

AUGUST 19, 1976

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Bipolar dynamic memory moves in on MOS/99

How to measure microcomputer input/output performance/ 105

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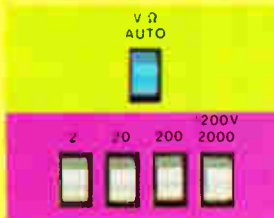
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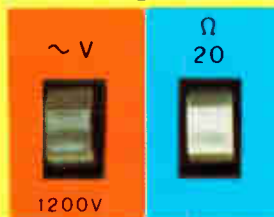
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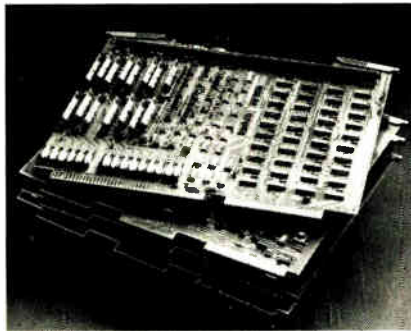
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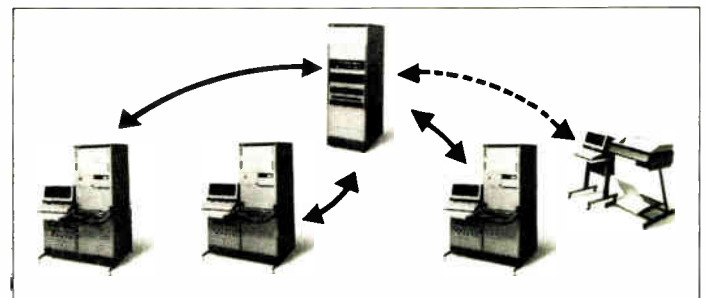
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Highlights

Cover: Light transforms isolation amplifiers, 81

By enhancing their response and bandwidth, shrinking their size, and getting rid of all electromagnetic interference, optical coupling opens up new applications for isolation amplifiers. Medical electronics, avionics, and nuclear-power generation will be among the beneficiaries.

Cover design is by Art Director Fred Sklenar.

Consumers pose hazards for solid-state firms, 65

The fast-moving market of consumer electronics penalizes any manufacturer whose products fall behind in reliability, technology, delivery, and cost-competitiveness. But the high potential profits are encouraging some semiconductor firms to persevere.

Z-80 heralds third microprocessor generation, 89

With up to five times the throughput of its predecessors and half to a quarter their program memory, the Z-80 chip set achieves a new high in microprocessor performance. It's also software-compatible at the machine-code level with the popular 8080A.

Bipolar RAM butts into main-memory field, 99

A 4,096-bit random-access memory, employing integrated injection logic for its technology and sophisticated processing methods, is the first serious bipolar competitor for 4-k metal-oxide-semiconductor designs. It is twice as fast as them, dissipates about the same amount of power, and costs only a little more.

And in the next issue . . .

Wescon preview: the people, the program, and the products . . . tips for users of 4-k semiconductor memories . . . analog-to-digital conversion at 10 times the speed—a new technique.

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Microprocessors are certainly among the most versatile devices ever created by electronics technology, and it's hard to believe that just a few years ago they did not even exist. Yet new as they are, not even microprocessors are sheltered from progress.

For example, on page 89, you'll find a technical article on a new microprocessor chip set that warrants being called part of the third microprocessor generation. The article, by a team from Zilog Inc., points out that "the Z-80 microprocessor chip set represents as big an advance as was made between the 8008 and the 8080." Incidentally, two of the co-authors of the article—Zilog president Federico Faggin and Masatoshi Shima—also co-authored the first full technical article on the Intel 8080 microprocessor [*Electronics*, April 18, 1974, p. 95].

Amazingly, reports Faggin, "The first time we tested the Z-80 chip, it was almost workable, except for a couple of instructions. But the second time, after we made the changes, we put the wafer under the probe and ran the software directly on it." It worked. "And then we had a celebration, of course."

Incredible as it sounds, this success story has a rationale. "This was probably the first time that a chip was developed at the same time as the software and the development system," explains Zilog's president. Without such an approach, even a small change in one of the three areas can ripple through the other two, requiring many other changes.

Faggin says Zilog, which obtained its final financial commitments from Exxon Enterprises in June 1975, started with a team of 11 people who

remained together throughout the development of the Z-80. Now the company totals 42 employees and is getting ready to move next month from Los Altos to a new plant in Cupertino that will hold the company's own wafer fabrication facilities. Till now, Zilog has had to use outside suppliers.

There's more, too, in this issue about microprocessors. On page 105, we are presenting an article on how to evaluate a microprocessor's input/output performance, which in most applications is as important a parameter as the device's internal data-handling ability.

As Howard Raphael of Intel Corp., who wrote the article, explains: "Through its input/output lines, the microprocessor correlates the activities of all the other system elements, including keyboards, printers, and disk units. Its value to the system depends heavily on how well it performs these input/output functions. For a designer to choose the most cost-effective microcomputer for a given application, therefore, he requires a standard by which to measure and compare different microcomputers."

The article describes a valid method of comparing such performance. The activity index presented should be of help in evaluating what is, after all, a prime characteristic of a microcomputer—its ability to communicate with other system elements.



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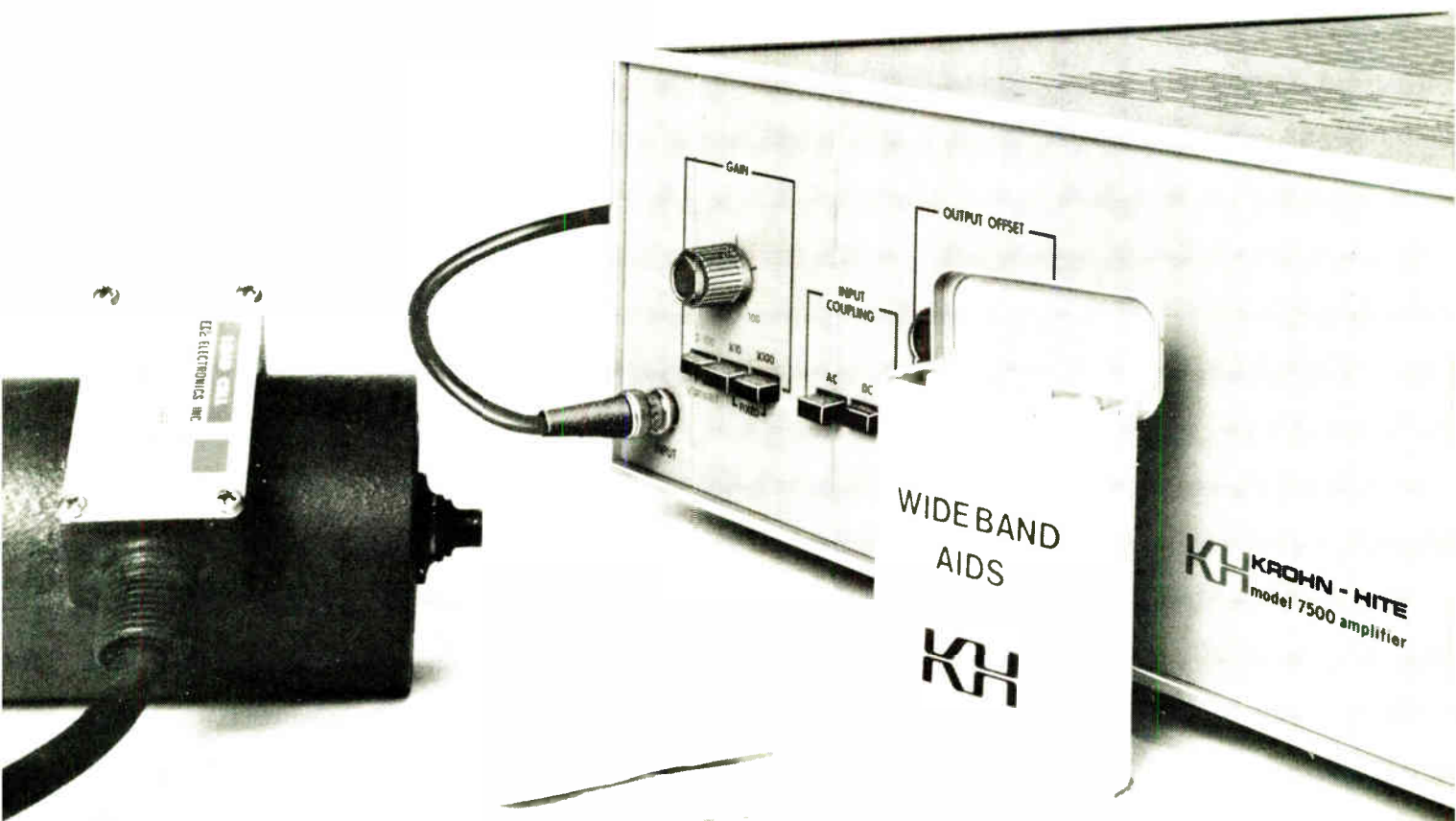
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Readers' comments

Collector resistor was too big

To the Editor: In the circuit shown in "Triangular waves from 555 have adjustable symmetry," by Devlin M. Gualtieri [Jan. 8, p. 111], I do not understand how transistor Q_1 switches on and off, depending on collector voltage of Q_3 . The base of Q_1 seems to be pegged at 3.3 v due to the zener connected between supply positive and Q_1 base. Q_3 does not change this voltage.

I. A. Dasan
Salem, India

■ **The author replies:** Dasan is correct in pointing out that the V_{BE} of Q_1 never goes below about 3 volts for the circuit shown because of the current flow through the zener in the base circuit of Q_2 . When Q_3 is off, its collector never goes above about 7.5 v, whereas about 11 v is needed to turn Q_1 off.

In my zeal to simplify the circuit and decrease its current drain, I specified the Q_3 collector resistor too high; 390 ohms or smaller would be correct. Likewise, the current-limiting resistors for the two zeners could be increased. Q_2 , however, has no turn-off problem, since Q_3 clamps its base voltage nearly to ground; thus, a change of one resistor value will correct the circuit.

Encouraging acupuncture

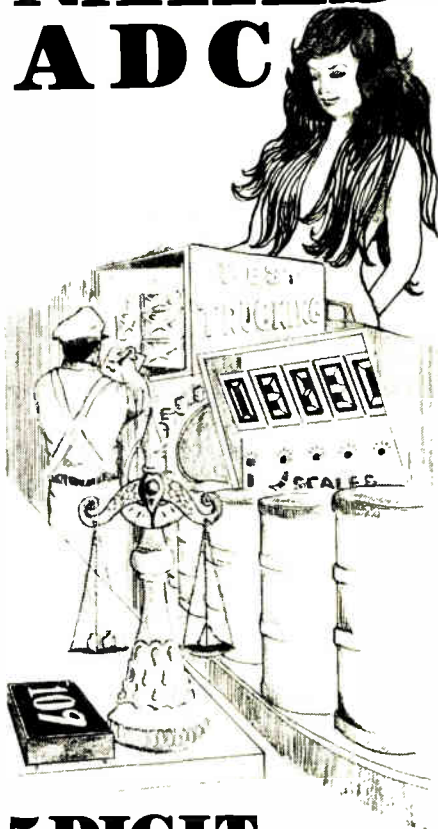
To the Editor: For the last three years, we have been producing electronic acupuncture devices for both "detecting" and "treating" acupuncture points. These devices, while experimental (FDA requirement), have been patterned after both Japanese and Chinese approaches to this field. We have also been offering educational courses to doctors of various disciplines and have earned an excellent reputation for devices and instruction.

Most recently, we have been supporting education and devices for a "newer" discipline, which is done almost exclusively on the ear and is called auriculotherapy, patterned after a French Dr. Nogier's work.

I appreciate the international emphasis ("Laser allows 'needleless' acupuncture," p. 8E, Jan. 8).

Jerry J. Tomacek
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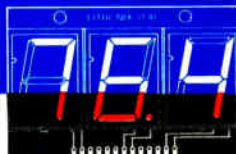
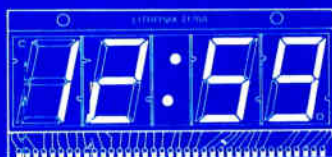
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Circle 163 on reader service card

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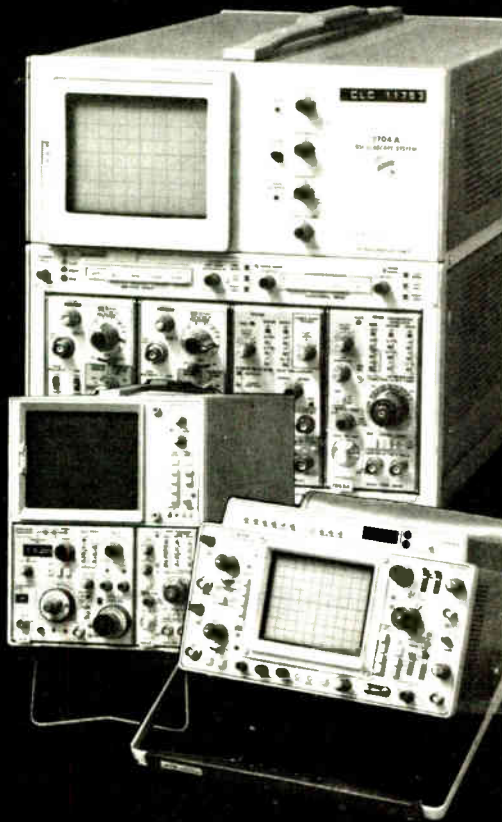
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News update

■ When Hewlett-Packard Co decided to compete head-to-head with oscilloscope-industry front-runner Tektronix, it brought out a 100-megahertz-bandwidth scope, the model 1740A. In the year since it challenged the then three-year-old Tektronix model 465 [*Electronics*, Sept. 4, 1975, p 31], HP has done at least well enough to have identified receptive market segments.

Thus, again following Tektronix' lead, it has added a TV-synchronizing option to better fit the scope to market needs. The option, says Herman Hinton, oscilloscope product-line manager at HP's Colorado Springs division, "allows you to conveniently synchronize on the video signal of a TV set." The option will cost between \$150 and \$200, he says, and HP is just beginning to ship it to customers.

As to how well HP, a distant second to Tektronix in overall scope sales with about 15% of the sales dollars, is doing with the model 1740A, Hinton says sales have "exceeded my expectations." He adds that the scope "has been well received at the marketplace," though he concedes that HP's market share has not increased.

■ Fairchild Camera and Instrument Corp.'s variable analog delay line using charge-coupled devices has been available for a year to audio and video processors. Although the company had a large market in mind for the model 311 and even talked of prices in the \$15 area for large-quantity orders [*Electronics*, Sept. 4, 1975, p. 36], it realizes now that the 311 probably was never destined to be produced in high volume because it had only 260 elements—a pair of 130-bit analog shift registers on a single chip.

Now, to expand the market potential a bit, Fairchild has built a second model—a dual 455-element device with a NTSC-standard one-horizontal-line delay. Labeled the CCD-321, it is priced at \$72 in 100-unit orders. The 311, by the way, now carries a \$40 price tag for the same volume, instead of its original \$50.

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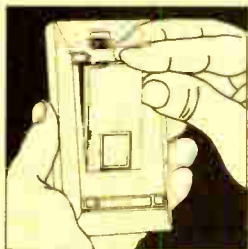
1. It lets you key in your favorite program—debug it—and retain in memory for repeated use. So you gain accuracy as well as time.

2. You can add additional functions not on the keyboard (hyperbolics, octal/decimal conversions, etc.), simply by writing programs and storing them permanently in memory.

3. It enables you to gather data one place (such as at a survey jobsite) and retain your results until you get back to work with them later (just think of the time you'll save and the accuracy you'll gain because you *won't* have to re-enter information).

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Am25LS241	Am 54/74LS241	Octal Bus Inverter	4th Q.
Am25LS273	Am 54/74LS273	Octal D-Type Register	4th Q.
Am25LS299	Am 54/74LS299	Eight-Bit Shift Register, Asynch. Clear	Now
	Am 54/74LS322	Second Source to Am25LS22	Now
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Am25LS373	Am 54/74LS373	Octal Transparent Latch	4th Q.
Am25LS374	Am 54/74LS374	Octal D-Type Register	4th Q.
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	Am 54/74LS385	Second Source to Am25LS15	Now
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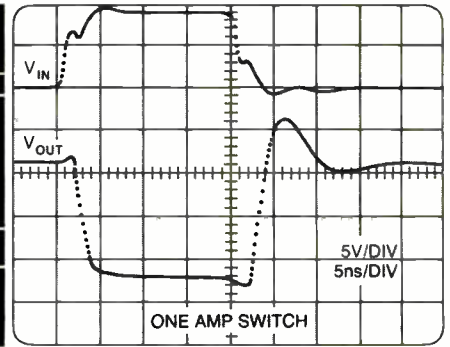
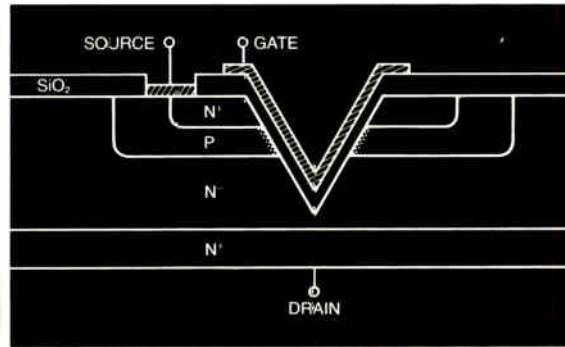
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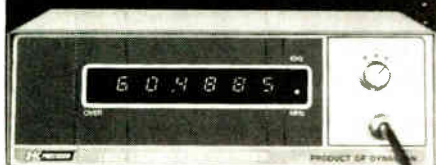
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People

Jasper: launching opposition
to the communications act

Not many jobs are designed so their successful completion leaves the worker out on the street and happy to boot. Yet, that is the prospect facing 47-year-old Herbert N. Jasper in his new post as executive vice president of ACCT—the *ad hoc* committee for competitive telecommunications.

Formed recently by four specialized common carriers, ACCT's sole purpose, says Jasper, is to oppose and defeat "the telephone-monopoly legislation currently before the Congress," better known as the Consumer Communications Reform Act of 1976 [*Electronics*, March 4, p. 33].

But it is unlikely that Jasper's job will end soon. Lobbying against the Bell System and its supporters is an enormous task, particularly in view of ACCT's limited resources. Its only members so far are Data Transmission Co., MCI Telecommunications Corp., Southern Pacific Communications Co., and U.S. Transmission Systems Inc., although it also receives contributions from several other companies as well.

Credentials. His new employers consider that Jasper's seven years of legislative experience in the Federal Government and his contacts on Capitol Hill more than offset his newness to the telecommunications field. He has worked for the Library of Congress, the U.S. Comptroller General's office, and the Senate Labor Committee. He also served from 1969 to 1973 as special and legislative counsel to Sen. Walter Mondale (D., Minn.).

Operating from a small suite in Washington's Commodore Hotel, Jasper, a one-man staff, reflects an appropriate bias: "The telephone companies' position is unsound. They want a guaranteed statutory monopoly." Of the specialized carriers' competitive threat, Jasper contends the Bell System's "claims are egregiously exaggerated." Bell's description of the bill as a consumer



ACCT's man. Herb Jasper is fighting what he sees as a statutory monopoly for Bell.

measure, he calls "fraudulent."

Jasper is more cautious about disclosing specific strategies ACCT will employ, saying only he wants to disseminate the competitors' side of the story "as widely and dispassionately as we can. My role is to coordinate the effort."

Catch up. Beyond ACCT's limited resources, Jasper considers that his main problem is to catch up with the Bell System's eight-month head start in the legislative drive. However, Jasper, who holds a master's degree in public administration, enjoys the role of underdog. "This may sound like a lot of pap, but I wanted a job I could throw myself into," he says. "And I agree with the position of the companies in ACCT" that the bill will eliminate competition in data communications, private-line services, and interconnect hardware.

Wolkins plans GI's
MOS lead in Europe

"We're already the leading manufacturer in Europe of metal-oxide-semiconductor units for the telecommunications and consumer markets, combined," asserts Otis Wolkins, the new vice president and general manager of General Instrument Corp.'s Microelectronics Group Europe, based in Glenrothes, Scotland. "And we intend to become the No. 1 house in total MOS sales dollars to

designed for the User, —logically.



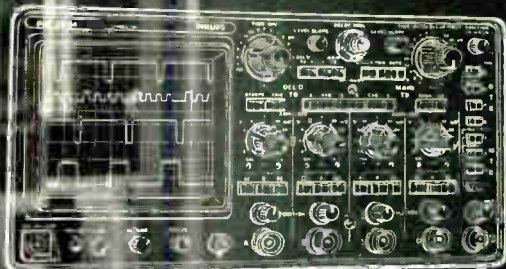
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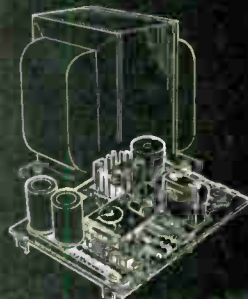
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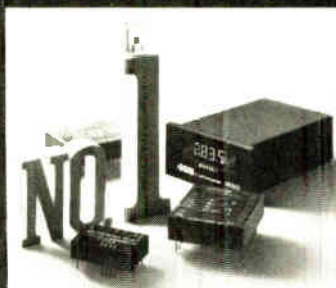
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both of those markets as well."

The youthful-looking, 36-year-old Wolkins predicts that the Western European MOS market will increase 30% to 35% by 1980 to represent about one fourth of an estimated \$7 billion world market. But unlike his major rivals, such as Philips, Siemens and the American MOS contenders that have set their sights on a broad spectrum, Wolkins is happy to specialize.

"You just can't beat the volume you find when you're producing tuning circuits for television sets and dialer circuits for telephones," says Wolkins in his low-key Midwestern accent. "It far surpasses the numbers in the area that's getting the most attention—microprocessors."

GI, headquartered in Hicksville, N.Y., has been maintaining its pace in Europe with new video-game chips, remote controls, and digital tuning circuits. All are made at GI Microelectronics' sole European production facility at Glenrothes.

Motorola man. Wolkins came to GI in Scotland after 14 years with Motorola's Semiconductor Products division, where he was most recently director of Federal high-reliability operations. And, since he was instrumental in setting up Motorola's complementary-MOS facility in East Kilbride, Scotland, he should know about turning out products.

GI has several new MOS products in the works. "We're expanding our family of telephone circuits that convert push-button tone signals into rotary pulse signals and *vice versa*. And there are plans to produce early next year a family of MOS devices—likely two-chip, p-channel circuits—for commercial facsimile systems."

He envisions a large demand for a new two-chip set that enables record-player turntables to be converted from electromechanical to solid-state control, as well as new chips for the booming video-games market. And the Glenrothes plant will soon begin producing new TV remote-control and tuning circuits, he says. However, he declines to comment on reports that GI has nailed down as customers two of the larger TV set producers in Europe.



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Circle 19 on reader service card

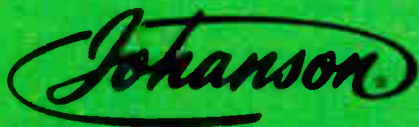
The image shows several small, cylindrical thin-trim capacitors with gold leads, arranged in a semi-circle. In the background, a portion of a Pulsar Watch is visible, showing its intricate internal mechanism and a black crystal component. The entire scene is set against a dark green background.

Thin-Trim capacitors

Tucked in the corner of this Pulsar Watch is a miniature capacitor which is used to trim the crystal. This Thin-Trim capacitor is one of our 9410 series, has an adjustable range of 7 to 45 pf., and is .200" x .200" x .050" thick.

The Thin-Trim concept provides a variable device to replace fixed tuning techniques and cut-and-try methods of adjustment. Thin-Trim capacitors are available in a variety of lead configurations making them easy to mount.

A smaller version of the 9410 is the 9402 series with a maximum capacitance value of 25 pf. These are perfect for applications in sub-miniature circuits such as ladies' electronic wrist watches and phased array MIC's.

The logo for Johanson Manufacturing Corporation, featuring the name "Johanson" in a stylized, cursive script font enclosed within an oval border.

Johanson Manufacturing Corporation
Rockaway Valley Road
Boonton, New Jersey 07005
(201) 334-2676 TWX 710-987-8367

Meetings

Comcon 76 Fall, IEEE, Mayflower Hotel, Washington, D.C., Sept. 7-10.

1976 International Machine Tool Show, National Machine Builder's Association (McLean, Va.), International Amphitheatre and McCormick Place, Chicago, Sept. 8-17.

Intersociety Energy Conversion Engineering Conference, IEEE *et al.*, Sahara Tahoe Hotel, Stateline, Nev., Sept. 12-17.

25th Annual Conference of Standards Engineers Society, SES, Chalfonte-Haddon Hall Hotel, Atlantic City, N.J., Sept. 13-15.

Oceans '76, Marine Technology Society and IEEE, Sheraton-Park Hotel, Washington, D.C., Sept. 13-15.

Electro Optics/Laser '76 Conference and Exposition, Industrial & Scientific Conference Management Inc. (Chicago, Ill.), New York Hilton Hotel, New York, Sept. 14-16.

WESCON—Western Electronic Show and Convention, IEEE, Los Angeles Convention Center, Los Angeles, Sept. 14-17.

6th European Microwave Conference, Microwave Exhibitions & Publishers Ltd. (Sevenoaks, Kent, England), Palazzo dei Congressi, Rome, Italy, Sept. 14-17.

Convergence 76—International Symposium on Automotive Electronics and Electric Vehicles, IEEE and SAE, Hyatt Regency Hotel, Dearborn, Mich., Sept. 20-22.

International Broadcasting Conference, IEEE *et al.*, Grosvenor House, London, U.K., Sept. 20-24.

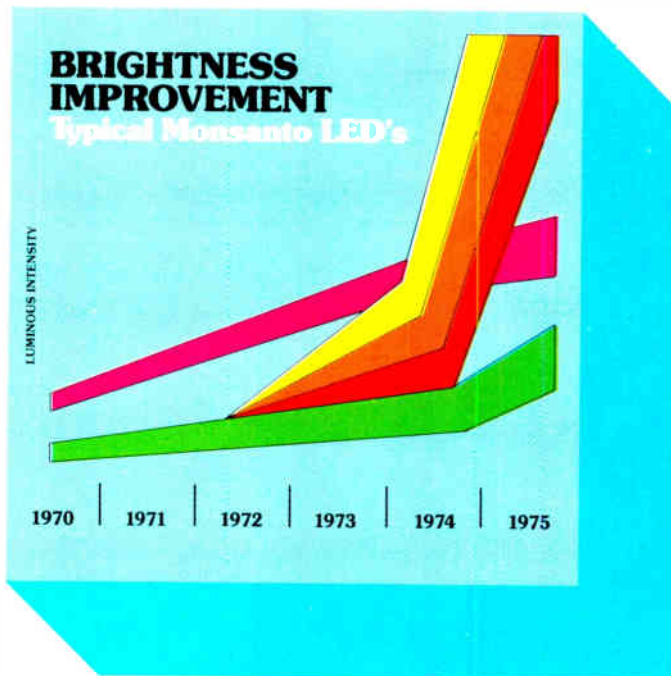
22nd Annual Holm Seminar on Electrical Contacts, Illinois Institute of Technology and IIT Research Institute, Pick-Congress Hotel, Chicago, Sept. 21-23.

Semicon/East 76, Semiconductor Equipment and Materials Institute

O.K., you guys, back to the old drawing board.

It's a whole new ball game. And just when you'd made all your panel lamp decisions, right? But Monsanto's patented nitrogen doping process for GaAsP on GaP substrates has improved the light-emitting efficiencies of our LED lamps so dramatically that every good designer will want to take another look.

Monsanto has T-1 and T-1 $\frac{3}{4}$ replacement lamps in standard red color (improved significantly over last year's red LEDs) and new bright red which is *unbelievably* bright. Red. Plus green, yellow, and a dazzling new orange. In two lens choices and two lead lengths. And all improved, as you can see on the chart.



Model Number	Color	Size	Luminous Intensity	Viewing Angle
5174B*	Orange	T-1	5.0 mcd	90°
5274B*	Green	T-1	1.0 mcd	90°
5374B*	Yellow	T-1	4.0 mcd	90°
5774B*	Red	T-1	5.0 mcd	90°
5152**	Orange	T-1 $\frac{3}{4}$	40.0 mcd	28°
5252**	Green	T-1 $\frac{3}{4}$	15.0 mcd	28°
5352**	Yellow	T-1 $\frac{3}{4}$	45.0 mcd	28°
5752**	Red	T-1 $\frac{3}{4}$	40.0 mcd	28°

*Also available with 1" lead lengths, low profile (.138" high) lens, and 180° viewing angle.

**Also available with 24° and 65° viewing angles.

Last year there were some sockets that demanded filament lamps, despite their inherent failure-and-replacement problems. *Bright* was needed, and damn the torpedos.

This year you just might find the bright you need in a shake-rattle-and-roll-proof LED lamp. Come and see.

If you can take the time, you just might be able to add a lot of T to your MTBF.

So it's reset to zero, folks, if you want the best indicator lamps (and widest choice of functional differentiation colors) in your gear.

For product information, circle the service number or call your local Monsanto man. Or write Monsanto Electronics Division, 3400 Hillview Avenue, Palo Alto, CA 94304.

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Circle 23 on reader service card

Meetings

(Golden Gate Enterprises, Santa Clara, Calif.), Nassau Veterans' Memorial Coliseum, Uniondale, N.Y., Sept. 21–23.

APT.76—Putting APT. to work, ACM, Skyline Hotel, Ottawa, Canada, Sept. 22–24.

Broadcast Symposium, IEEE, Washington Hilton Hotel, Washington, D.C., Sept. 22–24.

EASCON—Electronic and Aerospace Systems Convention, IEEE, Stouffer's Inn, Washington, D.C., Sept. 26–29.

MICRO-9—Ninth Annual Workshop on Microprogramming, IEEE and ACM, Delta Towers Hotel, New Orleans, Sept. 27–29.

Quality Testing Show, American Society for Nondestructive Testing (Columbus, Ohio), Shamrock Hilton Hotel, Houston, Tex., Sept. 28–30.

Canadian Computer Show and Conference, Canadian Information Processing Society (Industrial and Trade Shows of Canada, Toronto), Place Bonaventure, Montreal, Sept. 28–30.

IIC/USA—International Telemetry Conference, International Foundation for Telemetry (Woodland Hills, Calif.), Hyatt House Hotel, Los Angeles Airport, Sept. 28–30.

Nepcon Central—National Electronic Packaging and Production Conference, Industrial & Scientific Conference Management Inc. (Chicago, Ill.), Hyatt Regency O'Hare Hotel, Chicago, Sept. 28–30.

1976 Microwave Mobile Communications Symposium, IEEE, Department of Commerce Laboratories, Boulder, Colo., Sept. 29–Oct. 1.

IC SQUID—International Conference on Superconducting Quantum Devices, European Physical Society and Physikalische-Technische Bundesanstalt, Berlin, West Germany, Oct. 5–8.

This is what multifunction counters are supposed to be all about.

Model 5740, 7-digit, 100 MHz Multifunction Counter/Timer. \$295*

Quality you can count on. Data Precision's Model 5740 is a 7-digit, 100 MHz Timer/Counter; a superb laboratory quality instrument.

Data Precision built the 5740 to be exceptionally versatile. It measures frequency, period, period average, elapsed time and total events with the kind of accuracy, sensitivity, and upper frequency capability generally found only in higher priced units.

Consider: 10 mV RMS sine-wave to 20 MHz. 50 mV RMS at 100 MHz. That's excellent sensitivity in anyone's book. And this



sensitivity is a minimum specification (not a typical) allowing lock-in measurements from even extremely weak signals. The 100 MHz bandwidth means the 5740 handles everything from sub-audio to VHF. Seven, not six digit resolution, means 0.1 Hertz resolution at 1 MHz, 1 part in 10 million in period measurements, with the decimal point always automatically correct.

Want even more? A low-cost optional BCD output provides printer and/or computer/system compatibility while providing

counter status timing and control/signals as well as reading and decimal-point data. And an optional remote start/stop control makes this a most flexible elapsed time indicator.

The 5740 Multifunction Counter/Timer. Its quality, versatility and value are unmistakable. And it comes with something no one else gives you: Data Precision dependability.

For complete information or a demonstration contact your local Data Precision representative or Data Precision Corporation, Audubon Road, Wakefield, MA 01880, USA, (617) 246-1600. TELEX (0650) 949341.

*Price U.S.A.

DATA PRECISION[®]
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High-accuracy V-f converter to sell for \$8.95

Look for Intech Inc. of Santa Clara, Calif., to begin production soon of a single-supply monolithic voltage-to-frequency converter that has 11-bit accuracy and $\pm 0.05\%$ linearity at 10 kilohertz without external components. **And the device is priced at only \$8.95.** Comparable modular and discrete V-f systems typically cost \$40 to \$70 and require more than one power supply.

Other monolithic converters now available have only 7-bit accuracy with external components and usually require two supplies. Prime applications for such a high-accuracy device are the automotive and data-acquisition markets.

October RFPs due for updated air surveillance system

A request for proposals for the Air Force's Joint Surveillance System will probably come from the Electronic Systems division, Hanscom Air Force Base, Mass., in October. The JSS is an ambitious effort **to update continental U.S. air-surveillance capability** and to improve the Federal Aviation Administration's air-route traffic control by using radar and other sensors at joint FAA-Air Force sites in the U.S. to simultaneously monitor approaching civilian and military air traffic. Some 48 radar installations ringing the periphery of the U.S. will report their data to five regional operations control centers. Although their locations have not been determined, it's known that there will be two centers each on the East and West Coasts, and one in Alaska. The upcoming request for proposals will cover computers, displays, and software to go into those centers.

In all, the JSS program will cost about \$200 million, but it's expected to save the Air Force substantially more than that by replacing SAGE (for semi-automatic ground environment) air-defense system. Its centers were constructed in the 1950s.

GI working on big brother for CP 1600 . . .

General Instrument Corp. is working with manufacturers of process-control and communications equipment to develop a "big brother" to its CP 1600 microprocessor. The new n-channel MOS device, like the 1600 tailored for those industries, **is expected to be available by mid-1977.** While GI declines to specify whether the new processor will offer higher speed, a more powerful and easier-to-use instruction set, or improved input/output interfacing, a spokesman at the Microelectronics Group in Hicksville, N.Y., says it will offer "more than just improved performance."

Honeywell Inc.'s Process Control division in Fort Washington, Pa., is believed to be one of the firms participating in the development effort. That division developed and benchmarked the architecture for the 1600, with circuit design and manufacturing implementation by GI, as part of a two-year multichip development program.

. . . and gains British Post Office stamp of approval

Meanwhile, GI's Microelectronics Group has become the **first MOS LSI manufacturer to receive full British Post Office approval** as a supplier of microcircuits for telephone-exchange equipment. The Post Office, which controls all telecommunications in the country, has approval procedures that are designed to simulate and confirm a 20-year life under adverse anticipated operating conditions with no more than a total of 2% cumulative

Electronics newsletter_____

failures. The approval relates to the MTNS metal-thick-oxide-nitride process, pioneered by GI, because of its rugged electrical characteristics.

Itek enters typesetting field

A microcomputer-controlled system, the Quadritek 1200, marks the first foray by Itek Corp. into the phototypesetting market. Officials of the Graphic Products division in Lexington, Mass., estimate that phototypesetting was a **\$200 million-a-year business in 1975**. The division, which unveiled the system last week, is aiming it primarily at in-house or small commercial-printing operations. Use of National Semiconductor Corp.'s PACE 16-bit microprocessor allows keyboard selection of four interchangeable font types at will by the operator without stopping production, as some competitive systems require. Some 50 typefaces will be available when the system is marketed this fall for \$9995.

The Quadritek 1200 is small enough (42 by 17½ by 28 in.) to fit on a small table or desk top. Justification, centering, tabulation, and flush right and left are all automatically controlled, and the unit offers 12,288 words of memory, which allows predetermined instructions to be stored. Itek Graphics division officials say the system is a natural extension of their other photocomposition products, which include camera processors, plate makers, and duplicating equipment.

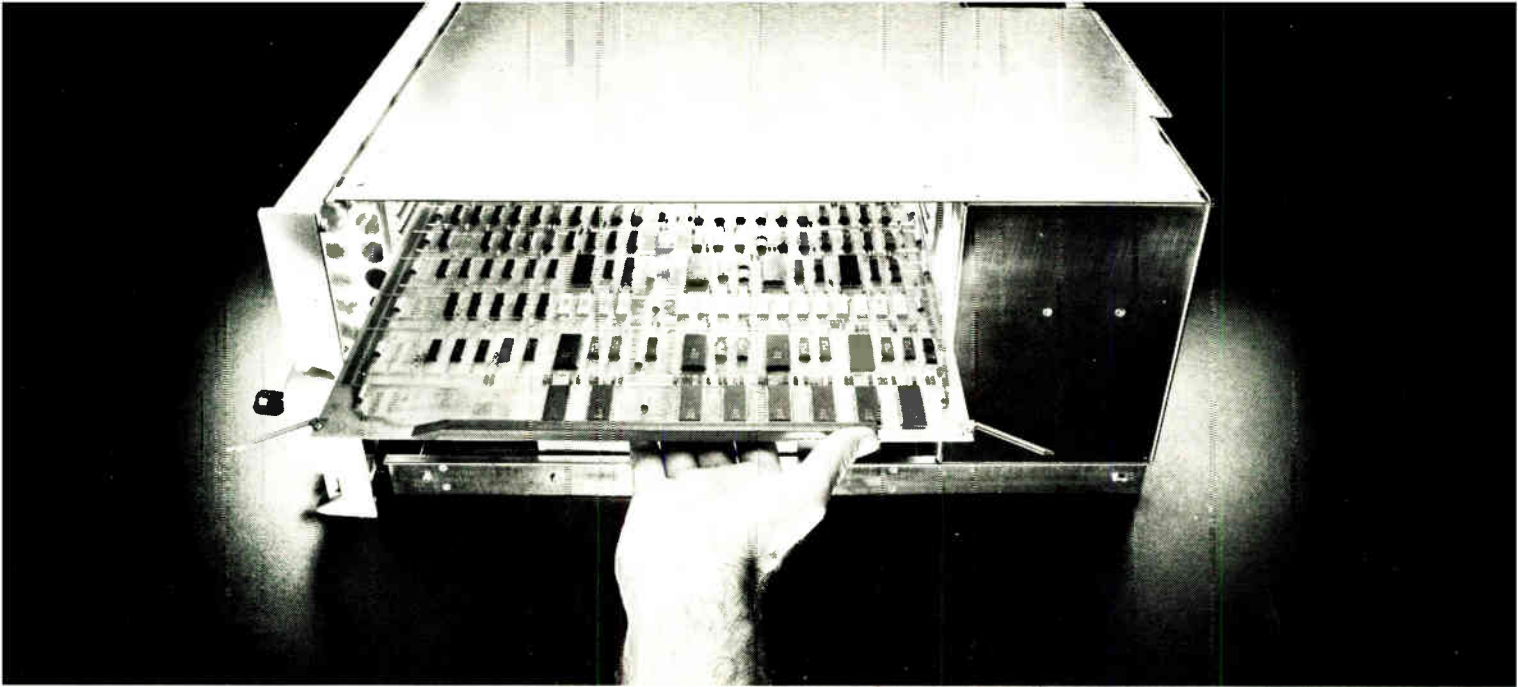
Nonvolatile memory gains at TI lab

Texas Instruments is working on an MOS memory technology that is both nonvolatile and erasable. Called DIFMOS (for dual injection floating-gate MOS), the work is being done at TI's French IC facility where a 256-bit memory has been operating. Unlike the nonvolatile and erasable read-only memories built with Intel's FAMOS technique, which require ultraviolet irradiation to erase, **TI's DIFMOS device is written and erased electrically**. Present performance parameters are: read time, 1 microsecond to 500 nanoseconds; erase and write time, 0.5 millisecond when operating with 30-volt write and erase signals.

The circuit uses a parallel-in/serial-out shift register in the read mode and a serial-in/parallel-out in the write mode. Apparently the technique is still speculative, with size and reliability hurdles still to be overcome. However, progress in reducing cell size has been dramatic: from 120 mil² to 25 mil² per bit.

British offer first high-level compiler for 8080A

The first commercially available compiler that can run a resident high-level language on a microprocessor has been announced by GEC Semiconductors, which has built a Coral 66 compiler for the Intel 8080A microprocessor. Developed to run on the MDS 800 microprocessor-development system, the RCC 80 compiler is aimed for designers in real-time military, telecommunications, and process-control applications. Coral 66 is claimed to be the first high-level language approved for microprocessors. Priced at about \$2,700, the self-compiling program is built to run on the MDS 800 with a 48-kilobit random-access memory, console, and output devices. Options include a line printer, high-speed paper tape, and additional 16-k RAM.



Give your data communications system a little goose and it'll put out ten times as much.

