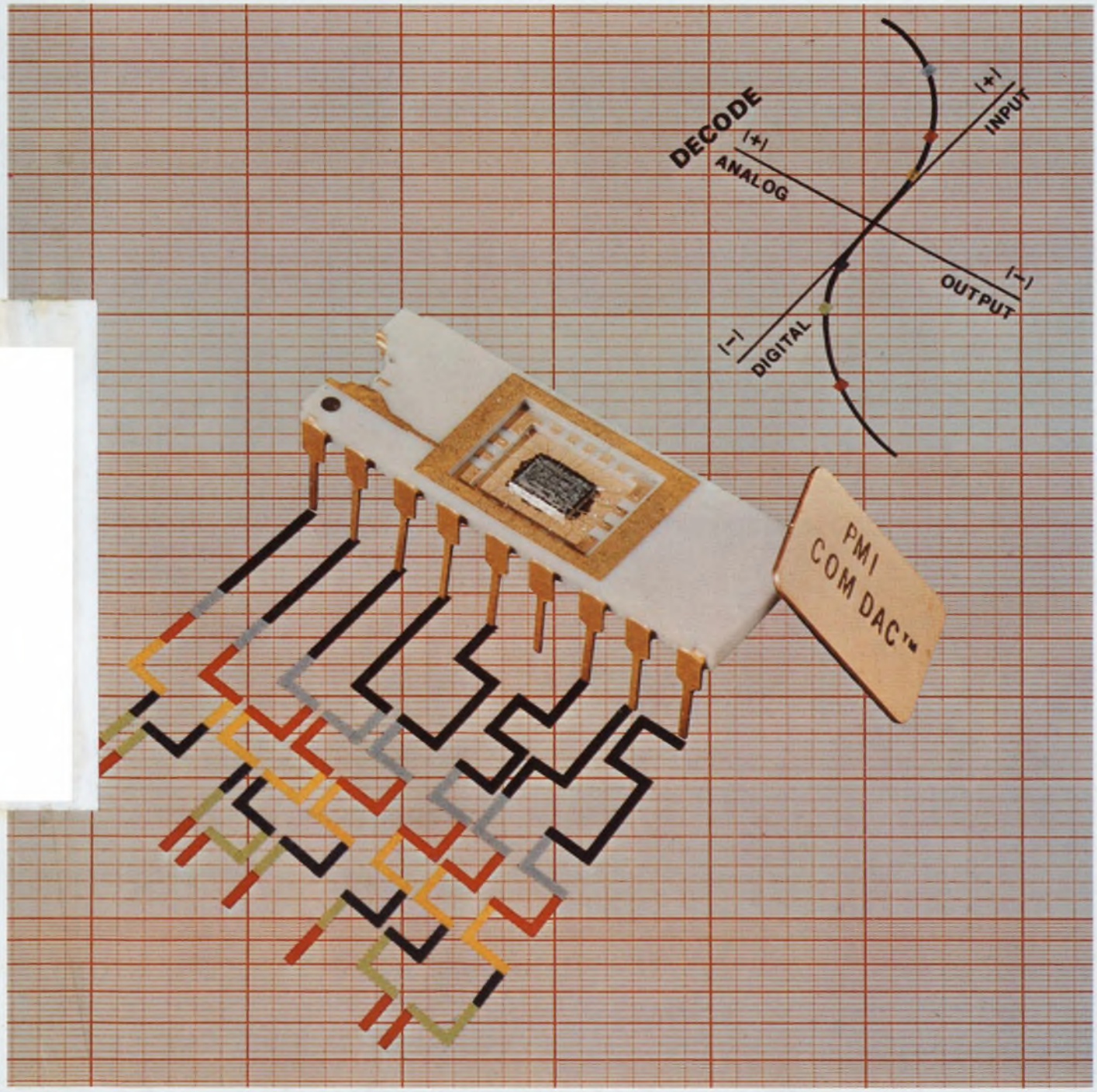
VOL. 24 NO. 9

Electronic Design®

FOR ENGINEERS AND ENGINEERING MANAGERS

APRIL 26, 1976

A monolithic companding DAC can provide 12-bit resolution and dynamic accuracy with an 8-bit input code. A single control line permits the converter to do log or antilog coding of an incoming signal. The versatile unit should find wide use in audio, PCM-telemetry and μP-based systems. For DAC details, see p. 111.



Swage-Bond™ ... a revolution in trimmer reliability!

... here today at no extra cost in every Trimpot® Potentiometer

Historically, pin-to-element termination problems have been one of the primary causes of trimmer failure . . . especially during handling and PC board process operations. Bourns exclusive Swage-Bond™ process virtually eliminates pin termination failure . . . truly a revolution in trimmer reliability. Furthermore, Swage-Bonding results in a marked improvement in temperature coefficient consistency.

Other trimmer manufacturers utilize a simple clip-on termination. Some solder this connection, some rely on tension pressure alone. In the Swage-Bond process, the P.C. pins are secured **through** the substrate, with a high-pressure compression swage on both top and bottom sides. The pressure of the swage locks the pin solidly into the element, and thoroughly bonds it to the thick-film termination material.

Swage-Bond™ eliminates pin termination failure, provides more reliable tempco. Microphotograph shows trimmer element magnified 20X.

The seal that seals . . . without springback

Bourns trimmers stay sealed when others fail. We know. We've tested them all. Bourns uses a chevron-type sealing technique, that seals without O-rings . . . eliminating the windup and springback that frequently occurs with such seals. The result is faster and more precise adjustability . . . with a seal that really works.

Wrap-around wiper for better setting stability

Bourns multi-fingered, wrap-around wiper delivers more consistent, more reliable performance. The unique design significantly reduces CRV fluctuations and open circuit problems due to thermal and mechanical shock . . . by maintaining a constant wiper pressure on the element. Compare the ruggedness of Bourns design with the common "heat-staked" wiper designs. Compare performance. Specify Bourns.

HERE'S PROOF:

Send for a copy of our new engineering report on TRIMMER PERFORMANCE. Tell us about your application, and we'll provide qualification samples that best suit your needs.

Bourns reliability is available at ordinary prices . . . off-the-shelf from nearly 100 local distributor inventories . . . plus our largest-ever factory stock. TRIMMER PRODUCTS, **TRIMPOT PRODUCTS DIVISION,** BOURNS, INC., 1200 Columbia Avenue, Riverside, California 92507. Telephone 714 781-5320 — TWX 910 332-1252.

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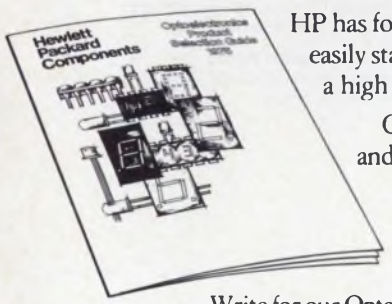
CIRCLE NUMBER 243

SURPRISE!

HP's New Stackable Subminiature Lamps



HP has four new LED lamps in radial lead subminiature epoxy packages. And they can be easily stacked on 2.21mm (0.087") centers for high density applications. These lamps offer a high on/off contrast ratio combined with a wide viewing angle.

Choose the HP 5082-4100 for the red, -4150 for the yellow, -4190 for the green and -4160 for our new high-efficiency red.

Contact Hall-Mark, Schweber, Wilshire or the Wyle Distribution Group (Liberty/Elmar) for immediate delivery.

Write for our Optoelectronics product selection guide and get all the details on HP's broad line of LED lamps.

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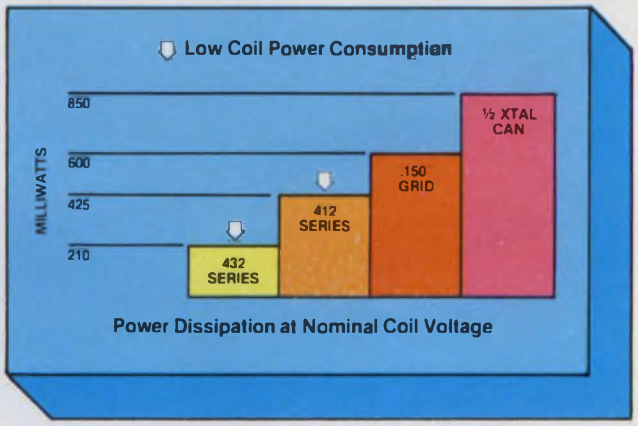
CIRCLE NUMBER 2

TO-5 RELAY UPDATE:

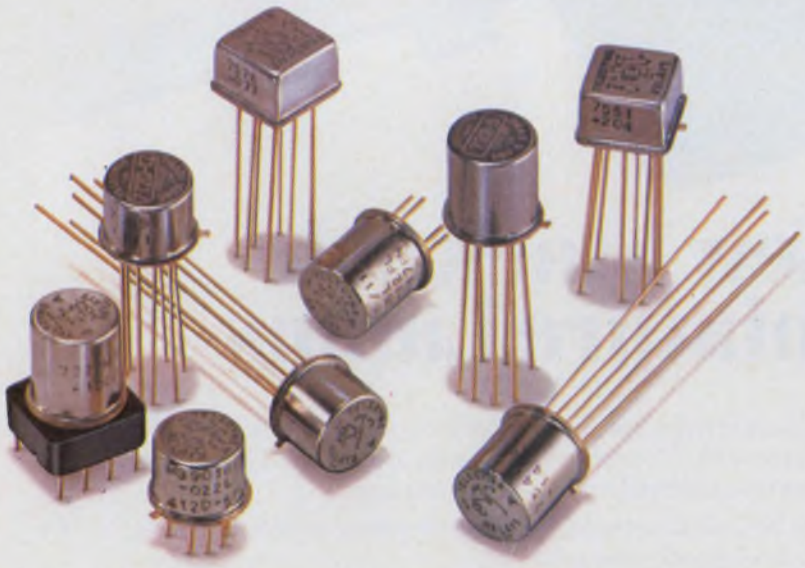
Solve your energy crisis with TO-5 relays



Subminiaturization and pc board compatibility — two obvious advantages of Teledyne TO-5 relays. But there's another outstanding advantage: low coil power consumption. This feature is best illustrated in the above graph which shows our TO-5 relay power savings compared to other miniature relays. The Teledyne 412 Series dissipates about 30% less power than the .150" grid relay, and 50% less than the ½ crystal can. Our sensitive 432 Series is 65% less than the .150" grid. And 75% less than the ½ crystal can.

This means you can save over 6 watts in a typical system using, let's say, ten TO-5 relays. In the end, you gain significant advantages in terms of thermal and power supply considerations that can help prevent an "energy crisis" in your system.

Our complete line of TO-5 relays includes military and commercial/industrial types, with virtually all military versions qualified to established reliability MIL specs. For complete data, contact Teledyne Relays — the people who pioneered the TO-5 relay.



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- **Maglatch Series**
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- **High Environment Series**
  Hi-temperature, Hi-shock, and Hi-vibration types

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Telephone (213) 973-4545

CIRCLE NUMBER 3

VOL. 24 NO.
Electronic Design 9
FOR ENGINEERS AND ENGINEERING MANAGERS
APRIL 26, 1976

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Cover: Photo by Harry Meier, courtesy of Precision Monolithics, Inc.

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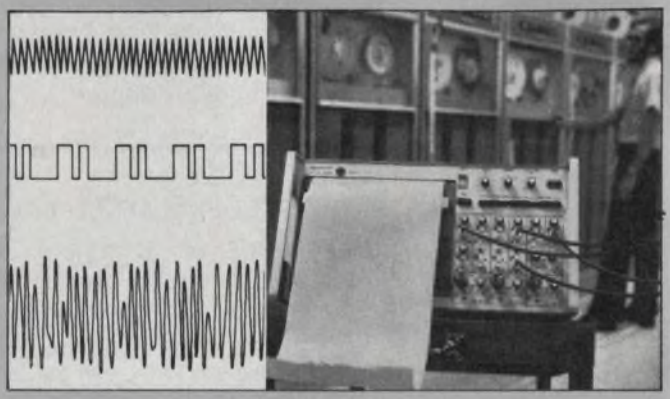
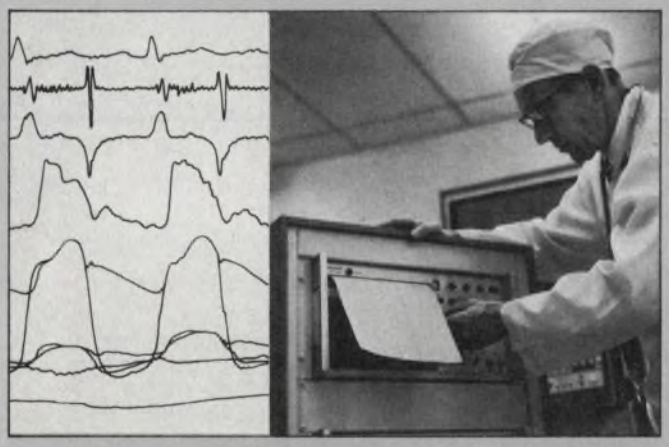
How to get the most record...for just about any

With its matchless combination of capability, portability, versatility, ease of operation and easy-to-read records, the Honeywell 1858 truly has to be the perfect go-anywhere data acquisition system . . . for just about any application. For example, in . . .



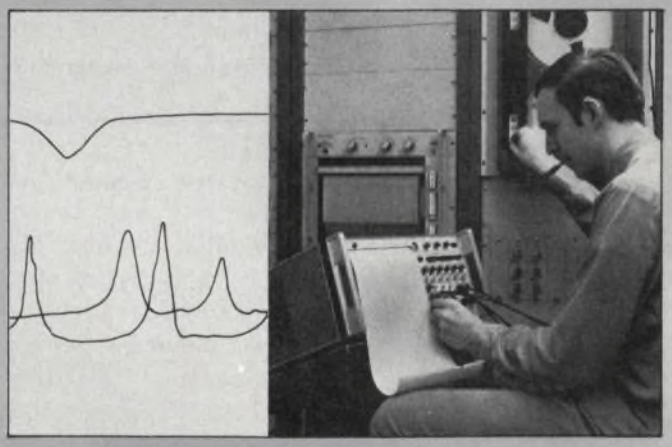
Computer and Data Communications Trouble-shooting.

By recording the transmitted and received data, bit by bit, in detailed analog form, the causes of those difficult-to-solve communications problems — equipment or programming related — can be readily identified.



Biomedical Research.

In cardiovascular diagnostics, the Model 1858 provides simultaneous multichannel recordings for valuable diagnostic information.



Research and Development.

More and more laboratories are discovering the Honeywell Visicorder is an unusually versatile instrument capable of delivering the most meaningful and accurate record available.

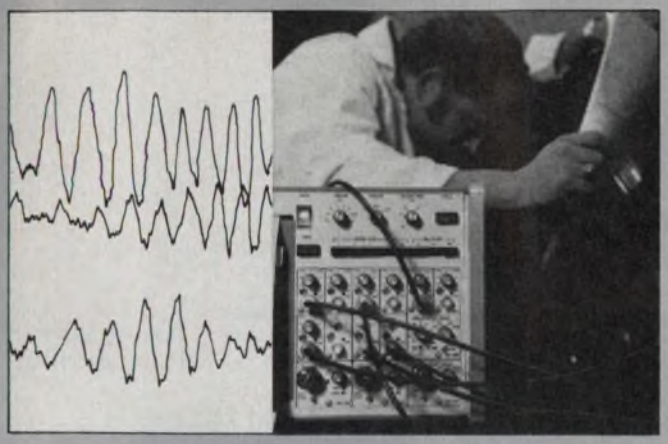
And when you choose the Honeywell Model 1858 data acquisition system, you don't just get 42 discrete paper speeds, from 0.1 to 120 inch/sec.

You also get precision time lines, accurate ± 0.1% across record width each 0.001, 0.01, 0.1, 1.0 or 10 seconds, each tenth line accentuated and selected interval coded . . . for remarkably readable and accurate recordings.

If you're concerned about size, here's another good reason to specify the Model 1858: It's an unbelievably short 8¾ inches high, including plug-in signal conditioning and internal paper take-up. The 65-pound-light 1858 is easy to take anywhere; it can be used in a rack, on a table, on the seat of a car or plane.

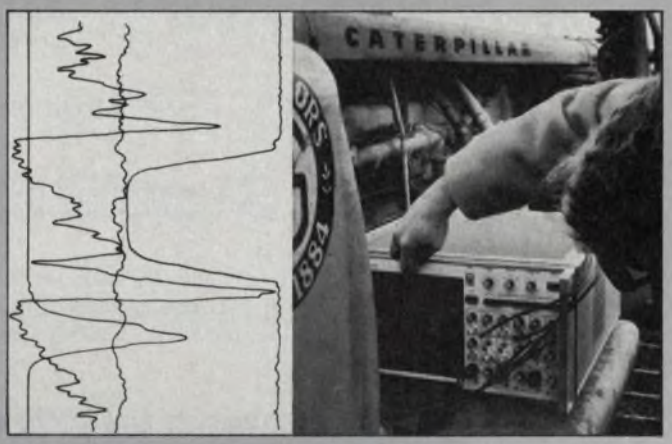
You'll also appreciate the total convenience offered by our 1858, with up to 18 channels (expandable to 32), each with dc to 5,000 Hz response (15 kHz squarewaves) and without amplitude restrictions for superior recording capability. What's more, the 1858 also allows you to get up to 7-inch trace amplitude for all channels, allowing for common baseline recording . . . the most useful and accurate record available.

meaningful and accurate application...anywhere.



Automotive Vibration Testing.

In this instance, recording yaw and rotational movement of an eight-cylinder engine on its flexible mounts about a vertical axis through the center of gravity.

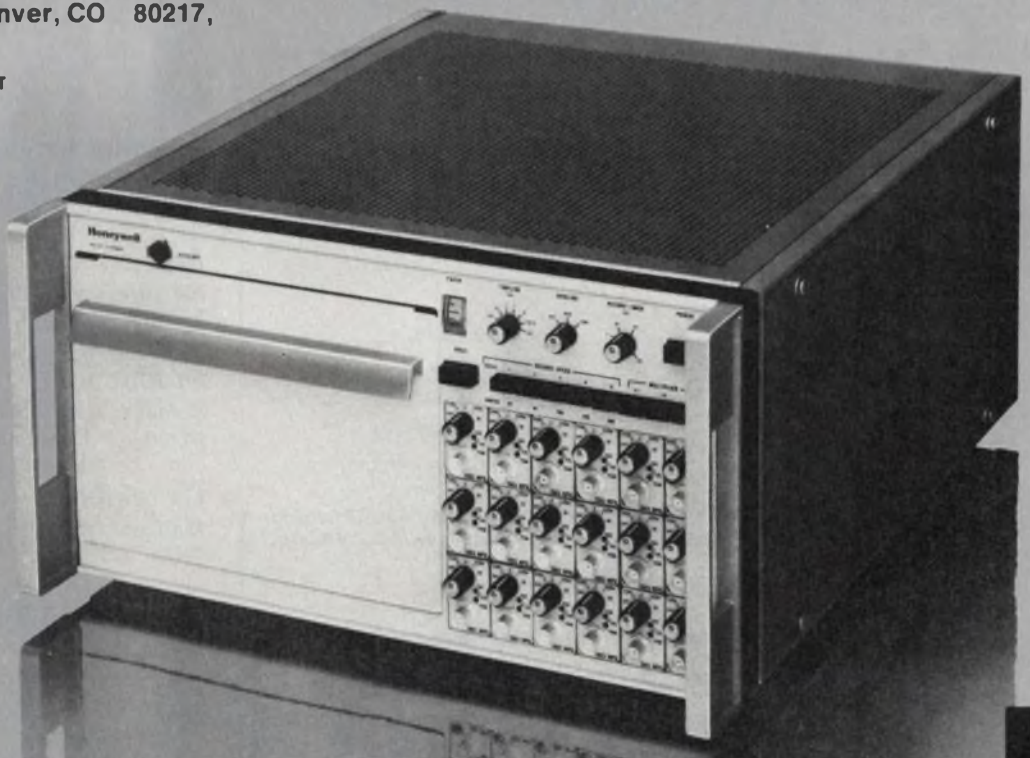


Diesel Engine Testing.

Visicorder records pressure variations in the exhaust manifold, cylinder, and intake manifold. These "heart beats" were taken through a series of complete combustion cycles.

For complete technical specifications, call or write Lloyd Moyer, Honeywell Test Instruments Division, P.O. Box 5227, Denver, CO 80217, (303) 771-4700.

FOR LITERATURE REQUEST CIRCLE #298



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Across the Desk

Agc time constant not related to amplitude

I would like to submit the following footnote to Dennis R. Morgan's article "Agc Extends the Range of A/d Converters" (ED No. 22, Oct. 25, 1975, p. 108).

A logarithmic gain-control function is required to obtain a time constant independent of input level. This feature is obtained in Morgan's system by a geometric attenuation sequence where the time constant is a function of the output level.

This relationship *(D. Rorbacher memorandum available)* shows that for small variations in input (see figure), the system's transfer function is

$$\frac{E_o^1(s)}{A^1(s)} = \frac{E_r}{K\bar{a}}\left[\frac{S}{S + \frac{E_r\,\alpha}{\tau}}\right],$$

where

$E_o^1(s)$ is the transform of the variation of the output envelope around the average value,

$A^1(s)$ is the transform of the variation of the input envelope around the average value,

E_r is the reference voltage,

K is the rectifier gain,

$\bar{a}$ is the steady-state (average) input-envelope amplitude,

S is the complex frequency operator,

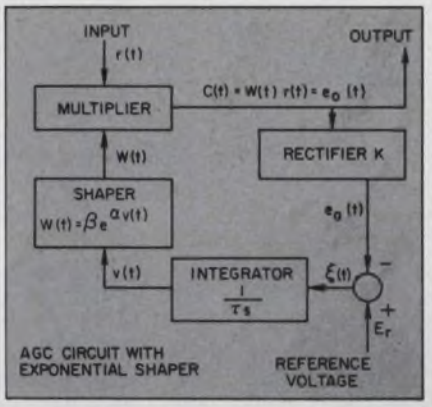
α is the shaper-input gain,

τ is the integrator time constant.

The time constant, extracted from the denominator, is

$$T_o = \frac{\tau}{\alpha\,E_r}.$$

Another article in the same issue "Use Auto Ranging Amplifiers" by Erik Ljung (p. 114) is a novel approach to agc. It might be helpful to other readers to point out that the a/d output must be multiplied by the gain to restore the intelligence and dynamic range. This may have been implicit in the article, but it took me awhile to figure out how the system was useful.



Russell Kincaid
Member of the Technical Staff
Sanders Associates Inc.
95 Canal St.
Nashua, NH 03060

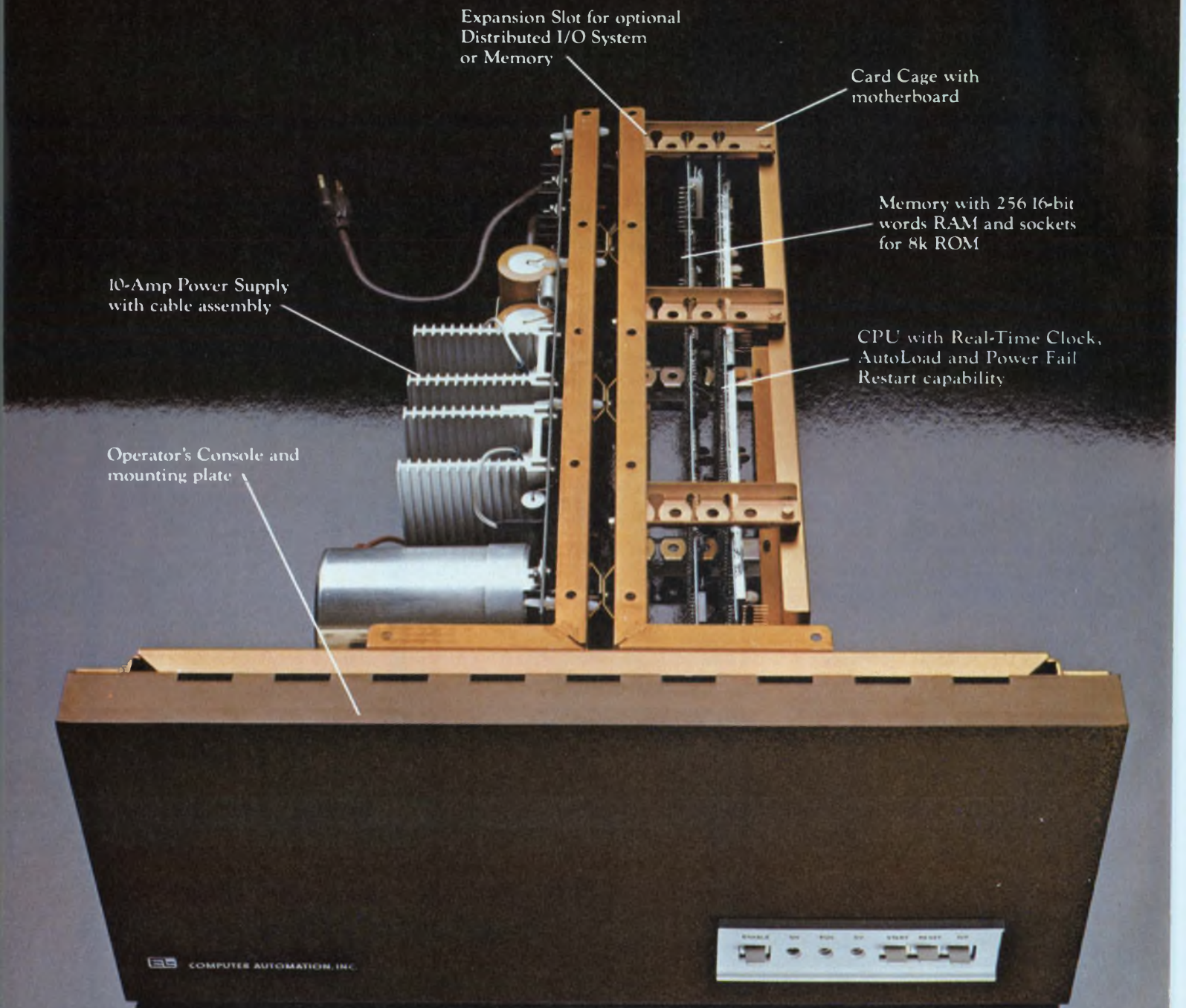
Editorial called in very bad taste

I have been a reader of your magazine for a great many years and, so far, I have liked the contents of it very much. But being of Russian descent, I strongly resent your last editorial, "The Czar's Consultant," (ED No. 1, Jan. 5, 1976, p. 75). It is indeed of very poor (if not worse) taste to refer to our last Monarch and his family in such a derogatory manner, es-

(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.

When you can buy all this for a total of $701*



The ALPHA® LSI-3/05 Millicomputer.
The lowest priced, 16-bit, full-scale, packaged computer in the world.

...building your own just doesn't add up.

Sum and substance. An unbeatable combination even for our competition, so you needn't feel too badly.

Especially when you consider everything we've got going for us.

Specialization, of course. OEM computers—*low-cost* OEM computers—are our only business. The NAKED MINI® people, remember? And when you do only one thing, you do it better.

Experience, too. Over 10,000 up-and-running, field-proven computers successfully integrated into all kinds of sophisticated OEM products.

Also, some things Henry Ford would have appreciated. Buying in volumes most OEM's can't manage. Building the same way.

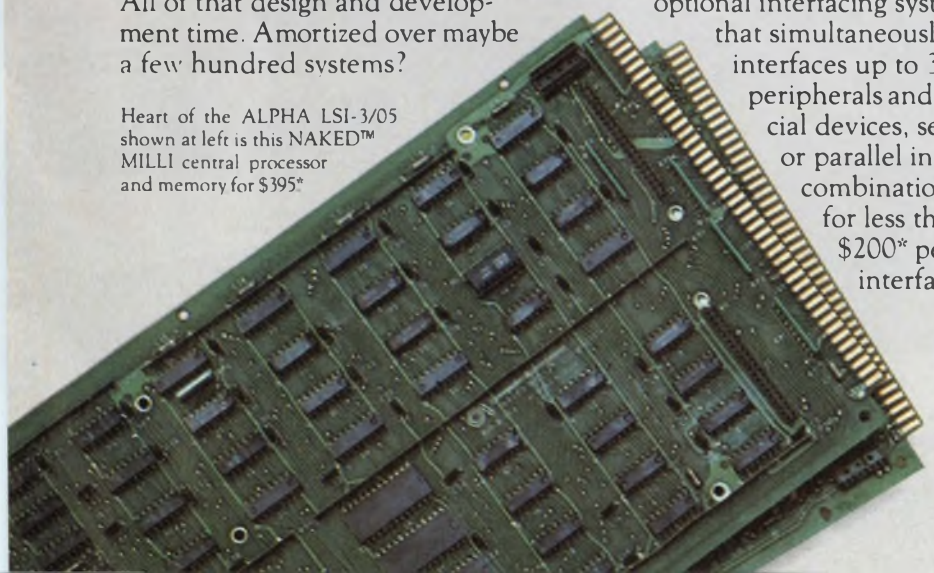
Where all that gets you is on the down-hill side of the learning curve...where we get our pay-off and you get the lowest-priced, most reliable computers around.

That explains why we can, but not necessarily why you can't. Here's the rest of the rationale:

The chip shot: a hit or a myth?

The fallacy of the microprocessor is that a chip set isn't a computer. Even if you got your chip sets *free* you still couldn't build a computer equivalent to our ALPHA LSI-3/05 for $701.

Price out the subassemblies shown in the picture and see what we mean. CPU, memory, card cage, power supply and console. All of that design and development time. Amortized over maybe a few hundred systems?



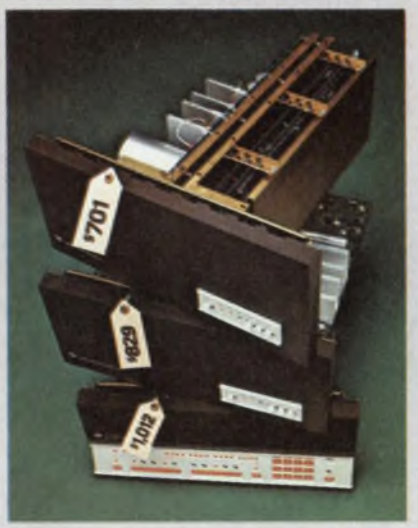
Heart of the ALPHA LSI-3/05 shown at left is this NAKED™ MILLI central processor and memory for $395*

ComputerAutomation will build thousands of ALPHA LSI-3/05 systems.

Then there's the packaging and fabrication. Cable assemblies, too.

Just think about the procurement activity alone. The lead time.

Getting our picture?



The ALPHA LSI-3/05 is offered in three series featuring a choice of card cages, consoles, memories and power supplies

Computers vs. computerization

How do you talk to a computer?

Mostly with money, it turns out. Interface money. And mostly a lot of it.

Interfacing a computer to one or two peripheral devices can easily cost as much or more than the computer itself.

Which is why we invented the Distributed I/O System. An optional interfacing system that simultaneously interfaces up to 32 peripherals and special devices, serial or parallel in any combination, for less than $200* per interface.

What you see is not exactly what you get

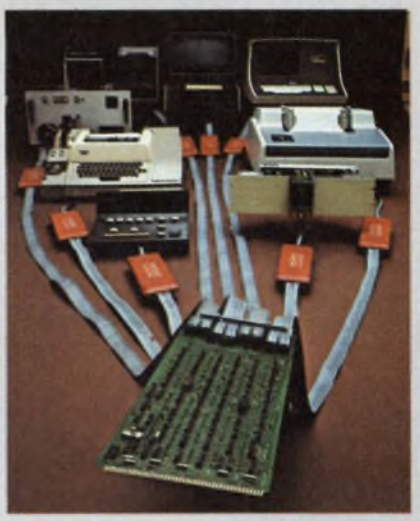
Here's what else you get when you buy an ALPHA LSI-3/05 millicomputer:

- ☐ 95 powerful instructions
- ☐ Individually vectored interrupts
- ☐ Direct Memory Access
- ☐ Memory expansion to 32K
- ☐ Maxi-Bus interchangeability for easy upward expansion to our full line of compatible minicomputers

Plus full-fledged minicomputer software.

From the people who brought you the NAKED MINI

The people with the largest line of compatible computers in the world.



Maxi-Bus compatible ALPHA LSI-3/05 achieves unprecedented cost-effectiveness with ComputerAutomation's new Distributed I/O System

The people with the lowest-priced computers in the world.

The people with the first and only Distributed I/O System in the world.

The people who've been simplifying OEM build versus buy decisions for years.

ComputerAutomation
NAKED MINI Division

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(714) 833-8830
EUROPE Hertford House, Denham Way, Maple Cross, Rickmansworth WD3 2XD, Hertfordshire, England; Telephone: Rickmansworth 71211

*All prices shown are for lots of 100 (U.S.A. only)
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FOR FURTHER INFORMATON CIRCLE #251
FOR SALESMAN CALL CIRCLE #252

Introducing the new AMP Zero Insertion Force pc connector. We call it failsafe for good reason.

Because it eliminates all the force you once needed to install printed circuit boards. No force, no failure. It's that easy.

Not only that. A unique side-entry capability lets you use all sides of the board for edge-type I/O connections, which opens new design latitudes.

This AMP innovation does it all with a simple camming mechanism that opens the contacts for push-free printed circuit board insertion.

And allows them to return to their failsafe operating position just as gently.

As much as 110 lbs. of push can be eliminated when you're installing a dual, 110-pin-count daughter card.

Now it's possible to use larger printed circuit boards without this risk of installation damage.

The design versatility of the ZIF connector is best demonstrated in terms of your specific need. Your AMP sales engineer is trained to help with your problems and work out the best ZIF solutions. With both of you keeping watch on the mechanics—and economics—it's hard to go wrong.

To find out how ZIF connectors can take the force out of high pin-count applications, call Customer Service at (717) 564-0100. Or write AMP Incorporated, Harrisburg, PA 17105. It might take some pressure off you, too.

SEE US AT NEPCON, TORONTO

CIRCLE NUMBER 8

AMP
INCORPORATED

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(continued from page 7)

pecially in view of his, and all his family's, tragic death. (They were shot without any semblance of a fair trial—and for what crimes?—by Bolsheviks.)

Your lack of any sound knowledge of the facts about which you have the impertinence to write, shows itself in every line and word of this "editorial." So, stick to engineering in your editorials, and don't try to be an authority in matters of which you know nothing.

George Chory
Chief Engineer

P.S. Do not try to imitate the jokes of Bob Hope. A few years ago he made some kind of idiotic wisecrack about the same subject.

Standard Center for Research and Development in Teaching
Stanford University
Palo Alto, CA 94305.

Misplaced Caption Dept.

". . . and she can bond 100 chips an hour."

Sorry. That's Pierre-Auguste Renoir's "Dancing at the Moulin de la Galette," which hangs in The Louvre, Paris.

To err is human

We goofed. Left out of the list of manufacturers of passive microwave components at the end of the FOCUS report in the Jan. 19, 1976 issue was Texscan Corp. For information on Texscan devices contact R. J. Shevlot at 2446 N. Shadeland Ave., Indianapolis, IN 46219. (317) 357-7881. Or **CIRCLE NO. 315** on the Reader Service Card.

Also left out was Telonic Altair, 2825 Laguna Canyon Rd., Laguna Beach, CA 92652. (714) 494-9401. Contact R. J. Aaron. Or **CIRCLE NO. 316**

Irreverent notes

I have some irreverent observations concerning the English Language as used by the dynamic-semiconductor industry.

1. "Die." Did you ever hear a farmer say "This land will yield at least 4000 tomato," or a carpenter say "To install this panel, I will need about 300 nail?" Yet we hear, every day, statements like "This wafer will yield about 5000 die." For shame, semiconductor people.

2. "T-squared-L." Did you ever realize that the effort required to say "T-squared-L" equals the effort required to say "Tee-Tee-L²?" It's obvious that one says "T-squared-L" to be hip: one is saying, in effect: "I went to engineering school. I learned TT is T². I don't care what effort it takes to say it: saying it makes me a member of an inside group."

An aside: "I-squared-L" makes a little more sense—it *is* easier to says, and "IIL" sounds ugly. OK—enough irreverence. Please excuse me, semiconductor people.

William J. Travis
Sprague Electric Co.
Nashua, NH 03060

A helpful editorial

On your editorial, "The Misunderstanding" (ED No. 3, Feb. 2, 1976, p. 51). Thanks—it helped. It is worthwhile to note that getting one's comprehension of the true facts up to spec is at least as significant as getting one's design into tolerance. The former sets the limits for the latter.

Dick Bowser
Custom Electronics, Inc.
4448 S. 84th St.
Omaha, NE 68127

What's oeno name?

As a tribute to the fact that Hewlett-Packard's new Santa Rosa division is at the gateway to the Sonoma Valley wine country, the engineers there have fittingly named some of their work rooms. They have the Pinot Room, the Zinfandel Room, the Chablis Room and the Chardonnay Room. Another location is called the Aging Room.

Just because our new Dumb Terminal (the ADM-3) is making a big splash doesn't mean we lack smarts. Take the tried-and-true ADM-2, for example. Thousands of these smart video terminals are out in the field. Working and working well.

The ADM-2 gives users and OEMs all the smart features they're looking for. Standard features, mind you, not options. Features like full editing facilities and 16 function keys (instead of the usual 8). Detachable keyboard. Both upper and lower case. 24 lines and 1920 characters on a 12" diagonal screen. Special numeric key pad. Protected data. Dual intensity. Up to 8 screen status indicators. Eight selectable data rates from 110 to 9600 baud. 4 transmission keys.

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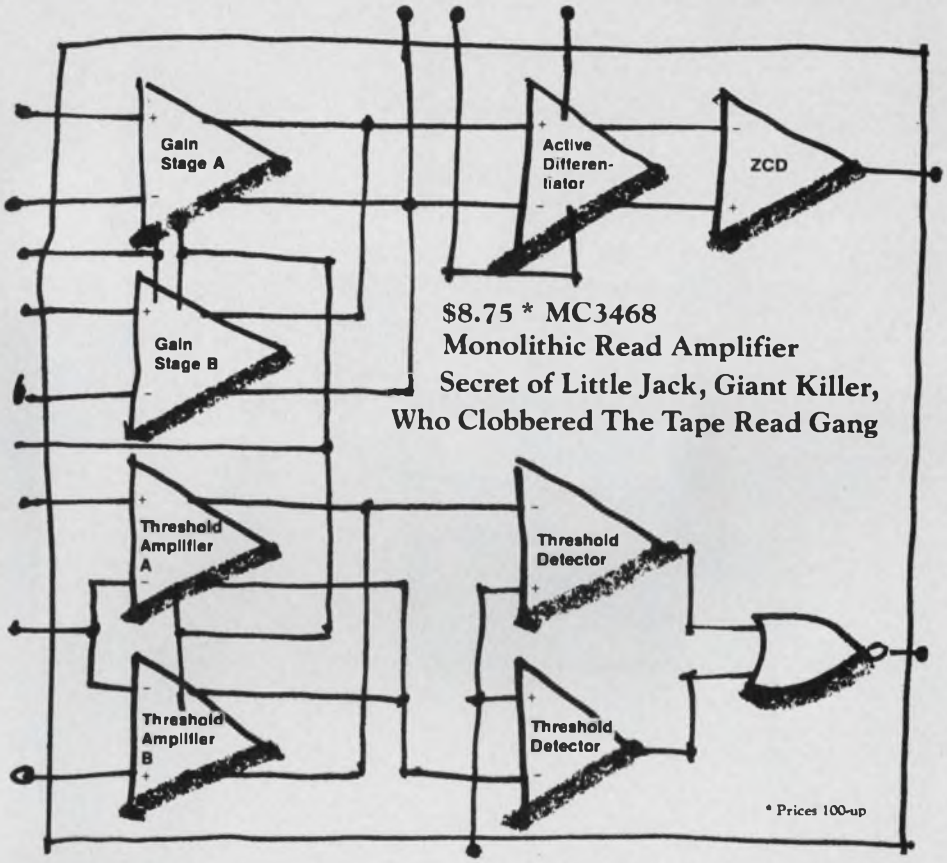
SMART TERMINAL.
SMART BUY.

CIRCLE NUMBER 10

Jack, The Giant Killer



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Monolithic Read Amplifier
Secret of Little Jack, Giant Killer,
Who Clobbered The Tape Read Gang

In Peripheraland, there lived 5 terrible giants. The Tape Read Chain Gang some called them.

Anyone traveling through their forest with a bit of this or that wandered torturous paths. For it was vastly overgrown with componentry which boggled the mind and scratched the head. And the giants exacted much tribute from the unwary.

Many champions from the Valley had battled them. They always lost.

One day Jack arrived.

I am the giant killer, here to free you from the primitive bondage of the ogres for under 9 bucks, list.

You are small, cheap, and have a monolithic look, laughed the people. You will never function effectively in that tangled maze.

We'll see about that, said Jack. I have a secret. And he set off.

From behind a great clump of ICs sprang Input Multiplex, the first terrible giant.

Your NRZI or your life! he roared.

Let me go and I'll tell you a secret, said Jack.

Tell it at once, growled the giant.

Well, I not only handle phase, group and NRZI coding from 9-track but cartridges and cassettes as well, cried Jack, dancing about. And I can digitally select between two of these formats!

O, no! cried the giant and ran crashing off through the wood.

Soon Gaynstage, the second giant, confronted him.

Halt, he frothed.

Control yourself and I'll tell you my secret, said Jack.

Do so, grunted Gaynstage.

My EGC (Electronic Gain Controlled) amplifier provides differential outputs for the active differentiator and a single output is available for threshold function.

AAAGH! screamed the giant. How awful! and fell backward into a wayside pool and drowned.

The third giant, Threshold Amplifier/Detector, leaped from the undergrowth. He shook Jack till his teeth rattled and he could hardly explain his secret.

Tell it! the giant bellowed.

My threshold amp gives an output signal whenever it exceeds the setting in pos or neg direction, replied Jack.

The bully turned red and choked on his own phase jitter.

Much the same happened with the fourth and fifth giants, Active differentiation and ZCD. Jack revealed his ensured linearity, optimum zero-crossing detection for excellent noise rejection and strict avoidance of timing distortion.

He laughed at the giants' horrorstruck faces as they took off.

When he returned the elated people cut down the forest and made him king, as he deserved.

Now it's no secret with a little jack you can go out and kill some giants of your own.

But you already concluded that.

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CIRCLE NUMBER 11

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CIRCLE NUMBER 12

News Scope

APRIL 26, 1976

GM develops A/D circuit for auto applications

A simple, rugged integrated circuit that can convert analog-sensor parameters into a pulse-duration-modulated signal has been developed by General Motors. The IC can be applied directly to microprocessors or standard automobile gauges for control or diagnosis of automotive systems.

Advantages of the analog-to-digital interface circuit include good accuracy, low cost and high reliability, according to researchers who developed the circuit at the General Motors Research Laboratories in Warren, MI.

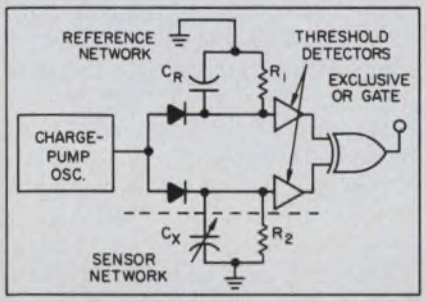
Two prototype applications are reported by GM circuit inventors, Paul Rabe, Eugene Greenfield and John Hile. One use is in a throttle-position indicator system in which a standard air-tuning capacitor is the sensor. Capacity varies from 5.4 pF for a fully closed throttle to 19.8 pF for a wide-open position.

The second application is in a solid-state fuel gauge in which a capacitor is formed by two concentric tubes immersed in the fuel. The dielectric constant of gasoline is approximately twice that of air, so a capacitance change proportional to the increasing or decreasing level of fuel is sensed. Working capacity varies from 60 to 130 pF.

Capacitors were chosen as sensors for these applications because they can be designed without rubbing contacts and because they can be shaped to compensate for nonlinearities in measured quantities.

The GM circuit converts sensor outputs into digital pulses that have a duration in proportion to the size of the quantity—position, displacement, pressure or fluid level—being monitored.

The circuit works by rapidly charging two RC (or L/R) networks, one of which is a reference, the other of which contains the variable-capacitor sensor.



At the "zero" setting of the capacitor sensor, the RC constants and discharge times of both networks are equal, and no output appears. At the maximum sensor capacity the difference in the discharge times, and in the output-pulse width, are a maximum.

The GM circuit, initially implemented using standard CMOS packages, was converted to a 1 × 1-mm IC chip. The basic circuit is composed of the elements shown in the figure.

These include a charge-pump oscillator that charges the capacitors in less than 1 ms, typically. Oscillator frequency can range from 500 Hz to 1 MHz, says Paul Rabe, but 100 kHz and 1 kHz were chosen for the throttle sensor and fuel gauge, respectively.

The circuit has been designed so that 10% of the operating cycle is used for charging the capacitors, and 90% for the discharge period, Rabe says.

The capacitors discharge through R and R. At a design threshold level, the threshold detectors are switched on, producing outputs.

To measure the time difference between the threshold detector outputs they are fed to an exclusive-OR gate. When the voltage across both capacitors is identical (such as during the charging cycle), or when the RCs of both networks are the same, the gate has no output.

Any of the fixed elements in the RC networks can be used to compensate for temperature variations or other factors influencing the input variable.

Several General Motors Divisions are now evaluating this circuit for use in low-cost monitoring-and-control systems.

Switched digital-data network is dual mode

Both packet switching and circuit switching are used in a new automatically-switched digital-data network being installed by the State of California. The network, designed by Computer Transmission Corp., El Segundo, CA, is scheduled for operation around mid-year.

Initial users of the network will be the California Dept. of Transportation and 19 widely dispersed campuses of the California State Universities.

The network handles synchronous data in a circuit-switching manner and asynchronous data in a packet-manner, says Jerry Berning of Computer Transmission. Maximum data rate on the network is 230-k b/s and packets are created at 10.256 packets/s.

Other packet-switching networks take data from individual or multiple terminals and group it together at a node for block transmission to the next node. These systems temporarily buffer the data at each node while they perform error checking and response functions.

In contrast, Computer Transmission's system only makes packets out of data traveling between common-source and destination nodes, so there is no need to error-check or buffer data at each intermediate node in the network. This minimizes end-to-end delays and reduces buffer storage requirements at each node, Berning says.

Microprocessors are used, both for circuit switching and for the construction and destruction of packets at the nodes.

Full duplex communications can be carried on the network over either common-carrier or dedicated private lines.

Four μP-controlled switching nodes control the entire network. A fifth switch is designated for network-management; it performs network diagnostics, programs the

addition of terminals and computer resources; and collects and stores network-station information and customer-billing data.

Every call will be logged, and on the magnetic tape will be written data covering the amount of time for each connection, data identifying the caller or terminal user, and the user's destination.

Color LEDs gain in brightness, reliability

Rapid progress is being made in raising the luminous output of primary material used for multicolor LEDs, a nitrogen-doped proprietary product of Monsanto. Luminous efficiency has increased 50% in the last year, and the reliability of devices made from the material has more than doubled in the same period.

So reports Dr. D. L. Keune, manager of device and materials research for the Monsanto Electronics Division, St. Louis, MO.

Although the material was originally invented in 1970 by Monsanto, these compounds have received intensive development only within the last three years.

The dominant red LED material that has been used in wristwatches and calculators for several years has been gallium-arsenide-phosphide grown on gallium arsenide. This is represented as $GaAs_{0.6}P_{0.4}$/GaAs, which means a compound that is 60% arsenic and 40% phosphorus.

Colors other than red have been produced by adding the nitrogen. For example, orange radiation is obtained from $GaAs_{0.35}P_{0.65}$:N/GaP. Yellow light is produced by $GaAs_{0.14}P_{0.86}$:N/GaP. Green light is radiated from gallium phosphide doped with nitrogen and grown on a gallium-phosphide substrate (GaP:N/GaP).

The significant improvement in performance and reliability of the nitrogen-doped compounds has evolved from new or improved growth technology, Keune says.

Strap-down navigator is accurate and low in cost

A low-cost inertial navigator with electrostatic gyros to allow high accuracy and reliability is being developed by the Autonetics Div. of Rockwell International, Anaheim, CA. Called the Micron, it will cost under $50,000 including full I/O and display-driving electronics. Accuracy will be better than 1 nautical mile per hour and ±4 min. of arc.

The system employs miniature electrostatic gyros that are strapped down. The gyros are about 7.6 cc in volume and weigh 1/2 lb each. The entire navigator is only 7.5 × 7.6 × 15.2 in. Although gimbaled navigators with the same accuracy have been built in the same sized box, they cost more than $50,000.

Included in the Micron's electronics are a custom-LSI, 16-bit MOS computer with 4 k of NMOS RAM, 12 k of bipolar ROM and a hybrid package containing all of the inertial electronics.

Two models of the navigator have been built so far, according to Jerry Schwarz, program manager for the Micron. Feasibility has already been proven and a final prototype will be delivered in February, 1977 to the Air Force at Wright-Patterson AFB.

Schwarz says that Autonetics is designing a more accurate version of the Micron as well.

"It will have an accuracy of 0.1 knots/h instead of 1.0 knots/h and an MTBF of 1216 hr instead of the current 1250 hr." The advanced version will not be a strap-down unit. It will have a cluster of two electrostatically suspended gyros and three electromagnetic accelerometers. The cluster will constantly be rotated 180° clockwise and then 180° counterclockwise about the azimuth.

This back-and-forth rotation, says Schwarz, averages out certain case-related drift errors that are present in all gyroscopes.

"Laboratory tests have proven the feasibility of the new concept."

Nontracking solar concentrator developed

A nontracking device developed for concentrating sunlight may find wide use in solar energy conversion systems. The trough-shaped reflector, which can concentrate sunlight by a factor of 10, was demonstrated recently by its inventor, Dr. Roland Winston, a University of Chicago physics professor.

One use for the new reflector is in a solar-cell electric storage pack manufactured by M-7 International Inc., Arlington Heights, IL.

The pack consists of an array of solar cells and four rechargeable nickel-cadmium storage batteries, and is designed to power portable radios or any other low-voltage small appliance.

Sunlight concentrators play an important role in solar-energy conversion. For example, in the process of producing electricity directly from sunlight, concentrators can reduce the amount of solar cells required for an equivalent area of coverage.

In the case of thermal conversion—where the sunlight raises the temperature of a circulating fluid—concentrating the sunlight produces higher temperatures and increased conversion efficiency.

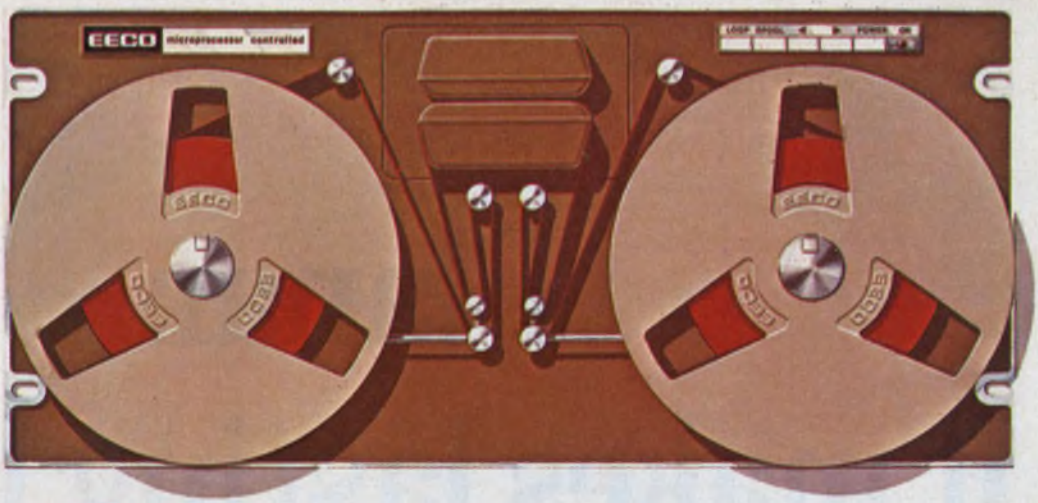
Winston's concentrator removes a major handicap reflecting devices have. Present-day reflectors must be carefully aimed at the sun, and since the sun's angle of elevation varies during the course of a day, mechanical tracking must be provided.

