 9 × 7 dot matrix for generating characters. A variety of character sets is available.

**CIRCLE NO. 356**

## Data cassette provides 50% more storage

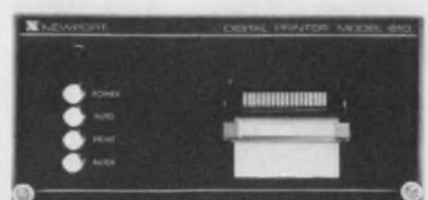


*Information Terminals Corp., 323 Soquel Way, Sunnyvale, Calif. 94086. (408) 245-4400.*

Designed to comply with ANSI and ECMA standards, the new T450 cassette provides 450 feet of computer-grade tape—50% more storage capacity than previously available data cassettes, according to Information Terminals. Its reinforced fiberglass case is molded from a conductive compound to dissipate static charges. Write lockout tabs are permanently attached with hinges, and the tabs can easily be moved to permit re-recording of data.

**CIRCLE NO. 357**

## Data printer interfaces easily, TTL-compatible




*Newport Laboratories, Inc., 630 E. Young St., Santa Ana, Calif. 92705. (714) 540-4914. See text.*

Half-rack size (4-1/2 × 8-1/2 in.) and low cost ($495 for the basic nine column printer), the Model 810 data printer features interface simplicity. TTL-compatible, rear-connector data inputs and control signals can easily be converted from positive to negative logic. The 810 also features programmable two-color printing, fixed or floating decimal point and uses standard adding machine paper.

**CIRCLE NO. 358**

## Dc supplies deliver 0.05% regulation

*Todd Products, 123 Milbar Blvd., Farmingdale, N.Y. 11735. (516) 293-3440.*

The MX Series power supplies have 0.05% regulation, 1 mV ripple, and ±10% output adjustment. They also offer adjustable overvoltage protection (thru 24 V nominal), foldback current limiting, remote sensing, remote programming, full enclosed construction, and no supplementary heat sinking or forced air cooling. The use of series regulators provides low noise, fast response, stable outputs with freedom from spurious RFI and EMI.

**CIRCLE NO. 359**

## Modular dc supplies claim high reliability


*National Power Products, P.O. Box 292, Haverhill, Mass. 01830. (617) 374-0777. From $23 (1 to 9); stock to 2 wk.*

The HRSE 900 Series of power supplies has a high reliability factor (MTBF) of 150,000 hours typ, a 100%-100-hour burn-in, UL listings (915, 902 and 904), standard package size and pin configuration for direct replacement and are backed by a full five-year warranty. The specifications include output voltage of ±15 V dc at output currents of 25 mA (HRSE-915R), 50 mA (904R), 100 mA (902R), 200 mA (920) and +5 V dc at output currents of 500 mA (903) and 1000 mA (905). The input voltage and frequency is 105 to 125 V ac for 50 to 440 Hz. Regulation for line and load is 0.05% and 0.1%, respectively, and the Pard is 0.5 mV rms.

**CIRCLE NO. 360**



INFORMATION RETRIEVAL NUMBER 132

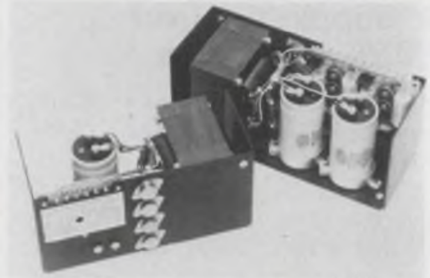
## Lab voltage standard has six-digit resolution

*Systron Donner, 10 Systron Dr., Concord, Calif. 94518. (415) 682-6161. $1995; 60 day.*

Model M106A is an isolated, floating source of dc voltage to 999.999 V in four ranges—from 1 to 1000 V. Resolution is six digits on all ranges. Other specifications of the Model M106A include a calibration accuracy and over-all stability to 0.003%, a regulation better than 0.001% and a response time to 0.003% of final output within 300 ms. It also offers remote BCD programming of output range, polarity, and voltage as well as manual pushbutton programming of the same functions.

**CIRCLE NO. 361**

## Dc supplies offer three different power ratings



*Abbott Transistor Labs, 5200 W. Jefferson Blvd., Los Angeles, Calif. 90016. (213) 936-8185. From $72 (1 to 24); stock.*

The "LC" Series of power supplies converts 115 V ac, 47 to 420 Hz to regulated voltages of 5, 12, 15, 24 or 28 V dc. Output power available is 30, 60 or 120 W. Line and load regulation are better than 0.1% and ripple is 10 mV rms with a 30 mV p-p maximum. Full output power is available up to 50 C ambient with no derating, forced air cooling or heat sinking. Standard features include short-circuit protection, remote error sensing, input transient protection and isolated outputs. Overvoltage protection is available as an optional feature. The overvoltage circuitry will reduce the output voltage to approximately 1 V dc within 25 $\mu$s after the output voltage rises 10% or 2 V dc above its nominal value.

**CIRCLE NO. 362**

## Precision power source is stable to 10 ppm

*Rotek, 40 Guinan St., Waltham, Mass. 02154. (617) 899-4611.*

The programmable E/I/R source features an accuracy of 0.005% dc and 0.05% ac. It covers a voltage range from 1 mV to 1000 V, and currents from 1 $\mu$A to 1 A. Short-term stability is better than 10 ppm. Closed-loop operation and a special, patented circuit provide fast, automatic response.