Open up the back of any Data General communications system, pop in our single-board DCU/50 Data Control Unit, run through a little step called COMGEN and stand back. Because that system can start pumping out ten times as much data. And possibly a good deal more.

What makes this all possible is a rather clever piece of engineering.

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On the other hand, you may not need more throughput. Instead, you may need more lines or different types of lines. Both of which are just as easy to get. You just plug in some different boards.

We make modular synchronous and asynchronous multiplexors you can mix

in any proportion. They can handle anything from one to sixteen lines, are fully software supported and work equally well with or without the DCU/50.

Which brings up a rather significant point.

When you buy your communications equipment from Data General, you can get exactly what you need right now. And later, if you need more throughput, more lines or different types of lines, you won't have to throw out anything. All Data General communications hardware and software are completely compatible. So you can add on to what you already have.

Write for our free brochure, "The Sensible Way to Use Computers in Data Communications" and detailed information about the DCU/50 Data Control Unit.

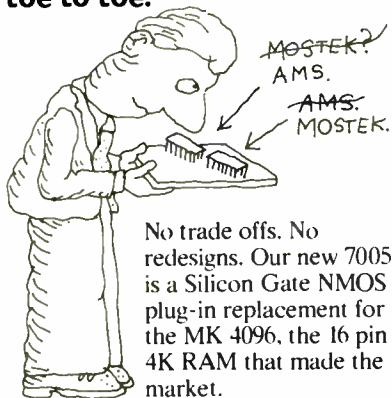
And if that isn't enough information, we'll send a sales engineer who can also put out ten times as much.

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Pin for pin, spec for spec, toe to toe.

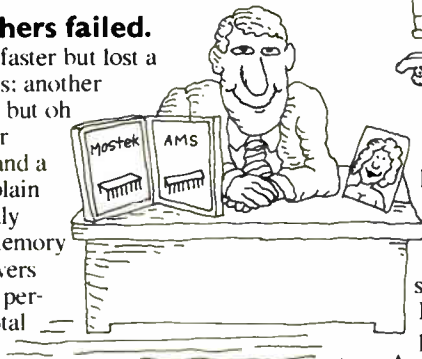


No trade offs. No redesigns. Our new 7005 is a Silicon Gate NMOS plug-in replacement for the MK 4096, the 16 pin 4K RAM that made the market.

Same specifications. Super reliable.

Where others failed.

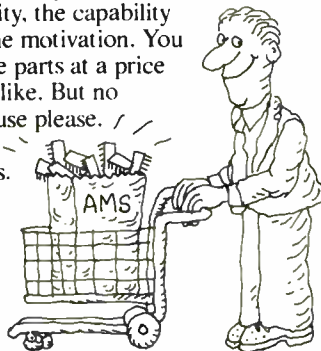
One made it faster but lost a spate of specs; another hit the speed but oh my the power dissipation; and a third is just plain different. Only Advanced Memory Systems delivers the identical performance, total



compatibility, and the outstanding quality our vast systems experience has helped us build into all our RAMs. Nice.

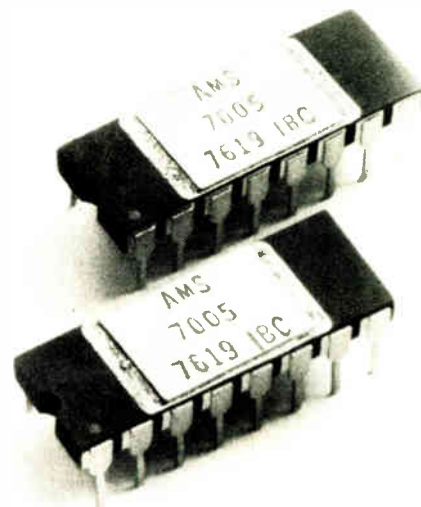
Priced for purchasing.

We've priced the 7005 to gain a significant share of the market. We've got the design and process technology, the capacity, the capability and the motivation. You get the parts at a price you'll like. But no applause please. Just orders.



4K OK your way.

Now with our 16 pin 7005 we've got you covered in 4K RAMs. 16, 18 or 22 pin. Our 18 pin 7270 and 22 pin 7280 take the socks off T.I. in Read/Write/Modify and leave Intel burning power and crying out for capacitors. And there's no shortage of sources



on the 7270/7280 either. The same masks are in production at National.

No bad memories.

We're closer to that goal than any other supplier. With over thirteen million RAMs shipped to date, our cumulative history is 0.03%/1000 hrs; and the current rate is a whopping 0.01%/1000 hrs.

MK4096, 16 pin 4K RAM.

made it. got it.

Our systems helped.

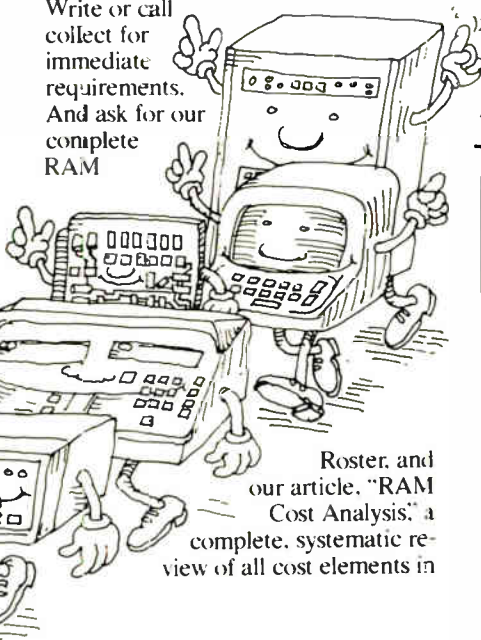
Our expertise in RAMs derives naturally from the fact that we're the largest independent memory systems producer in the world. No other RAM supplier can touch our systems experience. Testing alone is a science in its own right, and we have perfected it. The benefits?

Advanced technology.
Advanced components. Device performance. Production. Testing. And above all, systematic thinking.



Information is free.

Write or call collect for immediate requirements. And ask for our complete RAM



Roster, and our article, "RAM Cost Analysis," a complete, systematic review of all cost elements in

building RAM memories. It's the definitive work on the subject. Advanced Memory Systems, 1275 Hammerwood Avenue, Sunnyvale, California 94086. (408) 734-4330. Ask for Semiconductor Marketing.

The RAMS what AM in '76.

Dynamic RAMs	16 pin	18 pin	22 pin
1024X1		6002 (150ns)	6002 (150ns)
2048X1			6003 (350ns)
4096X1	7005 (250ns) Mostek 4096	7270 (200ns) Nat I 5270	7280 (200ns) Nat I 5280 Intel 2107B T14060
		7271 (250ns) TTL Clock	7281 (240ns) TTL Clock
8192X1			7008 (150ns) Pin for pin with 7280
Static RAMs			
256X4	7112 (250ns) Intel 2112	7111 (250ns) Intel 2111	7101 (250ns) Intel 2101
1024X1			7001 (60ns)
2048X1			7003 (60ns)

Access time in ()

AMS Advanced Memory Systems.
Memories with a future.

The Raytheon 2900 family gains five new members

Whereas: Raytheon is the established alternate source for the Am2901 and Am2909, (franchised distributors stocked), and,

Whereas: Raytheon brought you RAYASM, the powerful micro-assembler available on the NCSS computer network,

Now Therefore: Raytheon announces five additional 2900 family components, giving us a total of seven, To Wit:

2901 A 4-bit Microprocessor Slice—the fastest, most powerful LSTTL microprocessor in the world. With its cycle-saving two-address architecture, the 2901's speed can't be touched.

2905 A 4-bit Bus Transceiver— general purpose open collector bus interface device. Data to the 100 milliamper bus drivers is provided by a 4-bit register with a two-way multiplexer at its inputs. Data from the bus receiver may be held in the 4-bit receiver latch on its way to the three state receiver outputs.

2906 A 4-bit Bus Transceiver with parity —is equivalent to the 2905 but with the addition of an on-chip parity generator/checker.

2907 A 4-bit Bus Transceiver—similar to the 2906 with the two-way multiplexer at the input to the bus driver register elimi-

nated to allow the device to be packaged in the space saving 20-pin DIP.

2909 A Microprogram Sequencer—that can branch anywhere in memory, perform sub-routines, then return with up to four levels of sub-routine nesting. The device is a cascadable 4-bit slice which allows addressing of up to 4K words of microprogram with three devices.

2918 A General Purpose 4-bit Register—with two sets of outputs: TTL and three state. This useful combination can reduce your package count for those status, command, and instruction registers which must drive both your control logic and a data bus.

93415 A 1024 × 1-bit Fully Decoded Random Access Memory—for your high-speed data and control stores.

Raytheon LSI is on the move. More 2900 family components soon to come include PROM's, sequencers, look-ahead carry generators, additional RAM's, and other goodies now in process.

For complete details, contact your local distributor or Raytheon Company, Semiconductor Division, Dept. 2900, 350 Ellis Street, Mountain View, CA 94042, (415) 968-9211.

Am 2900 SOLD & SUPPORTED HERE



SEMICONDUCTOR DIVISION

Analyzers for microprocessors coming on strong

Next month, Wescon will show more than a dozen units designed to outdo logic analyzers

"It's going to hit like a wave," predicts David J. Blecki, marketing vice president of Biomation Corp., Cupertino, Calif. He's referring to a blitz of microprocessor analyzers, a dozen or so of which are to be shown at the Wescon show in Los Angeles next month by logic-analyzer makers and newcomers.

Although logic analyzers have proved their usefulness in testing and troubleshooting digital circuits, when it comes to microprocessors, they are found wanting. They display data as it passes through a circuit to the point where a trigger or failure occurs. But they have too many separate test leads that are likely to wind up in a tangled pile, and it is difficult to interpret the 1s and 0s or timing diagrams they display.

For these reasons, microprocessor analyzers are being introduced in ever-increasing numbers. In addition to the companies that have already shown these analyzers—Pro-Log Corp., Monterey, Calif., and Motorola Data Products division, Carol Stream, Ill.—analyzers will be shown at Wescon by Systron-Donner Corp., Concord, Calif.; Hewlett-Packard Co.'s Colorado Springs division, and Scanoptik Instrumentation Co., Rockville, Md. Also, Tektronix Inc., Beaverton, Ore., and Biomation are expected to bring new instruments to Wescon, though nei-



Lots to say. Readout of mnemonic operating codes that match up with the actual program steps makes debugging much easier with HP's \$5,000 microprocessor analyzer (p.32).

ther firm is now discussing its plans. And two firms, E-11 Research Laboratories Inc., Oakland, Calif., and Vector Associates Inc., Bellport, N.Y., will have instruments with state displays, which, although not microprocessor analyzers, are aimed at aiding microprocessor-circuit designers.

No two microprocessor analyzers are alike. They range in price and features from Pro-Log's \$500-to-\$650 units, developed for specific microprocessor types, to HP's \$5,000 model 1611A [*Electronics*, July 8, p. 28]. The HP instrument, depending on plug-ins, tests Intel's 8080 or Motorola's 6800, and other plug-ins are in the offing.

All types simplify troubleshooting. Instead of the separate test leads of the usual logic analyzers, the new units interface with the test circuit via a single multipin test clip that fits directly onto the microprocessor package. Readouts of microprocessor analyzers are often hexadecimal displays on either a built-in cathode-

ray-tube screen or an external oscilloscope, in contrast to the 1s and 0s of a logic-state analyzer or the waveforms of a logic-timing analyzer.

Readout. Hexadecimal readout is preferred by software programmers, who use it to compare actual circuit operation to documented programs. Hexadecimal notation also compacts test information, making it easier for production-line personnel to interpret. In smaller, less expensive analyzers, this readout may be presented one program step at a time on a single row of light-emitting diodes.

Another basic difference between a logic and a microprocessor analyzer is the latter's capability to interact with units under test. Logic analyzers, on the other hand, are passive readout devices, with no control over the circuit being tested. Most microprocessor analyzers have halt or wait controls that permit the user to step the microprocessor through its program.

But, unlike the generally more

expensive microprocessor-development systems, microprocessor analyzers cannot be used to prepare programs. "I think of it more as a diagnostic tool," says Robert Bahns-

en, product manager at Motorola Data Products. The analyzer becomes valuable only after the microprocessor is working in a real system, he points out. □

For \$5,000, a fancy analyzer

By far one of the fanciest of the microprocessor analyzers is Hewlett-Packard's model 1611A. Itself built around an 8080-type microprocessor, the 1611A has the important features of its competitors and then some. Like others, the 1611A can be configured to deal with particular microprocessors ("personality modules" to handle the 8080 and 6800 are available, and others are in the works). It can also halt, single-step, and reset the microprocessor under test.

In addition, the 1611A displays system activity on its cathode-ray tube in the alphanumeric mnemonics of the microprocessor's instruction set, as is shown in the photograph of the company's logic-state analyzer on p. 31. This eliminates the need to interpret timing diagrams, 1s and 0s, or hexadecimal notation.

The Hewlett-Packard instrument also has lots of ways to pinpoint a step within a program. It can trigger on a specific address, data word, or combination of 1s and 0s on any or all of eight auxiliary lines. Or the instrument can trigger on any address within a range, or require up to 256 repetitions of the trigger conditions.

The 1611A can also count the number of valid triggers between two points in a program and measure the time taken for a section of a program to run, thus aiding the programmer in minimizing system software.

With a clip-on connector to the microprocessor and keyboard controls, the 1611A is easier to operate than earlier HP logic analyzers, which have a myriad of test leads and rows of operating switches. But despite the 1611A's \$5,000 price, Bruce Farly, HP's digital product planning manager says, "I expect to see more production applications for this instrument than for other analyzers because it can be operated by someone who is far less skilled."

Land-mobile radio

Talk of standards stirs makers, users

Should there be a set of national standards for land-mobile communications hardware? The financial crunch that's hit all levels of government is causing officials to look at standards as a way to save money. But no standards timetable has been set, and attempts to adopt such standards are opposed by major manufacturers and even some users.

This opposition was evident earlier this month at the Association of Public-Safety Communications Officers' conference in New York.

Craig Jorgensen, telecommunications coordinator for Utah's Depart-

ment of Transportation in Salt Lake City, wants standards because it would enable agencies to buy less equipment. "They [the systems] don't interface with one another and, in most instances, they don't interface with older equipment even from the same vendor," says Jorgensen.

Incompatible units. He adds that not only do differences exist in the performance of radio units, but there is incompatibility in the cable assemblies, control heads, battery chargers, and other major system elements. Thus, the agencies must maintain a large inventory of parts, and service and maintenance expenses are high.

"If there were standards for control heads and cables, for example, then if a GE radio goes out, it could easily be replaced with either an RCA or Motorola unit, or even another GE radio of a different

vintage," he continues. "Right now, these aren't compatible."

APCO is an association of officials responsible for the design, operation and maintenance of telecommunication systems serving public-safety agencies. It has formed a committee to produce a set of standards covering the performance, physical characteristics, and test parameters for land-mobile communications hardware. But the committee's efforts have just begun, and a draft won't be ready until the annual meeting next summer in Chicago.

Marshall Treado, communications-systems program supervisor for the National Bureau of Standards in Washington, is, like Jorgensen, in favor of standards. It would lead to "the ability to move equipment in and out [of cars] without having to rip out panels or dismantle a portion of the car," he says.

Competition threat. But user benefits are of less concern to equipment manufacturers than the threat of foreign competition. "One reason we are able to operate in this country without serious offshore competition is that we don't have standards," notes Stuart Meyer, manager of government and industry relations for E. F. Johnson Co. in Waseca, Minn. "If we standardize, offshore producers would have incentive for going after a much broader segment of the market than they have now."

Bob Savajian, a regional manager for RCA's Communications Systems division in Camden, N.J., echoes Meyer's sentiments. "We would be doing all the engineering for them. Without standardization, we are able to keep one step ahead."

Standardization would allow no variation of lines or performance edge, notes Michael Rosen, district sales manager for Motorola's Communications and Electronics Inc. subsidiary in Schaumburg, Ill. "Getting the business would just become a matter of who wants to discount the most," he adds.

User opposition. Users who look askance at standardization do so because they fear their costs would increase. Any standards should have tiers of performance levels, says Al

Talbott, chief engineer for Illinois' division of telecommunications in Springfield, "otherwise we would be forcing the costs of high-performance radios into low-performance operations."

And he cites reasons for opposing standardization that have been cited in other industries when standards have been considered. Too high a degree of standardization "could inhibit engineering prerogatives and systems design" and "impair advances in technology."

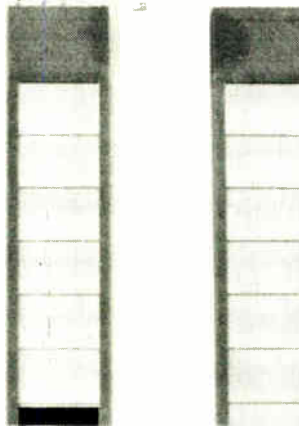
But the final say on standards will probably turn on costs. As Jorgensen puts it: "Communities are having to justify expenditures for communications equipment like never before. The days where they could get funds *carte blanche* are over." □

Radar

Balloon-borne radar to look for low fliers

Some time this fall, the Air Force Electronic Systems division will issue an unusual request for proposals for an operational surveillance radar to detect low-flying aircraft approaching the U.S. across the Straits of Florida from the direction of Cuba. The radar will be housed in the underbelly of a tethered balloon, or aerostat, at an altitude slightly higher than 10,000 feet. Data will be telemetered to the ground for digital processing and evaluation. A feasibility-demonstration model of such a radar is aloft now at Cudjoe Key Air Force Station in Key West, Fla.

Solutions sought. In a novel RFP, the Air Force will ask bidders to submit in general terms their most cost-effective answer to the service's needs. For example, the frequency band and kind of antenna probably won't be specified. But Col. Stephen J. Vogel feels industry has the capability "to innovate and come up with ingenious schemes to answer our needs." Vogel is director of the Seek Skyhook program, as it's now called, at ESD headquarters, Hanscom Air Force Base, Bedford, Mass. He says



Radar carrier. Aerostat being test-flown at Patrick Air Force Base is the type being considered for Seek Skyhook radar.

Seek Skyhook presents these challenges:

- About triple the range of ground-based surveillance radars, now limited by line of sight to about 35 nautical miles.
- The capability to operate in a severe radar subclutter environment, looking down through clouds and at heavy sea states.
- The capability to detect targets as small as 2.2 square meters—about the size of a Soviet MIG-21 fighter—as well as ships in a search and rescue operation.
- The capability to operate in any weather, although the balloon won't be airborne in winds above about 90 knots.

The need for light weight will be a big consideration, Vogel emphasizes, because the radar's weight will dictate how large the balloon must be. But if the transmitter and receiver are designed so small that they would have to exceed the state of the art, it could lead to a costly development effort.

Weight will also be an important factor in non-electronic portions of

Seek Skyhook. The Westinghouse S-band radar that's been operating since mid-1974 at Cudjoe Key is powered by an on-board generator, but the new system may call for using the tether to carry power or fuel to an on-board system.

Design open. Seek Skyhook will undoubtedly operate in either the L band (390–1,550 megahertz) or S band (1,550–3,900 MHz), Vogel says, but he doesn't want to prejudice any design by backing either one. "L band is purported to be better for the subclutter-visibility problem," Vogel observes. "But it's also purported to be more complex and heavier, and therefore costlier, than S band. There are a lot of tradeoffs, and we will be presenting these tradeoffs and letting industry propose systems to answer them."

Seek Skyhook is funded at about \$12 million for two systems—one aloft and one to go on station while the first is being refueled—plus a backup. Vogel was encouraged by the response to an earlier request for quotations about Seek Skyhook. He won't say how many companies responded, but notes that "we were pleased by the number and strength of those who replied when we asked what parts of the system could be done off-the-shelf and what parts would be needing research and development." □

Computers

Intel 8080 box woos systems business

Intel Corp., the sales leader in microprocessors, has been trading on minicomputer makers' toes by offering not only chips but also one-board computers to original-equipment manufacturers. Now the semiconductor company is about to unnerve mini makers still further with a low-cost fully packaged microcomputer based on its SBC 80/10 one-board computer [*Electronics*, Feb. 5, p. 77].

With this move, the Santa Clara,

Calif., semiconductor manufacturer has placed itself squarely in the minicomputer business. It's going after non-OEM customers like systems houses, which write expensive software for a specific piece of hardware—which they generally buy from a mini maker.

Nearly here. The 80/10 package is already in production. Built around Intel's 8-bit 8080 microprocessor, it comes complete with resident memory, programable input/output, system monitor, power supply, cooling fan, and front panel. The housing measures 3.5 by 19 by 19 inches.

The microcomputer has the 8080's typical instruction-execution time of 1.95 microseconds, a six-source interrupt structure, system bus control and TTL bus drivers for system bus expansion. In addition to 1 kilobyte of static random-access memory, it has up to four kilobytes of read-only memory or programable ROM as resident program storage. Also standard are 48 lines of parallel I/O, organized as six programable I/O ports.

"We weren't reaching all the potential customers we expected to with the single-board computer approach," says Wayne Gartin, system 80/10 marketing manager. Single-board systems like Intel's SBC (\$295 in quantities of 100) were conceived

as a way of reaching "that very broad middle ground between high-end packaged microprocessors and minicomputers," he explains.

Like Digital Equipment Corp.'s single-board LSI-11 and Data General Corp.'s microNova, the SBC 80/10 is aimed at applications in industrial process control, test and instrumentation systems, word processing, and smart terminals.

Bottom line. Several of the mini-computer companies, he says, have also recognized this and supply packaged versions of their single-board computers. "But there is considerable difference in price," Gartin says. The packaged version of the LSI-11 (the PDP11/03) costs \$2,495. The packaged microNova is priced at \$1,995 in single units, \$1,237 in hundreds. The system 80/10 costs \$1,495 in single units and under \$1,000 in hundreds.

A spokesman for mini-maker Data General is not surprised by Intel's 80/10. "We expected it," he says, adding that in any case the microNova is a 16-bit microcomputer. "I suspect there might be some business for a packaged 8-bit computer," he concedes, "but our customers are looking for a more sophisticated software, peripheral, and input/output capability." □

circuits. Should the effort become widespread, the FCC believes smaller CB makers, with limited competence to make the changes, may end up increasing interference and require the FCC to step in and halt the conversion program.

Importers stuck. But importers of Japanese CB transceivers—supplying upward of 70% of the \$500 million U.S. market—are the ones who are really stuck, industry sources agree.

Dealers have a large inventory now but cannot make free modification offers because they cannot ship the sets back to Japan. Big retailers like J.C. Penney Co. and Sears, Roebuck and Co., Chicago, who sell Japanese imports under their own labels, have cancelled all orders, according to industry reports.

Penney headquarters in New York confirmed that its principal CB buyer and two aides were in Japan in mid-August "trying to work out the problem" with suppliers. But a spokesman was unable to provide details.

Other retailers believe they can handle both types of radios. "We haven't cancelled any orders with our Asian sources," says Charles W. Tindall, vice president of Tandy Corp., the Fort Worth, Texas parent of Radio Shack, the electronics retailer that's selling CB radios at a \$45-million-per-quarter clip. "But we're carefully writing new purchase orders with the ability to flip production over to 40-channel units if the 23s don't sell."

After the 40-channel sets are on the market, the question is whether the 23-channel radios can be priced attractively, Tindall believes. "With a \$30 to \$40 spread between them, a 23-channel CB would be an attractive offering," he says, pointing to the fact that Radio Shack now successfully sells a six-channel CB radio for \$69.95.

Some manufacturers are expected to petition the FCC to permit sales of new 40-channel models to begin earlier, with the proviso that the 17 new channels between 27.235 and 27.405 kilohertz not be used by licensees. However, this restriction would be virtually unenforceable.

The Electronic Industries Associa-

Citizens' band

FCC's go-ahead on 40 channels slows sales of 23-channel units

Manufacturers in the booming citizens' band radio market are troubled by the short-term consequences of the Federal Communications Commission's decision to allow CB more air space even while they welcome its long-term potential. Even more upset are big CB radio importers.

Sales are slowing. Since the FCC announced its plan to expand the number of CB channels to 40 from 23 next January [*Electronics*, Aug. 5, p. 49], sales of present 23-channel Class D receivers have been slowing, and fast. That much is acknowledged by the CB radio manufac-

turers' representatives in Washington, D.C., few of whom expect the slowdown to be halted by some makers' offers to modify, at no extra charge, all 23-channel units bought now to 40 channels after next January. Such offers are already being made by Hy-Gain Electronics Corp., Lincoln, Neb., and Pathcom Inc.'s Pace Communications division, and other domestic makers are expected to follow suit.

The FCC's engineering office is also troubled—by the offers, which promise to upgrade transceivers by modifying their phase-locked-loop



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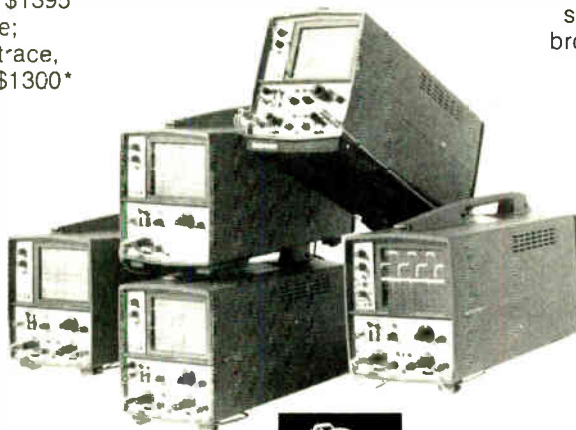
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tion has problems with the decision, too, but of a different nature. Long an advocate of expanding CB through a new Class E service in the 220-megahertz region, the association views the latest action as merely an interim solution to the overcrowding of the CB spectrum. "We need a two-band CB service in this country just as we have a-m and fm in broadcast radio," explains EIA's John Sodolski, vice president of the Communications and Industrial division.

Tougher tests. In the new 40-channel CB units, the requirement for harmonic radiation suppression will be raised from 49 to 60 decibels, to minimize interference with TV channels, and much less spurious radiation will be permitted at antenna terminals and from the transceivers' chassis.

In addition, the FCC's laboratory will begin testing for overmodulation effects—excessive transient emissions in adjacent channels.

Modulation transients that show up at the center of either channel adjacent to the one under test must either be attenuated by at least 33 dB or be less than 100 milliseconds long, the FCC says. A manufacturer whose transceivers fail this test will be permitted to redesign his units till they comply. According to the agency, the transients "can readily be measured using a spectrum analyzer (of the type used) for time-domain measurements."

Industry sources expect all the new test criteria to become permanent some time this month, as soon as the FCC issues its revised set of rules. □

Packaging & Production

Thick-film hybrid circuits shrink electronics in brushless motors

Thick-film hybrid technology seems far removed from motor manufacturing. But thick-film techniques applied to the packaging of the internal electronic commutation circuits of a brushless motor have enabled Aeroflex Inc., of Plainview, N.Y., to make a motor that is shorter, lower in cost, and also more

reliable than ever before.

The resulting hybrid structure can accommodate additional power amplifiers so the substrate can be used with a broad range of motors. Previous discrete electronics packages have been limited to lower-power motors.

Brushless dc motors, which are

generally four to five times as expensive as conventional ones, are used in military and aerospace applications. Their "sparkless" commutation adds up to long life, high reliability, efficiency, and low electromagnetic interference.

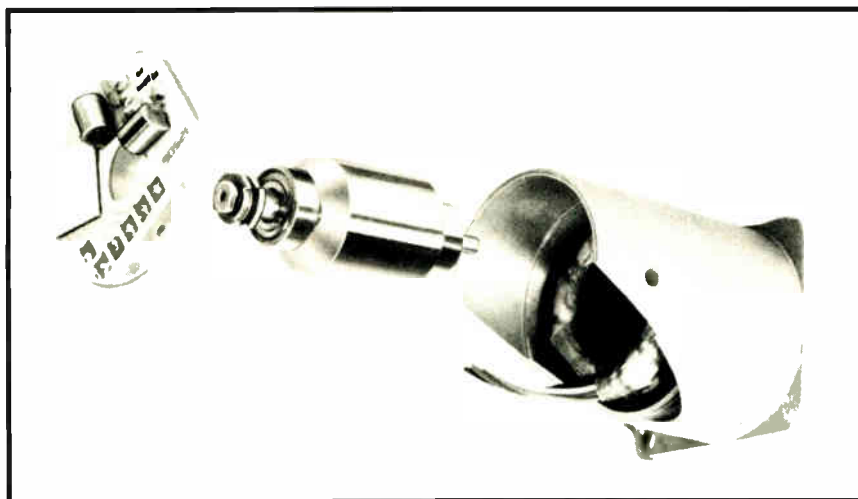
In an earlier version of Aeroflex's brushless motor [*Electronics*, June 26, 1975, p. 120], the commutation circuitry, composed of discrete components and linear integrated circuits, are placed on a round, two-sided printed-circuit board slightly smaller than the diameter of the motor housing. Two Hall-effect position sensors for commutation are fastened in a ring to the bottom of the board, and the package, although fitting inside the motor, is fairly bulky—about 3/4-inch thick.

In the new electronics package, which is only about 1/8-inch thick, a single-sided alumina substrate, shown in the photo, has screened-on low-cost silver conductors and thick-film resistors. All semiconductors and critical passive parts are sealed under a ceramic lid. Two cylindrical Hall-effect sensors are mounted at right angles on an uncovered part of the substrate.

Cost cut. Mike Schwartz, chief scientist at Aeroflex, says, "The new assembly should cut the cost of production of brushless motors by about \$15. The assembly is only one third the volume of the older pc type, and overall motor length for the same size motor is reduced by 1/4 inch. Actually the new substrate, plus parts, takes up less space than conventional motor-brush assemblies."

Since the packaging density of the hybrid is so much higher than the board it replaces, the unoccupied area on the substrate can hold power-transistor chips that are driven by the basic circuitry. These transistors act as power boosters for large motors. Aeroflex has already fabricated circuits for relatively large size-23 motors (1/6 horsepower) on the hybrid substrate.

More than 100 substrates have already been made for prototype motors, Schwartz says. Most of the motors are size 15s, which have a



Good fit. Aeroflex's thick-film hybrid (left) that fits inside a brushless dc motor contains critical parts under a ceramic lid with Hall-effect sensors at right angles to each other.

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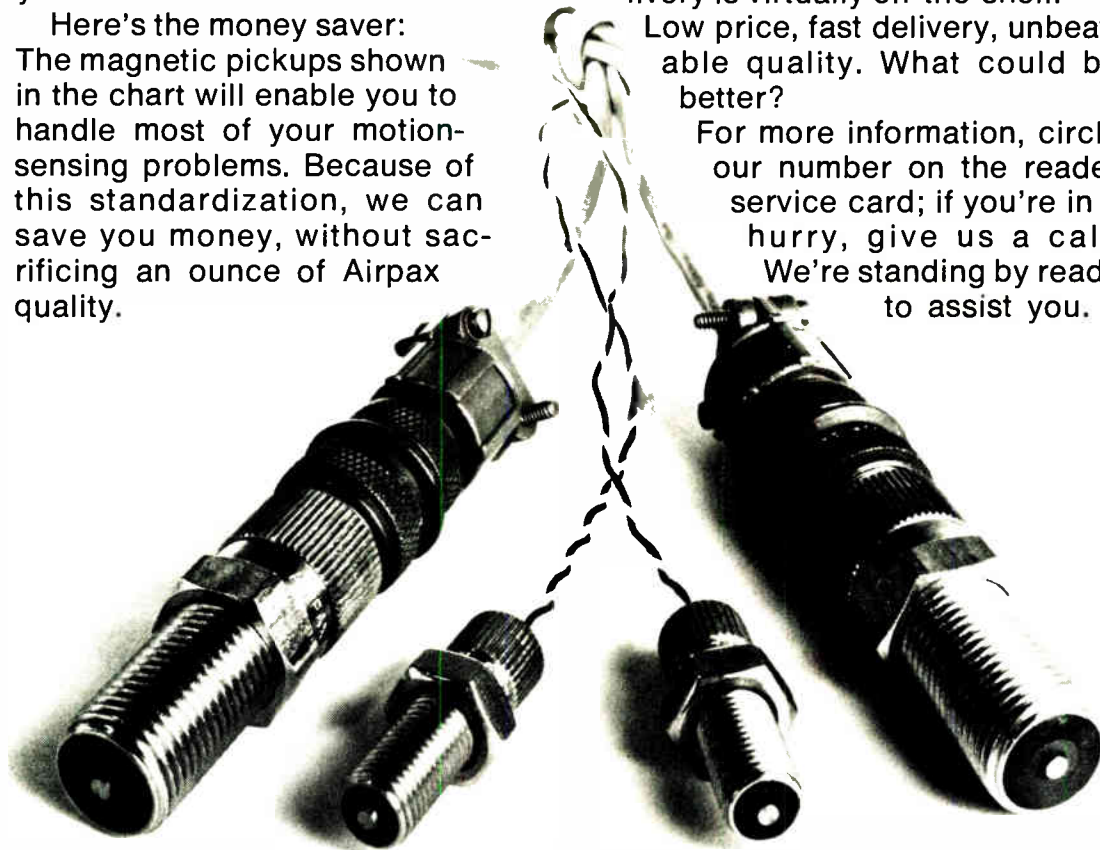
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Output voltage:	40-60V (P-P)	150-230V (P-P)	20-32V (P-P)	55-85V (P-P)
DC resistance:	100-130 ohms	1200-1500 ohms	85-115 ohms	550-700 ohms
Inductance:	33mH Ref.	360mH Ref.	22mH Ref.	125mH Ref.
Operating Temp:	-100 to 225° F	-100 to 225° F	-100 to 225° F	-100 to 225° F
Description:	General purpose; stand. sensitivity	General purpose; high sensitivity	Miniature; stand. sensitivity	Miniature; high sensitivity
Model number:	1-0001	1-0002	1-0007	1-0032

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stall torque of 1.5 ounce-inch, stall power of 13 watts, a rotor moment of inertia of 5 grams per square centimeter, and a no-load speed of 3,000 revolutions per minute. The diameter of the new motor is 1.437 in., and the length is 1.90 in.

The design is particularly suited, Schwartz points out, to operating in gas and liquid environments, which have no effect on the magnetic sensor or the sealed-in hybrid circuitry. Other conventional and brushless motors cannot operate under these conditions. □

Computers

Self-repairing unit being put together

Engineers at Raytheon Co.'s Equipment division in Sudbury, Mass., have reached the systems integration phase for the Air Force's self-repairing fault-tolerant spaceborne computer. In fact, program manager Arnold Van Doren expects the computer [*Electronics*, Dec. 25, 1975, p. 36] will be delivered to the Space and Missile Systems Organization on schedule in November.

Samso, in El Segundo, Calif., needs a computer with a 95% probability of operating in space for five years. To achieve that goal, Raytheon is not just building redundancy into the general-purpose computer, but is employing a novel "ripler switch" to perform the self-repairing function while reducing redundancy and simplifying the switching hardware.

C-MOS design. The brassboard for the Air Force uses complementary metal-oxide semiconductors almost everywhere. The exceptions are two of the memory modules, one of which uses n-channel MOS random-access devices while the other employs plated wire. In addition, C-MOS-on-sapphire LSI devices in the arithmetic/logic units and some register files in the central processor assure that the system will achieve the speed of 200,000 instructions per second, says Jack Stiffler, consulting

News briefs

Delco adds big, new MOS plant

Delco Electronics will dramatically increase its MOS capability next April when it turns on a new 25,000-square-foot plant that's going up in Kokomo, Ind. It will have p-channel, n-channel, and complementary-mos production lines and will eventually build custom microprocessors to be used in vehicle engines to meet Government regulations on emissions, safety, and fuel economy. The firm also sees a need for LSI chips for auto radios, perhaps as early as next year.

Delco has a limited MOS capability now: for 1977 General Motors cars, it's supplying p-MOS chips for thief-deterrent and cruise-control systems and is shipping a few n-MOS prototypes to its Santa Barbara, Calif., R&D center for an airborne computer. The GM subsidiary also has extensive bipolar and hybrid facilities.

Unitrode invests in LSI-maker Synertek

Unitrode Corp., Watertown, Mass., will become the largest stockholder in Synertek, the Santa Clara, Calif., manufacturer of MOS LSI devices, under the terms of an agreement in principle to purchase stock. The purchase is worth \$1.25 million to Synertek. It should be concluded by Sept. 30 and would give Unitrode about 20% of the outstanding Synertek common stock. Unitrode makes discrete semiconductors, including power transistors, triacs, and silicon-controlled rectifiers. Synertek, which uses neither "Co." or "Inc." after its name, began operations in 1974 and was profitable in the year ended June 30, with sales of \$5 million.

Award for F-18 radar goes to Hughes

The multimode radar for the Navy's new F-18 air combat fighter will be built by Hughes Aircraft Co., following its selection by prime contractor McDonnell Douglas Corp. Under a \$64 million fixed-price/incentive contract, Hughes will build 11 radar systems for the flight-test phase of the aircraft's development. Hughes was chosen over Westinghouse Electric Co., which is already developing the multimode radar for the Air Force's F-16 fighter [*Electronics*, July 8, p. 33].

Packet-mode network goes international

Tymshare Inc., Cupertino, Calif., and the Trans-Canada Telephone System have agreed to interconnect Canada's packet-switched network with Tymshare's international data network. This is the first international linking of packet-mode networks for commercial use. The interconnection will give customers in Canada direct packet-mode access to a large universe of computers and data bases in the U.S. The interconnection additionally means that subscribers in the U.S. may now interconnect to Canadian computers tied to Datapac.

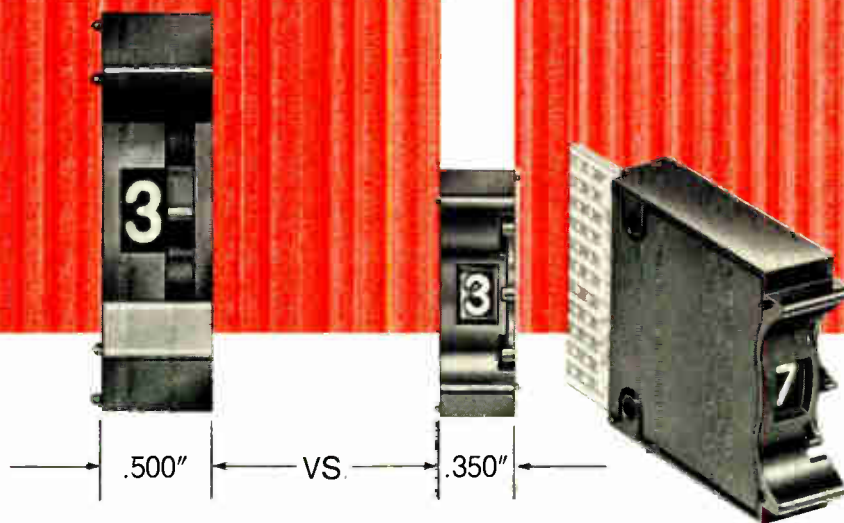
Retailer orders \$6 million in POS terminals . . .

A \$6 million, three-year agreement has been signed between National Semiconductor Corp., Santa Clara, Calif., and National Tea Co. for Datachecker electronic point-of-sale terminal systems. The equipment, to be installed at more than 100 National Tea stores, includes T-2500 stand-alone terminals with polling subsystems, scanning equipment, and key entry systems without scanners. National Tea already has installed Datachecker equipment in more than 60 stores in Chicago and St. Louis.

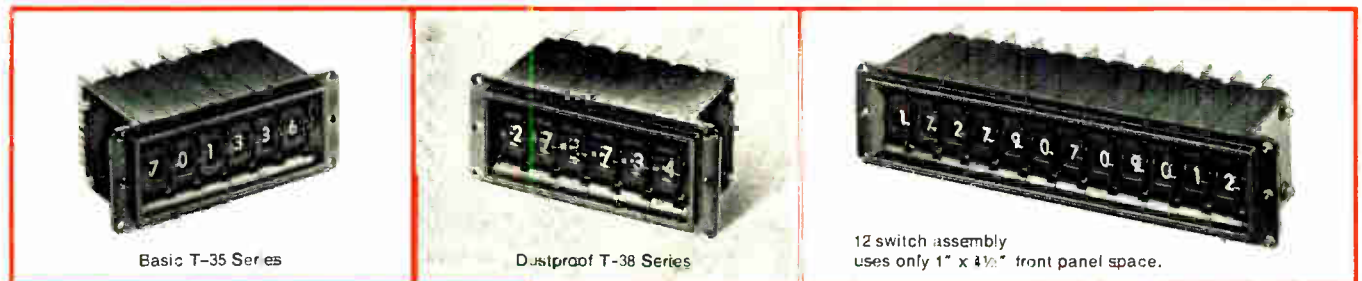
. . . as manufacturer orders hand-held scanners

TRW Inc. has awarded a \$15 million contract to Recognition Products Inc., a subsidiary of Recognition Equipment Inc., Dallas, for the company's hand-held optical-character-recognition wands. All the same model, the wands will be attached to electronic point-of-sale terminals. According to Jay Rodney Reese, REI president, the TRW contract may be the largest OCR order ever received by any manufacturer.