The new fixed concentrator is capable of focusing sunlight that is incident over a wide spread of elevation angles, the exact angular aperture being a design option. It does this through its unique shape —a compounding of a number of differently shaped surfaces.

The device does have to be reaimed periodically to accommodate seasonal variations in the sun's angle, Winston says.

In the M-7 solar storage pack the concentrators take the form of solid plastic wedges contoured to Winston's specifications. Light enters the wedge over an angular spread of about 20°, and by means of total internal reflection is directed toward a solar cell at the bottom. This technique is reported to reduce cell area by about 83%.

The complete M-7 package, recently introduced on the market, is 3-1/4 $in.^2$ in area, produces 1/4 W of peak power, and costs $39.95. A unit of 3 × 5 $in.^2$, to be available late this summer, will sell for 25% less than the current model, a company spokesman says.



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CIRCLE NUMBER 14

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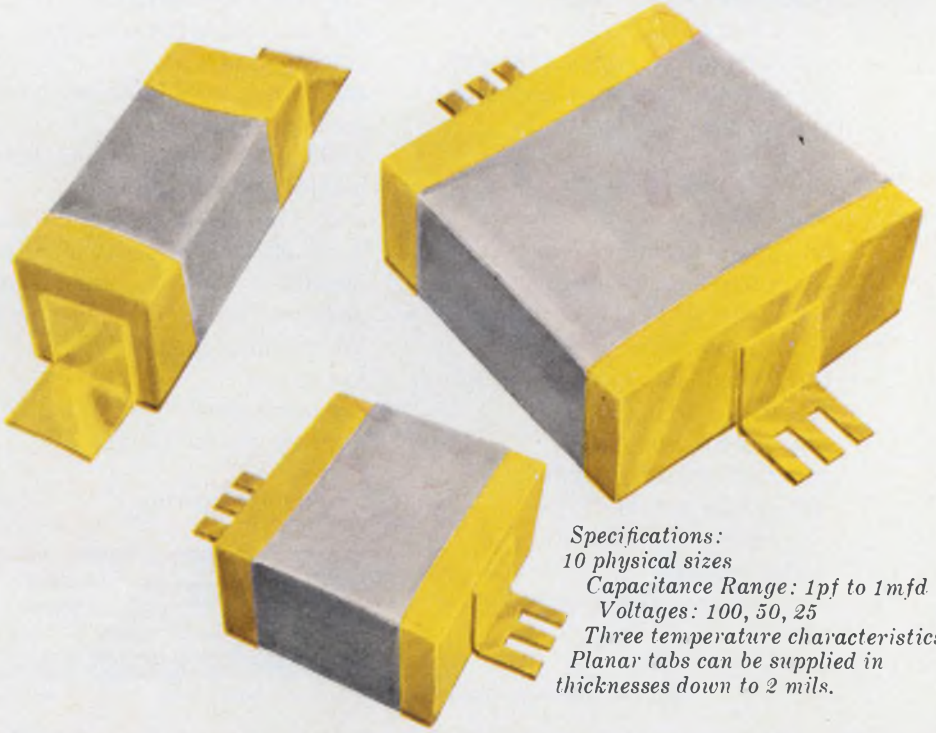

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Voltages: 100, 50, 25
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CIRCLE NUMBER 15

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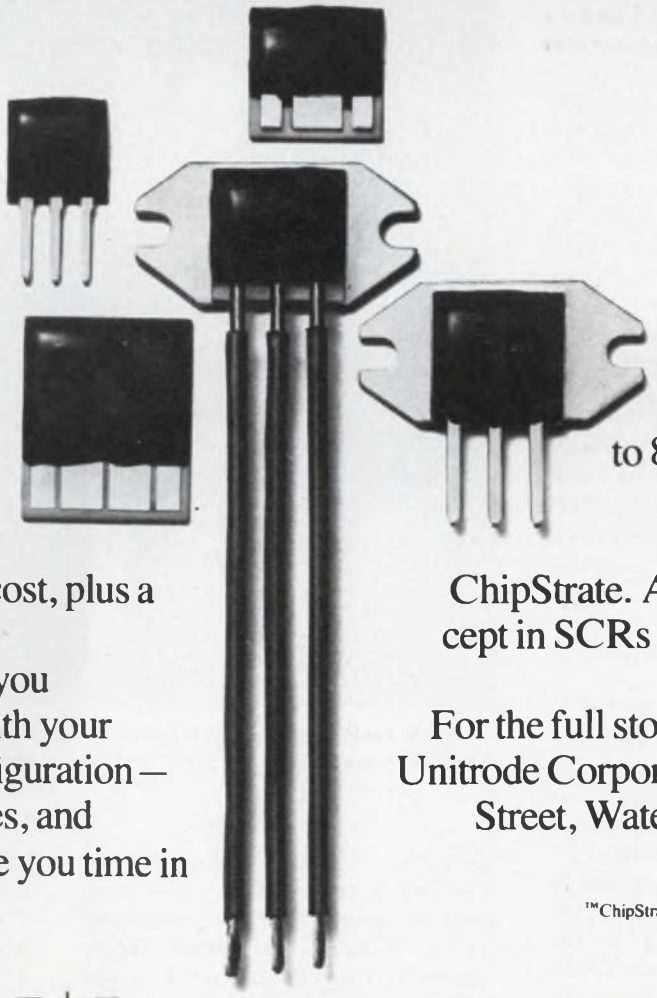
Now they also save you time.



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UNITRODE

CIRCLE NUMBER 16

An electronic linesman decides where the tennis ball bounces

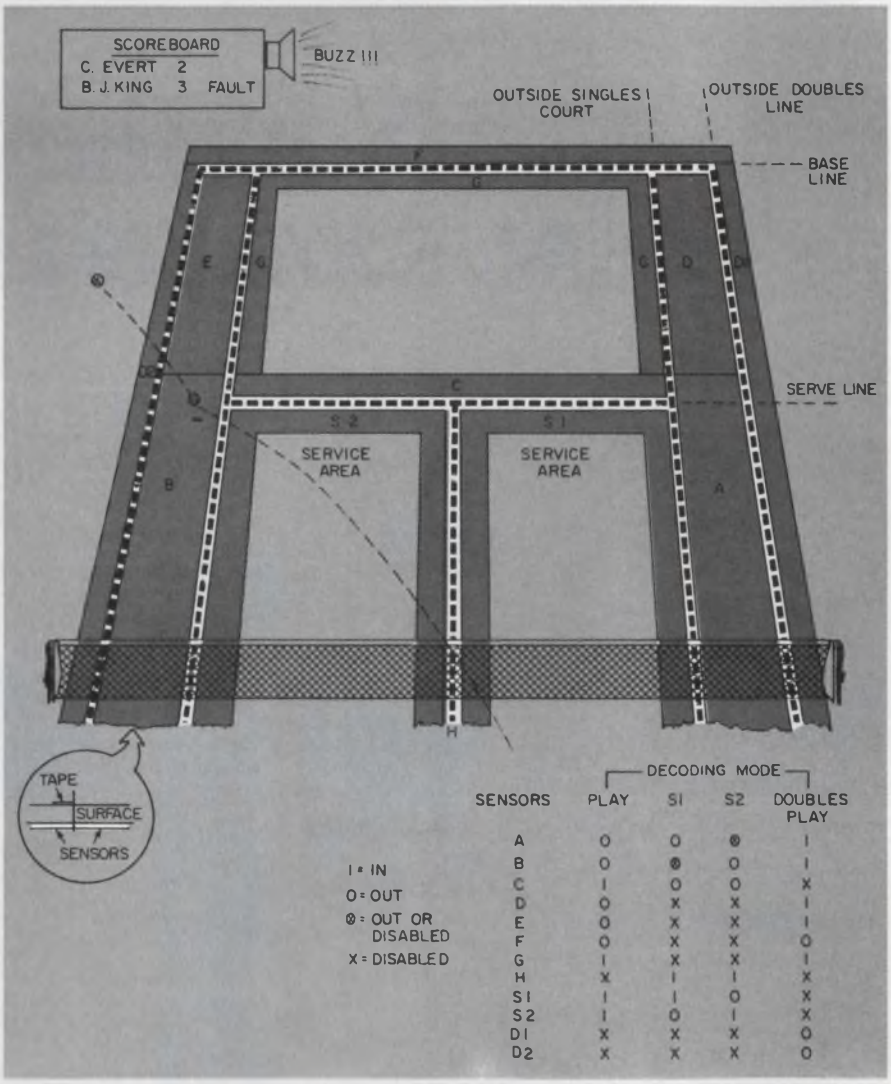
Billie Jean King's explosion of temperament during the 1975 L'Eggs World Series of Women's Tennis—which she lost—is now legend. A linesman's indecision over the first tie-breaking point in her game against Chris Evert gave Evert the lead.

Exasperation wasn't entirely out of place when you consider that the champion's self-confidence was threatened, as well as $50,000 in prize money; and the decision on where the ball had hit had to be based on the lineman's visual acuity.

A system was needed to determine, with more accuracy than the eye can muster, where a ball bounces. Sometimes, for example, a ball appears to be out, when actually it touches the line for a split second as it flattens out on impact with the court.

Now an electronic "line judge" has been developed that is expected to be far more accurate than any human linesman could ever be. The developers are Robert W. Nicks, an electronics specialist, and Geoff Grant, an enthusiastic tennis player. At Nicks-Grant Enterprises, Del Mar, CA, they have built one network consisting of plastic sensors buried in the court. Another system using magnetic sensors is still being developed.

The plastic system was tested in 1974 at the World Championship Tennis finals in Dallas and the Virginia Slims championships in Los Angeles. Parts of the system were used in the World Team Tennis Spectacular in 1975 and will be used there again next season. Before being officially used at the World Championship Tennis finals, the players agreed to accede to the electronic system's "rulings" on whether a ball was in or out. In general, Nicks says, they were relieved to have the human factor removed. Patents are pending for both plastic and magnetic systems.

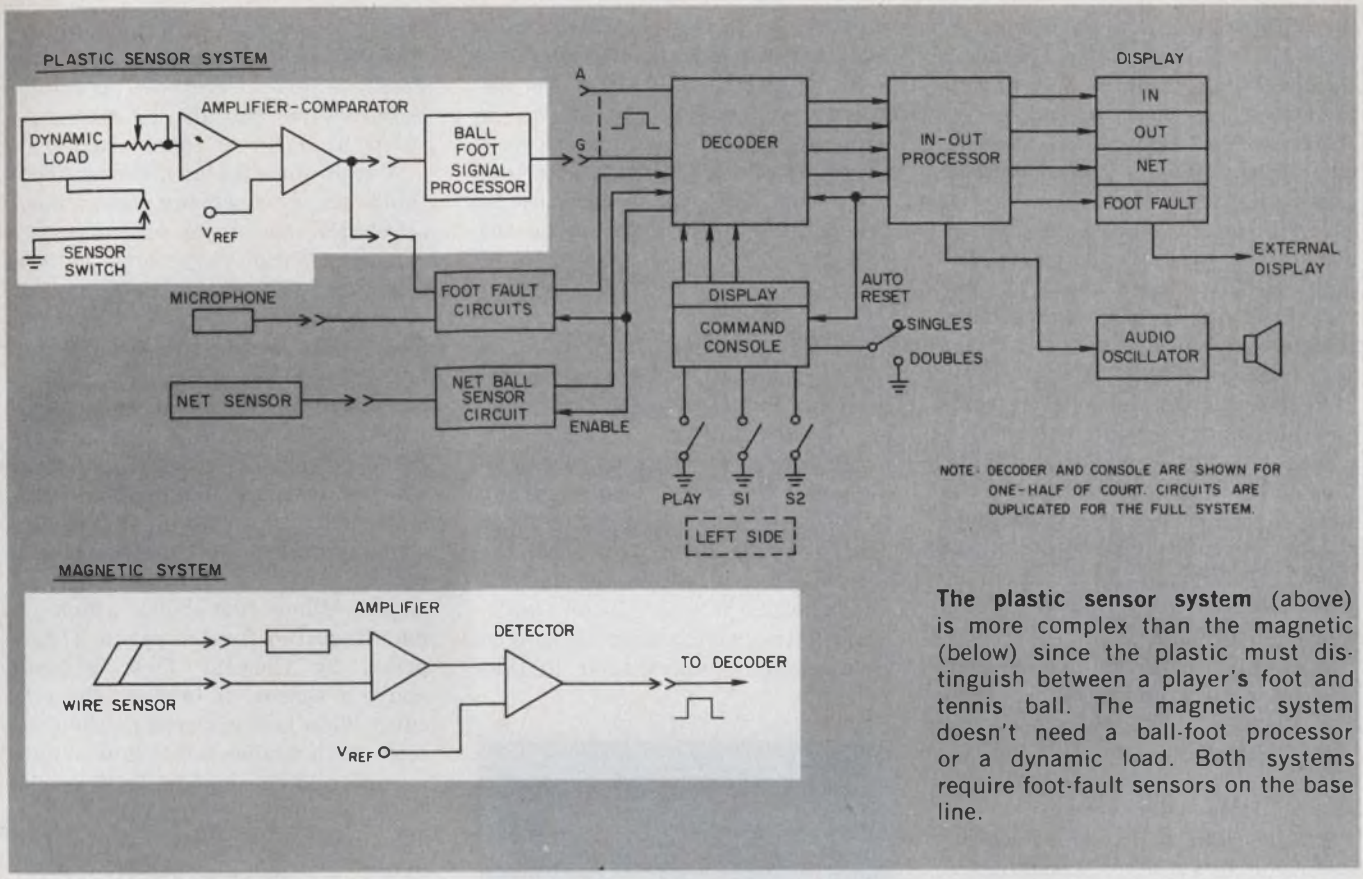


Variable resistance sensors made of conductive plastic sheets buried a half-in. below the court's surface tell whether a ball is "in" or "out."

An electronic linesman must solve five specific problems, Nicks says. It must:

- Detect foot faults—when the server steps over the base line before serving the ball;
- Detect a "let" ball—when a served ball touches the top of the net, yet continues a normal trajectory.
- Distinguish between a ball and a player's foot.
- Sense a ball even though a player is standing on the sensor.

John F. Mason
Associate Editor



The plastic sensor system (above) is more complex than the magnetic (below) since the plastic must distinguish between a player's foot and tennis ball. The magnetic system doesn't need a ball-foot processor or a dynamic load. Both systems require foot-fault sensors on the base line.

■ Display "out" balls correctly at every stage of the game.

(The "In-Out" perimeters of the court differ according to the number of people playing—four or two—and after each serve. A served ball must land in the corresponding service area. But the moment this ball is returned, the service area lines are disregarded and the whole court becomes "in." The whole court for a doubles match includes the alleys, but excludes them when only two people are playing.)

Four elements in system

The basic elements of the plastic system consist of four subsystems: the sensors, a dynamic load, an amplifier comparator and a signal processor.

The magnetic system is somewhat simpler: its front end is made up of a sensor loop, an input amplifier and a detector.

The output from either system is fed into a decoder display system that consists of a decoder (controlled by a command console), an In-Out processor and a display panel. The foot-fault and net circuits are also fed into the decoder and command console.

The display consists of a buzzer and a small array of lamps on the console. Individual LEDs show the status of each line sensor prior to the decoder. The display outputs can also run external score boards and display for audiences.

An umpire is required to operate the system, arming certain sensor lines and disarming others as the game progresses.

As a player prepares to serve, his base line is activated to notify the linesman if the server breaks the rules by stepping on his base line before serving. Also armed are the service areas into which he's to serve the ball, and the net, to reveal whether the served ball touches it. If any of these violations is committed, lights flash and a buzzer sounds.

If the serve is good, the service area lines are disarmed, and so are the base line for the foot fault and the net for the let ball. At the same time, the four outer perimeter lines of the court are armed—with the alleys if four people are playing, and without the alleys if it's a singles match.

The plastic sensors, which are buried beneath the surface of the court about one-half in., are custom-made variable-resistance switches made of conductive plastic sheets 4 mils thick and 18 in. wide. The sensors are cut and arranged to cover each side of a line, and each is connected individually in a circuit from the dynamic load to the amplifier-comparator and on to the ball-foot signal processor.

A foot-fault is detected by a combination of sensors. A directional microphone hears the racquet hit the ball, and the buried sensor tells whether the server has stepped on the base line. If the step occurs before the ball is hit the serve is invalid.

The foot-fault circuits allow only long-duration inputs—such as a foot standing on the sensor—to pass to a comparator. Another comparator input receives the sound signal. If the foot signal is present first the sound signal triggers an output timer. If the sound signal arrives first an inhibit-timer prevents secondary sounds from false triggering. To compensate for the time required for the sound to travel from the racquet to the microphone, the signal from the base-line sensor is delayed accordingly.

A piezoelectric sensor in the top of the net is triggered by the ball's grazing the top of the net—contact

so slight it cannot be seen, felt or heard. The contact activates a signal that is amplified and sent to the display.

When a ball bounces on a sensor it produces signals with fast rise times and pulse durations in the low millisecond range. A ball is distinguishable from a foot because a player can't move as fast as a ball can, even though certain foot movements are almost as fast as a bouncing ball.

Very tight control of time comparison and signal integration screens out these unwanted signals. The ball-foot processor detects the short duration of a ball signal and allows it to trigger an output timer. The longer pulse times of a foot signal are prevented from reaching the timer.

A sensor can detect a ball even if a player is standing on the sensor, because a dynamic load prevents saturation. The ball-foot circuit amplifies the signal and squares it for processing.

The decoder is the heart of the electronic line judge, according to Nicks. All the line-sensor outputs are brought in and routed to the "In or Out" circuits. To set the proper flow pattern from the line sensors to the display, gates are controlled by voltages from the command console.

The output of the decoder is a delay-and-compare circuit that allows an "In" signal to be displayed within a preset time of an "Out" signal. This gives a correct "In" line call when a ball hits outside the line, but flattens out sufficiently to touch the line. This is a tremendous help, says Nicks, since even a good line judge can't see more accurately than one to one and a half inches.

The "In" and "Out" display signals are sent to the command console to reset or change the keyboard function. For example, a serve mode is selected on the command console. If the served ball is good, the "In" signal sets the console to the "Play" mode. If the serve was "Out" the console is reset for the second serve. The same thing occurs with the Net and Foot-Fault display outputs.

The command console is an interconnected switching arrangement that allows only one of three modes to be in effect at a time: Serve to S_1 (the left-hand service court), Serve to S_2 (the right-hand service court) and Play.

Another switch changes the decoding patterns for a singles or doubles game. The console allows a single umpire to officiate at a tennis match and can be designed to be operated by the players on the court.

Magnetic system uses wires

The magnetic system under development uses a sensor network of wires about one in. under the court's surface. These wires can be arranged in an X-Y configuration. A corresponding display decoder circuit would be used to show the specific area in which the ball hit and whether it was "In or Out."

With the wire sensors arranged in a configuration similar to that of the plastic sensors, the same decoder and display can be used. The tennis balls, however, must contain a magnetized filler compound. The pattern is arranged so that when any area of the ball passes within a certain distance of the sensor a signal pulse is generated. The pulse is amplified and detected by a comparator whose output goes to the decoder circuits. The fact that a player doesn't produce any signals makes the system much simpler. Permanent installations in cement, clay, and grass tennis courts are possible. Sensor wires can also be manufactured in portable tennis carpets.

Geof Grant (left) and Robert Nicks installed the Mylar sensor for their line-judge system at the World Championship Tennis finals in Dallas.

A technique for monitoring footfaults prior to serving hasn't been selected. Some form of proximity detector, Nicks says, may be the solution.

Lauravan Enterprises, Miami Beach, FL, has developed a conductive system that works with wires embedded in the court and a specially made tennis ball manufactured with a conductive surface. The white lines, plus eight in. inside each line, contain 4-V bridge circuits built of fine wires placed parallel to each other, 3/8-in. apart. When the ball, which is manufactured for Lauravan Enterprises by General Tire, impacts above a sensor, it bridges the circuits. This is registered at the console which flashes lights and sounds a buzzer if the ball is "In."

The system is organized into five distinct circuits: the deuce court; the add and service court; the center line between the deuce service courts; the singles, doubles and baseline boundary lines; and the top of the net.

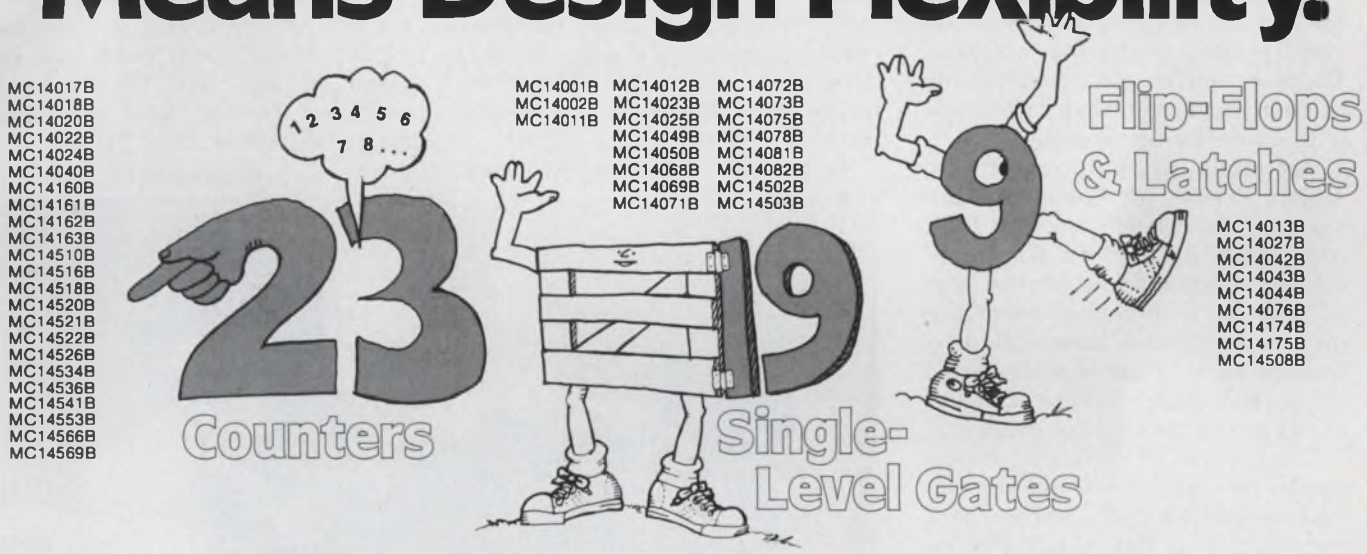
Detection depends on surface

The detection circuits in the court vary with the type of surface. Flexible roll-down surfaces such as Supreme, Boltex, Sport Face and others can be equipped with circuits sewn in with conductive thread or fine stainless steel wires. Hard surfaces such as Laykold or Plexipave can be overlaid with a fine Fiberglas screen mesh containing 0.015-in. stainless steel wire spaced 3/8-in. apart. A variation of this system is used on Hartru or clay installations where the screen mesh is covered lightly with additional fine particles after installation. All detection circuits are collected at the net and brought out to a terminal plug connected to the control console.

The console is equipped with test circuits to check the individual circuits for shorts or opens at periodic intervals. Sensitivity controls vary the response of the individual circuits to compensate for varying court conditions.

A system is currently being installed in the Costa Del Sol Racquet Club in Miami Beach, FL. ■■

Motorola's B Series CMOS Means Design Flexibility.



It's a matter of numbers.

There are other good reasons for picking Motorola's B Series of CMOS logic functions for your systems, but the design flexibility derived from the industry's outstanding B Series device selection is probably the best.

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CIRCLE NUMBER 17

Unusual heterodyne system capable of detecting huge Doppler shifts

A unique three-frequency heterodyne system for both radar and communications permits observation of targets having unknown Doppler shifts of considerably greater magnitude than is possible with conventional systems.

According to its inventor, Dr. Malvin Teich of Columbia University, the system uses a technique that is based on the simultaneous transmission of two signals having a very small frequency difference between them. The system, he says, is particularly useful in optical radar where Doppler shifts are on the order of gigahertz.

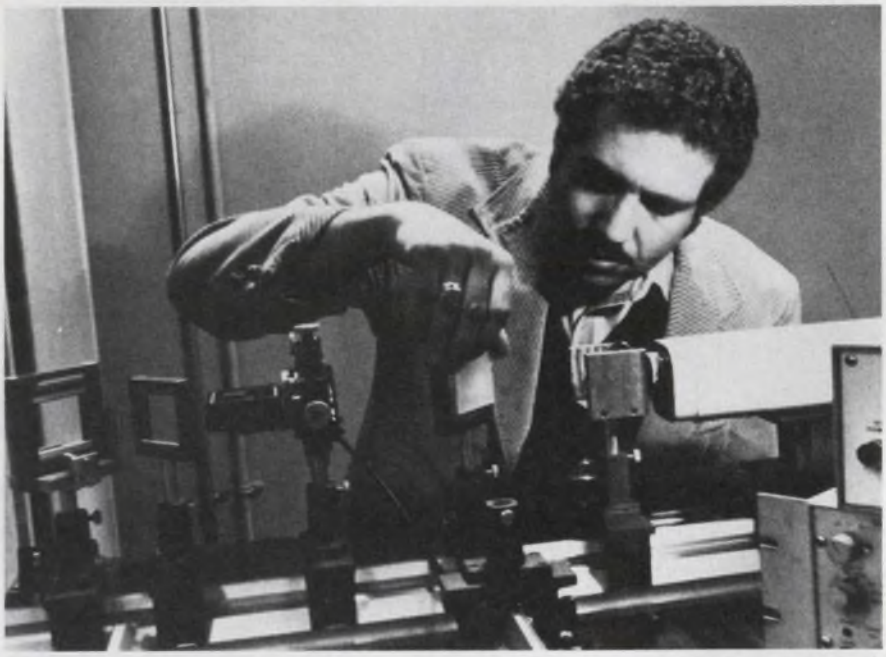
Teich, who is associate professor in the dept. of electrical engineering and computer science, says the technique has the following advantages:

- The receiver rejects the Doppler-shifted returns which are normally of unknown frequency. Instead it supplies an output that is a known low-frequency difference—in the order of hertz to 1 MHz—between the transmitted signals.
- Band-searching circuitry that is normally required to seek and lock onto Doppler-shifted returns is not required.
- Receiver i-f section design is substantially simplified because the i-f frequency is low and the returns have a narrow spectral bandwidth. Consequently, only a simple low-frequency bandpass system is required, in contrast to the complex wideband, high-frequency circuitry of conventional radar and communications receivers.
- The Teich system automatically compensates for local oscillator instability.

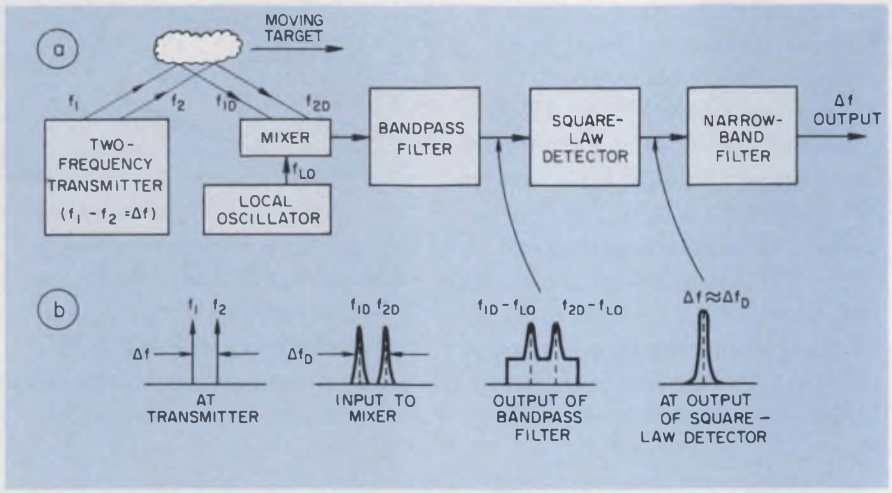
Teich says the system is similar in principle to a heterodyne radiometer; it makes use of a two-frequency transmitter and a nonlinear second detector. For example, a CO_2-laser radar operating at 10.6 μm could be used to acquire and track a satellite having 1-m radius and rotating at 1 rpm. To eliminate any spectrum overlap, the difference in frequency between the prime laser beam and the second beam, Δf, is chosen as 1 MHz.

In practice, this small frequency difference can be achieved by splitting the laser output and modulating one of the beams. A fraction of the unmodulated beam can be taken off and used for the local oscillator. The CO_2 laser frequency is approximately 28.3 THz.

(continued on page 26)



A He-Ne radar version of the three-frequency heterodyne system is adjusted by Dr. Malvin Teich.



1. **This three-frequency heterodyne system for radar** provides an output of Δf that is not dependent on the Doppler shift of the transmitted signals. The power-spectral-density of transmit and return signals is shown (bottom).

Jim McDermott
Eastern Editor

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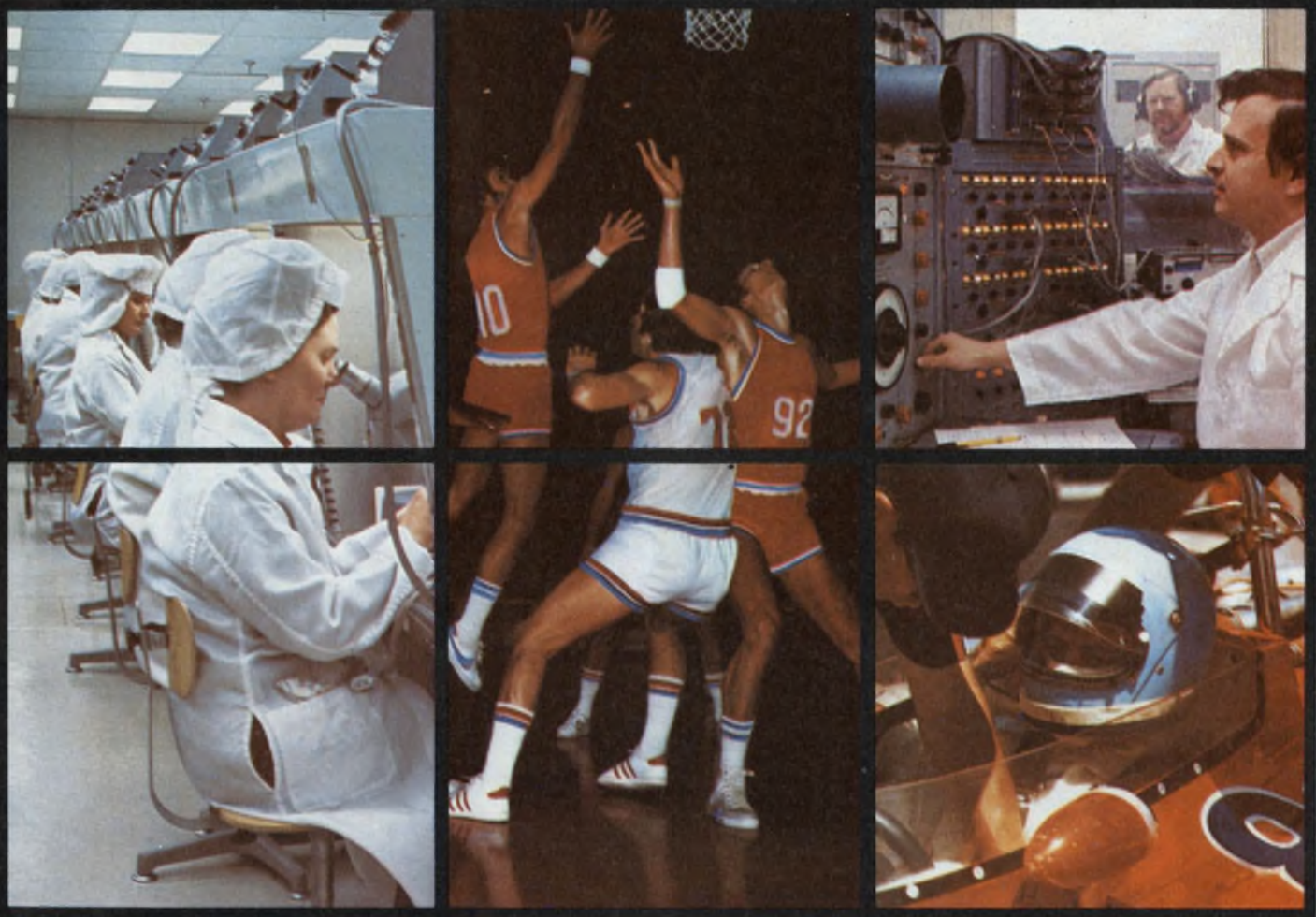

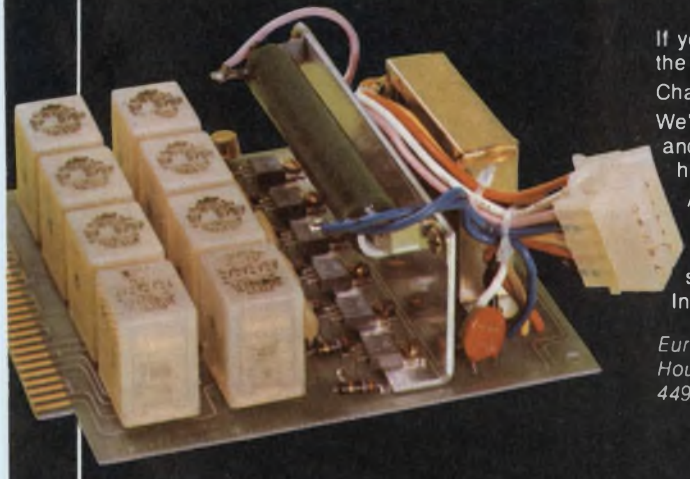

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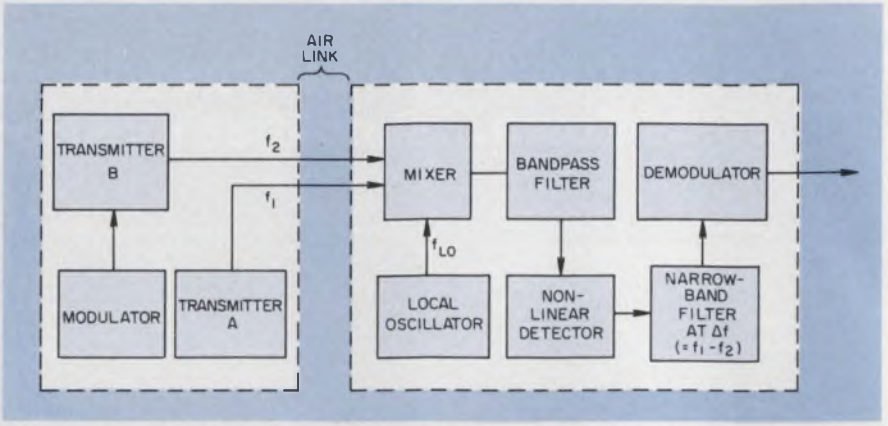
NEWS

(continued from page 24)



2. **Communications systems with transmitters and receivers moving with respect to each other** can use the Teich system to provide an output that cancels the Doppler shift. The analog-system shown has one carrier modulated.

For a radial velocity of the satellite of 10 km/s the Doppler-shifted return is about 2 GHz. This means that the twin beams are both shifted in frequency by that amount. However, the key to the system lies in the fact that the Doppler-shifted difference between the frequencies of the twin beams is only about 60 Hz, which is negligible. Teich's system is designed to recover the basic difference frequency, in this case 1 MHz.

If Doppler information is required, the system can readily be switched to a conventional heterodyne mode of operation.

For optical radar, Teich calls it a "three-frequency" system since it includes a local oscillator—the transmitter output of two frequencies (f_1 and f_2) is bounced off the moving target (see Fig. 1). The Doppler-shifted returns of f_{1D} and f_{2D} are fed into a heterodyne mixer —a photodetector, in this case.

The returns are mixed with a second laser beam, which acts as the local oscillator, and a frequency of f_{L0}. The output of the mixer provides two difference-frequency signals of $f_{1D} - f_{L0}$ and $f_{2D} - f_{L0}$. These signals are passed through a broadband filter that has a bandwidth sufficient to pass the difference frequencies produced in the mixer.

The output of the filter is fed to a square-law device, which produces a component at the frequency determined by $(f_{1D} - f_{L0}) - (f_{2D} - f_{L0}) \approx \Delta f$. In this case, the frequency is 1 MHz.

The output of the square-law detector is applied to a narrow-bandpass filter that is 20 kHz wide and centered at 1 MHz. The minimum detectable power (MDP) of this system is improved over conventional heterodynes, where the MDP is proportional to the bandwidth. In the three-frequency system the MDP is proportional to the square root of the product of the bandwidth between the heterodyne detector and the filter, and the small final bandwidth. So the Teich system improves the signal-to-noise ratio.

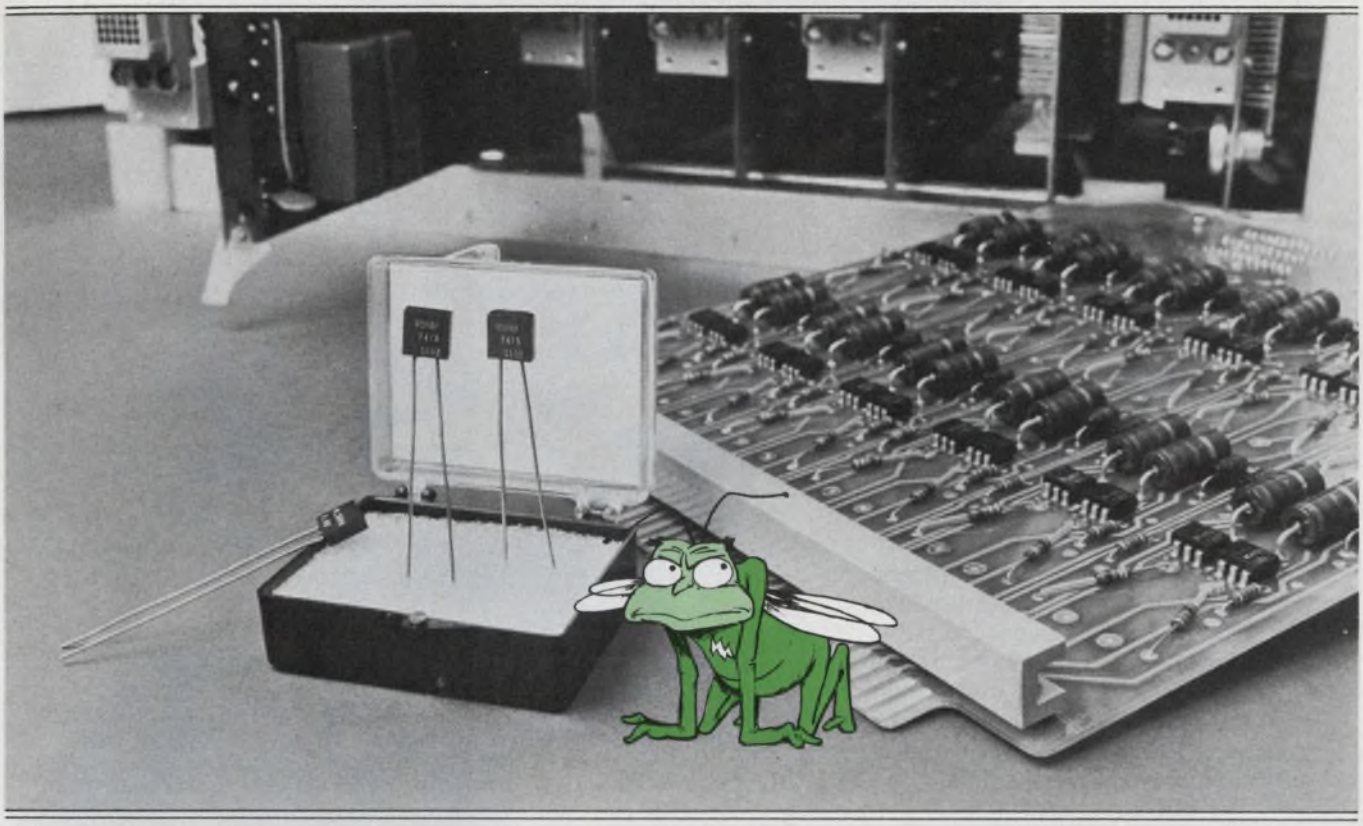
The MDP for the CO_2-laser radar, which has a final bandwidth of 20 kHz and a Doppler shift of 2 GHz, is equivalent to that of a conventional system with a bandwidth of about 10 MHz, Teich points out.

Where a microwave system is used instead of an optical system, the difference between the transmitter frequencies may be as low as tens of Hz.

For cases in which the transmitter and receiver are moving in respect to each other Teich's system can also be used. Then only one of the transmitted carriers is modulated; the input to the receiver demodulator is the original spectral information, which is ready for demodulation by a mixer, an envelope detector or a discriminator.

Much of the recent work on Teich's system has been funded by the John Simon Guggenheim Memorial Foundation, in New York City. ■■

THAT BUG IN YOUR EQUIPMENT: YOU MAY NEED VISHAY RESISTORS.



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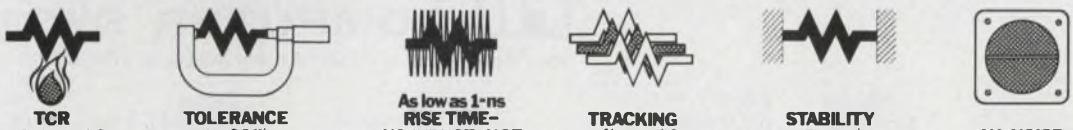

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CIRCLE NUMBER 20

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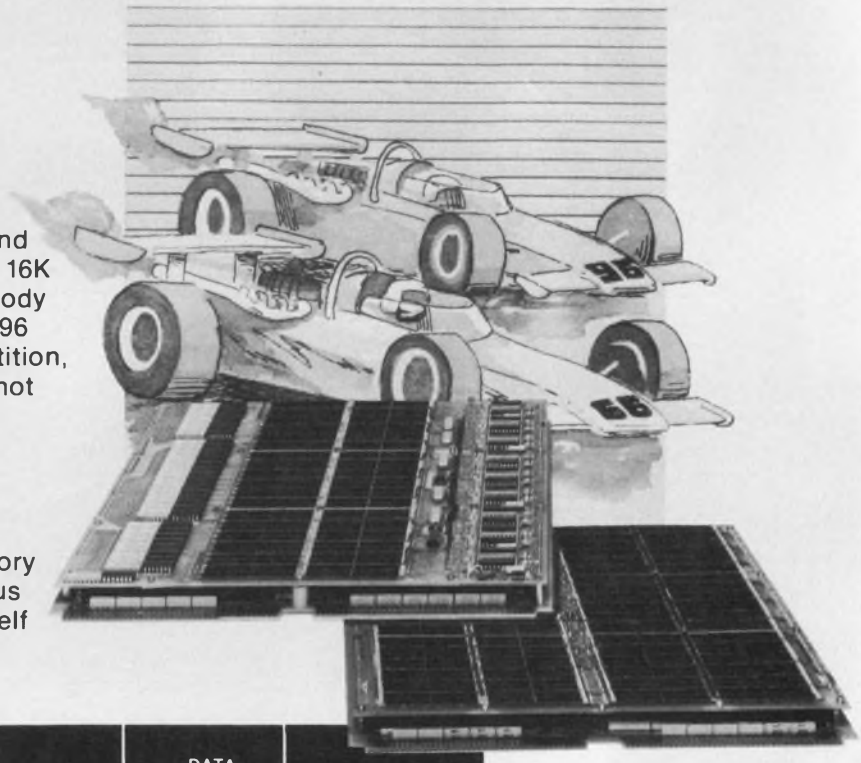

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CYCLE TIME	650	650	650	850	650		650	750
ACCESS TIME	250	250	270	300	280		265	300
PHYSICAL SIZE	11.75x15.4 x1.0	11.75x15.4 x1.0	11.75x15.4 x1.0	11.75x15.4 x1.0	11.75x15.4 x1.0		11.5x13.7 x1.0	11.5x13.7 x1.0
COMPATIBILITY 16K TO 32K	YES		NO		NO		NO	

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One Real Variable Function Keys: ln, log, e^x, 10^x, 1/x, $\sqrt{x}$, x^2, SIN, COS, TAN, INV SIN, INV COS, INV TAN sinh, cosh, tanh, INV sinh, INV cosh, INV tanh

Two Real Variable Arithmetic Function Keys: + − × ÷

Two Complex Variable Arithmetic Function Keys: j +, j −, j ×, j ÷

Two Real Variable Analytical Function Keys: →P, →R, P^n_m, y^x, $\sqrt[y]{}$, %, Δ%, C^n_m

Statistical Function Keys: x↔y, SLOPE, INTCP, GAUSS, BINOM, POISS, x_s, y_s

Hours-Minutes-Seconds Mode: HMS

Unit Conversions: (°F) C, (d) dms, (d) gra, (gal) l, (oz) g, (lb) kg, (ft) m, (mi) km, (f oz) l, (in) cm, (BTU) J

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CIRCLE NUMBER 23

Washington Report

Defense agency urges more use of off-the-shelf test gear

Greater use of off-the-shelf electronic test equipment could reduce Defense Dept. acquisition and logistics costs by $80 million annually. That's the conclusion of a new report by the Defense Science Board.

Other advantages, according to the report, would be shorter delivery lead times, more assurance of equipment reliability, and a simpler logistic-support system. In all, a special joint task force of the defense industry and government came up with 28 recommendations that will now be considered by the military departments for adoption.

After looking at the situation, the task force generally concluded that the military pays more than private firms for the purchase and logistic support of electronic test equipment of equal value, availability, and reliability. Two major reasons were cited: the services overspecify performance requirements, and procurement red tape and creaky logistics systems inhibit the purchase of new equipment and parts and the use of commercial repair and calibration facilities.

Some export reforms may occur

Permission to export electronic products may be easier to obtain in the future, and U. S. technology will be guarded more strictly. Further, the red tape in obtaining an export license will be reduced.

These are recommendations made by a special task force of the Defense Science Board, headed by J. Fred Bucy, newly elected president of Texas Instruments. The group's objective was to identify exactly what the U. S. is exporting, and how such exports affect the nation's technological lead.

Dr. Malcolm R. Currie, director of defense research and engineering, agreed with Bucy's conclusion that products not directly vital to national defense should be freed from strict Federal controls. The safeguards, he said, should, instead, be directed toward high technology.

A slow-down for CB expansion?

The Federal Communications Commission is having serious reservations about allowing the Citizens Radio Service to expand as rapidly as some groups would like. CBers will probably get the 100 new channels they want, but not before the first of next year.

Plagued by a flood of license applications and concerns about interference, the agency says it is now going to delay a decision on frequency allocation, types of emissions to be authorized, antenna-type acceptance, and technical standards. Such topics have been under examination by the

FCC for some time, but now additional areas are being studied. Among these areas are the possible intermodulation (IM) interference between Class D transceivers operating at certain frequency spacings.

Although there is a strong push from industry to permit the retailer to issue the CB license, or to simply forego licensing altogether, FCC Chairman Richard E. Wiley rejects the proposal, arguing that it would turn the already chaotic bands into "a mess."

With regard to the intermodulation problem, the FCC is investigating its severity and is seeking answers to these questions: Can an external device be added to existing Class D transceivers to minimize the effects of IM products? Should the IM problem affecting existing equipment with 455 kHz i-f frequencies be a deterrent to Class D frequency expansion? What requirements, if any, should be made to minimize the problems involved in coupling Class D transmitters and antennas? What new standards are needed to reduce the potential for harmonic-radiation interference to other services?

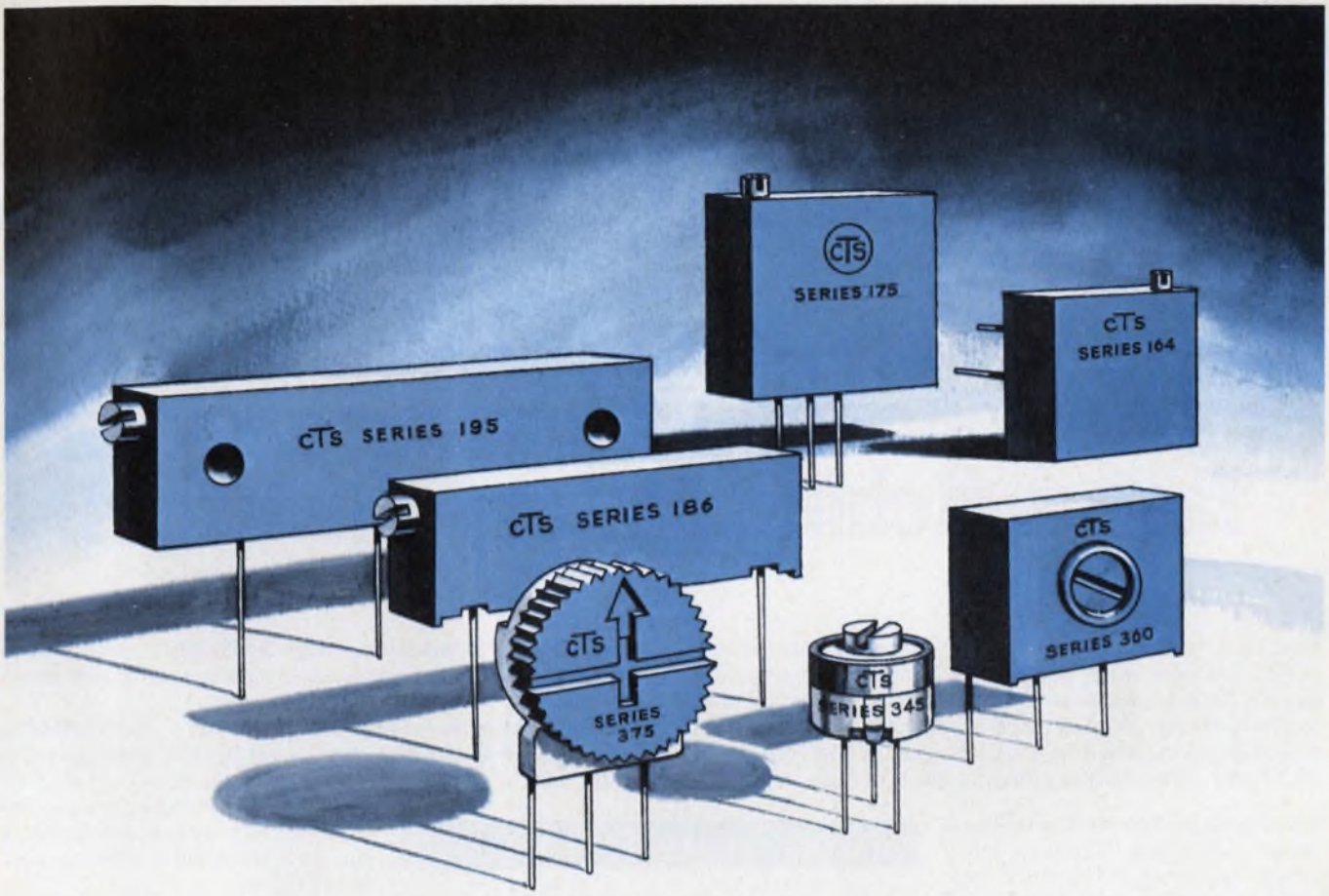
Stricter procurement guidelines for Federal agencies

The Pentagon's rigid guidelines for buying major studies and hardware systems will be adopted by all Federal agencies, according to a new White House directive.

The guidelines are a consolidation of a dozen reform recommendations from the now defunct Commission on Government Procurement. "System concepts," as the initial studies of large systems are called, will be wide open to competitors at the start of any Federal program. Next, extensive competitive demonstrations will be analyzed before a contractor is chosen. Congress is expected to approve the White House plan.

While simplified decision making is stressed, the new policy specifies that agency heads themselves should make four important milestone decisions: they should identify and define the mission, set the priority and allocate the resources; select competitive system-design concepts for test or demonstration, or authorize the development of a noncompetitive system; commit a system to full-scale development and limited production; and finally, make the decision to go into full production.