**CIRCLE NO. 363**



INFORMATION RETRIEVAL NUMBER 133

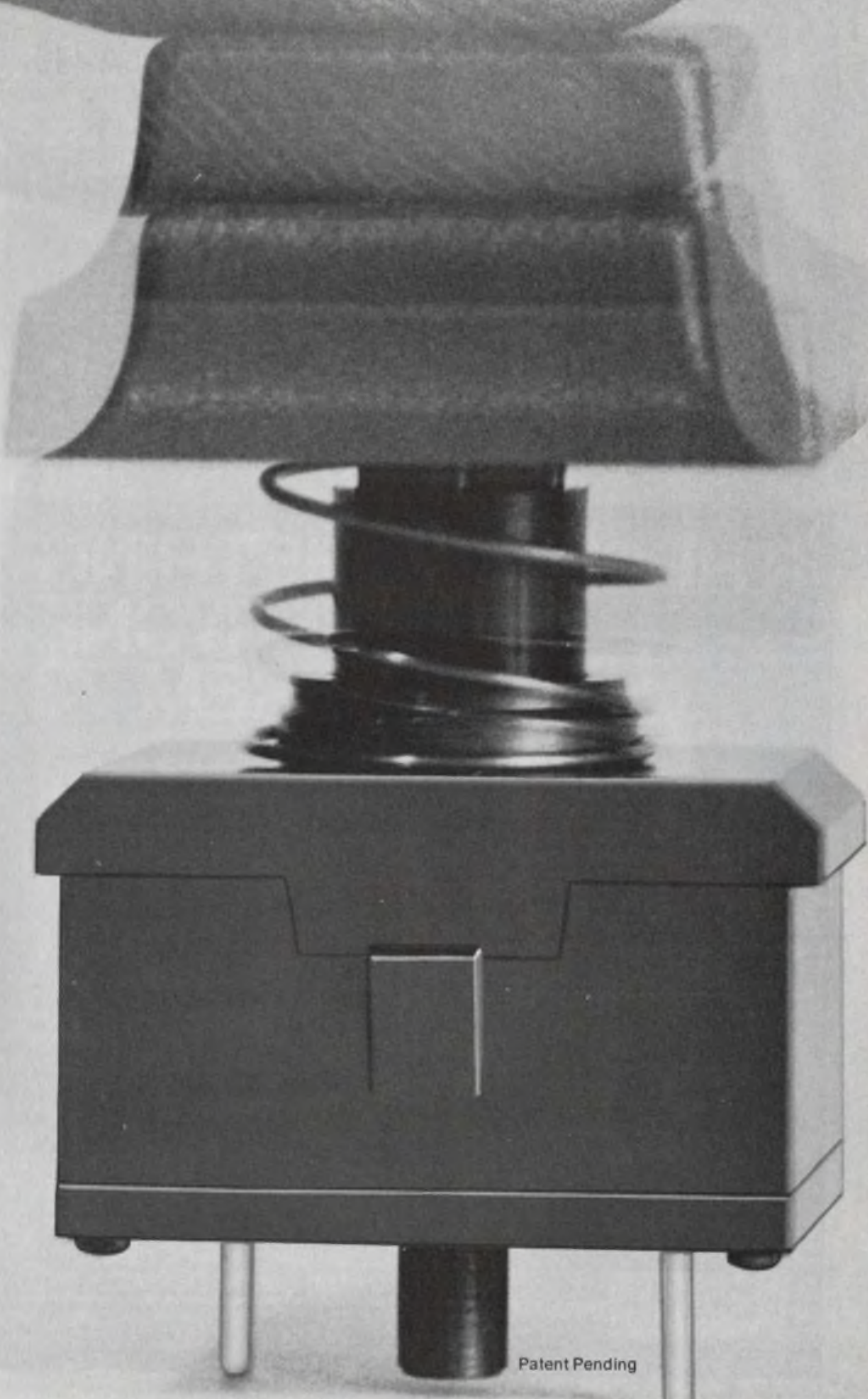
# Economical 7/16" Profile Keyswitch Sets New Standard of Value

The Stackpole Lo-Pro™ keyswitch, with a new combination of features and rugged design, is becoming an industry leader for cost-conscious applications like desk top calculators, electronic tuning, data terminals, communications equipment, and point-of-sale devices.

- completely enclosed case makes the switch "coffee-proof." Simplified design consists of only 6 parts, has a body profile of less than 7/16" with .160" or optional .100" total stroke.
- exclusive coil spring cross point contacting, with controlled wipe, provides high force per unit of contact area. This self-cleaning action assures reliability. Contact closure interference from environmental contaminant is essentially eliminated.
- wave soldering is simplified by a specially designed terminal to base interface, coupled with the ultrasonic welding of base to housing for protection against flux contamination.
- center snap-in mounting post allows perfect key adjustment and alignment prior to wave soldering to PC board. Integral snap-in panel mounting feature available at no extra cost.

This dramatic new design, backed by the manufacturing capability of the world's largest producer of slide switches, makes Lo-Pro a new standard of value . . . and price. Write or call for Bulletin No. 77-103.
Stackpole Components Company,
P.O. Box 14466, Raleigh, N.C. 27610.
Phone: 919-828-6201.
Patent Pending

STACKPOLE®
COMPONENTS COMPANY



## Power load-bank handles 1 kW in small case

*Cal Power Corp., 140 Kansas St., El Segundo, Calif. 90245. (213) 772-2171. $425; 3 to 4 wk.*

Model LB1000 is a solid state load bank that combines high power in a very small package (2.5 W per in.$^3$). It can replace bulky resistors, load banks, and rheostats and can be used for manual or electronically controlled ON-OFF switching. It can also simulate dynamic loads up to 50 kHz. Power dissipation is 1000 W max while the input current range is 0 to 100 A.