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scientist for the fault-tolerant computer in the division's Computer and Displays Laboratory [*Electronics*, June 24, p. 25].

Redundancy is provided in the key computer modules through four central processors (two of which work at all times), three main memory modules, two serial interface modules, two direct-memory-access modules, and three configuration-control units. These last have the job of monitoring the entire system for faults and, when they find one, triggering a status word that initiates the reconfiguration of the system by dropping out a failed unit and calling in a spare.

But because redundancy adds weight and volume, Stiffler has come up with the rippler switch to keep both factors in hand. This switch exploits the interchangeability of the modules and module subelements into which the computer is partitioned—it reconfigures functioning subelements into a new operating system after a failure is detected. And it does so without being so complex that it degrades overall reliability—a possible problem in other kinds of switching techniques, Stiffler says.

Backup neighbor. The rippler replaces any subelement in a linear array of identical subelements with its nearest neighbor, then replaces that device with that device's nearest neighbor, and so on, until the last active device is replaced down the line by the first available spare. In each memory module, for example, there are three spare and 38 active bit lines.

If a bit line is faulty, the configuration-control unit is notified and establishes a hardware status word that alerts the central processing unit to the fault. The CPU, using a program stored in its read-only memory, isolates the failed bit line and triggers the rippler switch.

With the C-MOS LSI rippler “we can get as much protection against a failure in a bit line as we could with a complete duplicate memory,” Stiffler says. According to him, it's also much simpler than a switch that directly substitutes a spare bit line in

the same location as the failed line.

If the fault is elsewhere than in the memory, error-code decoders, “watchdog” timers or the CPU monitor will detect it. The watchdog timers measure, among other things, the interval between the time a computer element is asked to transfer data and the time it actually does. When a fault is noted, the configuration-control unit is alerted and interrupts the CPU to start the reconfiguration program. In addition, software diagnostics periodically verify that the hardware monitors are operating. □

Materials

Ceramic's properties enhanced for hybrids

A small California company is marketing a ceramic with properties it says could reduce the cost of manufacturing hybrid circuitry for high-reliability avionics equipment.

Designated RW-97, by RW Products Inc., San Carlos, the alumina-based ceramic is priced, depending on how much it is preworked for the customer, from 2% to 10% less than conventional material, says Robert Wire, the company's president. And even further savings are possible for the customer, he continues, because testing can be much simplified.

These benefits are obtained, Wire says, because RW-97 combines the electrical, mechanical, metalization, and temperature characteristics previously found separately in three or four different compounds. Accordingly, fewer separate test procedures and equipment are needed to check out the material.

Others also. RW Products is not alone in developing such a general-purpose material, which is also suitable for the insulators in microwave vacuum tubes. It is, however, the first to reach the market, and its material has been approved by the Defense Electronics Supply Agency.

Considerably larger ceramic-material suppliers than the \$800,000-a-

year RW Products are also rumored to be hard at work on similar materials. These include Coors Porcelain Co., American Lava Inc., a subsidiary of Minnesota Mining and Manufacturing Co., and Western Gold and Platinum Corp. (Wesgo).

To produce hardened alumina ceramics with the right mix of properties, suppliers have their own proprietary mixes of silicas, clays, and rare earths that are combined with aluminum oxide in its raw, powdered form and then compressed and molded into a “green,” unfired substance. Depending on the end application, each particular mixture has a characteristic “body” that's related to the mix of raw materials.

The characteristics important for vacuum-tube and substrate applications in the avionics industry have a 94% to 99.5% body range. For example, says Wire, material with a 99.5% body is optimized for physical strength and electrical properties; 97%, for a balance among metalization, electrical, and physical characteristics, and 94%, primarily for metalization properties.

In unfired form, these materials are soft and chalky, but firm enough to be machined to the shape required. They are then heated to about 3,000°F in kilns to produce tough alumina ceramics that are nearly as hard as diamond.

Wire and his engineers have come up with a process that is similar to the old approach, except, of course, for the details of the rare-earth/silica/clay combination and the firing schedule. But Wire says it produces an alumina ceramic that combines the optimum metalizing properties of a 97% body and the electrical characteristics of a 99% body.

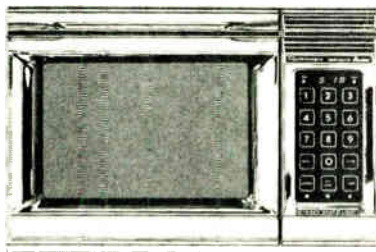
According to the company, the only limit to the size of the ceramics it can turn out is set by the equipment. Presently, the limit is six inches in diameter and 10 by 10 inches in area. Surface finish, a measure of the root-mean-square peak-to-valley distance over the entire substrate, is about 28 to 32 microinches in an “as fired” state. Flatness, or camber, a measure of the amount of bowing in the

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Electronics review

substrate is typically 0.002 to 0.003 inch/inch.

Into production. Wire says that Litton Industries, Microwave Associates, and the Relmag division of Varian Associates are gearing up to use his material in their microwave vacuum tubes. In addition, he says, several other companies—including Varian's Solid State division and Aeronutronic Ford—are evaluating RW-97 for use in hybrid-substrate assemblies in satellites.

But these companies aren't saying much yet. However, a materials specialist at Varian says, presaging what could be a problem for small RW Products, "I can't help wondering what companies like Coors and Wesgo have up their sleeves." □

Automotive

GM picks custom chip for digital ignition

Ending speculation on whether auto companies will go to custom or standard microprocessors, General Motors, the biggest of the Big Three, has come down on the custom side. Its first digital computer under the hood will include a 10-bit processor designed by the Delco-Remy and Oldsmobile divisions, produced by Rockwell International, and targeted for the 1977 Toronados.

Economy improvement. The microprocessor will be the brain of an ignition timing and spark regulation system that is expected to increase the Toronado's fuel economy by an average of 8%, or 1.2 miles per gallon.

Called Misar for microprocessed sensing and automatic regulation, the system processes inputs from three sensors—coolant temperature, manifold vacuum, and crankshaft position, related to engine speed. Honeywell is producing the pressure sensor for vacuum and Delco-Remy, the other two.

The microprocessor is programmed to take the speed and vacuum information and interpolate from its memory optimum ignition timing

based on engine conditions. It then establishes the crank position at which to fire the spark, controls dwell time, and adjusts firing based on coolant temperature.

Analog at Chrysler. As for the others in the Big Three, only Chrysler has a similar electronically controlled spark advance as part of its lean-burn system [*Electronics*, April 3, 1975, p. 38]. However, the Chrysler computer-controlled spark is an analog system, less flexible than the new GM Misar. Most likely Chrysler, too, will go to a digital microprocessor for the next generation of lean-burn controls, which it will use on more models.

Ford, meanwhile, has put plans for a microprocessor-controlled fuel-management system on the back burner, preferring to stay with established electromechanical devices.

In GM's case, the microprocessor as designed is far underutilized in its present format. But that was anticipated since the Toronado is obviously a means of getting the auto maker's feet wet in digital technology. After the shakedown expected in making the estimated 35,000 1977 Toronados, the Misar system will be extended to other intermediate-sized cars.

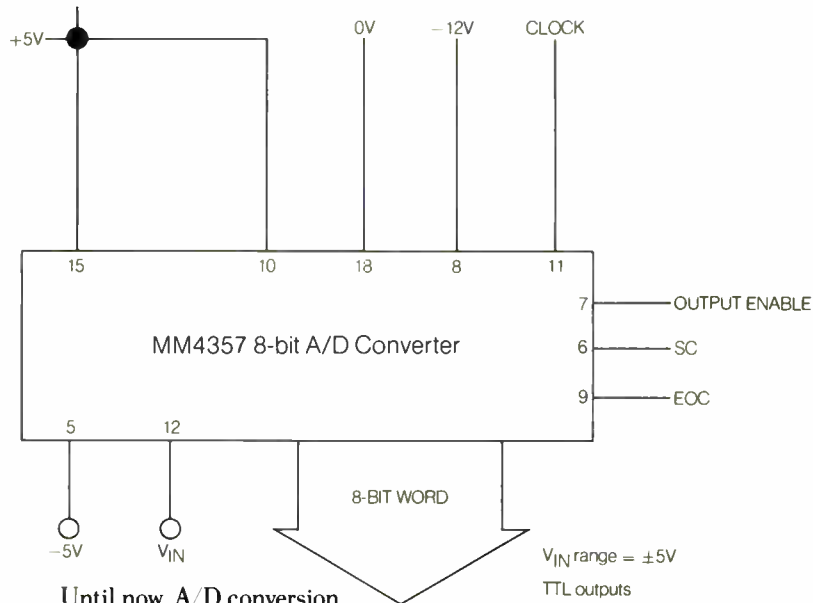
Ease of conversion to other engines for various model cars will be one of the payoffs to GM. The microprocessor can be programmed with engine performance data for individual engines, much as the auto companies now put a preset advance into distributors to match each engine.

More capacity possible. According to Elliott M. Estes, GM president, who unveiled the Misar at the recent West Coast meeting of the Society of Automotive Engineers, the full capacity of the microprocessor may some day be used to cut unwanted engine knock by retarding or advancing the spark to keep it below trace levels. "GM hopes to introduce a knock limiter in the next couple of years," Estes disclosed.

Like the analog Chrysler system, the GM Misar's objective is to meet Federal emission control regulations without limiting performance. □

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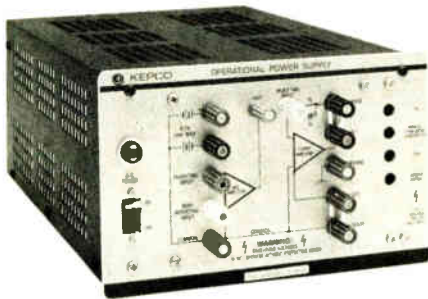
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Electronics firms finding Bombay offshore haven

A U.S. State Department report that has not yet been made public touts Bombay, India, as "tomorrow's Taiwan." That judgment by an international industry analyst at State is based on the growing number of electronics companies—**51 so far, including 17 with American ties**—that have been attracted to the Indian city. They have set up manufacturing operations in an area known as Seepz—the Santa Cruz electronic export zone—which contains 100 acres.

For example, Intersil Inc. has made a deal for production and assembly of digital-watch modules. One of the attractions of Seepz is that it can offer high engineering skills. Unlike Taiwan or Korea, says the report, "there will be very few assembly units operating on a low-technology, labor-intensive basis." So far, the average value added to exports is 60%.

FCC conditionally OKs trades, remakes, resale of CB radios

Citizens' band radio makers that plan to upgrade to 40 channels their 23-channel transceivers (see p. 34) now have FCC approval. The commission says makers **may modify any sets taken in trade and resell them** after expansion of the service on Jan. 1, 1977. [Electronics, Aug. 5, p. 49]. That ruling by the Federal Communications Commission's chief engineer—a compromise on the FCC's earlier prohibition on any alteration of 23-channel radios—contains important provisions, however.

All upgraded transceivers must meet all new 40-channel equipment requirements, including type acceptance and certification. Moreover, the FCC says it plans "extensive sampling of equipment from each manufacturing location" and will hold each manufacturer "solely responsible" for modified units, even though upgrading may be done by others under his direction. "We're going to be very sticky on this," insists one commission official. "Failure of one test unit could lead to cancellation of type acceptance for a complete model line."

FAA awards \$36.7 million more to Univac for ARTS III

Sperry Rand's Univac division has picked up nearly \$36.7 million from the Federal Aviation Administration for **five more ARTS III automated radar-terminal systems**, plus upgrading of 29 of 65 existing stations. Univac says the new contract boosts its ARTS funding to \$131.6 million since its first award in 1969. New systems are set for the New York terminal radar-control room, the San Juan, Honolulu, and Anchorage en-route control centers, and the fifth will go to Nellis Air Force Base, Las Vegas.

The ARTS III enhancement project will expand 29 of the existing 65 installations. Changes include addition of on-scope alphanumeric radar tracking for aircraft not equipped with an identity and altitude transponder, capacity for additional radar displays, and upgraded computer efficiency.

Addenda

The push for electric vehicles got a small but significant boost from a Department of Transportation recommendation to **omit them from Federal energy conservation and mileage-labeling regulation**. Reason: regulation would boost vehicles' costs, slow production and introduction, as well as require redefinition of "fuel" to include electrical energy. . . . Another small boost for U.S. makers of airport X-ray baggage scanners came with a Federal Aviation Administration order requiring all foreign airlines at U.S. airports to use only scanners **meeting performance and safety standards set for hardware used by U.S. airlines**.

Untangling the jumble at the FCC

In a midsummer's mixture of three separate judgments critical to the future of the nation's telecommunications, the Federal Communications Commission has inadvertently provided its critics with some of their best evidence for congressional review of its operation.

First, the FCC inaugurated a second computer inquiry with Docket 20828 "to consider again the use of computers in providing communications or data processing services by common carriers"—an issue it presumably resolved in 1971 with its "final decision" in Docket 16979, its first investigation of the issue. And there is no evidence that the new effort won't occupy several more years of the FCC's time, like that of its predecessor. Under its proposed new inquiry, common carriers would be banned from offering arithmetic or word processing and process-control services unless they established new and separate corporations for that purpose.

Kraushaar as Solomon

Next came the widely publicized and long-awaited verdict of FCC administrative law judge David I. Kraushaar, urging the commissioners to go slowly before advocating any breakup of the Bell System "in the holy names of 'competition' and 'free markets.'" Although Kraushaar's 535-page ruling in Phase II of the FCC's monumental investigation of the lawfulness of AT&T's private-line tariffs is not binding on the commissioners, industry and Government sources agree that Kraushaar's praise of much of AT&T's service quality and corporate and rate structures is well balanced by specific criticisms calling for the opening of the Bell System market to suppliers other than Western Electric Co. and, conversely, permitting WE to compete in other telecommunications markets.

However, to implement these and other recommended changes in AT&T operations, Kraushaar detailed a strong need for upgrading both the company's and the FCC's accounting procedures. He sharply criticized FCC staff challenges to Bell's expenditures and rate-base items, noting these were derived from company records maintained under FCC rules—a system never thoroughly overhauled in 40 years. "The Government has no business taking a citizen out on the proverbial limb and then cutting it off," he declared.

It was those same unenforceable and outmoded accounting principles that caused the FCC in mid-August—a week after Kraushaar's Solomon-like decision—to turn down AT&T's

request to add 40 more cities to the 24 in which it now offers data-under-voice digital Dataphone service. The FCC's reason: AT&T's alleged "failure to keep records of actual costs as previously ordered" and the FCC's resultant "inability to determine the actual cost and revenue relationships" for the service. (In DUV, digital bit streams are transmitted on a full-duplex, simultaneous basis by means of the unused portion of the 4- and 6-GHz baseband of high-capacity microwave radio.)

But in a 3-to-1 split, the commission did grant AT&T authority to expand the service in the 24 existing cities where DUV is employed. Dissenting commissioner Benjamin L. Hooks hit the majority's rule as contrary to the FCC's five-year-old policy on permitting competition, charging that it serves only to tighten "the tentacles of regulatory rigor around one of the most innovative data services yet devised."

Ending indecision

What the three separate FCC decisions have in common is that each of them represents an incompleting action despite many months of investigations, hearings, and study. The Kraushaar judgment alone required 103 days of hearings that took more than a year to complete. More and more, it seems the FCC itself is becoming a classic case of suspended bureaucratic animation where nothing is settled.

In ordering a second computer inquiry, the commission sought to lay the blame on "dramatic advances" in technology, particularly large-scale integrated circuitry, the resultant development of mini- and microcomputers, and "the emergence of a new phenomenon—the distributed-computer network." These advances outdated its first "final decision" five years ago, the FCC now contends. But there is no guarantee that technology will grind to a halt while the FCC muddles through yet another investigation. Who can say that by 1978, say, still a third inquiry may not be warranted—for precisely the same reasons as the second?

But clearly the final resolution of the bedeviled commission's problems must come from the Congress. This is not to say that any satisfying answers rest within the AT&T-sponsored Consumer Communications Reform bill, which would stifle telecommunications competition. Yet that now seems most likely to become the vehicle by which Congress will be obliged to take its first look at FCC since its creation—an underfunded, understaffed anachronism where hand calculators and paper files substitute for computers and data banks. —Ray Connolly

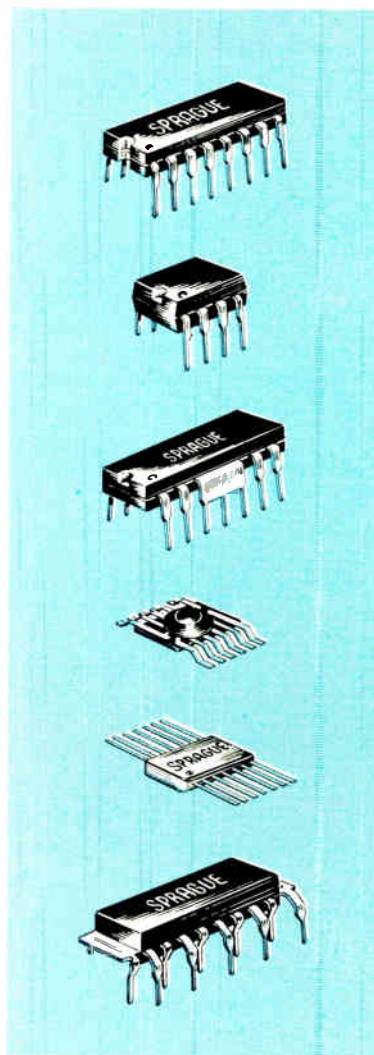
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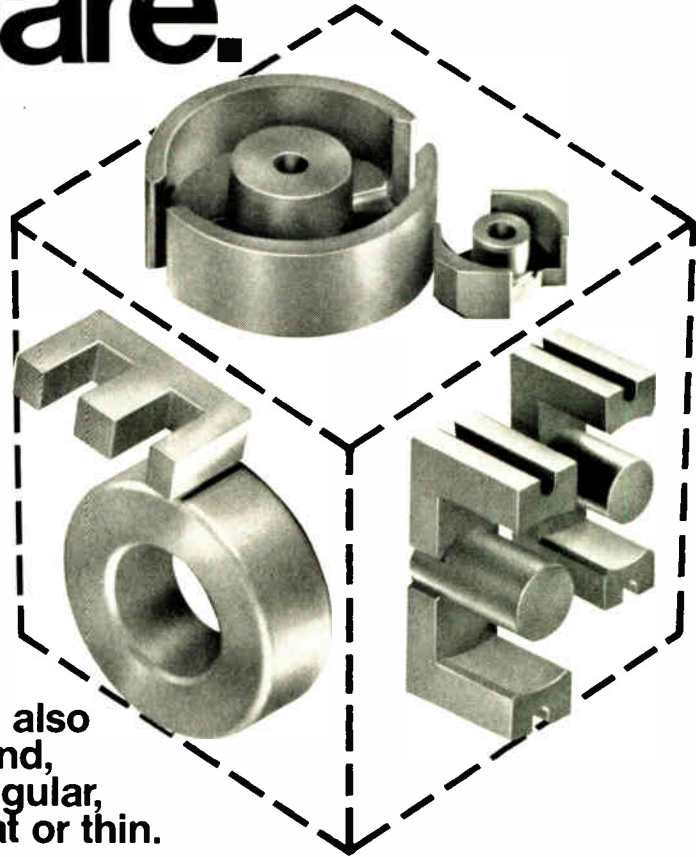
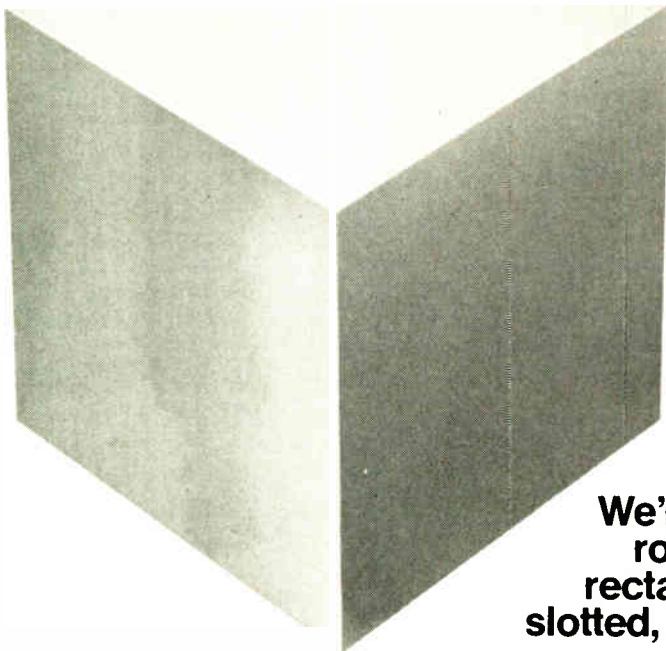


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Mechanical mass memories challenged by Plessey's bubbles, CCDs, holograms

Most memory makers are busy these days building up the arsenal of high technology they'll need to capture customers as the bastions of the mass-memory market—disk and drum stores—crumble before the assault of new technologies. The Plessey Co. is no exception. The British firm will have magnetic-bubble memories on the market within a few months. Charge-coupled devices will follow, and Plessey has a holographic mass-memory well along in development.

Plessey already is sampling a 256-kilobit bubble-memory system based on 16-kilobit chips. David C. Stapleton, European marketing manager for Plessey Memories, expects bubble memories will find a place in hierarchical computer-memory systems with a capacity of 500 kilobits to 10 megabits. The cost per bit will be lower than for disk memories, Stapleton expects. And there are other applications in sight for industrial-control systems and point-of-sale systems that currently use tape cassettes.

Bubbling. Plessey is not alone here, of course. Announced competitors in bubble memories include Fujitsu and Hitachi in Japan and Rockwell and Texas Instruments in the U.S. So, the UK company already has plans to move up to 64-kilobit chips.

The 256-kilobit system that Plessey is sampling now is built up of 16 dual in-line packages, each carrying a 16-k chip and two sets of coils. The basic chip is 180 mils square and uses samarium-doped yttrium iron garnet on a single-crystal gadolinium gallium garnet substrate. For good circuit performance and packaging, an "elementary shift-register layout" is used, explains Tony Marsh, a Plessey memory-development engineer.

In the near future, the company plans to announce 64-k chips.

They'll need only slightly more chip real estate because the bubble size—now 6 micrometers in diameter—will be halved. Later, there'll be 256-k and even 1-megabit chips, Plessey hopes. To keep the millisecond access times, though, the layout would be changed from a shift register to a "major-minor loop" for the large chips. In this layout, a row of small loops feeds a long circular

bubble track. There'll also be a new package design that will relocate the coils for easier assembly.

As for CCD memories, Plessey has two kinds of applications in mind, says William Holt, manager of the applications division of Plessey's Allen Clark Research Centre. CCDs will find a place as add-on memories because their lower cost "more than compensates for their longer run-

Around the world

Japanese JFET provides fast logic

So far, the static induction transistor—a junction field-effect transistor with triode characteristics—has made its mark mainly as a power device. Now, however, it looks as if an upside-down version of this particular JFET can score in high-speed logic with an eye-opening delay-power product. At Tohoku University's Research Institute for Electrical Communication, a group has developed models of a variant of integrated injection logic. It substitutes upside-down static induction transistors with multiple drains for the bipolar transistors with multiple collectors used in conventional I²L mainly because the junction capacitances of the static induction transistors are extremely low—about a tenth of those for I²L bipolar transistors. The propagation delay-power product for the new logic layout is also extremely low—somewhat less than 0.01 picojoule. What's more, packing density is high, and the structure can be fabricated with only four masks.

The group fabricates the basic upside-down static-induction transistor in an n⁻ epitaxial layer atop an n⁺ substrate. The gate is a doughnut-shaped diffused p region with a shallow n-diffusion drain at the center. The n⁻ region below it becomes the channel, and the n⁺ substrate the source.

British multiplex data on land-mobile net

A group at the University of Bath in Britain is multiplexing data with voice traffic on a very-high-frequency channel for civil land-mobile radio networks. Within a 12.5-kilohertz channel, the researchers are adding a single-sideband channel to carry voice, and the usual double-sideband amplitude-modulated voice channel transmits data at 2.4 kilobits per second. The Bath group has been testing the idea for two years over an experimental network.

This technique, which allocates 5 kilohertz to the speech channel and the remaining 7.5 kHz to the data and protection channels, unjams traffic from the transmitters to the mobile receivers. What's more, the group chose a "radical" sideband-diversity approach to overcome the problems of multipath fading, which is often encountered in sending data signals from transmitters to mobile units with slightly modified conventional transceivers. A strong signal is transmitted by phase-shifting the modulation applied to several double-sideband transmitters sending on the same frequency. This shifting destroys fade patterns so that a mobile receiver "hopping between sidebands" merely picks up the strongest signal. Error rate is 1:10,000.

The network, if adopted by the group's sponsor, the Home Office, would use available technology and require little additional equipment. Intended for utility and security fleets in public-safety nets, routine messages would be sent to teleprinters and visual displays.

ning/access times," Holt feels. And CCDs will have a niche in the special-purpose memory sector for applications like a 7-k store for Teletext decoders. So far, Plessey has readied only 16-k CCD chips and their introduction has been momentarily delayed by a problem with current leakage. But this 16-k chip, which has a serial-parallel-serial layout, is really just a forerunner to the 64-k chip that Plessey believes is crucial for competitive computer memories.

For archival memories where the need runs to a trillion bits, Plessey claims to be close—technologically—to a commercial system; marketing strategy, though, will govern the timing of the introduction of the company's holographic system. Plessey's system employs conventional laser projection and a special page composer to image holograms on an ultrasensitive Kodak 16-milli-

meter film. A modulator, which flashes 32 tracks of holograms onto the film, transforms the data stream to be stored into holographic "pages." To retrieve the stored data, a replay lens images the page onto an array of photodiodes. The read and write light beams have different polarities, meaning the same optics can be used for both operations.

With 32 tracks across it, 1,000

meters of 16-mm film could store about a trillion bits of data. Access time for a page, mainly a function of film-transit speed, would run between 5 and 10 seconds. In addition to the read-only film system for data retrieval, Plessey is looking at materials like amorphous glasses and photochromic substances that could be used for read/write holographic memories. □

West Germany

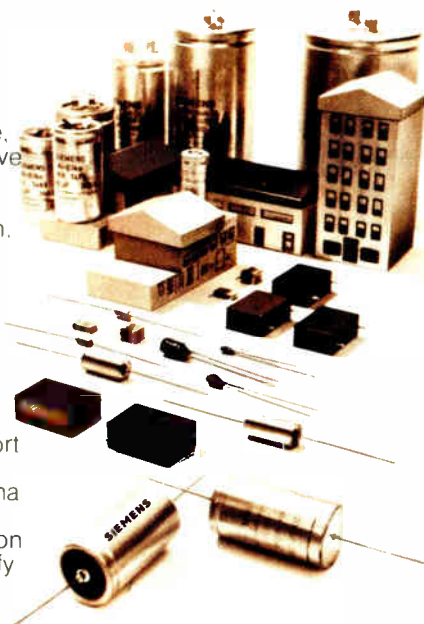
Hybrid RC filter is standard product, but it can be customized

In hybrid circuits, as in monolithic integrated circuits, there is a tendency to move away from custom design toward standard approaches. Standard hybrids, so the reasoning goes, cost less because the development

costs are amortized through mass production of a device that can be used in several applications. One hybrid producer taking advantage of this trend is Siemens AG, which has introduced a number of standard

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hybrids this year. One of the latest is an active RC filter that is freely programmable.

Designated B91117, the coil-less filter, made with tantalum thin-film technology, is designed to operate from 20 hertz to 20 kilohertz, primarily in industrial equipment. Significantly, the filter, contained on a single substrate, needs no external components to get the desired parameters. It incorporates an active RC resonator and four operational amplifiers in a 24-pin dual in-line package of only 30.5 by 19.5 by 6 millimeters.

Setting parameters. As Joachim-Ullrich Schwarz, product manager for hybrid circuits, explains it, there are two possibilities in setting the filter parameters. One involves the manufacturer, who, by laser trimming, adjusts the parameters to customer requirements. After that operation, the customer need not

connect any external components to the filter to obtain the desired parameters.

In the second option, the manufacturer supplies the freely programmable filters to the user, who determines the filter parameters himself. When the user has specified the parameters for a particular application, the manufacturer, again by laser trimming, adjusts the filters accordingly.

At the output of the device, three basic filter characteristics are available: low-pass, high-pass, and band-pass—additional characteristics can be obtained by way of suitable combinations of the three basic ones.

Specifications. The high input resistance—about 100 kilohms—and an output resistance of less than 10 ohms make it possible to connect together a number of B91117s without any buffer amplifiers between

them. The temperature coefficient of a trimmed filter is $\pm 40 \times 10^{-6}^{\circ}\text{C}$. This value, in addition to the film circuit's high resistance to aging, makes possible the fabrication of filters that could not heretofore be implemented with conventional inductance-capacitance design techniques or with discrete active filters, Siemens workers say.

The supply voltage for the new filter can be between ± 4 volts and ± 12 v. In applications where a high output voltage and low power-dissipation levels are called for, filter versions are available with separate supplies for the RC resonator and for the amplifiers. For example, the resonator can have a ± 4 -v supply and the amplifiers ± 12 -v supply. With such a configuration, the quiescent power dissipation is reduced by a factor of 30. The operating temperature range for the B91117 extends from 0°C to 70°C . □

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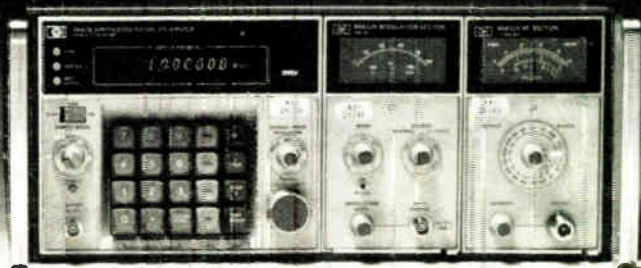
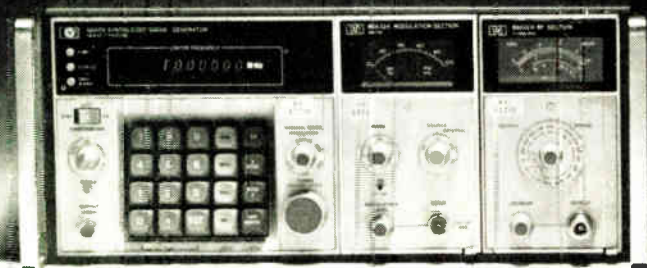
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Darlington vies with thyristors for dc controls

A high-power Darlington transistor is challenging thyristors for direct-current control applications involving moderate voltages but high currents. Applications include chopper control of vehicular motors, inverters, power-supply-control circuits, low-frequency amplifiers, and vibration-test equipment. The manufacturer, Toshiba, points out that **the Darlington turns off when its drive signals are removed.** In contrast, a thyristor used for commutation in dc circuits normally requires a second thyristor of similar size, plus large capacitors and choke coils.

The chip, 40 millimeters in diameter and offered in a flat package similar to that used for large thyristors, has maximum ratings of 400 amperes and 300 volts. The device's Darlington connection typically yields a current-amplification factor of 400 to 500, with a guaranteed minimum of 100. **Such a gain level eliminates the need for high driving power,** formerly a major disadvantage of transistors in high-current applications. A saturation voltage drop of 1.5 volts typical, 2 V maximum, although somewhat higher for the Darlington than it is for a thyristor, is not too high for practical use.

Siemens introduces two microcomputer kits for hobbyists

A couple of do-it-yourself microcomputer kits are being introduced for both the professional engineer and the electronics hobbyist. West Germany's Siemens AG, which is building the kits around the SAB 8080A 8-bit microprocessor, is including assembly and programing instructions, as well as the necessary data books.

The simpler version, the Sikit-N/8080, sells for about \$200. It contains an electrically programable and erasable 256-by-8-bit read-only memory, a static random-access memory, a clock generator, and several other devices. **The more sophisticated \$430 Sikit-DK/8080 comes with two RAMs, two PROMs, and more other components and peripheral devices than the Sikit-N/8080.**

Norway goals set for electronics output in 1980

By 1980, Norway's 40 electronics companies should increase their output by 12.5% in volume by 1980 from the 1973 level, or 21% in value from a 1973 base of \$8.3 million at current prices. That is the conclusion of a survey conducted by an independent consultant for the Norwegian Ministry of Industry. **To achieve these goals, the consultant warns that the government must provide financial support, that both the government and industry must "buy Norwegian,"** and that the work force must be increased by 1980 to 20,400, which is 9,500 above the 1973 level.

French push study on environmental detector for NATO

The French Ministry of the Quality of Life is spearheading a NATO campaign to study the teledetection techniques of member countries. The goal is to evaluate existing systems' efficiency in detecting waste and oil spills at sea, measuring the influence of atmospheric pollution, and gauging the coastal dissemination of pollution.

The studies, which are to begin late next month, will attempt to formulate specifications for a uniform system that may be purchased by participating nations. A French-government spokesman says **the result will probably be a proposal for a teledetection system that combines parts of existing systems in France, the United States, Canada, Belgium, and Britain.**

Japanese JFET puts out 1 kW in ultrasonic band

Output power of 1 kilowatt at ultrasonic frequencies is the March goal set for a vertical junction field-effect transistor by a group at Tohoku Metal Industries Ltd. The first semiconductor product to be developed by the manufacturer of ultrasonic power generators and transducers, the chip will measure 12 to 13 millimeters square.

Potential applications include ultrasonic cleaning equipment, nebulizers, and concrete breakers. The company is also developing smaller units with outputs of several hundred watts for such applications as small broadcast-band transmitters. Manufacture of the transistor will give a total in-house ultrasonic capability to Tohoku, which received a development loan from the Research & Development Corp. of Japan.

UK government cool to industry warning on Japanese imports

The British consumer-electronics industry has lost another round in its battle for import controls on Japanese and Far Eastern television and audio products [*Electronics*, July 22, p. 65]. The British Department of Trade, unconvinced that its policy of voluntary agreements with Japan won't work, says, in effect, that all must wait until the Japanese respond to requests for reduced imports of monochrome sets.

Privately expressing disappointment, the industry—led by giants GEC, Philips, and Thorn—say they will keep up the pressure to prevent what they allege are predatory pricing practices from undermining the “home” electronics industry. **Meanwhile, Mullard Ltd., a Philips subsidiary, is starting a parallel campaign for an annual government investment of \$180 million for the next 10 years** to aid British electronics companies in competition with Japanese and U.S. companies.

High power avoided by video-disk laser pickup from Hitachi

An experimental semiconductor-laser pickup for video disks eliminates the need for a potentially dangerous high-power supply. Developed by Hitachi in Japan for disks of the kind originally produced by Philips of the Netherlands, **the pickup is smaller and simpler than helium-neon-laser types.** The assembly, which uses a buried-heterostructure injection laser, has been simplified by using a single beam for automatic focusing, tracking, and the video-pickup signal.

When operated at a current of about 10 milliamperes, the laser has a spot size of about 2 micrometers. The output power level is about 0.5 milliwatt, and video signals are reproduced with a signal-to-noise ratio of more than 40 decibels, the usual requirement for television.

Addenda

In heavy international competition, AEG-Telefunken has won a contract from Belgian air-safety authorities to deliver a radar system of the German company's SRE-M5 series. **The system, to be installed in the Ardennes region, is to improve the monitoring of traffic in Belgium's airspace and to deliver information to Eurocontrol,** the European air-traffic-control agency. . . . The French government hopes the \$750 million contract it won earlier this month to extend Saudi Arabia's television network will be a marketing boost for the Secam color-television system in other developing Middle East nations. **The contract will be undertaken primarily by Thomson-CSF, which will supply distribution centers and other infrastructure** for the Saudi color-TV system, to become operational in 1982.

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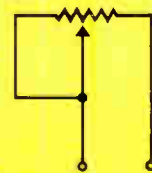
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AVAILABLE CIRCUIT OPTIONS

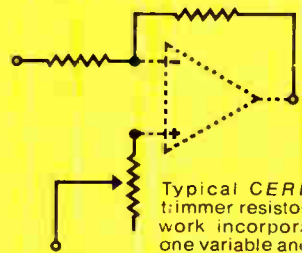
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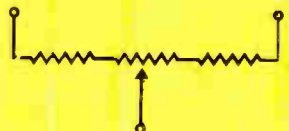
One of five electrical termination options available.

OPERATIONAL AMPLIFIER NETWORK

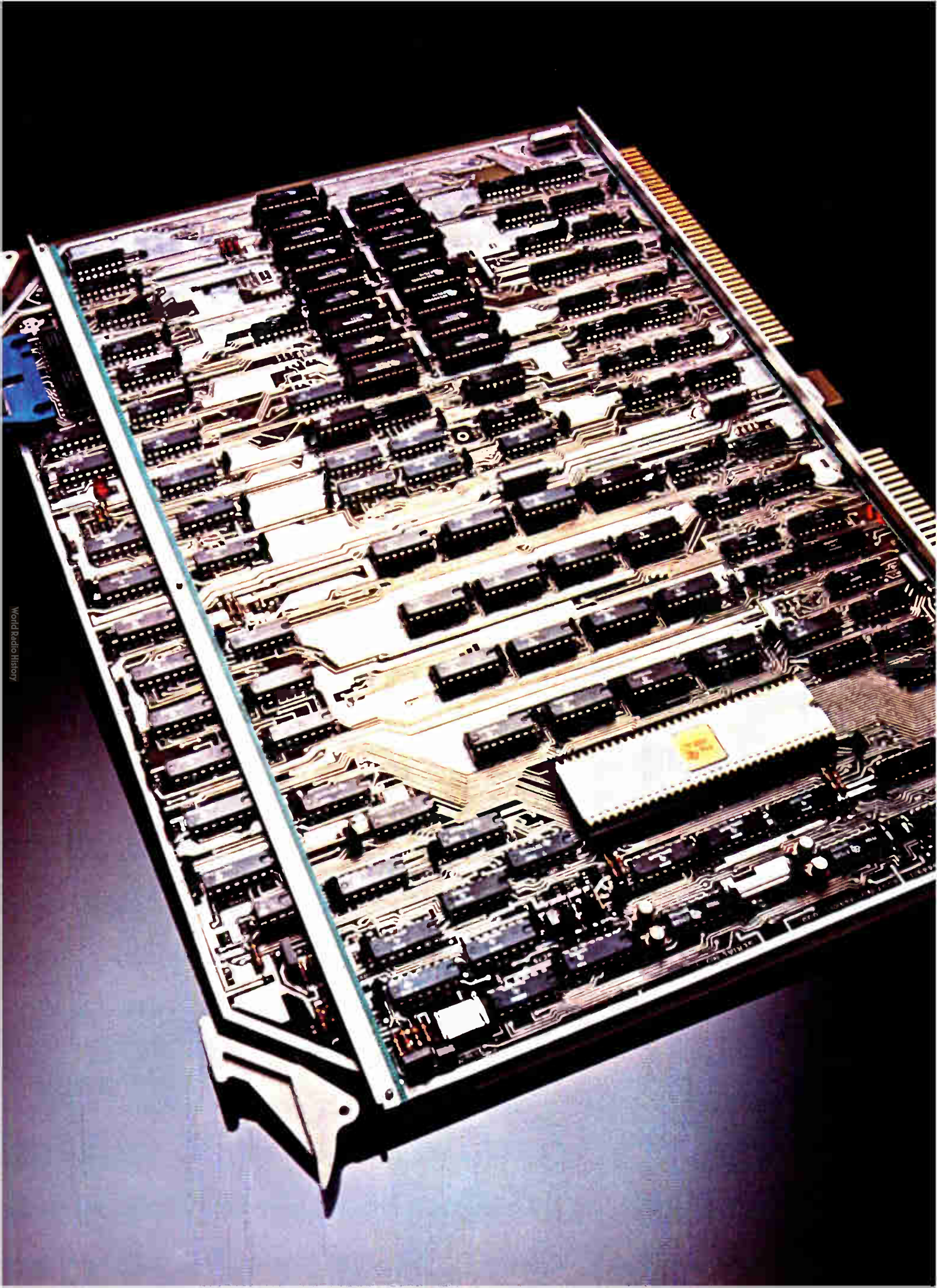


Typical CERBON trimmer resistor network incorporating one variable and two fixed resistors on dual substrate configuration.