Capital Capsules: The House has passed and sent to the Senate a **$3.7-billion NASA authorization for fiscal year 1977.** That's slightly less than the Ford Administration asked, but $133 million more than was authorized for this year. . . . **The Air Force is redesigning its tactical air-control system,** replacing obsolete, manual communications equipment with solid state, computer-aided gear. The result: fewer men will be needed, and efficiency will be improved. . . . A conference of Pacific nations to discuss international planning and the **future direction of telecommunications technology** will probably take place this fall. It's the brainchild of the White House's Office of Telecommunications Policy. . . . The Dept. of Commerce, urging U. S. electronics manufacturers to exhibit at the **Farnborough (England) Air Show, Sept. 5-12,** predicts avionic equipment sales of $196.8 million in the U. K. in 1978. . . . The Energy Research and Development Administration is seeking a combined manager-operator and an initial site, with an option for **a future site, for the Solar Energy Research Institute (SERI).** A five-year contract is the plum.



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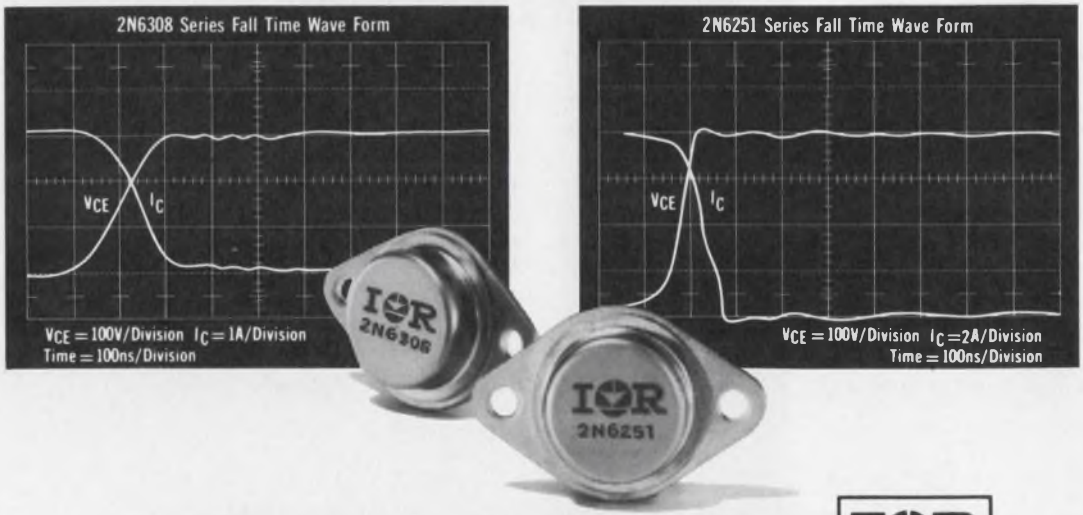
IR Part No	$V_{CEO(sus)}$ (Max V)	I_C Peak (A)	h_{FE} (min/max)	@ I_C (A)	$V_{CE(sat)}$ (Max V)	@ I_C (A)	P_d (W)	t_r/t_f (μs)
2N6306	250	16	15/75	3.0	0.8	3.0	125	.6/.4
2N6307	300	16	15/75	3.0	1.0	3.0	125	.6/.4
2N6308	350	16	12/60	3.0	1.5	3.0	125	.6/.4
2N6542	300	10	7/35	3.0	1.0	3.0	100	.7/.8
2N6543	400	10	7/35	3.0	1.0	3.0	100	.7/.8
2N6544	300	16	7/35	5.0	1.5	5.0	125	1/1
2N6545	400	16	7/35	5.0	1.5.	5.0	125	1/1
2N6249	200	30	10/50	10.0	1.5	10.0	175	2/1
2N6250	275	30	8/50	10.0	1.5	10.0	175	2/1
2N6251	350	30	6/50	10.0	1.5	10.0	175	2/1



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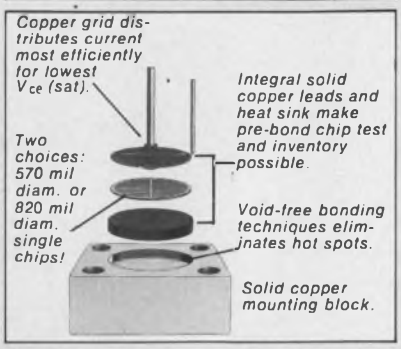
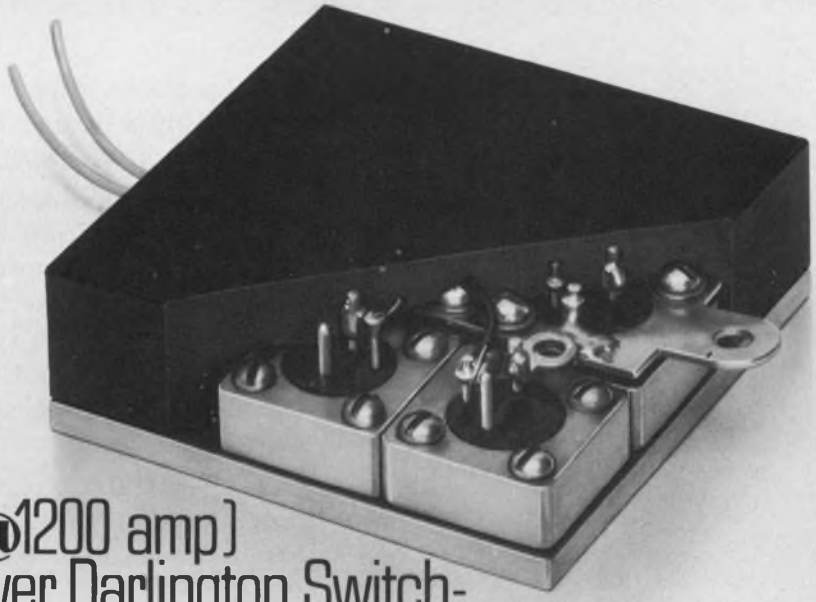
Type #	V_{ce}*	h_{fe} @ I_c	P_D	Size
MT-5001	80	100 @ 250A	0.3 KW	5.7 cu. in.
MT-5003	80	100 @ 500A	0.7 KW	11.0 cu. in.
MT-5005	80	100 @ 800A	1.4 KW	18.7 cu. in.
MT-5007	80	100 @ 1200A	2.1 KW	18.7 cu. in.

*Voltage ratings to 400 V available.



1200 AMP 80 V POWERBLOCK



[h_{FE} 100 min. @ 1200 amp]
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CIRCLE NUMBER 27

Programming system can handle any 8-bit microprocessor

A completely self-contained microprocessor programming system offers everything needed to write and document programs. The unit, called the μScope or the Model 8000, is based on the 8080 μP, but can be used to write programs for any 8-bit μP presently on the market.

The Model 8000, developed by Tranti Systems (1 Chelmsford Rd., North Billerica, MA 01862. 617-667-8321), contains a full alphanumeric keyboard and a separate numeric and control-key keypad. Also built into the system are a CRT display for program viewing, a small alphanumeric printer for documentation, a magnetic-tape cartridge reader for program entry and storage, and a semiconductor memory expandable up to 57-kilobytes.

The μScope's resident software is stored in ROM and consists of three sections—a monitor, an editor and an assembler. The software assembles the program as it is entered to speed operation.

The monitor program reads, writes and verifies magnetic tapes, copies and compares blocks of data, permits direct entry or modification of any memory location, and allows you to put multiple breakpoints in an entered program.

Features of the editor program include con-

(continued on page 38)

Program analyzer debugs 8080-based systems

With the Model 640 analyzer, programs for 8080-based systems can be debugged and run in the actual hardware without the use of a computer simulator or other debugging equipment.

The Model 640 from Data Works Instrumentation (9748 Cozycroft Ave., Chatsworth, CA 91311. 213-998-8985) provides a 4-digit hexadecimal display that shows either the program address or data-bus contents. Controls are provided for stepping the program from a selectable address, cycling through loops, and examining bus contents by instruction step or cycle.

The unit can be plugged directly into any of the company's μP-card systems. The analyzer can be adapted to other 8080 systems by attaching the proper μP signals to its input circuits. The analyzer costs $650. Delivery is 2 to 4 wks.

CIRCLE NO. 535

(continued from page 37)

trols to facilitate program entry, to set program address, to increment addresses, to decrement addresses, to label, list, move, assemble and disassemble programs. You can easily alter or rework programs with the built-in editor facility. Selective program listings are also possible.

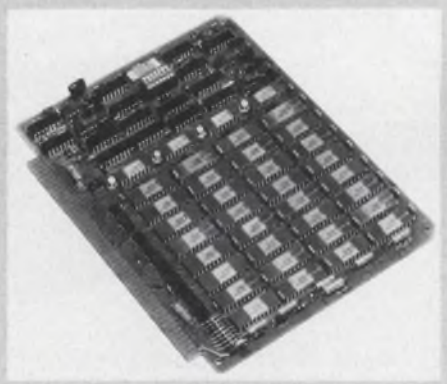
The assembler program converts entries into object codes in accordance with a conversion table entered into memory for the particular processor being programmed. Since the object-code and label memory requirements typically are about equal, you can generate 2-k words of object codes with only 4-k words of RAM.

To switch from one μP to another, a different look-up table of mnemonic labels and their object code equivalents must be entered, either by keyboard or by magnetic tape. A complete data bus is available from the rear of the μScope to permit full system interconnect with high-speed printers, computers and other peripheral equipment. The μScope system is housed in an 18 × 10 × 20-in. cabinet and requires 200 W at 115 V.

Prices for the μScope start at $6995, for a system with 8-k words of RAM. Additional RAM costs $350/4-k words. Delivery will be in 60 days.

CIRCLE NO. 536

16-kbyte memory systems feature 8-bit μC compatibility



Two compact memory systems built with 4-k bit dynamic MOS RAMs offer direct compatibility with 8-bit μC systems.

Offered by Intel Memory Systems (1302 N. Mathilda Ave., Sunnyvale, CA 94086. 408-734-8102) and called the in-481 series, the systems store 16 kilobytes (16,384 × 8-bits) per board. They are designed for use with equipment based on 8080A and 8008 8-bit μPs.

The memories and all refresh and interface circuitry are contained on a single PC board, measuring 8 × 6.18 in. Up to four cards can be used to expand the system to 65,536 words.

Both memory systems feature synchronization of all refresh, write and cycle-time requests with specific CPU states or requests.

The dash-1 version is compatible with the 8080A and has an access and cycle time of 450 and 600 ns, respectively. The in-481 is compatible with the 8008 and has an access and cycle of 650 and 1100 ns. Refresh is totally "transparent" to the CPU, thus minimizing the total number of Wait-cycle requests.

Single unit price for each system is $975.00 and delivery is 30 days.

CIRCLE NO. 537

Current crop of 8-bit μPs draws ire of a system designer

Although the market is currently bursting at the seams with new 8-bit μPs, at least one system designer feels many of these chips have been poorly planned and designed. And they are not really meeting the buyer's needs, according to Matt Biewer, Vice President of Pro-Log, Monterey, CA, which manufactures logic modules that employ μPs and support circuitry.

"Despite manufacturers' claims," Biewer says, "none of the present 8-bit MOS μPs really perform logic processing well." In such an application, Biewer says, current μP chips suffer from one or more of the following limitations: inefficient addressing, too few general-purpose registers, slow subroutine and interrupt handling, and an inability to manipulate bits easily.

In logic processing, a μP can function as a peripheral controller or replace relay logic. The micro has relatively modest memory requirements

(continued on page 40)

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(continued from page 38)

—up to 1-k words of ROM, and a hundred or less words of RAM—and can be programmed readily in assembly language. In comparison, for a data-processing application memory size might well run to more than 4-k words of ROM and 4-k words of RAM. In that case a high-level language like Basic or Fortran would probably be used.

In Biewer's view, one of the flaws of current μPs is that several memory locations are typically required for each of the instructions that address operands. Since μPs have a large addressing capacity—up to 64-k words—they require a longer execution time than they should.

"To make a decision, such as a jump on a condition, requires three 8-bit bytes; one word to tell you to make the jump, and two words (the 16-bit address) to tell you where to go," Biewer observes. His solution: reduce the addressable memory capacity from 64-k locations to about 4-k locations.

Another reason μPs are not suited for logic processing, in Biewer's view, is that they don't have enough general-purpose registers to avoid the need for external RAM chips. These registers could be used instead of RAM, for working storage, thus speeding up instruction execution time.

"In terms of the number of internal registers that each has, I would classify the 8080 as a better logic processor than the 6800." The 8080 has seven internal registers, with one used as an accumulator. The 6800 has only two—though both are used as accumulators.

In addition these μPs do not have an internal pushdown stack to process subroutines and interrupt. Instead, the stack resides in RAM with only the stack pointer inside the μP chip. This architecture requires some RAM memory capacity and lengthens the execution time of some important instructions.

A jump to subroutine (CALL instruction in the 8080), for example, requires 17 clock periods to complete—one of the longest execution times of any instruction. Biewer says a faster hardware stack, of just three to seven levels, is sufficient for logic-processing applications.

Still another feature missing in many of the new units is good bit manipulation. To sense changes in bit inputs, present μPs require time-consuming software techniques.

Assembled microcomputer costs just $245

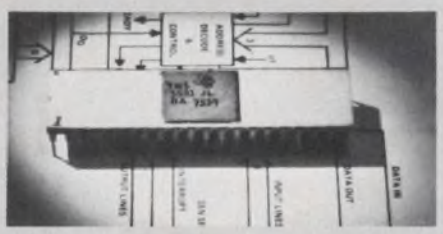
A complete microcomputer based on the 6502 μP costs only $245. Introduced by MOS Technology (950 Rittenhouse Rd., Norristown, PA 19401. 215-666-7950), the unit comes on a single circuit board and needs only a power supply for operation.

Besides the company's 6502, the μC (called KIM-1) contains 1-k bytes of ROM, a 24-station keyboard and a 6-digit LED display, but only 1-k bytes of RAM. All interface circuitry necessary to permit operation with a serial I/O device is also included.

A single 5-V, 1.2-A power supply is needed for operation, and an additional 12-V, 0.1-A supply is required to power a low-cost audio-cassette data interface. All bus signals needed for system expansion are brought to connector pins.

CIRCLE NO. 538

I/O controller for 8080-based systems reduces package count



Replacing five or more standard support circuits for systems based on the 8080/8080A, the TMS 5501 multi-function I/O controller operates under μP-software control.

Offered by Texas Instruments (P.O. Box 5012 M/S-84, Dallas, TX 75222. 214-238-2481), the controller chip provides for transmission of serial data, input and output of 8-bit parallel data, interrupt servicing, and interval timing. Asynchronous serial data are handled at baud rates from 110 to 9600, selectable by software. Eight-bit output and input ports transfer data to and from the μP and other system components.

The TMS 5501 establishes priorities for eight interrupts and generates the appropriate

(continued on page 42)

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(continued from page 40)

RST instruction for the 8080. Interrupts are individually maskable by software and can be accepted as they occur or can be polled. Five software-programmable timers generate interrupts after counting intervals of up to 16 ms. The timers can be cascaded for longer intervals.

Commands to perform the various functions or to change the programmable modes of operation are transferred to the controller via the μP data bus. The 8080 addresses the TMS 5501 as memory via four address inputs, and uses memory referencing instructions, such as MOV, to send commands. Like the 8080, the controller uses supplies of 5, −5 and 12 V.

The TMS 5501 in a 40-pin ceramic package costs $20.25 in quantities of 100 to 999.

CIRCLE NO. 539

Data terminal uses μP for increased flexibility

A versatile, remote data terminal has been designed by MSI Data Corp. (340 Fischer Ave., Costa Mesa, CA 92627. 714-549-6000.) Called the Source 7600, the unit uses an 8080 μP. The terminal can accept data formatted by the operator and transmit them over a phone line. It can also handle preformatted information such as ordering and inventory data.

As information is entered in via a typewriter keyboard or 10-key numeric touchpad, it first appears in a buffer display that allows the operator to edit each line before it is printed on tape and transmitted. The Source 7600 is priced from $3500 to $4500, in quantities up to 10.

CIRCLE NO. 540

Multiplexer turns to a μP to control data flow

A microprocessor-based data multiplexer handles point-to-point multiplexing between terminal clusters and computer centers. The M1308 Multitran multiplexer developed by Computer Transmission Corp. (2352 Utah Ave., El Segundo, CA 90245. 213-973-2222) accommodates up to 16 asynchronous or 8 synchronous digital channels, or a mix of both.

Because it is based on a μP, the multiplexer is flexible; a new program loaded into the system can completely alter the channel-scanning and data-handling sequence. The byte-interleaved, time-division multiplexer handles asynchronous inputs at standard rates of 75, 110, 134.5, 150, 300, 600 and 1200 b/s. Synchronous speeds of 1200, 2400, 3600 and 4800 b/s can also be handled.

Three M1308 models are available. The basic M1308 with RS-232/V.24 high-speed trunk interface for 9600 b/s transmission has a chassis cabinet and power supply. The M1308-1 has all the basic features and automatic speed recognition. The M1308-2 adds synchronous terminal support to the features of the 1308-1.

Three optional interfaces for the multiplexer that provide indicators for control functions and diagnostics include a synchronous single-channel unit (Model M1396), an asynchronous dual-channel unit (M1399) and a bare-bones indicator-only unit (M1399-1).

Prices for the three multiplexer models are $1800, $2000 and $2250 respectively. Interface option prices are $450, $300 and $260, respectively.

CIRCLE NO. 541

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The Am2911. The world's only sequencer that offers a space-saving package and a low 100-piece price of $7.77.

Both are expandable to generate any length address. Both have built-in microprogram counters. Both can branch immediately to any address.

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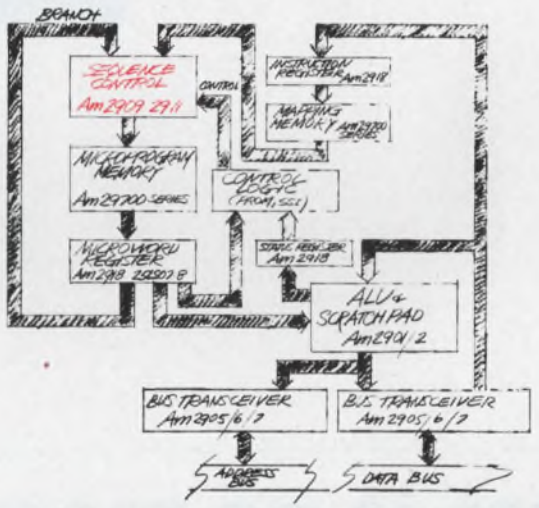

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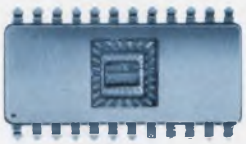
CIRCLE NUMBER 30



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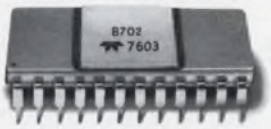

The 8702 has some other important advantages, too. CMOS technology means very low power dissipation — typically less than 20 mW. It is easy to use; no active auxiliary components are needed. And its latched parallel outputs are ideal for inputting to microprocessors or other digital logic.

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CIRCLE NUMBER 31

Editorial

Is imported wine the best?

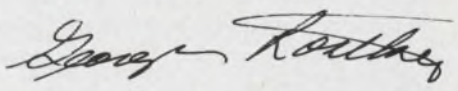
On a recent visit to Oregon, I was told the tale of a visitor from Maine. Some of the fellows from Tektronix took him to their favorite restaurant and before he opened the menu he commented: "I don't suppose you get fresh sea food here. After all, you're 3000 miles from the ocean."

Richard Preiss, Tek's manager of terminal-equipment development, assured the New Englander that Oregon's distance to "the ocean" is not quite 3000 miles. The man's reaction may have been similar to mine when I asked a waiter in a Paris restaurant if they had any good California wine. Just before he hit me I muttered: "I was always told the imported stuff is best."

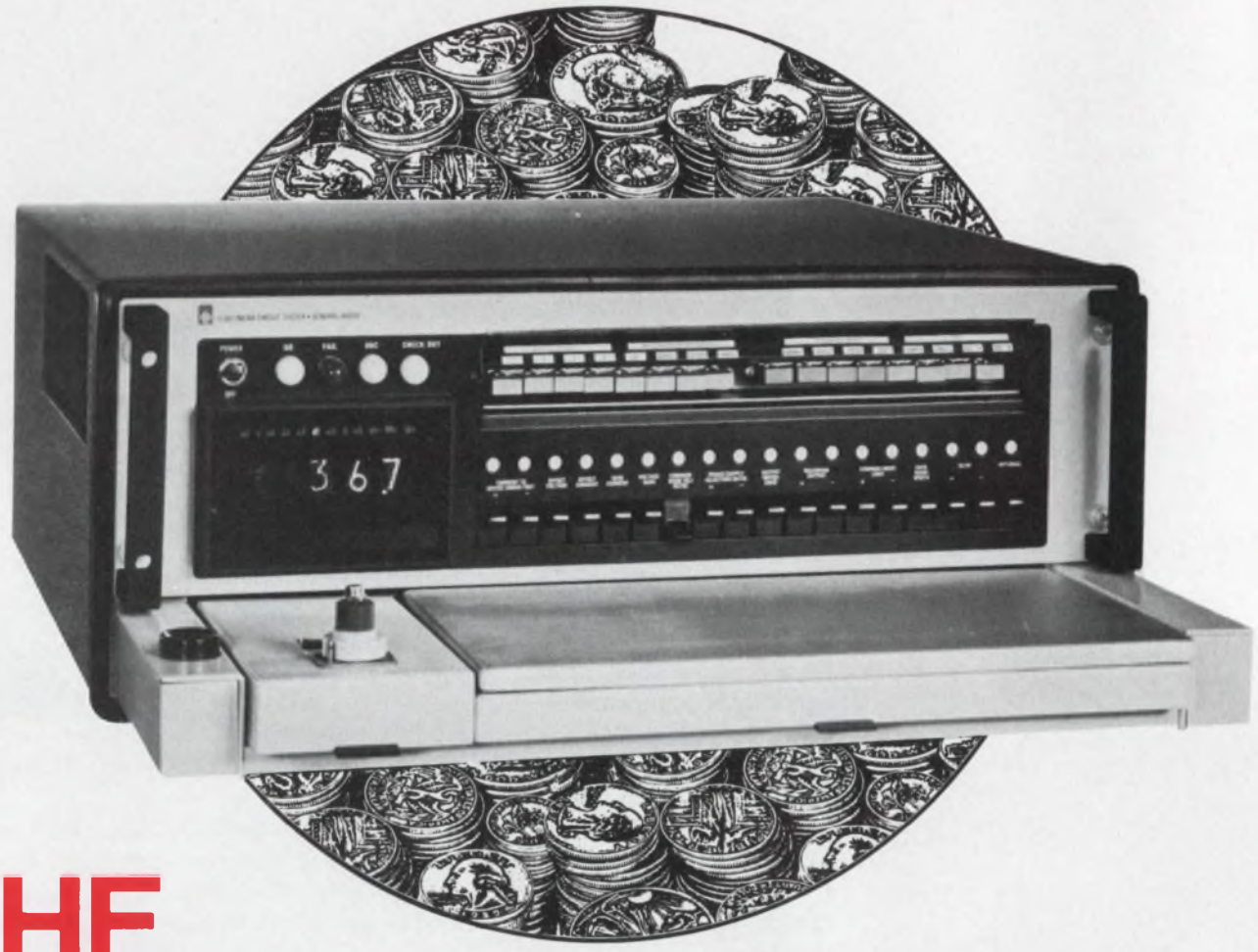
The two reactions, I suspect, are opposite sides of the same coin. The fellow from Maine felt that only "Down Easters" have an ocean. And I felt the best wine always comes from elsewhere. With minor modification, these two views are far too prevalent in our industry. Too many managers feel that their engineers are always divinely guided. And too many others feel their engineers never design anything worth while.

Both managers are blind hero-worshippers. The first sees heroes only in his own department, and the second sees heroes only elsewhere. Both attitudes can be dangerous. The man who thinks his own engineers are perfect won't goad them to greater performance levels. He won't challenge mediocre efforts and won't be critical of design shortcomings. The other fellow will always put down his own people. As a result they won't pay much attention when he finds fault. He acts as if anybody working for him must be inferior, possibly because he has deep inferiority feelings. So he can't inspire people to heroic efforts.

The man who tends to be the best manager finds engineers who are capable of both bad mistakes and brilliant achievements. He knows that none of us is perfect, and none of us dreadful. He knows that Oregon has an ocean and France has good wine.



GEORGE ROSTKY
Editor-in-Chief



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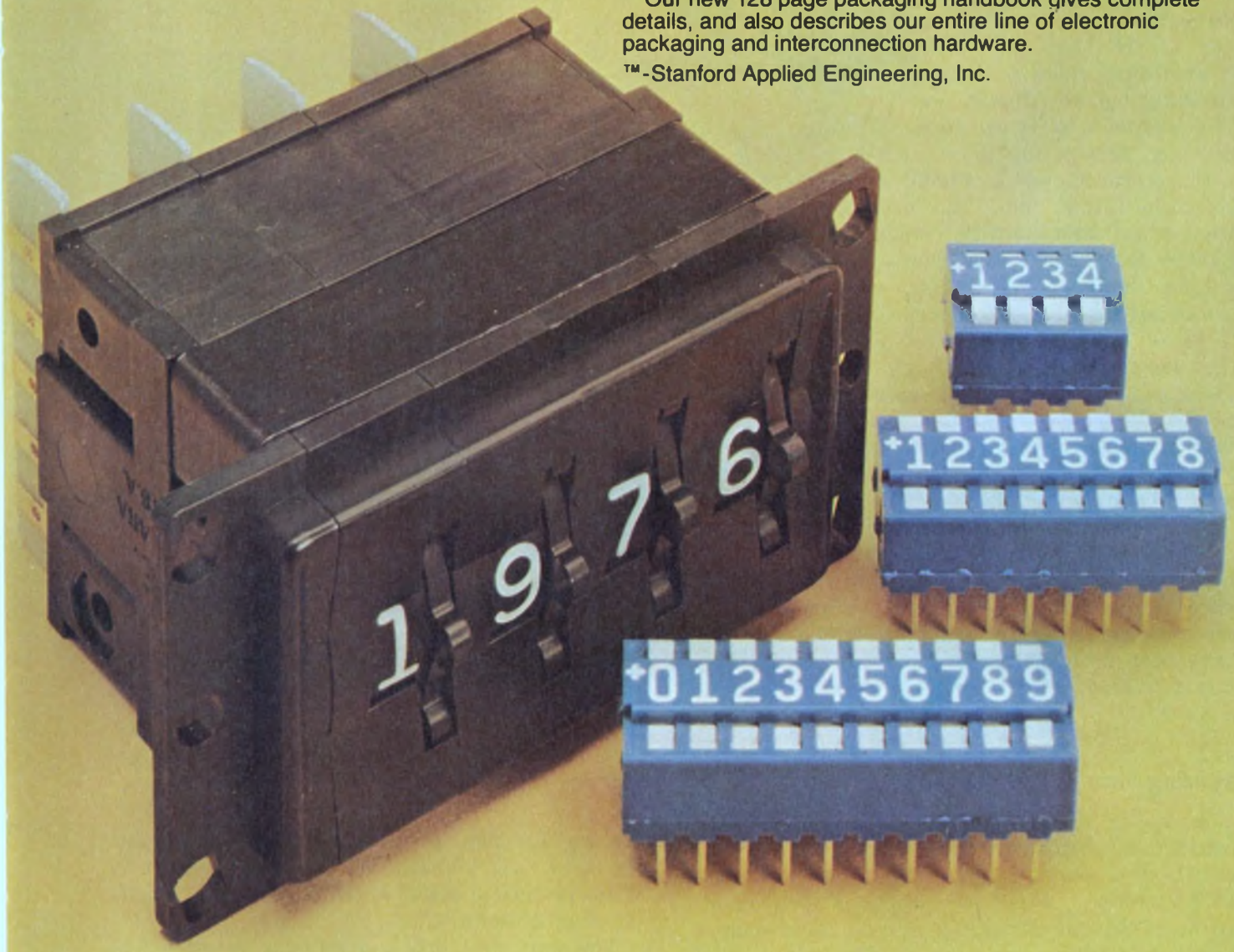

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FOCUS on IC Testers

Hacking through a jungle of IC-test-equipment specs is anything but an Alice-in-Wonderland trip. It can be a grueling, frustrating job.

If you're buying a $1000, limited-capability benchtop tester, fine. You pretty much know what it can and can't do. When you get to the $50,000 to $500,000 class, that's another story.

Like diamonds or minks, elaborate, high-priced testers are pretty much a blind purchase to those who just walk in off the street. So as they say in the fur trade, if you don't know furs, know your furrier. That's not a bad piece of advice. Before you speak to a tester vendor, however, first learn what you really need, then arm yourself with some knowledge of the potential traps. At least that way you can ask some intelligent—and probably embarrassing—questions.

Which tests to run? What patterns to use? How much testing to do? Is testing really necessary in the first place? These are questions to ask yourself. The pros and cons of the answers have been hotly debated ever since the first IC was delivered to an incoming inspection department.

Graphic displays of test results are one benefit of computer-controlled test equipment. Evaluation of LSI circuits is shown here on the Tektronix S-3260.

Avoiding fumbles and mumbles

As an IC user, you test to deliver a reliable product, to keep costly field repairs down, or to pin down a device's design limits and performance variations. Whether you opt for 100-percent go/no-go functional testing, for dc, ac or pulse-parametric testing—or some combination—problems await.

Throughput is a case in point. The faster you get an IC out of test, the less it costs you. So you look for high speed in a machine—the higher the better. And you can find it—at least on paper. What you get in actual operation is another matter. For instance:

The spec sheet lists a maximum test-rate frequency of 20 MHz. Super. When you start shooting your ICs in, though, the DIPs come out only half as fast as you expected. What happened? Simple. The spec listed the rate at a double-pulse clock frequency—twice the actual test rate.

Even when a tester can wring out a device in, say, 10 ms, this doesn't necessarily mean ten de-

Stanley Runyon
Associate Editor

vices will take 100 ms. A bunch of often-forgotten factors come into play here—set-up time, handling time, system downtime, fault-isolation time, memory-access time, and more—all of which cut into throughput.

Another thing to watch for: When a vendor talks about how quickly his equipment can test, is he including all possible tests? Chances are, he isn't. Some tests, such as leakage, take more time than others.

Remember, too, that when you start hanging extra equipment on your tester you usually add capacitance, and capacitance kills fast waveforms. While you're thinking about capacitance, don't forget to ask the vendor where he specifies it—right at the device or ten feet up the cable?

Perhaps the most meaningful throughput spec —one that accounts for all pauses—is the number of ICs you can test consistently over a long period—months or even a year. With this criterion, you include the hidden 50% downtime of a machine that looks, on paper, 10 to 20% better in throughput.

But where do you find this information on the spec sheet? Nowhere.

Testing of linear circuits usually requires measurement of a fair number of circuit parameters. GenRad's 1730 sets test limits with a programmable memory panel.

Paper-tape diagnostics identify defects on a printed-wiring assembly. The equipment is the Faultfinder's 101A, an in-circuit test system that probes solder nodes.

Anyone got a large-scale aspirin?

With the biggest testing headache today—LSI —the type and order of tests can make a significant difference in test time. With LSI it may be impossible to run through every possible test combination in a reasonable amount of time. Consequently throughput assumes less significance, and worst-case or pattern-sensitive testing increases in importance.

Another speed spec of widespread interest in linear and digital testing is slew rate. You might like to know how fast you can go from one voltage level to another. So you take the tester manufacturer's figure for slew rate and divide that into the difference between the levels. On the test stand, however, the results don't pan out.

What happened? Any of a number of things.

First, how does the vendor define slew rate? It may be an extrapolated figure, taken from the linear portion of the exponential curve. Second, was the slew specified at one amplitude, one frequency, one pattern configuration? If so, change any of these and—bingo—bye, bye fast slew.

Actually, you can't blame the tester manufacturer when even the IC vendor plays games with slew. Since many definitions exist for slew rate, you can be sure the IC vendor will pick the one that gives his device the best possible rating. The tester vendor does the same. Be particularly careful when you see the word "typical" in front of the spec.

Some questions to ask are these: What is the programmed gain of the device under test? Is the device operated in the inverting or noninverting mode? Was settling time considered? All of these affect the slew rate.

Going hand-in-hand with a machine's speed is its accuracy, although you're not always told this on the data sheet. Super-high accuracy is listed on page 1, and a blazing test rate dazzles you on page 3. What you weren't told: you can't get

You can check 5000 different ICs on Teradyne's J133 digital tester. The unit never needs calibration, and can interface with an automatic handler.

Hardware and software flexibility are keys to practical testing of LSI, μPs and other ICs. Fairchild's Sentry I takes aim at such difficult problems.

both together.

Of course, you can always sacrifice accuracy for speed in digital testing. After all a ONE is a ONE and a ZERO is a ZERO, isn't it? So why look for 0.02% accuracy when 1% will do? Actually, the answer isn't pat. It depends on how close to the vest you work, and how much margin you allow for errors in the test equipment. The object, of course, is not to bomb out good devices or boards, or to let marginal ones pass.

Realize that even when you start with 0.02% accuracy, by the time you get to the device through cables and sockets, the accuracy can suffer. As one wit phrased it: "The further you get from the equipment, the further you get from the specs."

Low-level specs got you down?

Whatever the accuracy, make sure the stated resolution of the machine is consistent with the accuracy. Picoamp or picosecond resolution is fabulous. But such resolution is entirely meaningless if the equipment's accuracy works out to nanoamps or nanoseconds.

Whether such fine resolution and such high accuracy are really needed is debatable. Still, if you're paying for resolution, you'd certainly like to know you've got it. But nanoseconds, picoamps and microvolts aren't easy to come by—or to keep once you've got them. Moral: Be sure a tester meets its low-level spec; be doubly sure it can repeat that spec every time.

Timing variations are especially important for MOS memories, which have failure patterns that are sensitive to timing. Thus, pulse jitter and stability are significant and should be pinned down.

One way to avoid signal deterioration is to place pin electronics right at the device location. Then, when a driver is specified as having low impedance, you'll be getting the performance where it counts. If you're testing CMOS or other high-impedance logic, you'll at least appreciate the absence of loading problems.

In checking out a tester, one aspect you won't appreciate is the evaluation of software.

Software: the hard sell

The vendor hasn't been born that hasn't cited his computer-controlled tester for easy-to-use software. "Flexibility" and "English-like language" are the usual superlatives. Since every vendor develops his own software packages and test languages, system comparisons are next to impossible. Your first step: Do I need a software-controlled system at all?

Software is easily the second largest expense of a computer-controlled tester, and perhaps the prime source of headaches. If you can avoid software, you'll be better off. But the more complex the testing job, the more you'll probably need programming. (Some testers, mostly small bench-top units, are "programmed" with switches or cards, not software.)

Thus if you're testing TTL only, why buy programmable voltage levels? If you're testing logic boards with only a few types of ICs, maybe you can sidestep a software-based system.

On the other hand, if your operation involves test or evaluation of many different devices, boards or families, if testing LSI or microprocessors is your cross, then you're just about forced to use a computer system or one of the newer, microprocessor-controlled testers. One vendor says that 20 to 30 programs will justify the extra cost of software by saving 50 to 70% of a test engineer's time.

Of course, you'll want software that's "easy to use." Many vendors claim that you don't have to be a programmer to use their machine. Despite the claim, you do just about have to be one to find out what you are—and aren't—getting.

No matter how "flexible" a system appears, what you'd like to know is, how difficult it is to develop a practical program. Can you develop programs yourself, or must you lean on the vendor? Remember, the more you get wrapped up in esoteric software, the more isolated you become from the hardware. If you do get isolated, it's all too easy to lose sight of the job you're trying to do.

When you buy software packages, watch for things that can slow testing or force shut down—such things as reloading from one storage medium to another, for instance, or accessing disc memory.

Naturally size of memory is important and you'd like to know if you've got sufficient storage to hold the needed software. But go beyond size. Find out what kind of local memory is offered, RAM or shift register. It can make a big difference in performance.

One overworked buzz word in computerized testing is "foreground/background," a feature that lets the computer run tests (foreground) while it performs some other job (background). This possibly useful feature may be beneficial—if it really works. If it doesn't—that is, if the computer services requests when it's good and ready—you may find the entering, compiling and debugging of programs painfully slow.

Fault diagnostics in logic-board testing form an increasingly important area of system software. If only 10 to 15% of your boards initially fail, then you may not care about isolating faults. As you stuff your boards with more and more ICs, however, you greatly increase the chances of failure. With 60 to 70 ICs, expect a 30% failure rate; with 150 to 200 ICs, look for a whopping 90%.

Isolating fault-isolation specs

With such a high rate, go/no-go testing may not be enough, and fault isolation can become crucial. With 200 ICs on a board, it's reassuring to know that a fast computer will have the difficult diagnostic task, not you. When a spec sheet says a tester can do the job, you'd like to lie back and depend on it. Don't.

One advantage of computer control is that it allows multiple test stations. On Lorlin's SS100 station, you can test op amps, voltage regulators and interface ICs.

In some cases the spec sheet may imply automatic fault diagnosis, but there's a good reason why that's only an implication. Manual labor is necessary every time, and you end up troubleshooting almost alone. A careful examination of the unit's isolation techniques should get you around this problem. Check carefully, too, for software aids that supposedly generate test programs, but that really don't.

Industry insiders—users and vendors—are generally split on the software/hardware question. Some believe software is the weak link in testing; others feel it's the hardware that limits test effectiveness. A few middle-of-the-roaders point to the need for improvement in both areas.

The difficulty of testing LSI circuits spotlights the questions that must be asked and the decisions that must be made:

Can I test my LSI circuits adequately with a limited number of special patterns designed to weed out intrinsic flaws? Will the transition-count method using pseudorandom patterns work? Perhaps I can speed things up by using more than one test station? Will a dedicated tester do a more efficient job than a general-purpose or flexible unit?

Or perhaps the best approach to testing consists of still another choice: hardware-generated, firmware-controlled patterns, and comparison of the response with a known good board or device.

If you decide that the simple, functional-test benchtopper is best for you, there are a number of products to choose from. Keep in mind that this class will weed out the 10 to 20 bum digital ICs in every shipment of 1000, nothing more.

Real-time dynamic analysis of LSI circuits for telecommunications—that's the job performed at four remote sites by this unit, from Instrumentation Engineering.

You can test six important op amp parameters with the ESI 1234: E_{os}, $\pm I_B$, gain, CMRR and stability. Go/no-go testing is also possible.

But when you pay under $1000 for units like Alpha Data's C1416 ($985), and Electro Scientific Industries' Model 1248 ($630), you can't expect much more. Both units perform go/no-go tests on TTL, DTL and CMOS. The C1416 compares the test sample against a known good unit, and the 1248 keeps track of output ONE/ZERO transitions, which are then compared with a predetermined number.

If, on the other hand, you feel you must detect border-line ICs or measure device parameters for other reasons, then you've got to move up the tester scale to parametric test systems. Here, a wide product range exists in benchtop form, and the decisions get tougher. The price, of course, goes up too—by about a factor of ten.

The wide choice in parametric testers

Should you buy a switch-programmable unit like the popular Alma 480B? A unit that programs with device boards, like the Biomation/Sitek 3200A? Or should you opt for something like Fairchild's 901, a benchtopper that accounts for different devices with an optically coded plastic card?

In evaluating programming differences, you'll most likely be interested in the time it takes to program, the level of skill needed, the price and availability of cards or program libraries (some are free), whether you must buy a program or can do it yourself, and other factors.

Of course, programming is just one of many selection variables. Many benchtop-tester manufacturers offer a variety of test features—Siemens and Teradyne, for two. And companies periodically enter the market with entirely new benchtoppers—HP's recently introduced 5045A, for instance.

Not to be forgotten is the linear IC tester, though shortly after you become a prospective customer you may wish you could forget it. The problem here is the large number of tests usually needed with, say, an op amp or other linear IC, and the lack of definitions and standards. (Remember slew rate?)

To check a linear IC's max and min specs (forget about "typical" values, unless you want practically a 100% rejection rate), you first have to find out how an IC vendor does it. Next, you've got to agree or disagree with his method. Then you've got to find out exactly how the IC tester does it. To reach a consensus can be quite a hassle.

One item that may not help is the IC-tester data sheet, which, in many cases, doesn't say exactly how each test is performed. Don't expect to buy a tester and worry later about "which tests and how." Probably no benchtop tester today can check all parameters of all linear ICs.

Thus you must compromise. One way is to check off all essential parameters, then include these tests as a condition of purchase. Another way: search for especially sensitive test conditions, and find out how the tester in question

Using a device library, an operator programs the Alma 480B digital tester with front-panel controls. Kelvin wiring in the 480B provides 0.1% accuracy.

handles these tests.

Two linear units slugging it out in the marketplace are the GenRad (formerly General Radio) GR 1730 and the Siemens 735. The 1730 can buzz through 18 tests (20 parameters) in a single, automatic sequence, and displays both measured data and test limits. Capabilities include testing for popcorn noise, gain-bandwidth product and low currents.

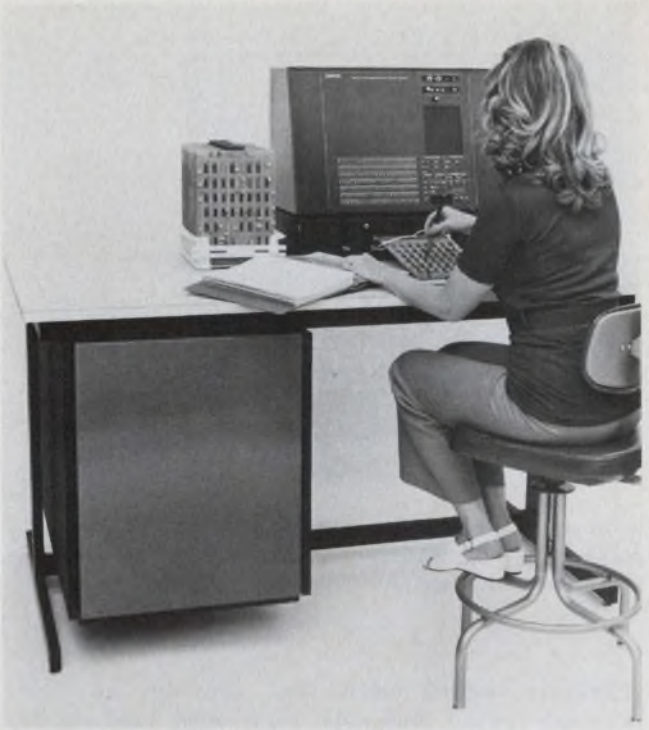
By contrast, the Siemens 735 zips through 14 tests in a fairly fast 1.2 s and handles devices ranging from 741 op amps, to quad current-mirror ICs, to regulators, comparators and custom ICs. An added benefit: you can add handlers, probes, and data logging if you wish.

Others competing strongly in linear benchtop testers or combined digital/linear units include Alma and Teradyne.

A mixed breed of equipment can be found on the next higher rung of the IC-tester ladder. These can be classified according to price range (roughly $10,000 to $50,000) or degree of testing complexity. Included here are dedicated machines, board testers and the newer, microprocessor-controlled equipment. When you reach this stage, you'll be sitting on a fairly lofty level of testing sophistication.

The higher you climb, the deeper you get

At this stage, you'll run into equipment like Mirco Systems' 500 Series of logic-circuit testers and Testline's 2100, 2200 and 3000. All are microprocessor controlled and all are aimed at printed-circuit boards or individual ICs. Various operating modes, test patterns, software options and other characteristics—attributable to the μP—set these units apart. For example, the Test-



Microprocessor-based testers, such as this one from Mirco Systems, give computer-like performance in a compact—or even portable—package.

line equipment can check ICs either in or out-of-circuit, and the Mirco offers either programmed ONEs and ZEROs or pseudorandom patterns.

Dedicated memory testers are an important class that generally fall in the medium priced, and higher, category. If you're going to test semiconductor memories and other logic, you'll have to decide whether to take the dedicated route or the general-purpose trail. Arguments abound for both choices. You must find the best way for your particular problem.

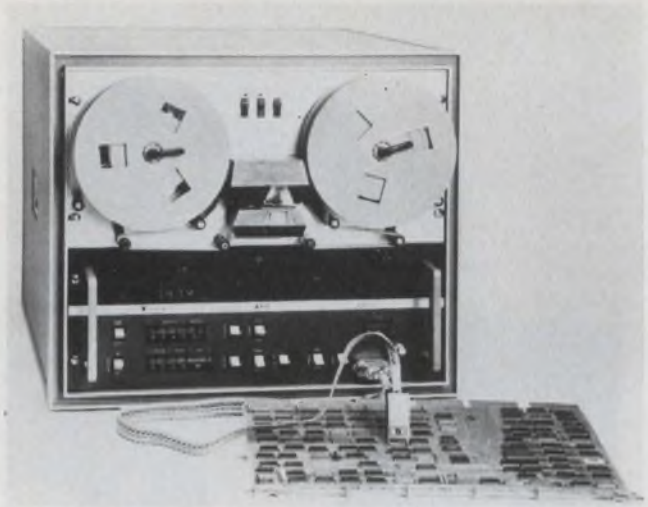
When you think of dedicated memory testers, you think of such well-known names as Adar, Macrodata, Siemens, Tektronix and Teradyne. But relative unknowns like Pacific Western Systems (PWS) are in there pitching, and new equipment like the Series 5000 from Technology Marketing, arrives with disturbing regularity.

Although the $65,000 PWS Mustang memory tester sells for a bit over those in the medium priced class, it comes with features that usually cost a lot more. The price gets you two 32-pin stations; parametric, pattern and timing generation; 12 digitally programmed supplies; and data logging and I/O via a dual-cassette terminal.

In contrast, Technology Marketing's new marvel starts at about $17,000 (seven configurations are available), and claims 100-ns cycle time for all test patterns.

Memory and other dedicated testers can be found today even in the uppermost price bracket.

One example: the Siemens 203, a $100,000-to-$200,000 machine with computer control and a



In or out-of-circuit testing of digital ICs with low-energy pulses is a characteristic of Testline's 2100. This μP-controlled unit executes punched-tape programs.

The Hustler 44, from Datatron, performs simultaneous functional and parametric tests on a variety of ICs. Up to eight remote stations can be multiplexed.

crystal-controlled clock that provides 16 independent timing channels, each with 1-ns resolution.

Perched together on the top rung in testing complexity are general-purpose and LSI testers, printed-circuit-board testers, in-circuit units, system-checkout and various other equipment. Most share the distinction of computer control. Most cost between $50,000 and $500,000. And most are large-scale machines calling for a large-scale selection analysis.

Purchase in haste, repent at leisure

Like standing on a ledge at 50 stories, the effects of selection at this level can be dizzying. Spec sheets in this highly competitive, high-dollar atmosphere begin to give way to slickly illustrated brochures, and solid technical arguments to emotional, blind-faith appeals. Only a careful, leisurely analysis of test needs will avoid a headlong plunge into an overbuying or underbuying disaster.

A case in point: At one time, it may have been obvious to an engineer that a PC-board tester was what he needed. After all, most problems do occur at the stuffing-and-soldering stage—parts reversed, solder shorts, defective through holes, IC failure under too-high temperatures, and the like.

But the situation isn't that clear today. With the advent and proliferation of LSI, μPs, random logic, memories and other not-so-easy-to-test devices, what kind of tester to buy is an increasingly difficult decision.

Board-tester and other vendors are attempting to solve the puzzle with new testers or ones that can be updated. Thus, Computer Automation's wide Capable line handles diversity with diversity: many models are available, with such add-on features as software test simulation, automatic fault isolation and multiple voltage levels.

Another unit, Datatron's top-of-the-line Hustler 50, attempts to meet the testing challenge with fast, simultaneous, dc-parametric and functional tests. The 50 doesn't blink at devices and technologies ranging from SSI to μPs, from bipolar to MOS.

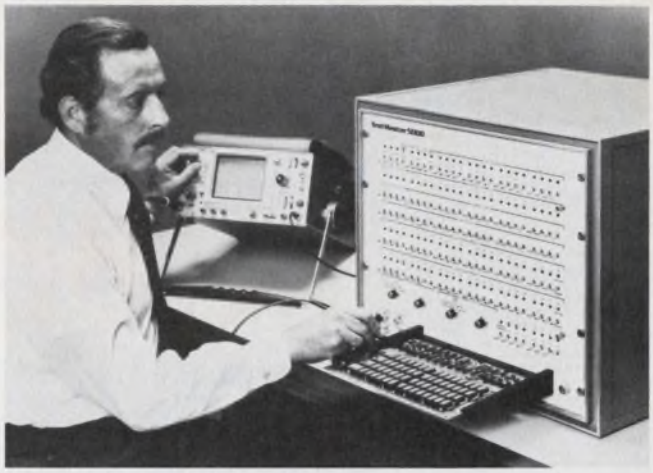
One tester designed to take on "super" LSI is a 96-pin behemoth from E-H Research Labs—the 4700. Like its younger brother, the 4500, the 4700 is one of the few that offers ac parametric testing with a single-shot, picosecond-resolution technique.

New in the ranks of general-purpose LSI machines is the seven-month-old Sentry II, from Fairchild Systems Technology. Fairchild has always ranked high in testing circles and the II represents the company's determination to stay at the peak.

An entirely different approach to testing is the hallmark of Faultfinders, Inc., which markets a family that can be characterized as in-circuit testers. In the FF101 series, a multiple-probe test fixture makes contact with up to 900 preselected test points located anywhere on a PC board (instead of the edge connector). Components—active and passive—are then electrically isolated and tested one by one. Later models include functional IC testing as well.

The headache of "mixed" boards—those with analog and digital circuits or combinations of LSI, RAMs, etc.—is the forte of Instrumentation Engineering's System 390. Large production

Two testers team up to provide 10-MHz functional checkout and dc-parametric memory tests (Siemens).



Speed is essential for LSI tests. This unit, from Technology Marketing, cycles in 100 ns.

runs with many types of boards are taken in stride by the 390's interactive programming.

Fighting obsolescence is nothing new in the tester industry. To battle changing needs, Lorlin Industries offers its latest creation, the Impact II—a modular system that can be upgraded as necessary.

The Model 6000, from Optimized Devices, also stresses change. Got a digital or linear IC to be tested? Just change the IC adapter and use the keyboard to request the appropriate program. The 6000 computer speaks English.

Teradyne, an established and respected name in testers, continues to set the pace. Latest at Teradyne: the J325 digital system (TTL, ECL, CMOS, static MOS), which can also functionally and parametrically verify μPs; and the J387 memory tester, designed to handle bipolar and MOS RAMs and ROMs.

Finally, in board and LSI testers, don't overlook these important companies: Data Test, Fluke/Trendar, GenRad, Hughes, Macrodata, Tektronix and TRW/Colorado—all have made or are making significant contributions. ■■

Need more information?

The products cited in this report don't represent the manufacturers' full lines. For additional details, circle the appropriate number on the Reader Service Card. For data sheets and more vendors, consult ELECTRONIC DESIGN's GOLD BOOK.

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Teradyne Inc., 183 Essex St., Boston, MA 02111. (617) 482-2700. (B. Sigsby). **Circle No. 529**

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An introduction to microprocessors—basics for the newcomer. Here are the key features of these revolutionary ICs that promise to reshape logic systems.

Some engineers find all the talk about microprocessors a little like walking into an eight-hour lecture several hours late. This article tries to take some of the mystery out of the subject. It will cover some of the key features common to most μPs. If you have already designed with μP chips you may want to skip this article—or even the rest of the series, which will discuss basic hardware and software capabilities of specific models.