**CIRCLE NO. 364**

## Mini dc supplies offer 1% line and load reg

*Reed Devices Inc., 21 W. 183 Hill Ave., Glen Ellyn, Ill. 60137. (312) 858-2050. $18 (25 up); stock.*

The P1 series of power supplies offers short-circuit and overload protection and delivers up to 1.5 W. They are available with output voltages of 6, 12 and 24 V dc, with other voltages available on special order. The input is 115 V ac. The output is regulated to within ±1% for 10% line and load changes. The supply's size is 3 in. square by 2-7/8 in. high.

**CIRCLE NO. 573**

## Three phase SCR supply delivers up to 500 A

*Christie Electric, 3410 W. 67 St., Los Angeles, Calif. 90060. (213) 750-1151.*

The M series of three-phase SCR constant-voltage constant-current power supplies is available in three different ratings up to 500 A or 135 V. Standard features of the "M" series include: 230 V ac (±10%), three phase inputs; regulation of ±0.1% for voltage and current; dc voltage range is continuously adjustable from 0 to maximum; current limiting goes down to 0 V; remote sensing handles up to a 3 V drop per load lead and reverts to local sensing if sense leads are interrupted; response time is 50 ms for full load application and drift is less than 10 mV, +0.005%/°C. The supply also includes a voltmeter/ammeter that has ±2% accuracy. Operation from 0 to +50 C is guaranteed.

**CIRCLE NO. 501**

## High voltage supply delivers six outputs

*Sierra Systems, 2255 Old Middlefield Way, Mountain View, Calif. 94043. (415) 969-3056. $285 (1 to 4); 4 to 6 wk.*

The model 730 high-voltage CRT power supply operates from a 24 V ac or dc input. The high voltage output is factory set at 12 or 16 kV. Ripple and regulation are 0.05%. Other outputs are +450 V at 100 μA, +300 V at 50 μA, −100 V at 1 mA, −1000 V at 1 mA and a 0 to −90 V output which is user adjustable with a multiturn pot located on the supply. Built-in protection circuitry insures that the CRT is not damaged by improper operating conditions—the intensity voltage at turn-on is initially −90 V and remains there for a minimum of 60 s and then switches to its preset value. When the input power to the supply is removed, the intensity voltage switches from its preset value to −90 V and remains there until all other outputs have decayed at least 50%. The supply is fully shielded and filtered for both radiated and conducted RFI. All power connections, except for the high voltage, are made through a 12-pin connector.

**CIRCLE NO. 502**

# new literature


## Lafayette catalog

Catalog 740 is a buyer's guide to "Everything in Electronics." It features four-channel stereo high fidelity components, plus a new line of speakers and Citizen's Band two-way radio equipment. Lafayette Radio Electronics, Syosset, N.Y.

**CIRCLE NO. 503**

## Digital counters

An eight-page Buyers' Guide is sectionalized to provide descriptions, photographs and diagrams on counters of the following type: mechanical stroke, revolution and direct-drive, electric, panel-mount and elapsed-time indicators. Both resettable and nonresettable versions are covered. ENM Co., Chicago, Ill.

**CIRCLE NO. 504**

## Troubleshooting digital ICs

A 28-page application note explains the logic of troubleshooting ICs digitally, and develops an analytic algorithm that will hurry the remedy to virtually every digital IC problem. Not a guide to automatic testing, it tells how to reach fast bench solutions with inexpensive digital instruments. The fundamental differences between analog and digital circuits, which necessitate new troubleshooting methods, are made clear. Hewlett-Packard, Palo Alto, Calif.

**CIRCLE NO. 505**

## Microelectronic packages

Flatpack microelectronic circuit packages are described and illustrated in an eight-page brochure. Eight standard flatpacks are covered, with all critical dimensions called out. Cover sizes and types of materials and plating are indicated. Tekform Products, Anaheim, Calif.

**CIRCLE NO. 506**

## Breadboarding equipment

Circuit design and breadboarding equipment, power supplies and pulse generators are described in a catalog. E&L Instruments, Derby, Conn.

**CIRCLE NO. 507**

## Audio amplifiers

Concepts and techniques employed in the design of transistor audio power amplifiers and 38 silicon power transistors specially selected for use as input, driver, output and overload-protection devices are described in a 20-page brochure. RCA, Somerville, N.J.

**CIRCLE NO. 508**

## Data-communication printer

Brochure DCP-1088A gives particulars on the TermiNet 300 data-communication printer for OEM or end user needs. General Electric, Lynchburg, Va.

**CIRCLE NO. 509**

## Crosspoint contact switches

A handbook and catalog covers crosspoint switches for low-energy circuits. Included are specifications, application and technical data and operating characteristics. Cherry Electrical Products, Waukegan, Ill.

**CIRCLE NO. 510**

## Ball slides

Features, dimensional drawings, specifications and mounting suggestions for circulating ball slides are highlighted in a four-page catalog. Chassis-Trak Div., General Devices Co. Indianapolis, Ind.

**CIRCLE NO. 511**

## Deposition system

Descriptive data, specifications and prices for an electron-beam deposition system are given in a 16-page catalog. The system includes a 10-in.-diameter automatic-diffusion-pump vacuum station, 14-kW electron-beam source and power supply, domed planetary substrate fixturing and Kronos rate/thickness controller. Veeco Instruments, Plainview, N.Y.

**CIRCLE NO. 512**

## Matrix boards

Descriptions, applications and specifications of matrix program boards and pins are listed in a catalog. Info-Lite Corp., Corona, N.Y.