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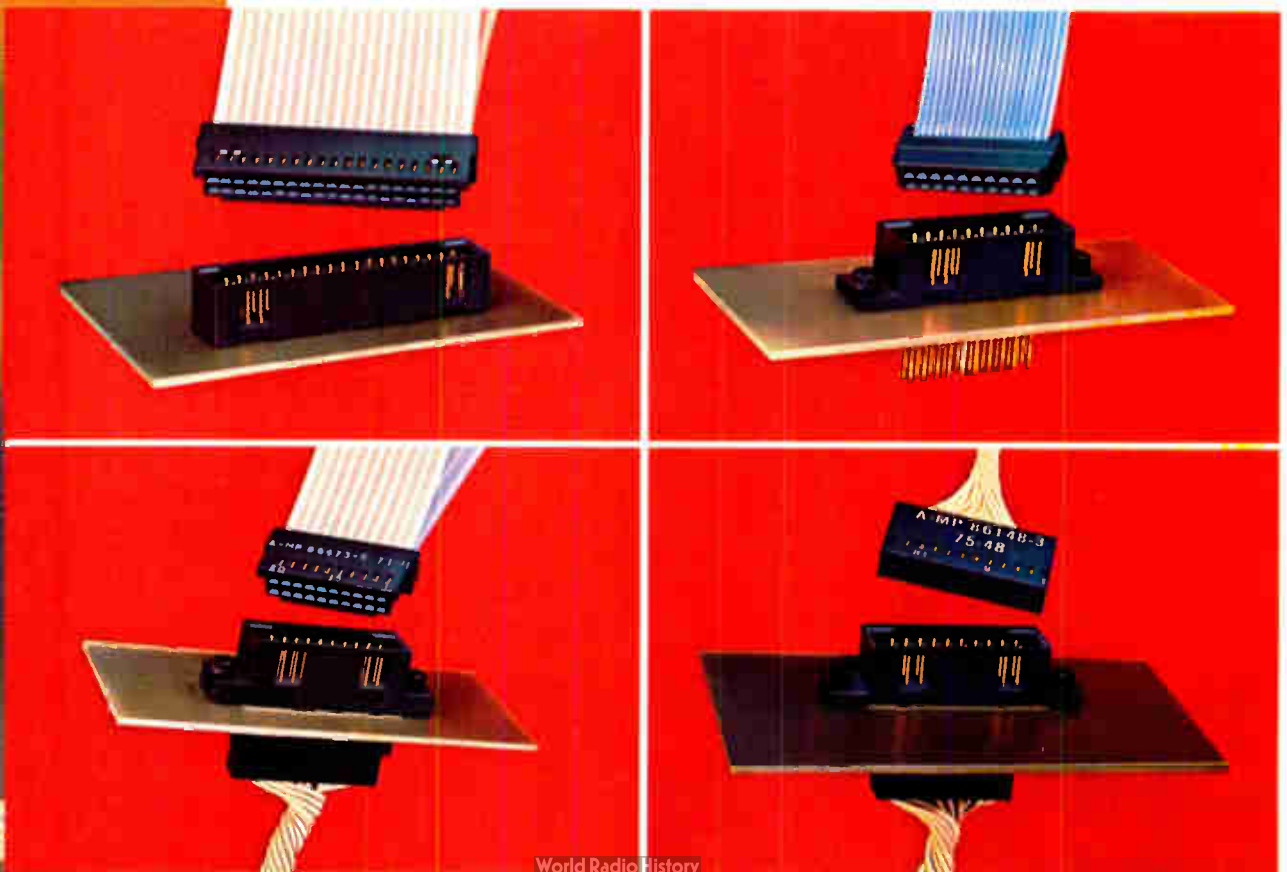
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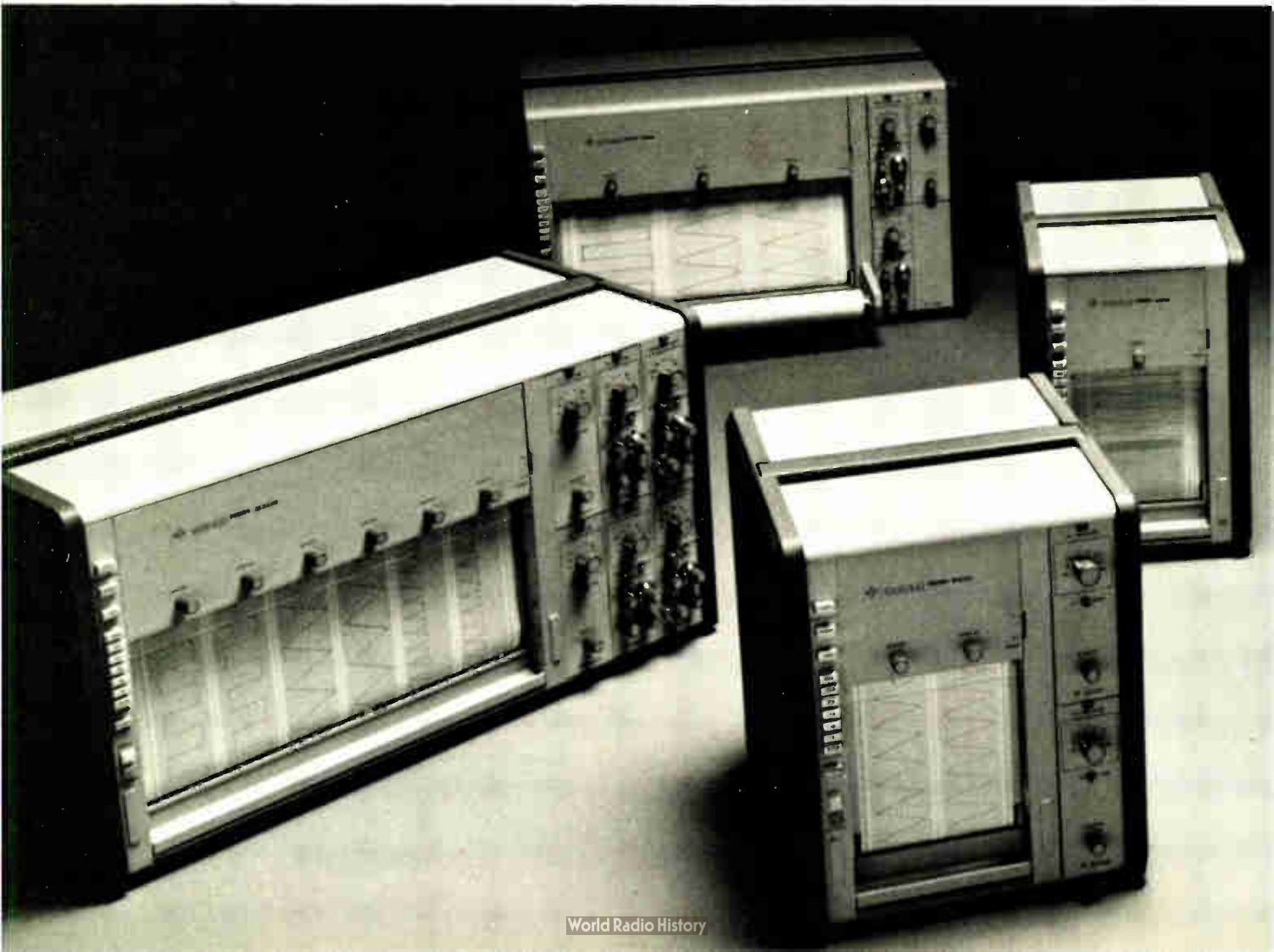
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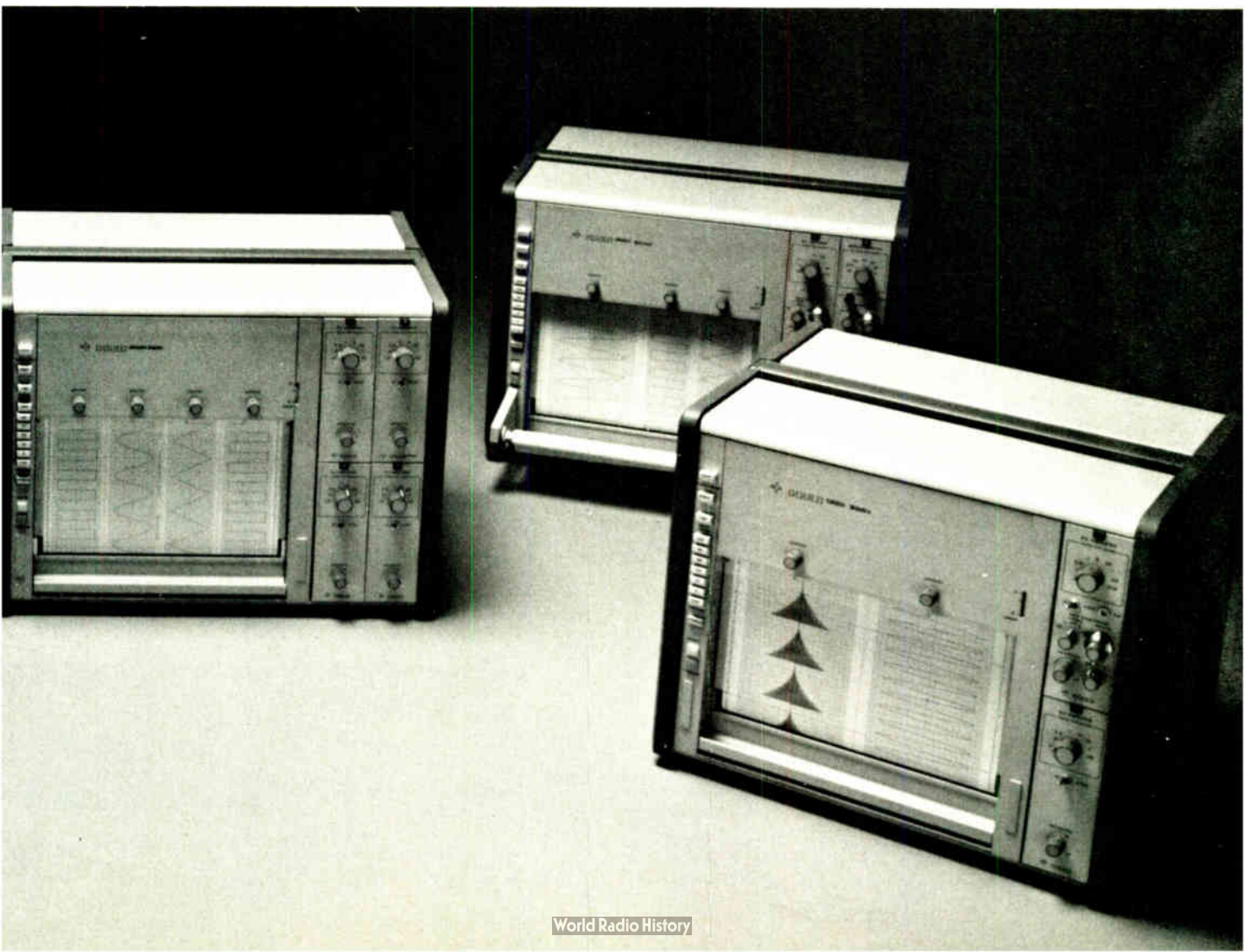
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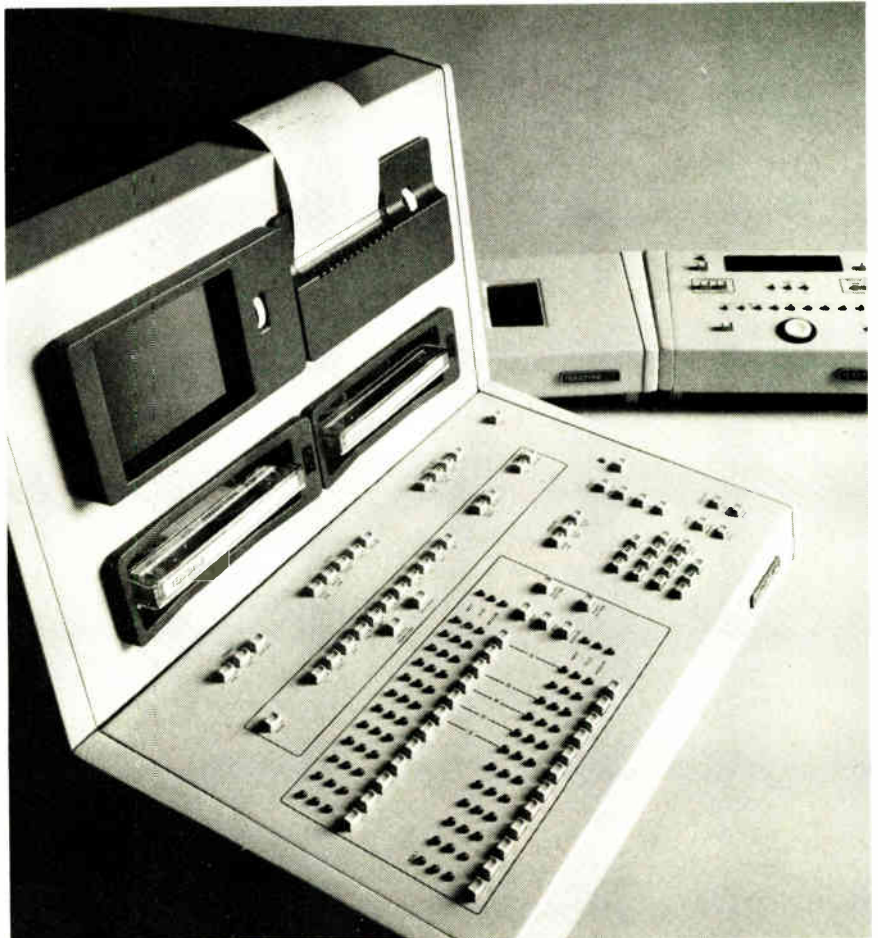
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Road to consumer riches is rocky

Semiconductor firms making end products are squeezed between low profits and high delivery pressure

by Bernard Cole, San Francisco bureau manager

Can semiconductor makers find a pot of gold at the end of the consumer electronics end-product rainbow? That question has been raised again after National Semiconductor Corp.'s announcement last month that due to start-up yield problems on its new complementary-MOS watch chip, its profits in consumer electronics would not be as high as estimated. National's stock dropped from the mid 50s to the low 30s and is just now beginning its climb back up.

In addition to highlighting the continued wariness the stock-market community has about the semiconductor industry, the occurrence brings home again a very important fact of life—that making consumer-electronics end products involves both high risks and high profits. "We are all vulnerable to the same problems," says Stewart Carrell, group vice president in charge of Texas Instruments' Consumer Electronics group. "Consumer electronics moves at a phenomenal speed. There's a short cycle time, and if a company is not on top of the shifts, it can be in trouble in a hurry."

The risk is in trying to come out with a small-profit-margin product with a high-technology content under extreme delivery pressure, yet deliver high reliability. That's a tough combination—one that companies like Hughes Aircraft Corp. and Motorola Semiconductor decided not to take on and one that has forced companies like Mostek Corp., American Microsystems Inc., and Intersil Inc. to back off—at least in supplying and merchandising the end product, whether it is watches,

calculators, or home video games.

The Hughes operation, which shipped 1 million watch modules last year and expects to top 3 million in 1976, never has been tempted to jump into selling directly to the consumer. "We're kind of simple minded," quips William M. Weakland, manager of the Newport Beach, Calif., Solid State Products division. "We felt we should stick to what we know."

No go. Motorola looked at the watch business, and even went so far as to put out a digital watch kit several years ago. But the decision was made then by corporate and Semiconductor group executives not to risk the market. Two basic reasons influenced them: a belief that watches would go the calculator route, with price cutting and subsequent losses, and Motorola's lack of experience in jewelry design and selling. John Welty, who runs the group, has since stated most emphatically that his operation is "in the components business, not the jewelry business."

Mostek was one of the first semiconductor companies to go the vertical integrated route in the consumer-electronics business, making and selling hand-held calculators, then taking a bath and getting out in a wave of red ink. Now, several years later, Mostek is returning to profitability by doing what it was doing before it tried merchandising calculators—producing ICs—and staying away from end products. At AMI, the Mostek experience is being repeated with watches. Divesting itself of its entire consumer-end-products business is costing AMI \$9 million in this half alone (55% to





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Probing the news

60% of that in watches) on \$32 million in sales. "It just became too costly," says Kenneth Zerbe, financial vice president.

Hanging in. But, despite the apparent risks, the end-product business is one that semiconductor companies like Intel Corp., National Semiconductor, Fairchild Camera and Instrument Corp., and Texas Instruments, in particular, plan to be in for the long term. "It's an extremely important application area for a large fraction of our new designs and technologies," says Gordon Moore, president of Intel, whose Microma subsidiary makes C-MOS watches with liquid-crystal displays.

Staying in each of these particular segments over the long term, says Floyd Kvamme, vice president and general manager of National's Semiconductor division, means being more than merely a supplier of circuits or modules. "It means getting into the end product," he says. "There is no real choice about it. It's a fact of life that is both market- and technology-driven."

To remain competitive in a very price-sensitive consumer electronics business, says Kvamme, vertical integration—from circuits and displays to modules and finished goods—is necessary. "This means that, as a particular segment matures and several vertically integrated companies begin to dominate, the available non-captive share of the market declines," he says. "The only way to remain in a particular segment and grow is to make the end product."

Problems. But as National's recent experience shows, even the semiconductor companies most successful in the end-product business have had their problems. In calculators, start-up problems caused TI and National to report lower earnings and helped keep Fairchild out of the market altogether. In watches, Intel had trouble with the reliability of the liquid-crystal displays, and Fairchild, spectacularly successful as it has been so far with watches, is rumored to have had at least several minor problems that slowed production temporarily. But, says Kvamme,

referring to National's report, "One glitch does not a disaster make."

But what makes these companies unique is that they seem to have learned from their mistakes and worked out similar approaches to this highly volatile marketplace. Like TI's Carrell, all of the executives at the four companies agree that design-production discipline is important. TI learned that lesson with calculators. He says, "We lost sight of our marketing plan and strategy. Our products were not well positioned in price, there was an overlap, and we had an inventory imbalance. We've corrected this with a clear plan.

"And now, we use design-to-cost strategy. Calculators are designed to a price that is profitable throughout their life cycle and not just at the time of introduction. We've improved production and inventory control." He now believes that both the calculator and watch lines are under reasonably tight control.

Strategy. "It's not the technology that is so important; it is how you manage it," says Greg Reyes, vice president and general manager of Fairchild's Consumer Products group. What this means, says National's Kvamme, is organizing things so that glitches are not likely to occur, but also so that the situation is manageable.

All four companies are similar in the way they have approached particular end products. All maintain some degree of presence in all price and volume segments: in calculators, both TI and National use the larger margins on their middle- and high-priced calculators to counterbalance their low-priced, high-volume units. In watches, Intel, National, and Fairchild are in the market with high-, middle-, and low-priced units. "Any semiconductor company that gets into any end product without the expectation of at least a 10% margin, overall, had better not get in," says Reyes.

Another common characteristic of these four companies that would seem to ensure their success in the consumer-electronics business is size and financial stability. All four have yearly sales in the hundreds of millions of dollars, and all have healthy financial reserves.

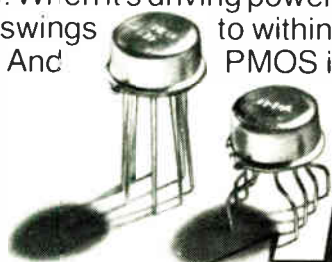
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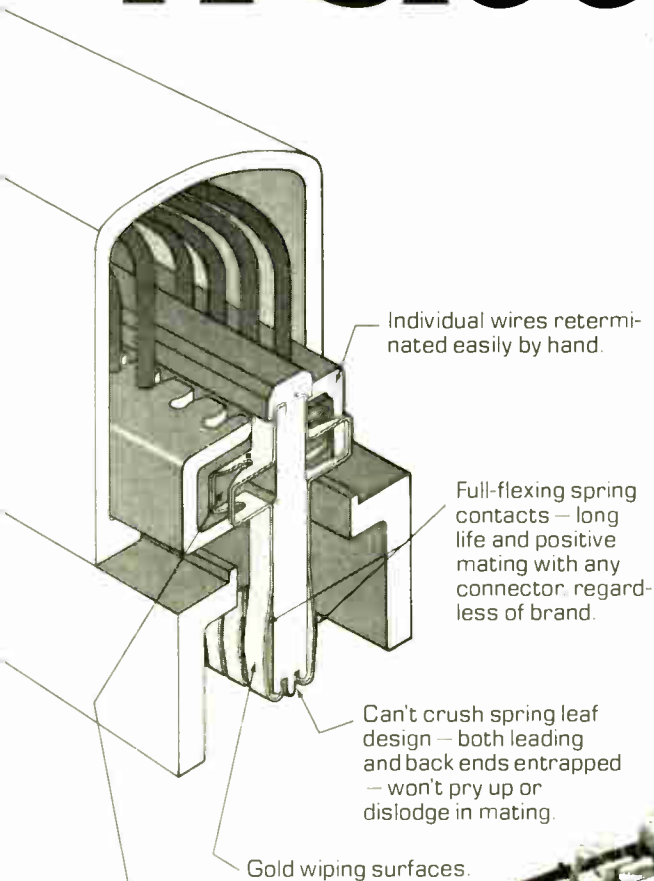
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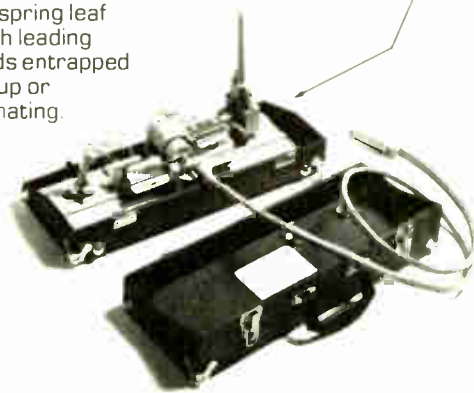


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Work at Sandia helps IC makers

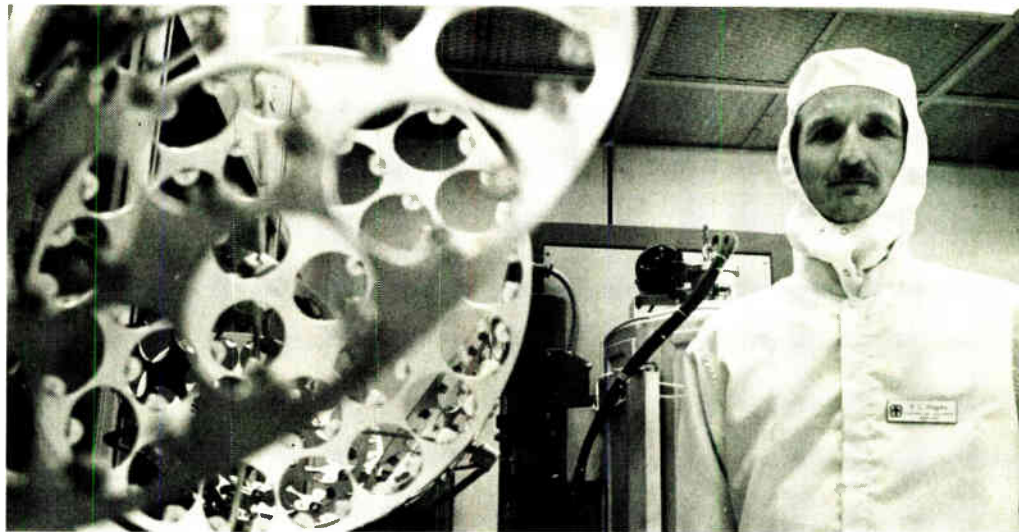
New semiconductor lab develops processes and techniques to radiation-harden devices and offer them to commercial makers

by Larry Waller, Los Angeles bureau manager

It should come as no surprise that Sandia Laboratories' brand-new Semiconductor Development Laboratory is acknowledged to be the free world's leader in radiation-hardening of integrated circuits. After all, nonprofit Sandia, in Albuquerque, N.M., pioneered this critical technology for the Department of Defense in the early 1960s, when ICs first went into nuclear weapons. But what isn't generally known is that the lab sometimes shares its expertise with commercial IC houses.

The Sandia semiconductor lab, built at a cost of \$1.5 million, is crammed with \$2 million worth of equipment. Although it opened only last spring, it already has come up with impressive results in its specialty. Robert L. Gregory, manager of the Integrated Circuit Process department, reports that large-scale-integrated complementary-MOS metal-gate circuits that have been fabricated can operate after exposure to radiation doses as large as 10^6 rads. "This is several orders of magnitude better than commercially available devices, which run from 10^3 up to 10^5 ," Gregory observes. But the four commercial houses that now closely follow the Sandia process—RCA Solid State, National Semiconductor, Harris Semiconductor, and Texas Instruments—also can reach the 10^6 level, he says.

Although simple and workable, this way of bringing Sandia semiconductor expertise to the outside world represents a big change, and it is an important reason for building the new microelectronic lab. As Gregory tells it, Sandia scientists had functioned largely as advisers to commercial vendors for about 10 years,



Inner space. Sandia lab's Robert L. Gregory poses beside the planetary wafer fixture. It holds wafers inside a vacuum system for deposition of aluminum.

until 1972–73. "Starting with available devices, we evaluated why one was better in tolerating radiation and suggested to companies they try this or try that. It just didn't work and nothing improved." So Sandia had to "get involved, not only to improve LSI-MOS-device characteristics, but look at the entire technology—to optimize the entire process," he recalls. Yet reaching this objective meant that Sandia had to have a complete in-house design and prototype facility.

Restrictions. But there are ground rules governing who can take advantage of Sandia's semiconductor skills. "We only do work for ourselves and other Government agencies," says Gregory. (Sandia, a nonprofit subsidiary of Western Electric Co., is a prime contractor to the Energy Research and Development Administration, which includes nuclear-weapon responsibilities, as

well as various national-security and energy projects.) "We only work for private companies if they have a Government contract and the agency asks us for help," which it often does, he says.

One indication that things are working right, as the new lab establishes new radiation-hardening processes, is the yields obtained on the first LSI devices fabricated. W.R. Dawes Jr., supervisor of device design and processing, says these yields were an unusually high 49% for 117-by-143-mil devices. Commercial semiconductor houses cannot expect to maintain such yields, but scrupulous attention to the Sandia processes should help them reach an acceptable level, he says.

Probably of most intense interest to the semiconductor industry is a key discovery, by Dawes and others, of a simple way of gold-doping CMOS to prevent latch-up. A major

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disadvantage of bulk CMOS circuits, gates may be jammed or destroyed when they are exposed to modest doses of ionizing radiation or to an overvoltage. It can be caused, Dawes says, by the injection of less than a microampere into gates. "Even if it doesn't destroy the device, you have to kill the power and also lose data stored in flip-flops or registers."

Adaptation. The solution, called "incredibly cheap," grew out of the group's bipolar experience. "Anybody versed in bipolar [technology] would see it in 10 minutes," he observes, "but most people were reluctant to try it." It involves only one added process, evaporating 50 angstroms of gold "worth one millionth of a penny," on the back of the wafer.

The concentration of gold limits the substrate-carrier lifetime to approximately 25 nanoseconds, preventing latch-up. Tests have confirmed that the process does not degrade performance, yield, reliability, or radiation hardness. It is also commercially feasible, Dawes points out, but can be used only on static devices.

Another major need that prompted the decision to build the new lab is rapid feedback and redesign capability that gives the short turnaround time required in weapons development. This turnaround, or the period from drawing the final logic diagram to a package device, averages about 16 weeks, Gregory says.

A number of serendipitous by-products of Sandia's main business are starting to surface. Closely related developments have been achieved in single photovoltaic solar cells, which have reached 15% efficiency [*Electronics*, July 22, 1976, p. 41] and show promise of further increases. Another is a course put on by lab people, teaching logic designers how to develop new IC's without costly breadboarding. They are shown how to use the much cheaper techniques of employing computer simulation and standard cells, which do not require wasteful experimental hardware. □

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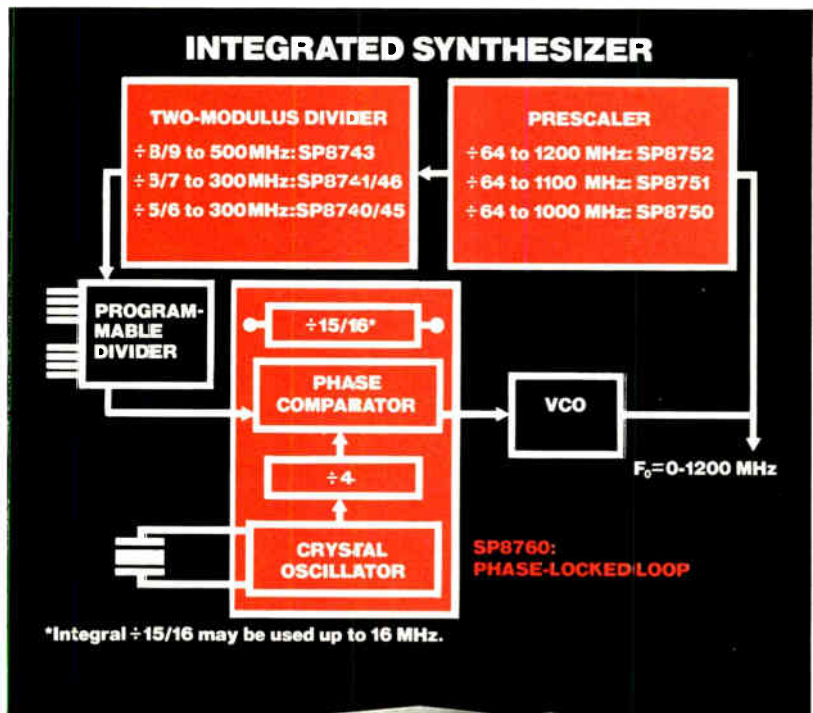
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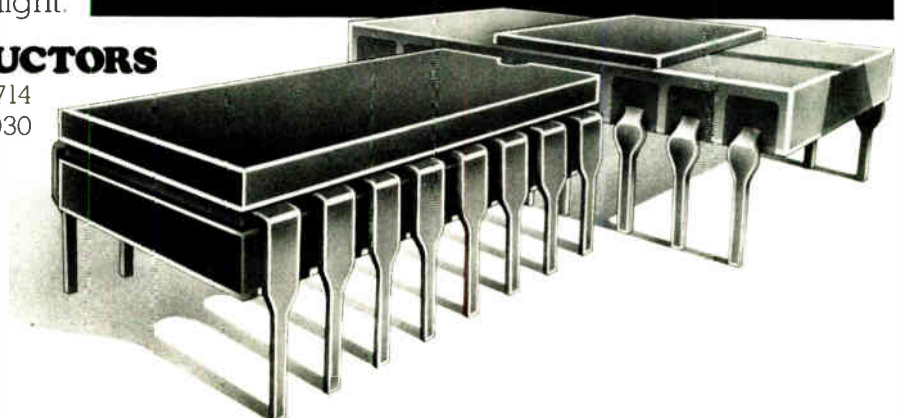
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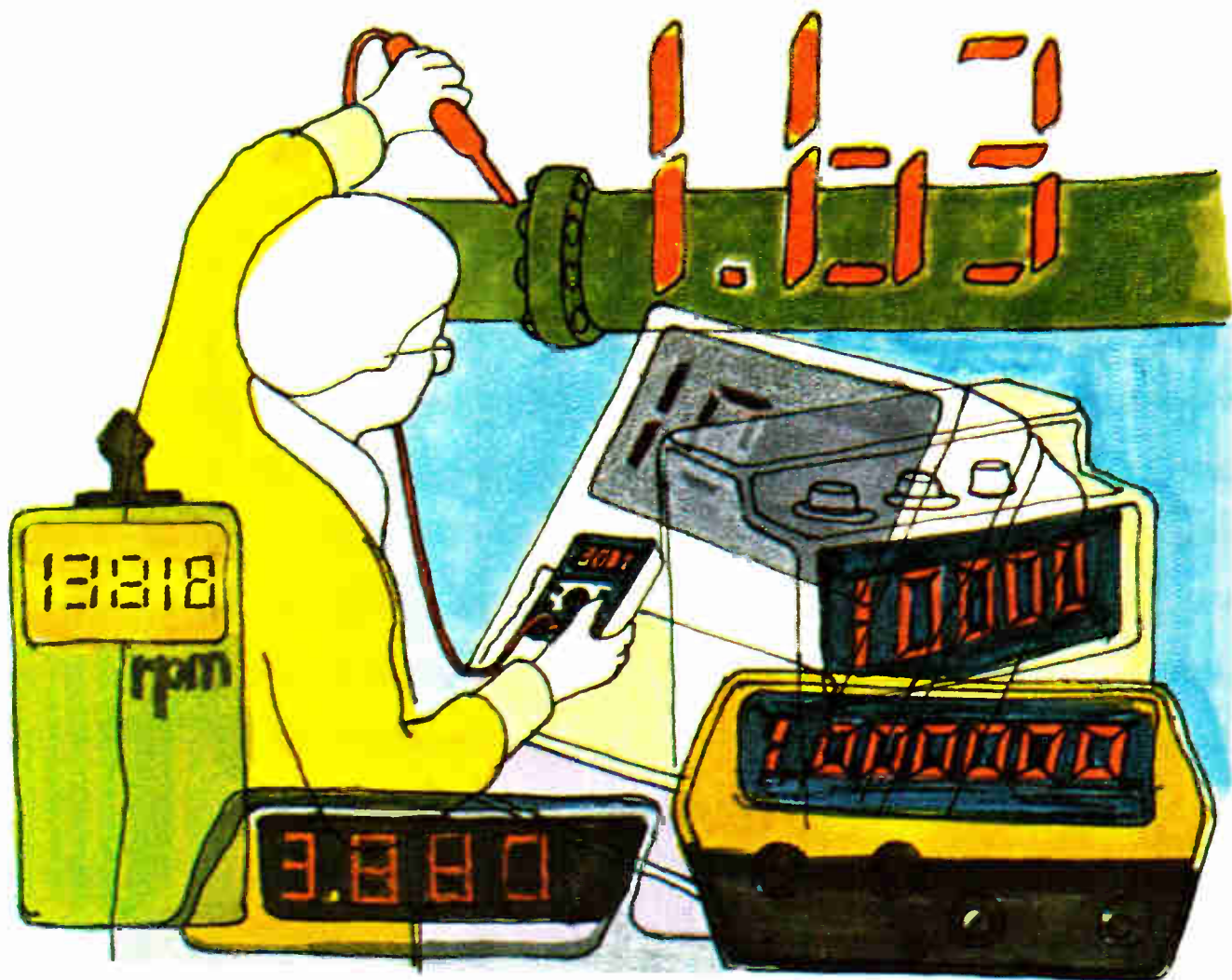
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Communications

Europe refreshes its tactical systems

New technologies ranging from digital switches to PCM incorporated in upcoming battlefield communications



European battlefield commanders in the 1980s will be able to exchange voice or data traffic in less time than it takes today's citizen to dial a telephone call. They'll acquire this facility, even on mobile units, as soon as sophisticated tactical trunk-communications systems become operational with the Belgian, British, French, and West German armies.

By employing digital switching, stored-program control, and other up-to-date techniques in the field, these "mesh" or area-type systems will give corps, division, and brigade commanders speed and capacity to cope with what is expected to be a highly mobile battlefield. Starting the march will be the West Germans, who next year are to begin development of Autokonetz, a pulse-code-modulation system with channel-transmission speeds of 48 kilobits per second. Expected to follow in the 1990s is Audinetz, a more advanced 16-kb/s system.

The French and Belgians are due to be next into the field in 1979 with

RITA—for le Réseau Intègre de Transmission Automatique—a mostly digital system with 48-kb/s transmission speeds. And the British will follow by 1983 with Ptarmigan, a digital 16-kb/s system, intended in the first place for the First British Corps., which is on duty in West Germany.

Contracts. These systems also signal large contracts for the electronics industries. Although the British army won't decide on how much equipment to buy until next year, Ptarmigan's price tag has varied between \$162 million for 20 central switches and \$288 million for a much larger system.

By comparison, the U.S. Army's Tri-Tac system is a far more elaborate and expensive program. Destined for use in the 1980s at the corps and division levels, Tri-Tac's development costs alone reached \$500 million. The entire program will cost \$5 billion over the next 20 years.

The European plans still will be a

Reading RITA. Soldier works with RITA, the tactical communications system being put together by France and Belgium. It is due to go into the field by 1979.

plum for the contractors. For Ptarmigan, Plessey Co. Ltd. is the major contractor. Subcontractors are Standard Telephones and Cables Ltd. for super-high-frequency radio-relay equipment, Marconi Space and Defence Systems Ltd. for ultrahigh-frequency radio-relay and cryptographic gear; British Insulated Callender's Cables Ltd. for cables, and Airtech Ltd., for vehicle fittings. Comparable rewards will be shared by RITA suppliers Thomson-CSF, for transmission equipment, CIT-Alcatel for radio integration, Le Matériel Téléphonique for switching equipment, and CIT for computers. What's more, both countries are lining up prospective export business.

RITA basically consists of mobile central exchanges interconnected by radio links to form a meshed network with high operational flexibility. The meshed structure covers the army corps zone and follows the tactical situation quite independently of unit or subscriber positions. Headquarters are also connected to the network by radio links, while isolated subscribers are connected via single-channel radio-access points located near nodal exchanges. The result, explains Alfred Pirotte, head of the Laboratoire Central de Télécommunications section on the application of electronic switching to military equipment, "is quasi-complete coverage of the army corps zone."

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tions by transmitting pulse-code-modulated data over the multiplex highways that connect the exchanges with line concentrators and each other. The saturation-routing technique allows a quick search for a called subscriber in an unknown location and enables communications to be established in the event of partial destruction by automatic bypassing of faulty equipment. A radio-integration device provides the same services to all subscribers whether concentrated or isolated.

Ptarmigan, though more sophisticated, also bristles with all the best features of a modern telephone exchange. Its comprehensive direct-dialing facilities include pre-emption so that authorized subscribers can make priority calls at any time and conference calls can be prearranged if needed. Other capabilities include broadcast calls, automatic call transfer to an alternate number, a unique permanent directory number for each subscriber, compressed dialing codes, call-holding, and subscriber assistance.

Moreover, Ptarmigan's voice, telegraph, facsimile, and data traffic are all cryptographically protected. There's fully automatic connection with automatic alternative routing to handle such events as movement by a subscriber, regrouping, and traffic overloads. Telegraph messages can be either cleared terminal to terminal, or automatically distributed by a computer-controlled store-and-forward system.

Problems. However, these national systems also present problems because differing levels of technology will be coming into operation at different times. For example, although RITA, a 24-channel, 48-kb/s system, offers better speech quality than Ptarmigan (32 channels, 16 kb/s), its radio-relay links require twice the bandwidth and need twice as much precious spectrum. "If every country on the battlefield bought RITA, you'd be in dead trouble," snaps one military expert. Also, Ptarmigan employs delta modulation, considered by some experts in Europe to be better than RITA's PCM approach.

Perhaps a more serious question is, can the different systems talk with each other? The West German Autokonetz system cannot operate with RITA, Ptarmigan, or the British Bruin system now in West Germany, reports an expert. Until Audinetz comes on line, the West Germans won't have a European standard system. And the French won't be able to hook up their mobile subscribers with single-channel radio access points until 1980, nor with the West German tactical system until much later.

Col. T.M. de Bie, chairman of Eurocomm, a NATO committee in the Hague that designs common interface equipment, concedes that there are problems in hooking up fast PCM, slower delta modulation, and present analog systems. Nevertheless, an arsenal of NATO-standard interface boxes is being developed—in the French and British RITA and Ptarmigan systems, for example—although experts agree that there will be some loss of efficiency in actual operation.

Interfacing. The concept of an interface box may be as near to common as the systems will get. One NATO staff member says, "While you can argue that a single common communications system can represent cost savings for all partners, it would increase costs for some governments who feel they need a system with limited capabilities." And there's always national pride and lucrative contracts for industry at stake.