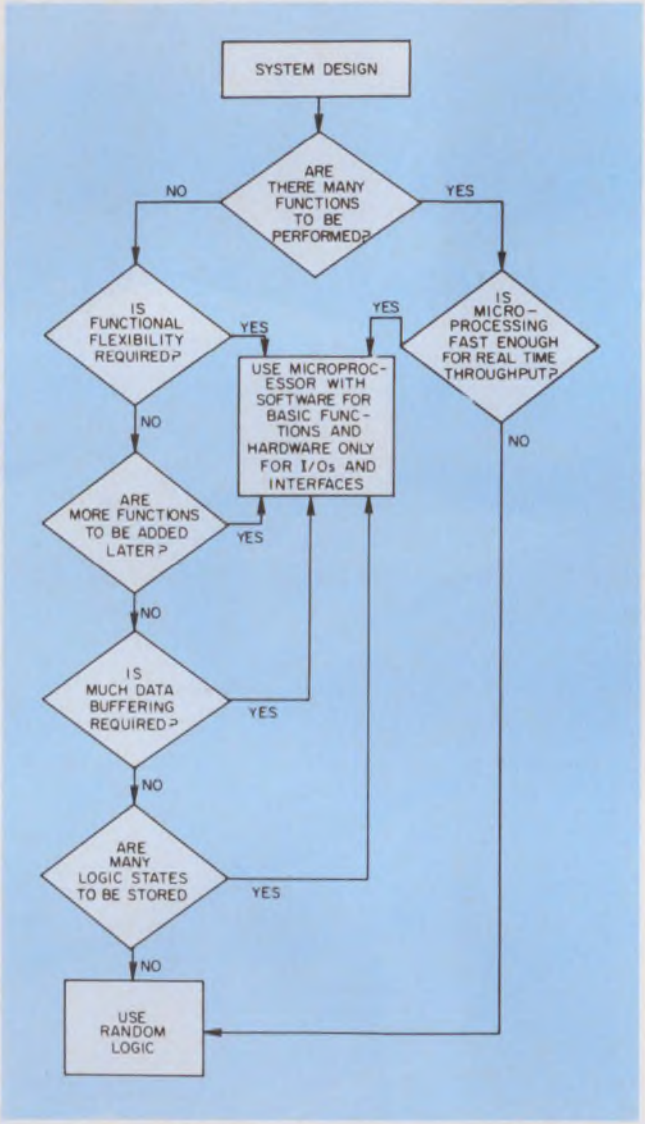
Microprocessors are a remarkably versatile new tool. They can lower the cost and increase the flexibility of electronic equipment and are ushering in a new era for digital designers.

Together with memory and peripheral circuitry, μP chips form complete microcomputers. In complexity, these micros fall somewhere between conventional minicomputers and small, hand-held calculators.

They're as compact and inexpensive as calculators, but, like minicomputers, can be programmed for a wide range of tasks and work with such peripheral computer devices as printers and magnetic memories.

When many functions must be performed, microprocessors can be used economically to replace or upgrade hardwired, or random-logic, designs involving scores of standard digital ICs (Fig. 1). And in applications emphasizing the random collection and routing of data they use less circuitry than is required with hardwired logic (see "Microprocessor or Random Logic," ED No. 18, Sept. 1, 1973, p. 106).

Of course, for some applications microprocessors aren't the sole LSI (large-scale integration) alternative. Complex logic decisions can be handled just as well by PLAs (programmable-logic arrays). Numerical computations are performed by ALU (arithmetic-logic unit) or calculator chips—from which a number of microprocessors have evolved. Custom LSI chips form yet another alternative, especially when very high volumes of a system must be produced (see "MOS/LSI Microprocessor Selection," ED No. 12, June 7, 1974, p. 100).



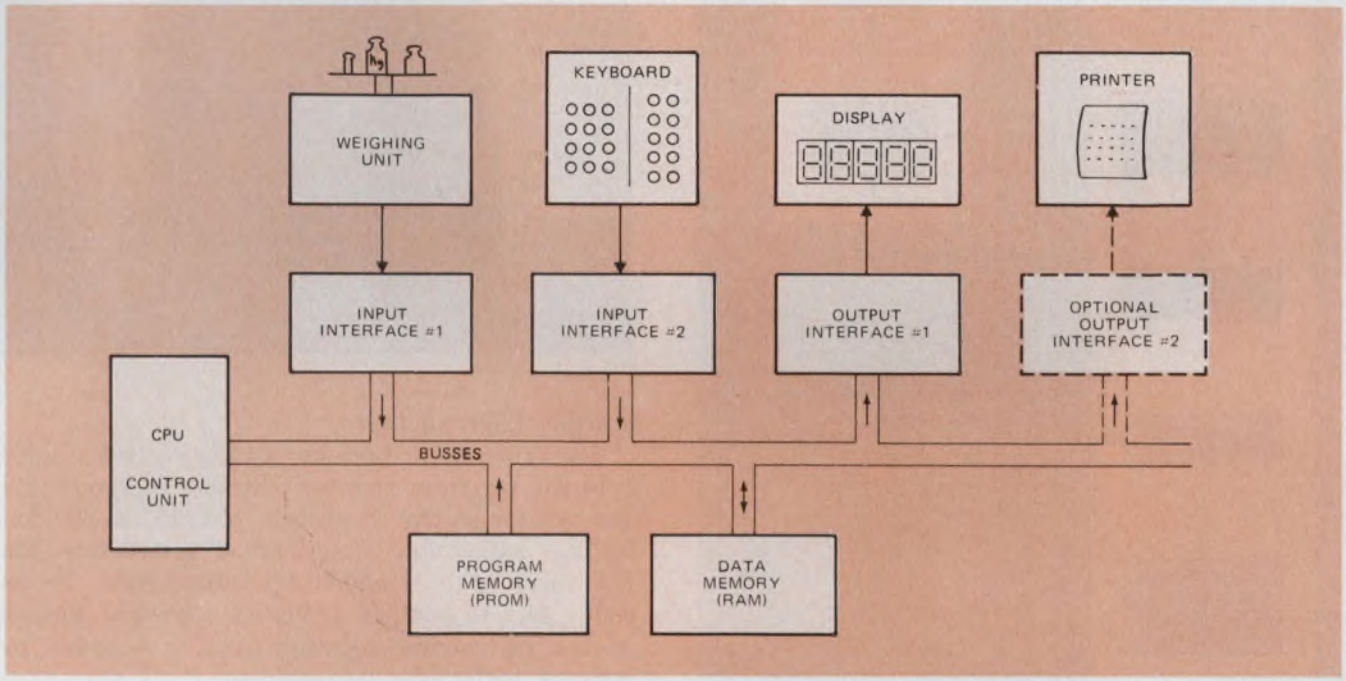
1. **The choice between microprocessors and random logic** depends on a series of tradeoffs that are illustrated in this flow diagram.

The high chip density needed for microprocessors has generally been obtained by the use of some form of MOS (metal-oxide semiconductor) technology. At first PMOS (p-channel MOS) was employed. Then manufacturers turned to NMOS (n-channel MOS) to obtain increased speeds. More recently, power-saving CMOS

Edward A. Torrero, Associate Editor

(complementary-MOS) μPs have appeared. The latter form of MOS combines p and n-channel transistors and features lower dissipation than either PMOS or NMOS.

Microprocessors that use bipolar technology have also been produced, and offer the highest speeds. However, the bipolar units generally aren't complete microprocessors. In most cases, several bipolar-μP "slices" must be combined to obtain the capabilities offered by a single MOS μP chip.



2. **A simple microcomputer application**—an automated scale—can be built with a single μP that communicates with various system components over interconnecting paths known as busses.

Regardless of the technology used, μP systems are organized in basically the same way as conventional computer systems. The major blocks are a central processing unit (or CPU), memory and input/output (I/O) facilities (Fig. 2). In their simplest form, each of these blocks can be a single chip. The μP chip (or chips) contains the CPU.

Within memory there are *instructions*. These are coded pieces of information that direct the activities of the CPU. A group of interrelated instructions stored in memory constitutes a *program*. The memory also holds coded data that are processed by the CPU.

Typically, the kind of memory used for programs is a ROM (read-only memory). From a ROM, information can be obtained, but that information cannot be altered during operation. A PROM (programmable ROM) provides the same function, but internal bit patterns can be set by the user rather than the manufacturer. Data, on the other hand, reside in RAM (random-access memory). This kind of memory allows information to be written and modified as well as read.

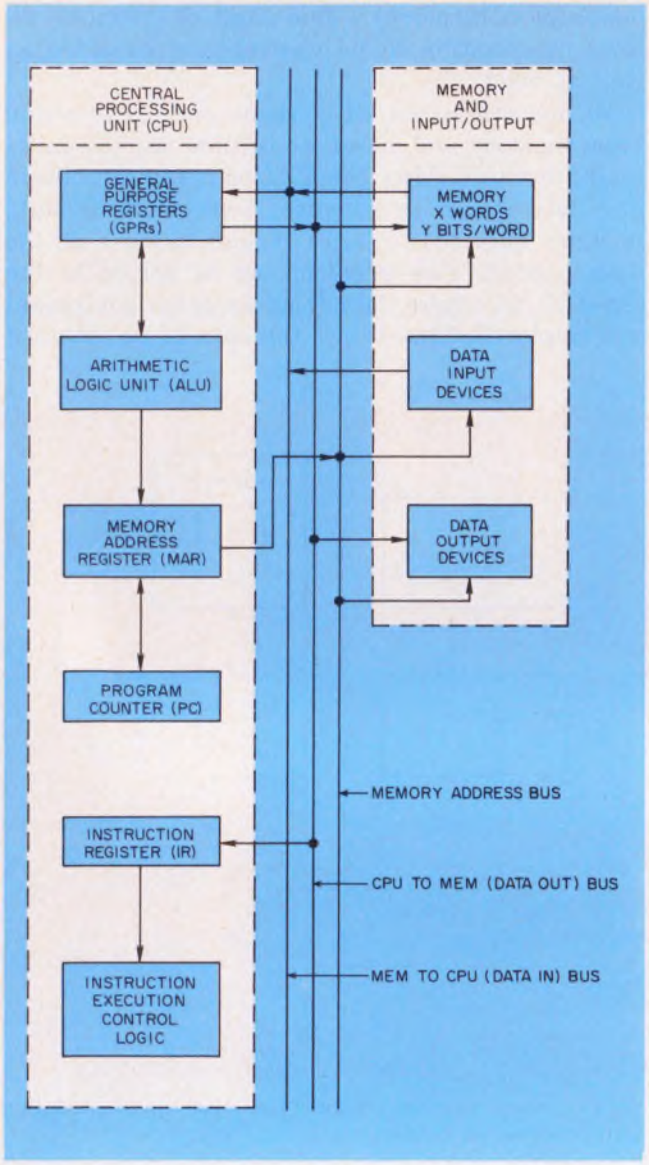
In operation, the CPU reads each instruction from memory and uses it to initiate various processing actions. Also, the CPU can rapidly obtain any data stored in memory. Sometimes, though, memory may not be large enough to store all the data needed. This problem can be solved at the *input ports*, where data from external equipment can be stored. This allows the data to be obtained by the CPU at high rates of speed and in large quantities.

A μP also requires *output ports* through which it communicates its results to the outside world. The output may go to a display or peripheral device, or it may consist of control signals that direct another system.

Throughout the operation, the CPU is very much the system's supervisor. The μP controls the functions performed by other components. It fetches instructions from memory, decodes their binary contents, and executes them. During the execution of instructions the μP references memory and the I/O ports as necessary. It also recognizes and responds to various externally generated signals.

Microprocessor architecture

A μP must incorporate various functional units if it is to properly supervise and manage the operations of a system (Fig. 3). Besides control



3. **The internal structure of a μP**—its architecture—resembles that of a conventional computer. Three busses are generally needed to provide communication among the μP, memory and I/O devices.

circuitry, a μP typically has an ALU and a number of registers that provide temporary storage (see "Design Your Own Microcomputer," ED No. 20, Sept. 27, 1975, p. 72).

The *accumulator* constitutes the one essential general-purpose register. It can serve both as the source and as the destination register for operations involving some other register, the ALU, or memory. Other general-purpose registers often included in a μP can be used to store operands or intermediate data, thereby lessening the possibility of accumulator bottlenecks (see "Software for MOS/LSI Microprocessors," ED No. 7, April 1, 1974, p. 50).

Additional registers have dedicated uses. The *program counter*, for example, keeps track of program instructions by maintaining the *address* of the next instruction in memory. An address is the coded number that differentiates one memory location from another.

Table 1. Available software tools

Operating software:

- Customer application programs
- Binary loaders
- Relocatable binary loaders
- Operating systems
- Miscellaneous utility programs:
  - Math subroutines
  - I/O control subroutines
  - Paper tape copy and list programs
  - Etc.

Program development software:

- Assemblers
- Relocatable assemblers
- Paper tape editors
- Macroassemblers
- Compilers
- General-purpose microassemblers

Diagnostic software:

- CPU diagnostics
- Memory diagnostics
- I/O device diagnostics
- Software diagnostics:
  - Debuggers
  - Simulators

Each time the μP fetches an instruction it adds 1 to the program counter, thereby incrementing the counter so that it always "points" to the following instruction. The fetched instruction (in the form of a so-called operation code, or op code) goes to another dedicated register—known as the *instruction register*—and is decoded by internal logic.

The μP tackles each instruction in sequence. It proceeds from numerically lower memory addresses that give the instructions to be executed early, to higher addresses that give later instructions. However, the sequential order can be broken by a "jump" instruction, which directs the μP to a different part of the program.

The order can also be broken by a "call" instruction that gives rise to the execution of a *subroutine*—a program within a program. The subroutine usually consists of a series of instructions that must be executed repeatedly during the course of a main program.

Prior to its handling of a subroutine, a μP makes use of a storage area known as a *stack*, which may be either on the chip (a hardware stack) or in memory (a software, or *pointer*, stack). The stack is used to save vital μP information, such as the address in the program counter, while the subroutine is being executed. The information saved can then be used to resume operation of the main program once the subroutine has been executed.

Stacks can also be used to *nest* subroutines, in which case one subroutine can call another, and that one can call still another. The extent of this

capability is limited by the depth of the stack and its ability to store return addresses following each subroutine.

Interrupt and DMA: μP time savers

Most μPs allow for these kinds of I/O-transfer control techniques: program, program-interrupt and hardware. In the first two cases, used in most simple applications, the μP controls the transfer. In the third case, hardware external to the μP controls it. (See "Explore Microcomputer I/O Capabilities," ED No. 10, May 10, 1975, p. 114.)

When all I/O operations are under program control, all instructions to receive or transmit information are included in the program. Data are transferred whenever the corresponding instruction is executed.

However, considerable μP time can be conserved by the use of either program interrupts or direct-memory access (DMA)—a hardware control. Both allow a computer to devote most of its time to a long program, while simultaneously providing immediate response for shorter, more urgent functions (see "Increase Microcomputer Efficiency," ED No. 23, Nov. 8, 1975, p. 70).

The program-interrupt function provides what its name implies: the ability to suspend a running program to perform a higher-priority one. When the latter program is completed, the original one resumes.

One example of the usefulness of an interrupt is in printer buffering. Serial printers are often slow, about 10 characters per second. To print a line of characters without interrupt, the μP transfers a character to the printer, waits 100 ms until that character is printed and then transfers the next character.

This procedure repeats until all the characters in the line are printed. However, only a few microseconds are needed to transfer a character. So the μP spends most of its time waiting for the completion of print operations.

The program-interrupt feature eliminates this waiting time. Now the printer causes a program interrupt when it has completed a character, and the μP then executes a special subroutine. And while the printer is busy, the μP begins or continues the execution of other tasks (see "Printer Control," ED No. 25, Dec. 6, 1974, p. 74).

The direct-memory-access feature provides data-transfer rates that are higher than those possible with program-interrupt. DMA allows high-speed transfer of data directly between the memory and an I/O device. Memory cycles are taken from the μP for use by the I/O device that is transferring data.

Typically DMA is used to transfer blocks of words to memory. The I/O device supplies the memory address and data for each word to be transferred. It also contains the logic to increment addresses to succeeding words, count the number of words transferred and determine

Table 2. Employ addressing modes to specify data

Addressing mode	Processing required to load address into internal address register	Byte appearance of instruction	Comments
Immediate	Current value of PC indicates the op code and the digital information represented by PC + 1 is the data the op code is to perform its operation on.	op code K data K + 1 see comments K + 2 bit 0 7	Only one data byte is used except for mnemonic instructions CPX, LDS and LDX which use a second byte.
Direct	The current value of the PC indicates the op code. Increment the PC and then move the data from the location specified by PC + 1 to the address register.	op code K address K + 1 0 7	Two data bytes are used.
Extended	The current value of the PC indicates the op code. Increment the PC by 1 and transfer the data from the location specified by PC + 1 to the address register. Increment the PC again to PC + 2 and transfer the data from the location specified by PC + 2 to the address register.	op code K address K + 1 address K + 2 16 bits 0 7	Two data bytes are used.
Relative	The current value of the PC indicates the op code. Increment the PC by 1 and add the contents of the location specified by PC + 1 to the value of the PC after it is incremented again (PC + 2)	op code K displacement K + 1 0 7	One data byte used. This applies only for branch instructions.
Indexed	The current value of the PC indicates the op code. Increment the PC by 1 and add the contents of the location specified by PC + 1 to the index register.	op code K data from memory location K + 1 0 7	One data byte used.

when the transfer is complete.

With the availability of a host of software tools, a designer seeking to program microcomputer systems need not become enmeshed in the ONEs and ZEROs that make up the micro's inherent *machine language*. Properly used, the software tools can greatly speed development and reduce errors (see "Employ μP Software Tools Properly," ED No. 26, Dec. 20, 1975, p. 50).

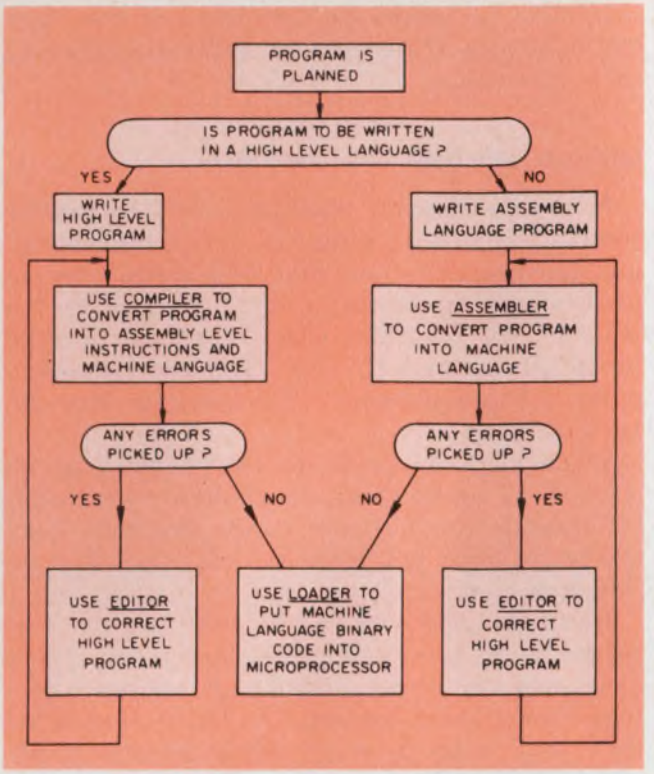
Vendors offer three kinds of software: operating, diagnostic and program-development (Table 1).

Operating software is the group of programs that run on the microcomputer under normal use. In a finished system the programs reside in ROMs or PROMs. The user must write his own operating software because it represents the logic design of the system or product being built. A vendor may supply some prepackaged items, such as mathematical subroutines, but the rest must be created to suit the application.

Diagnostic software, on the other hand, is a fixed package of programs supplied by the μP vendor. These test the microcomputer hardware and verify that the system is operating properly. There are also software diagnostic programs, such as simulators and debuggers, that test for proper program sequencing and functioning.

Program-development software represents the largest investment on the part of the μP supplier. It is this type of software that is usually referred to when one speaks of a vendor's "software support." (See "Experts Tell How to Hold Down High Cost of Processor Programs," ED No. 26, Dec. 20, 1975, p. 20).

For a designer, much of the start-up (development) effort is linked to the coding phase. Coding converts system programs, or algorithms, into instructions that can be loaded directly into memory (Fig. 4). The basic tools, themselves programs, typically require the use of time-sharing services or other computer facilities (see "MOS/LSI Microcomputer Coding," ED No. 8, April 12, 1974, p. 66).



4. **The binary code to be placed in a microcomputer's read-only memory** can be prepared with the aid of a compiler or assembler, and with an editor and a loader. The compiler permits programming in a high-level language, which is simpler to use than an assembly language.

Assemblers—a shorthand way to program

Of all the available software tools, few are more important to designers than the assembler, a program that converts symbolic mnemonic commands into the binary form needed by a microcomputer. The mnemonic commands themselves form an *assembly language* that offers a shorthand way of writing the binary instructions (see "Assembly Language for μPs," ED No. 26, Dec. 20, 1975, p. 58).

Generally, a single assembly statement generates a single storable command. The shorthand statements are grouped into fields designated by the following four names: *label, operator, operand* and *comments*.

The four elements, when combined on a single line, are separated from one another by some form of delimiter, such as one or more blank spaces, a slash or a comma. The comments field is used only to help others understand what the programmer intends; it will not generate any instructions for the microcomputer.

A sample assembler statement might appear as follows:

UPDAT	LDA A	NB	Begin the Loop
label	mnemonic	operand	comment

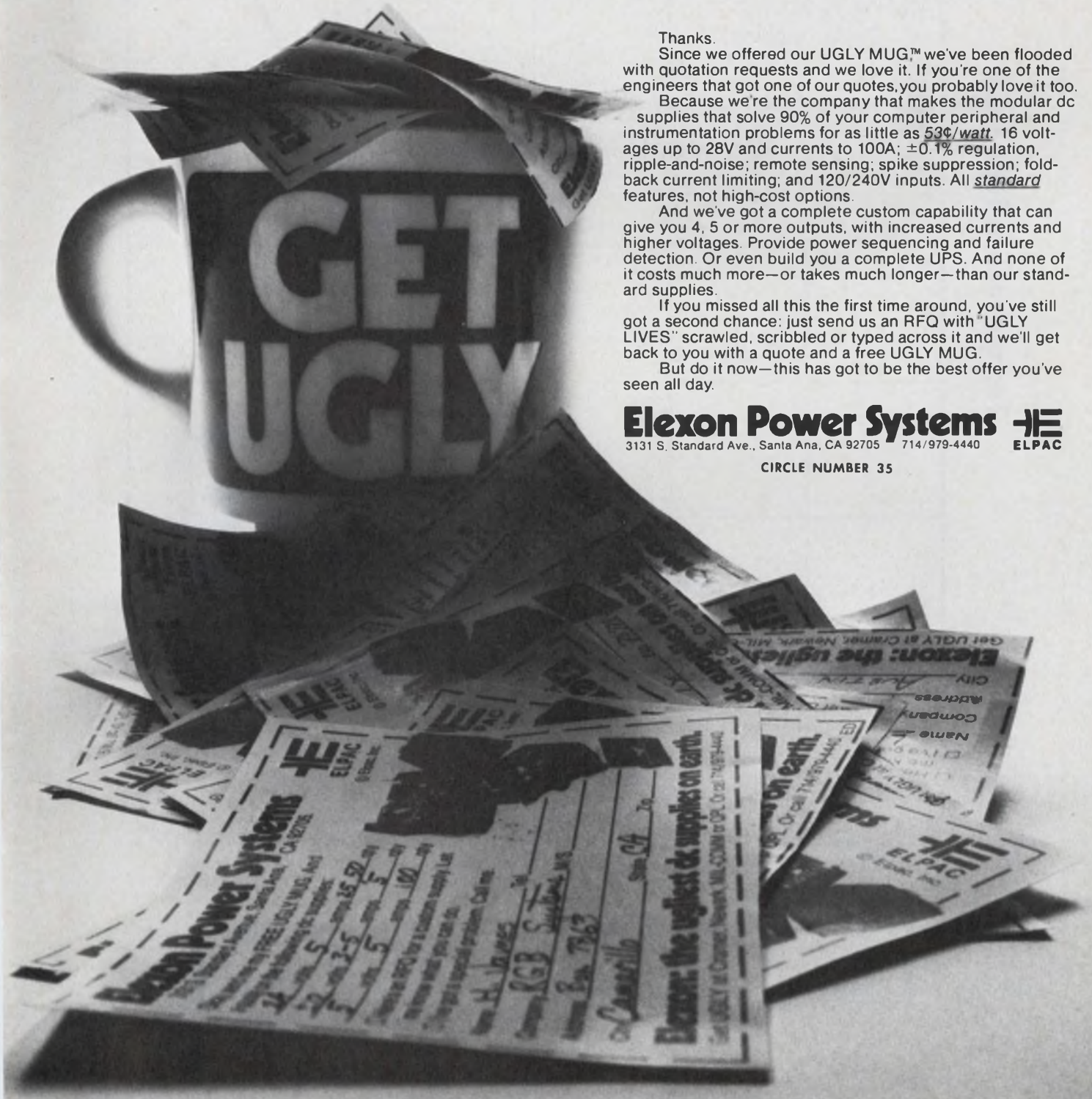
Labels help the programmer use *branch* commands; he can direct the program to go backward or forward to a specific statement in an assembly listing just by giving the statement's label. The mnemonic command LDA A instructs the μP to load the accumulator known as A with the data that will come from the location described by operand NB. The operand tells the μP to fetch data from the location called NB.

How data are addressed affects computing efficiency. Too long an address can slow the micro down. Too short an address can limit the number of words that can be accessed readily.

Common addressing modes appear in Table 2. ■■

The next article will appear in the May 10 issue and will discuss the 8080 μP.

OUR CUP RUNNETH OVER



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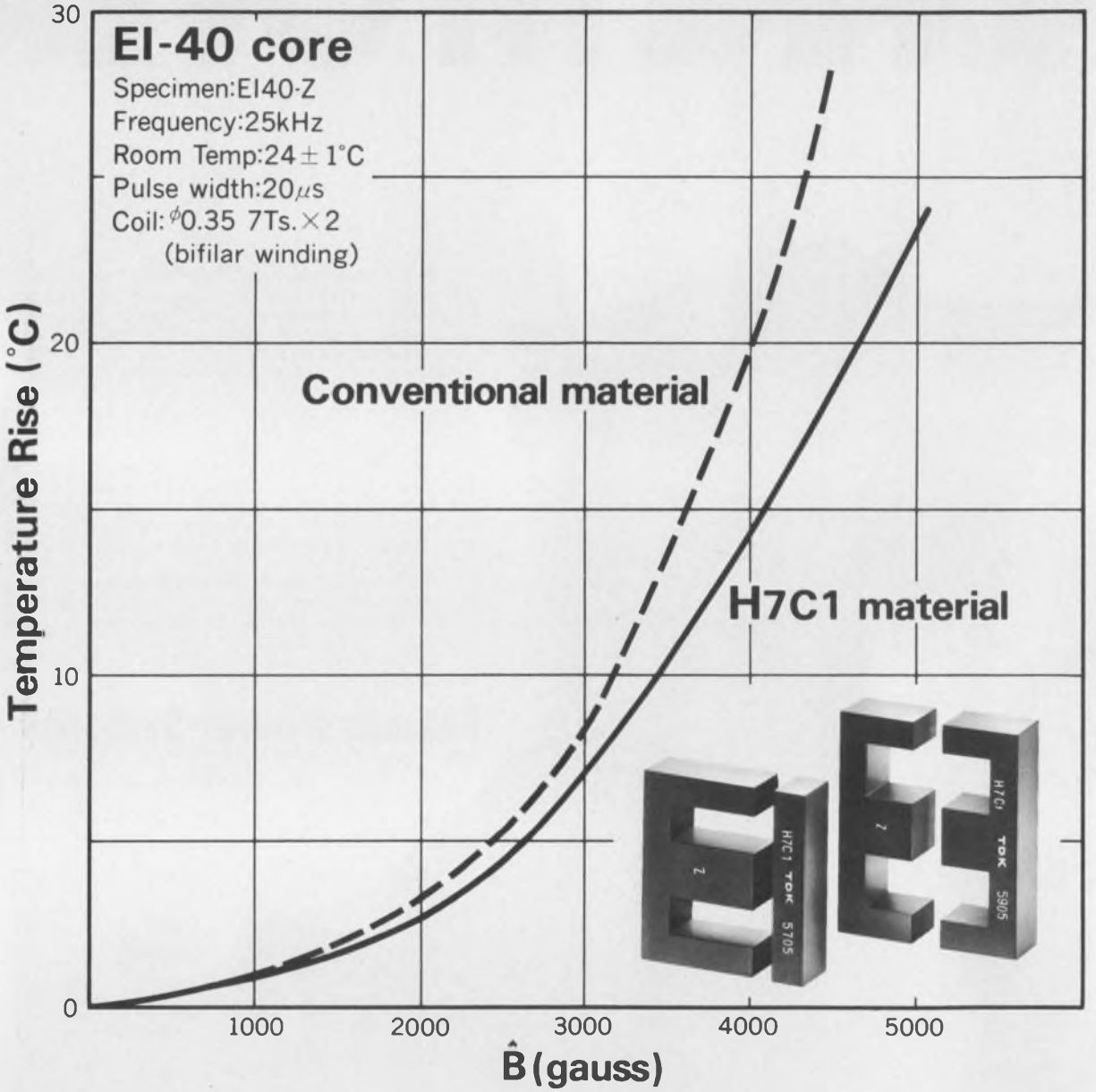

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Use FETs to switch high currents.

New types of MOSFETs and JFETs can handle current levels of several amps and have almost negligible drive-current requirements.

You can boost the efficiency of power-switching circuits by using large-area power FETs to handle currents of 2 A or more. High-power field-effect transistors offer switching speeds as low as 5 ns. They are, however, relatively new and still in the early stages of refinement.

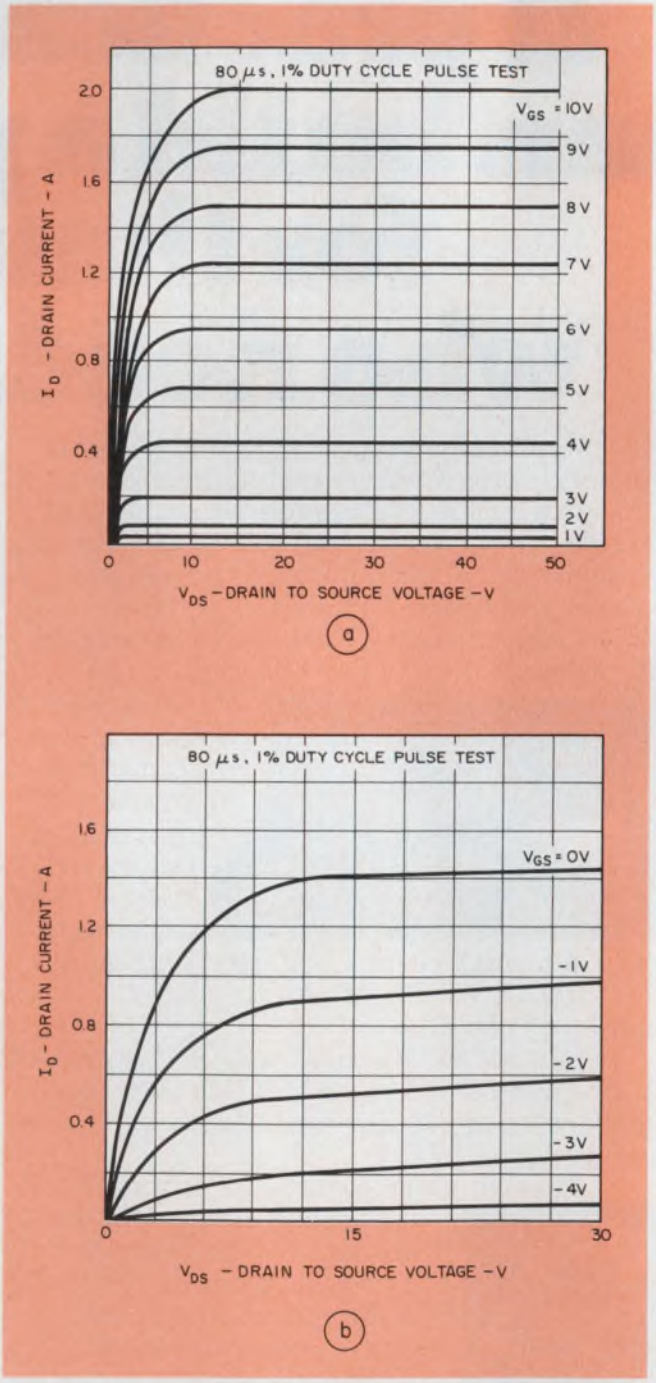
Traditionally, FETs have filled small-signal, low-current applications. Recent developments increased the current-handling capability through the use of VMOS (vertical MOS), VFET (vertical junction FET) and DMOS (double-diffused MOS, a cousin to VMOS) construction techniques. Standard power FETs are presently available from only a handful of companies—Siliconix, Teledyne-Crystalonics (Cambridge, MA) and such Japanese manufacturers as Sony and Nippon Electric.

Select the right type of FET

Two basic types of FETs are available—the enhancement mode and the depletion mode (Fig. 1). Enhancement-mode devices are normallv off, and turn on when the gate voltage is applied. On the other hand, depletion-mode devices are normally on when no gate voltage is present, and turn off when the gate voltage is increased. If off time is greater than several hundred milliseconds, depletion-mode FETs require dc level shifting and thus higher drive currents. Enhancement-mode devices, therefore, require less energy in slow switching applications than do depletion-mode FETs.

A typical enhancement-mode FET operates from a V+ supply and ground. Depletion-mode units, though, require a reverse-polarity gate drive, which may mean an extra power supply. This, in turn, means additional circuitry for many applications. Power JFETs are available only as depletion mode devices; enhancement-mode devices are not technologically feasible.

All power FETs have high values of beta (current gain)—with the gate current almost zero.



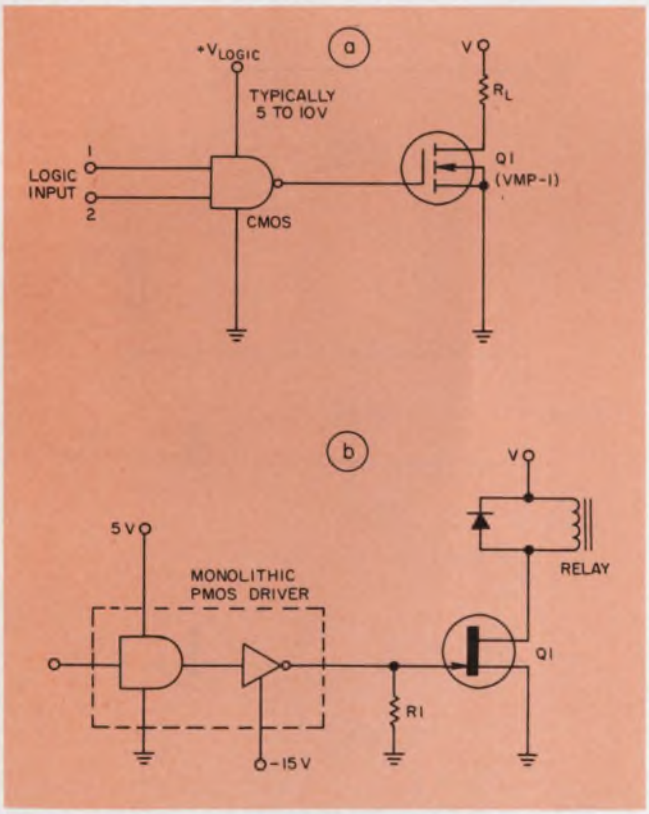
1. **Plots of drain current vs drain-to-source voltage** for power n-channel MOSFETs (a) and for n-channel JFETs (b) are similar to those of small-signal devices but drain currents of up to 2 A are possible.

Lee Shaeffer, Applications Engineer, Siliconix, 2201 Laurelwood Rd., Santa Clara, CA 95054.

Table 1. Comparison of power switching transistor specs

Technology	Typical Device No.	Output Characteristics (absolute max ratings)			Drive current for 1-A out	Drive voltage swing (V)	Typical ft (MHz)	t_{on} (ns)	t_{off} (ns)	at current (A)	Approx. price (100+)
		Power (W)	Current (A)	Voltage (V)							
Bipolar	2N6308	175	8	350	~250 mA	~1.0		600	2000	3.00	$5.00
Standard JFET	U295	5	1.5[1]	30	< 1 μA	10		35[2]	35[2]	.03	6.00
Vertical JFET (VFET)	2SK60	63	5	170	~100 μA	25	20			0.5	11.00
Vertical MOSFET (VMOS)	VMP-1	35	2	60	< 1 μA	10	600	5 typ[2]	5 typ[2]	1.0	5.50

1. Min I_{DSS} is 0.5 A.
2. 50-Ω pulse drive.



2. **Enhancement-mode MOSFETs require no extra components** to interface to CMOS logic circuits (a). N-channel JFETs, on the other hand, require an extra interface circuit to provide the negative gate bias (b).

Most of the gate current present is caused by leakage. With a power FET, a load of several amperes can be controlled by microamperes or even nanoamperes of steady-state drive current. This situation permits you to switch a load on or off from almost any point in a logic circuit without using specialized interface or drive circuits.

To interface a load—such as a relay—to logic gates, simply use the power FET. Connect the gate input of the FET to the logic-circuit output and place the load in series with the power supply, source and drain, with the source grounded (Fig. 2a). This type of interface can simplify many control problems, especially when CMOS logic circuits are used. Even a 1-A relay can be controlled directly by a microprocessor, just by using a power FET.

Depletion-mode devices can be used easily with PMOS circuitry because the negative supply is readily available. Fig. 2b shows an n-channel JFET driving a relay load. To turn off the current flow in the drain, make the JFET gate more negative than the source.

The pull-up resistor connected between the FET gate and ground keeps the turn-on time low, but increases the power consumption when the FET is off. And unless a high-speed drive circuit is used for the FET, the advantage of the

fast switching speed will be lost.

The high-speed, high-frequency capability of the FETs stems from the fact that they are majority-carrier devices. The carriers are swept through the channel by an electric field, rather than diffusing along a gradient of carriers, as they do in the base region of a bipolar device.

A bipolar device can't turn off until the base region is free of minority carriers. Since the FETs have none, they turn off faster. Schottky-diode clamps can eliminate the effects of excess carriers in bipolar devices, but they also lower the transistor's reverse breakdown voltage and require the collector-emitter saturation voltage to be kept low; that is difficult when there are high current levels in the collector.

On the other hand, carriers in a FET stop flowing the moment the electric field is removed, so the turn-off time is determined by external circuit capacitance and parasitic inductance. These stray reactances are minimized in some of the newer power devices because chip areas are kept small. Power FETs can switch currents of one amp or more in only 5 to 30 ns. Comparable bipolar devices require anywhere from 100 to 3000 ns to turn on and 200 to 3000 ns to turn off.

Switching applications demand efficiency

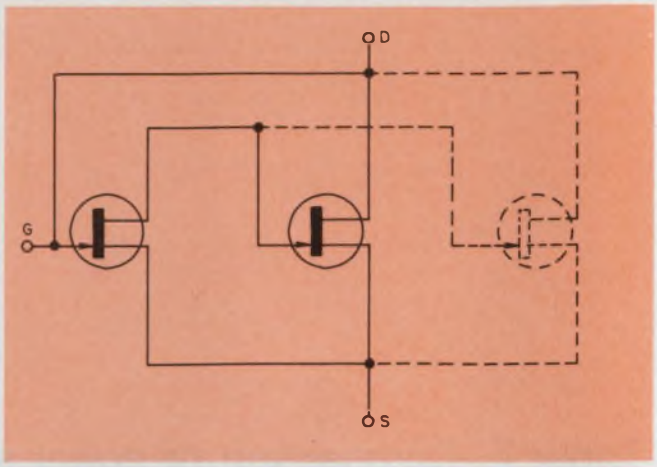
The power FETs are well suited for applications—in switching regulators, power supplies and Class D (switching) audio amplifiers—where a high switching rate is desirable and efficiency is limited by the rise and fall times of the waveform.

Limiting the switching speed is the dynamic gate-source and gate-drain capacitance. These capacitances slow down a medium or high-impedance driver and increase power consumption at high switching rates. Although the capacitances are usually quite small, the effect on a system designed for low power consumption can be significant.

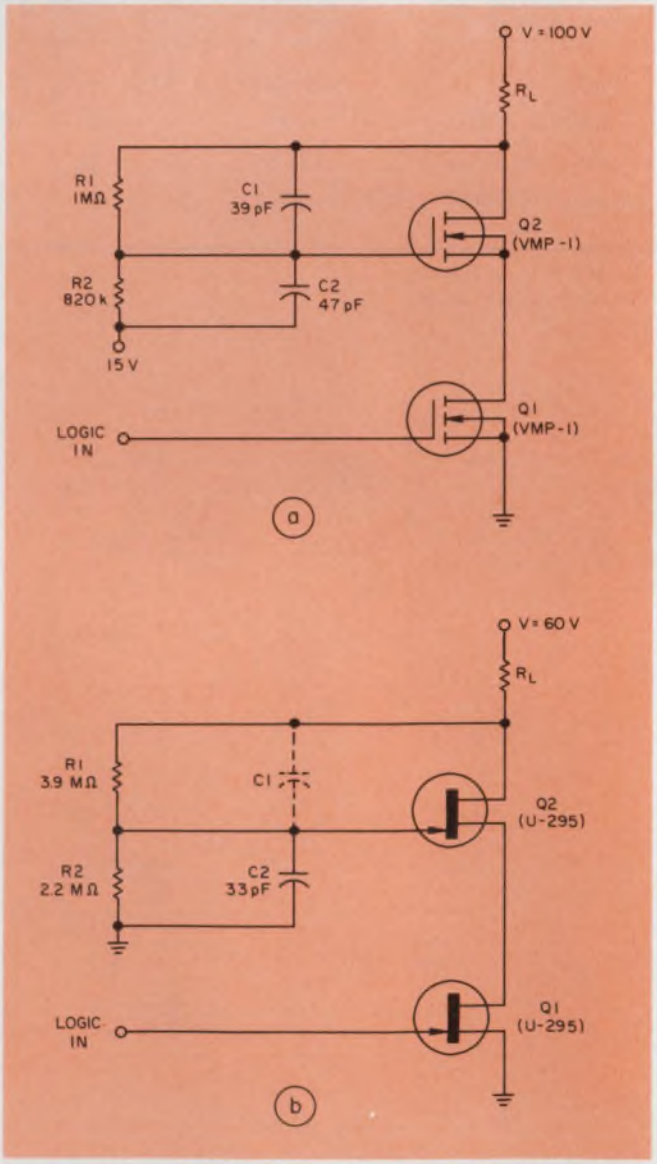
Calculating the effect of the capacitances is difficult since both the input capacitance (which appears on the data sheets as $C_{gs} + C_{gd}$, or sometimes as C_{iss}) and the feedback capacitances (C_{gd} or C_{rss}) are a function of both the gate-drain and drain-source voltages. Because of the Miller effect the nature of the load, resistive, capacitive or inductive, and the operating point of the FET also determine the feedback capacitance.

You can make a piecewise linear approximation by determining the circuit time constants at increments of V_{GS}. The calculations can be greatly simplified if you assume that the input and feedback capacitances are independent of V_{DS} (actually, they change relatively little for $V_{DS} > 3$ or 4 V).

It is easier, though, to find the switching times



3. **Paralleling power JFETs or MOSFETs** is simple because they draw negligible gate current and don't current-hog. The drain-source voltage drop can be very close to zero since FETs don't have any offset voltage.

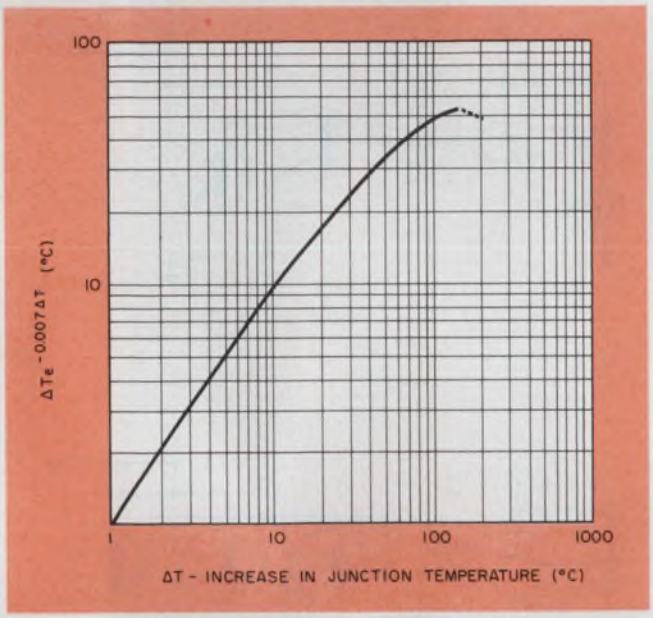


4. **FETs can be connected in series** for operation at higher voltages. Whether you use a MOSFET (a) or a JFET (b), the circuit to keep Q_2 ON is similar. Power dissipation, though, is low since very little current is needed to keep Q_2 ON.

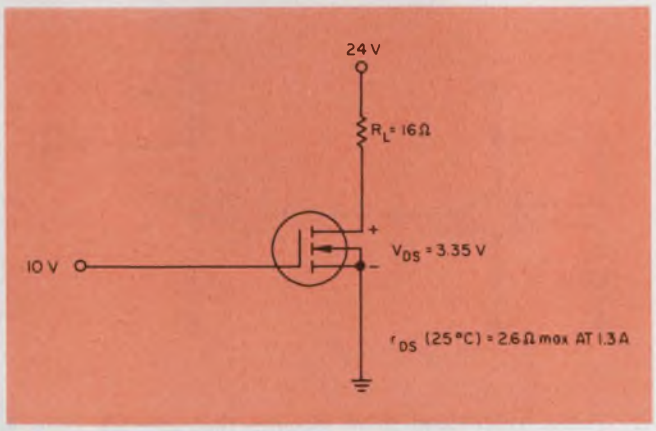
experimentally and then to add a safety margin. FET capacitances change only about 10 percent from lot to lot at the most, since capacitance is primarily a function of chip dimensions and layout and is not sensitive to process variations. Allowances for the worst-case driver spec can be added on top of that.

Even with medium-impedance drivers, such as the 4000 series CMOS, 1 A can be switched on in 50 ns and off in 60 ns when a vertical MOSFET is used. The typical drive circuit of Fig. 2a is all that's needed. In this circuit, the VMOS FET has an input capacitance of about 70 pF. If the CMOS supply increases to 15 V, switching times decrease by 30 percent.

FETs can be paralleled to boost the current level or lower the voltage drop. A low value of ON resistance can be obtained by simply connecting the transistors in parallel (Fig. 4). Even though JFETs are shown in the figure, MOSFETs will work equally well.



5. **This plot of $\Delta T\ e^{-0.007\Delta T}$ versus ΔT** is useful when you have to find the rise in junction temperature and you know the power dissipation at ambient.



6. **A typical ON condition for a MOSFET switch,** starting at a room ambient of 25 C produces an initial V_{DS} of 3.35 V. As the FET warms up, the V_{DS} increases.

Combine devices for higher performance

Since the FET is purely resistive, no current hogging occurs. Variations in individual FETs usually cause no more than a 20 to 30 percent imbalance—which is not serious because the tempco of the drain-source current is negative, and counteracts any current increases by increasing the drain-source resistance, r_{DS}.

If one device draws more current, its power dissipation will be higher, and its temperature rise greater. The temperature rise causes r_{DS} to increase, thus lowering the current.

Connecting FETs in series will increase the breakdown voltage of the new composite "FET" at the expense of a larger r_{DS}. Fig. 5a shows a typical MOSFET circuit; the circuit of 5b uses JFETs. Resistors R_1 and R_2 establish the dc gate voltage of Q_2 while C_1 and C_2 tailor the transient response of the circuit. Power dissipation can be kept low because R_1 and R_2 have high values and C_1 and C_2 are low.

C_1 and C_2 should be large enough to minimize effects caused by stray capacitance, and C_1/C_2 should approximately equal R_2/R_1. Both circuits shown in Fig. 5 are fast because C_1 and C_2 permit fast voltage transitions on the gate of Q_2. The bottom of the divider shown in Fig. 5a returns to a positive voltage rather than ground to ensure sufficient enhancement for Q_2 when power is applied. Otherwise, the drain of Q_2 only swings to within 10 or 20 V of ground to enhance Q_2 by 5 or 10 V. In Fig. 5b, current through R_1 can forward-bias the gate of Q_2, but that just lowers the ON resistance.

Temperature increases can cause problems

The positive tempco of $r_{DS(ON)}$, although beneficial, can cause problems under certain circumstances. For instance, when FETs act as switches, current through the ON device is almost constant. The longer the FET is on, the greater its temperature rise and the higher its ON resistance becomes. This resistance increase causes the voltage across the FET to increase, which increases the power dissipation and sends the temperature up higher.

The temperature can increase until the channel generates large numbers of excess carriers, which stabilizes the r_{DS}. However, in the process the junction temperature can easily exceed 150 C and thus cause reliability problems.

The ON resistance of most FETs changes 0.5 to 0.7%/°C. The worst-case r_{DS} increase at an elevated temperature can therefore be expressed

Table 2. Switching-circuit cost comparison

Circuit (a)		Circuit (b)		Circuit (c)	
Q_1	3.90	Q_1	6.00	Q_1	5.50
Q_2	4.00	Q_2	6.00	P.C. holes (3)	.06
C_1	.06	Q_3	6.00	Handling and insertion (1)	.10
					5.66
R_1	.05	C_1	.06		
R_2	.05	R_1	.05		
P.C. holes (12)	.24	P.C. holes (13)	.26		
Assembly (5)	.50	Assembly (5)	.50		
	8.80		18.87		

in terms of the initial resistance (at ambient) as:

$$r_{DS}\,(T_J) = r_{DS}\,(T_A)\,e^{0.007\Delta T},$$

where T_J is the junction or channel temperature and Δt is the difference between T_J and ambient temperature, T_A.

Power dissipation determines the temperature rise, and $r_{DS(ON)}$ sets the dissipation. The temperature rise can be determined in terms of the thermal resistance and power dissipation:

$$\Delta T\,e^{-0.007\Delta T} = I^2\,r_{DS}(T_A)\,\theta_{JA}.$$

This equation is the standard expression for the temperature rise of any resistor, except for the additional exponential term that represents the FET tempco. Once $\Delta T\,e^{-0.007\Delta T}$ is calculated, it can be translated into the actual temperature rise with the aid of Fig. 5. The change should not be permitted to exceed 52.6 C since actual junction temperatures will then rise above 150 C.

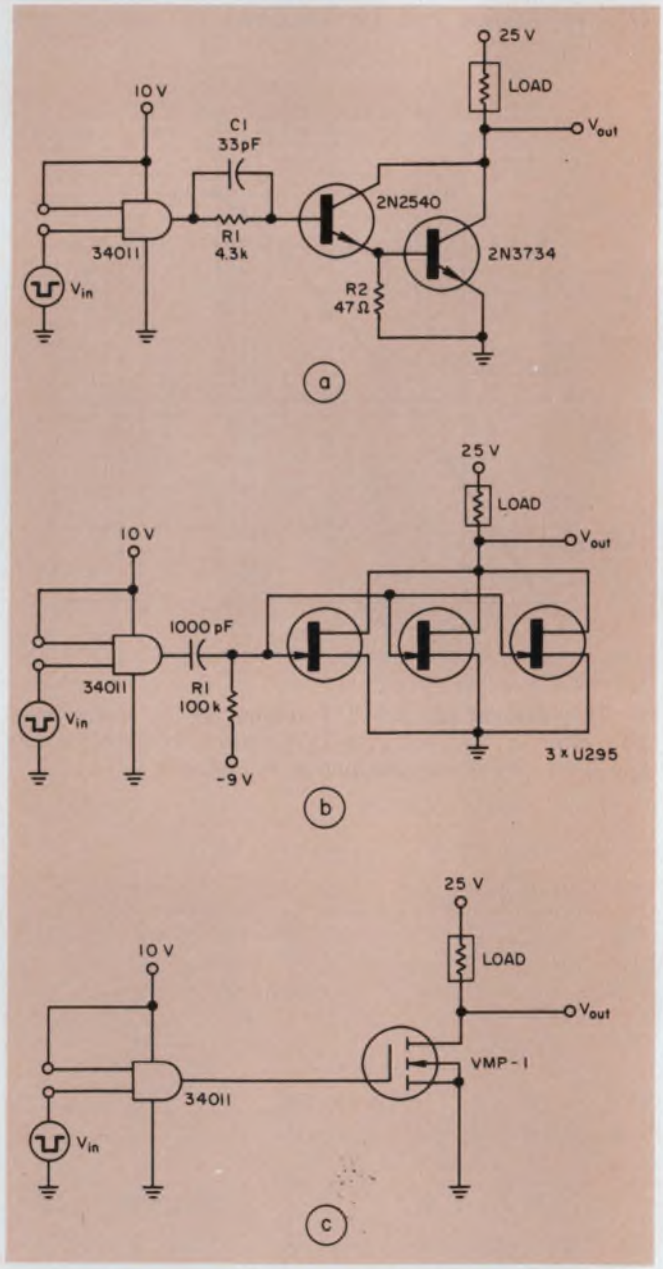
An assumption made in this analysis is that the load current remains constant as the voltage drop across the FET switch increases. Actually, the current will decrease slightly. If necessary do a second iteration to obtain better accuracy.