**CIRCLE NO. 513**

## Digital displays

Techniques for economically fabricating digital displays as well as methods of constructing both ac and dc gas-discharge flat-panel display tubes are described in a bulletin. Data are presented on materials using screen-printing techniques for large matrix arrays. Electro-Science Laboratories, Pennsauken, N. J.

**CIRCLE NO. 514**

## Thermistors

A four-page bulletin describes thermistors, varistors and temperature controllers. The bulletin includes photographs, diagrams, tables and graphs, product options and applications. Victory Engineering Corp., Springfield, N.J.

**CIRCLE NO. 515**

## Test instruments

A 16-page test-instrument catalog with an easy-to-read selection guide features VOMs and accessories. Triplett Corp., Bluffton, Ohio.

**CIRCLE NO. 516**

## Resistors

Discrete resistors (wirewound, metal-film, deposited-carbon and tin-oxide); thick-film resistor networks; trimmer potentiometers (wirewound and cermet); connectors; inductors; electromechanical products (relays and surge arresters) are described in a 28-page catalog. Dale Electronics, Columbus, Neb.

**CIRCLE NO. 517**

# Some of the best things about our new Digivac® 1000 are what you can't see.

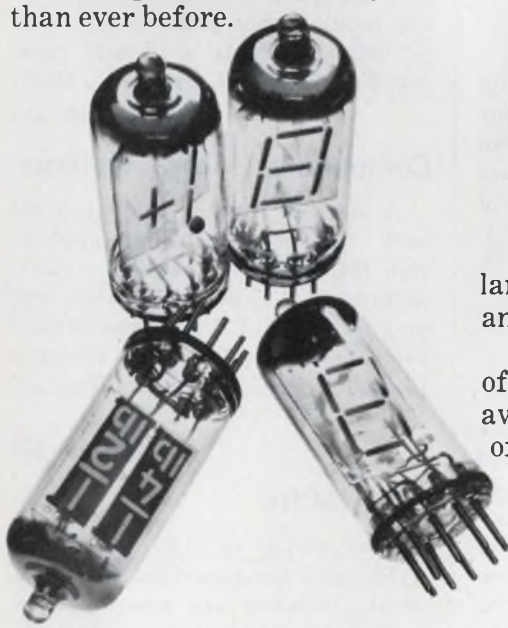
When you look at our vacuum fluorescent readout, you won't see the low voltage requirements making it directly compatible with available MOS IC logic packages.

You won't see the exclusive mica substrate which supplies mechanical strength and helps emphasize lighted segments through a desirable halo effect.

You won't see the low cost, lower than competing readouts with fewer customer advantages.

Of course, there are things about our Tung-Sol® Digivac 1000 you can see.

Like the Digivac 1000's brightness. 50% more brightness and greater uniformity than ever before.



You can see the flexible language with alpha, numerical and symbolic figures.

You can see the wide range of colors, including white, available with common types of filters.

And because of the unique construction, you can see the accurate viewing assured from virtually any angle.

With the Digivac 1000 readout, whether you see it or you don't . . . it's still nice to know it's all there.

For additional information on the Digivac 1000, write to: Wagner Electric Corporation, 1 Summer Avenue, Newark, New Jersey 07104.

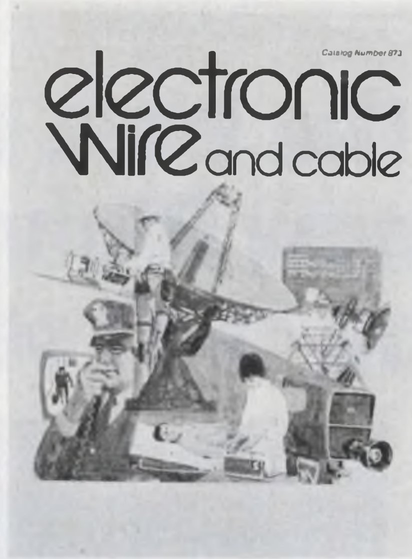
*Wagner makes other quality products in volume for the electronics industry, including bridges, power supplies and subsystems, silicon rectifiers, resistors, miniature lamps and status indicators. And Wagner offers contract manufacturing.*

**WAGNER®**

**We've got a lot more riding for you.**

®Trademarks Wagner, Tung-Sol and Digivac, Reg. U.S. Pat. Off. and Marcas Registrados

INFORMATION RETRIEVAL NUMBER 140




## Electronic wire and cables

A 72-page publication includes a section devoted to appliance, power supply and extension cords, all meeting OSHA requirements. Other sections cover cables, wires, and transmission lines, etc. Belden Corp., Geneva, Ill.

**CIRCLE NO. 518**

## PC card guides

Printed-circuit card guides and component-mounting spacers are shown in a 20-page catalog. Bivar, Santa Ana, Calif.

**CIRCLE NO. 519**

## High-temp adhesives

Properties of 910 MHT and THT adhesives for use on various substrates and information on techniques and pretreatments recommended for specialized bonding problems are described in a bulletin. Eastman Chemical Products, Kingsport, Tenn.

**CIRCLE NO. 520**

## Temperature measurements

Along with the latest thermocouple calibration tables released by the National Bureau of Standards, the company has added response-time curves, temperature-conversion tables, material-selection guides and new technical data on thermocouples, RTDs, thermistors and related instrumentation to its 160-page Temperature Measurement Handbook. Omega Engineering, Stamford, Conn.

**CIRCLE NO. 521**

## Rf/i-f components

"RF/i-f Components" covers filter, multicoupler, amplifier and coaxial components. The brochure includes mechanical features, electrical characteristics and specifications. Americal Electronic Laboratories, Lansdale, Pa.