Overall, "the real problem has nothing to do with electronics," comments one industry source. "It's a problem of language: the Germans speak German, and the English speak English." He foresees that hurdle shrinking with increased digital communications, but in the meantime, the interface may well be human: the German operator may simply be forced to sit in the British communications van to link the two systems. □

By William F. Arnold, London bureau manager; James Smith, McGraw-Hill World News, Brussels; and Joel Stratte-McClure, McGraw-Hill World News, Paris

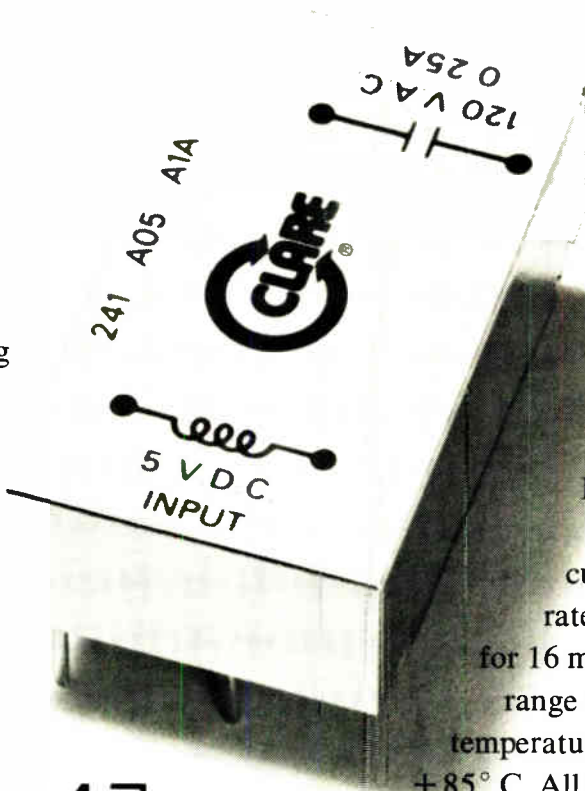
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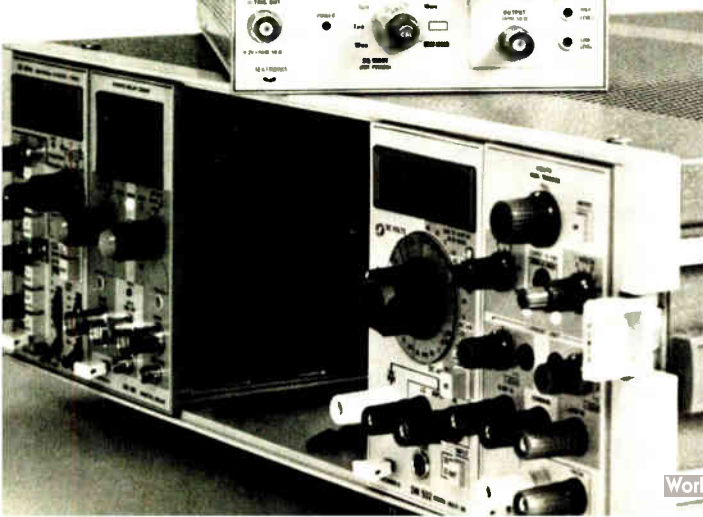
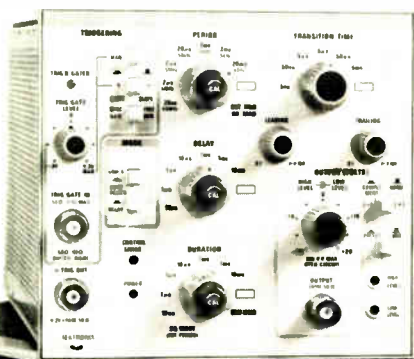
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Air-traffic control

JETS to speed planes in Canada

Sanders handling displays for Joint En route Terminal System, a \$16.8 million setup including 154 displays and 210 minicomputers

by Lawrence Curran, Boston bureau manager

The Canadian government will begin acceptance tests in December of a new air-traffic-control system that will replace older plan-position indicators and scan-converter monitors. The minicomputer-based distributed-processing network, called JETS, for Joint En route Terminal System, will be installed at eight sites to control both en route and terminal air traffic.

The system is being built for Transport Canada in Ottawa, formerly the Canadian Ministry of Transport, by CAE Industries in Montreal. Sanders Associates Inc., Nashua, N.H., the subcontractor for the display subsystem, also assisted CAE with the overall system definition and designed the computer interface for the display subsystem. The first 14 preproduction displays are now undergoing performance-evaluation tests at CAE.

Sanders and CAE share in the \$16.8 million contract for JETS, which includes 154 display subsystems for various radar data, and 210 minicomputers. Under terms of the contract, which calls for 60% Canadian-dollar content, Sanders has licensed CAE to build all elements of the display subsystem except the cathode-ray-tube module itself, which is a direct-coupled XYZ oscilloscope-type monitor. "It's a precision instrument, not a TV-quality monitor," says Everett Kirtledge, JETS program manager at Sanders.

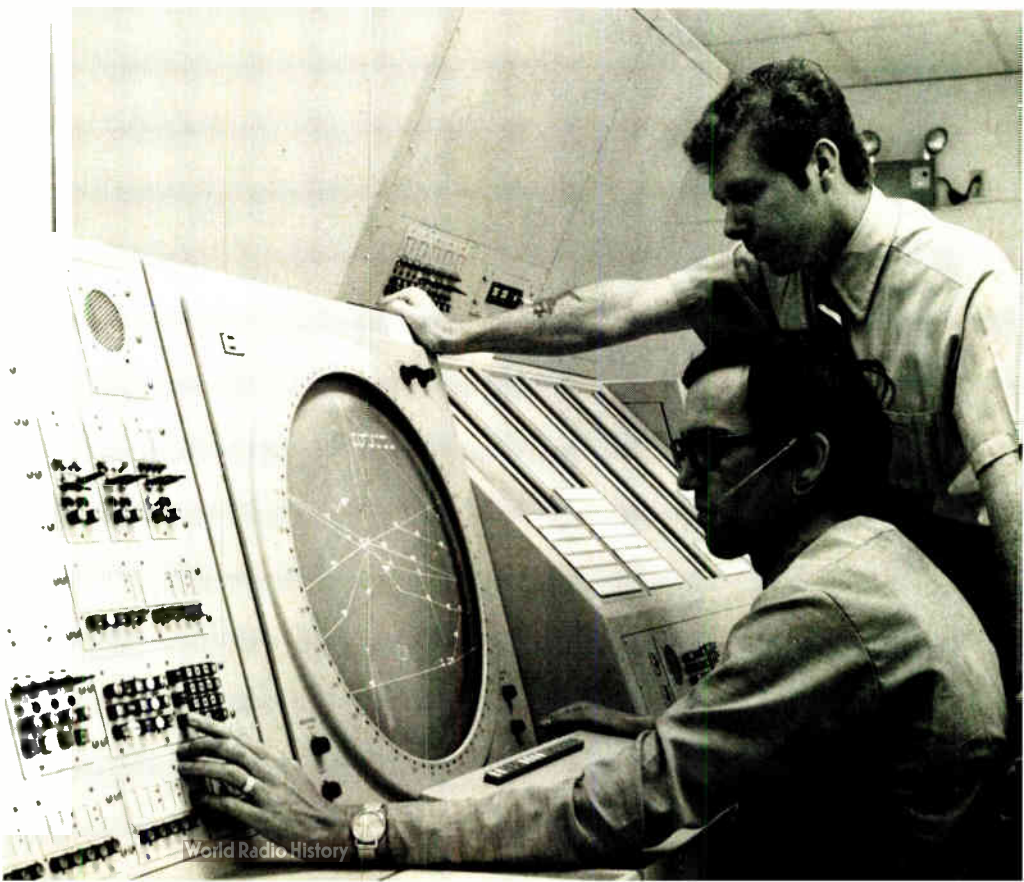
The Canadian JETS system embodies later technology than the

U.S. Federal Aviation Administration's National Airspace System for en route traffic control and the ARTS-3 terminal-control system. JETS can handle both en route and terminal-control functions—the Montreal and Toronto systems will do both—with the aid of dual-redundant Interdata Inc. Model 70 minicomputers. The Interdata minis are 16-bit machines, whereas the National Airspace System uses a more complex central-processor-based system that has a 64-bit word. In JETS, minicomputers function both as central and display processors.

But it's the sophistication and flexibility of the alphanumeric display subsystem that will aid Canadian air-traffic controllers. They'll

be able to see a wide variety of radar-derived data about the planes under their control, including the airline, flight number, altitude, ground speed, present position, and a dotted trail showing flight direction, as well as vector-velocity information that predicts where the plane will be after an interval. The scope, which can also display blinking emergency or other special conditions provides for weather symbols to be displayed, plus conventional plan-position-indicator symbology.

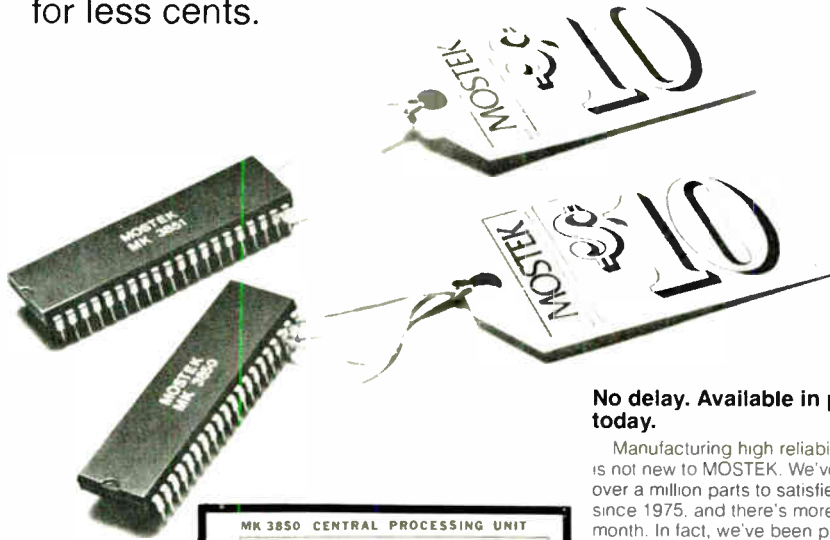
Sanders engineers have drawn on earlier experience with the National Aeronautics and Space Administration and knowledge of the FAA's systems to come up with what they believe is a simple and versatile



Picture this. Canadian air-traffic controllers check data on Sanders display during their test of minicomputer-controlled Joint En route Terminal System.

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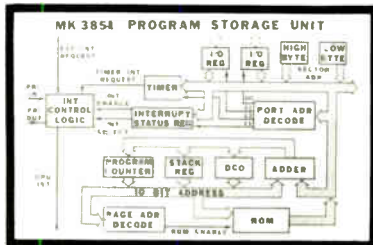
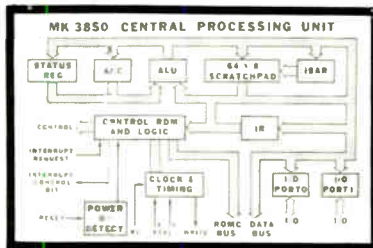
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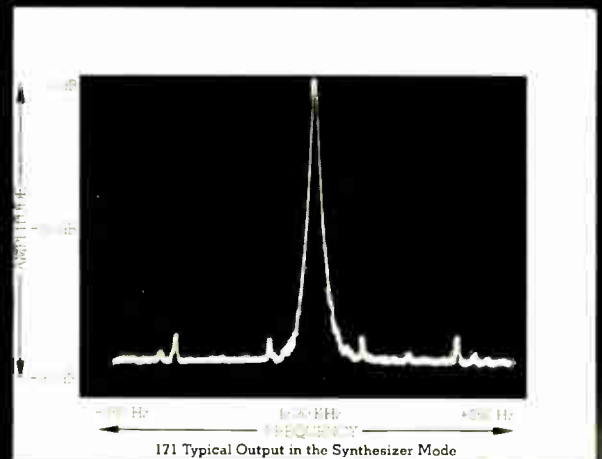
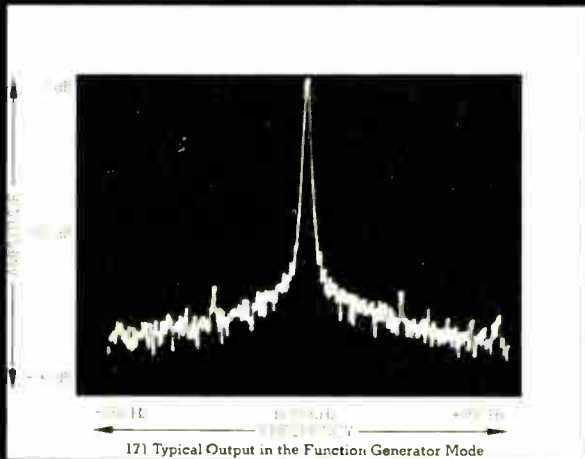
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Optical coupling extends isolation-amplifier utility

Faster response and larger bandwidth overcome disadvantages of transformer-coupled amplifiers

by Bill Olschewski, *Burr Brown Research Corp., Tucson, Ariz.*

□ Sooner or later, almost every analog designer will have to solve an isolation problem. It may arise when a signal to be amplified is superimposed on a high potential, a signal must be transmitted between systems having separate grounds, or a signal path must be completely isolated from a source.

Until recently, the only analog components commercially available to solve such problems were transformer-coupled isolation amplifiers. They work fine for most isolation tasks, but they are usually bulky, costly and have limited bandwidth, as well as slow response. Now, however, optically coupled isolation amplifiers not only eliminate these disadvantages, but also can be used in a number of applications that were previously closed to isolation amplifiers.

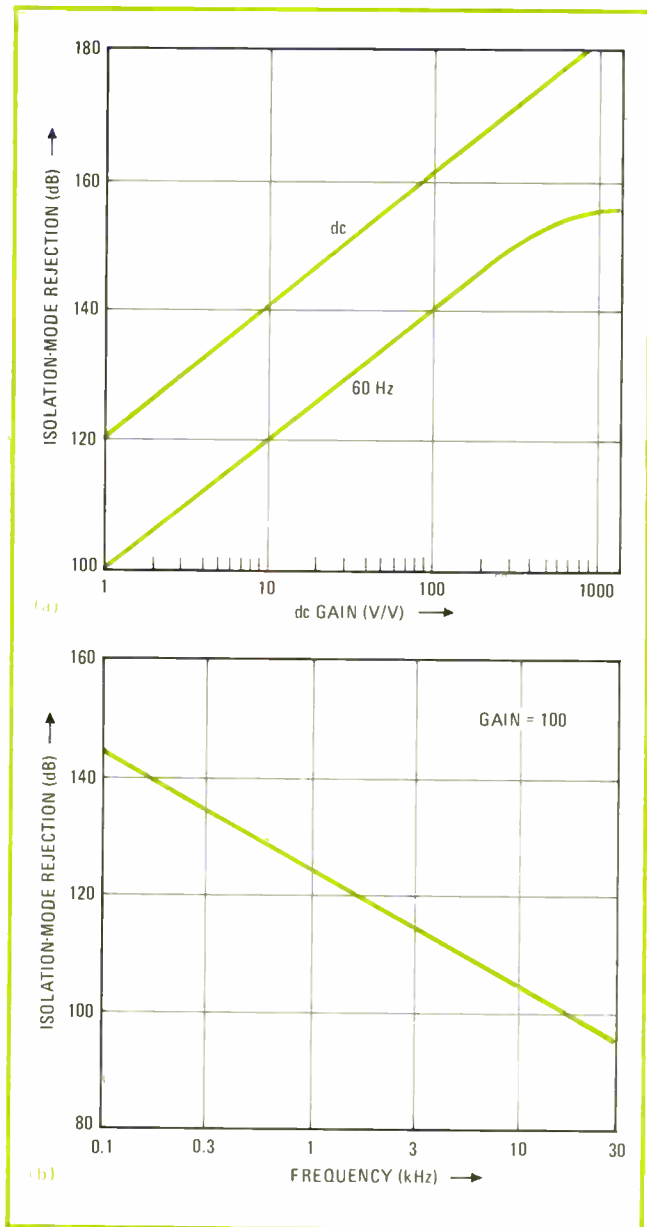
Because of the small size and light weight of these hybrid thick-film optically coupled devices, they are the first isolation amplifiers to be suitable for electronic gear in aircraft. And because their optical isolation barrier can be closely controlled, they are also useful for medical electronics, as well as for monitoring and fail-safe equipment in nuclear-power generation, where isolation must be maintained under all possible conditions.

Although not as linear as some transformer-coupled units, these new optically isolated amplifiers provide an operating bandwidth that is 10 times broader and a response time that is five to 10 times faster. High operating frequency is especially important in such biomedical applications as electromyography, which is a method of monitoring the body's nervous system. Additionally, since optical isolation amplifiers do not generate any electromagnetic interference at all, they do not require shielding, as transformer-coupled units do.

Transformer-isolated amplifiers are comparatively large modular units whose volume may even reach 10 cubic inches. In contrast, optical isolation amplifiers are supplied in integrated-circuit-compatible dual in-line packages that measure less than 0.5 in.³ Price differences are significant, too. Optical units cost half as much as transformer units and often less.

One version of the optical amplifier even has a field-effect-transistor input buffer, together with built-in over-voltage-protection resistors. This model is particularly suited to patient-monitoring applications in biomedical instrumentation when high impedances are involved.

As a matter of fact, all the optical amplifiers surpass



1. Typical characteristics. Isolation-mode rejection, an important property for an isolation amplifier, indicates the change in output voltage as a function of the voltage across the isolation barrier. This specification increases with gain (a), decreases with frequency (b).

Which amplifier is which?

With today's proliferation of specialized dc amplifiers, the differences between the three fundamental types—operational, instrumentation, and isolation—can easily become a bit muddled. In fact, though, the differences are easy to spot, and the type selected depends on what must be done.

As a rule, the op amp is a general-purpose device that can be used in a variety of ways, as an integrator, an oscillator, a level detector, or a straightforward amplifier. For stable operation, the feedback loop between the device's output and its inverting input is usually closed externally.

In transducer-sensing applications, the signal to be amplified—typically a differential voltage of a few millivolts between two wires—is generally superimposed on a higher common-mode voltage of up to several volts from both wires to the ground, guard, or shield connection. To amplify the desired signal and reject unwanted common-mode signals—like hum, interference, spikes, or attenuated bridge-supply voltages—the amplifier must have high common-mode rejection, as well as a true balanced or floating input.

Although the op amp can be used in a differential fashion, the input-resistor matching it requires in this mode of operation reduces its common-mode rejection and lowers its input impedance. In fact, even if the op amp has a field-effect-transistor input and the input resistors used are matched within 0.1%, common-mode rejection is only around 60 decibels, and common-mode input impedance is just a few megohms.

On the other hand, in a differential sensing configuration, the instrumentation amplifier or the isolation amplifier can provide considerably higher—by several orders of magni-

tude—common-mode rejection and common-mode input impedance than the op amp.

The instrumentation amplifier achieves its superior dc-sensing performance by means of an internal voltage-feedback loop, as opposed to the external current-feedback loop of the op amp. Although the instrumentation amplifier is committed to a voltage-in/voltage-out transfer function, its gain can be varied, and it offers ultra-stable closed-loop performance. Common-mode input impedance is typically greater than 100 megohms, and common-mode rejection is about 90 db. However, this device's common-mode voltage capability is usually limited to a voltage somewhat lower than that of the power supply.

Like the instrumentation amplifier, the isolation amplifier has an internal voltage-feedback loop, but its input stage is electrically isolated; that is, the input is completely floating because it is separated from the output by a large dielectric impedance. This input-to-output separation enables the isolation amplifier to withstand, as well as operate with, extremely high common-mode voltages.

For three-wire input connections, the common-mode-input characteristics of the isolation amplifier are the same order of magnitude as those of the instrumentation amplifier. Additionally, though, the isolation amplifier provides an impedance of several gigohms between input and output. And rejection of common-mode signals applied between input and output is generally around 120 db, but can even be as high as 160 db. Typically, isolation-mode test voltages range from 2,000 to 8,000 v, making the isolation amplifier suitable for continuous operation at common-mode voltages, between input and output, of 500 to 3,500 v.

the standard established by Underwriters Laboratories for this type of component, holding leakage-current levels 20 times below permissible limits. Additionally, they are the first isolation amplifiers to provide completely balanced inputs, so that residual hum, which is often encountered in patient-monitoring applications, is negligible.

Analyzing isolation amplifiers

Isolation amplifiers are best suited for sensing and conditioning dc analog signals and ac signals in the low-frequency range. In addition to isolation, these devices can provide linear amplification and high input impedance to avoid loading the signal source. In effect, an isolation amplifier takes the capability of an instrumentation amplifier, which has a very high common-mode input impedance, one step further—to provide a completely floating input that is insulated from the output by a high withstanding voltage.

To achieve this floating input, an isolation amplifier must have a built-in isolation barrier. The component most often used to create the barrier is a transformer. Its excellent linearity and low noise are ideal for signal isolation, and various modulation techniques can be utilized for isolating dc signals.

Instead of a transformer, an optically coupled isolator, consisting of a gallium-arsenide light-emitting diode

paired with a silicon photodetector, can be used as the barrier element. With this device, however, special feedback techniques are needed to compensate for the inherently nonlinear output of a GaAs LED. Other possible isolation techniques include acoustical coupling, Hall-effect devices, and utilization of electric or electromagnetic fields.

An isolation amplifier's characteristics are much like those of an instrumentation amplifier (see "Which amplifier is which?" above) so that most specifications correspond one for one. As might be expected, an isolation amplifier requires additional characterization for its isolation properties between input and output. Depending on the manufacturer, these properties may be referred to as isolation-barrier characteristics, input-to-output common-mode characteristics, or common-mode II characteristics.

Considering key specifications

There are three principal isolation-related characteristics— isolation impedance, isolation-mode rejection, and isolation voltage. Isolation impedance is usually specified as the resistance and capacitance across the isolation barrier. But sometimes the leakage current at a specific voltage and frequency is given instead.

Isolation-mode rejection reflects the change in the output voltage as a function of the voltage applied across

COMPARISON OF ISOLATION AMPLIFIERS

Characteristic	Transformer coupling		Optical coupling
	Amplitude modulation	Pulse-width modulation	Light-intensity modulation
Nonlinearity, max (%)	0.03 – 0.25	0.005* – 0.025*	0.1* – 0.2*
Isolation voltage, test (kV)	up to 7.5	up to 5	up to 5
Isolation-mode rejection, @ 60 Hz & unity gain (dB)	up to 120	up to 120	100
Frequency response (kHz)	2.5	2.5	10 – 30
Emi generated	low, if shielded	low, if shielded	none
High-frequency susceptibility	high	low	very low
Size (in. ³)	5 – 10	6	less than 0.5
Price in lots of 100	from \$49	from \$90	from \$26**

*Measured at full output-voltage swing **Without input power supply

the isolation barrier. Usually expressed in volts per volt or decibels, it may be specified at unity gain or at some higher gain. Typically, isolation-mode rejection increases with rising gain (Fig. 1a), but decreases as frequency becomes higher (Fig. 1b).

As the term implies, isolation voltage is the maximum voltage that may be present between input and output without causing internal breakdown or excessive leakage. In general, a test voltage and a continuous operating voltage, which should be derived by the manufacturer with derating factors, are specified.

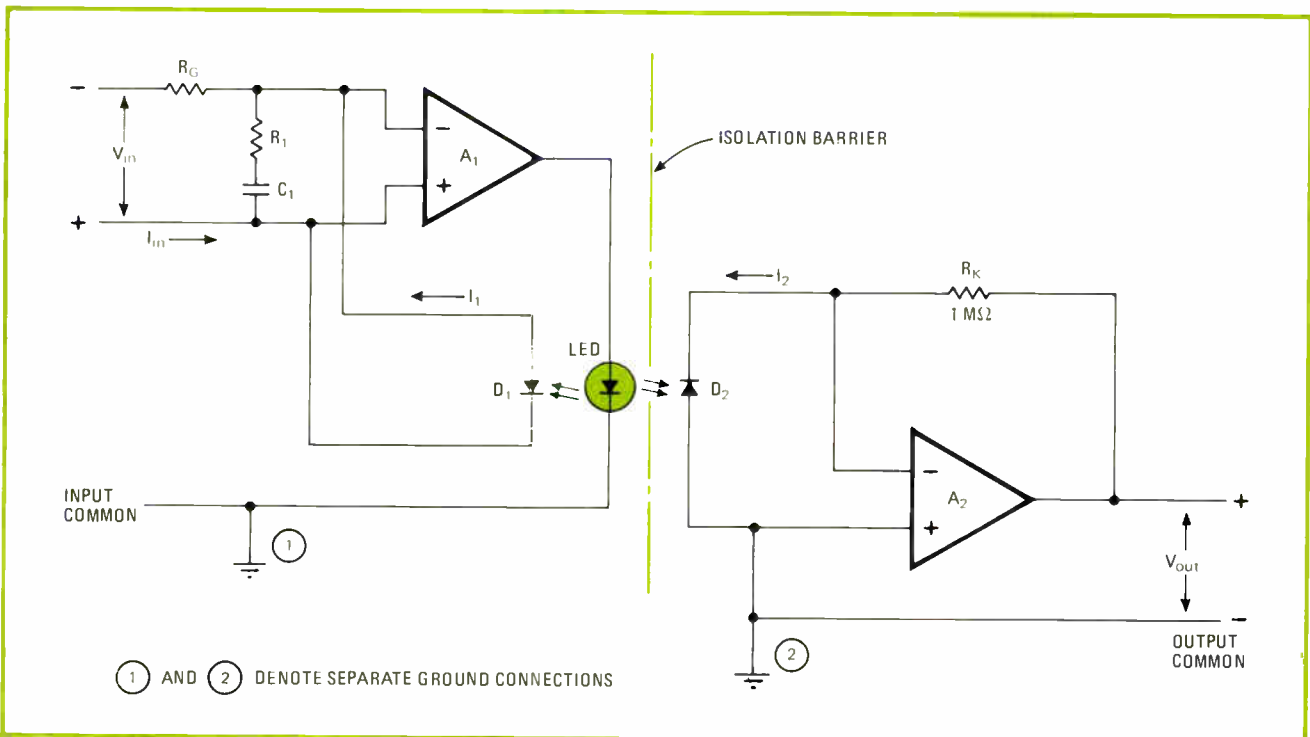
Most isolation amplifiers have a three-wire input, like an instrumentation or operational amplifier, giving rise to common-mode characteristics, in addition to their isolation-mode characteristics. Common-mode param-

eters, however, should not be confused with isolation-mode parameters. The former are measured between both inputs and the third input connection, which is usually referred to as a common or guard connection.

Examining modulation schemes

Besides the two different types of isolation—transformer or optical—there are three different possible modulation methods: amplitude modulation or pulse-width modulation for transformer-coupled amplifiers, and light-intensity modulation for optically coupled amplifiers. In each, the isolation amplifier internally generates the carrier that is modulated with the input signal.

Amplitude modulation, the oldest technique, usually



2. Optical but linear. In optical isolation amplifier, photodiodes in differential configuration correct for inherent nonlinearities and instabilities of optical semiconductors. Since the matched photodiodes detect the same LED output, they produce equal currents.

involves a double-sideband suppressed carrier having a frequency of around 100 kilohertz. As in the a-m radio, the amplitude of the modulated signal is easily affected by electromagnetic interference, so that this technique has a high degree of emi susceptibility. For demodulation, the carrier and the modulated signal are switched on and off in synchronism, and then the residual carrier is filtered out. This is the same technique commonly employed in chopper-stabilized op amps.

With pulse-width modulation, the carrier is a fixed-frequency square wave having a duty cycle of 50% when no input modulating signal is present. Since only the duty cycle is varied with the modulating signal, all information is contained in the transition time, and the amplitude of the modulated signal can be clipped without affecting accuracy. Pulse-width modulation, therefore, is considerably less susceptible to emi than amplitude modulation. Demodulation is generally accomplished with a de-restore circuit (like a one-shot) or a balanced diode pair followed by a low-pass filter.

With light-intensity modulation, the input signal modulates the output of a light source whose quiescent light level is fixed. Demodulation is done automatically by the photodetector. Emi susceptibility is low because this technique does not produce cross-modulation products. Also, any emi can be removed by filtering the demodulated signal.

Comparing isolation amplifiers

The table compares the key characteristics among the three classes of amplifiers. Amplitude modulation provides good linearity—sometimes at almost half the cost of pulse-width modulation. On the other hand, pulse-width modulation results in better linearity, with errors down to as little as 0.005%. In many ways, optical modulation is superior to these other techniques, providing higher frequency response and generating no electromagnetic interference at all. Cost, too, is considerably lower, but linearity is moderate in comparison.

At present, there is little compatibility between the products of various manufacturers, except that they all offer isolation. Most include an isolated power supply, but the supply voltage itself can range from the usual ± 15 v dc required for conventional operational amplifiers to a single +28 v dc connection to an ac-line hookup of 115 v ac.

Additionally, input impedance can be either low or high, and a few models have a current, rather than voltage, output. Input connections also vary—from two-wire inverting or noninverting affairs to three-wire hookups that may be two differential inputs plus a common or high- and low-potential inputs plus a guard connection. What's more, since not all manufacturers specify nonlinearity at the full output-voltage swing, this specification can appear to be deceptively better than it actually is.

All of this variation is keeping many potential users at arm's length from isolation amplifiers because finding a second-source supplier, a critical requirement in numerous applications, is extremely difficult, if not impossible. The isolation amplifier that delivers the best cost-performance combination will ultimately gain the widest

market acceptance. The optically isolated amplifier may well represent the first step toward realizing a cost-effective, yet versatile, industry standard.

Optical couplers have a number of inherent stability problems. The luminance of LEDs and the quantum efficiency of photodiodes vary with temperature. LED luminance is also degraded appreciably over a long period of time. What's more, the transfer function of LED input current versus light output is nonlinear, and the LED light output is noisy.

Linearizing the optics

To overcome these instabilities and nonlinearities, a differential photodiode arrangement can correct for errors much like the differential input transistor pair of a dc operational amplifier. Figure 2 shows a simplified schematic of a linear, stable, optical amplifier circuit.

Amplifier A_1 drives the LED; diodes D_1 and D_2 form the differential photodiode pair. Diode D_1 closes the feedback loop around A_1 , so that A_1 drives the LED until:

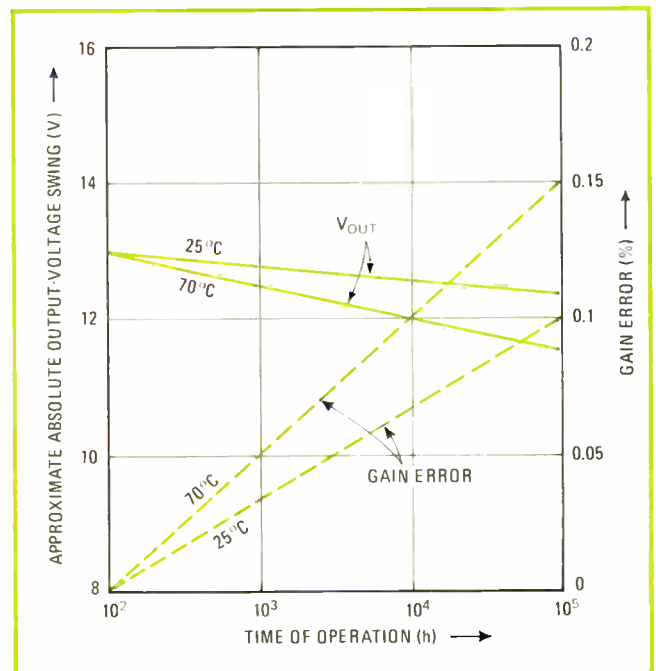
$$I_1 = I_{in}$$

where I_1 is the current generated by diode D_1 . The output amplifier, A_2 , performs as a current-to-voltage converter; it is driven by diode D_2 . Since the photodiodes are matched and are detecting the light output of the same LED:

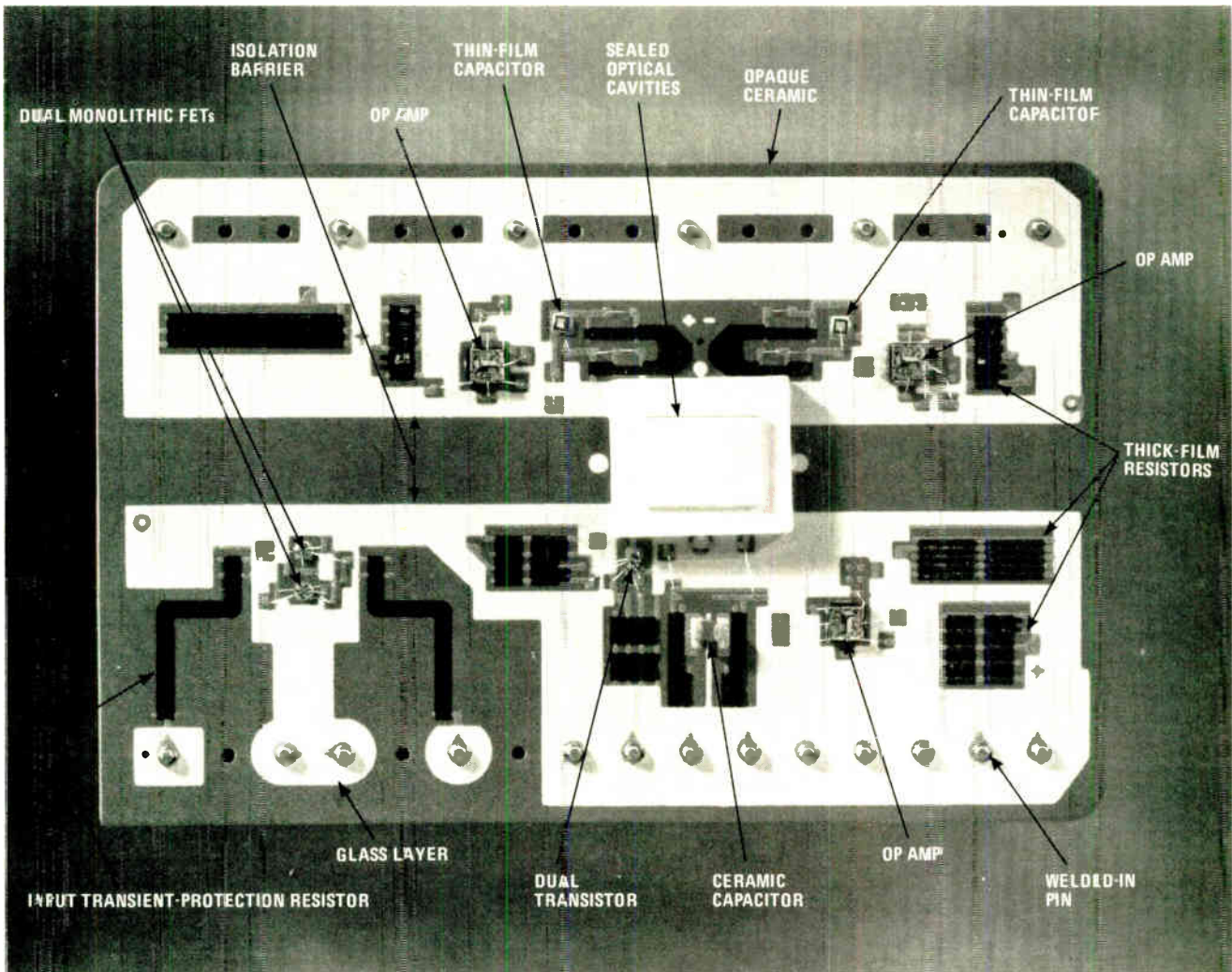
$$I_2 = I_1$$

where I_2 is the current generated by diode D_2 . The transfer function of the current-to-voltage converter can be written as:

$$V_{out} = I_2 R_k = I_{in} R_k$$



3. Optical but stable. Gain error of optical isolation amplifier is only about 0.1% after 100,000 hours of operation at 25 C. Similarly, under the same conditions, output-voltage swing drops by 0.5 V.



4. Under the lid. Opaque ceramic header serves as substrate for hybrid isolation amplifier. The circuit consists of nine chips, excluding the optical semiconductors, which are encapsulated and sealed in their own housing. The resistors and interconnect pattern are made of thick films. This version of the amplifier includes a differential FET-buffer input and overvoltage-protection resistors.

where R_k is the integral feedback resistance for amplifier A_2 . The overall transfer function for the entire circuit becomes:

$$V_{out} = I_{in}R_k = (V_{in}/R_G)R_k,$$

which is linear and independent of the LED parameters. Resistor R_G is the user-selected gain-setting resistance.

For this circuit, the direction of the unipolar photodiode light current limits amplification to positive signals only. To provide bidirectional signal capability, a second set (not shown here) of LED and differential photodiodes must be employed. Alternate biasing techniques could be used instead, but employing a duplicate set of optical components is more cost-effective in a thick-film hybrid circuit. Resistor R_1 and capacitor C_1 simply phase-compensate the closed-loop input circuit, generating a rolloff of 6 dB per octave.

The long-term stability of such a design is more than adequate. In Fig. 3, output voltage and gain error are plotted against time for the optical isolation amplifier. After 100,000 hours of operation at 25°C, gain error is around 0.1%, and output voltage drops by about 0.5 v from its 100-hour value. At 70°C operation, gain error

increases to 0.15%, while output voltage decreases by approximately 1.5 v.

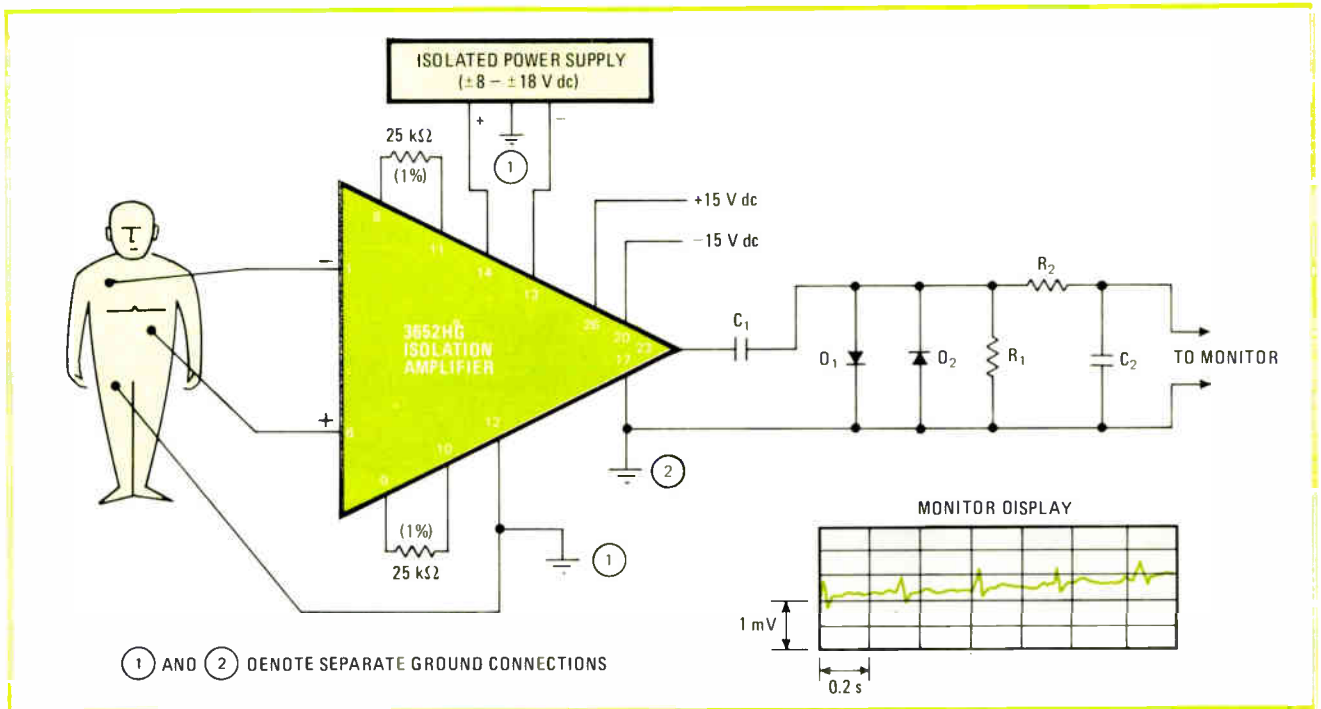
The voltage gain of the optical isolation amplifier is determined by the input resistors selected. But if high gain is desired, the input impedance drops to a low value, for example, 10 kilohms for a gain of 100.

To overcome this limitation for applications involving high source resistances, one version of the optical isolation amplifier has a differential FET buffer at its input. This model also has integral high-voltage transient-protection resistors for safe operation in the presence of overvoltages as large as 6 kilovolts.