Be careful when you select the $r_{DS(ON)}$ value you use, since r_{DS} increases with I_{DS}. When a maximum r_{DS} is specified at a certain value of I_{DS}, it is valid for any value of drain current up to and including the specified I_{DS}. If the actual I_{DS} is higher, a new value of r_{DS} must be determined.

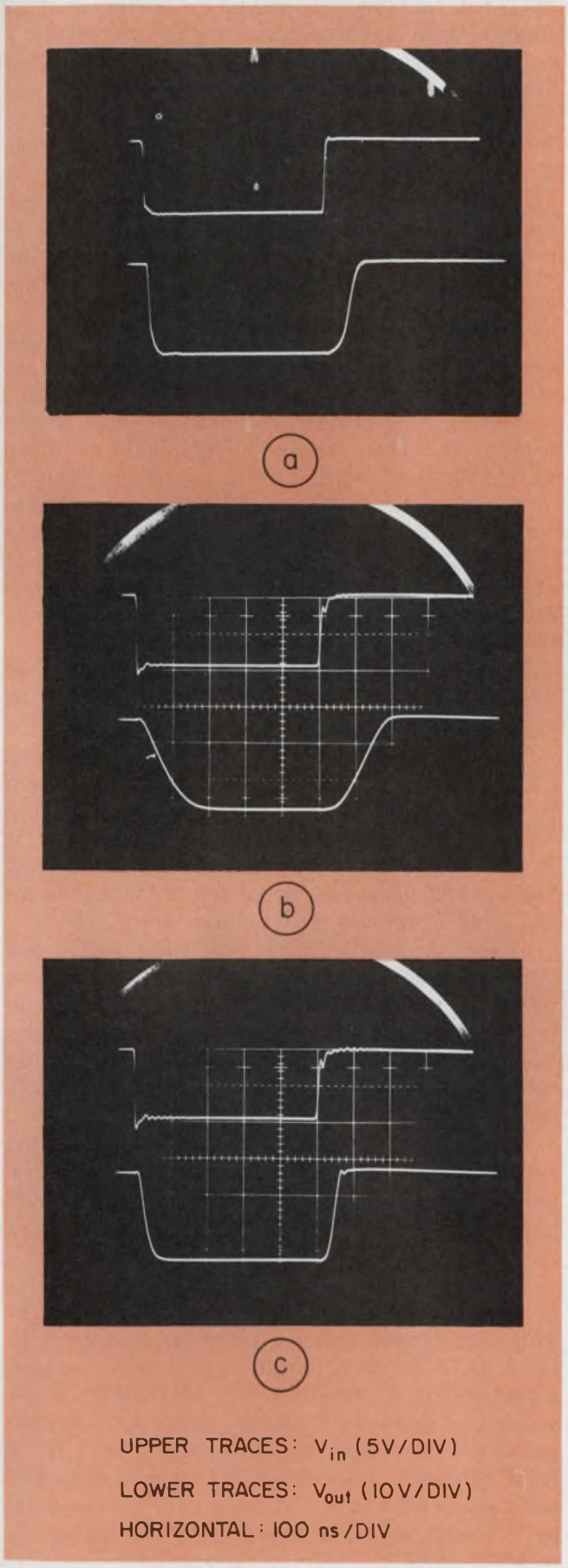
The θ_{JA} changes with temperature, too. Unless the θ_{JC} of the FET is specified as a function of temperature (and it usually isn't), the calculations are only approximate.

Put the calculations to use

The simple circuit shown in Fig. 6 has output characteristics similar to those of Fig. 1a. At an ambient of 25 C let's assume an i_L of 1.3 A and a V_{gs} of 10 V; thus r_{DS} is about 2 Ω. A typical worst-case value would be 30 percent greater, or 2.6 Ω, which redefines i_L as 1.29 A.



7. **Three typical-load drive circuits** that operate from a CMOS gate's output show that you can use bipolar transistors (a), paralleled JFETs (b) or a single MOSFET (c) to provide a 1-A, 500-ns pulse to a load.



8. **These scope photos show the actual performance** of the circuits described in Fig. 7. The circuit of Fig. 7b cannot meet the 100-ns switching requirement of the design example because of high internal capacitance.

Also, let's assume Q_1 is housed in a TO-3 case and mounted so that the θ_{JA} is 8.9 C/W. Then if the assumed values are substituted into the temperature change formula:

$$\Delta T\, e^{-0.007\Delta T} = (1.29)^2 \times 2.6 \times 8.9\ C/W$$
$$= 38.5\ C.$$

From Fig. 5 you can now find the actual temperature rise: $\Delta T = 68$ C. The junction temperature is then 93 C, well within maximum limits. The ON resistance, though, will increase to 4.2 Ω.

As a second example, let's decrease the load resistance to 12 Ω; the i_L then increases to 1.6 A and the ON resistance typically goes up to 2.4 Ω, but could reach 3.2 Ω. If the worst case r_{DS} is used, i_L becomes 1.58 A and $\Delta T\, e^{-0.007\Delta T}$ becomes 71 C. This value is not on the curve in Fig. 5. In fact, it will cause T_{JC} to increase above 150 C.

You can also work this problem backwards. If a 100-C maximum temperature rise is allowed, $\Delta T\, e^{-0.007\Delta T}$ is 50 C and θ_{JA} must be 6.25 C/W. To obtain the lower θ_{JA}, a larger heat sink must be used. Since the temperature rise is large, the ON resistance of the FET increases somewhat, causing the load current to decrease. These calculations are accurate to about 2 percent.

Now, let's look at a typical switch-design problem: A CMOS control system needs a 500-ns, 1-A pulse with a 10 percent duty cycle. To ensure that this pulse doesn't overlap similar pulses from other parts of the system, the total turn-on and turn-off times can't exceed 100 ns. The OFF voltage that the switch must block is 25 V, max.

There are three possible approaches to solving this problem—using a bipolar, JFET or MOSFET switch. Whichever approach is used, you must be able to answer these questions:

- Can a suitable device be found to provide the necessary voltage, current and power? (For this example there should be no problem.)
- Can the device be easily driven by the signal source? If the current and voltage-drive requirements of the switch are poorly matched to the impedance of the drive signal, voltage amplification and/or buffering will be necessary.
- Will the switching times be adequate? Data sheet values must be evaluated with respect to actual drive conditions to obtain optimum performance.
- Is the design cost-effective? Parts costs are not the only factor; don't forget to add insertion costs, board drilling and handling.

It goes together like this . . .

A medium-current high-speed bipolar transistor can meet the requirements of the design problem posed (Fig. 7a). The 2N3734 is a 30-V, 1.5-A transistor that is guaranteed to switch 1 A ON in 48 ns and OFF in 65 ns under specified drive conditions. A minimum base drive current

of 33 mA must be supplied and a buffer must be used between the MOS gate and the transistor.

The noise margin of a CMOS gate operating from a 10-V supply is 2.9 V and its current-output capability is at least 2.6 mA. For the gate to interface with the transistor, a buffer that has a current gain of 13 or more must be used. A 2N2540 provides the buffering with an ample margin and a good switching speed. When it is connected in a Darlington configuration with the 2N3734 to prevent the 2N3754 from saturating, free-air dissipation is about 250 mW.

A JFET can also be used to generate the pulses necessary to solve the design problem—but not at the required switching speed. Since the pulses are short, the JFET gate can be capacitively coupled to obtain the required negative drive (Fig. 7b). Devices with a $V_{GS(OFF)}$ of less than 10 V (such as the U295 or 2N6568) are suitable for the application. However, these JFETs have a guaranteed I_{DSS} of only 500 mA so at least two of them must be paralleled to obtain the 1 A pulse at 25 C. Since I_{DSS} drops at elevated temperatures, three JFETs should be used to guarantee 1 A.

The U295 has a maximum ON resistance of 2.5 Ω—but this is specified at a current of 10 mA. At 500 mA, $r_{DS(ON)}$ will be much higher.

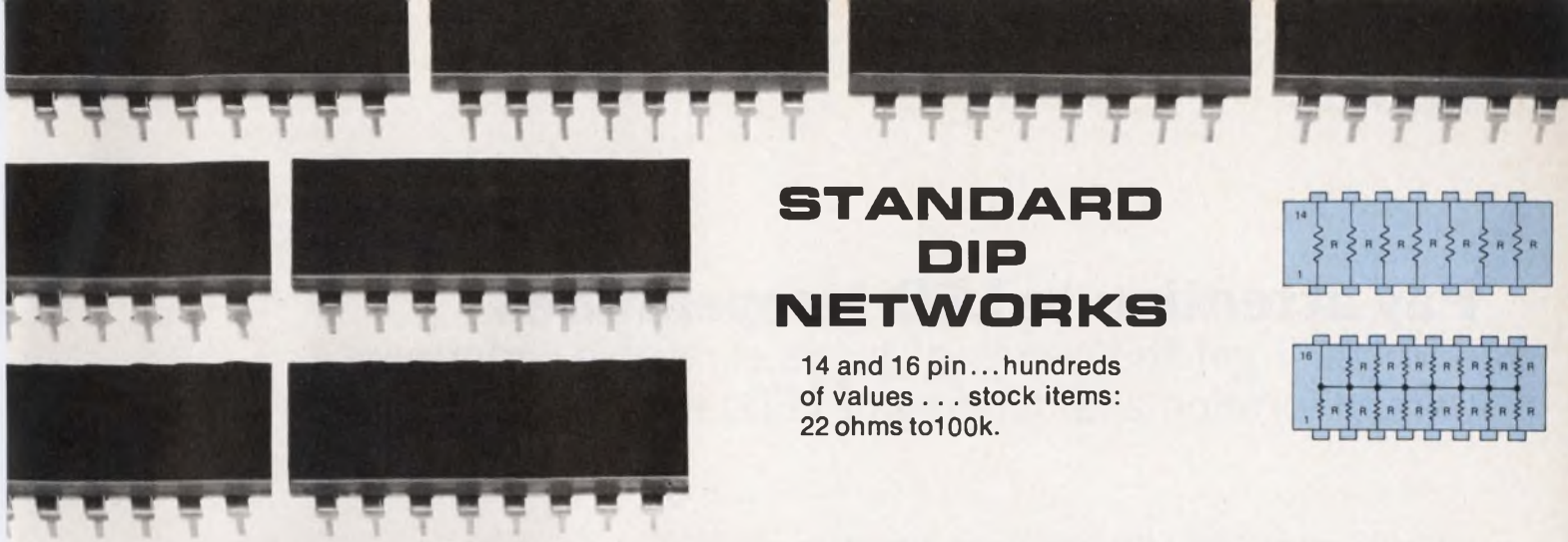
The ON voltage of the FET can be calculated by $[V_{DS}/V_{GS(OFF)}]^2 + 2V_{DS}/V_{GS(OFF)} = -I_D/I_{DSS}$. When $I_D = I_{DSS}$ and $V_{DS} = -V_{GS(OFF)}$, you can find $V_{GS(OFF)}$ from the manufacturer's curves, and it is typically about −4.5 V. A 30 percent guard band would make V_{DS} equal 5.9 V, which is an excessive worst-case ON voltage drop.

Three paralleled JFETs, operating well below their pinchoff knee, will do the job. When you solve the previous equation for V_{DS}, the drop can be found to be 2.4 V, maximum. Power dissipation is about 150 mW and if θ_{JA} is specified as 150 C/W the ΔT (using the curve of Fig. 5) is only 25 C.

Resistor R_1 is connected to +9 V since this voltage is the average that appears on the JFET gates. However, because of the high combined gate capacitance of the JFETs, this design does not meet the 100-ns switching requirement.

The third possible solution to the problem is to use enhancement-mode n-channel MOSFETs (Fig. 7c). These devices interface directly with the 0-to-10-V CMOS output. The most important consideration is whether the MOSFET switch will pass the required current with a 10-V gate voltage. (More may be required.) The VMP-1 from Siliconix is specified for a maximum ON resistance of 2.5 Ω at 1 A with 10 V on the gate, so it should perform well. Power dissipation is only 250 mW.

All three circuits are compared in Fig. 8 for input and output performance and in Table 2 for assembly and parts costs. ■■



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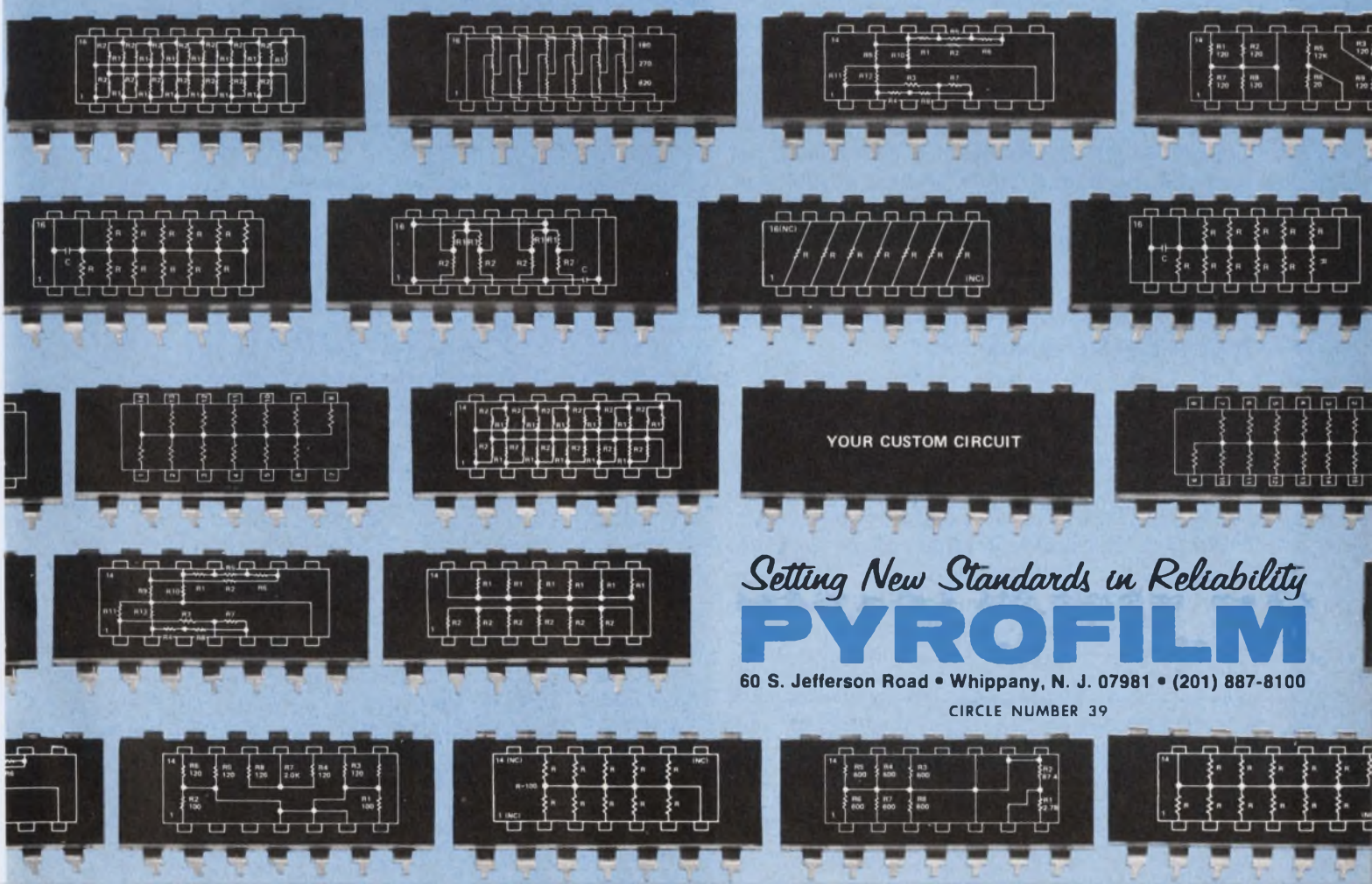

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Plastic-encapsulated LED displays are very reliable, but they have temperature limitations that are often overlooked. To avoid trouble, the design engineer must pay careful attention to the manufacturers' specs.

A typical LED consists of a GaAsP or GaP chip mounted on a substrate with a wire bond from the top of the chip to a metallized trace on the substrate. The entire assembly is encapsulated in epoxy. When the temperature changes, the different materials of the assembly expand and contract at different rates.

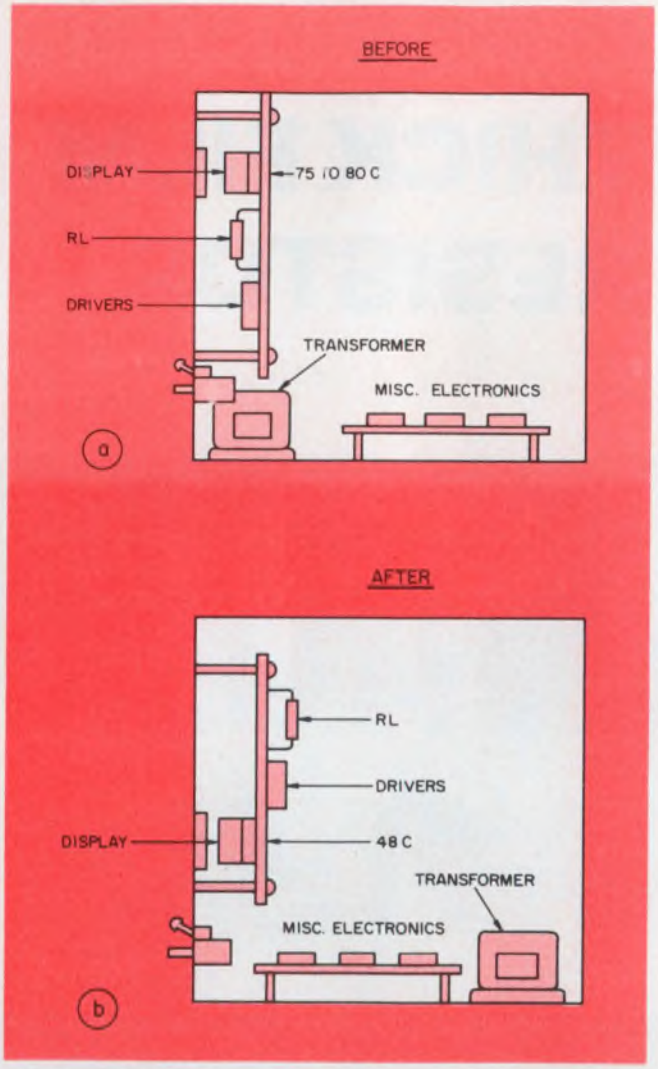
Material constraints—obviously only clear or translucent epoxies can be used—prevent the use of fillers to adjust expansion coefficients between epoxy and substrate. Thus thermal excursions cause movement and mechanical stresses that can damage wire bonds—the least robust parts of the assembly.

Generally, temperature excursions below −20 C are not recommended because of the unique thermal stresses produced; reliability below this temperature is predictable only under closely controlled conditions. In any event, LEDs should not be operated beyond a manufacturer's published limits except under scrupulously monitored test conditions, preferably after the manufacturer has reviewed the system and agreed in writing.

Since equipment rarely operates in this low temperature range, most thermal-design problems occur at temperatures above 25 C.

The effects of high temperature

When current at normal operating levels is passed through a LED, the temperature at the junction increases almost linearly with the current. Also, as the ambient temperature goes up, the internal operating temperature of the equipment increases. The ambient temperature, the LED current or a combination of both must be limited to prevent damage. Since a reduced drive current decreases the luminous intensity of LEDs, the better solution is to limit the ambient temperature, which tends to raise the LED's intensity.

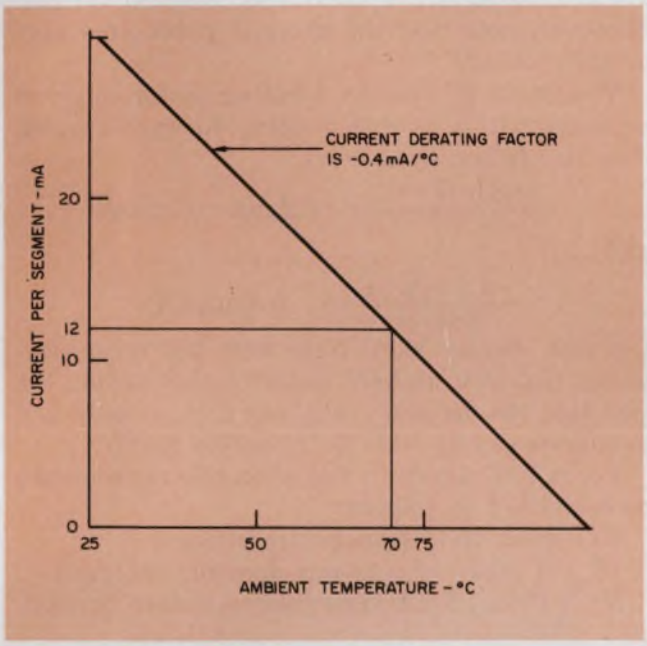


1. **Careful rearrangement of heat-generating components** reduces the ambient temperature in the vicinity of the LED display from over 75 to about 48 C.

Unfortunately, lowering ambient temperature is more difficult than reducing drive current. Often both must be changed to obtain a safe operating temperature.

For example, consider this case. A manufac-

Robert Woods, Product Reliability Manager, Litronix, 19000 Homestead Rd., Vallco Park, Cupertino, CA 95014.



2. **The current-derating factor is the slope of the line** plot of allowed maximum current (per LED segment) vs ambient temperature.

turer of measurement equipment used seven-segment numerical displays made up of 0.6-in.-high LEDs driven at 25 mA per segment. Abnormally high failure rates occurred after only a month of operation.

A study of thermal patterns in the system revealed that the temperature close to the displays ranged from 75 to 80 C although the ambient temperature in the cabinet averaged only about 30 C, which is well within the LEDs' ratings. The drive currents of 25 mA were also within the ratings.

Drivers and load resistors for the LEDs were mounted directly below the display. The unfortunate layout of parts trapped heat in the display area and raised the temperature to over double that of the average ambient (Fig. 1a).

To improve the temperature distribution, the load resistors were moved to the back of the PC board above the display, and the area above the board was opened up to assist the convection of air (Fig. 1b). The display LEDs were moved about 2 mm closer to the panel to allow its large area to carry away more of their heat. Also, a transformer was moved from the front of the cabinet to the back. Finally, the display drive current was reduced (derated) to 20 mA per segment with only a small sacrifice in brightness.

These steps reduced the hot-spot temperature to about 48 C, and failures almost disappeared.

Temperature derating curves are based on the LED's diode-junction temperature. The heat generated at a junction must eventually be dissipated into the ambient air at a rate that depends upon the air temperature, which must be carefully determined. The best method uses thermocouples mounted directly on the board that holds the displays—preferably mounted between two adjacent displays or under a display. A number of readings taken at various points will allow mapping of the hot spots and temperature gradients.

Derating LED displays

As an example of how to derate LEDs for use at elevated temperatures, let's use the Litronix DL-747 seven-segment, decimal-point display. Two LED chips are connected in series to make up each segment; a single chip serves as the decimal point. The display's pertinent specs are as follows:

Power dissipation at 25 C ambient	960 mW max
Derating factor from 25 C	−12.8 mW/°C
Storage and operating temperature	−20 to 85 C
Continuous forward current (total)	240 mA
(per segment or decimal)	30 mA
Forward voltage per chip	2 V_{max} at 20 mA

Let's assume the display might be exposed to a maximum ambient of 70 C in its immediate vicinity. This temperature is 45 C higher than the value (25 C) at which the specs allow a maximum power dissipation of 960 mW; thus the unit must be operated at a lower power to avoid failures. Since a LED's forward voltage doesn't change substantially over its operating range, its current becomes the controlling factor that must be reduced, or derated.

The first step is to determine the forward-voltage value, V_F, that the manufacturer used to establish the power rating. It's not necessarily the maximum forward-voltage; many manufacturers include a safety factor. For the DL-747, V_F is

$$\frac{960\ \text{mW}}{240\ \text{mA}} = 4\ \text{V}.$$

This value is merely a working number for calculation purposes; for the DL-747, it happens to equal the maximum forward voltage of the two series-connected chips that make up each display segment. The chips and decimal point are each rated at 2-V maximum forward voltage. However, note that the decimal point uses only a single chip.

The power-dissipation derating factor can now be converted to a corresponding forward-current derating factor as follows:

$$\frac{-12.8\ \text{mW}/^\circ\text{C}}{4\ \text{V}} = -3.2\ \text{mA}/^\circ\text{C, total,}$$

and

$$\frac{-3.2\ \text{mA}/^\circ\text{C}}{8\ \text{parts}} = -0.4\ \text{mA}/^\circ\text{C}$$

for each display part. Note that the seven segments plus one decimal point total 8 parts; the fact that the decimal really has a V_F of only 2 V maximum merely adds to the safety factor.

For a 70-C ambient, the allowable current can be calculated as follows:

$70 - 25 = 45$-C temperature increase
$45 \times (-0.4) = -18$-mA derating required
$30 - 18 = 12$-mA allowable maximum current.

When brightness rules

But what if 12 mA doesn't provide the brightness level required, and instead, what is needed is the brightness that 22 mA generates? One approach is to use a pulsed power source with a duty cycle of less than 50 percent.

It is generally agreed that the common LED materials appear significantly brighter when pulsed than when they are dc-driven by the same average current. Let's assume that the DL-747, for example, produces the brightness of 22-mA continuous dc with a pulsed drive current that has a 108-mA peak and a duty cycle of one sixth.

However, the average range of the pulsed current is only $108 \div 6 = 18$ mA. The allowable ambient for the pulsed drive is 55 C, hardly the original target value of 70 C.

But then, design engineering calls for many compromises. Perhaps a better arrangement of components, more efficient circuitry or improved cooling could lower the ambient. Or perhaps 20-mA brightness will do.

LEDs will do their part by offering lifetimes well in excess of 100,000 hours, if operated within specs. ■■

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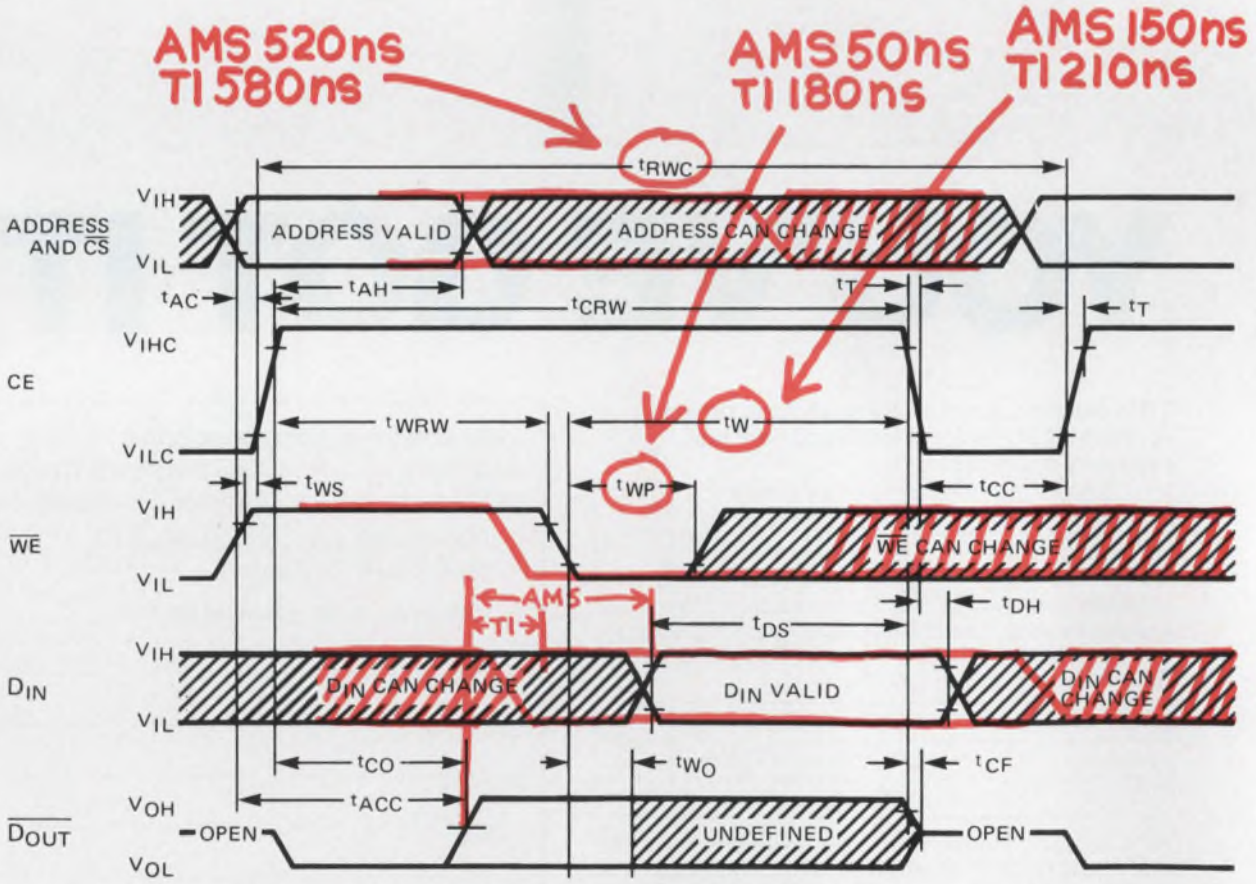

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t_W	$\overline{WE}$-to-CE OFF Time	150	210	200	210
t_{DH}	D_{IN} Hold Time	0	40	0	40
t_{DS}	D_{IN}-to-CE OFF Set Up Time	150	210*	150	210*
min	RMW cycle	520	580	580	600
t_{mod}	@ min cycle	20	20	80	20
t_{mod}	@ TI's min cycle	(580 ns) 80	20	(600 ns) 100	20

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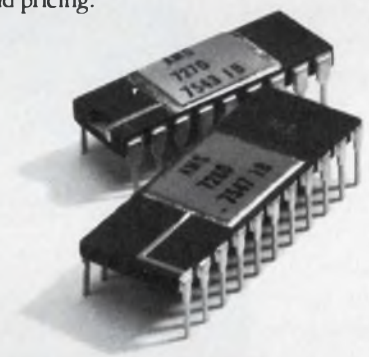

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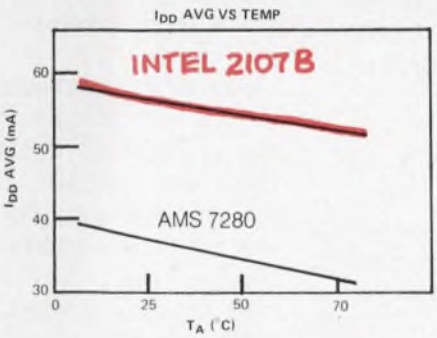

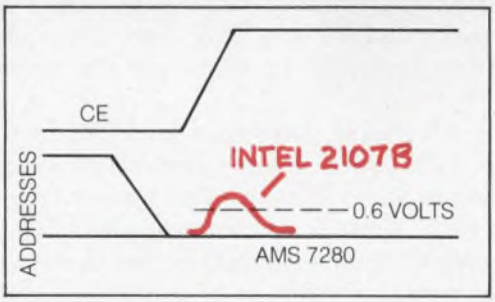

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Teitaro Hiraga of TDK Speaks On

Everybody is in favor of creativity. Nobody will vote against it. We all want our engineers to develop great products. But how do we get them to do it?

I feel that one of the most important factors in developing creativity is the atmosphere you provide. Of course, there are some individuals who are constantly driven by a creative urge. These are rare people who will create, no matter what you do with them. You can keep them in a dungeon, and when they emerge, they will have developed something great.

But for most of us mortals the environment we work in can have a profound effect on our performance. So the question becomes: What do you do to the environment if you want engineering creativity? In my opinion the most important ingredient—but not the only one—is difficulty. You must challenge your engineers with difficulties. You must pose genuine problems that pose a real challenge. You must set difficult—but achievable—design goals.

An example of this took place a few years ago when Sony acquired the exclusive rights in Japan to duPont's Crolyn tape for video magnetic recording. That was a severe blow because Crolyn, a chromium dioxide tape, was clearly superior to conventional ferrite tape in many ways—and we have a large stake in that business.

We threw this challenge to our engineers. We wanted tape that would be superior to Crolyn and we challenged our engineers to develop one though it looked very difficult. In time, we were successful. That was fortunate because, normally, when you mix two materials, their inferior features tend to multiply and their desirable qualities diminish. In this case the reverse was true.

We developed Avilyn, a cobalt-absorbed iron oxide tape with many properties superior to chromium dioxide tape. The tape is an application of a surface anomalous phenomenon that may point to new directions in theoretical and experimental physics, so it's a significant achievement.

This brings us to the second important ingredient in the creative environment. It's essential to share the pleasure of success with your engineers.

Pleasure-sharing is something you can't quantify; you can't measure it. But it's important. I try to create the kind of spiritual climate that shows my engineers I'm one of them. I share their successes. And I share their disappointments.

My own background is as a research engineer so it's not difficult for me to feel for them. If you can develop this feeling, if you can convince them that you are one of them, your engineers will apply themselves with astonishing vigor to any reasonable challenge you confront them with. But you must show them that you are on their side, that you are with them.

There's more to this challenge business than might appear on the surface. We want to encourage our engineers to challenge commonly accepted ideas. That's the only way to get breakthroughs. We want to encourage them to go down different and untrodden paths, even if the chances of discovering something there are slight. They learn, when they see a little bit of something on these strange trails, to jump on it.

Creating the Creative Atmosphere

We encourage our engineers to take risks. That's more exciting and more interesting for them.

When the engineer takes risks, he works harder. He finds his job more stimulating. He knows he is less likely to succeed. But we encourage him not to worry about failure. He knows there's no shame in failing if the challenge is tough. But when he succeeeds, the success is usually big. When one of these risks pays off, it's a grand payoff. Our reward is great. And the engineer's reward is great, too, because we share his joy with him.

But that's just part of it—that psychic reward. There's also more tangible evidence of our appreciation for his success. When an engineer in a research department develops a breakthrough product important enough so that we'll produce it in significant volume, we'll try to place that engineer in charge of its production. This is a very high honor for an engineer working for a manufacturing company.

But after a time that man may hunger for the intellectual stimulation of the laboratory again. So he can return to the research laboratory—in a higher position.

These are the critical ingredients in the creative environment—tough challenges with no stigma attached to failure; management's participation in an engineer's successes and failures; a significant reward for achievement. Those are the basic ingredients in this great dish, but we can add seasoning to enrich the dish and make it even more succulent.

I think engineers, like anybody else, should work in a bright and pleasant physical atmosphere. It should not be gloomy—like so many places in the world today. The physical surroundings should be so pleasant that a person should look forward to going to work and should anticipate with pleasure the time he spends there. One way we help provide this atmosphere at TDK is by taking advantage of a hobby of our president, Fukujiro Sono. His hobby is growing roses. He's really good at it and, in fact, has developed a new variety that has been named after him—the Sono rose.

Our laboratories are surrounded by lovely rose gardens. If you think engineers are insensitive to that, you are mistaken.

The roses aren't just outside, they're inside as well. When they are in season we cut them and have dozens of them decorating the interiors of the lab. Surprisingly, perhaps, this beautiful work of nature, brought into the surroundings of a "cold" laboratory, contributes almost magically to high spirits and an eagerness to accept challenges that appear insurmountable.

But we surround our engineers, not merely with the art of nature, but with the art of man as well. We have pictures around the lab, and other works of art. I believe that paintings, especially, are important in an engineering environment because they encourage engineers to look at things from different directions.

The greatness of great artists often comes from their ability to see things as others don't. Great engineers are that way, too. ■■

Who is Teitaro Hiraga?

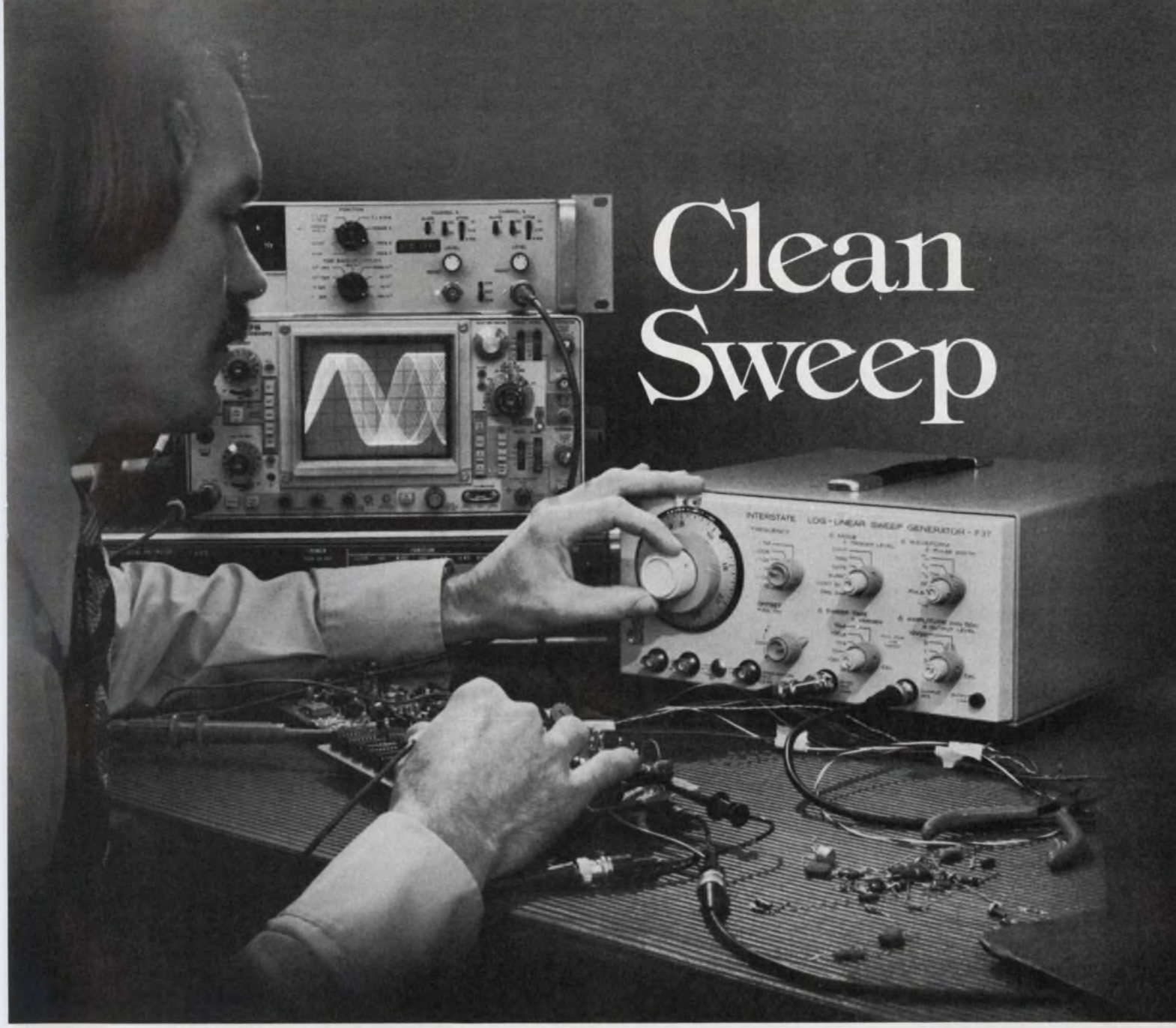
It should come as no surprise that TDK Electronics is one of the world's leaders in ferrite technology. Ferrites represent a significant part of TDK's sales volume, which, in 1974, exceeded 56-billion yen, almost $190-million. And ferrites have been a constant source of fascination to Dr. Teitaro Hiraga, TDK's managing director. In a recent paper, "A Prophetic View of the Future of Ferrites," Hiraga foresees vital roles for ferrites in industrial fields extending beyond electronics.

Hiraga earned his doctorate 15 years ago from the Tokyo Institute of Technology. His doctoral thesis covered disaccommodation or magnetic instability in ferrite materials.

But ferrites are not his only interest. He has a great love for oil painting and, though he feels he's not a good painter, he hopes to devote more time to it some day, perhaps after his retirement.

Travel and golf occupy much of his spare time. Since he has already covered most of the beaten and unbeaten tourist paths in Japan, he expects to spend more time playing golf.

Though his passion for the game is undeniable, he considers his skill less than enviable. Still, he accepts the challenge of getting the little ball into the distant hole and stoically bears occasional quips about disaccommodation and instability.



F37 Log/Lin Sweep Function Generator

Precision Performance. F37's frequency setability is more accurate to begin with, because you can set your desired frequency with one fully calibrated coarse/fine control. The fine-tune vernier is centered on the dial so the output frequency meets accuracy specs wherever the vernier is set. And for easy and accurate sweep limit settings, you just swing the sweep limit cursor around.

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CIRCLE NUMBER 44

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Schmitt-trigger circuit controls firing angle of SCR or triac power systems

A Schmitt-trigger circuit can be used to trigger SCR and triac power-control systems. The 7413 NAND Schmitt trigger contains two independent trigger circuits that can provide simple, economical circuits (Fig. 1).

Clipped half-wave voltage is applied to the A input of the Schmitt trigger (Fig. 2). Initially, capacitor C_1 charges to the logic-ONE level via resistor R_1. When the signal at A crosses the 1.9-V positive-going threshold voltage of the Schmitt trigger, the Schmitt's output changes to a logic ZERO. This forces capacitor C_1 to discharge through R_1 to the Schmitt's 0.9-V negative-going threshold, where its output goes back to logic ONE to recharge C_1 and repeat the discharge cycle of the capacitor. The cycling continues as long as the input voltage to input A remains above the 0.9-V threshold level.

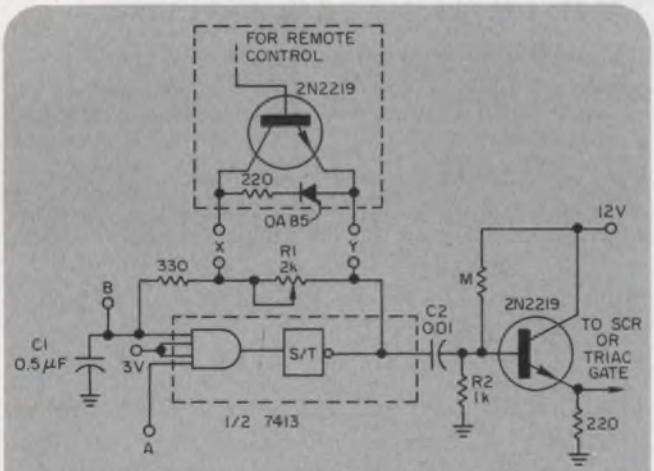
The output signal, Y, is differentiated by R_2 C_2 and becomes a series of positive-pulse bursts that can be used to trigger an SCR or triac. The timing of the position of the first pulse, t, of each of these bursts is determined by the discharge time of C_1. Control of resistor R_1 can vary the position (phase angle) of this first pulse, which would control the firing time of the SCR or triac.

For full-wave control, a full-wave voltage, rectified and clipped, would be applied to A; thus trigger pulses would be generated for both halves of the ac-power cycle.

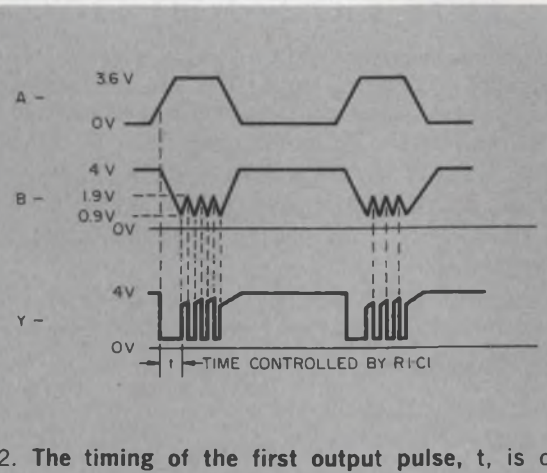
To operate with remote control, resistor R_1 located between points X and Y, could be replaced with the circuit shown in the dotted box (Fig. 1). Controlling current applied to the base of the 2N2219 transistor would vary the discharge time of C_1. The charge path for C_1 would be via the 220-Ω resistor and the series diode. In a closed-loop control system, the control current could be derived from the driver output of the error amplifier.

F. B. Chowdhury, Saha Institute of Nuclear Physics, 92, Acharya Prafulla Chandra Rd., Calcutta-9, India.

CIRCLE No. 311



1. **A Schmitt SCR or triac firing circuit** can be remotely controlled by replacing R_1 with the circuit in the dotted box.



2. **The timing of the first output pulse,** t, is determined mainly by the R_1C_1 time constant as C_1 discharges from a logic-ONE level to the first 0.9-V threshold.

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Another Super-VOM from Triplett with 50 ranges, 1½% DC accuracy... only $130.

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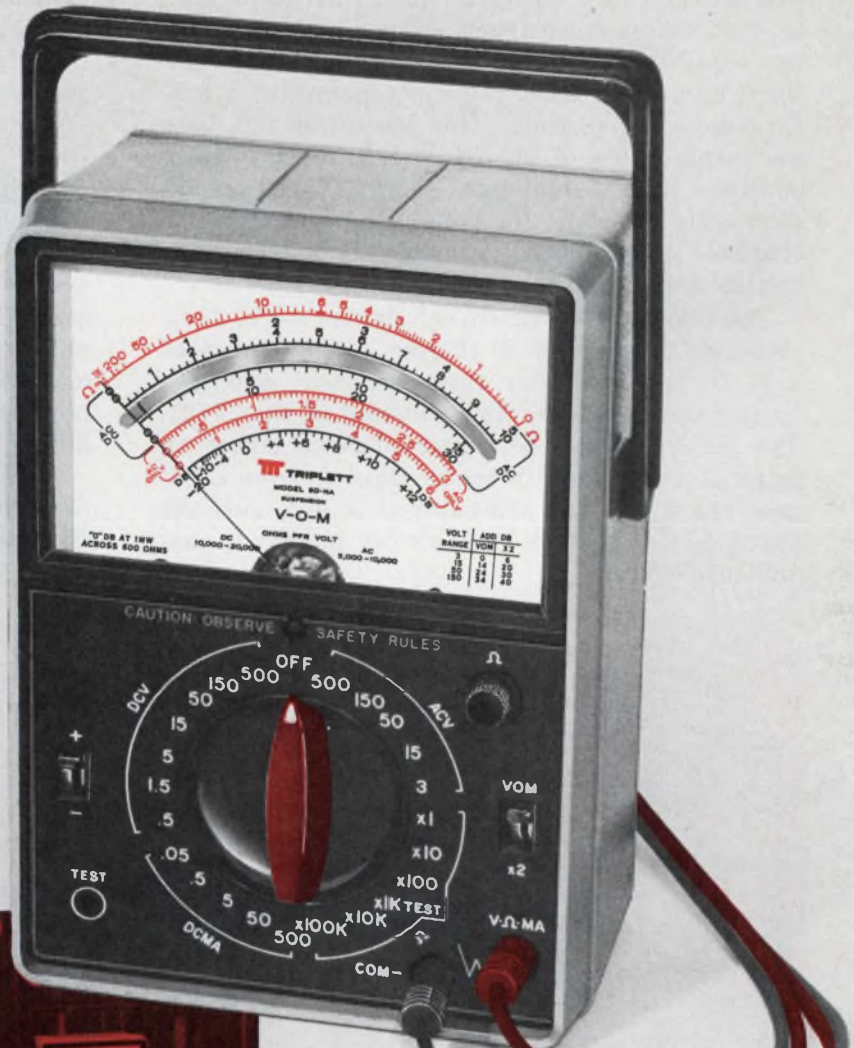

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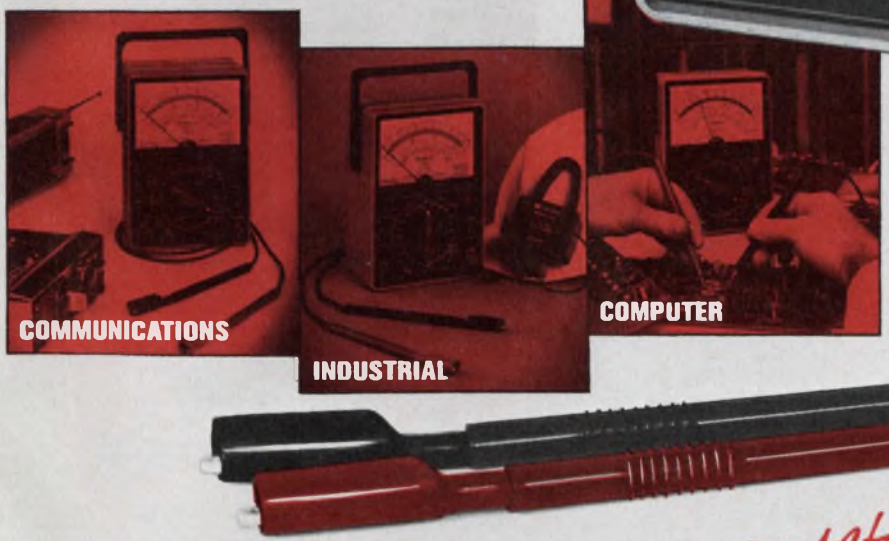

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CIRCLE NUMBER 45

High-voltage pulse generator offers variable delay and only 3-ns jitter

Tubes continue to be the most reliable devices for delivering high-power pulses to poorly matched loads—where reflections or other transients might destroy a semiconductor driver. Thyratron tubes such as the 2D21 have been used in the past; however, a large amount of jitter—approximately 100 ns—is generally encountered because of the thyratron's inherent stochastic delay in ionization. This limitation has been overcome by use of an EG&G Krytron cold-cathode tube with a solid-state predriver and associated logic circuitry for construction of a multichannel, high-voltage variable-delay generator having only 3-ns jitter (Fig. 1).

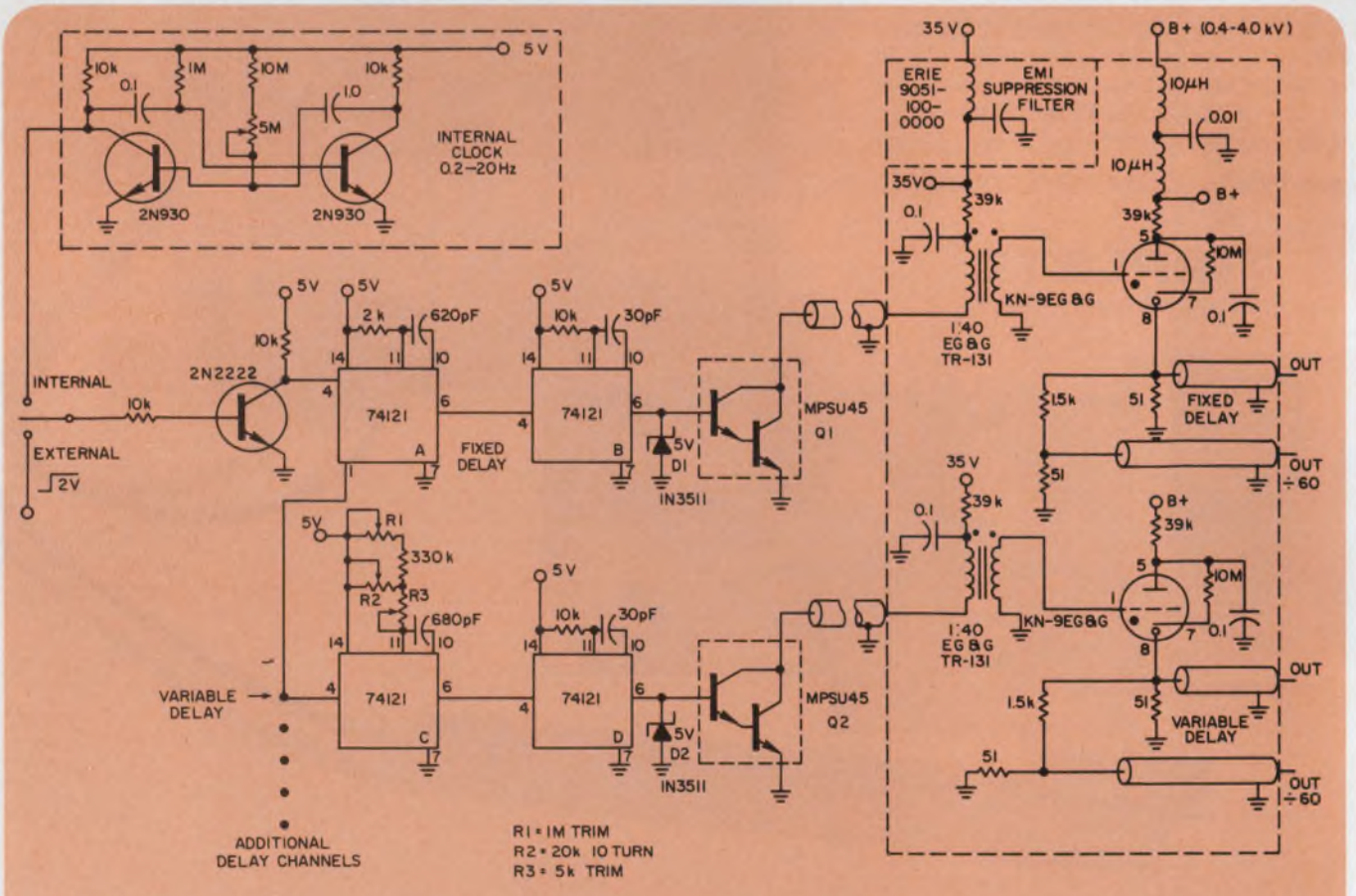
The circuit in the figure can deliver 4-kV, 10-ns rise-time pulses into 50 Ω over a delay range of 0 to 10 μs. The delay range is easily extended by increasing the RC time constant of the 74121. The generator can be triggered from either an internal astable-multivibrator clock or from a 2-V external input. The generator is shown with one fixed-delay output and an almost identical variable-delay circuit.