**CIRCLE NO. 522**

## No-bounce switch

Examples of how to use a no-bounce electrical switch are contained in a 20-page booklet. Product design areas covered range from appliances and automotive to machine controls and security alarms. Fifth Dimension, Princeton, N.J.

**CIRCLE NO. 523**

## Electromagnetic delay lines

Included in a delay-lines handbook are specifications, photographs and drawings for a variety of delay lines. The handbook explains how to specify delay lines and define characteristics. Test methods for electrical requirements are shown. RCL Electronics, Irvington, N.J.

**CIRCLE NO. 524**

## Instruments

Photographs and descriptions of magnetic tape recorders, pressure and vibration transducers, recording oscillographs and business data products illustrate a 12-page catalog. Bell & Howell, Pasadena, Calif.

**CIRCLE NO. 525**

## Components, servo systems

A 56-page catalog, tabulated for easy reference, contains application information, electrical specifications, dimensional drawings and photographs of electromechanical components and servo systems. Clifton Precision, Clifton Heights, Pa.

**CIRCLE NO. 526**

## 1.6-A SCRs

Two series of 1.6-A SCRs in TO-5 cans are described in a data sheet. Included are seven graphs, a dimensional outline drawing and a photograph of the devices. Ratings and specifications are provided. International Rectifier, El Segundo, Calif.

**CIRCLE NO. 527**

## Testing system

Measurement of semiconductor resistivity and conductivity using a four-point probe is detailed in an eight-page brochure. Included is a discussion of various methods of conductivity typing and simplified diagrams to illustrate each typing technique. Keithley Instruments, Cleveland, Ohio.

**CIRCLE NO. 528**

## System components

Air-quality instruments and computer-compatible data-acquisition components are shown in a 20-page catalog. Monitor Labs, San Diego, Calif.

**CIRCLE NO. 529**

## Opto-electronic devices

Three new devices—resistor LEDs, commercial LEDs and commercial seven-segment indicators—are described in a catalog. Hewlett-Packard, Palo Alto, Calif.

**CIRCLE NO. 530**

## Slide assemblies

Catalog G-73 describes basic and special slides. The catalog shows standard UniSlides with metric lead screws in addition to English system lead screws. Velmex, East Bloomfield, N.Y.

**CIRCLE NO. 531**

## Soldering equipment

Conduction and resistance-type soldering equipment, thermal wire-strippers, tubing shrinkers and ultrasonic cleaners are described and illustrated in a four-page condensed catalog. American Electrical Heater Co., Detroit, Mich.

**CIRCLE NO. 532**

## 5-1/2-digit DVM

A two-page bulletin describes the 3000 series 5-1/2-digit voltmeters for single-range application. The bulletin includes specifications, pricing and features. Data Precision, Wakefield, Mass.

**CIRCLE NO. 533**

## Closed-circuit TV products

Features and capabilities of closed-circuit TV products are outlined in a short-form catalog. Cohu, Inc., San Diego, Calif.

**CIRCLE NO. 534**

## Semiconductor devices

Rectifiers, diodes, zeners and unpackaged devices are listed in a 12-page catalog. Physical and electrical specifications are included for JAN and JANTX as well as the company's house numbers. For easy selection, devices are indexed and cross-referenced. Microsemiconductor Corp., Santa Ana, Calif.

CIRCLE NO. 535

## Diode switch modules

A list of SPST diode switch modules is available in a four-page data sheet. The modules are categorized by switching speed, power handling, insertion loss, isolation and VSWR. Alpha Industries, Woburn, Mass.

CIRCLE NO. 536

## Plunger switches

Dimensions, lengths, hole sizes and other features of plunger switches are listed in a catalog. Rocker, toggle and vacuum actuated switches are also included. The Carr Co., Cambridge, Mass.

CIRCLE NO. 537

## Circuit packages

Modular sidewall cases, enclosures for hybrid microelectronics applications, are described in a four-page bulletin. Tekform Products, Anaheim, Calif.

CIRCLE NO. 538

## Opto-electronic products

A short-form catalog highlights the company's solid-state opto-electronic products such as discrete light-emitting diodes, LED displays and readout assemblies, opto-isolators and solid-state relays. Monsanto, Cupertino, Calif.

CIRCLE NO. 539

## Special-purpose resistors

A four-page bulletin includes specification data on ceramic and organic-type resistors, size and shape ranges and applications. Curves show typical electrical performance characteristics. Stackpole Carbon Co., St. Marys, Pa.

CIRCLE NO. 540

## Thick-film hybrid circuits

General design guidelines useful to potential hybrid users are included in a thick-film hybrid-circuit brochure. Vector, Newton, Pa.

CIRCLE NO. 541

## Capacitors

A 128-page component selector includes application information and electrical and mechanical specifications on ac and dc capacitors, electromagnetic interference filters and relays. Cornell Dubilier Electronics, Newark, N.J.

CIRCLE NO. 542

## Switches and keyboards

An eight-page brochure contains complete prices and discount schedules for the company's switches and keyboards. Cherry Electrical Products, Waukegan, Ill.

CIRCLE NO. 543

## Magnetic-core memories

ECOM and PINCOMM magnetic core memory systems are covered in a six-page catalog. Included are digital-stack modules of 4096 and 8192 words with associated digital-stack controllers; four series of PINCOMM form, fit and function plug-in compatible core memories; ECOM F and MINI-MASS general-purpose core-memory systems with cycle time of 750 ns and capacities to 131,072 words and 18 bits; and ECOM SERIES F-11 expansion core-memory systems for expanding and upgrading DEC PDP-11 minicomputer capacities to 128-k in 4-k or 8-k increments. Standard Memories, Fort Lauderdale, Fla.