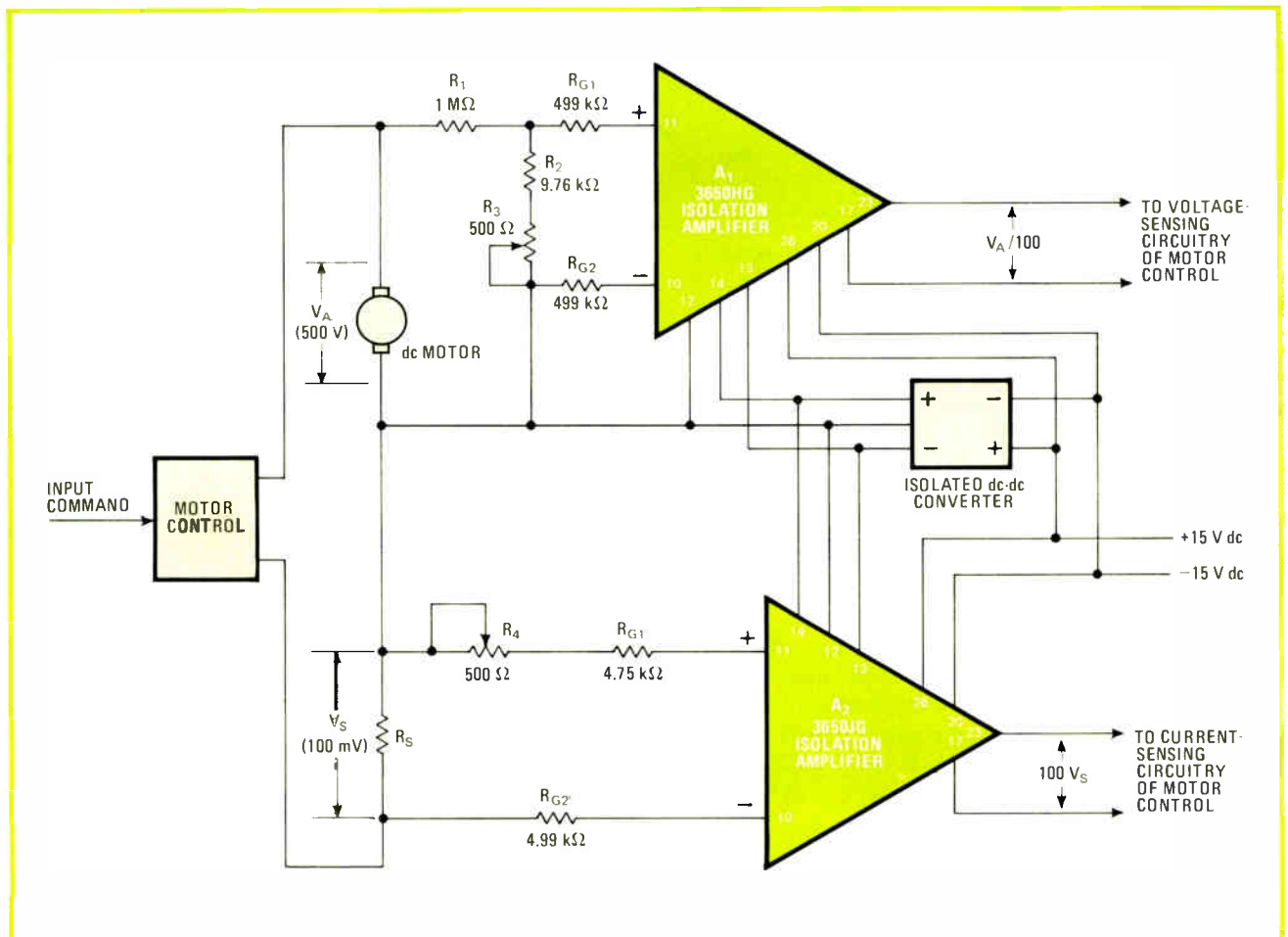
How the hybrid is made

To obtain high isolation breakdown voltage and to space input and output pins as far apart as possible, the amplifier is housed in a DIP that is three times wider than a standard IC DIP. The package is ceramic, with an opaque header that also serves as the circuit substrate and has welded-in pins.

The fully assembled substrate (Fig. 4) contains the optoelectronic circuit, as well as all active and passive chips, plus the interconnect pattern. Not visible here, the



5. Biomedical. Because of its high frequency response, the optically coupled isolation amplifier is suitable for a variety of biomedical applications. Here, it's used to isolate the patient from the possibly lethal potentials of electrocardiographic instrumentation.



6. Motor control. Pair of optical isolation amplifiers put a voltage barrier between driving circuitry for the motor and the circuits for voltage and current sensing. A single dc-dc converter is used to supply isolated power for both of the amplifiers.

photodiodes are made from silicon, and the LEDs from gallium arsenide. All resistors are screened on with a thick-film cermet material, and the interconnect pattern is printed with a thick-film gold paste. Extra insulation is provided by a layer of printed thick-film glass. Interconnections between the chips and the conductor patterns are made with thermocompression-bonded gold wire.

The isolation barrier is 200 mils wide, narrowing to a 15-mil gap between the LEDs and the photodiodes. This gap is encapsulated in a transparent resin having a high dielectric withstanding voltage, thereby providing a light-transmission medium that has good insulation properties. The resin is contained inside a cavity that is bonded onto the substrate. The cavity also serves as a reflector to distribute the infrared light emitted by the LEDs onto the photodiodes.

After the substrate is complete, the thick-film resistors are laser-trimmed to bring the amplifier's gain and offset voltage within data-sheet limits. Prior to capping with a ceramic lid, the substrate is put through temperature cycling and a stabilization bake.

The device does not have a built-in isolated power supply like most other commercially available isolation amplifiers. This may be less convenient in some applications, but gives the user more flexibility in multiple-channel systems or in systems where isolated power is already available elsewhere.

A companion isolated power-supply module is available for those users who need isolated power. This module can drive from three to 10 amplifiers, depending on the amplifier model and the required output-voltage swing.

Helping medical electronics

Optical isolation amplifiers are particularly suited to biomedical applications because of their clearly defined isolation gap and their extremely low coupling capacitance. Moreover, such monitoring functions as electromyography require a fairly wide frequency response—too wide for most transformer-coupled isolation amplifiers.

In electrocardiography (ECG), for example, the electrical activity of the heart is analyzed by measuring potentials at various surface points of the body. Electrodes are applied to certain body points, and the measured potentials are displayed in real time, usually on a cathode-ray-tube monitor. The signal levels thus generated by the heart range from 300 microvolts to 2 millivolts, superimposed on a galvanic potential of up to 500 mv.

When used as an ECG amplifier (Fig. 5), the optical isolation amplifier is dc coupled, with its gain limited to 20 to prevent it from being saturated by the galvanic potential. The dc-coupled input also provides the fastest possible recovery from input overvoltages of up to several kilovolts, such as those caused by the application of a defibrillator pulse to stimulate the patient's heart.

The galvanic-potential dc component is decoupled at the output of the amplifier by resistor R_1 and capacitor C_1 , which form a high-pass filter having a cutoff frequency of 0.05 hertz. Diodes D_1 and D_2 speed up the discharge of capacitor C_1 after the amplifier has been

saturated by a defibrillator pulse. (This particular circuit has a settling time of less than 0.1 second.) Resistor R_2 and capacitor C_2 serve as a low-pass noise filter. The amplifier's frequency response of better than 15 kilohertz far exceeds the required ECG range of 80 Hz.

Vectorcardiography is a variation of ECG. With this technique, electrodes pick up the heart's signal along three axes, and two of the three axes are displayed as vectors on a CRT monitor. The resulting display is similar to a Lissajous pattern. Such a system requires three isolation-amplifier circuits (identical to the one in Fig. 5) that can utilize a common isolated power source.

Electromyography, a different method of monitoring electrical body impulses, also requires an isolation amplifier for patient safety. In this procedure, the electrodes detect electrically stimulated or normal nerve pulses.

Yet another biomedical application for an optical isolation amplifier is electroencephalography, which involves the measurement of brain waves on the surface of the head. An isolation-amplifier circuit for these waves must have low noise. The circuit of Fig. 5 would have to be modified for higher gain, say, around 1,000.

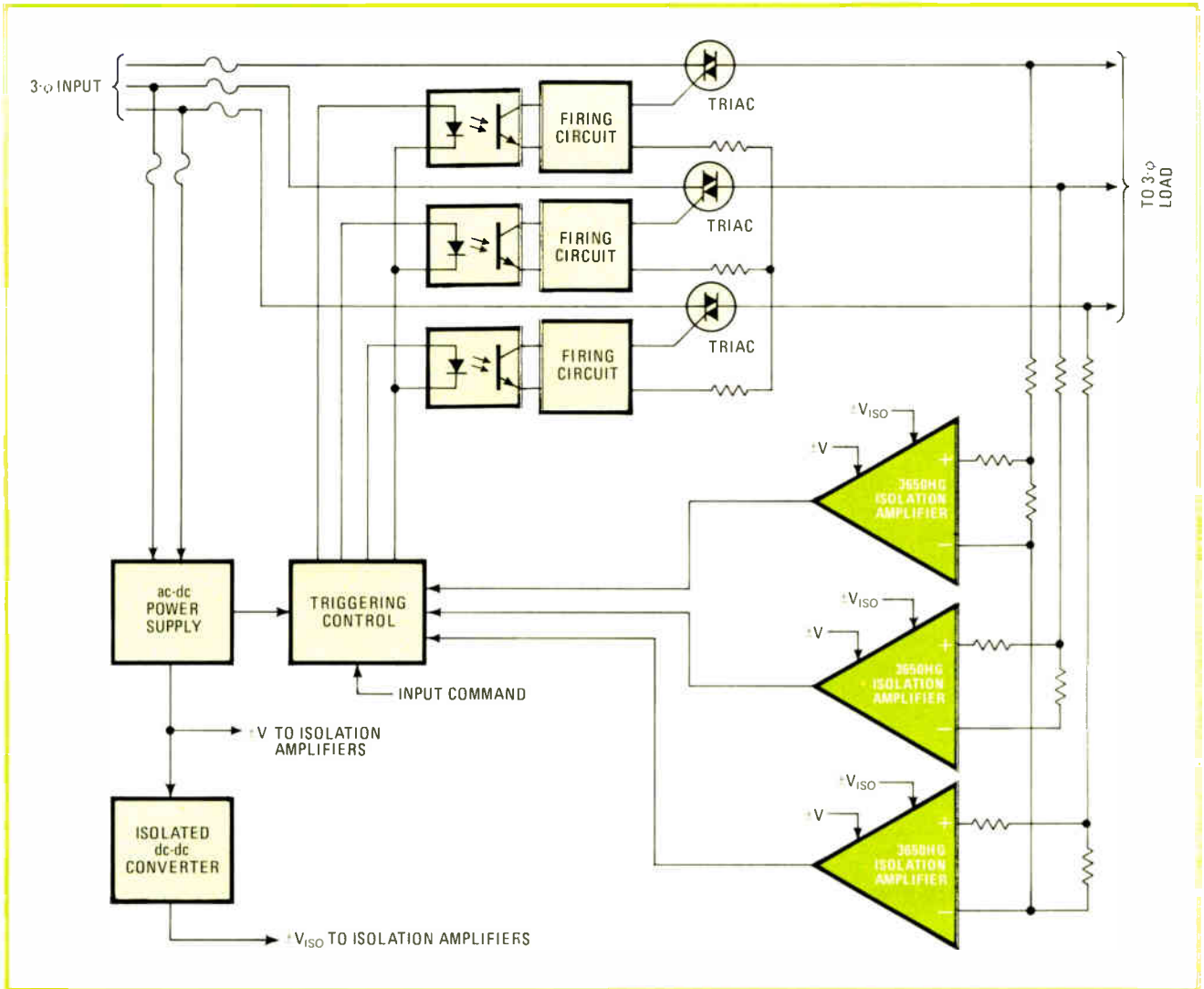
Controlling industrial motors

Because of their low phase shift, optical isolation amplifiers are also suitable for motor-control applications. In the circuit of Fig. 6, two devices are isolating the drive circuitry from the sensing circuitry for a dc motor requiring an armature voltage of 500 v. This sort of circuit is frequently needed in industrial situations because ground connections are usually dictated by safety considerations, rather than the convenience of the design for the motor-control circuit.

Amplifier A_1 delivers an isolated output that is 1% of the armature voltage ($V_A/100$) to the voltage-sensing portion of the motor-control circuitry. Gain-setting resistors R_{G1} and R_{G2} fix A_1 's gain at unity, while resistors R_1 , R_2 , and R_3 simply serve as a voltage divider, and R_3 permits fine adjustment of the gain. Amplifier A_2 develops an isolated output for the current-sensing portion of the control circuit by amplifying the voltage (V_S) across shunt resistor R_S , which parallels the amplifier's differential input. The gain of A_2 is set at approximately 100 by resistors $R_{G1'}$ and $R_{G2'}$, with resistor R_4 to provide fine gain adjustment. A single dc-dc converter is used to generate the isolated power-supply voltage for both amplifiers.

Controlling single- or three-phase ac loads is still another application for optical isolation amplifiers. Their broad frequency response makes them good candidates even for 400-Hz systems in which transformer-isolated devices would be too slow. In ac applications, isolation becomes necessary when the potentials between input and output are not well controlled because of lengthy wire runs and safety requirements for grounding.

In the bidirectional (triac) control circuit of Fig. 7, three optical isolation amplifiers operate from the same isolated power supply. Each isolation amplifier senses the output voltage of one phase of the line. The phases are sensed against an artificial neutral generated by the output-resistor bridge. Because of the fast frequency



7. Load control. In circuit for switching three-phase ac loads, three optical isolation amplifiers operate from the same isolated dc source. The triacs provide bidirectional control of the load, while the optical couplers guard against false triggering by transients.

response of the amplifiers, the phase-controlled ac waveform is accurately reproduced at the input of the triggering control, permitting further processing, such as averaging or root-mean-square conversion, if desired.

Observing fundamental precautions

To get the most out of any isolation amplifier, some basic guidelines should be followed:

- For low-noise applications, twisted-pair shielded input cable should be used.
- To reduce the effects of output-stage parameters on overall accuracy, the amplifier gain should be set as high as possible without saturating the input. This is a customary practice with instrumentation amplifiers.
- External capacitance across the isolation barrier should be minimized, or it will degrade the amplifier's isolation-mode rejection.
- To reduce the possibility of arc-over, external components and conductors should be located at a distance equal to or greater than the spacing between input and output pins. And in very high-voltage applications, the entire assembled circuit should be conformally coated.

In the future, optical isolation will certainly be a major factor in linear isolation-amplifier designs. Although today's devices have a limited operating-temperature range (0°C to 70°C) and their linearity is comparatively moderate, there are likely to be vast improvements in both parameters shortly. What's more, product cost will probably drop as manufacturing technology improves.

Size reductions are also well within reach. However, user acceptance of smaller units having closer pin spacing is questionable, at least for amplifiers having isolation test voltages in the 5-kV region. Layout standards, as well as just good design practice, will probably continue to keep isolation amplifiers in somewhat larger packages than other amplifier products. □

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Z-80 chip set heralds third microprocessor generation

Fast execution of large instruction set, plus efficient handling of I/O and interrupts, boosts throughput

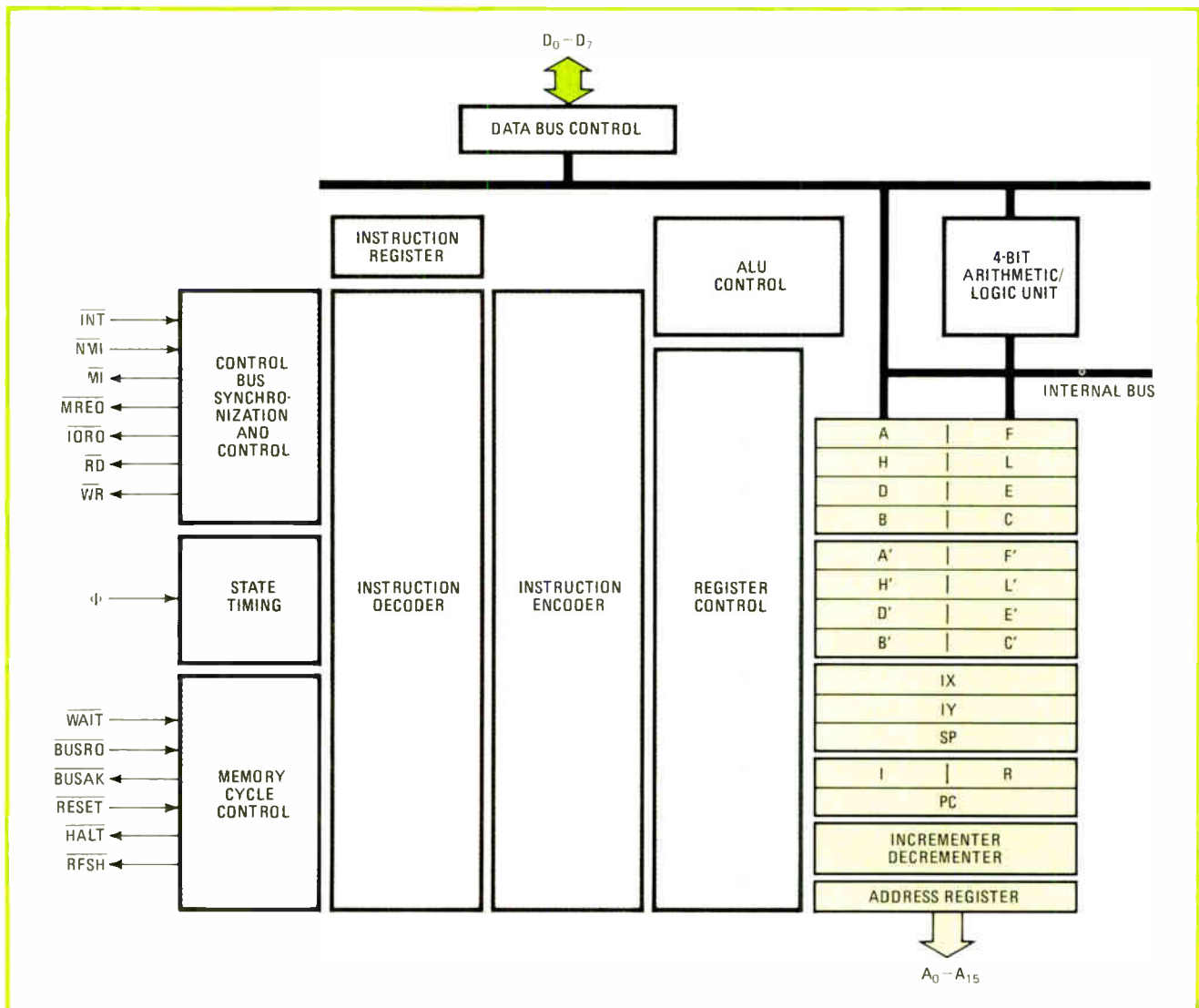
□ The Z-80 microcomputer chip set represents as big an advance as was made between the 8008 and 8080. Throughput of the Z-80 is two to five times that of its predecessors, yet it needs only half to a quarter of their program memory.

The set's central processing unit has 158 instructions, including all 78 of the 8080A, and executes each of these instructions in an average of 1.5 microseconds. It also streamlines the handling of input/output operations and interrupts.

Because of the large instruction set, programs for the Z-80 will be shorter, so that they will require less preparation time as well as less memory. More convenient yet, the device is software-compatible at the machine-code level with the widely used 8080A, so that 8080A users can not only understand and master the Z-80 quickly, but can design it into new systems with comparative ease.

The chip set is an integrated family of CPU and

by M. Shima, F. Faggin, and R. Ungermann, *Intel Inc., Los Altos, Calif.*



1. Central processor. The Z-80 CPU chip has a bank of 8- and 16-bit registers (right) that allow it great flexibility in such functions as handling interrupts. The device has an 8-bit data bus and a 16-bit address bus, and it employs a single-phase clock signal (ϕ).

Lines of control

The Z-80 has three types of control buses: system-control, CPU-control, and CPU-bus-control.

The system-control signals are:

M₁ (machine cycle 1)—the current machine cycle is the operation-code-fetch cycle of an instruction.

MREQ (memory request)—the address bus holds a valid address for a memory-read or a memory-write operation.

IORQ (input/output request)—the address-bus holds a valid I/O address for an input or output operation. An IORQ is generated during M₁ to indicate an interrupt acknowledge.

RD (memory read)—the CPU wants to read data from memory or an I/O device.

WR (memory write)—the data bus holds valid data to be stored in a memory address or I/O device.

RFSH (refresh)—the lower 7 bits of the address bus hold the refresh address for dynamic memories.

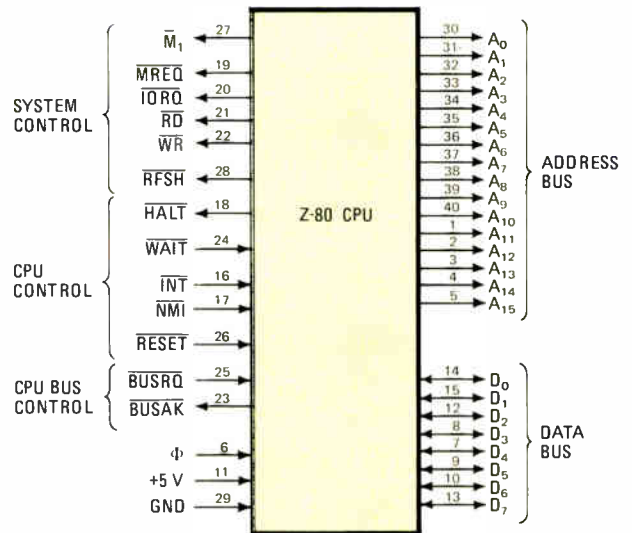
The CPU-control signals are:

WAIT (wait request)—the address memory or I/O device is not ready for a data transfer. The CPU will continue to enter wait states as long as this signal is active.

INT (interrupt request)—a signal generated by an I/O device. The request will be honored at the end of the current instruction if the internal software-controlled interrupt-enable flip-flop is activated.

NMI (nonmaskable interrupt request)—an interrupt with higher priority than INT. It forces the CPU to restart to memory location 0066H independent of the status of the interrupt-enable flip-flop.

RESET—this signal is used to initialize the CPU.



HALT (halt state)—the CPU has executed a HALT instruction.

The CPU-bus-control signals are:

BUSRQ (bus request)—used to request the CPU address and data buses, as well as MREQ, IORQ, RD, and WR, to go to a high-impedance state so that other devices can control them.

BUSAK (bus acknowledge)—the tristate buses are in their high-impedance state following a BUSRQ.

peripheral controllers that uses a single 5-volt supply and a single-phase, 5-v clock. The metal-oxide-semiconductor CPU chip, built with n-channel depletion-load silicon-gate technology, has about 8,500 transistors in an area of 179 by 192 mils, for a density of about 133 gates per square millimeter. In comparison, the AMD Am9080—the smallest of the 8080 types—has a density of 102 gates/mm². The circuits in the Z-80 use static logic, and thus a user may step through every clock cycle while debugging system designs.

The Z-80 CPU is packaged in a standard 40-pin dual in-line package. These pins, apart from those used for the power supply, ground, and clock (Φ), are organized into three buses. A 16-line address bus provides the address for memory (up to 65,536 bytes) and I/O data exchanges. A bidirectional 8-bit data bus serves for data exchange with memory and I/O devices. A control bus is subdivided into system-control, CPU-control and CPU-bus-control elements (see "Lines of control").

The importance of the registers

The heart of the CPU (Fig. 1) is its set of registers, which are built into a 208-bit on-chip static random-access memory, containing 13 words that are each 16 bits wide. The chip also contains the other blocks necessary to its operation—arithmetic/logic unit, instruction register, and logic for various control and timing functions. To understand the operation and the innovations in the Z-80, however, one must look closely at its array of registers.

There are two independent 8-bit accumulators (A and A') with associated 8-bit flag registers (F and F'). The accumulator holds the result of 8-bit arithmetic or logic operations, while the flag register indicates specific conditions for the result of operations on words of almost any size—1, 4, 8, or 16 bits. The programmer can work with either set of accumulators and flag register simply by invoking a single exchange instruction (EX AF, AF').

There are two sets of six general-purpose 8-bit registers (B, C, D, E, H, L and B', C', D', E', H', L'). Since the programmer can call either set into action with a single command (the instruction for the exchange-register set, EXX), there is rapid-context switching following interrupts. Instead of being forced to store the contents of all the registers in an external random-access memory, the programmer can simply deactivate one set without destroying its contents and switch to the other set to service the interrupt. The registers can operate as single 8-bit units or as 16-bit pairs, BC, DE, HL, and so on.

Each of the index registers, IX and IY, contains a 16-bit base address to point to a region of external RAM from which data is to be stored or retrieved. Each indexed instruction specifies an 8-bit signed-2's-complement displacement that is added to the base to calculate the effective address.

The stack pointer is a 16-bit register that contains the address of the top of the stack stored in external RAM. The external stack is a last-in, first-out file, allowing simple implementation of multiple-level interrupts.

There are two special-purpose registers, I and R, which

aid interrupt and memory-refresh operations, respectively.

The **I** register is used in one of the chip's three different programmable interrupt-response modes. It holds the upper 8 bits of the address of a memory pointer, while the interrupting peripheral controller supplies the lower 8 bits during the interrupt-acknowledge cycle. The CPU then makes an indirect call to the memory location pointed to by the 16-bit address. With this method, the interrupting device will cause the CPU to push the program counter into the stack and go to the beginning of the previously stored required service routine, which can be anywhere in memory.

The **R** register contains the current memory-refresh address. Its content is sent out to the address bus during the second half of each operational code-fetch cycle (M_1 cycle), together with the memory-refresh-control signal (**RFSH**). The content is automatically incremented at every M_1 cycle to refresh a new portion of memory. With this technique, the Z-80 CPU interfaces to dynamic memories with practically no hardware overhead.

Finally, there is a conventional 16-bit program counter, which holds the address of the instruction being fetched from external memory.

The extra instructions

The CPU can execute 158 instruction types with a total of 696 different operational codes. As mentioned, the CPU includes all 78 instructions of the 8080A CPU (a total of 244 op codes) and, since the compatibility is at the machine-code level, it can execute 8080A programs

stored in a read-only memory without needing changes in the ROM pattern.

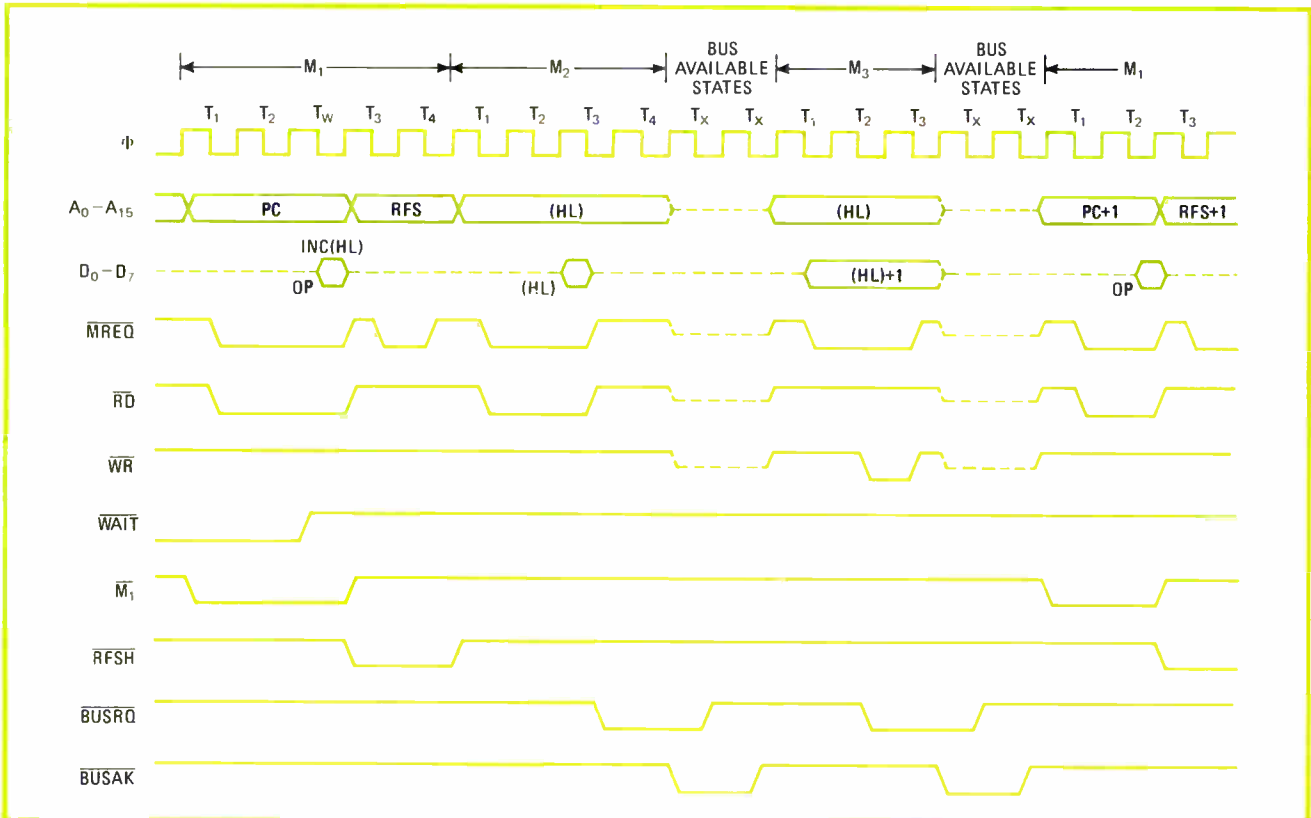
Among the new instructions are the block-transfer and block-search instructions. With a single instruction, a programmer can transfer a block of information from one region of memory to another region or search for a single character in any block. Other instructions allow block transfers from I/O devices directly to any internal register or to any region of memory. Although this differs from direct-memory-access transfers in that it ties up the CPU during the block transfers, it can serve as a form of DMA in relatively low-speed applications, since it transfers one byte in about 8 microseconds.

There is a full set of rotate-and-shift instructions applicable to any register, rather than just to the accumulator, as in second-generation microprocessors. There are also byte-manipulation instructions, useful in word-processing applications, and bit-manipulation instructions that allow the CPU to set any bit in any memory location or any register. The addressing modes offer programmers more flexibility than any of the second-generation microprocessors (see "How the Z-80 addresses memory," p.93)

The matter of CPU timing

The CPU executes instructions by stepping through a set of basic machine cycles. Thus an instruction cycle is a combination of one or more of the following basic cycles: op-code fetch; memory read or write; I/O-device read or write, and interrupt acknowledge.

Each memory cycle lasts from three to six clock

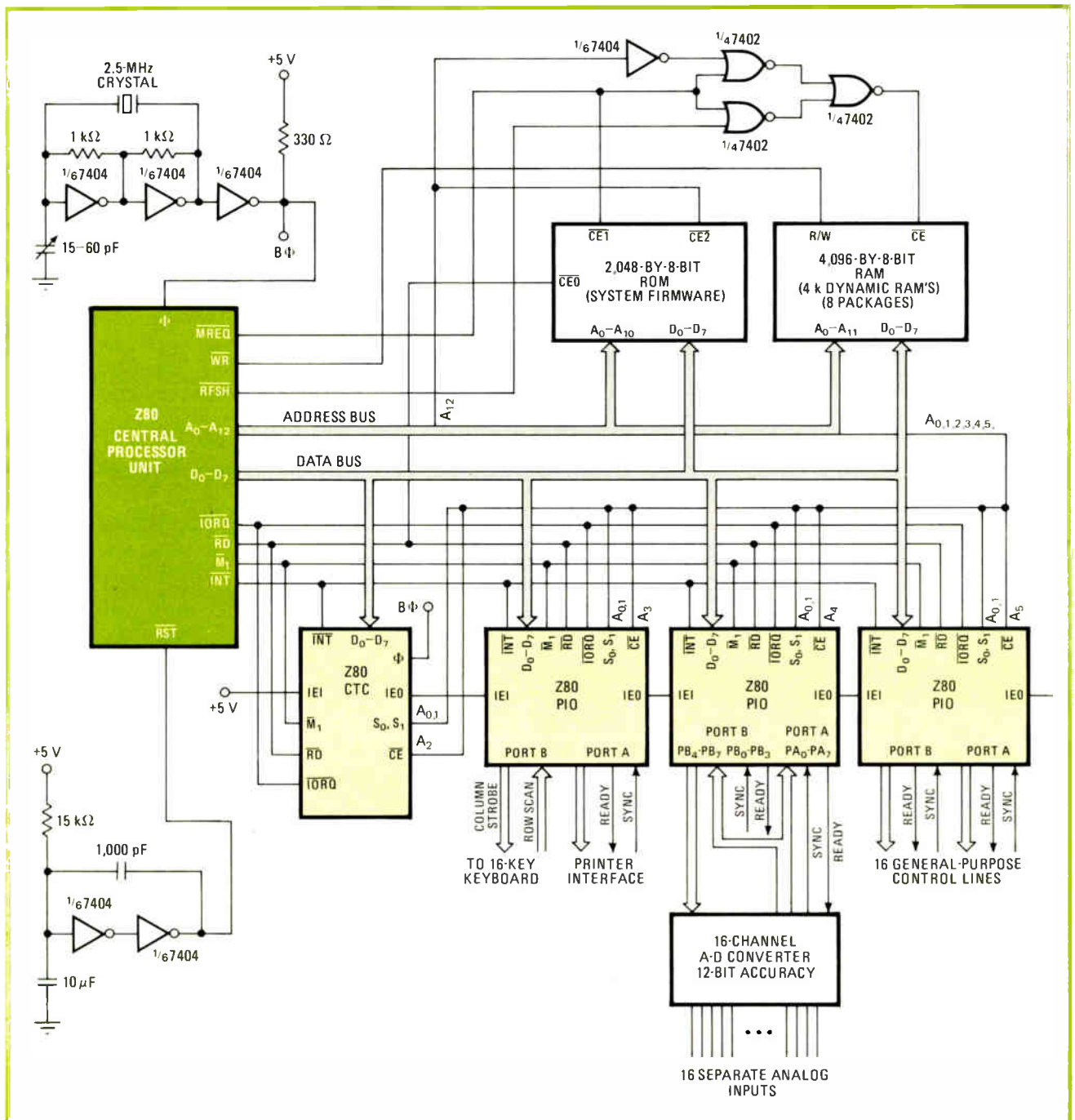


2. Timing counts. During the execution of an instruction—in this case, increment the memory location designated by the content of register HL—note that the refresh address is put out on the address bus while the central processing unit is interpreting the op code.

periods, which are 0.4 μ s each for the standard-speed version (higher-speed versions with 250-nanosecond cycle times will soon be available). However, a memory cycle can be lengthened by two control signals: wait request (WAIT) and bus request (BUSRQ). WAIT allows the designer to synchronize the speed of external memory or peripheral devices to the CPU's speed by introducing extra idle states (wait states) into a machine cycle. BUSRQ allows external devices to have access to the address, data, and control buses. The CPU will complete its current machine cycle and then float its buses for as many cycles as required by the external BUSRQ signs.

An example of CPU timing is shown in Fig. 2 for the case of execution of the INC (HL) instruction—increment the content of the memory location addressed by the content of HL. For illustrative purposes, it is assumed that a wait state is requested during the M₁ cycle and that BUSRQ is active during M₂ and M₃ period.

During the M₁ cycle, the op code is fetched from memory and decoded during clock times T₃ and T₄. At the same time, while the CPU is fully occupied with the op code, the refresh-counter contents are placed on the address bus along with a refresh-control signal. Thus a totally transparent refresh of the memory occurs during



3. Process controller. To handle peripherals, three programmable parallel I/O devices (PIOs) are added to the Z-80 CPU. On the PIOs, the IEI and IEO pins form a daisy-chain interrupt-control structure, with the device closest to the CPU having the highest priority.

How the Z-80 addresses memory

One of the advantages of the Z-80 is the variety of addressing modes available. Listed below are some of them, including an example of each mode.

Immediate [LD E, n]—load register E with 8-bit value n.
Immediate extended [LD HL, nn]—load register HL with the 16-bit value nn.

Modified page zero [RST 48]—call to location 48.

Extended [LD DE, (nn)]—load DE with the contents of memory locations (nn) and (nn + 1).

Indexed [ADD (IY+d)]—add the content of memory location (IY+d) to the content of the accumulator (d is an 8-bit signed-2's-complement value).

Relative [JR e] or [JR kk, e]—jump from the current program-counter location to a new location offset by an amount indicated by e, the signed 8-bit quantity. This allows jumping up to +127 or -128 locations. A condition code, kk, may also be added to the instruction for conditional jumps.

Register [INC B]—increment the content of register B.

Implied [NEG]—negate the content of the accumulator (2's complement).

Register indirect [LD (DE), A]—load location addressed by the content of DE with the accumulator's content.

Bit addressing [SET 4 (HL)]—set bit 4 of memory location addressed by HL.

Stack addressing [PUSH IX]—push the content of register IX into the stack.

Since many instructions include more than one operand, two types of addressing modes may be employed, one to specify the source and one to specify the destination. The Z-80 CPU is provided with many such addressing combinations:

LD C, (HL)—load register C with the memory content addressed by HL.

LD (IX+d), B—load memory location (IX+d) with register B

LD (IY+d), n—load memory location (IY+d) with the value n.

EX (SP), IX—exchange the contents of the top of stack and register IX.

SBC HL, BC—subtract the content of BC from HL, which then will contain the result of the operation.

OUT (C), D—send the content of register D to the peripheral device addressed by the content of register C.

LDDR—move a string of data from one area of memory to another. At the beginning of the instruction, HL points to the top of the source string, DE points to the top of the destination string, and BC holds the string length.

INIR—move a block of data from the peripheral whose address is the content of register C to a memory area addressed by HL. At the beginning of the instruction, C points to the peripheral, HL points to the bottom of the memory block, and the content of register B represents the block length.

this time without slowing down the processor.

During cycle M_3 , the data from the memory location pointed to by register pair HL is read from memory. This four-cycle operation has been extended two clock periods by an external device that requests the bus for a DMA cycle during the T_4 time periods. During cycle M_3 , the incremented data is written back into the memory.

A versatile system

A set of peripheral controllers allows the implementation of a wide variety of systems, ranging from simple controllers to sophisticated computing systems. There are four of those building blocks.

- The Z-80 PIO is a programable circuit that allows parallel communication between the CPU and peripheral devices such as printers, plotters, paper-tape readers and punches, keyboards, and many other peripherals.

- The Z-80 CTC is a programable counter/timer circuit that contains four independent interval counter/timers and allows easy control of practically any electromechanical system, as well as several different communication protocols.

- The Z-80 DMA is a programable circuit that may be used where there is a requirement for fast direct memory access. However, note that the memory-to-I/O block-transfer instructions in the CPU will allow many applications to do without a DMA channel if the transfer rates are less than 125 kilobytes per second.

- The Z-80 SIO is a programable circuit that allows easy interface with most serial communications protocols.

A key feature of these peripheral controllers is the interrupt structure. They can be daisy-chained together

to form a priority structure that allows nested interrupts to be handled by the CPU with no hardware or software overhead. Using the interrupt mode, the requesting controller will cause the CPU to go to the beginning of its service routine. At the end of its service routine, a special instruction—return from interrupt—is recognized by the controller, and this allows controllers with lower priority to interrupt the CPU and allows the CPU to automatically resume service routines interrupted by a higher-priority device.

In the example of a small Z-80-based process-control application in Fig. 3, the peripheral devices consist of a 16-key keyboard, a printer, a 12-bit analog-to-digital converter interfacing 16 analog lines into the system, and 16 discrete system-control lines. Three Z-80 PIOs handle the interfaces to the external I/O devices. For each peripheral device, the CPU merely configures a PIO for the required interfacing.

On the peripheral devices, two pins—the IET (interrupt enable in) and IEO (interrupt enable out)—form a daisy-chain interrupt-control structure where the device closest to the CPU has the highest priority. Here, this device is the CTC, which performs all timing functions to avoid software timing loops. The complete computer requires only 14 circuits, nine of which are memory—2,048 bytes of ROM and 4,096 bytes of RAM.

In such systems, the Z-80's requirement of a single power supply and single-phase clock significantly eases the system design. And, since the CPU carries on-chip memory-refresh circuitry, standard memory chips may be selected. Thus, the Z-80 extends the range of cost-effective applications for MOS microprocessors. □

Micropower comparators generate 2-phase clock

by Norman G. Wheelock
Siliconix Inc., Santa Clara, Calif.

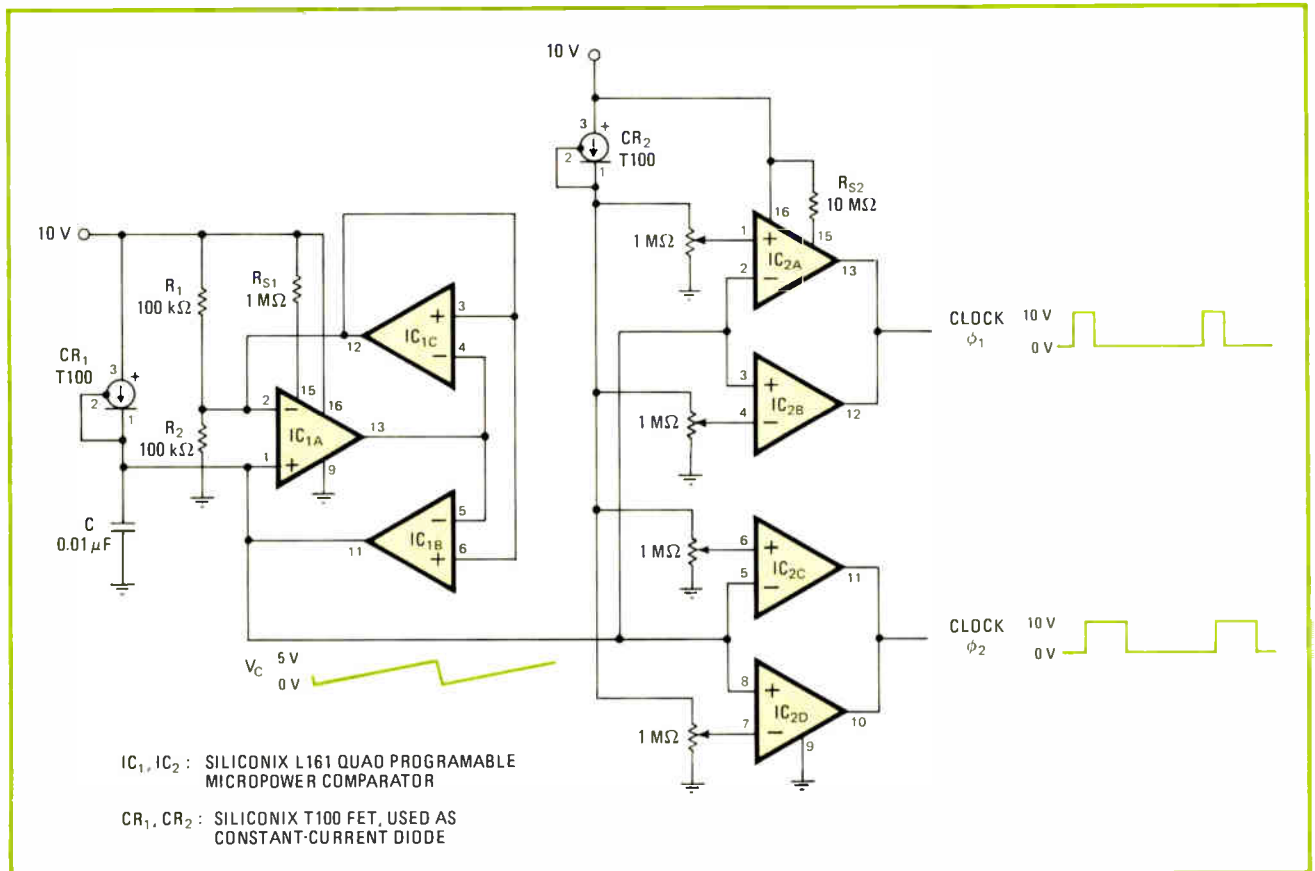
A versatile two-phase clock generator that uses two L161 quad micropower comparators provides signal outputs with variable phase and variable pulse widths. The entire circuit draws only 300 microamperes from a 10-volt supply. The 3-milliwatt power consumption allows the circuit to be used in a broad variety of applications such as time-delay generators, logic sequencers, hand-held signal injectors, and other systems where a multiphase clock is required.