In the variable-delay circuit, resistor R_2 is a 10-turn potentiometer to enable the delay to be calibrated in microseconds; potentiometer R_3 adjusts the channel's minimum delay to match the fixed-delay output; and potentiometer R_1 adjusts the channel's maximum delay to exactly 10 μs. Darlington transistor pairs Q_1 and Q_2 drive step-up transformers that trigger the Krytron tubes.

The tubes operate with a supply of 700 V; 100 V is dropped across the tube when conducting. Supply voltages as high as 4 kV are permissible. Each channel has a dual output that can simultaneously provide output pulses at 600 V and 10 V. Cross-talk between channels can be controlled by placing the Krytron tubes and pulse transformers inside a shielded box and by maintaining at least 4 cm between the tubes. All power-supply leads entering the box should be filtered to suppress coupling.

R. H. Vandre and G. M. Molen, Materials Science Laboratory, The Aerospace Corp., P.O. Box 92957, Los Angeles, CA 90009.

CIRCLE No. 312



1. **A pulse generator** that can deliver up to 4 kV into 50 Ω with a 10-ns rise time uses a cold cathode tube.

Select from this family of aluminum electrolytic capacitors designed for output filtering in switching power supplies

TYPE 672D

- Suitable for parallel stacking
- Plug-in PWB mounting
- Low to medium ripple current capability

TYPE 604D

- True 4-terminal isolation
- Low profile PWB mounting
- Medium ripple current capability

TYPE 622D

- Symmetrical ESR and capacitance tolerance
- Conventional stud mounting
- High ripple current capability

TYPE 432D

- Lowest available ESR and impedance
- Bus-bar mounting
- Maximum ripple current capability

Construction	Rolled-Section		Rolled-Section		Rolled-Section		Stacked-foil
Terminal Configuration	2 terminals, wire pins		4 terminals, wire leads		2 terminals, low or high female threaded		2 terminals, strip-line, female threaded
Case Size Range (D. x L.)	.326″ x .505″ to 1.000″ x 1.625″		.750″ x 1.625″ to 1.000″ x 3.625″		1.375″ x 2.125″ to 1.375″ x 5.625″		1.375″ x 2.125″ to 3.000″ x 5.625″
Operating Temperature Range	−55°C to +105°C		−55°C to +105°C		−55°C to +85°C		−40°C to +85°C
WVDC Range	6.3 to 100		5 to 200		5 to 55		6 to 50
Capacitance (Range (μF)	4.7 to 6800		50 to 16,000		2,800 to 67,000		470 to 100,000
Capacitance Tolerance	−10, +100%		thru 50 V: −10, +75% over 50 V: −10, +50%		±20%		−0, +100%
Max. Inductance (@ 1 MHz & within .125″ of capacitor)	20 nH		2 nH		20 nH		2 nH
Max. ESR (@ 25°C and 120 Hz)	1200 μF @ 6.3 WVDC	.11 ohm	16,000 μF @ 5 WVDC	.022 ohm	67,000 μF @ 5 WVDC	.004 ohm	100,000 μF @ 6 WVDC	.0015 ohm
RMS Ripple Current (@ 85°C)		2.61 A @ 100 kHz		7.00 A @ 10 kHz		19.5 A @ 120 kHz		54.6 A @ 1 kHz
Max. Impedance (@ 25°C)		.06Ω @ 100 kHz		.017Ω @ 10 kHz		.010Ω @ 10-40 kHz		.001 Ω @ 10 kHz
Engineering Bulletin	3452		3458A		3459		3443A
	Check 161 on Reader Service Card		Check 162 on Reader Service Card		Check 163 on Reader Service Card		Check 164 on Reader Service Card

4SE-6102

For complete technical data, write for Engineering Bulletin(s) (see table for bulletin numbers) on the capacitor(s) in which you are interested to: Technical Literature Service, Sprague Electric Company, 347 Marshall St., North Adams, Mass. 01247.

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Build a simple fire alarm with metal-oxide temperature sensors

A low-cost, sharp-transition thermal sensor, when combined with a dual voltage-controlled oscillator (VCO) makes a simple inexpensive fire-alarm system (Fig. 1). The sensor is a Moxie—a two terminal metal-oxide device whose resistance decreases orders of magnitude within a few degrees of its trip point.

The T53-75S Moxie provides a trip point of approximately 75 C. When the temperature reaches this point, the Moxie's resistance drops to roughly 4 kΩ, which is sufficient to trip an SCR and activate the VCO circuit.

The 74LS124 dual VCO is connected so that the output of its VCO-1 provides a binary frequency control of VCO-2. The frequencies of VCO-1 and VCO-2 are set by the values of C_1 and C_2 respectively, in accordance with the relationship

$$f_o\ (\text{Hz}) \simeq \frac{500}{C\ (\mu\text{F})}$$

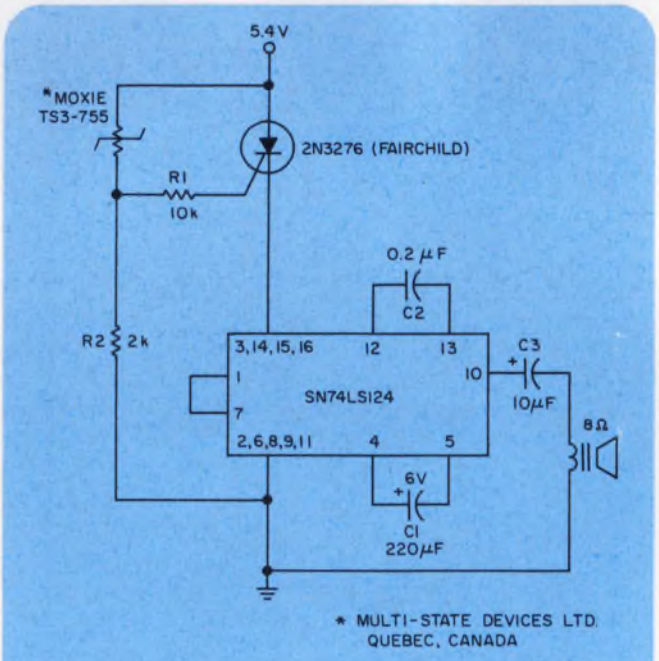
When the SCR latches on, the circuit generates a distinctive two-tone audio alarm, alternating 1-kHz and 300-Hz tones at approximately 1-s intervals.

The circuit is powered by a 5.4-V mercury battery. Standby current is only about 25 μA; operating current is 30 to 40 mA.

Capacitor C_3 prevents overloading the VCO-2 output and also enriches the harmonics content of the audio-signal ouput.

Since the temperature sensor's nominal resistance below the trip point is greater than 100-kΩ, several sensors may be connected in parallel to provide sensing at remote locations. Sensors with different trip points may be intermixed.

Jim Lipman, Member of the Technical Staff, Hewlett-Packard Laboratories, 1501 Page Mill Rd., Palo Alto, CA 94304. CIRCLE No. 313



A two-tone fire-alarm warbler is turned on when a solid-state temperature sensor fires an SCR.

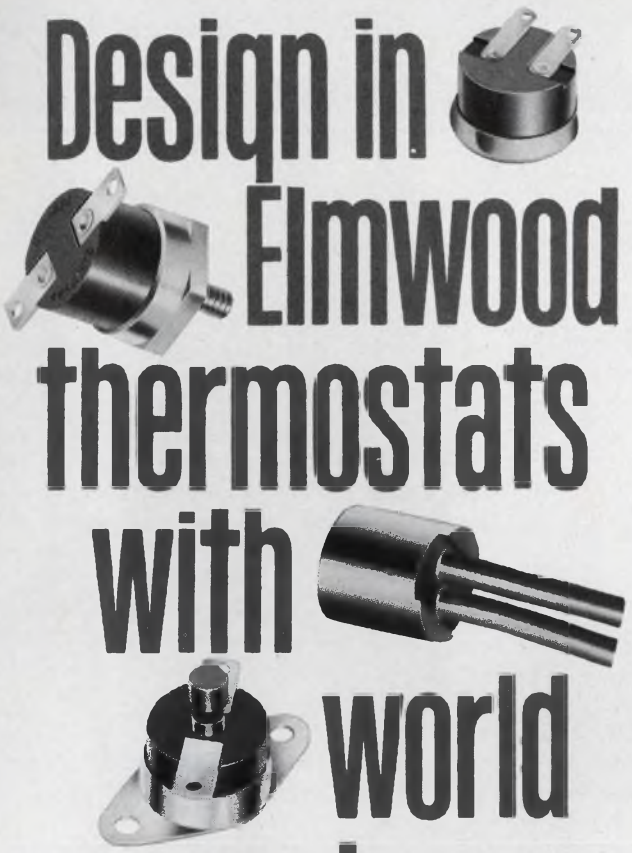
IFD Winner for December 20, 1975

Ram N. Sahni, Project Engineer, NCR Corp., Ithaca, NY 14850. His idea "Keyboard Circuit Saves Time, Needs No Microprocessor Scanning Software" has been voted the most valuable of Issue Award.

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

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

Design in Elmwood thermostats with world acceptance



Why eliminate world-wide sales with unlisted temperature controls? Many Elmwood snap-action thermostats are available to meet U.L., C.S.A. and European requirements for high limit or control. Choose wide or narrow differentials and tolerances to suit your application at minimum cost. Each is factory pre-set and tamperproof, 100% thermally and operationally tested and available with a variety of terminals, mounting brackets or custom packages. If your application requires exposures from −65° to +550°F, ask for suitable commercial or precision prototypes and prices to meet your needs. Elmwood Sensors, Inc., 1675 Elmwood Ave., Cranston, R. I. 02907. Phone 401/781-6500. European Div., Elmwood Sensors, Ltd. North Shields, England

ELMWOOD SENSORS

CIRCLE NUMBER 47

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CIRCLE NUMBER 48

International Technology

Japanese firm achieves first GaAsP photocells

The first use of gallium-arsenide-phosphide (GaAsP) as a photocell has been achieved in a new type of cell developed by Nippon Electric. The device has a spectral response much closer to that of the human eye than photocells.

Light-sensing elements made from cadmium sulphide are slow to respond to light changes. Silicon photocells are often insensitive at low light levels and their sensitivity is greatest in the infrared part of the spectrum. In contrast, the human eye is most sensitive to green light.

The GaAsP photocell has two major advantages over silicon devices, according to a Nippon Electric spokesman. Whereas, the peak sensitivity of silicon devices occurs at 7500 Å, GaAsP devices are most sensitive at 6500 Å. This is much closer to the maximum sensitivity of the human eye at 5600 Å. In dim light, the sensitivity of GaAsP devices is 1.6 times greater than that of the silicon units.

Bipolar IC improves speed of a/d devices

A new semiconductor device that gives a threefold improvement in the speed of ultrafast analog-to-digital converters, such as those used in radar and video processing equipment, has been developed by Plessey Semiconductors of Swindon, England.

Using Process III, a bipolar process that is used in the manufacture of high-speed counters, Plessey produced an IC comprising a comparator, an output latch, gating for decoding the comparator outputs in a multilevel comparator chain and a switched precision-current source.

A five or six-bit converter using these devices can handle 100 million samples per second, providing bit-rates of up to 600-Mb/s.

By summing the precision-current outputs, an additional digital-to-analog capability is obtained for use in parallel-series-parallel conversion methods. The comparator can acquire and hold an input signal in 2 ns. Maximum offset is 5 mV. Propagation delay is 3.5 ns.

CIRCLE NO. 317

Photomasking glass has small thermal expansion

A new glass developed specifically for photomasking overcomes the undesirable thermal expansion of the hard glass normally used in photomasks for integrated circuits. This expansion causes a deviation in line width of 1 μm/°C rise for a 100 mm² mask.

For LSI, with line-widths of about six μm, the expansion is tolerable, but it becomes a problem with very large-scale integration that requires line widths of 1 μm.

The Hoya Glass Work, Ltd., of Toyko has produced an alumina-silicate glass, which has an extremely low coefficient of thermal expansion of not more than 0.3 microns per 100 mm². It is also three times more resistant to water penetration than current glasses and has a greater resistance to acid corrosion.

Chip size reduced by half in ECL RAM

A 1024-bit ECL random-access memory has been produced with fabrication techniques that have reduced the chip size by 56% compared with the standard approach using p-n junction isolation. The adoption of new oxide-isolation techniques and fine-pattern processing has enabled Hitachi, of Tokyo, Japan to increase the packing density in its new RAM.

Another factor in the higher circuit-density on the chip is the use of (100)-oriented silicon wafers in place of the conventional (111)-oriented material. A lower defect density that is obtainable with the (100)-oriented wafers also improves reliability.

Access times of the Hitachi RAM are as low at 25 ns, and power dissipation is 0.5 mW/bit.

CIRCLE NO. 318

Computer laser display

A computer-controlled laser display, developed by Laser-Scan Ltd. of Cambridge, England, is said to produce clear and detailed graphics for design and applications. It can draw a map defined by 350-k bytes in less than two minutes. The unit can reproduce more than 5000 by 3500 resolvable lines on a 100 by 70-cm screen.

Electronic Design Announces "Top Ten" Winners.

On the following pages you will see the advertisements from the January 5th issue of *Electronic Design* which won this year's "Top Ten" contest. In 1976, as in the past, thousands of *Electronic Design* subscribers around the world tried to match wits with our Reader Recall survey in picking the winners. Two measurements were used, "Recall Seen" and "Recall Read." Look at the following pages and find out how well you rated. You may be a winner, perhaps of the Grand Prize—— a week's vacation for two on a windjammer cruise in the Caribbean and $1,000 in cash.

As you will see, the winning advertisements combine well-written copy with superior design to achieve impact and memorability. Here are the winners:

1. Nobel Electronics, Inc.
2. Powertec, Inc.
3. Hewlett-Packard (Loveland Calculator)
4. Guardian Electric Mfg. Co.
5. Hewlett-Packard (Loveland Instrument)
6. Hewlett-Packard (Associates)
7. Hewlett-Packard (Colorado Springs Div.)
8. Buckbee-Mears Co.
9. Keithley Instruments, Inc.
10. National Semiconductor Corp.

★ NATIONAL ANTHEM ★

ALL THE NEWS THAT FITS

A Review of New Products and Literature from National Semiconductor

National Rewrites the Book: LF 156 a New Standard of Comparison for Op Amps

National is very pleased to tell you about a new IC process that we've been working on. In fact—brushing modesty aside—we've come up with the industry's first major new linear process in a decade.

Put rather simply, we married the best that JFET technology offers to the best that bipolar technology offers. We call the union Bi-FET™ technology, and its first offspring are our LF155/156/157 op amps . . . so spectacular that they set completely-new standards for op amp performance.

The secret of Bi-FET performance is in the combination, on a single monolithic chip, of JFETS—well-matched via ion-implant techniques—with standard bipolar transistors. When reduced to practice—as in an op amp with JFET

(continued on page 3A)

Tri-share RAM puts 4096 bits in 18-Pin Package

We've entered the 4K RAM marketplace in a big way with our MM5270—a read/write memory that represents a major breakthrough in the design of MOS memories.

The MM5270 makes use of a unique design concept, which we've dubbed Tri-Share™. The Tri-Share concept lets a single port serve three functions —read/write, logical chip select, and VCC—saving three leads needed by all other RAMs.

And since our new RAM also features a Tri-State®, common input/output lead, we've managed to reduce the package lead count for 4096 bits of memory from 22 leads, which most of you have had to deal with 'til now, to only 18 leads on our MM5270. This allows a PCB memory density nearly *twice* as great as that possible with 22-lead, 4K RAMs, which translates directly into dollars saved. Thus, you can assemble 4K memory systems at a cost lower than previously possible.

And while you're saving money you're acquiring high-speed performance: the access time of the MM5270 is 200 ns min.; its cycle time is 400 ns max. So if you're looking for an unbeatable combination of system economy and performance, look into our MM5270; it's got it all.

NSC does SO Make FETS

Junction FETs . . . by the carload. We make virtually every type of JFET on the market today, including some with characteristics superior to anything else available.

Look at our brand-new PF5101-3 (molded TO-92) and NF5101-3 (metal TO-72), for example. Specially selected for ultra-low-noise audio and video applications, these JFETs feature a common-source spot noise figure at 10 Hz of only 1.5 dB maximum; and a typical e_n of only 5-7 nV/$\sqrt{Hz}$ at 10 Hz, 2-3 nV/$\sqrt{Hz}$ at 1 kHz . . . superb in preamps for hydrophones, vidicons, particle detectors, and high-quality audio/video equipment in general.

Remember too that we pride ourselves on being the most flexible and cost-effective JFET supplier you'll find anywhere. So when you think FETs, think National.

We're Big on Small-Signal Transistors

Singles, duals, quads . . . Metal can, molded, and ceramic packages . . . All popular commercial, industrial, and military types, and in volume . . . The best prices in town . . . And customer service unequaled in the industry.

We've just upped our capacity for both existing and new JAN/JTX/JTXV types, for example. Check out our 2N3498/99, 2N3500/3501, and 2N3700. Or our 2N2920, a dual for which we're one of the few active suppliers of its JAN/JTX/JTXV versions.

We support memory and peripheral houses too: witness our DH3467/3725/6376 quads in both epoxy and ceramic.

We second-source Motorola, Fairchild, TI, GE, and Sprague, which gives us a package/pinout versatility second to none. And this lineup now even includes the popular "Silect" types—our new Series TIS9X, 2N581X, etc.

We're the only supplier of all-copper-lead-frame, Epoxy B TO-92 types; a combination that gives you the most advanced product you can buy.

Small-signal transistors are a very big business with us. Just tell us your needs; we'll meet them.

In Support of RAMs

Imagine a diagram that shows a large block of random-access memory surrounded by an array of smaller blocks; each of the smaller blocks is an interface circuit necessary to the operation of the memory itself. If you imagine further that National part numbers fill all the interface blocks, then you can see the significance of our DS3640-49 and DS36147/149 families of RAM support circuits.

Regardless of function, these circuits share a number of features: they can drive highly-capacitive loads; they have DTL/TTL-compatible inputs; there is a damping resistor in series with each output. (Companion series DS3670-79 and DS36177/179 feature,

(continued on page 4A)

NATIONAL INTROS ACTIVE FILTER LINE

Whether you're after a Bessel, Butterworth, Cauer, or Tschebycheff function, our new AF100 active filter will do the job. You need only four external resistors to program it for any specific, second-order function; so if you wish to form, say, a sixth-order function, simply cascade three AF100s, embedding each in an appropriate resistive-programming network.

Lowpass, highpass, and bandpass functions are available simultaneously at separate outputs; notch and allpass functions are available by combining outputs in the unit's uncommitted summing amplifier.

Available to meet either commercial or military specs, and housed in both TO-8 metal-can and dual-inline packages, the AF100 operates from ±5 to ±18 V, and features independent frequency, gain, and Q adjustments, a Q range to 500, and operation to 10 kHz.

MD² Cuts System Display Costs

We've got a nifty item for any of you who have to display multiple digits. It's our MultiDigit Display family—MD²™ for short. Any member of this display family can significantly cut your display costs and, at the same time, improve the appearance of your LED readout because of MD²'s uniform segments, uniform digit-to-digit brightness, and good contrast.

Clocks, clock radios, appliance timers, instrumentation—you name it and MD² can handle it. Not only are dozens of display combinations possible, but MD² interfaces directly to MOS clock chips, MOS segment and digit drivers, DPM chips, even microprocessors and transducers.

MD² units are common-cathode displays (so far), with heights of either 0.3 inch or 0.5 inch. Both heights are end-stackable in multiples of five, for the 0.5-inch displays, or eight, for the 0.3-inch displays. And they're available in both multiplexed and direct-drive versions.

To find out more about the unique MD² concept, we suggest you call your local National sales office. Between our standard list and our custom options, we're pretty sure you'll find just what you're looking for.

Durawatt 92-Plus™... *A Surefire Way to Beat the Heat*

We bet you're one of many designers who've been playing the do-it-and-keep-your-fingers-crossed game. You know what we mean—trying to keep parts costs down by specifying TO-92 types and overstressing them "just a bit," because the next-higher-dissipation package costs maybe three-times more.

Sure, you win on short-term parts costs but . . . ZAP! You lose on long-term equipment reliability and service costs. Just when you thought you had it knocked.

That's been the story—either pay up or take a chance. Until now.

For our Durawatt 92-Plus™ types change the whole picture. A new line of general-purpose, complementary-symmetry power transistors, Durawatt 92-Plus devices take over where TO-92s fall short. They finally fill that long-empty slot—in dissipation *and* price—between TO-92s and the much-more-expensive, much-higher-dissipation packages.

With a 1200-mW dissipation capability, a built-in heat-dissipator tab, and 80-V/2-A maximum ratings, the Durawatt 92-Plus family is just what you've needed all this time.

No more "add on" dissipative components; no more compromises. Durawatt 92-Plus power types give you a solid dissipation capability at an affordable price, in an operating region where neither existed before. Remember the name—Durawatt 92-Plus. You can uncross your fingers now.

A Lamp for all Reasons

We call our new NSL4944 a *universal* lamp, for you can drive it with as little as 2 V or as much as 18 V, ac or dc. In response, our new lamp gives you uniform brightness (0.8 mcd, typ.) across that operating voltage range. Add a PIV of -18 V, and you've got a lamp unmatched in versatility by anything else in the marketplace.

The key to the NSL4944's wide-range operation is an IC current-regulator built into the two-lead T-1¾ package. As a result, the NSL4944 is the only lamp available that you can place directly across a TTL output and have it come on at TTL's guaranteed "1" state of 2.4 V. (The only other current-regulated lamp on the market comes on at 4.5 V, is usable to only 11, 12.5 or 16 V depending on the version, and its PIV is limited to 3 V.)

So no matter how you look at it—forwards or backwards—our NSL4944 universal lamp is unbeatable. Get a data sheet; or better yet—call your National salesman, ask for a sample, and see for yourself.

4-Digit Counters

We've recently introduced a family of 4-digit counters with some rather nice features that make them eminently suitable for clocks, DVMs, DPMs, and so on.

Each counter, for example, has an internal multiplexing circuit (which doesn't need an external clock) with four multiplexing outputs, NPN output sourcing-drivers for 7-segment displays, and an internal output latch. All of the counters operate from 3 V to 6 V, and source 80-mA (typ.) segment currents.

Let's start with the MM74C925—a basic 4-decade counter with Latch Enable, Clock, and Reset inputs. Next is the MM74C926: like the 925 except it adds a Display Select input, and a Carry-Out for cascade connection. (The Carry-Out goes high at 6000, low at 0000.)

The MM74C927 is like the 926, except that the second MSB divides by six, rather than by ten. This means that for a 10-Hz clock frequency the display reads tenths of seconds, seconds, and minutes.

Finally—the MM74C928: like the 926, except the MSB divides by two and the Carry-Out is an overflow indicator that is high at 2000, and goes back low only when the counter is reset. Thus, the MM74C928 is a 3½-digit counter.

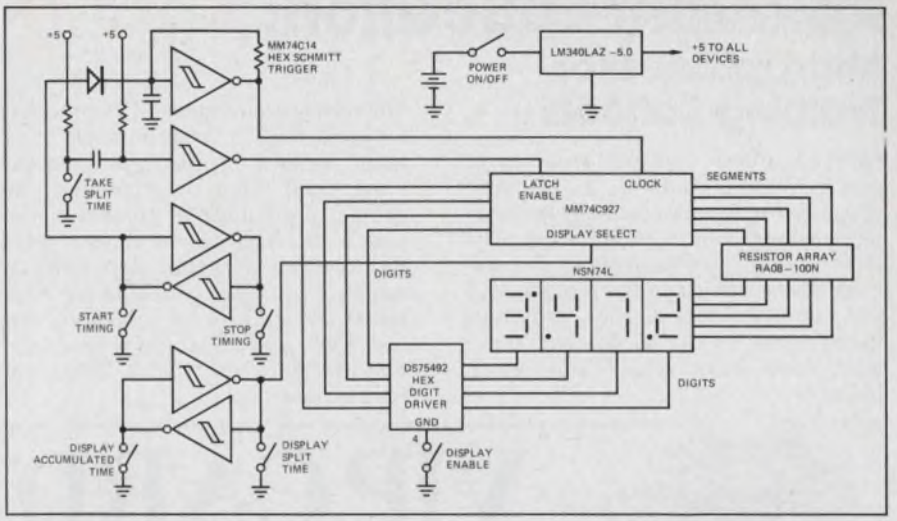
APPLICATIONS CORNER

Taking Time Apart... The Easy Way

Our MM74C925-928 family of 4-digit, multiplexed-output counters is well suited to a variety of instrumentation uses in which events must be counted and then displayed in a numeric format.

Consider the MM74C927, for example. In this part the second-MSB divides by six, which means that for a 10-Hz clock input the output display format is tenths of seconds, seconds, and minutes. This capability is exploited in the stopwatch design shown here, a very inexpensive circuit suitable for the timing of laboratory events, horses, swimmers, cars, soap-box racers, or whatever. The accompanying diagram shows the complete circuit.

A 10-Hz, RC, Schmitt-trigger oscillator provides the MM74C927's clock, which is started or stopped by a debouncer/latch formed by cross-coupled Schmitt triggers.



The Display Select debouncer/latch enables the contents of either the counter or the internal latch to the on-chip display drivers, which lets you read either accumulated time or split time (pulsing the Latch Enable line allows the taking of split time).

Grounding the emitter rail of the digit drivers enables the display; this technique yields a brighter display and longer battery life than would be otherwise obtainable. Uniform display brightness over the lifetime of the battery is assured by regulating the battery voltage to +5 V.

The voltage regulator, which also assures the stability of the RC clock oscillator, is our LM340LAZ-5.0, an inexpensive device housed in a TO-92 package. The switches, too, are inexpensive; with the exception of the main power-ON/OFF switch, all switches are Form-A contact, momentary-on types.

LF 156-Op Amps

(cont'd)

input, bipolar intermediate, and bipolar/JFET output stages—Bi-FET technology yields unbeatable performance. Witness these LF156A/LF356A specs, for example:

V_{OS}	2 mV max.
V_{OS} Drift	5 μV/°C max.
I_{OS}	10 pA max.
GBW	4 MHz min.
Slew Rate	10 V/μs min.
0.01% Settling	1.4 μs typ.
e_n	12 nV/$\sqrt{Hz}$, 1 KHz; 15 nV/$\sqrt{Hz}$, 100 Hz (typical)
i_n	0.01 pA/$\sqrt{Hz}$ typ., 1 kHz and 100 Hz
CMRR	80 dB min.
Power BW	200 kHz

These specs are for our prime version; but if you look over the 14-page data sheet, which presents the specs of all prime and standard types (including wideband and low-current-drain versions of the basic LF156), you'll find that *all* our Bi-FET op amps offer you performance superior to anything you've seen before, whether for military, industrial, or commercial usage.

Our UAR/T, Your FIFO Make Beautiful Music Together

Our MM5303 Universal Asynchronous Receiver/Transmitter, while often found snuggled cozily next to a FIFO, quite contentedly makes its home wherever data processing equipment interfaces to data transmission lines—as in modems, quite obviously. But remember, too, that even in more esoteric situations—data rate changers, for example—an LSI UAR/T such as our MM5303 still buys you more for your dollar than does any other approach.

So much for philosophy. Getting right down to it, our MM5303 replaces the TR1602A and COM2017 in many applications, as well as the TR1402A, COM2502, and TMS6011 in many other sockets.

The MM5303 is fully programmable for 5-, 6-, 7-, and 8-bit word lengths, and operates at full or half duplex, simultaneously receiving and transmitting at different baud rates (30K max.). Parity generation/checking may be even, odd, or inhibited. Stop bits, either one or two; and, in addition, our MM5303 is internally connected to generate one-and-a-half stop bits when programmed for a 5-bit code.

For Sale by Owner: Voltage Regulator Handbook

At last . . . A definitive, how-to book of contemporary power-supply design, which tells you everything you'll have to know to design local power sources using three-terminal and dual-tracking monolithic voltage regulators.

In its more than one hundred pages, our Voltage Regulator Handbook takes you from the raw basics of power-supply design, through heat flow and thermal resistance theory, and on to applications. Along the way, you're shown the inner workings of these regulators, and learn how to expand their capabilities beyond the expected.

Finally, our Handbook not only describes and specifies most of National's extensive line of three-terminal and dual-tracking regulators, but also provides you a cross-reference listing that puts major, competing types in perspective.

The Voltage Regulator Handbook is yours for four dollars; at three cents a page, it's a bargain.

Relevant Education:
Microprocessor Training Schools

National offers complete, microprocessor training courses . . . in-depth sessions divided about equally between lectures and hands-on lab work. The lecturers are professionals in the microprocessor field, and you work with the same National devices, prototyping systems, and so on, that you'll use when you leave school and return home.

The courses offered are Microprocessor Fundamentals, Programmable Systems Design, Advanced Programming, and Microprogramming; the course prerequisites guarantee that you work with others at your level. Each course lasts four days (with an optional fifth day available for additional lab work or consultation), they cost $395, and are taught at permanent NSC facilities in Miami, Dallas and Santa Clara.

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Please send me the literature that I have circled:

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- ☐ **Durawatt 92-Plus,** Page 2, Col. 2
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THINGS TO READ:
A Compendium of Recently-Issued Literature (e.g., stuff to file)

- ☐ **AN-125** LM377, LM378, and LM379 Dual 2-, 4-, and 6-W Power Amplifiers
- **AN-132** A new Interfacing Concept: the Monolithic Temperature Trans-
- ☐ **AN-139** MOS Encoder plus PROM Yield Quick-Turnaround Keyboard Systems
- ☐ **AN-142** Using a Microprocessor Beyond Apparent Speed
- ☐ **AN-144** Designing Memory Systems Using the MM5262
- ☐ **AN-147** Low-Cost IC Stereo Receiver
- ☐ **AN-151** Low-Noise JFET—the Problem Solver
- ☐ **LB-29** Low-Cost AM-Radio System Using the LM1820 and LM386
- ☐ **LB-30** Low-Cost LED Thermometer
- ☐ **μSpec 7** POWR I/O
- ☐ **μSpec 9** IMP-16 Assembler Programs
- ☐ **μSpec 13** Arithmetic CROM

WANTED:

QUESTIONS TO ANSWER

We would like to have a Question-and-Answer column as a regular feature of the National Anthem. We know that many of you, from time to time, have questions about our products . . . questions pertaining to their use, specs, or whatever. We will use the new column to answer as many of these as we can fit into a given issue.

The questions that we use in the Anthem will be those we feel to be of general interest to our readers. Nonetheless, all questions submitted will be answered, either in the Anthem or by direct correspondence.

Obviously, we need your help to make this idea work. We need your questions; and the sooner we receive them, the sooner we can answer them. To speed things along, we've allowed space on the VIP card for a question. Make use of it, and by helping us you'll help yourself.

Question: _____

_____ ED 1/6

Your End Product or Application: _____

Please print clearly. This will be used as a mailing list. Have Salesman Call ☐ **YES** ☐ **NO**

NAME _____ **TITLE** _____

COMPANY _____

ADDRESS _____

CITY _____ **STATE** _____ **ZIP** _____

In Support of RAMs
(cont'd)

instead of a damping resistor, direct, low-impedance outputs.) In addition, all of our RAM interface circuits make use of Schottky technology for good ac performance, and PNP input transistors to minimize loading.

The individual circuits that comprise our DS3640-49 and DS147/149 series of RAM support elements include Tri-Share™ port drivers, latch drivers (ours minimize propagation time and address skew because we use fall-through latches), refresh counters, address drivers, I/O registers, an enable demultiplexer, and clock drivers of all kinds (including the only available N-channel, single-supply device—our DS3642/72).

So if you're using a RAM (and who isn't?), remember who supports it. We've got the circuits that make it work.

6.95 V 'til Hell Freezes Over (and then some)

We've come up with the most stable Zener you've ever had the pleasure to work with . . . a Zener with an ultra-low TC (1 ppm maximum), in which both the Zener voltage (6.95 V ±2%) and the TC are insensitive to current over a 20:1 range (0.5 to 10 mA) . . .a Zener with an incredibly-low and stable dynamic impedance (typically, less than an ohm), very-low broadband noise (20 μVrms max.), and fantastic long-term stability (20 ppm typ.)!

We're talking about our LM199: a Zener combined with a temperature-stabilizer circuit on a single monolithic chip. From −55° to +85°C, the LM199 shows a 1-ppm max. TC (0.3 ppm typ.), which increases to only 15 ppm max. (5 ppm typ.) at +125°C. And it shows these TCs at currents from 500 μA to 10 mA. (Try this with any other so-called low-TC Zener and see what happens.) And if you need still better, we've got a prime version (suffix-A); this one even comes with 883 processing and/or certification of long-term stability.

Of course, if you don't need quite such a virtuoso performance, consider our LM299—0.3 ppm (typ.) to 1.0 ppm (max.) from −25° to +85°C; or our LM399—0.3 ppm (typ.) to 20 ppm (max.) from 0° to +70°C. Other than these differences in TCs, the LM199/299/399 are pretty much identical. So no matter what area you work in—military, industrial, or commercial—our super-low-TC Zeners stand ready to do a super job.

A Review of New Products and Literature from National Semiconductor

The Right DMM Decision Means Five-Function Autoranging for only $225*

Introducing HP's 3476A DMM

The price is a big story in itself. But performance and reliability play a large part too. Take a look at the 3476A:

Autoranging—a big plus in a low cost DMM. It lets you concentrate on the point of measurement... minimizes reading errors... and speeds readings too. All readings are made directly in volts, kilohms, or amps—on an LED display. And there's a rangehold button to speed and simplify repetitive measurements.

Five functions—all the functions you want and need in a low cost DMM. Simply push the appropriate button to read AC volts, DC volts, AC or DC current, and ohms. There's no worry about polarity or zero... they're both automatic.

Advanced design—both circuit and packaging. And both contribute to high reliability. One circuit board contains all the electronics.

Tantalum nitride on sapphire processing allows replacement of all front end precision resistors by a single chip. That means greater reliability and better temperature stability. Of course it's input protected.

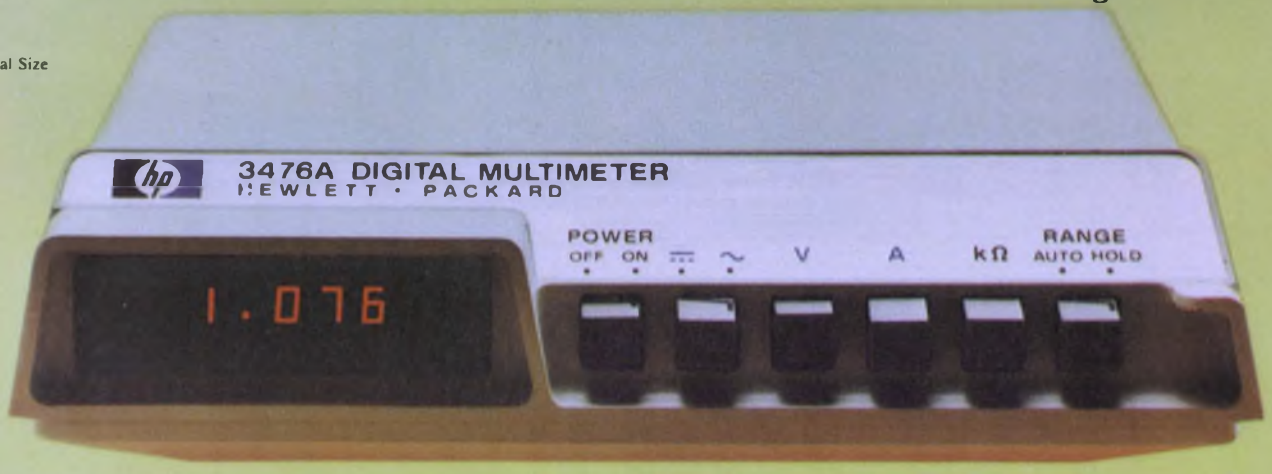
Convenient size—just right to hold in your hand...take with you in a brief case... or use on your bench. An optional carrying case and probe kit let you hang the instrument from a strap for "no-hands" operation. The "A" version ($225*) operates from the AC line for lab use. And for portable applications, the "B" version ($275*) has built-in batteries and recharging circuitry.

The 3476A is backed by HP's service organization ...another big plus for a low-cost DMM. With these prices and features, why not put your hands on the 3476A for your 3-1/2 digit measurements? Your local HP field engineer can tell you how.

*Domestic U.S.A. prices only.

HP DVM's— the right decision

Actual Size



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CIRCLE NUMBER 51

KEITHLEY OFFERS: A 3½-DIGIT MULTIMETER. 4 EXCLUSIVE FEATURES. $315.


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VOLTS-AMPS
DC AC mA A
INPUT
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KEITHLEY
168 AUTORANGING DMM

The Keithley 168 Digital Multimeter gives you every key performance feature offered by other first-line 3½-digit DMMs.

But only the Keithley 168 gives you 4 extra features—all useful and all at a competitive price. Compare our 3½ with the others and you'll come to an inescapable conclusion: the 168 is the best buy in 3½-digit DMMs.

For $315: a superior DMM

For openers, you get a rugged, reliable, easy-to-read, general-purpose, 5-function DMM with more ranges than you'll normally need. Measure from 100 microvolts to 1000 volts dc, 100 microvolts to 500 volts ac, 100 milliohms to 20 megohms, 100 nanoamps to 1 amp, ac or dc. Basic accuracy is 0.1%. All modes fully overload protected. The 168 brings Keithley quality to general-purpose measurement.

4 extra features, no extra cost.

- *Automatic ranging* gives you the most accurate reading, with decimal in the right place, faster than you could do it with switches. Saves you time every time you make a measurement.
- *HI-LO Ohms* lets you turn on a semiconductor junction to see if it's good or measure an in-circuit resistance without turning on a semiconductor.

- *2-terminal input* for all measurements on all functions. You can't get it wrong. Terminals accept banana plugs, alligator clips, spade lugs or bare wire.
- *Lighted function indicator* so you know precisely what you're measuring, instantly.

Surprise: more valuable features.

That's not all. We've packed even more value into the 168. Optional battery pack that you buy now or add later. Patented A-D converter to simplify circuitry. No-nonsense, full-year guarantee on parts, workmanship, and specs—including accuracy. Convenient calibration instructions right inside the cover. Light weight for easy portability.

Full complement of accessories.

Use these optional accessories to make your Keithley 168 DMM even more versatile: Wide-range RF probe. Test lead sets. Clamp-on ammeter. 50-amp shunt. High-voltage probe. Carrying case. Rack mount kit.

Now the logical choice.

The 168 is out-front in value. And it's backed up by our reputation for quality. Don't you wish all decisions were this easy?

Ordering a 168 is easy, too. Just contact: Keithley Instruments, 28775 Aurora Road, Cleveland, Ohio 44139. (216) 248-0400. Europe: D8000 München 70, Heiglhofstrasse 5, West Germany. (089) 7144065.

DMMs for all your needs.

We know you have a variety of measurement requirements. So we offer a growing family of DMMs to meet your application and price objectives. Send for our Selector Guide.

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The measurement engineers.

CIRCLE READER SERVICE CARD NO. 241 FOR A DEMONSTRATION, NO. 242 FOR TECHNICAL DATA

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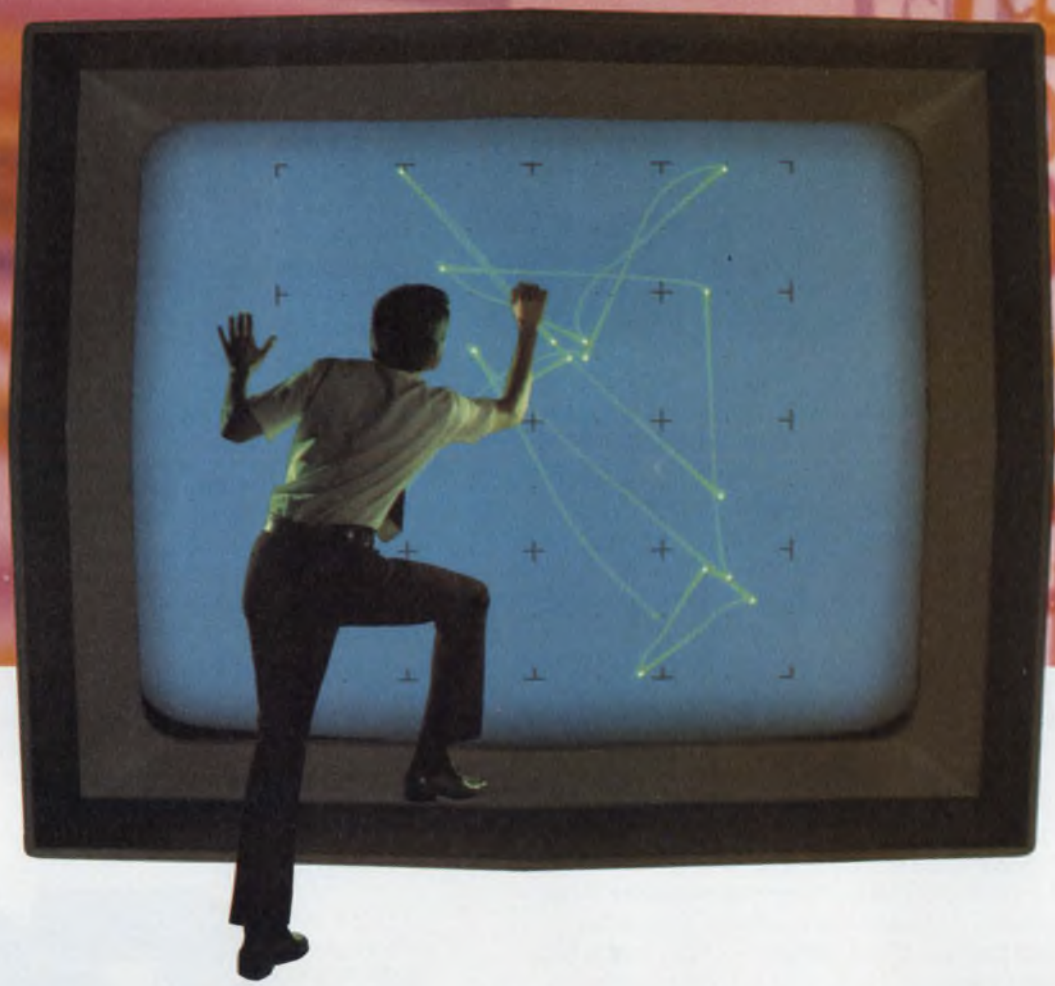

HP invites you to step inside your 16-bit parallel circuits for an overall view – and a detailed view – of logic-circuit operation. How? Just connect our new 1600A Logic State Analyzer to an operating circuit, and view actual logic states on the CRT – at clock rates to 20 MHz. Select the data you want to observe with pinpoint accuracy. And choose from two display methods for viewing the data words.

What does this mean to you? It means a better way to see hardware and software in action . . . a faster way to spot problems and find solutions. For example:

In the mapping mode, the 1600A can display all possible combinations of its 16 data-channel inputs – over 65,000 in all. Each input combination or "word" appears as a discrete point whose location on screen identifies its address. Spot intensity shows relative frequency of occurrence, and the vectors show the sequential state locations.

This mode converts parallel data into a pattern that your eye can easily scan to quickly spot changing conditions or unusual events. You can even expand the view to zoom in on data of interest. And, with a cursor, locate the address of any spot. You can then use the address as a trigger point for a detailed look with the tabular display, or to trigger your scope for electrical analysis.

In store and compare mode, the 1600A triggers on any preset word up to 16 bits wide. The analyzer then displays the trigger word and 15 sequential words before, after, or surrounding the trigger word, so you can easily analyze logic states in detail. You can store one table of data and compare it with an active data display . . . have the analyzer compare the two tables and give you a display of logic differences on a bit-by-bit basis for easy comparison . . . or you can set the instrument to automatically halt when all the data in one table isn't identical to data in the second – freeing you from the tedious task of waiting and watching for infrequent sequences.

And that's just the beginning. The 1600A gives you qualifier inputs to help locate the specific data you want on a busy bus. It gives you a sequential trigger by providing a trigger arm that inhibits the word trigger until an arming signal is received. You can

hrough

logic designs: Mapping..... Store and compare.

delay the display up to 99,999 clock pulses from the trigger point, which lets you look virtually anywhere in your program flow.

The 1600A, priced at $4,000*, gives you new insight to operating logic circuits. With 16-bit word size, parallel operation, and 20 MHz speed, it's the ideal instrument for designers of minicomputers, peripherals, microcomputers, and microprocessor-based systems.

If 16-bit words aren't enough, our new 1600S, priced at $6,800*, displays words up to 32 bits wide. This powerful system includes both the 1600A and our new 1607A Logic State Analyzers. Hook it up to your 16-bit machine, and in single clock you can look at both the data and address simultaneously. In dual clock, you can view two independent active tables of 16 bits each—synchronized together through the bus triggering capabilities.

When you have all the details, you'll see how these new logic-state analyzers put you inside your logic programs for a better overall picture... and for a clear detailed look. And you'll see how they can save you

hours in design, debugging and troubleshooting. For the complete story, just contact your local HP field engineer. Or, write for our new 8-page data sheet on Logic State Analyzers.

*Domestic USA price only

085/7

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FOR TECHNICAL INFORMATION CIRCLE # 281

FOR IMMEDIATE APPLICATIONS ASSISTANCE CIRCLE # 282

Thirteen

just became your lucky number!

Three new 10 amp relays give you 13 small enclosed relays from which to choose.

Your Guardian Angel calls them the 1300 series, of course.

Amazing. Versatile. Small. Enclosed. Multi-pole. These five words sum up Guardian's 1300 line of 13 basic models . . . in hundreds of variations. Each relay in a choice of AC or DC, solder lug or printed circuit termination. Each with its own mating socket. Each your ideal spec for any application requiring uncompromising high quality at low, affordable price.

NEW! 1345DC relay in your choice of SPST-NO, SPST-NC or SPDT. Small in size but built to take hard knocks. Just over a cubic inch small, yet specifically designed for a minimum of 50,000 miles of maintenance free operation in automotive controls . . . or an equally amazing trouble-free life anywhere you need small size, long life and low, competitive price.

NEW 1390 and 1395 DPDT

NEW! 1390AC and 1395DC relays, DPDT with 10 amp rating in a space-saving, compact new design. To give you large control capacity in a package about half the size of competitive relays that do the same job. The cost? Just about the same as competitive units . . . in many cases quite a few cents *less.*

NEW 1345 SPST-NO, SPST-NC, SPDT

SEND FOR THE BOOK THAT TELLS IT ALL:
Guardian's 48 page relays catalog. Full of facts and specs to make selecting a relay a snap. Yours free for the asking.

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CIRCLE NUMBER 13

◂ ***Also new from HP:*** *The HP 9871 Page-width Printer/Plotter. Its unique bi-directional platen and 96-character printing disk let you run program-formulated charts and graphs; tables and text. Works with all HP 9800 series computing calculators.*

Meet the new HP9815. Look what your bucks will buy now.

High-speed data cartridge provides up to 96,384 bytes of program and data storage. Dual-track, 140 foot magnetic tape can be searched bi-directionally at 60 inches a second.

Thermal printer has full set of alphanumeric characters. Prints up to 16 characters per line at 2.8 lines a second.

Easy-on-the-eyes display can display up to 16 numeric characters or up to 10 digits in scientific notation.

15 user definable keys allow single keystroke execution of programmed routines.

Auto-Start switch initializes programs so an operator need only switch on the power and Auto-Start, and begin interacting with programs. It also provides power-fail restart.

Simplified programming, based on easy-to-understand logic and easy-to-remember mnemonics, lets you write powerful, complex programs easily.

Powerful editing features allow you to modify and update programs quickly and accurately.

Built-in math and trig functions provide simple, convenient keystroke calculations—just like you get from HP hand-held calculators.

HP stack-oriented notation is the efficient, powerful method for arithmetic operations. It reduces equations to a few easily-handled steps.

Compact and portable, the 13 pound HP 9815 is just 13½" x 13½" x 4".

*U.S. domestic price only. Does not include options, programs or peripherals.

And that's just for starters.

At its base-price, the new HP 9815 computing calculator is a price/performance leader. And the powerful 9815 becomes a uniquely versatile performer as you add optional features.

Interfacing capability is provided through an optional $200* two-channel I/O module. It allows a choice of seven different HP peripherals to work with the 9815, including the new 9871 page printer. You just plug them in, and they're ready to go. HP interface cards and cables allow the 9815 to control, gather and process data from a variety of instruments. And by adding an HP-Interface Bus, up to 14 instruments can be monitored simultaneously.

HP general-purpose programs are now available for statistics, electrical engineering design, surveying and radioimmunoassay. With them, problem solving is reduced to data entry.

Power, versatility, simplicity, low-cost—these are the characteristics of the new 9815. We call it a four-dimensional machine. Call your local HP sales office, or write for a copy of the HP 9815 brochure, and you'll see why.

HP computing calculators put the power where the problems are.

HEWLETT hp PACKARD

085/17A

Sales and service from 172 offices in 65 countries.
P.O. Box 301 Loveland Colorado 80537

CIRCLE NUMBER 52

We'll never forget Janice.

Such a nice, quiet English girl.

Lover of Jane Austen, good music, country walks, big sloppy dogs and, of course, Jermyn customers.

For whom she slaved early and late to send off data, answer inquiries and put nice packages of DIP sockets and other Jermyn goodies on the UPS truck the same day she got the order.

Fact is, her tour of duty, as they say in the best British regiments, has come to an end.

Here's what we've done about it.

We've moved all the stock, all the data and all the famous Jermyn service over to the east coast.

And the guy to talk to is Steve Scorza.

CIRCLE NUMBER 53

No, of course he doesn't look like Janice.

He's more your rugged type, and he has a fantastic personality to rely on.

Plus a fantastic new Jermyn ultra low-profile socket, with six advantages of which no other brand has more than three.

If you're happy with your TI, Augat or Robinson Nugent low-profiles we're happy too, but you ought to see the Jermyn.

PS. Yes, we do have Janice's address, but not for publication. If you have an urgent message we'll happily pass it on, especially if it comes with an order.

This is Steve

And this is the new socket.
Call Steve on toll-free 800 431 1072 for details.