CIRCLE NO. 544

## Industrial instrumentation

"Fundamentals of Industrial Instrumentation," a 96-page booklet, defines measurement and control terms and explains process variables such as pressure, temperature, humidity, flow, liquid level and pH. Included is information on program, cascade and ratio flow control, and on miniature electronic, miniature pneumatic and computer control systems. Copies are available at $2 each. Honeywell Inc., Industrial Div., M/S 436, 1100 Virginia Dr., Fort Washington, Pa. 19034.

## MOS/LSI

A 16-page brochure describes the company's capabilities for designing, developing and manufacturing custom and standard MOS/LSI devices, as well as manufacturing devices from customer tooling. Highlights include descriptions and a comparison of the company's seven available MOS production processes. American Microsystems, Santa Clara, Calif.

**CIRCLE NO. 545**

## Relays and switches

More than 200 stock relays, switches and other control components are listed in a 12-page brochure. Included are miniature, intermediate, wire-spring, polar and dry reed relays, as well as rotary stepping switches. GTE Automatic Electric, Northlake, Ill.

**CIRCLE NO. 546**

## Power cells

A family of standard stock master and slave power cells that permit rapid delivery of almost unlimited combinations of single and multiple output custom power supplies is described in a bulletin. Deltron, North Wales, Pa.

**CIRCLE NO. 547**

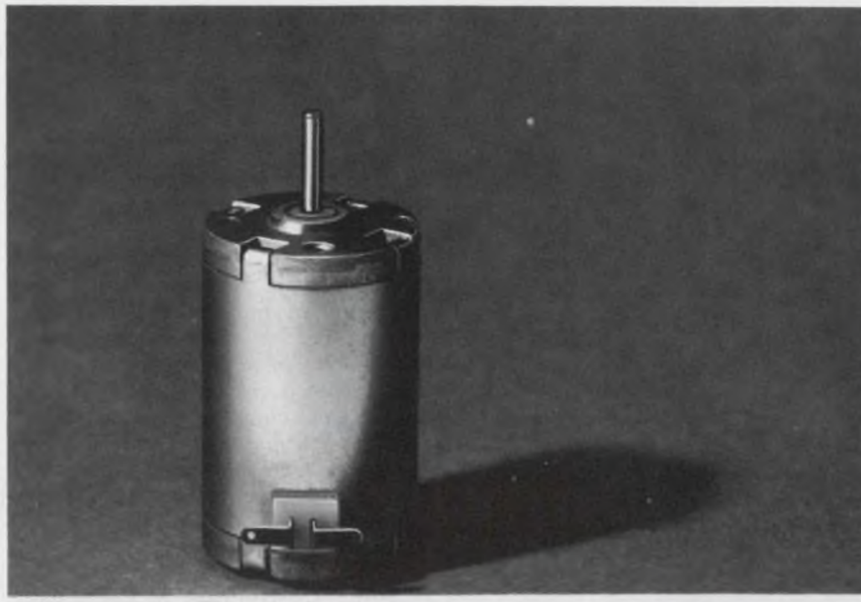
## Dc motors

A 12-page brochure gives details on more than 30 dc motors in a variety of frame sizes from 8 to 45. The catalog contains tabulations, photographs, dimensional drawings, performance curves and schematics illustrating each dc motor. The Singer Co., Kearfott Div., Little Falls, N.J.

**CIRCLE NO. 548**

## Semi chips data book

An illustrated, 295-page Semiconductor Chips Data Book covers the discrete and linear and digital ICs presently manufactured in packaged form. Sections covering selection, availability, use and packaging/shipment methods are included in the one-volume source book. Copies are available by writing on company letterhead to Motorola Semiconductor Products Div., Box 20924, Phoenix, Ariz. 85036 and enclosing $2.50 per copy.





# vendors report

Annual and interim reports can provide much more than financial-position information. They often include the first public disclosure of new products, new techniques and new directions of our vendors and customers. Further, they often contain superb analyses of segments of industry that a company serves.

Selected companies with recent reports are listed here with their main electronic products or services. For a copy, circle the indicated number.

**Engelhard Minerals & Chemicals Corp.** Ores, minerals and precious metals.

CIRCLE NO. 549

**Interdata, Inc.** Computers, peripherals and software.

CIRCLE NO. 550

**Siemens.** Components, data systems, power engineering, medical electronics and telecommunications.

CIRCLE NO. 552

**SRI.** Independent and nonprofit research.

CIRCLE NO. 553

**Tracor, Inc.** Components, instruments, medical electronics, sonar, electronic and electromechanical systems.

CIRCLE NO. 554

**American Precision Industries, Inc.** Rf coils and transformers, electromechanical products, air pollution control equipment, heat transfer equipment and temperature control instruments and gauges.

CIRCLE NO. 555

**Edo Corp.** Sonar, avionics and consumer electronics.

CIRCLE NO. 556

**Information Magnetics Corp.** Magnetic-disc recording heads, magnetic-tape recording heads, linear motor actuators, capstan motors, servo positioning systems and instrumentation tape heads.

CIRCLE NO. 557

**Cryogenic Technology, Inc.** Low-temperature equipment.

CIRCLE NO. 558

**Airco, Inc.** Cryogenics, industrial gases, alloys, anodes, resistors, capacitors, coils, thin and thick-film and carbon-film resistors, power supplies and components.