The waveforms in Fig. 2 illustrate circuit operation. As a ramp generated by the first L161 increases in amplitude, the outputs of two window comparators, which are formed by the second L161, rise and fall. A rise occurs when the lower limit of the window comparator is crossed, and the fall comes when the upper limit

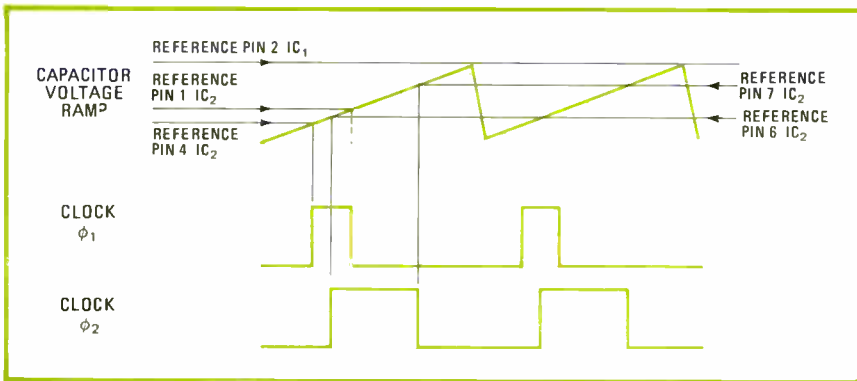
is reached. The upper and lower limits of the window comparators are variable throughout the full voltage range of the ramp. Variations in the upper and lower limits of the window comparators allow for change in pulse widths and relative phase of the signal outputs.

The actual circuit diagrammed in Fig. 1 is composed of two sections: a ramp generator, formed by three of the four comparators on IC₁, and two window comparators, formed by IC₂. The operating speed and power consumption of the comparators are set by the value of the resistor R_s between the power supply and pin 15 of the integrated circuit; each comparator draws $5 V_{sup}/R_s$, and a bias circuit draws V_{sup}/R_s , so the total current is $21 V_{sup}/R_s$. The $210 \mu A$ drawn by IC₁ provides moderately fast operation of the comparators in that IC, and the $21 \mu A$ set for IC₂ limits its comparators to slow switching.

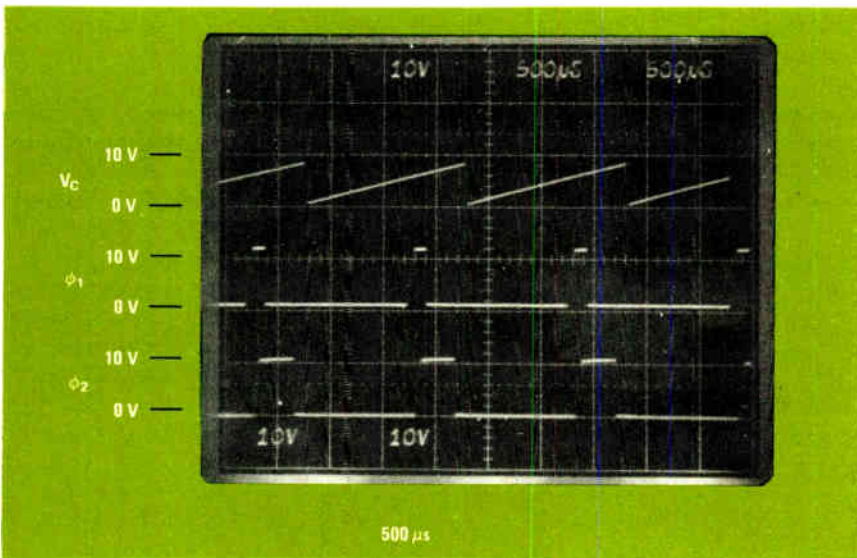
The ramp-generation circuit is controlled by the charging of C by a constant-current diode, CR₁. When the charge on C reaches the voltage of pin 2 of IC_{1A}, IC_{1B} is turned on, and C is quickly discharged. IC_{1C} is also turned on at the discharge point, grounding the reference pin. This action provides a form of positive feedback such that IC_{1B} is prevented from being turned off as the charge on C falls below the reference level at pin 2.



1. Power miser. This clock uses two quad comparators to produce the two pulsed waveforms. Each IC includes provision for programming the current drawn by the comparators, and thus controls their speed. Clock frequency is 100 Hz to 100 kHz.



2. Go in and out the windows. Two clock signals, with independently variable widths and variable relative phase, are generated by setting the reference levels of two window comparators driven by a voltage ramp. A biphasic clock finds application in various logic systems.



3. Picture this. Scope photo shows linear voltage ramp across capacitor, plus output pulse trains of the two clock signals, from circuit of Fig. 1. Calculated frequency, for 35- μ A charging current and 5-V ramp height, is 70 kHz; waveforms indicate about 67 kHz. Note complete absence of unwanted glitches in clocks' waveforms during capacitor discharge.

The time T during which the ramp charges is:

$$T = CV_{ref}/I$$

where I is the current provided by CR_1 (30–48 microamperes), V_{ref} is the reference voltage on the inverting input of IC_{1A} (5.0 v), and C is the value of the capacitor charged through CR_1 .

Because the comparator used to generate the ramp has its supply current programed to provide moderate switching speeds necessary for quick discharge of C , the discharge time is negligible. Therefore, the rate, f , at which the ramp cycles is effectively:

$$f = I/CV_{ref}$$

This frequency is set by choosing the value of C , and it can be trimmed by adjusting V_{ref} , if necessary.

The remaining portion of the circuit is composed of

two classic window comparators. Upper and lower limit references are provided by a second current-reference diode (CR_2) and several potentiometers. The comparators in the circuit are programed for slow switching to prevent signal output during the discharge period of C .

Most of the current to the circuit is drawn by IC_1 (210 μ A). IC_2 consumes 21 μ A and the current-reference diodes a total of 60 μ A. The remaining current flows through the resistor network that provides reference voltage for IC_{1A} . The total current delivered to the circuit (341 μ A) is a factor of 100 smaller than that required by nonprogramable comparators.

The T100 field-effect transistors that are used as constant-current diodes also contribute to circuit economy, passing less than an eighth of the current of conventional constant-current diodes. They have a temperature coefficient of only about 82 nA/ $^{\circ}$ C. \square

Amplifier adds sign bit to a-d converter output

by Jerald Graeme
Burr-Brown Research Corp., Tucson, Ariz.

In feedback systems, digital-to-analog converters frequently require bipolar outputs to supply both polarities of feedback-correction signals. One means of developing both polarities is to offset the output, but this method sacrifices the convenience of BCD bit-coding.

A better way to control output polarity is to provide sign-bit control to the digital-to-analog converter by connecting the output operational amplifier of the d-a

converter as a gated amplifier. This connection is possible when the op amp has uncommitted feedback to permit coding options. However, the technique can be applied to any current-output d-a converter by using an external op amp.

Shown in the figure is the gated-amplifier connection that provides the sign-bit control. The op-amp output is switched at the circuit output by transistor Q_2 in response to the sign-bit signal. When the sign bit is high, Q_2 is off, so the amplifier does not control output voltage e_o , and operation is that of a current-output d-a converter driving resistive load R_2 . The output current from the converter, i_o , divides between the internal resistor R_0 and the path through R_1 and R_2 to ground. The output signal, which is negative, is determined by:

$$e_o = -i_o R_0 R_2 / (R_1 + R_2 + R_0)$$

If the sign bit is low, switch Q_2 is turned on so that the op amp can control e_o . Then the amplifier performs as a current-to-voltage converter, giving an output signal of

$$e_o = i_o R_1$$

For a symmetrical response, the above opposite-polarity signals are made to have the same magnitude for a given i_o . This requires that

$$R_2 = R_1(R_0 + R_1) / (R_0 - R_1)$$

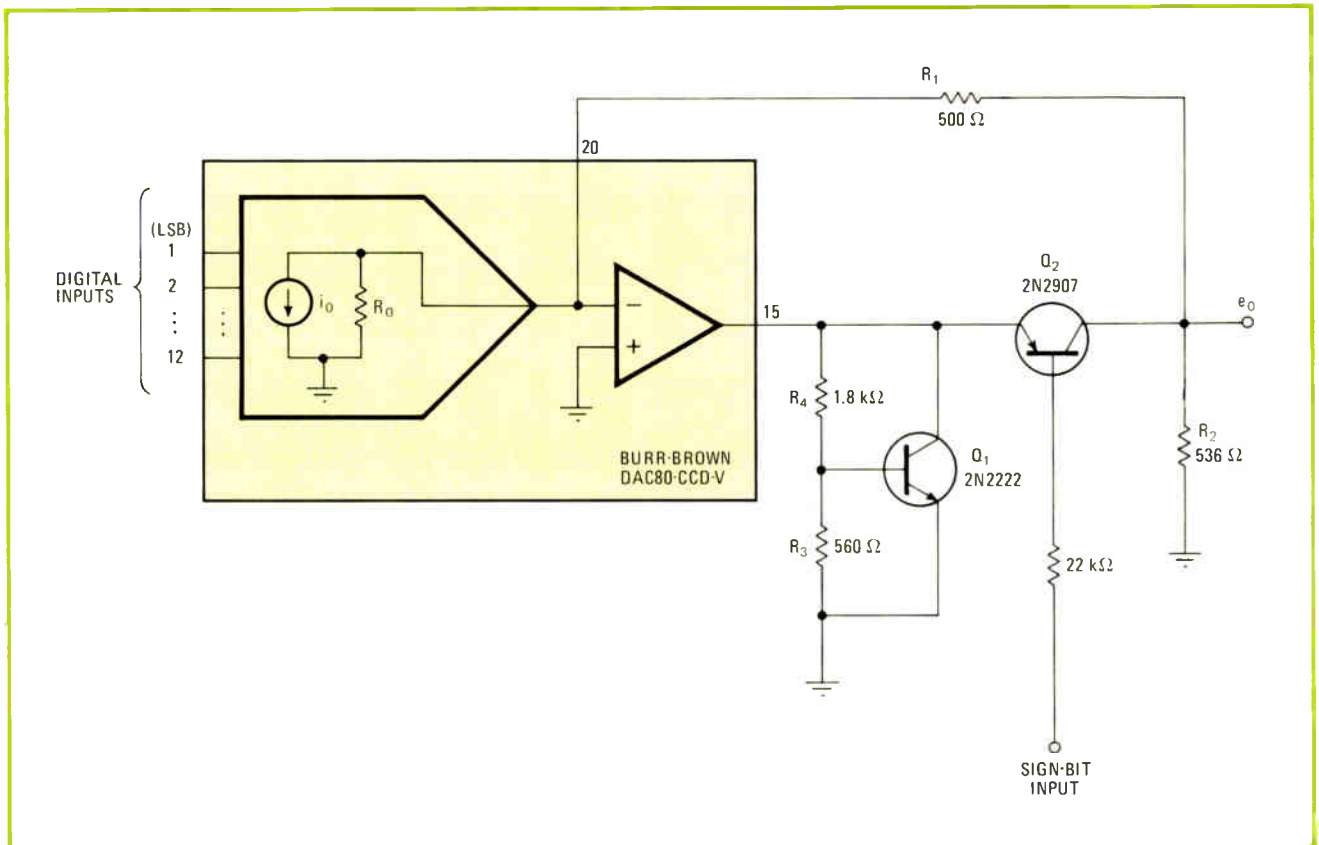
The value of R_0 is given on the data sheet for the d-a converter; for the DAC-80, it is 15 kilohms. The values

of R_1 and R_2 are chosen so that the full-scale output current from the converter develops about 2 volts across them. The full scale i_o is 2 milliamperes, so $(R_1 + R_2)$ is approximately $2/0.002$, or 1 kilohm.

Also connected to the gated amplifier is a clamp formed by transistor Q_1 and resistors R_3 and R_4 . This clamp ensures logic-level compatibility for the sign bit. By clamping the positive swing of the op amp, it is possible to turn Q_2 off with the high-state voltage available from command logic. With the values of R_3 and R_4 illustrated, TTL-compatibility is achieved. To clamp the amplifier output, Q_1 performs as a simple shunt regulator by limiting its collector-emitter voltage to a maximum of $(1 + R_4/R_3)V_{BE1}$. At that voltage, Q_1 turns on to clamp the amplifier output by forcing it into current limit.

Preservation of conversion accuracy requires three trimming adjustments to the circuit. First, an offset correction signal should be added to the op amp with Q_2 turned on and only the least significant bit on. Then, the positive output gain is adjusted by trimming R_1 with full-scale output—all bits turned on—and Q_2 on. Finally, Q_2 is turned off, and the negative-output gain is set by adjusting R_2 . In this circuit mode, the op amp's input is overloaded, so it must maintain high input resistance under overload to avoid shunting the signal current. □

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Sign bit sets analog-output polarity. In this circuit, the sign of the output voltage of the digital-to-analog converter is determined by a sign bit applied to Q_1 . If the sign bit is low, the output voltage e_o is positive, and if the sign bit is high, e_o is negative. Here the sign bit is added to the d-a conversion by gating the internal output op amp, but an external op amp can be used on any current-output d-a converter.

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Dynamic I²L random-access memory competes with MOS designs

With an access time of only 100 nanoseconds, this 4,096-bit bipolar RAM satisfies main-memory needs

by Wendell B. Sander, William H. Shepherd, and Richard D. Schinelle, *Fairchild Camera & Instrument Corp., Palo Alto, Calif.*

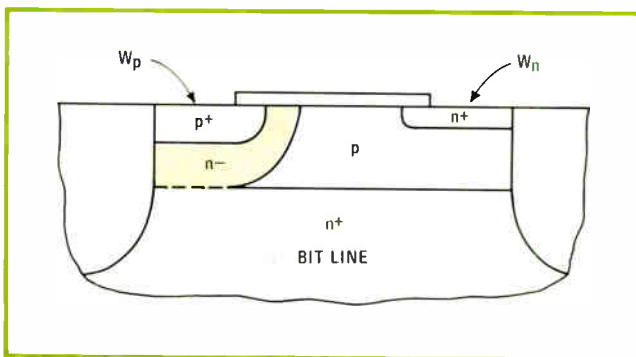
□ For the first time, bipolar-memory devices are invading the field of dynamic, main-memory systems now dominated by MOS designs. The intruder is a 4,096-bit random-access memory that combines advanced integrated-circuit processing with an elegant integrated-injection-logic or merged-transistor-cell design.

Bipolar devices are prominent in only the fastest static-memory cache and buffer systems. Now they may have the edge over metal-oxide-semiconductor devices in those main-memory applications where the 93481's sub-100-ns speeds offset its modest premium in price.

Those typical access times make the chip twice as fast as most 4-k MOS RAMs, yet with a similar active power dissipation of only 400 milliwatts. The device is powered by a single 5-volt supply (MOS RAMs need three voltage supplies) and can operate easily over the 0–70°C temperature range. It is housed in a standard, 16-pin, dual in-line package and uses the input multiplexing schemes that are standard in 16-pin, 4-k systems. Moreover, chip size is only 112 by 129 mils (less than 14,000 mil²), considerably smaller than most of its metal-oxide competitors.

Being twice as fast makes it a good high-speed companion to MOS 4-k and 16-k RAMs. And, fortunately, the increased speed won't kill the budget: thanks to the compact cell (about 648 square micrometers) and small chip size, the 93481 will sell for a small premium over MOS devices in production quantities.

The heart of the device is the dynamic I²L memory cell



1. Minimal art. The beauty of the dynamic I²L RAM is its extremely simple cell structure, consisting of only a single pair of merged transistors. The entire cell occupies little more space than a single transistor and needs no separate charge-storing capacitor region.

(Fig. 1). In contrast to six-transistor conventional bipolar static cells, this design is astonishingly simple. It consists of a single transistor pair—an npn and pnp—merged on silicon so that it occupies little more space than a single transistor.

The cell design

Moreover, the cell needs no separate space-consuming capacitors to store charge, as do even the most advanced double-level MOS cells. Here 1s and 0s are stored on the easily accessible junction capacitance in the shared collector-base of the merged transistors (the shaded n region in the figure). Since this junction is usually reverse-biased during cell operation, it is nicely isolated from the rest of the circuit. This makes for an extremely efficient charge-storage mechanism.

The new design saves still more space because its operation requires only three access lines (Fig. 2a), or the same number as dynamic MOS cells. There are the two word lines, W_n and W_p , connecting the npn and pnp emitters respectively, plus the bit line connected to the common npn collector and pnp base region.

Using this cell is simple, too, as shown in Fig. 2b, where the action of the npn switching transistor is illustrated. Again, word line W_p is usually reverse-biased. A cycle is initiated with an external timing signal, which controls the level of the bit line—high for 0 and low for 1. When this occurs, the W_n line is pulled from 3.4 v to 0.4 v and remains low until the timing signal is dropped.

The state of the cell is now ready for detection. For the read 1 case, the capacitor is initially uncharged. When the W_n line is pulled down to about 1 v below its resting voltage, the emitter-base diode of the npn, which had been reverse-biased, becomes forward-biased, driving the npn into its active region. The collector-base capacitance then acts as a feedback capacitor, coupling the W_n signal to the bit line through the storage capacitor for multiplication by the beta of the npn transistor.

Typically, the storage capacitance is about 0.1 picofarad, and the npn's β is about 70, making the effective coupling capacitance about 7 pF—enough to assure easily detectable logic swings of 200 millivolts. The result is illustrated by the bit-line 1 signal of Fig. 2b, where this coupling pulls the bit line low.

For the read 0, the capacitor is charged positive-to-

negative (Fig. 2a). When the W_n line is pulled low, the emitter-base diode of the transistor does not become forward-biased, and little or no signal is coupled to the bit line, as illustrated by the bit-line 0 signal in Fig. 2b.

The sense amplifier detects cell signals as soon as the bit line has settled sufficiently for its two states to be distinguishable. A sense-amplifier latch compares the bit-line signal to a reference signal generated from an identical bit line to determine whether a 1 or 0 is present.

A neat feature of the cell's design is its ability to reinforce the nature of its output during each reading. If the bit line is low, the sense amplifier latches, forcing it to a lower active state. If, however, the bit line is high, then the sense-amplifier latch forces it to its rest state, which is high. Therefore, if some charge has been lost, the bit line will force the capacitor to be recharged, refreshing the charged 0 condition.

Writing into the memory is done by changing the state of the sense-amplifier latch while the W_n line is low. To write a 0, the latch is forced to the high-voltage state and the capacitor is charged. To write a 1, the latch is forced to the low-voltage state, and the cell is discharged at the end of cycle.

To refresh a logic 1

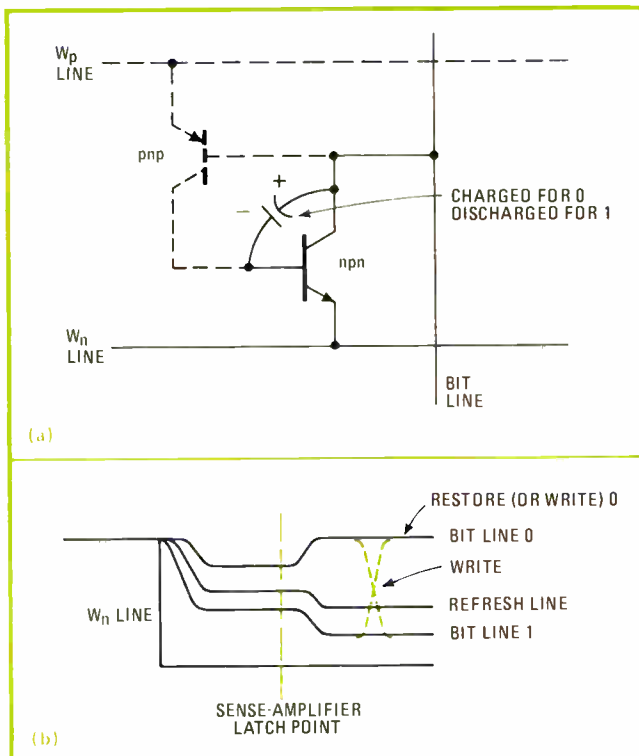
Like any dynamic memory, the cell of the 93481 must be refreshed—in this case each of the 32 row addresses every 2 milliseconds with any read/write cycle. As already discussed, the refresh action for 0s takes place during the active part of the cycle. The refresh 1 action,

How cells are built

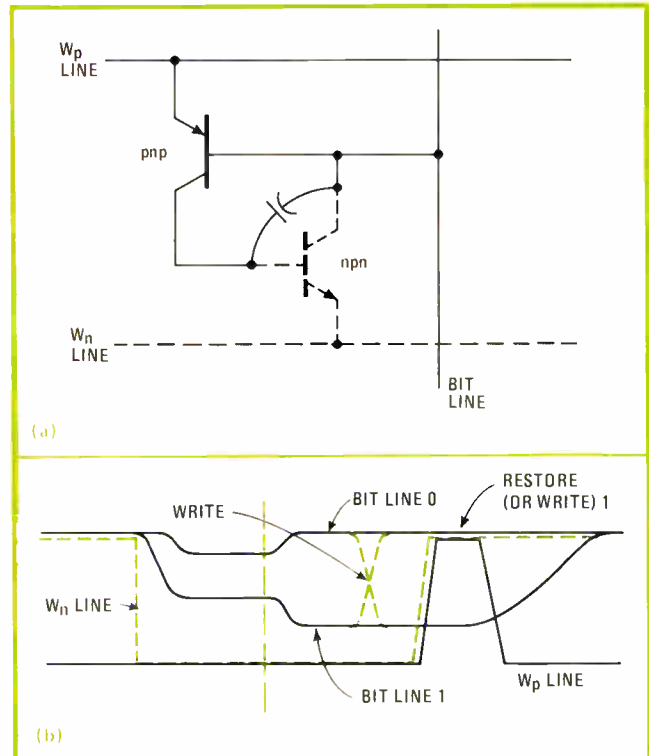
Although the I^2L cell configuration is conceptually very simple (Fig. 1), it requires a high degree of process sophistication. For one thing, the cell's npn transistors must be fast, which means an epitaxial base with unusually low emitter-base capacitance. That, in turn, requires ion-implanted base layers that must be controlled over a dense LSI chip. The result, however, is outstanding—a β of 70 and an f_T of 1 gigahertz.

Likewise, the pnp is formed in an unconventional manner, by successive diffusion of n- and p-type impurities through a common window. The result is a lateral pnp transistor, with a graded, highly efficient base, with a β of 8 and an f_T of 1 GHz. Because of the high-concentration base, this lateral device has much greater current-carrying capacity for the same geometry than does an epitaxial pnp lateral transistor.

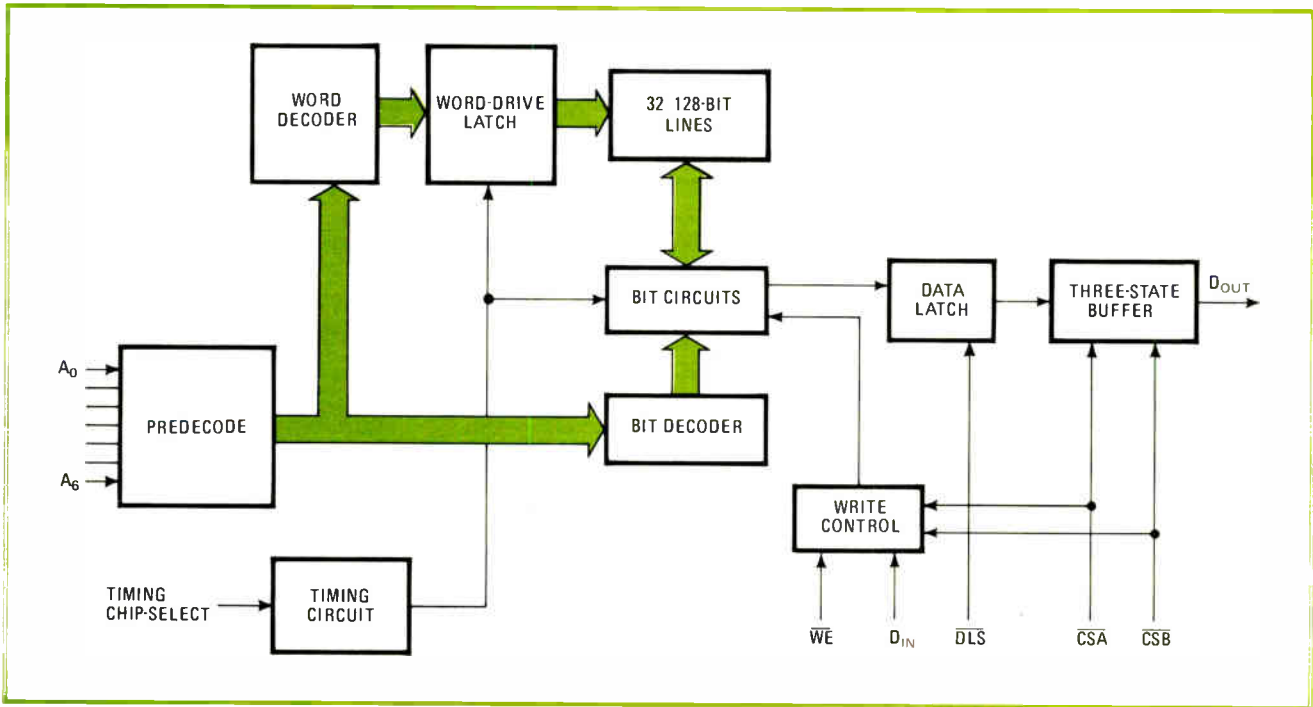
Finally, all stops were pulled out in process technology—washed, walled emitters, isoplanar isolation, and self-aligned photomasking. But (and this is the key) it was not necessary to use component-layout rules that would present difficulties in mask fabrication or in photomasking. Indeed, the requirements in each of these areas are less stringent than those presented by high-density MOS designs. Fabrication is further simplified by using a single layer of metalization, while the full use of ion implantation for doping control at selected steps assures good parameter control where needed. The combination of process techniques results in high yields because of greatly reduced active areas and easy process control.



2. Reading and writing. Once the cell's capacitance is charged (a), a sense-amplifier latch (b) compares the bit line signal with a reference and determines whether a 1 or 0 is present. Writing is done by changing the state of the latch while the W_n line is low.



3. How to refresh. First, the storage capacitor is discharged, and the W_n line is returned to a low level. Then the sense amplifier is turned off, the bit lines are returned to their high rest state, and the memory cell is ready for the next cycle.



4. Addressing. Seven input address lines are predecoded to drive the word and bit decoders. The first five addresses (A_0 to A_4) are used for the word decoder, while all seven addresses are used for the bit decoder. This latter operation is a simple ripple-through action.

COMPARING THE CHIPS		
	93481	Typical 4-K dynamic MOS RAMs
Access time (ns):	100	200
Read/write cycle time (ns):	200	350
Read/modify-write cycle time (ns):	240	400
Refresh interval (ms):	2 (32 lines to refresh)	2
Chip select access time (ns):	30	60
Temperature range:	0 – 70°C case	0 – 70°C
Power dissipation (mW):	400 (active); 50 (standby)	300 (dynamic); 12 (static)

on the other hand, takes place at the end of the cycle. The end of the cycle is defined by dropping the external chip-selection timing line, which causes the W_n line to recover to its rest condition. Now the pnp region of the cell comes into play (Fig. 3). Because the sense-amplifier latch will remain on for a brief time after W_n goes high, the W_p line, which is tied to the pnp emitter, is pulled high for this brief period. In fact, it is pulled high enough to turn on (forward-bias) the pnp emitter-base diode if the bit line is low.

Thus, all cells on the word line that have low bit lines will have their pnps turned on, discharging the storage capacitors. This provides the refresh 1 action. After this happens, the W_p line recovers to a low level, the sense-amplifier latch is turned off, and the bit lines thereupon return to their high rest state in preparation for the upcoming cycle.

One thing that might not be evident from the discus-

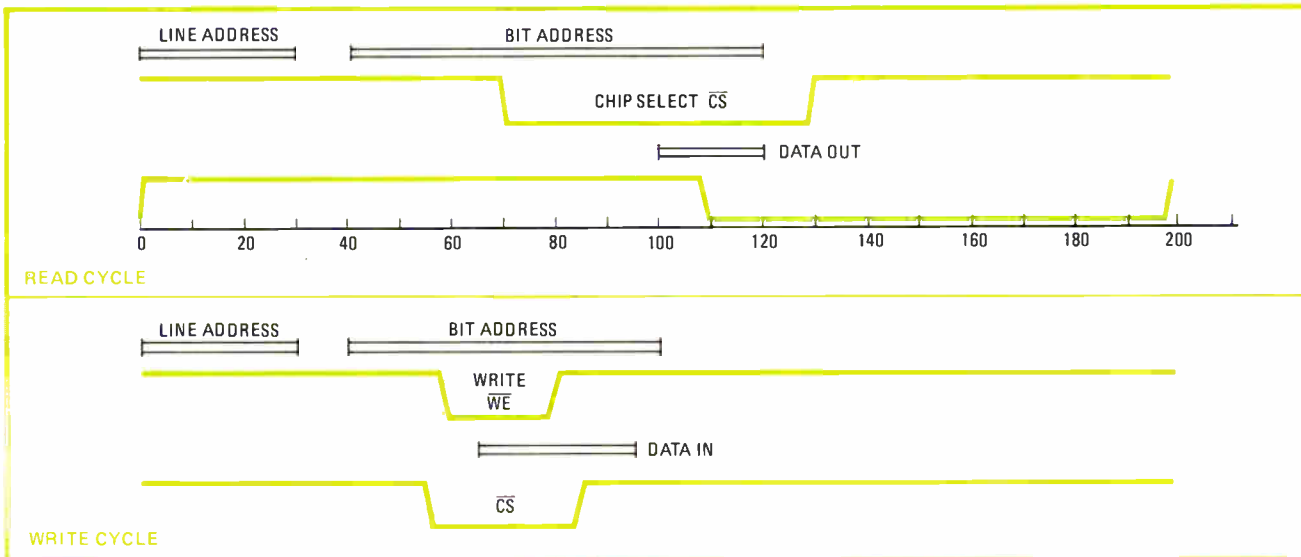
sion so far is the complexity of the peripheral circuitry. This contrasts with a static bipolar RAM, which doesn't need all the special waveform-generating circuits necessary to operate these cells. Moreover, since this cell inherently a single-layer metal design, the remaining peripheral circuitry has employed single-layer metal as well—an approach that imposes constraints on overall chip layout since it requires careful analysis to avoid problems with power distribution. Also, it requires an extensive computer-assisted design in local-circuit areas to minimize the effects of parasitic, buried-layer resistance and capacitance.

Happily, high-speed pnp transistors greatly relieve the difficulty of the peripheral-circuit design. They are in the active circuit elements on the periphery as well as in the cells. An example is the npn and pnp current mirrors, used extensively to provide high-speed decode and sense-amplifier circuitry that is accurate, sensitive, stable, and simple to power down.

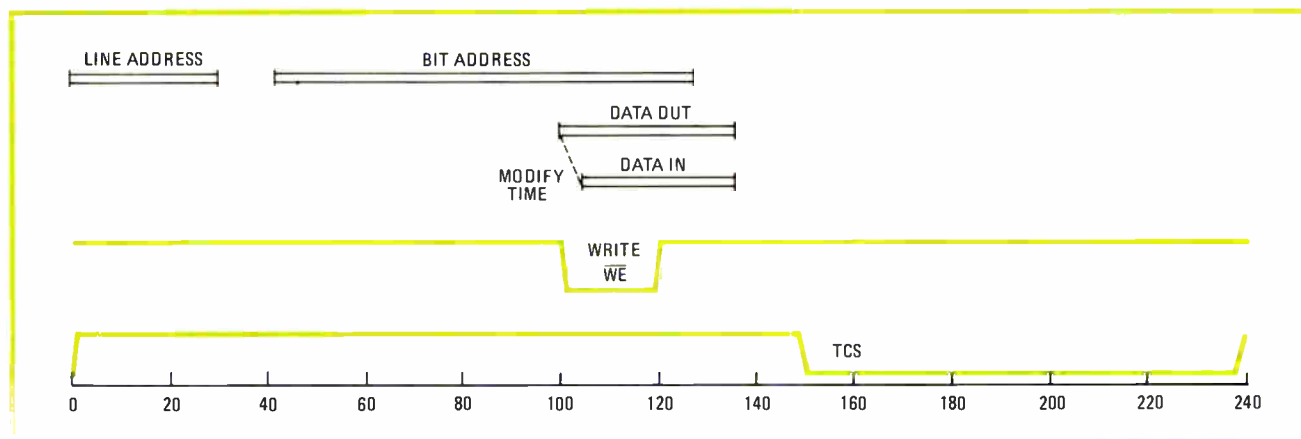
Using the memory

The overall chip layout is displayed in the block diagram of Fig. 4. Unlike in 16-pin 4-k MOS RAMs, there are seven input address lines, which are predecoded to drive the word and bit decoders. When the timing signal is activated to begin a cycle, the chip is powered up, and addresses A_0 – A_4 are fed to the word decoder and latched in the word driver, where one of 32 word-line pairs is selected. Subsequently, the 128 sense amplifiers are activated to latch the information for each bit stored in that line.

The bit circuits are accessed from the same predecoder by the bit decoders. For bit selection, all seven addresses are used to select one of the bit circuits. The data is then fed through a bypass data latch to an output



5. Timing. For reading, line addresses are held for 30 ns, while another 10 ns is used to change operating modes. Writing needs 30 ns for keeping the line address stable, 10 ns for address change, plus time to set up the bit address ahead of the write pulse.



6. Overlap. Read/modify/write is an overlap timing operation between the delay-in line and the write pulse. After the line address has remained stable for 30 nanoseconds and an address period has followed, then the modify-write pulse can be raised.

buffer. Since this addressing is a simple ripple-through action, the bit addressing looks exactly the same as in a 128-bit static RAM. Moreover, other bits on the same word line can be accessed by changing the input address and waiting the appropriate access time, with no further timing strobes required.

Notice that the data latch is placed in the circuitry ahead of the chip-select function. This permits data to be latched in a memory that is not even chip-selected. Thus, data can be held in the latches and subsequently read out via the chip-select lines even while the chip is doing a write or refresh cycle.

The table compares characteristics of the 93481 with a typical 4-k dynamic MOS RAM. Notice that no penalty is paid for the faster access time, except for slightly higher standby power.

The timing

Because most designers of bipolar-memory systems are used to the simpler timing requirements of static devices, it's helpful to walk through the details of a typical cycle timing for the new chip (Fig. 5). For a read

cycle, the line address must be held for 30 ns with another 10 ns for the user to change the operating mode from line address to bit address. The access time, from a stable bit address to data out, is 60 ns. To hold the data out longer, the chip-select timing signal may be tied directly to the data-latch strobe signal. The data will then remain in the output latch until the beginning of the next cycle.

For write cycles, it is again necessary to have the line address stable for 30 ns and to allow time to change the address. It is also necessary to have the bit address set up ahead of the write pulse. Moreover, the data-in line must be stable both before and after the trailing edge of the write pulse, but its state need not be related to the pulse's leading edge.

Figure 6 illustrates a read/modify/write cycle using the 93481. Again the line address must be stable for 30 ns, followed by an address-change period. Once the bit address is stable, the data-out line will become stable 60 ns later. When the required overlaps between the data-in line and the write pulse are observed, the latter can be raised, completing the cycle. □

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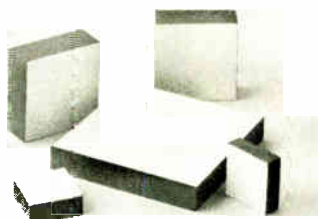
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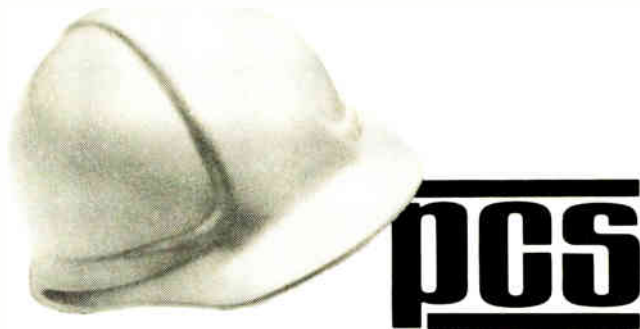
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Evaluating a microcomputer's input/output performance

An activity index measures a critical parameter of microcomputer-based systems—the processor's ability to communicate with other system elements

by Howard Raphael, *Intel Corp., Santa Clara, Calif.*

□ Most designers of microcomputer-based equipment rightly pay a lot of attention to a microcomputer's internal data-handling ability. But they really should give as much, if not more, attention to the ease with which a microcomputer communicates with the rest of the system.

Through its input/output lines, the microcomputer correlates the activities of all the other system elements, including keyboards, printers, and disk units. Its value to the system depends heavily on how well it performs these input/output functions. For a designer to choose the most cost-effective microcomputer for a given application, therefore, he requires a standard (figure of merit) by which to measure and compare the input/output performance of different microcomputers. And before he can measure I/O performance, he needs a detailed understanding of the various I/O functions carried out by most microcomputers.

The kinds of information

The microcomputer is called upon to process three types of information—data, status, and control—and it may do so in one of three ways. It may retain complete control of the information transfer, as in polled I/O. It

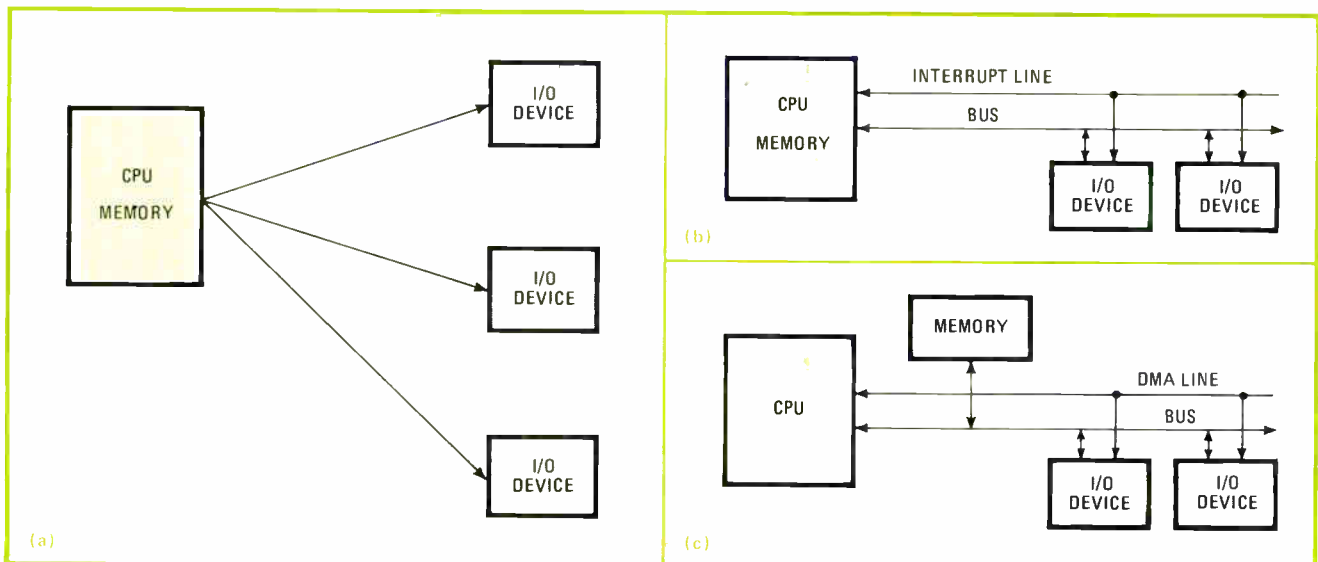
may allow the I/O device to initiate a transfer, but retain control thereafter, as when interrupts are used. Or it may relinquish control completely to the input/output devices, as in direct memory access (see Fig. 1).