Jermyn is now distributed by **Nobel**

Nobel International Inc.
265 Little Tor Rd. South, New City, New York 10956
Telephone: 914 634 3535 Toll-free 800 431 1072 Telex: 131540

If we sold OEM power supplies to our competition they wouldn't try to build their own!

FREE POSTER

So take a close look before you select your next supplier...

In the last four years Powertec has become one of the top three suppliers of quality power supplies for Original Equipment Manufacturers. Here's why . . .

Production. During this time we've shipped over 500,000 supplies to 3000 satisfied customers.

Versatility. Powertec is the only company to give you three important choices — open frame, sub-modules, and switching power supplies.

Creativity. These designs originated at Powertec and are the trend setters for the industry.

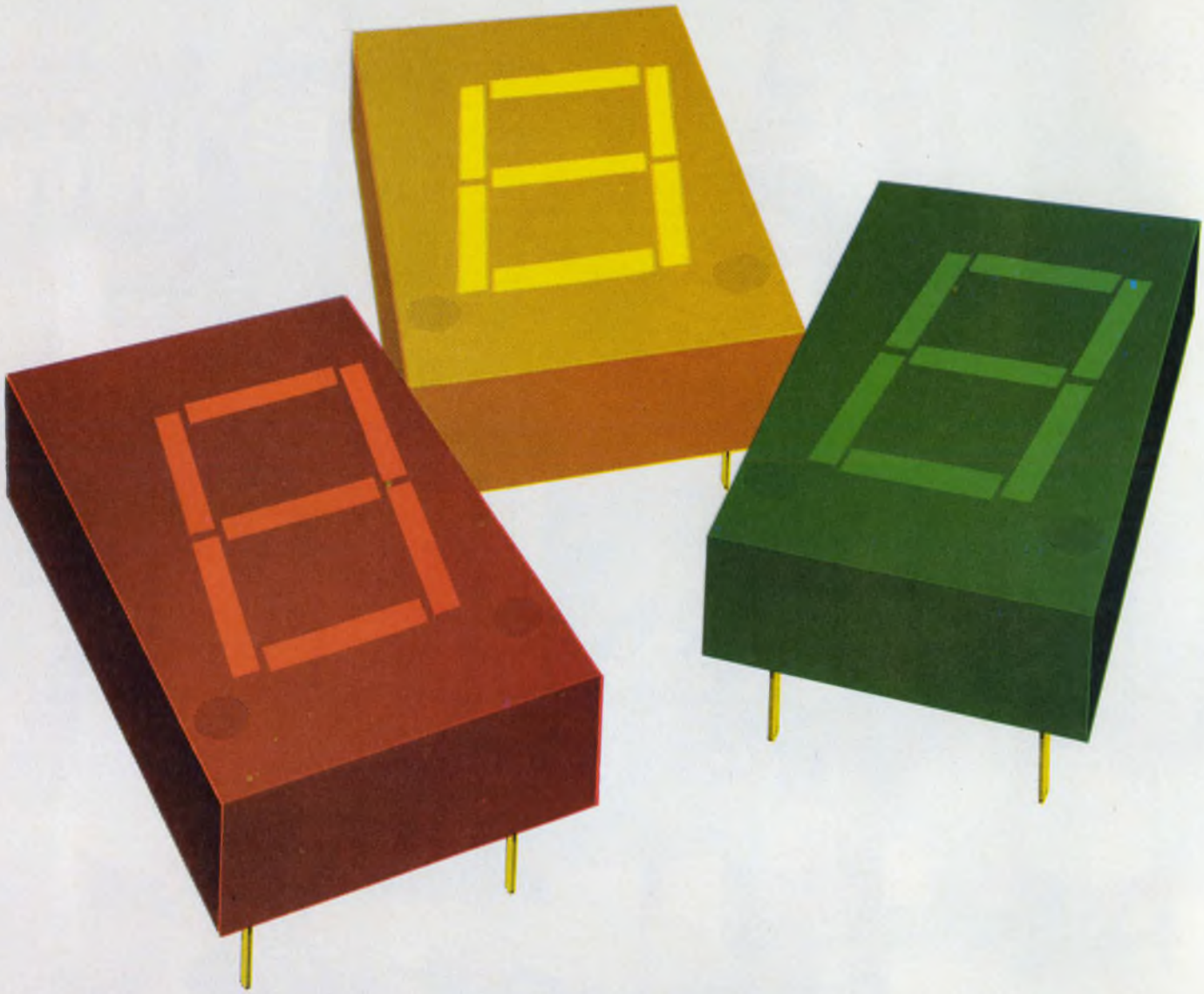
Speaking of creativity, this ad has already become a collector's item. Now, as a one-time offer only, you can have a poster-size reprint suitable for framing. Just circle the reply card.

Powertec, Inc.,
9168 DeSoto Avenue, Chatsworth, CA 91311
(213) 882-0004

CIRCLE NUMBER 54

POWERTEC

SURPRISE!



HP's 5 times brighter display!

At 20mA our new High-Efficiency red display is 5 times brighter than our standard red displays. Just 3mA per segment gives you all the brightness you need and makes it ideal for battery powered applications. These large .43" displays are offered in High Efficiency Red, Yellow, or Green and are readable up to 20 feet. The 5082-7650 (High-Efficiency Red), -7660 (Yellow), -7670 (Green) are available in standard DIP packages with left-hand d.p. and common anode configuration. Just $3.95* each in quantities of 100. Contact Hall-Mark, Schweber, Wilshire or the Wyle Distribution Group (Liberty/Elmar) for immediate delivery, or write us for more information and our new application note on contrast enhancement.

01503 *Domestic USA price only.

HEWLETT hp PACKARD

Sales and service from 172 offices in 65 countries.
1501 Page Mill Road, Palo Alto, California 94304

CIRCLE NUMBER 55

This is a flexible circuit for a heart pacer.

Certainly not if you're a heart patient.

And our customer who builds them feels the same way. He wants a product that heart patients can depend on.

This means reliable components. That's why he's more concerned that we build a dependable flexible circuit than a cheap one.

Not that we can't produce routine circuits just as inexpensively as anyone. We do.

But, when it comes to critical tolerances in super critical applications, we know it's optimum reliability that a customer is looking for.

And BMC delivers . . . everytime.

How do we do it?

Extra care and attention every step of the way. Including expert design advice and assistance. The ultimate in sophisticated artwork creation. Proprietary production techniques and more.

Sometimes this is going to cost you a little more. But, what's a little extra cost if it means your product will keep on ticking a lot longer?

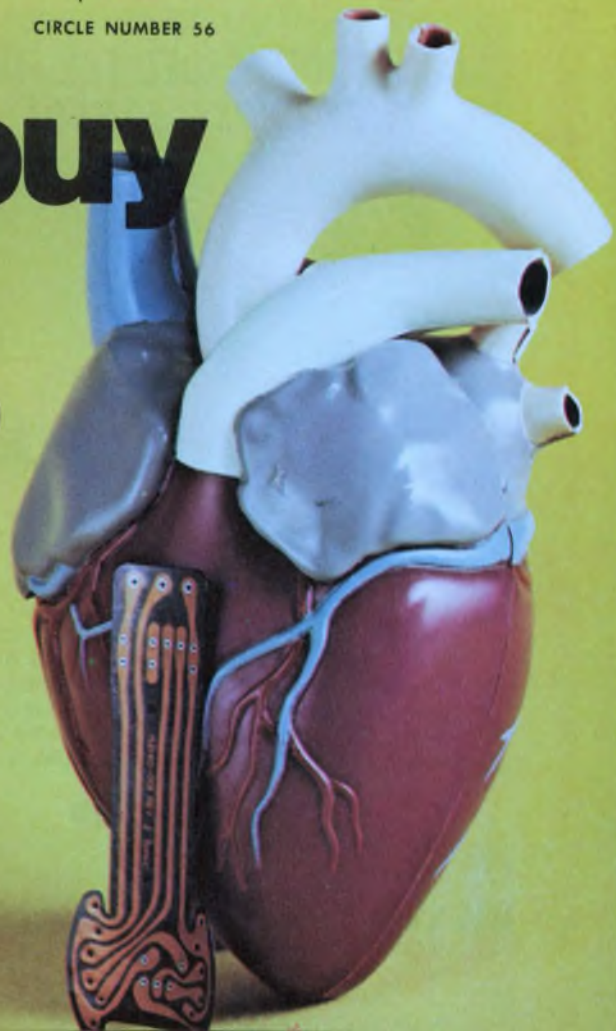
For more information, contact Ed Dugan, Circuits Division (612) 228-6371.

245 EAST 6TH STREET
ST. PAUL, MN 55101
612 - 228-6371

BUCKBEE-MEARS COMPANY
bmc

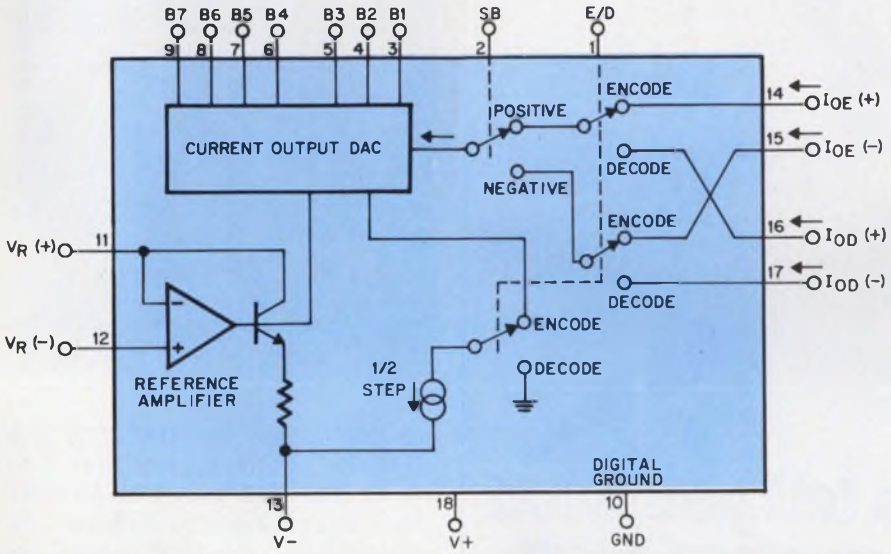
CIRCLE NUMBER 56

Would you buy it from the low bidder?



New Products

Companding d/a converters give 72-dB dynamic range with 8-bit inputs



Precision Monolithics Inc., 1500 Space Park Dr., Santa Clara, CA 95050. (408) 246-9222. P&A: See text.

With sign-plus-12-bit dynamic range on an eight-bit data bus, Precision Monolithics' companding digital-to-analog converters bring the designer a solution to many communications and data-handling problems.

When used as part of a successive-approximation a/d converter, the monolithic Comdac series of companding d/a converters can logarithmically compress an analog signal into a sign-plus-7-bit digital output that has a 72-dB dynamic range. The same device, when used as a d/a converter to expand the data back to analog form, provides constant-current outputs with wide voltage compliance.

The converters, also known as the DAC-76 series, accept a seven-bit-plus-sign digital input and deliver an analog signal with an accuracy that is level dependent. For low signal levels the accuracy is equivalent to that of a 12-bit d/a converter.

CHORD	STEP SIZE IN μA WITH 2007.75 μA F.S.	STEP SIZE NORMALIZED TO FULL SCALE	STEP SIZE AS A % OF FULL SCALE	RESOLUTION AND ACCURACY OF EQUIVALENT BINARY DAC
0	0.5	2	0.025%	SIGN + 12 BITS
1	1.0	4	0.05%	SIGN + 11 BITS
2	2.0	8	0.1%	SIGN + 10 BITS
3	4.0	16	0.2%	SIGN + 9 BITS
4	8.0	32	0.4%	SIGN + 8 BITS
5	16	64	0.8%	SIGN + 7 BITS
6	32	128	1.6%	SIGN + 6 BITS
7	64	256	3.2%	SIGN + 5 BITS

The companding (compression/expansion) transfer function is effected by using three bits to select one of eight binarily-related chords (or segments) and four bits to select one of 16 linearly-related steps within each chord. The eighth bit represents the sign of the output signal (see graph).

In the first chord, around zero, the step size is 0.5 μA. In the last chord, near full scale, the step size is 64 μA (see table). Since the step size changes from chord to chord, accuracy also changes. There is a 1.5-step change between the maximum code in each chord and the minimum code in the next chord; this helps smooth the transitions and meets the existing requirements of many communications specifications.

The DAC-76 conforms to the Bell System μ-225 law, which defines a piecewise-linear transfer function used in audio compression and expansion. In the compression mode, the unit is used with a successive-approximation register and a comparator to make an a/d converter. A single control line can switch the converter from the encode mode (a/d converter) to the decode mode (d/a converter).

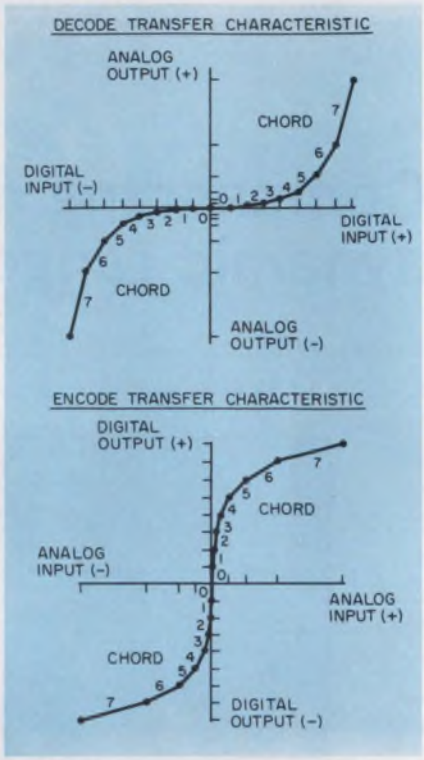
Settling time for the converter is 500 ns to within ±1/2 step for the two differential-current outputs. The two outputs permit the converter to be time-shared between encode and decode modes. The output current ranges from 0 to 4.6 mA, and with the addition of a resistor, the current outputs can be used as voltage outputs. The voltage compliance of each current output line is −5 to 18 V.

There are four versions of the Comdac available: the DAC-76 and DAC-76B, which operate over −55

(continued on page 112)

INTEGRATED CIRCUITS

(continued from page 111)



to 125 C, and the DAC-76E and DAC-76C, which operate over 0 to 70 C. The 76B and 76E versions have a precalibrated full-scale to within ±1/2 step and a total accuracy to within ±1/2 step. The 76 and 76C versions are calibrated to within ±1 step and are accurate to within ±1 step. Note that for these units the conventional LSB accuracy term is not used because the step size differs for each chord. All converters are housed in 18-pin ceramic DIPs and are guaranteed monotonic over their full operating temperature range.

Since the converters are most accurate near the zero point they are well suited for servo loops—where signals must be nulled. The 8-bit units, of course, interface neatly with 8-bit μP data busses.

Power consumption of the converters is low—only 192 mW, maximum. And, they operate from nominal ±15-V power supplies that can range from +4.5 to +18 V and −10.8 to −18 V.

Prices for the converters start at $19 for the 76C and increase to $24.80, $49, and $63.95, for the 76E, 76 and 76B, respectively, in 100-up quantities. Delivery is from stock.

CIRCLE NO. 301

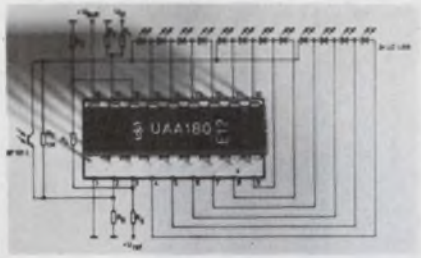
Bar-graph display driver contains all necessary circuitry

Siemens Corp., Components Group, 186 Wood Ave. South, Iselin, NJ 08830. (201) 494-1000. P&A: See text.

Consider a solid-state bar-graph display for your next visual indicator. Siemens Corp. has found a way to put all the drive circuitry needed for a bar graph on a single chip. The Model UAA-180 display-driver IC contains the comparator, drivers and brightness control, all in an 18-pin DIP.

The UAA-180 can drive a 12-LED array and costs only $2.75 in 1000-unit quantities. Each LED receives a drive current of 15 mA, maximum. Additional arrays and drive circuits can be cascaded for large, multipoint displays.

Except for several external resistors needed to set the reference



voltage levels, all the required circuitry is included in the UAA-180, thus eliminating the additional drive circuits usually required.

The driver operates from a +10 to +18-V power supply and handles input signals from 0 to 6 V. Quiescent current drain from the supply is a low 5.5 mA, typical, when no LEDs are being driven. Input drive current is 300 nA, maximum, so the circuit won't load any incoming signals. The operating temperature range of the circuit spans −25 to +80 C.

The input voltage range of the UAA-180 can be varied by selecting the reference and bias resistors. The typical voltage change required to increment the display is about 0.5 V, although voltage changes as low as 80 mV can be used.

The predecessor of the UAA-180, the 170, is a 16-pin circuit that can drive a single diode out of a series string of up to 16. Cost of the UAA-170 is the same as that of the 180—only $2.75 in 1000-unit quantities. The UAA-170 circuits can be cascaded to drive almost an unlimited number of LEDs.

CIRCLE NO. 307

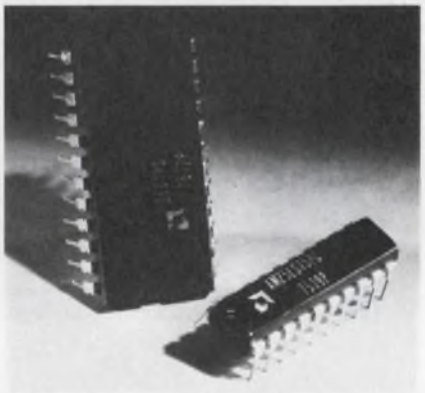
Hermetic, plastic DIPs house standard op amps

RCA, Solid State Div., Route 202, Somerville, NJ 08876. (201) 722-3200.

Even standard op amps are now available in the company's Gold CHIP (chip hermeticity in plastic) configuration, which features plastic packaged ICs that meet hermetic criteria but are offered at plastic-package prices. The new Gold CHIP circuits include eight single op-amps (the CA101, 107 and 748 series), two dual op amps (CA1458 and 1558) and one quad op amp (CA3401). Prices in 100 quantities range from 75¢ to $4.75. Delivery is from stock.

CIRCLE NO. 310

20-pin DIP holds four adder/subtractors



Advanced Micro Devices, 901 Thompson Pl., Sunnyvale, CA 94086. (408) 732-2400. $8.75 to $27.50 (100).

A quad serial adder/subtractor—the Am25LS15—is designed for use with the company's Am25LS14 serial/parallel two's-complement multiplier. The new low-power S-TTL devices can also be used for magnitude only or one's-complement addition or subtraction. Four independent adder/subtractors are provided with common clock and clear inputs. A clear function sets the internal carry function to logic ZERO in the add mode and to logic ONE in the subtract mode. The Am25LS15 comes in a 20-lead DIP in both molded and hermetic versions.

CIRCLE NO. 320

Miniature open-frame supplies rival potted modules in size and price

Alpha Power Inc., 9020 Eton Ave., Canoga Park, CA 91304. (213) 998-9873. See text.

If you like the size and price of potted power modules, but would prefer a unit that's repairable, look into Alpha Power's Micro Reg series—open-frame supplies that are about as small as potted modules, but which, in many cases, cost less.

In fact, the Micro Reg may be the smallest, least-expensive open-frame supply on the market today; case size is as small as 1.80 × 2.8 × 1.15 in., and cost is as low as $16.95 for a 5-V, 0.5-A unit. The most expensive unit—a triple-output supply—sells for only $39.95.

By contrast, one of the lowest priced potted modules around is the Semiconductor Circuits P741-5005, a 5-V, 0.5-A supply that sells for $31.95 and occupies a 2.25 × 2.50 × 1.25-in. case.

At present, 21 models comprise the Alpha Power series. Included are single, dual and triple-output units, each of which is available in three case sizes, depending on current rating. Dimensions of the largest case are 3.20 × 4.00 × 1.65 in.

A fixed-voltage monolithic regulator is the key behind the Micro Reg's compactness and much of the performance specs. Nominal output voltages (5, ±12, ±15 V) are fixed within ±3%, with regulation of ±0.5% for both line (105-to-125-V variation) and load (0-to-100% variation).

Other key specs include a max ripple and noise of 15 mV rms, 50 mV pk-pk; tempco of 0.03%/°C; and a 20-μs response time for a 50% load change. Operating temperature is 0 to 60 C.

(Note: single-output units in the largest case don't use the monolithic regulator and therefore carry a different set of specs.)

The Micro Reg's regulators are internally protected against thermal overloads and excess current, but continuous output shorts aren't advisable. Some models also offer overvoltage protection as standard.

Alpha Power Inc. **CIRCLE NO. 305**
Semiconductor Circuits

CIRCLE NO. 306

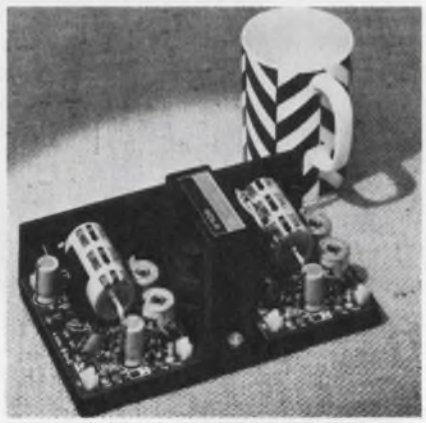
Switchers offer 5-year warranty

Power/Mate, 514 S. River St., Hackensack, NJ 07601. (201) 343-6294. $625; stock.

Available in four models with output voltages ranging from 5 to 24 V dc and currents from 25 to 100 A, this switching-regulated series features efficiencies approaching 90% at 24 V dc. Line/load regulation is better than 0.1% for all models. Stability is 0.1% after initial warmup. The universal, front-panel-selected input enables the user to select a variety of input voltages from 104 to 254 V ac, single or three-phase.

CIRCLE NO. 321

Multiple-output units power μP systems



Sola Electric, 1717 Busse Rd., Elk Grove Village, IL 60007. (312) 439-2800. $49.95 to $84.95; stock.

An eight-model line of multiple-output, IC-regulated power supplies is intended for OEM use in microprocessors. The units feature fully isolated, independent outputs to prevent interaction between μP logic circuits. Four dual-output models and four triple-output models provide the most popular output-voltage combinations. Several units have an output that is adjustable to conform to precise voltage requirements. Output power levels are designed to accommodate accessories such as RAMs, ROMs, FPROMs, clocks and I/O devices, as well as the μP logic itself.

CIRCLE NO. 322

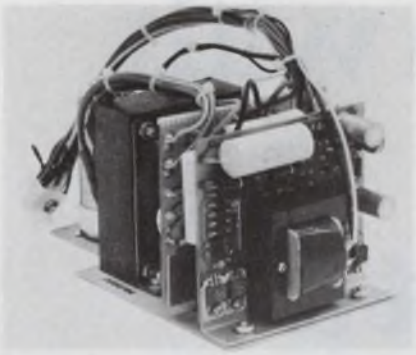
Uninterruptible power supply delivers five output voltages

Elexon Power Systems, 3131 S. Standard Ave., Santa Ana, CA 92705. (714) 979-4440. See text.

For $122.40 you can stop worrying about memory loss in small computers and other data-handling equipment. The money buys you protection in the form of an OEM uninterruptible power supply (UPS) from Elexon Power Systems.

Elexon's Model 1379 comes on a 4 × 4 × 8-in. open-frame chassis and delivers five output voltages: +5, −15, −14, +26 V dc and 1.7 V ac. If your ac input power (120/240 V) fails, a 12-V external backup battery (lead-acid or gelatin-cell) takes over and keeps things going for three to five hours, depending on the load drawn.

The 1379's closest competition appears to be a unit from Semi-



conductor Circuits, the UPS12, which costs anywhere from about $186 to $253 depending on current rating, and which provides three outputs—+5 and ±15 V dc—and a 13.5-V-dc charging voltage.

Both the +5 and −14-V outputs of the Elexon supply are regulated to ±250 mV (line and load); the remaining dc outputs, although filtered, are unregulated. A sixth output, of 14 V, keeps the battery charged and operates the dc/dc converter, from which all outputs are derived.

Current capabilities of the 1379 are as follows: 1 A for the 5 V, 0.3 A for the −14 V, 0.6 A for the +15 V, 0.03 A for the +26 V and 0.4 A for the 1.7 V ac. Other models are available to 250 W.

The Elexon unit is designed to operate with convection cooling (no fan needed) over 0 to 55 C. Efficiency is listed as 55%.

Model 1379 meets Underwriters Laboratories' specifications UL478 and UL114. Delivery takes five weeks.

Elexon Power Systems

CIRCLE NO. 308

Semiconductor Circuits

CIRCLE NO. 309

DISCRETE SEMICONDUCTORS

Slotted optical switches have infrared filters

Optron Inc., 1201 Tappan Circle, Carrollton, TX 75006. (214) 242-6571. From $1.70 (100-up); stock.

A series of slotted optical-limit switches has a built-in infrared transmitting filter that eliminates background illumination problems and provides dust protection. The OPB 813, OPB 814 and OPB 815 consist of a GaAs infrared LED coupled with a silicon phototransistor in a molded-plastic housing. Typical output current for the OPB 813 is 2 mA with a 20-mA input and for the OPB 814 it is 3 mA with a 10-mA input. The OPB 815 has a minimum current output of 1.8 mA with an input of 20 mA.

CIRCLE NO. 323

Power Darlingtons have current gains of 2000

Lambda Electronics, 515 Broad Hollow Rd., Melville, NY 11746. (516) 694-4200. From $1.95 (small qty.); stock.

Power Darlington transistors in the PMD series are available with 100, 150 and 225-W dissipation ratings. They have current gains of up to 2000, can operate at junction temperatures of up to 200 C and have collector voltage ratings of 40, 60, 80 or 100 V. The transistors have thermal resistances of 0.67 to 1.5 C/W and are 100% tested for second-breakdown current and leakage-current stability.

CIRCLE NO. 324

Varactor tuning diodes have 5:1 tuning ratios

MSI Electronics, 34-32 57th St., Woodside, NY 11377. (212) 672-6500. $5.75 (100 to 999); 2 wks.

The ZC807 series of varactor diodes has capacitance values of up to 250 pF. They operate at bias levels of about 2 V and have tuning ratios of greater than 5:1. Q values at 20 MHz exceed 100 and the 25-V breakdown rating permits use of these diodes in large-signal applications. The tuning diodes are housed in DO-7 glass packages.

CIRCLE NO. 325

Darlington arrays handle currents up to 600 mA

SGS-ATES Semiconductor, 435 Newtonville Ave., Newtonville, MA 02160. (617) 969-1610. From $1.50 (100-up); stock.

The L201/2/3 family of transistor arrays consists of seven silicon, npn Darlington transistor pairs on a common monolithic substrate. All units feature open-collector output and integral suppression diodes for inductive loads. Continuous-collector-current ratings are 500 mA, with allowed peaks of 600 mA. The L201 is a general-purpose array, which may be used with DTL, TTL, PMOS, CMOS, etc. The L202 is specifically designed for use with 14-to-25-V PMOS devices. Each input has a zener diode and resistor in series. L203 has a series base resistor to each Darlington pair, and thus allows operation directly with TTL or CMOS at 5 V. All devices are supplied in a 16-pin plastic DIP and are pin-for-pin, spec-for-spec equivalent to the Sprague ULN2001A, ULN2002B and ULN2003A, respectively.

CIRCLE NO. 326

Pre-screened transistors available in four types

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. (415) 493-1501. See text; stock.

Users of microwave transistors now can quickly obtain units screened by high-reliability test programs. Four small-signal npn transistors are presently offered: the 35824A in a TO-72 package is for general-purpose use to 1 GHz; the 35826E in a low-parasitic hermetic package, for microstrip use to 4 GHz; the 35829E is optimized for high tuned gain at 2 GHz; and the 35866E is optimized for low noise at 4 GHz. Four levels of high-reliability testing patterned after MIL-S-19500 are available. Prefix TX indicates 100% screening and preconditioning using MIL-STD-750. The TXB prefix indicates a part coming from a lot subjected to Group B tests. Prefixes TXV and TXVB indicate a precap visual test in addition to the other screening. Prices for the transistor start at $61.50 for 25-to-49 quantities of TX devices.

CIRCLE NO. 327

Dual-digit LED displays come in four styles

Monsanto Commercial Products, 3400 Hillview Ave., Palo Alto, CA 94304. (415) 493-3300. $6.40 (100-up); stock to 4 wks.

A family of 0.6 in. numeric displays has two digits on a single module. Designated the MAN6600 series, the double-digits are available in orange with a radiated wavelength of 630 nm. The devices have a typical luminous intensity of 2000 μcd at 20-mA forward current, and 500 μcd at 5 mA. There are four digit configurations available: the MAN6610 with two common-anode digits and right-hand decimal, the MAN6630 with 1-1/2 common-anode digits (overflow ±1.8) and right-hand decimal, the MAN6640 with two common-cathode digits and right-hand decimal and the MAN6650 with 1-1/2 common-cathode digits (overflow ±1.8) and right-hand decimal. The over-all width of the two-digit module is 0.985 in. (25.02 mm) and the modules can be stacked.

CIRCLE NO. 328

DISCRETE SEMICONDUCTORS

Microwave tuning diodes have Qs of up to 2500

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. (415) 493-1501. $20.25. (10 to 99); stock.

Three microwave tuning varactors, Models 5082-1346, 1349 and 1351, have minimum breakdown voltages of 45 V. Type 1346 has a capacitance of 0.8 pF and a Q of 2500 when measured at −4-V bias referred to 50 MHz. The capacitance ratio is typically 4.2. Model 1349 has a capacitance of 2.6 pF, a Q of 2000 and a capacitance ratio of 5.4. Model 1351 has a capacitance of 4.4 pF, a Q of 1700 and a capacitance ratio of 5.6.

CIRCLE NO. 329

LED numeric display has 0.5-in. high characters

AEG Telefunken, 570 Sylvan Ave., Englewood Cliffs, NJ 07632. (201) 568-8570. See text; stock.

The CQY91, a 7-segment red LED display, has a character height of 0.5 in. (13 mm). The display has a right-hand decimal point and is available as either a common-anode or common-cathode unit. The 0.5-in. character height and wide viewing angle (80°) gives the display a viewing distance of 20 ft or more. The CQY-91 red display costs $1.50 when purchased in 5000-unit quantities. Green (CQY92) and yellow (CQY-93) displays are also available.

CIRCLE NO. 330

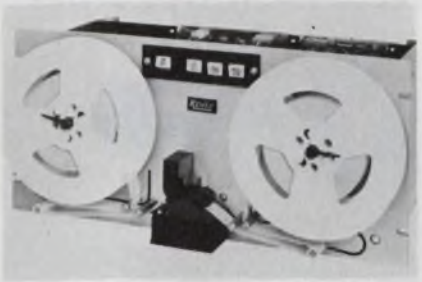
High-current SCRs also operate at high speed

International Rectifier, 233 Kansas St., El Segundo, CA 90245. (213) 678-6281. 10 to 99 prices: $39.45 (PAM60), $31.50 (PAL60); 4 wks

Two series of 250 A rms fast-switching inverter SCRs, the 140-PAM and the 140PAL, are available with blocking voltages of up to 600 V. They feature high di/dt and high dv/dt, with maximum turn-off time of 10 μs for 140PAM and 20 μs for the 140PAL. The SCRs are housed in TO-200AB cases.

CIRCLE NO. 331

Paper-tape reader designed for economy



Remex, 1733 Alton St., Santa Ana, CA 92705. (714) 557-6860. $1045: single qty; 30 days.

The Remex RRS7200 paper tape reader/spooler is designed for applications where low cost is important. The unit offers bidirectional read speeds of 200 char/s asynchronous and 300 char/s synchronous. It has 7-1/2-in. servo controlled reels, with a stepper motor drive and sprocket tape feed. Employing a fiber-optic light distribution system, the unit will read paper or Mylar tape with infrared transmissivity up to 57%.

CIRCLE NO. 332

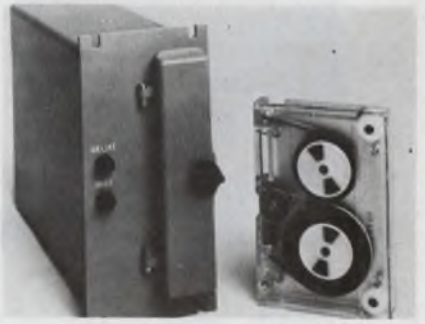
Controller interfaces tapes and discs

Data Works Instrumentation, 9748 Cozycroft Ave., Chatsworth, CA 91311. (213) 998-8985. From $595 (unit qty); 30 days.

The RS-232 interface, Model 6600A, adds a communications interface to existing paper-tape equipment and is a compatible controller for paper-tape readers, magnetic tapes and floppy discs. The controller accepts remote commands from an RS-232 line, provides control signals to the paper-tape equipment and transfers data to and from the paper-tape unit. When storing data on a floppy disc, the unit can transfer data from the line onto a disc, and when required, reverse the process. Incremental magnetic-tape recorders are handled in the same manner as paper-tape punches. The Model 6600A accepts a two-character sequence for each remote command. The first character is fixed as the ASCII escape character and the user may select the second character.

CIRCLE NO. 333

Cartridge drive is made for military users



Raymond Precision Industries, 217 Smith St., Middletown, CT 06457. (203) 632-1000. $3500 (single qty).

The Model 6412 1/4-in. data-cartridge tape drive operates in a military environment. Construction features include a cast-aluminum mainplate with a ruggedized and simplified transport design. The unit is ANSI compatible. Recording density is 1600 bit/in., with an operating speed of 30 in./s. Dimensions are 7.5 × 3.5 × 10.7 in. (h × w × l) allowing four drives to mount in an EIA 19-in. panel. The drive weighs 7.5 lb and consumes 30 W when operating.

CIRCLE NO. 334

Optically based wand reads many type styles

Key Tronic Corp., OCR Div., Bldg 14 S.I.P., Spokane, WA 99216. (509) 928-8000. KT3: $3250; KT9: $9000 to $16,000; 6 wks.

The Models KT3 and KT9 optical character recognition (OCR) systems generate digital signals for feeding to a computer by scanning letters, numbers, and symbols typed on a sheet of paper. To read a row of characters, a wand (a small rectangular box measuring 0.5 × 1 × 3 in.) is first aligned with the character line, and placed in contact with the surface on which the data appear. Then, the wand is moved by hand either from left to right or right to left at speeds up to 10 in./s. Data printed with 10-characters-per-inch spacing produce a reading rate of 100 characters per second. There is no restriction on the slowness with which the wand scans the line. The wand connects through a cable to a box containing recognition circuitry. The output from this module may be ASCII, an 8-bit parallel code, which in turn can be sent to a computer. Should the character be poorly printed, smudged or otherwise unrecognizable, the recognition circuits will acknowledge their inability to develop an appropriate output code by emitting an audible beep. In this way, the wand operator can rescan the data line or enter the correct signal via user supplied interface equipment. The KT3 OCR wand and its recognition package read numerals 0 through 9 of the typed or printed OCRA font. The KT9 handles letters and numerals of the OCRA and six additional fonts, including hand print. The company can provide interface solutions to data handling equipment.

CIRCLE NO. 335

Calculator prints on 2-1/4-in. paper tape

Facit-Addo, Inc., 501 Winsor Dr., Secaucus, NJ 07094. (201) 866-5111. $169 (single qty); stock.

The Addo 9218 calculator prints on specially coated 2-1/4-in. width paper tape. It adds, subtracts, multiplies, divides and can also perform chain calculations. The unit features 8-digit printout with a fixed or floating decimal point. Two rechargeable nickel-cadmium batteries power the device. The calculator weighs 1-1/2 lb. with dimensions of 6.8 × 4.3 × 2.3 in. and comes in brown.

CIRCLE NO. 336

Tape recording system stores data at low cost

Sintrom Electrics Ltd., Dept. ED, 2 Arkwright Rd., Reading, Bershire RG2 OLS. In U.S. call (212) 752-8400. $3000; 60 days.

The Perifile 6000C tape cartridge recording system provides a low cost method of storing data. The unit can store data for minicomputers in 8-bit bytes. Each unit contains a double cartridge tape transport mechanism with storage capability of 2 megabytes/cartridge. The data transfer rate is as fast as 5000 bytes/s. It is capable of interfacing, via a bidirectional data and control bus with handshake, to most minicomputers. It also has software drivers and diagnostics.

CIRCLE NO. 337

A computer expert we know is under contract to do research on the lives of saints. He punches data into cards and feeds the cards into a computer for correlation studies. His problem is that the holes in the cards are healing.

Floppy-disc kit suited for microprocessors

Sykes Datatronics, Inc., 375 Orchard St., Rochester, NY 14606. (716) 458-8000. $1398 (single drive in unit qty).

A kit allows you to build a floppy-disc system that interfaces with microcomputers. It includes a controller capable of operating in either IBM (256-k bytes per diskette) or dual-density (630-k bytes per diskette) formats. Also included are one to four floppy-disc drives, interconnecting cables from the controller to the disc drives, and a hardware interface. The controller provides functions generally done in software, including address search, automatic sector and track sequencing, a FIFO buffer for asynchronous operation and automatic CRC generation and detection. The microcomputer interface is an 8-bit bidirectional data bus that looks like a memory port with only thirteen lines required for complete interface to transmit data, disc commands and disc status.

CIRCLE NO. 338

PACKAGING & MATERIALS

Adhesives designed for high temperature use

Aremco Products, P.O. Box 429, Ossining, NY 10562. (914) 762-0685. $102; stock.

High temperature adhesives Kit No. 524 includes an array of high temperature bonding materials suitable to 4400 F. The five different cements contained in the kit include: Ceramabond 503 and Ceramacast 505 alumina-base adhesives with a 3000-F limit, Ceramacoat 512 silica-base adhesive with a 2500-F unit, Aremco-Bond 515 epoxy-ceramic adhesive with a 400-F limit and Ultra-Temp 516 zirconia-base adhesive with a 4400-F upper limit. The cements included offer varying properties such as different thermal expansion rates. Typically, the 503 offers adhesion to dense ceramics, whereas the 512 will bond to carbon steels.

CIRCLE NO. 339

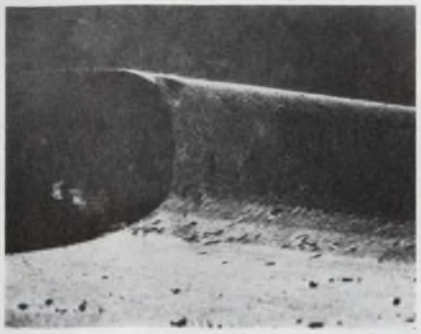
Prototype boards hold both DIPs and discretes

Chanex Inc., 153 N. Rampart St., Los Angeles, CA 90026. (213) 938-6897. P&A: See text.

Wired circuit boards, using preformed plastic channels, are claimed by Chanex to be easier and faster to assemble than wrapped wire boards by as much as 75%. The boards can hold DIPs and discrete components. Circuit changes are easily made by simply unsoldering and re-soldering wires. Individual wires may be shielded or the channels in which the wires are routed can contain layers of magnetic shielding. A wiring jig is also available to allow wires to be put in place a fast as an automatic wrap machine. An 8.25 × 2.25 × 0.0625 in. breadboard with all accessories and wiring jig costs $45. A 10 × 12-in. board with accessories costs $220.

CIRCLE NO. 340

Silicon wafer's edge rounded for better yield

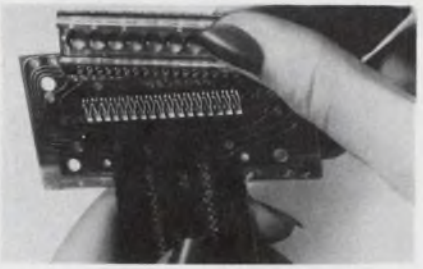


Siltec, 3717 Haven Ave., Menlo Park, CA 94025. (415) 365-8600.

Siltec introduces a new edge-rounded silicon wafer. Rounding the edge removes sharp corners and significantly reduces edge chips, photoresist beads and epitaxial crowns. The edge rounding evolved from a heavy-etch process to a mechanical chamfer and finally to a ground-radius corner, which provided the strongest edge. After rounding, the slice is etched to remove any work damage; approximately 25 microns of material is etched from all surfaces.

CIRCLE NO. 341

Connector 'bifurcated' into three fingers



Precision Concepts, Inc., 1596 B Ocean Ave., Bohemia, NY 11716. (516) 567-0995. $0.095: 17-pin connector (OEM qty).

Precision Concepts' snapper connector can be used as a display or keyboard connector in the calculator industry and as a mother-and-daughter-board connector in the computer industry. With three-fingered "bifurcated" construction on 0.1-in. centers, the contacts are joined together by a common tie-bar. Connectors are available with any number of contacts to meet customer's specifications, and they can accommodate either a 1/32 or 1/16-in.-thick board.

CIRCLE NO. 342

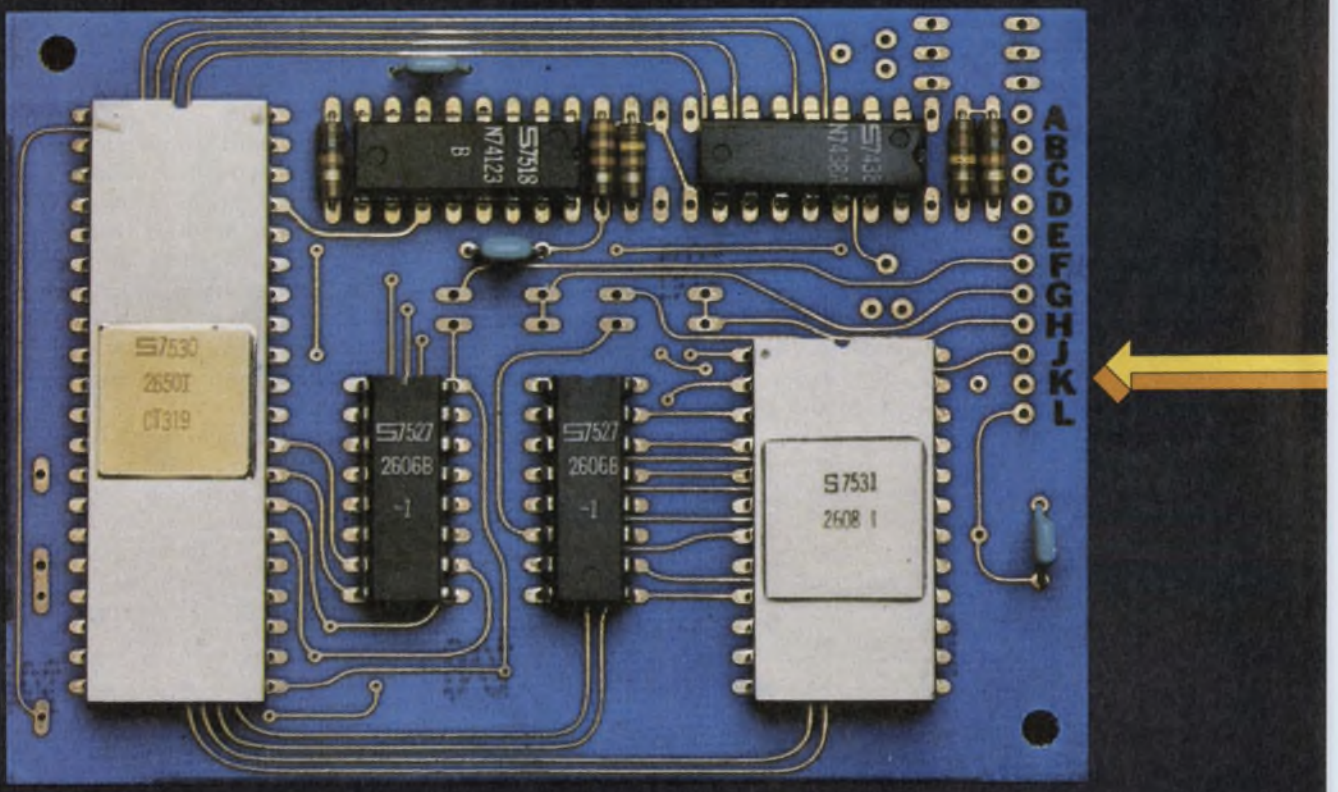
Screw terminals avoid bulky blocks on PCBs

Vector Electronics Co., Inc., 12460 Gladstone Ave., Sylmar, CA 91342. (213) 365-9661. See text.

A new screw terminal, Model T122, allows convenient circuit-board connections for single-conductor or stranded wire from 20 to 30 gauge. These 0.312-in.-diameter by 0.430-in.-high terminals are easily pressed into 0.154-in.-diameter holes and staked with a simple punch. Located anywhere on 0.0625-in.-thick circuit boards, the screws provide convenient termination without expensive and bulky terminal blocks. The tinned brass terminals, available off the shelf, are priced at $90.00 per thousand; evaluation quantities are available at $1.40 per package of 10, and $12.00 per package of 100. A free sample is available.

CIRCLE NO. 343

The easiest-to-use microprocessor



(Photograph approximately 2x actual size.)

The single-chip 2650 is easiest-to-buy, too. Now only $21.50 (100-up).

Full support of customer and product is the key to ease of development with the 2650. Applications engineers in the U.S. and abroad are at your beck and call at every stage. Software for almost anyone's requirements and machines. Development hardware is versatile and inexpensive. All circuits are multi-sourced.

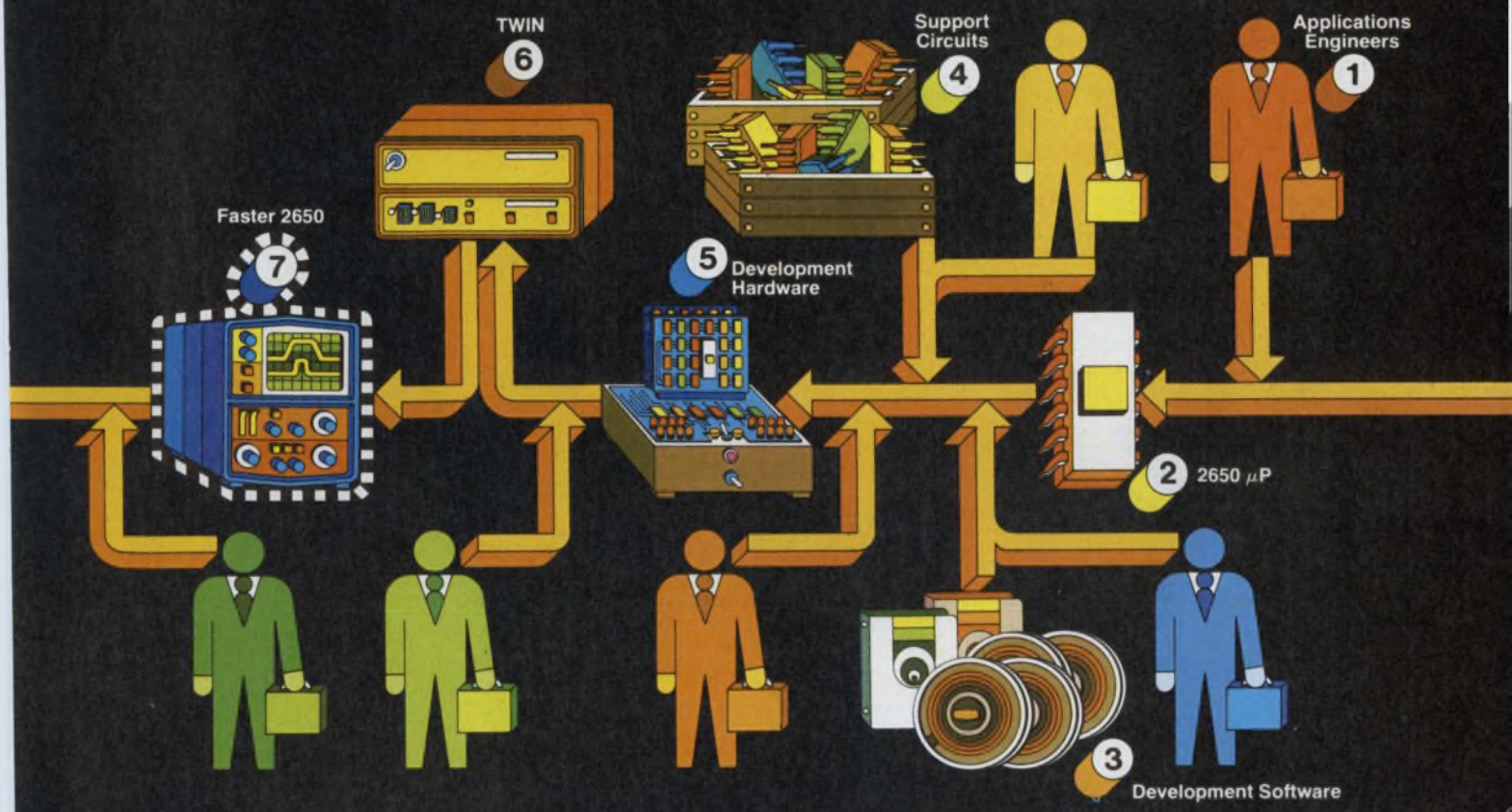
Flow Chart: How to travel safely and quickly from spec sheet to your μC.

1. Applications Engineers — in the field now, more coming. Specific assistance to you is available around the USA, and in Belgium, Holland, Germany, France, Sweden, Britain, Italy, etc.

2. Multi-sourced 2650 — available in any quantity from Signetics, at the unprecedented low price of $21.50. Also available from AMS and Philips, and from Signetics' authorized distributors.

3. Development Software — includes the PL μS, an extremely efficient High Level Language (compiler) that reduces programming effort and cuts development time. ANSI standard Fortran IV executes on most machines without alteration. 2650AS1000/1100 Assembler and 2650SM1000/1100 Simulator are available in both 32- and 16-bit, on GE and NCSS time-sharing.

4. Multi-sourced Support Circuits — You'll need MOS and/or Bipolar Memories, Interface and Logic. Signetics has *everything* for a complete system. Back up any item from other sources. Coming soon from Signetics are: Programmable Peripheral Interface and Communications Interface, A-D Converters, Synchronous Data Link Controller, 16k NMOS & Bipolar ROMs, 4k & 8k NMOS EROMs, and 8k Bipolar PROMs.



makes the easiest-to-develop microcomputer.

5 Development Hardware — Design/develop/prototype with a variety of cost/capability levels of hardware support. Including prototyping cards and kits, smart typewriter demo card, 4k-byte RAM card, and more. Applications help if you need it.

6 TWIN With Floppy Disks — "crashproofs" your system checkout. With DOS, Resident Assembler, and Text Editor. You develop programs and circuits together in an actual system environment with TWICE (*T*est*W*are *I*n *C*ircuit *E*mulator). PROM programming, too.

7 Over 30% Faster 2650 — By the time you've proven out your μC, you'll have available a faster 2650 if you want it. Uses the same software. For still higher speeds, call Signetics Bipolar Microprocessor Marketing about our 2650 emulator using 3000 series μP.

You go from gleam-in-your-eye to proven prototype in less time for less cost, and the μC you develop is easier and cheaper to produce in quantity, when you start with the 2650. Start now by mailing the coupon.

Attach this to your letterhead for fast response.

☐ Send me complete 2650 short form catalog.
☐ Have a Field Applications Engineer call me for appointment.
My need is: ☐ immediate ☐ 6 months ☐ information only

My application is _____

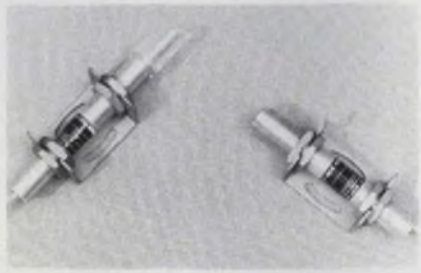
Name _____ Title _____

Telephone _____ Mail Stop _____

THINK **signetics μP**
A subsidiary of U.S. Philips Corporation
811 E. Arques Ave., Sunnyvale, Ca. 94086

CIRCLE NUMBER 82

Infrared photoelectric can see around corners



Micro Switch, 11 W. Spring St., Freeport, IL 61032. (815) 232-1122. $120; stock.