CIRCLE NO. 559

**The Foxboro Co.** Computers, instruments and analog products.

CIRCLE NO. 560

**General Telephone & Electronics.** Telephone systems, communications systems, consumer goods, lighting equipment, components, information systems and materials.

CIRCLE NO. 561

**ITT.** Telecommunications, environmental equipment, components, consumer products, avionics and aerospace.

CIRCLE NO. 562

**P. R. Mallory & Co. Inc.** Batteries, electrodes, contacts, timers, capacitors, controls, metals and hardware.

CIRCLE NO. 563

**Fifth Dimenson Inc.** Rf switching devices, switches, telemetry and data acquisition.

CIRCLE NO. 564

**Milton Roy Co.** Medical electronics, air-pollution controls and instruments.

CIRCLE NO. 565

**Electronic Memories & Magnetics Corp.** Core and semiconductor memories, magnetic-cartridge file memories, disc packs, ferrites and PM motors.

CIRCLE NO. 566

**Siliconix Inc.** FETs, solid-state switches, timing circuits, data-conversion ICs and LSI.

CIRCLE NO. 567

**Cubic Corp.** Military electronics, microfilm, computers, medical electronics, revenue-collection systems and radio-communication equipment.

CIRCLE NO. 568

**Unitrode Corp.** ICs, diodes, transistors, rectifiers, SCRs, PUTs and power supplies.

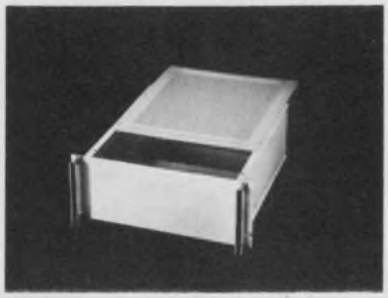
CIRCLE NO. 569

# quick ads

New and current products
for the electronic designer
presented by their manufacturers.

**Thin-Trim variable capacitors** provide a reliable means of adjusting capacitance without abrasive trimming or interchange of fixed capacitors. Series 9401 has high Q's and a range of capacitance values from 0.2-0.6 pf to 3.0-12.0 pf and 250 WVDC working voltage. Johanson Manufacturing Corporation, Boonton, New Jersey (201) 334-2676.

**INFORMATION RETRIEVAL NUMBER 151**



**Precision-engineered prefab** modular rack-mounting chassis units, card cages, cabinets & accessories assemble in many configurations to meet your space requirements. Kits & parts are in stock, ready for shipping. Free catalog includes prices. Techmar Omniclosure, 2232 S. Cotner Ave., Los Angeles, CA 90064, 213-478-0046.

**INFORMATION RETRIEVAL NUMBER 152**

**New low-cost compact** modular oscillator Model UC utilizes piezoelectric ceramic resonator for frequency control. Frequency range 12 Hz through 400 kHz, accuracy to .05%, output TTL or CMOS compatible. 1% tuning option available. Fork Standards, Inc., 217 Main St., West Chicago, Ill. 60185. (312) 231-3511.

**INFORMATION RETRIEVAL NUMBER 153**


**Rugged low cost quartz crystals** in low profile TO-5 cans. 10 to 250 kHz frequency range. ±0.01% calibration accuracy. Withstands 1000 Gs shock, 50 Gs vibration over 10 to 2000 Hz. Bypolar and MOS logic compatible. Price $1.40 ea. in 10 K qtys. Circle number for literature. Statek Corp., 1233 Alvarez Ave., Orange, Ca. 92668. (714) 639-7810.

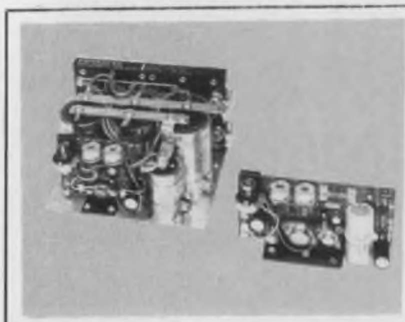
**INFORMATION RETRIEVAL NUMBER 156**


**Thick Film Technology**—Fundamentals and Applications in Microelectronics, by Jeremy Agnew. From design to finished product, this book details each processing phase, describing what to do and what pitfalls to avoid. 176 pp., 6 x 9, illus., cloth, $8.50. Circle number for 15-day examination copy. Hayden Book Company, Rochelle Park, N.J. 07662.

**INFORMATION RETRIEVAL NUMBER 157**

**Modular indicator lights cope with change**—Rubber bushing snap fits, eliminates retainers. **Interchangeable** 6, 14, 24 V. filament, neon, LED, Green Glow light sources. Lenses in 6 colors insert into bushing. Simplifies design changes, assembly, replacement. Inter-Market Inc., 1920 Waukegan Rd., Glenview, Ill. 60025. (312) 729-5330.

**INFORMATION RETRIEVAL NUMBER 158**



**50 sub modular,** D.C. power supply models for "In House" and custom designs, upto 30V, upto 75A. Unique "building block" design exclusive built-in rectifier, filter, regulator, protective functions. Transformers, heat sinks, wiring harness and chassis available. Send for catalog. Powertec, Inc., 9168 DeSoto Ave., Chatsworth, Ca. 91311. (213) 882-0004.

**INFORMATION RETRIEVAL NUMBER 161**

**IN ELECTRONIC ALLOYS, WE SPEAK YOUR LANGUAGE, EXACTLY.** We specialize in magnetic and controlled expansion alloys. Nickel-irons, stainless steels, beryllium, copper, down to .0005" thick. Rigid chemical and physical property control. Lots 5 lbs. 5 tons. Photoetching also our specialty. Magnetics, Butler Pa. 16001.

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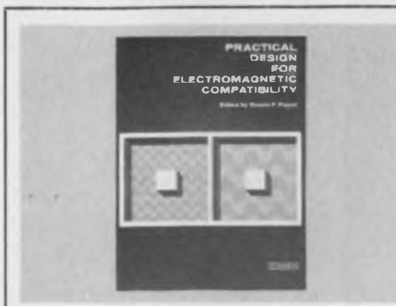


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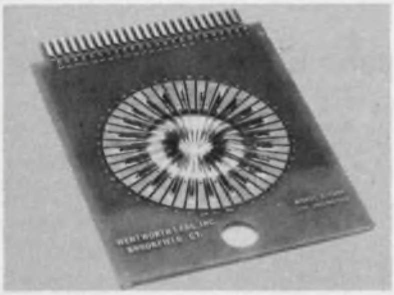









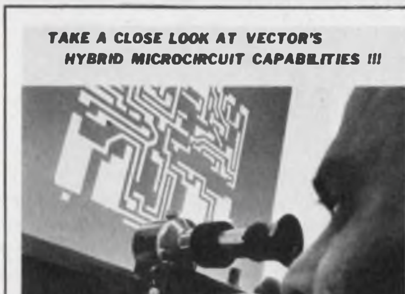




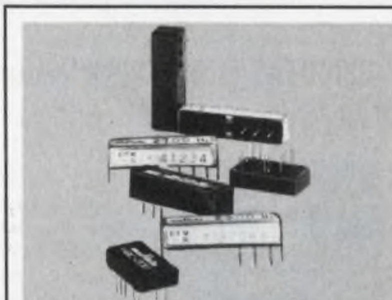



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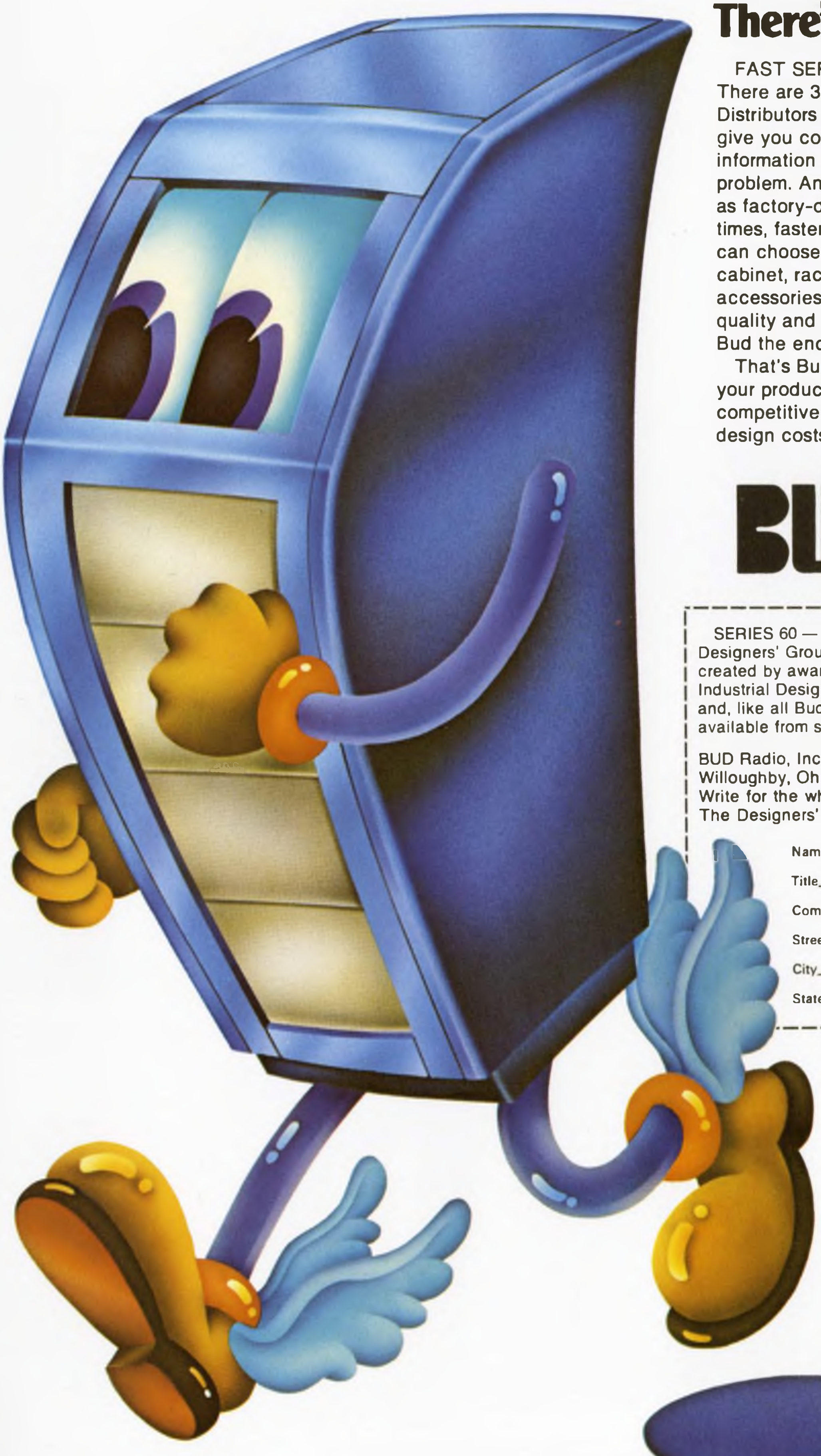

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