A through-scan infrared photoelectric device, the two part MLS4A can operate in nearly all ambient light conditions and even see around corners. The modulated light source has a diameter of 0.625 in. and requires no additional amplification for the 120 mA output to directly drive a relay. With optional right-angle beam deflectors the photoelectric can go around corners. The MLS4A can function speeds up to 125 operations per second. Both the emitter and receiver units are fully potted in vibration-resistant aluminum packages. An alignment indicator on the receiver speeds installation and checking procedures. Both emitter and receiver meet NEMA 3, 4, 12 and 13 sealing requirements. Output circuitry of the receiver is a current-sinking single-pole nomally open contact. Input voltage is 12 to 16 V dc for either unit.

CIRCLE NO. 344

Humidity sensing system has ±2% accuracy

Thunder Scientific, 623 Wyoming SE, Albuquerque, NM 87123. (505) 265-8701. See text.

A miniature humidity measurement system on a 1 × 2 × 0.875-in. PC card works over a 5 to 95% humidity range. The PC-2000 card and BR-101B sensor combination requires 5 V dc at 5 mA and operates over 0 to 50 C. Two versions are available: an uncalibrated model for $85 and a calibrated unit for $160. Typical accuracy is ±2% RH with a resolution of 0.1% RH.

CIRCLE NO. 345

Active filters also boost signal by 10 dB

Polyphase Instrument Co., Bridgeport, PA 19405. (215) 279-4660. $120 (1 to 4); 4 wks.

An active notch filter also offers up to 10 dB of signal gain without extra circuit stages. Five 3-dB bandwidths are available: 10, 25, 50, 75 or 100% of selected center frequency. Center frequencies from 0.01 Hz to 100 kHz are available. The filters plug-in for PC-board mounting, operate from 5 to 18 V dc and measure 1.9 × 1.25 × 0.5 in.

CIRCLE NO. 346

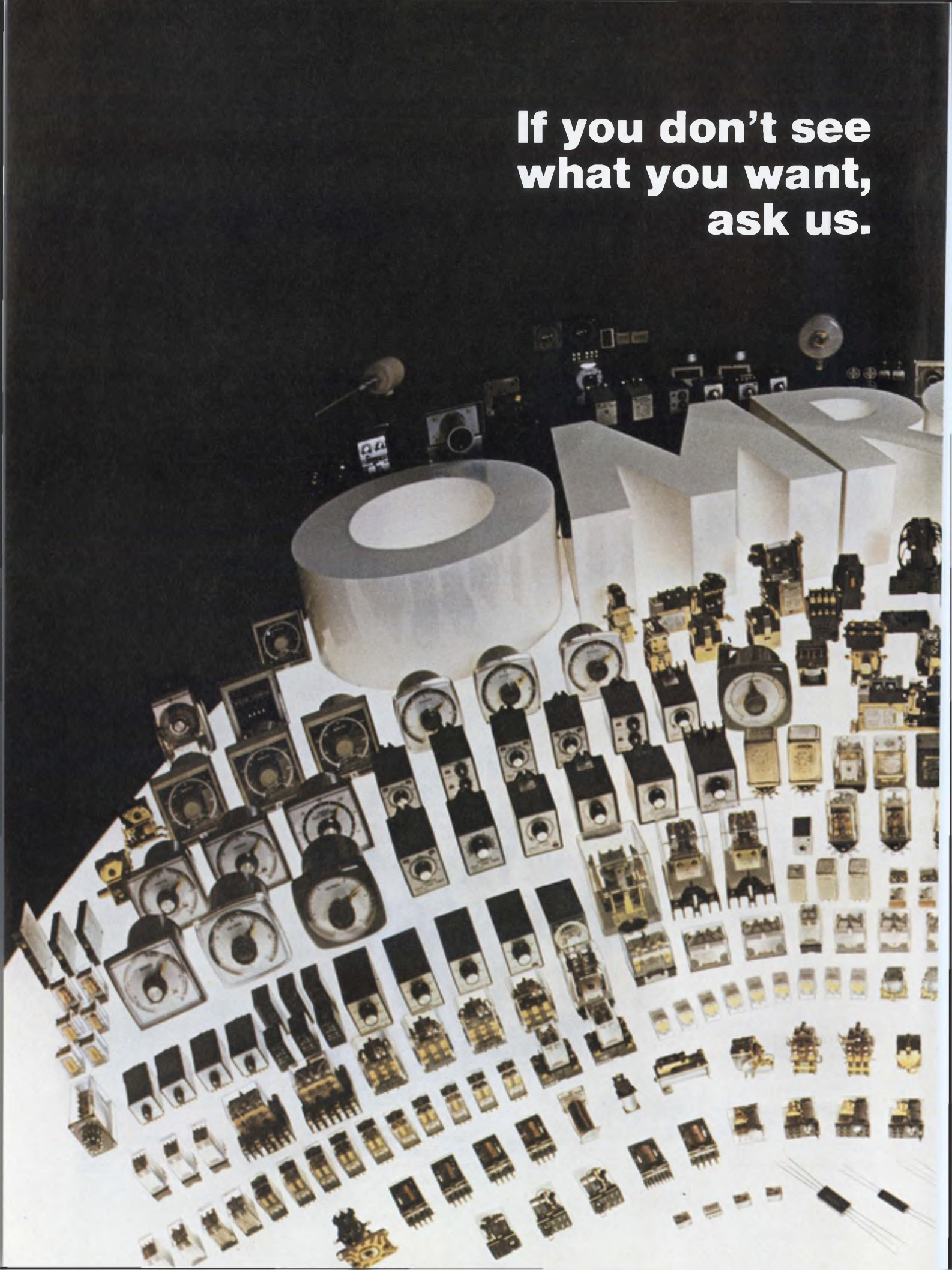
Power DAC delivers up to 2 A at ±30 V

Burr-Brown, International Airport Industrial Park, Tucson, AZ 85734. (602) 294-1431. $209 (1 to 24); stock.

The 4804 power-output d/a converter accepts a 12-bit input and delivers a programmable dc voltage up to ±30 V at 1 A. Output ranges of less than ±30 V with 12-bit resolution are easily set by adding one external resistor. Current limiting, which is factory set at ±1.2 A, can also be varied by changing the value of two easily accessible resistors. Maximum continuous current is 2 A, and maximum power dissipation in free air with no external heat sink is 20 W. The converter is packaged on a 4.01 × 6.038 × 0.875 in. card that includes an extruded heat sink for the power output stage. Power requirements for a ±30-V output include ±35 V dc for the power stage and ±15 V dc and +5 V dc for the converter. Settling time for the 4804 is 100 μs, maximum and the gain drift is ±50 ppm/°C. The output offset voltage is ±70 μV/°C, maximum and the output resistance is 1 Ω.

CIRCLE NO. 347

If you don't see what you want, ask us.



Chances are Omron has exactly the control component you need.

It's one of the advantages you get with Omron, the company with the widest total selection of relays, switches, and timers. (Shown here is less than 5% of our line.)

Since 1933, Omron has been a leader in supplying the world with control components, so we may already have your "unique" component in stock.

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We also offer you an exclusive Omron service: Phone inquiries for key data are answered within 48 hours.

So for key data, or to simply learn more about us, call or write us directly at our headquarters in Chicago.

We're here to fill your control components needs. You're not alone anymore.

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1051 State Parkway
Schaumburg, IL 60172
Phone: (312) 885-9500

CIRCLE NUMBER 87

MODULES & SUBASSEMBLIES

Multiplying DACs run over full MIL range

Hybrid Systems, Crosby Dr., Bedford, MA 01730. (617) 725-1570. From $89 (1 to 9); stock to 5 wks.

The DAC348-MIL-B series of four-quadrant multiplying d/a converters is fully processed to MIL-STD-883, levels A, B or C. No external components are required for operation, and by simple pin interconnection, the models perform two-quadrant multiplication with binary input coding or four-quadrant operation with 2's complement coding. The converters have a linearity tempco of 2 ppm/°C over the temperature range of −55 to +125 C and are housed in hermetically sealed 18-pin DIPs. Key specifications include: linearity error from −25 to +85 C of ±0.02% FSR max and from −55 to +125 C of ±0.03% FSR max, a settling time of 10 μs and a power supply requirement of +15 V ±20% at 5 mA and −15 V ±20% 3 mA.

CIRCLE NO. 348

Universal active filter has 5-MHz Q-f product

Kinetic Technology, Div. of Baldwin Electronics, P.O. Box 1222, Campbell, CA 95008. (408) 371-5880. $35 to $40 (100-up); stock to 4 wks.

The FS-120 second generation active filter has a Q-frequency product of 5 MHz. The filter provides high-pass, bandpass, low-pass and band-stop functions and has a frequency stability of 25 ppm/°C. Tuning accuracy is ±1% and the typical Q is 2000. Power requirements for the filter are ±5 to ±20 V dc. The filter is housed in a 14-pin DIP and is pin programmable.

CIRCLE NO. 349

Hybrid amplifier has 1000-V/μs slew rate

M. S. Kennedy Corp., Pickard Dr., Syracuse, NY 13211. (315) 455-7077. $38 (100-up); stock.

The Model 720 hybrid amplifier offers a slew rate of 1000 V/μs. Its full small-signal bandwidth is 150 MHz and for full power output it drops to 10 MHz. The amplifier settles in 50 ns to within 1% of its new output value and in 100 ns to within 0.1%. The output is short-circuit protected and the amplifier is internally compensated.

CIRCLE NO. 350

S/d converter series delivers 10 bit outputs

Analog Devices, P.O. Box 280, Rte. 1 Industrial Park, Norwood, MA 02062. (617) 329-4700. See text; stock.

The SDC1786, a 10-bit continuous tracking synchro-to-digital converter has an accuracy of ±30 arcminutes. The s/d converter accepts either 3-wire synchro plus reference input signals or resolver plus reference input signals and converts them into binary form. Four versions of the SDC1786 are available. They permit operation over either 0 to 70 or −55 to 105 C and at either 400 or 60 Hz. The 400 Hz models feature an 8640°/s (24 rps) tracking rate, 34,000°/s² acceleration, integral transformers and cost $199 or $299, depending on temp range 1 to 49 units). The 60 Hz models have a 1260°/s (3.5 rps) tracking rate, 850°/s² acceleration, and 1 to 49 prices of $192 and $292 plus $50 or $70 for a separate transformer module. The s/d converters come in 3.125 × 2.625 × 0.8 in. (79.375 × 66.675 × 20.32 mm) encapsulated modules and the transformers in 3.125 × 1.5 × 1 in. (79.375 × 38.1 × 25.4 mm) modules.

CIRCLE NO. 571

INSTRUMENTATION

Unit processes transducer outputs

LASICO Inc., 2451 Riverside Dr., Los Angeles, CA 90039. (213) 662-2128. $600.

The Auto-Scaler automatically processes transducer counts from a variety of measuring instruments with a built-in multifunction calculator. The calculator can also be used independently. When measuring areas on maps, blueprints or patterns, direct readout can be in any scale, such as ft^2, acres, $miles^2$, cm^2, km^2, etc. Similarly for linear measurements, readout is directly in inches, feet, meters, etc.

CIRCLE NO. 572

μP-controlled tester tracks down bad parts

Zehntel, Inc., 2440 Stanwell Dr., Concord, CA 94520. (415) 676-4200. Start at $47,950; 90 days.

Troubleshooter 400, a new μP-controlled, in-circuit test system, provides complete analog and digital fault analysis to the component level on complex PC boards plus extensive functional test capabilities. The μP makes it possible to handle with software, many functions that previously were hard wired. Programs can be generated and edited on-line; management oriented data such as statistics or component failures can be provided; and a fully formatted test program can be automatically produced from a list of components.

CIRCLE NO. 573

Temperature controller works in three modes

LFE Process Control Div., 1601 Trapelo Rd., Waltham, MA 02154. (617) 890-2000. $200.

Model 237 controller provides three-mode temperature control. The unit comes in a quarter-DIN size and extends only 6 in. in depth from the front of the panel. The analog setpoint has a ±50 F, or C, deviation indicator and is available with a single, dual or bidirectional output. The proportional band is adjustable from 1 to 20% of full span; derivative and integral actions are fixed at 1 and 6 min, respectively.

CIRCLE NO. 354

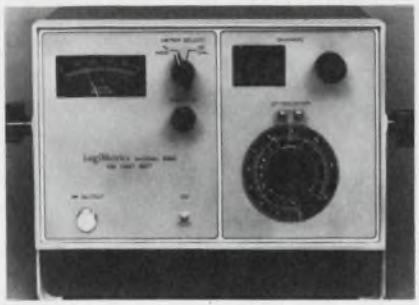
Logic probe 'mixes' with all kinds of logic

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. (415) 493-1501. $125; stock.

Model 545A logic probe indicates digital states and pulses in both high-level and low-level logic. An unambiguous, single-lamp displays HIGH or LOW level or detects bad levels and open-circuit conditions. CMOS or TTL operation is selected with a slide switch. CMOS logic threshold levels are variable and set automatically. Nearly all positive logic up to 18 V dc can be sensed using one probe. These families include: TTL, DTL, RTL, CMOS, HTL, HiNIL, NMOS and MOS.

CIRCLE NO. 355

Compact unit tests CB receivers

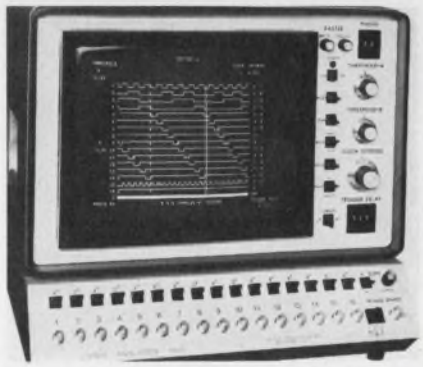


Logimetrics, 121-03 Dupont St., Plainview, NY 11803. (516) 681-4700. $1195; 90 days.

A citizens-band receiver test set, Model 980, weighs only 16 lbs and measures 7 × 11-1/8 × 13-1/4 in. The unit has a fully leveled rf output, selects the present 23 channels and can handle up to 64 channels as requirements increase. A large LED displays the channels. Output channels are derived from a single crystal-controlled synthesizer. The output attenuator is continuously adjustable from 0.1 μV to 10 mV, calibrated in both voltage and dBm, with an accuracy of ±1 dB.

CIRCLE NO. 356

Logic analyzer captures 16 channels



Vector Associates, 685 Station Rd., Bellport, NY 11713. (516) 286-9000. $4200; 60 days.

Model 1625 logic analyzer arrives ready to use complete with a 12-in. CRT, trigger-address register and trigger-delay generator. It can display 16 channels of captured data in a logic-state-vs-time presentation. The display also contains a character-generator readout of all front-panel switch positions, and can show two logic families (ECL/TTL, TTL/CMOS, etc.) in the same presentation.

CIRCLE NO. 357

INSTRUMENTATION

DVM burns up readings at 1000 conversions/s

Data Precision, Audubon Rd., Wakefield, MA 01880. (617) 246-1600. $2995; 60 days.

Probably the world's fastest integrating DVM, Model 7500 systems unit blazes along at 1000 conversions/s at its top speed. If that's too fast for you, you can choose from two other slower speeds—8 or 64 ms per conversion. The price includes full 5-1/2-digits, autoranging, BCD outputs, input filter, remote programming, ratio and dc V functions, and a lot more. Accuracy of dc V is ±0.004% rdg ±0.001% range ±1 LSD for 24 h.

CIRCLE NO. 562

Function gen doubles as 15-MHz counter

United Systems Corp., 918 Woodley Rd., Dayton, OH 45403. (513) 254-6251. $595; stock.

Model 304B is a combined function generator/counter featuring a 4-digit Monsanto orange LED display. The unit provides readout storage of a prior measurement while a new reading is made in either mode of operation. In the function gen mode, the digital display accurately indicates the output frequency, from 10 Hz to 1 MHz. The 10-s gate switch provides 0.1-Hz resolution without changing the output frequency range. In the counter mode, the 304B has a frequency range from 5 Hz to 15 MHz and six selectable gate times from 100 μs to 10 s for resolution to 0.1 Hz.

CIRCLE NO. 563

Automatic bridge speeds LCR measurement

Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, CA 94304. (415) 493-1501. $1740; 9 wks.

With this new automatic LCR bridge, you select the function—L, C, or R—the instrument selects the measurement range and equivalent circuit. Besides producing 3-1/2-digit LED readouts of LCR, the unit provides readouts in D, C/D, and L/D with the accuracy of manual bridges at rates as high as 1 reading/s. Accuracy is typically 0.2% of reading.

CIRCLE NO. 564

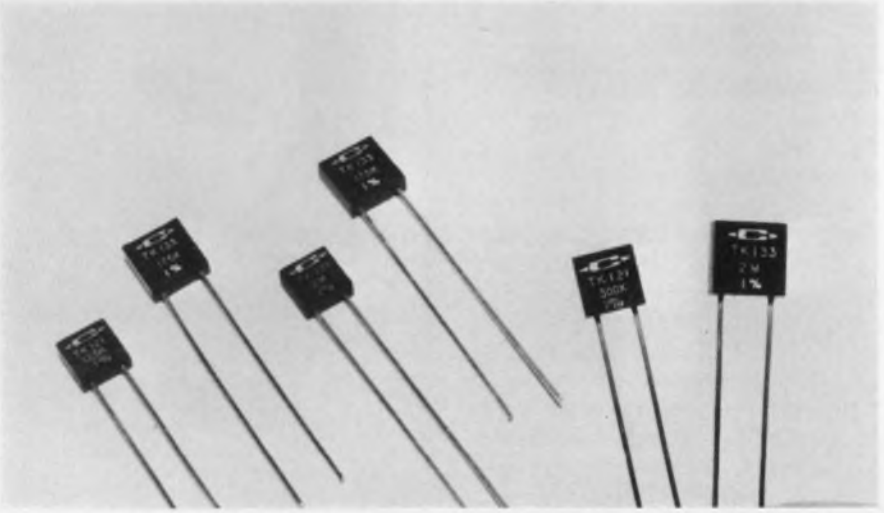
Field tester combines four functions in one

Weir Instrumentation Ltd., Durban Rd., Bognor Regis, Sussex, England.

An electronic field instrument for computer servicing provides a single test facility to replace separate oscilloscope, pulse-counter meter, frequency meter and digital multimeter units. The DTM 1000 field datameter measures 13.8 by 8.9 by 5.2 in. (including carrying case) and weighs 8.4 lb with accessories. The unit monitors input pulse levels and shows whether logic signals cross preset high and low threshold voltages. The DMM section indicates dc voltages from 100 μV to 1 kV, ac voltages from 1 mV to 500 V and resistances from 0.1 Ω to 9 kΩ.

CIRCLE NO. 565

Thick-film resistors give precision tempco at low cost



Caddock Electronics, 3127 Chicago Ave., Riverside, CA 92507. (714) 683-5361. See text; stock (small qty.), 3-5 wks (large qty).

Ultra-precision thick-film resistors with tempcos down to 5 ppm/°C and tolerances to ±0.05% are now available at less than half the cost of other resistors with competing performance.

Also, the type TK resistors from Caddock offer less variation in tempco over a larger temperature range than any other resistor on the market. They show tempcos of 5 ppm/°C from −55 to +175 C, with very little variation as a function of temperature.

A more expensive resistor, the S102 from Vishay, Malvern, PA, has a much lower tempco of 1 ppm/°C from 0 to 60 C, but it goes to 5 ppm over −55 to +125 C and to 10 ppm at +175 C. And another competing unit, the AR 90 from TRW/IRC, Burlington, IA, drifts 5 ppm/°C from −20 to +85 C, 10 ppm from −55 to +125 C, and even more over −55 to +175 C.

In 100-piece quantities, Caddock offers 100-kΩ, 5-ppm resistors with 1% tolerance for $2.53, and with 0.1% tolerance at $3.78. From Vishay, resistors with 1% tolerance cost $6.43 at the same 100-quantity level, and the 0.1% price is $7.56.

TRW/IRC charges $9.44 for its 1% part and $10.15 for a 0.1% resistor.

It should be noted, however, that aside from the resistors chosen for this comparison, Vishay offers tolerances to ±0.005% and TRW/IRC to ±0.01%.

Resistors from Vishay handle 0.3 W, are available with values from 30 Ω to 100 kΩ and come in 0.32 × 0.295 × 0.1-in. packages. The TRW/IRC resistors handle up to 1 W, have values from 1 kΩ to 10 MΩ and come in 1 × 0.4 × 0.4-in. cases. Caddock's resistors are available in 0.3 and 0.4-W models with resistances from 1 kΩ to 2 MΩ and come in 0.3 × 0.3 × 0.1-in. cases. Vishay also offers higher power resistors in other resistance ranges and larger cases.

Long-term stability of the Caddock resistors is an excellent 25 ppm/year. Vishay does as well. TRW/IRC comes in at 50 ppm/year.

Cases for the Caddock resistors are molded with radial leads and the thick-film elements inside are laser-trimmed in a serpentine pattern. Maximum voltage for the 0.3-W model is 200 V. The 0.4-W model can take 300 V.

The Caddock resistors also come in 10-ppm/°C, 1% versions.

Caddock **CIRCLE NO. 302**
Vishay **CIRCLE NO. 303**
TRW/IRC **CIRCLE NO. 304**

A PRIME STANDARD AT YOUR FINGERTIPS

$348

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High accuracy you can trust. Versatile measuring capabilities. An efficient, easy to operate meter. All at an affordable price. That's the DVM38. The complete DVM that sets new performance standards in 4 key areas.

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The DVM38 is more accurate in MORE circuits with these versatile ranges: 100μV to 2000V DC, 1KV AC; .01 Ω to 20 meg Ω; 0.1μA to 2A. Plus HI and LO ohms and a 50KV DC range with accessory Hv probe.

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CIRCLE NUMBER 97

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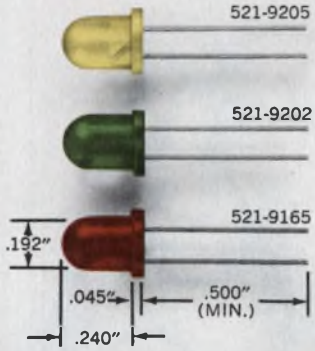
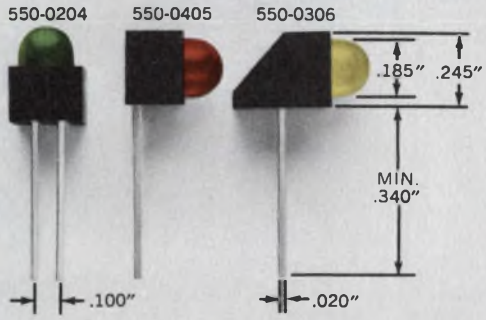
CIRCLE NUMBER 98

Dialight sees a need:

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



Now available in green, yellow and red. Mini-sized for maximum front panel density and easy panel mounting. High luminous intensity, low cost. Vibration/shock resistant. Solid state for long life. Wide viewing angles. Ideal for applications like panel lighting, film annotation and alpha-numeric displays.



Mix 'em or match 'em. LED logic state fault indicators are available in red, yellow and green, in a variety of shapes, some with a built-in integral resistor. Can be driven from DTL and TTL logic. Designed for easy alignment on PC boards so that multiple functions can be displayed.

Dialight, the company with the widest choice in switches, LEDs, indicator lights and readouts, looks for needs . . . your needs . . . and then they develop solutions for your every application. No other company offers you one-stop shopping in all these product areas. And no other company has more experience in the visual display field. Dialight helps you do more with these products than any other company in the business, because we are specialists that have done more with them. Talk to the specialists at Dialight first. You won't have to talk to anyone else. Send for your free new copy of Dialight's current catalog.

DIALIGHT
Dialight, A North American Philips Company
203 Harrison Place, Brooklyn, N. Y. 11237
(212) 497-7600

See Dialight.

CIRCLE NUMBER 99

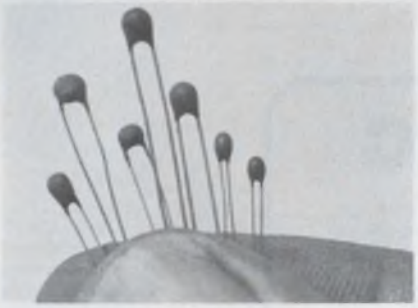
Slide pots protected by enclosed top slots

Centralab Electronics Div., Globe-Union Inc., P.O. Box 858, Highway 20 W, Fort Dodge, IA 50501. (515) 955-3771.

Series 700 slide potentiometers feature enclosed top slots which impede dirt, dust and other contaminants from entering the unit. The closed slots also guard against metal objects contacting electrically hot parts. The potentiometers use a composition resistor element with resistance values from 200 Ω to 5 MΩ. Both linear and audio tapers are available. Power rating is 0.25 and 0.5 W. Mounting is by twist tabs that may be top or bottom located. Terminal options include either PC or solder lugs. Two shaft lengths and alignment pins for stacking provide flexibility.

CIRCLE NO. 566

Chip thermistors easily interchanged

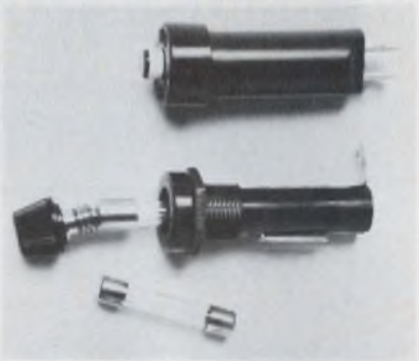


Western Thermistor Corp., 303 Via El Centro, Oceanside, CA 92054. (714) 433-4484. See text.

Point-matched chip thermistors with leads and a baked-on phenolic coating meet the requirements of temperature-control applications. These NTC thermistors are designed for interchangeability. Resistance tolerances are specified at temperatures other than the usual 25 C, such as 10,000 Ω ±1% at 80 C. This eliminates the uncertainties created by the ratio tolerances of standard thermistors. Cost may be as much as 50% less than that of curve-matched interchangeable thermistors. Resistance at the specified temperature is typically 2000 to 30,000 Ω; however, higher and lower resistance values are available.

CIRCLE NO. 567

Circuit protector replaces fuse and holder



Heinemann Electric Co., Magnetic Dr., Trenton, NJ 08602. (609) 882-4800. $1.77 (1000 up); stock.

The statement that "fuses are cheaper, and, besides, how often do they blow anyway?" is now officially obsolete. A new resettable circuit protector, the Re-Cirk-It, costs no more than a self-destructing glass fuse and its fuseholder. It also occupies the same panel space, and saves the cost of unnecessary service calls, according to Heinemann. The protector is available in current ratings from 3 through 20 A at 120 V ac or 32 V dc and 3 through 10 A at 240 V ac. A built-in time delay prevents nuisance tripping. The unit installs in a 5/8-in. round or "D" panel cutout, similar to that used for standard cylindrical fuseholders, and it extends only 1-3/4-in. behind the panel to the tip of its 1/4-in. quick-on terminals.

CIRCLE NO. 358

Motor/tach combination solves coupling problem

Servo-Tek Products Co., 1086 Goffle Rd., Hawthorne, NJ 07506. (201) 427-3100.

For high-performance velocity and positioning servo systems, a dc servomotor and tachometer generator are combined on a single shaft. This eliminates coupling problems that can limit servo-design specifications. Also, the low-ripple-torque, or slot-lock, characteristics of the motor portion results in wide speed-range capabilities. Integral gearing can be provided. General specifications include a speed range of 10,000 rpm and a continuous direct-drive output torque to 2.5 oz-in. and up to 300 oz-in. with gearing.

CIRCLE NO. 359

Filters handle 1 kW at 100 MHz

TT Electronics, 2214 S. Barry Ave., Los Angeles, CA 90064. (213) 478-8224. $150.00; 2 wks.

High-power low-pass filters (Series U) are rated at 1000 W for frequencies from 10 to 100 MHz. The units provide attenuation of 40 dB at 1.13 times the specified cutoff frequency. Passband insertion loss is less than 1 dB, and VSWR is 1.5:1 maximum.

CIRCLE NO. 360

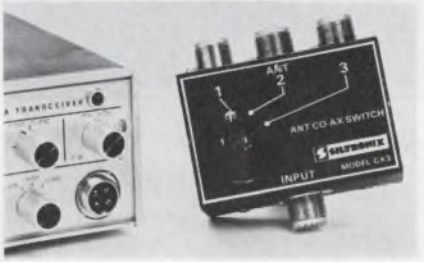
Low-cost lasers have compact housings

Laser Energy, 320 N. Washington St., Rochester, NY 14625. (716) 385-1150.

A line of low-cost, compact lasers, for laboratory and industrial use, doesn't require gas sources, vacuum pumps or controls. Prices are $495 for a nitrogen laser; $990 for a neon laser; $1500 for a hydrogen laser; and $1900 for a krypton-fluoride laser. The new lasers emit wavelengths ranging from 540.4 nm for the neon laser to 337.1 nm for the nitrogen unit, 244.8 nm for the krypton-fluoride model and 160.0 nm for the hydrogen laser. All are designed to deliver peak power of 3 kW at a repetition rate of 10 pps. Mounted on an aluminum chassis, the lasers measure only 20 × 5 × 4-in. Input power consumption is less than 10 W, and the lasers can operate from 115 V ac.

CIRCLE NO. 361

Switch interfaces 3 antenna systems



Siltronix, 269 Airport Rd., Oceanside, CA 92054. (714) 757-8860. $9.95.

A compact antenna switch permits 27-MHz CB transceivers to operate into up to three antenna systems. The Model CX-3 coax switch has a power rating of 150 W, with a standing wave ratio of less than 1.2:1 at 27 MHz. The unit weighs just 7 oz and measures 3-1/4 × 2-1/2 × 3-1/4 in.

CIRCLE NO. 362

Design Aids

Mini DataStation

The operation of the HP 2644 mini DataStation is shown in a reference booklet. The booklet contains 10 pages of charts, a photograph, an ASCII code chart, a generalized I/O control escape sequence and status information. Hewlett-Packard.

CIRCLE NO. 363

Heat sinks

A 25 × 38-in. heat-sink chart plots volume vs performance for quick, easy reference to a family of extrusions designed to meet specific applications. All extrusions are drawn to scale and information includes surface area, weight and thermal resistance. Thermalloy.

CIRCLE NO. 364

Miniature motors

A dc miniature motor selection chart shows motors with diameters from 7/8 to 2-1/4 in. and their standard planetary gearboxes. The chart indicates torque, speed, voltage, reduction ratios and armature windings. TRW Globe Motors.

CIRCLE NO. 365

Guide for mm threads

Metric screw pitch sizes, diameters of standard ISO thread sizes and fine thread are given on a stainless steel ruler. The reverse side gives the decimal equivalents of common fractions in inches and millimeters. Metric's.

CIRCLE NO. 366

Dielectric materials

Adhesive, casting, potting and encapsulating resins; conformal and varnish resins; electrically and thermally conductive resins, as well as tooling resins, are covered in a dielectric materials selector chart. Formulated Resins.

CIRCLE NO. 367

Application Notes

Shock spectrum

The fundamentals involved in measuring and analyzing shock spectrum are covered in a 30-page booklet, "Understanding and Measuring the Shock Response Spectrum." Spectral Dynamics, San Diego, CA

CIRCLE NO. 368

Microwave signal sources

"Recent Advances in Solid-State Phase-Locked Microwave Signal Sources," a 12-page brochure, describes briefly six units and presents principal reasons for using the phase-lock techniques. Communication Techniques, Parsippany, NJ

CIRCLE NO. 369

Semiconductor testing

The techniques of testing chip-to-header bonds in semiconductor devices and the temperature-compensation characteristics of zener diodes are covered in three application notes. Lorlin Industries, Danbury, CT

CIRCLE NO. 370

Vibration tests

An eight-page application note, "Shake, Rattle or Rap—How to Conduct Vibration Tests," describes three techniques for testing mechanical structures. Nicolet Scientific, Northvale, NJ

CIRCLE NO. 371

Three-phase motors

A four-page "Technote" describes causes and effects of unbalanced voltages on three-phase motors. Diversified Electronics, Evansville, IN

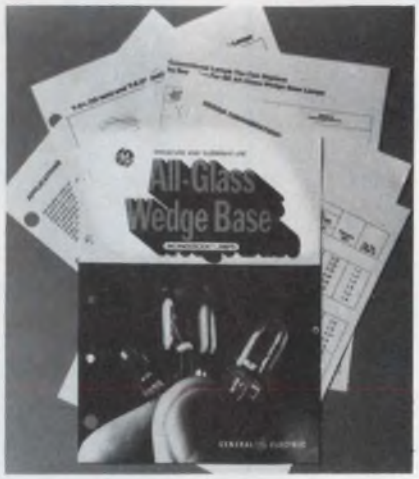
CIRCLE NO. 372

Heat-recovery units

Air-to-air heat recovery units are described and evaluated in an eight-page brochure. Hughes Electron Dynamics, Torrance, CA

CIRCLE NO. 373

New Literature



Wedge-base lamps

Engineering and physical specifications on 24 types of GE all-glass wedge-base lamps along with a list of metal-base lamps, which they can replace in new designs, are covered in a 12-page brochure. GE, Cleveland, OH

CIRCLE NO. 374

Relays and accessories

Over 1100 stock relays and accessories are contained in a 32-page catalog. List prices are shown for each item. Potter & Brumfield, Princeton, IN

CIRCLE NO. 375

Spectrum analyzers

A 12-page illustrated brochure presents spectrum analyzers. Accessory items such as preamps, filters, cameras, etc., are also shown, and there's a complete listing of the HP applications literature and video tapes pertaining to spectrum analyzers. Hewlett-Packard, Palo Alto, CA

CIRCLE NO. 376

Pots, switches & dials

Basic trimming potentiometers, miniature switches, precision pots and turns-counting dials are covered in an eight-page brochure. Full specifications and photos are given. Spectrol Electronics, City of Industry, CA

CIRCLE NO. 377

Heavy-duty connectors

A 94-page catalog features three series of heavy-duty cylindrical connectors for use in rugged outdoor environments. Technical and dimensional data are included. Bendix Electrical Components Div., Sidney, NY

CIRCLE NO. 378

Momentary PB switches

Basic switch materials, specifications and options of momentary snap-action pushbutton switches are described in a four-page brochure. Included are photographs, schematic drawings and diagrams. C&K Components, Watertown, MA

CIRCLE NO. 379

A/d conversion system

Specifications that describe the performance of the GMAD-4 a/d conversion system are given in a 12-page brochure. Preston Scientific, Anaheim, CA

CIRCLE NO. 380

Silicon power transistors

Included in a list of the company's products are npn and pnp transistors in all standard JEDEC packages. The list serves as a cross-reference to competitively manufactured brands. Kertron, Riviera Beach, FL

CIRCLE NO. 381

PC connectors

Printed-circuit-board connectors, ranging from microminiature, dip solder, right angle, pierced and wrapped-wire to miniature ribbon, are illustrated in a 48-page catalog. All dimensions are in English and metric systems. Viking Industries, Chatsworth, CA

CIRCLE NO. 382

Microwave components

"Solid-State Microwave Control Components," a 20-page catalog, contains specifications, performance curves, photographs and package outlines on switches, limiters and levelers, reflective and absorptive attenuators and integrated component assemblies. Omni Spectra, Merrimack, NH

CIRCLE NO. 383

Bulletin Board

Agreement has been reached by **National Semiconductor** and Synertek in which Synertek will manufacture National's full line of **4096-bit RAMS** as an alternate source.

CIRCLE NO. 384

Texas Instruments' optically coupled isolators—Models 4N22, 4N23 and 4N24—have received military qualifications and listing in MIL-STD-701.

CIRCLE NO. 385

EECO's fast-mount hardware provides for instant panel mounting of thumbwheel switches without tools, mounting holes, screws, nuts, bolts or washers. The hardware fits all panel thicknesses from 1/16 through 1/8 in.

CIRCLE NO. 386

Airpax has increased sensitivity and torque of its **edge-reading meters.** The meter's maximum sensitivity has been increased from 1 mA to a full-scale sensitivity of 100 μA dc.

CIRCLE NO. 387

General Electric Information Services has introduced **Production Fortran (PFN), a production-oriented language.** PFN provides computer output identical to that generated by Fortran IV, minus nonessential features like line number references in error messages, warning messages and subscript checks. PFN uses the same syntax as Fortran IV.

CIRCLE NO. 388

Intersil has completed an agreement with Signetics to **second-source Signetics' DMOS devices,** including ICs and a broad line of FETs.

CIRCLE NO. 389

The Electronic Components Div. of Burroughs has announced price reductions of up to 35% on its **SELF-SCAN bar-graph-panel line.**

CIRCLE NO. 390

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.

Computer Products. Computer systems and power modules.

CIRCLE NO. 551

Executone. Communications systems.

CIRCLE NO. 552

Unitrode Corp. Semiconductor devices.

CIRCLE NO. 553

Wabash. Electromagnetic products and systems, and magnetic-coated products.

CIRCLE NO. 554

Telefile Computer Corp. Disc memory systems and computer data communication systems.

CIRCLE NO. 555

Advanced Micro Devices. Integrated circuits.

CIRCLE NO. 556

ARi Industries. Cable, nuclear instrumentation, thermal instrumentation and heaters.

CIRCLE NO. 557

Logicon. Process control systems for materials handling, strategic weapons systems, training and tactical data systems and printing automation systems.

CIRCLE NO. 558

Medtronic. Biomedical electronics.

CIRCLE NO. 559

Data 100. Data processing equipment.

CIRCLE NO. 560

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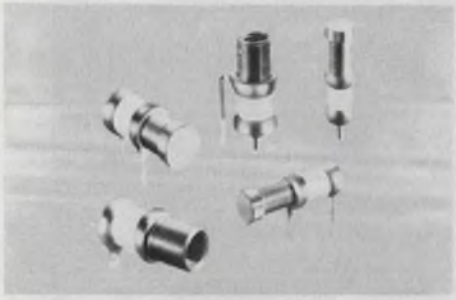
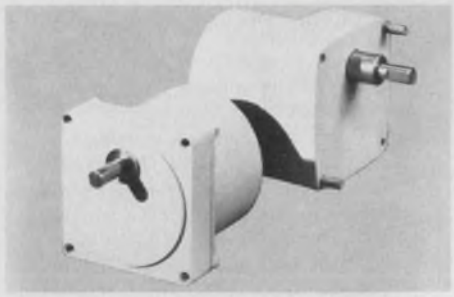
quick ads

New and current products for the electronic designer presented by their manufacturers.



MINIATURE LOW INDUCTANCE CAPACITORS, 50% more capacity in the same size is now available in these Johanson extended range capacitors. Beautiful for microwave, VHF and UHF applications, they offer fine tuning, ultra high Q, low temperature coefficients and "sizes" for hybrid and microcircuit as well as standard applications. Featured are capacitance range .5 to 5.0 pf, Q>10,000 @ 100 MHz, and extra fine tuning. Johanson Manufacturing Corporation, Rockaway Valley Road, Boonton, NJ 07005 (201) 334-2676.

MINIATURE CAPACITORS 141

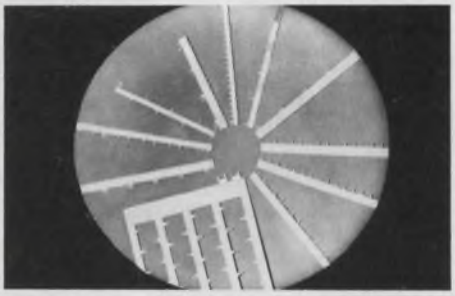


Dual Speed Unidirectional Synchronous Motor (Series 86000) offers advantages for instrument drives, especially strip chart recorders and telecopiers. Available torque to 35 oz-in. Choice of square or NEMA 2-11 gear box gives wide range of dual speed combinations. Fast start/stops eliminate need for clutching and prestarts. Available in 24, 120 or 240 VAC, 60 Hz, with CW or CCW rotation. Weight 30 oz. U/L listed. North American Philips Controls Corp. Cheshire, Conn. 06410 (203) 272-0301.

DUAL SPEED SYNCHRONOUS MOTOR 144

A high-reliability first. The "2972" Card Reader is fully qualified for Airborne or Ground Support Equipment. Eliminates human error. Saves space. Competitive with other reliable programming methods. AMP Incorporated, Capitron Division, Elizabethtown, PA 17022. (717) 367-1105.

MIL SPEC STATIC CARD READER 147

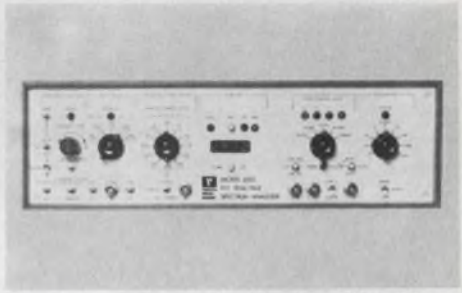


Mini/Bus® Evaluation Kit, $25, in stock. Lets you try Rogers' low-cost, noise attenuating, high packaging density power distribution system for PC boards. Millions in use. Standard parts on 2 weeks delivery, or less! Customer parts 4 to 6 weeks delivery. Rogers Corporation, Chandler, AZ 85224. Phone (602) 963-4584

MINI/BUS 142

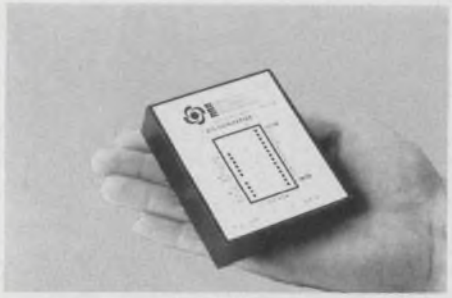
Free New '76 catalog contains over 34,500 quality power supplies from the world's largest manufacturer, Power/Mate Corp. Power Supplies for every application including submodulars, open frame, varirated, encapsulated, laboratory & system. All units UL approved and meet most military and commercial specs for industrial and computer uses. Power/Mate Corp., 514 S. River St., Hackensack, NJ 07601 (201) 343-6294

POWER SUPPLIES 145



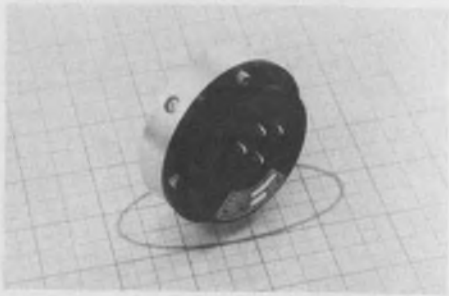
Princeton Applied Research announces the Model 4512 FFT Real Time Spectrum Analyzer. The magnitude spectrum is available with 512 lines of resolution spanning dc-10 Hz to dc-40 kHz, in twelve ranges. The full spectrum can be updated every 35 ms resulting in 16 kHz real time bandwidth. Transient capture and spectrum averaging modes are standard features. Both the temporal signal and spectrum can be displayed simultaneously. Price: $6,900 F.O.B. Princeton. Applied Research Corp., Box 2565, Princeton, NJ 08540

FFT REAL TIME SPECTRUM ANALYZER 148



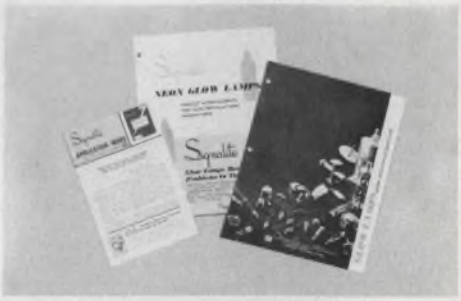
DIGITAL TO SYNCHRO CONVERTERS— 14, 12 or 10 bit input, 11.8/90V, 400 or 60Hz transformer isolated output, accuracy ±4, ±15 or ±30 min. Driving 1VA, 2VA (2.6" x 3.1" x 82"H module) or 5 VA loads (4½" x 9¼" PC card). Price from $350 in qty. Other CCC products are Synchro to Digital or DC, and DC to Synchro Converters, Solid State C.T.'s or CDX's, and Absolute Encoders. Send for Free Catalog & Application Notes. Computer Conversions Corp., East Northport, N.Y. 11731 (516) 261-3300.

DIGITAL TO SYNCHRO 143



LOW COST PENDULUM CP17-0601-1 provides vertical references for monitoring and control of pitch and roll angular displacements. Replaces expensive vertical gyros for many instrument and control system applications. Potentiometric output; hermetically sealed; fluid damped; range of ±45°; resolution less than 0.20°; linearity within 0.5; total error band of ±1% full scale. Wide range of models available. Humphrey, Inc., 9212 Balboa Ave., San Diego, CA 92123. Tel. (714) 565-6631

PENDULUM 146



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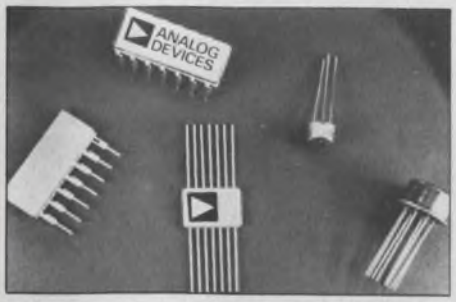

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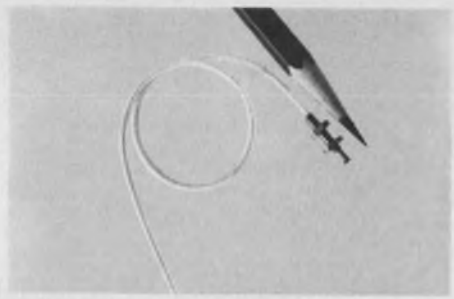

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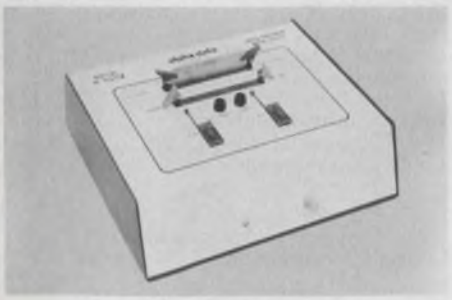

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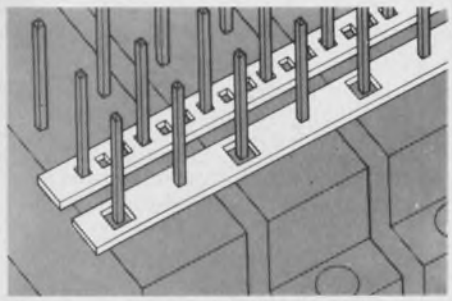

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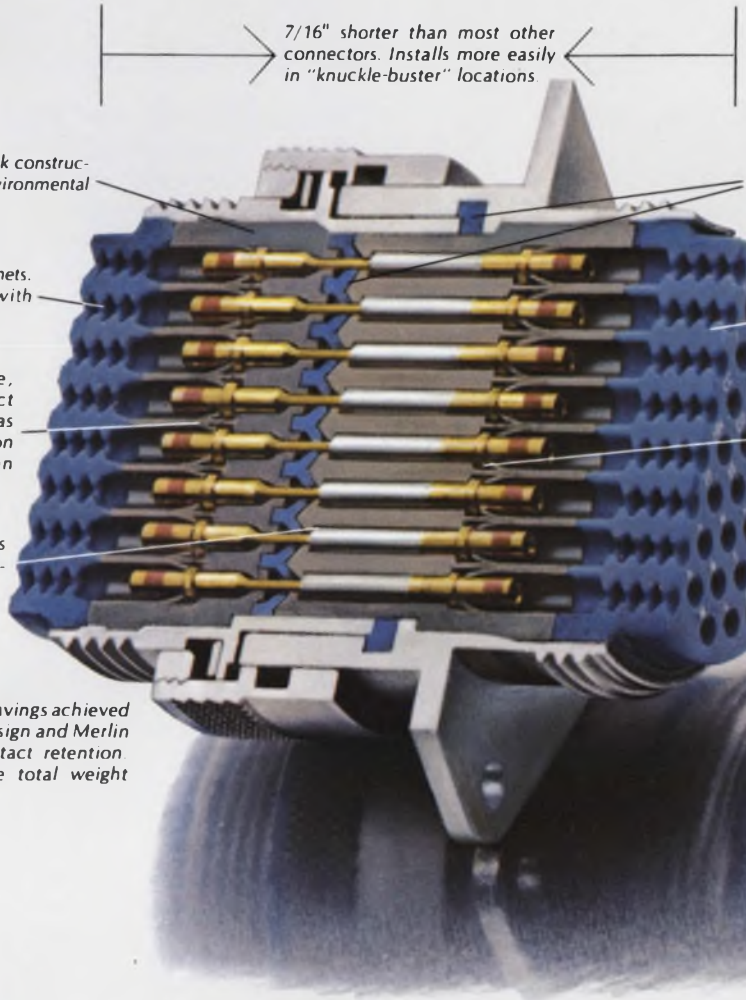

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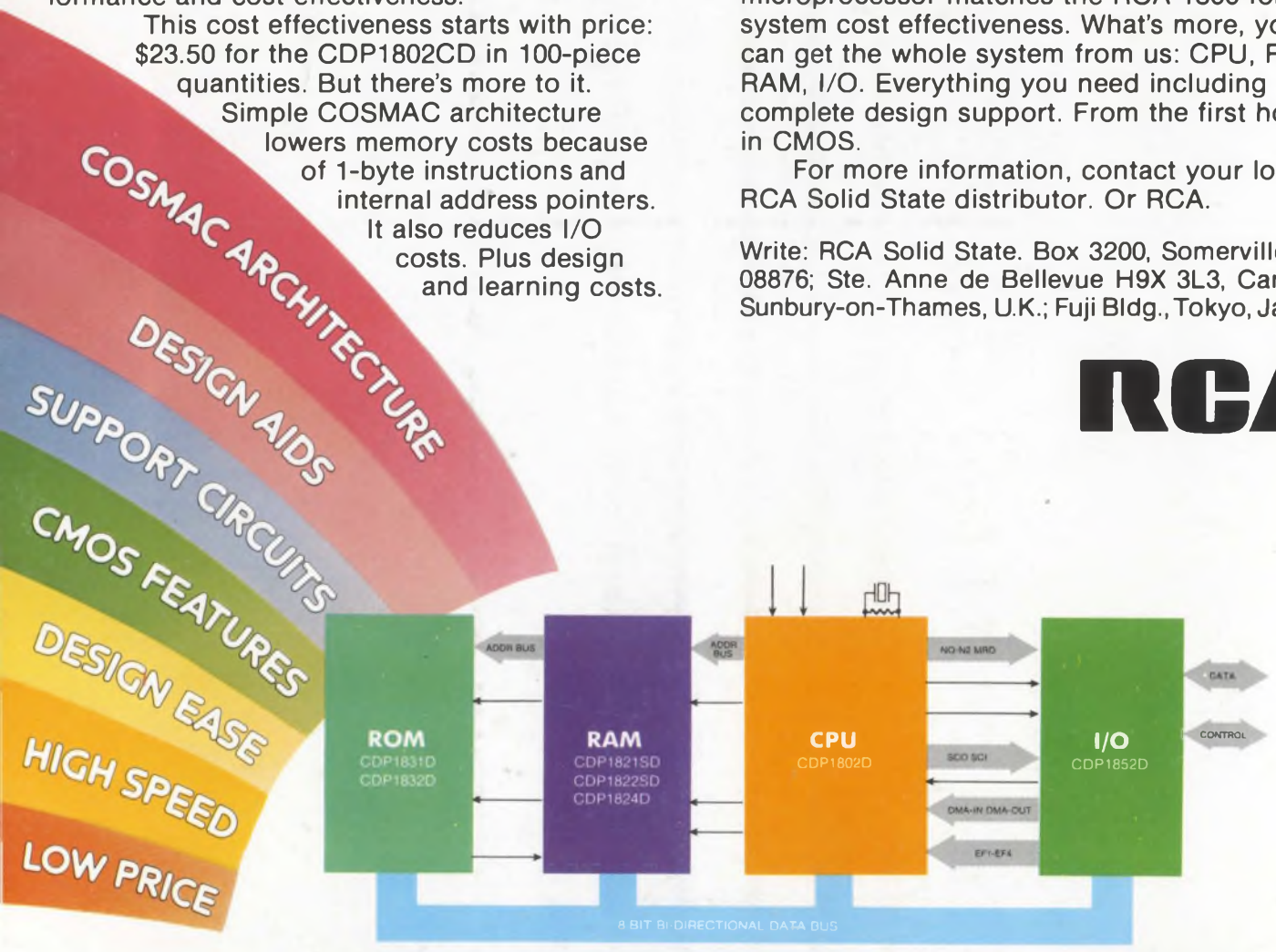

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