Data generally is bidirectional, flowing to the microcomputer from the I/O devices in the system and flowing from it to them. The nature of the data—whether it's alphanumeric (ASCII) or variable-length binary—strongly influences the microcomputer's optimum word length.

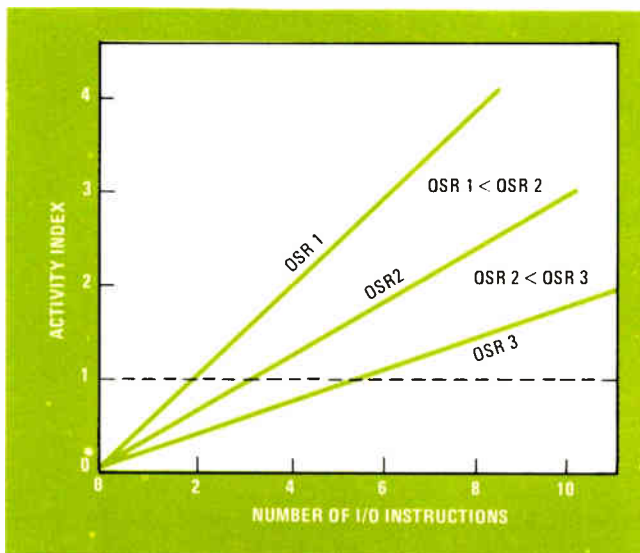
For example, if the data is predominantly ASCII, an I/O word of 8 bits should be selected for a first approximation. In systems where data is decimal or where only moderate performance is required, a 4-bit word may be good enough and indicate selection of a lower-cost microcomputer.

Status information generally flows from the rest of the system to the microcomputer. It describes the states of the peripherals and other input/output devices in such terms as READY FOR DATA, TIGHT TAPE, ON CYLINDER, BUSY, and END OF FORM.

Status information may be transferred in either decoded or encoded form. Decoded status words are assigned 1 bit (or line) each, that is, 1 bit for BUSY, 1 bit



1. Input/output. Three types of microcomputer I/O are polled I/O (a), where the CPU initiates and controls the transfer, interrupts (b), where the I/O device initiates the transfer but the CPU controls it, and DMA (c), where the I/O device is in complete control.



2. Service rates. An over-all figure of merit, the optimum service rate for a multi-port system can be calculated by taking the ratio of I/O instructions to the previously calculated activity index for each port. Different systems can then be compared.

for LIGHT TAPE, and so on. Encoded status words compress more information onto the same number of lines—for example, the four lines needed for four decoded words could handle 16 encoded status words—but do so at the cost of equipping the group of sending I/O devices with additional hardware that would be required to perform the encoding.

Control information flows in the opposite direction from status words, from the microcomputer to the peripherals and other I/O devices. It consists of instructions like TRANSFER CHARACTER, START PRINT, or SEARCH FOR INTER-RECORD GAP. Besides defining the nature of the transfer (data, control, or status), it usually tells whether the instruction is input or output. (In 16-bit machines and larger, control and data usually are contained within one I/O transfer, but with microcomputers, data usually takes the full word width, and the control word therefore is usually sent independently of the data.)

Control information, like status words, may be transferred in encoded or decoded fashion. If the number of control activities is less than the width in bits of the I/O command word, it is advantageous to transfer the information in decoded form, one word bit for each control function. This avoids the need for a decoding device at the receiving end.

Keeping in step

Besides control information, every microcomputer instruction to input/output devices includes selection, or routing, information in the form of an address. The nature of instruction formats and the way they are handled varies quite widely from one microcomputer to another. Some microcomputers provide the control information and selection information in two instructions, while others can provide it in only one instruction but may require several memory cycles. As will become more apparent later, this can have a marked effect on

the device's I/O efficiency.

To synchronize the transfer of data, control and status information between the microcomputer and the I/O devices, typical systems use polled I/O, interrupts, direct memory access, or any combination of these techniques.

In polled I/O, the microcomputer software interrogates each I/O device with an I/O instruction. It does this after setting up the address and control information.

Ideally, the sequence of instructions for a single interrogation should be as short as possible so that polling can be speeded up. A typical poll consists of the microcomputer addressing the I/O device and requesting its status, and the I/O device then responding with its status. The optimum case is for this complete sequence to be accomplished in one I/O read instruction, although three or four such instructions may not pose too much burden on some systems.

There are two basic polling schemes. In ring polling, the I/O devices are weighted equally—polled sequentially and serviced at the same rate. In priority polling, all I/O devices are unequally weighted, so that the certain of them are polled more often than others and are given a higher rate of service.

Priorities established in a polling scheme are relative. That is to say, a higher-priority device, while getting more frequent CPU attention, cannot override an “in-service,” lower-priority element.

Handling interrupts

Interrupts are the second way in which a microcomputer may communicate with the rest of the system. In this approach, the I/O device attracts the microcomputer's attention by activating a control line, to indicate that some external activity is either nearing completion or about to be initiated. An interrupt differs from polled I/O in three important ways. In the polled-I/O sequence, the microcomputer initiates the transfer of I/O and is synchronized with the program. In the interrupt sequence, the I/O element can initiate the transfer and is out of sync with the program. Also, interrupts may be given priorities within the system, but unlike polled I/O, a high-priority interrupt has the power to override a low-priority interrupt whenever “nesting” is permitted by the system design.

Once an interrupt has been initiated, the transfer of information between the interrupting I/O device and the microcomputer must ensue. This transfer can be made either by an I/O instruction or by a direct-memory-access scheme.

In all probability, a system will have several sources of interrupts, so that the microcomputer must determine which of them is requesting service. That done, it can ascertain what I/O transfer is required and will initiate the interrupt subroutine.

The interrupt subroutine consists of a predefined set of instructions unique to each interrupting I/O device. However, in addition to generating this custom I/O, the software must also perform certain housekeeping functions to ensure an orderly transition to the subroutine from the main program and back again.

In particular, before proceeding with an information

transfer, the microcomputer must arrange to preserve its current state. This includes the states of the accumulator and internal registers that are associated with the main program. The subroutine must contain utility codes both to store these elements in memory and to retrieve them later for use in restoring the microcomputer's prior state before the RETURN to the main program.

Ideally, the microcomputer should perform these utility functions with fewest possible instructions and in the shortest possible execution time. Complexity in an interrupt subroutine of course helps to reduce system throughput.

Direct memory access or "cycle stealing" is a technique of transferring data to and from the system memory at high rates of speed (between instruction executions). This feature is seldom found in low-performance microcomputers because DMA requires a lot of interface logic, but it is useful in devices that transfer information in large data blocks as opposed to single bytes.

Data transfers with this technique are typically initiated by the I/O device, which must provide a source and destination address and sometimes also describes the length of message and direction of transfer. The device first raises a DMA request via an appropriate control signal. The microcomputer responds at the completion of a memory or instruction cycle with a DMA acknowledge and relinquishes the bus. The I/O device then takes control of the bus and effects the transfer to or from the memory.

DMA and instruction cycles may be interleaved during the data-block transfer. The information will be transferred until the block-length counter is decremented to

zero or terminated by some other source.

Once the designer has determined how his system will be transferring its data, status, and control information among its various elements, he is then ready to measure the I/O performance of the microcomputer in relation to the rest of the system.

Measuring performance

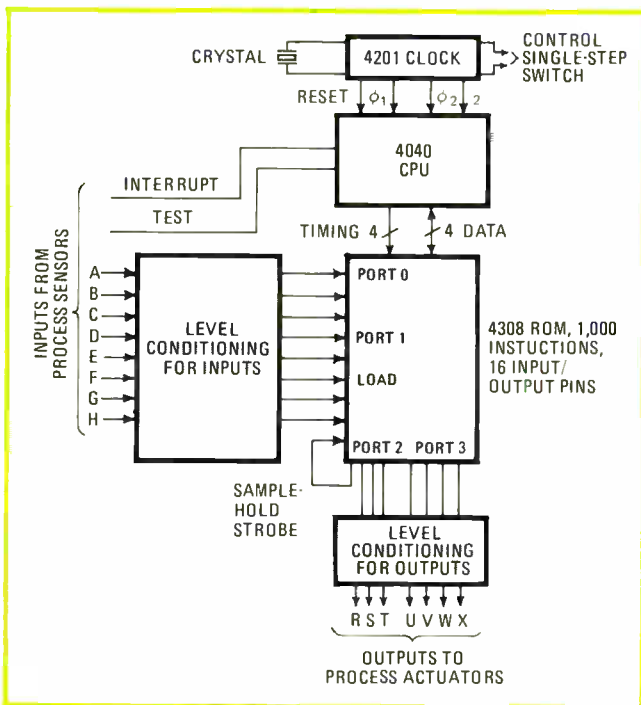
All I/O lines that must be controlled by the microcomputer should first be identified and then grouped into I/O ports of 4, 8, or 16 bits (depending on the microcomputer selected). Lines may be grouped together and encoded to reduce the number of I/O ports. Whether to reduce the number of I/O ports by adding decoding logic is a decision that the designer must make on the basis of the I/O line service rate, the I/O addressing scheme, and the cost of the hardware.

In measuring the microcomputer's responsiveness to the I/O activity at each of its ports, the first step is to derive a figure of merit called the activity index (AI). The larger the AI, the poorer the I/O performance of the microcomputer.

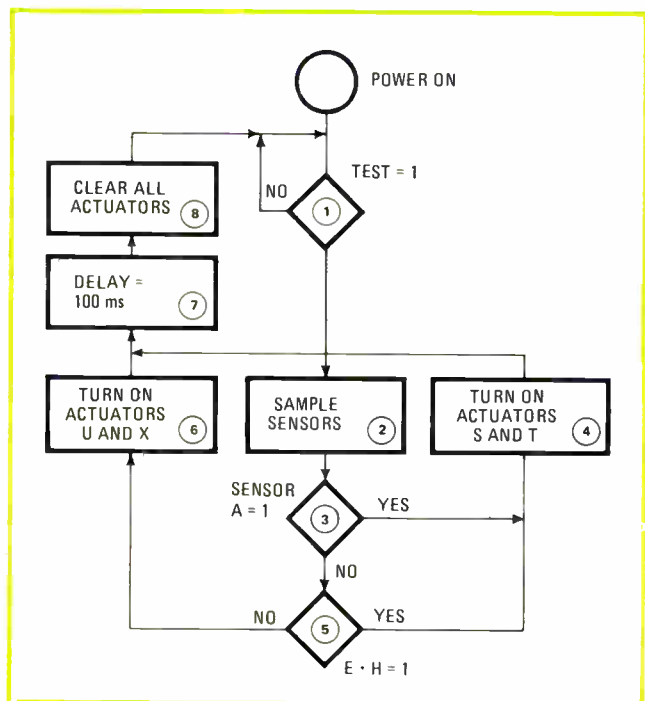
In most cases, the AI may be obtained simply by dividing the number of specifically I/O instructions (NIO) in an I/O routine into the entire length (total number of instructions) of the I/O routine (IR). To put it more briefly:

$$AI = IR/NIO$$

For example, an I/O routine may require four preparatory instructions before the actual I/O instruction can be allowed to occur and perform its function. Thus the total routine contains five instructions, including one I/O



3. Process-control system. A typical control system based on the 4040 microprocessor uses a ROM to interface the inputs from sensors and the outputs to the actuators. Data flows bidirectionally between the ROM and the CPU.



4. Flow chart. The operation of the controller in Fig. 3 can be described by a flow chart which in turn can serve as the basis for programming the controller. The numbers in each block refer to the routines in the program in Fig. 5.

FLOW CHART (Refer to Fig. 4)										
LABEL	CODE	OPERAND	COMMENT	ROUTINE	OPERATING PORT	LENGTH OF I/O ROUTINE (LR)	NUMBER OF I/O INSTRUCTIONS (NIO)	ACTIVITY INDEX (AI)	OPTIMUM SERVICE RATE (OSR)	
1	A	*JCN 9 A	;Test for TEST = 1		Routine 1	Port 2	5	1	5	0.200
2		*FIM 4 2,0	;Set up address for Port 2		2	0	8	1	8	0.125
2		SRC 4	;Send address		3	1	11	1	11	0.091
2		LDM 1	;Load strobe for accumulator (least significant bit Port 2)	1	4	2	3	1	3	0.333
2		WRR	;Write strobe		5	2 and 3	19	2	9.5	0.105
2					6	2	7	1	7	0.143
2					Total		53	7	7.6	
3		*FIM 0 0,0	;Set up address for Port 0							
3		SRC 0	;Send address							
3		RDR	;Read Port 0	2						
3		CLC	;Clear carry for test							
3		RAR	;Shift sensor A into carry							
3		*JCN 2 B	;Test sensor A = 1 if yes go to B							
5		*FIM 2 1,0	;Set up address for Port 1							
5		SRC 2	;Send address							
5		RDR	;Read Port 1							
5		*FIM 6 9,7	;Set for E · H test	3						
5		AN 6	;AND 9 with E · H							
5		CLC	;Clear carry							
5		ADD 7	;Add 7 to the accumulator							
5		*JCN 4 B	;If accumulator is ZERO, go to B							
4		LDM C	;Set data to turn on S and T two most significant lines Port 2							
4		SRC 4	;Send address for Port 2	4						
4		WRR	;Write turn on S and T							
4		*FIM 6 3,0	;Address for Port 3							
7	C	*FIM 0 0,0	;Set up for delay							
7		*FIM 2 0,E	by counting							
7	D	*ISZ 0 D	counter up to							
7		*ISZ 1 D	zero. The accumulative							
7		*ISZ 2 D	execution time will							
7		*ISZ 3 D	produce a 100-millisecond delay	5						
8		CLB	;Clear accumulator							
8		SRC 4	;Send address for Port 2							
8		WRR	;Clear actuators S and T							
8		SRC 6	;Send address for Port 3							
8		WRR	;Clear actuators							
8		*JUN A	;Jump to beginning							
6	B	*FIM 6 9,0	;Set up data to turn on U and X							
6		XCH 6	;Load in accumulator							
6		*FIM 6 3,0	;Set up address for Port 2	6						
6		SRC 6	;Send address							
6		WRR	;Write—turn on actuators U and X							
6		*JUN C	;Jump to C							

*Instructions requiring two memory cycles I/O instructions in color

5. Program. The assembly-language program for the controller in Fig. 3 is broken into six separate I/O routines associated with the various blocks of the flow chart in Fig. 4. The summary table shows the results of calculating an activity index for each routine.

instruction, and the AI works out at 5.

This measure of AI is adequate whenever all the instructions use the same number of memory cycles each. But sometimes some instructions will require two memory cycles, while others require only one. In this case, LR and NIO are more accurately defined in terms of the number of memory cycles each requires. In the above case, for example, if one of the four preparatory instructions is a two-cycle type, then the length of the routine will be six, and AI = 6.

It should be noted that an optimum performance level, AI = 1, occurs when the number of I/O instructions equals the length of the I/O routine. This is most closely approached in DMA routines, where activity prior to initiating the DMA is minimal. It should also be noted that although it is possible to achieve the optimum performance level of unity Activity Index it can never be exceeded, because the number of specifically I/O instructions can never exceed the number of instructions in the whole I/O routine.

In systems where there are several I/O ports doing I/O in a sequence, it is necessary to calculate the performance of the overall system. Such a system can also be described by an activity index. But to calculate the overall system performance it is most difficult to use merely the AI, since this cannot be equated over several ports. It is therefore necessary to define an entity called the Optimum Service Rate, equal to the number of I/O instructions per routine associated with an I/O port divided by the AI. In short:

$$OSR = NIO/AI$$

The graph of AI versus NIO in Fig. 2 shows that several I/O ports can have AI = 1 with different lengths of I/O subroutines. The OSR factors these differences in length into the calculation.

For example, assume there are two I/O ports, each with an AI of 1. Port A requires one I/O operation per routine (i.e., DMA). Port B requires four. The OSR for Port A is thus 1, and the OSR for Port B is 4. Port A hence has the better service even though both ports have an AI of 1.

The OSR for each port may be calculated from the system flow chart. Each port has an associated I/O service routine, which can be measured. Once the OSRs have been calculated for each port, the overall performance of the microcomputer may be calculated by the sum of the OSRs:

$$\sum_{n=1}^M \text{OSR}_n$$

The higher the sum, the more efficient the selected microcomputer is for the given application.

Note, however, that this technique assumes the following when different microcomputers are being compared for a given application:

- The number of I/O ports is the same for each application.
- Both I/O operation and I/O subroutine operation used in the calculation are reduced to a basic memory-cycle count; that is, if an I/O instruction requires two memory cycles, the NIO equals 2. If the IR is 8 instructions and 12 memory cycles, the IR equals 12.
- If the microcomputers being compared have grossly different cycle times, these must be factored in by proportioning the cycle times over the NIO and IR.

From theory to practice

To determine the nature of the I/O required for an application, it's best to begin by drawing a flow chart, showing the type of transfers (data, status, and control) and incorporating the number of I/O ports and the transfer method used (polled I/O, interrupt, and DMA). The next step is to pick a particular microprocessor and use the flow chart to program it for the application. Finally, an activity index for the microcomputer is derived from the program.

As an example, consider a system configured to perform a simple process-controller function (Fig. 3). Here, the 4040 central processing unit executes the program and performs the input and output program operations.

The 4201 system clock provides the CPU with its basic timing via a two-phase clock—a crystal attached to the appropriate lines. The 4201 also has a POWER ON RESET or CLEAR to initialize the system, plus a single-step RUN/STOP mode control to "step" the microcomputer one cycle at a time.

The 4308 read-only memory is linked to the 4040 via a 4-bit data bus and four lines of timing. It is a dual-function device—besides containing 1,024 8-bit words of program, it interfaces to 16 programmable input or output lines. (In Fig. 3 the 4308 has 8 bits of input and 8 bits of output, but any combination is possible.)

Since the MCS-40 is a 4-bit computer, the 16 pins of I/O are organized into four 4-bit ports. This does not prevent the computer from sampling some 4-bit multiple 4 bits at a time, as shown in Fig. 3.

The 4308 ROM has a load strobe input, shown being driven by the output labeled a sample-and-hold strobe. The input allows the CPU to sample, at some point in time, eight lines of information. This information can be digested 4 bits at a time after sampling.

The outputs are also organized around the 4-bit port of the 4308. They are fed to a level-conditioning circuit

that produces the final output, driving the system actuators and indicators.

With a flow chart describing the solution to a problem in a specified logical sequence, programming is a simple matter of converting the flow statements into the microcomputer's instructions. The flow diagram in Fig. 4 refers to the system inputs and outputs specified by the system block diagram shown in Fig. 3. Each part of Fig. 4 is numbered, and these numbers will be referenced in the description that follows.

Let us assume that when the test line is active (logical 1), the microcomputer will sample the input sensors and, on the basis of their states, provide a proper output-actuator response. The test line is a direct input to the 4040 CPU. Depending on its state, it can be branched on or used to perform a jump.

When power comes on, the program checks the test line ("diamond" 1). If it is not set, it will wait until it becomes set (test = 1) before proceeding to carry out the remaining instructions. When it has been set by some system variable (such as timer, liquid level, temperature, pressure, etc.), all other system sensors will be sampled and stored ("box" 2).

Sensor A will be the first sensor checked (3). If it is set, actuators S and T will be turned on (4). (For the sake of simplicity, it is implied that the test line is reset when any actuator is set). If sensor A were not set, then sensors E and H would have to be tested (5). If a logical AND existed between E and H, actuators S and T would be activated (4) as described above. If the logical AND of E and H were not true, then actuators U and X would be set (6).

Regardless of which actuators are selected to be turned on, a delay will be implemented (7) before the actuators are all cleared (8), and the sequence will be returned to the beginning.

Calculating performance

Referring to the program (Fig. 5), the code can be broken into Activity Index zones. Each zone is identified by a block in the flow diagram for the purpose of this example. The program can be divided into six discrete routines, or zones, each related to one or two of the major steps in the flow chart. If the number of memory cycles and the number of I/O instructions are counted for each zone, the summary table shown next to the program in Fig. 5 can be generated.

In the table, note that in zone 4, for which AI is 3, there are only two preparatory instructions preceding the I/O instruction, WRR. This represents efficient I/O control. However, note that zone 5 requires several instructions to generate the 100-millisecond delay before the actuators can be cleared, and this results in a rather high AI (9.5).

With the microcomputer chosen, the AIs of this particular program probably could not be reduced. However, greater efficiency might result if another microcomputer were designed into the same application—and now the designer has the tools to calculate the AIs for both devices, compare the two systems, and determine which will better serve the I/O needs of his application. □

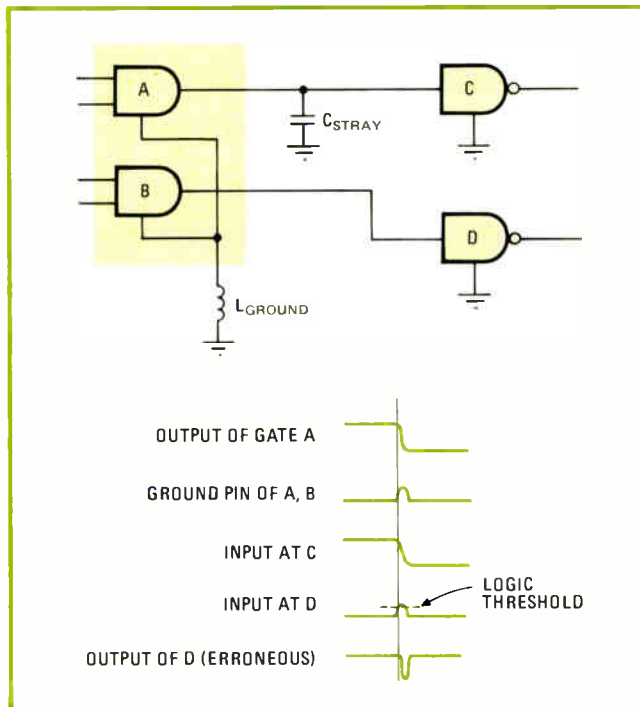
Circuit layouts minimize noise in digital systems

by Matthew L. Fichtenbaum
GenRad Inc., Concord, Mass.

Careful design of power and ground structures on printed-circuit boards and in multiboard systems can do much toward reducing the effects of noise from unwanted signal pickup. The layout techniques recommended here, which minimize ground inductance and stray capacitance, have contributed to the successful operation of many systems.

In Fig. 1, gates A and B, both of which are in one integrated-circuit package, drive gates C and D respectively. The ground path to A and B has some stray inductance, shown as L_{ground} , and each signal line has some capacitance to ground, such as C_{stray} on the output of A.

If A's output changes from high to low, the charge on C_{stray} causes a high instantaneous current to flow into A. The return path for this current is the ground lead, and the inductance in this path causes a voltage spike at the ground terminal. Output B, which should be in the low state, also carries this spike because the output cannot be lower than the ground level of the gate. So gate D,



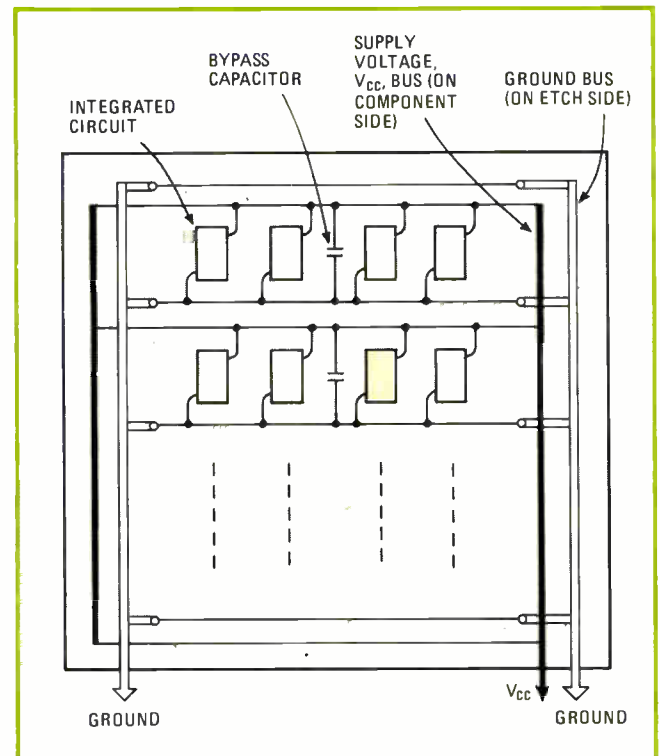
1. Shaky ground. Gates A and B suffer unwanted coupling through inductance L_{ground} in the common ground lead. When gate A discharges C_{stray} , an erroneous signal appears at gate D.

driven by B, sees an erroneous pulse at its input.

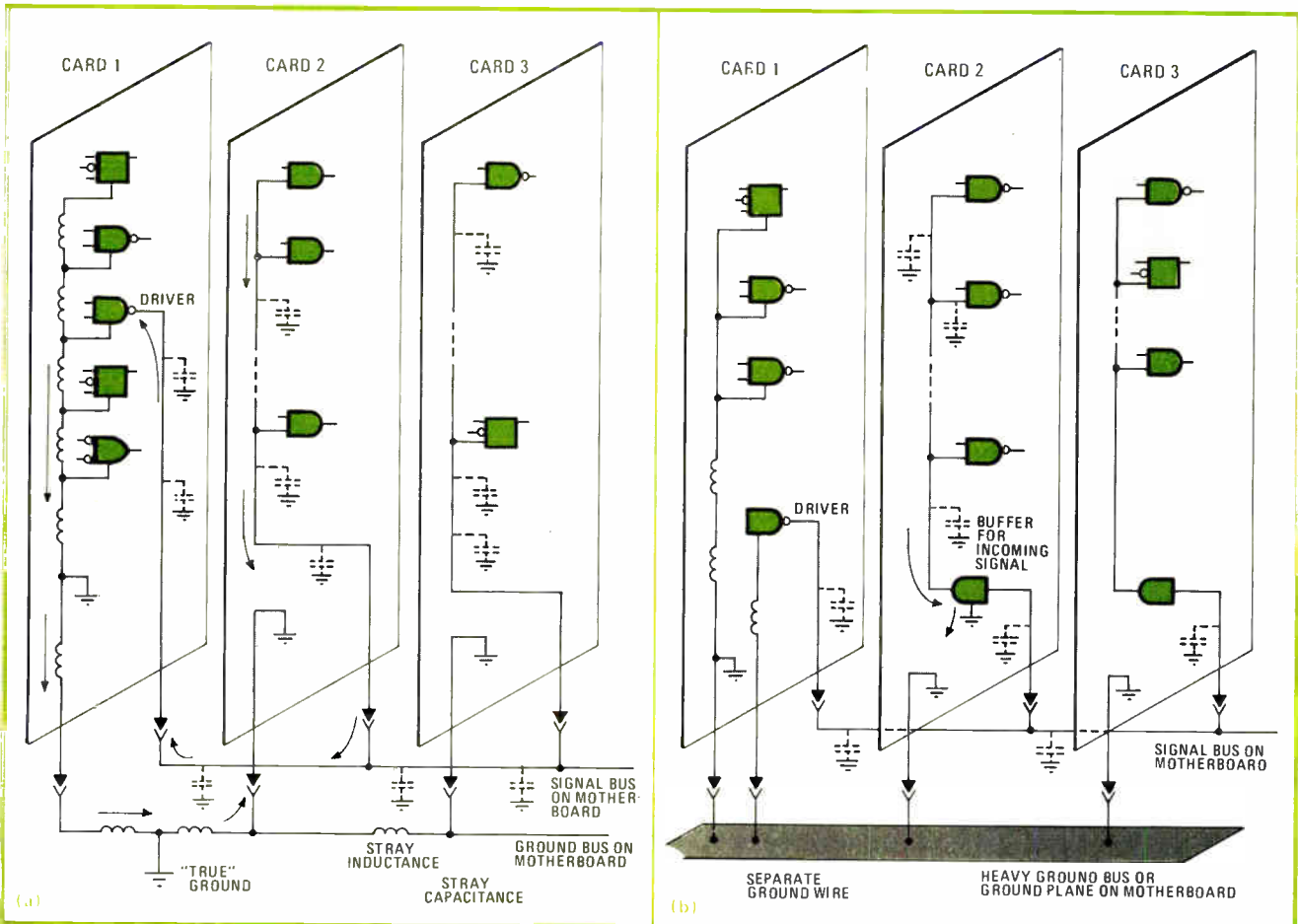
This effect may be lessened in several ways. Keeping tracks short, to decrease capacitance C_{stray} , reduces the spike amplitude. Although a resistor or inductor in series with the driver can limit the peak discharge current, they reduce system speed and can place unacceptable limitations on fanout. A better attack is to minimize the inductance in the ground lead through the use of a good ground structure.

An ideal solution is the full ground plane common to multilayer boards, which maintains minimal inductance and maximal amount of interconnection. Unfortunately, multilayer boards are expensive and difficult to justify for most circuitry.

The ground structure on a double-sided board in Fig. 2 gives a good approximation to a full ground plane. A V_{CC} bus runs up the right and left edges of the front surface of the board, and a ground bus runs up both edges on the back. Horizontal buses connected to the risers at the edges carry V_{CC} and ground for each IC. The buses' widely separated paths keep ground inductance low. Bypass capacitors, placed between the power and ground buses that feed a row of ICs, suppress the spikes in the supply current when an output switches. Because of the ample interconnection, few bypass capacitors are



2. Grounds for confidence. The solid bar represents the supply voltage bus on the front of the circuit card, and the open bar is the ground bus on the back. The round holes allow back-to-front crossover. The grid structure of the bus lines approximates power and ground planes to keep inductance and noise low.



3. Cool bus. Stray inductance and capacitance in a multicard system (a) can cause noise problems between cards. The changed signal paths and ground structure in the arrangement shown on the cards (b) make the system less noisy and more reliable.

required; even so, the distance between any IC and a capacitor is small, so the spike path is short.

The same sort of noise problems exist in multicard systems where the logic signals communicate between cards. In Fig. 3a, the driver gate on card 1 must necessarily drive the stray capacitance on three cards and the motherboard. The resulting ground transients at the driver couple into other devices on card 1, so there could be serious noise.

In Fig. 3b, the system has been restructured to reduce noise. A ground plane or several widely spaced heavy ground tracks on the motherboard help keep all card grounds at the same voltage. Cards 2 and 3 buffer

signals from the signal bus with a device near the bus connector. This buffering reduces the capacitive loading on the bus by shortening the length of track directly connected to it. It also keeps the heavy signal currents in the multiple loads local to the receiving card. Locating the driver near the bus connector keeps its paths short.

Perhaps most important, the driver receives its ground through a separate connection directly from the motherboard. This separate line keeps ground transients from affecting other devices on the card. It can dramatically increase the likelihood that the system will function properly, even with the long bus runs encountered when the card is on an extender. □

ICs replace memory scope for pulse measurements

by Daniel A. Swihart and Robert W. Thompson
DeWild Grant Peckert and Associates Co., Rock Rapids, Iowa

A 10-megahertz crystal oscillator is the secret ingredient in a circuit for reading out the time interval between two

nonrecurring logic pulses or the duration of a single pulse. The circuit is an inexpensive alternative to a memory oscilloscope or a commercial frequency counter for examining the nonrecurring pulses.

By counting oscillator cycles, the circuit provides a digital readout of the nonperiodic time intervals—for example, with proper interfacing circuitry, it can measure the cycle time of a microprocessor function or calibrate test equipment such as a pulse generator. Parts for the complete circuit cost about \$50.

As the figure shows, two-input exclusive-OR gates

FUNCTION TABLE FOR EXCLUSIVE-OR GATE (7486)			
Pulse edge to be detected	Inputs		Output
	Control	Probe	
Rising	Low	Low	Low
	Low	High	High
Falling	High	High	Low
	High	Low	High

(7486s) are the first stage in the pulse detection. The output of such a gate provides a high only when the logic levels on its inputs are different (see table). By using one input as a control (switching it to either the supply voltage, V_{CC} , or ground), the user can make the output go high, no matter whether a low or a high logic level is applied to the other input, which is connected to a test probe.

The gates' outputs are connected to a dual monostable multivibrator (74123). When a gate's output goes high, the multivibrator triggers on the rising edge, and an output pulse goes to a set-reset (\bar{S} - \bar{R}) latch (74279). The latch output, Q, controls a NAND gate, which passes the 10-MHz signal to a series of decade counters when Q is high. Each 10-MHz pulse corresponds to a time interval of 0.1 microsecond.

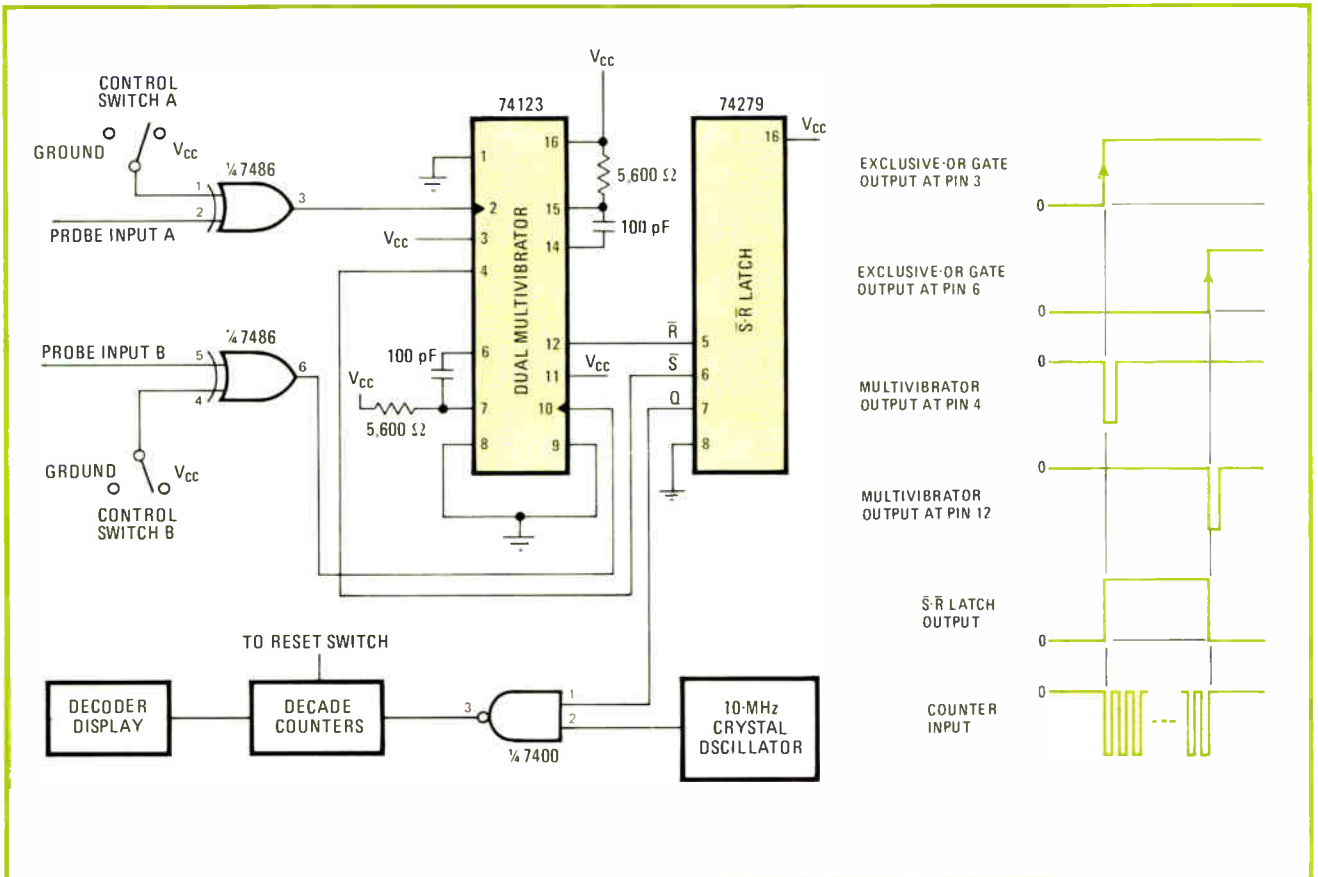
When a nonrecurring logic pulse occurs at probe input A, a pulse is applied to the \bar{S} input of the latch, setting the latch's output to a high logic level. Probe input B causes a pulse to be applied to the \bar{R} input of the latch, thereby resetting the latch's output to a low level.

The oscillator signal is counted only during the time interval between the set and reset pulses to the latch. The data displayed is the time interval between the rising (or falling) edge at probe input A and the rising (or falling) edge at probe input B. Of course, the input to probe A must always precede the input to probe B.

To measure the time interval between two nonrecurring pulses, connect probe inputs A and B to the circuit under test and switch control inputs A and B to the desired positions, whichever are necessary to detect rising or falling edges.

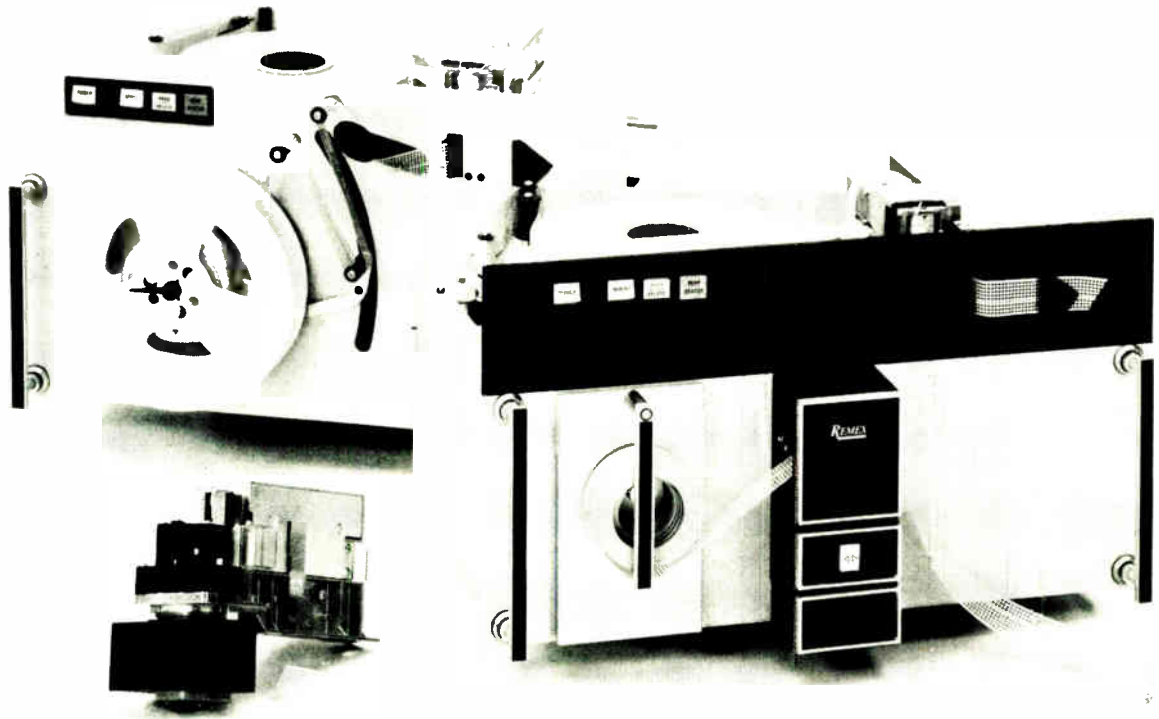
The duration of a single nonrecurring pulse is measured by connecting probe inputs A and B to the same place in the circuit under test, and setting the control inputs to the proper positions. For example, to measure the duration of a positive pulse, position switch A to ground and switch B to V_{CC} . The rising edge of the pulse will set a high on the latch's output, and the falling edge will reset the output to a low. The system's accuracy depends on the accuracy of the 10-MHz oscillator.

Engineer's notebook is a regular feature in Electronics. We invite readers to submit original design shortcuts, calculation aids, measurement and test techniques, and other ideas for saving engineering time or cost. We'll pay \$50 for each item published.



Alternative to memory scope. In this circuit, the spacing or duration of nonrecurring pulses is measured with transistor-transistor-logic detection circuitry that counts cycles of a 10-MHz oscillator. Seven digits can be displayed, giving readings from 0.1 microsecond to 0.9999999 second. This technique can be used in lieu of a memory scope for preserving nonrecurring pulses in digital circuits.

The Right Tape Perforators From REMEX Give More Punch For The Money



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Engineer's newsletter _____

The case builds against using LEDs on the ac line

Alan R. Miller's suggestion [*Electronics*, June 10, p. 132] of connecting a light-emitting diode and series capacitor directly to the ac line has come under fire from Nathan K. Weiner, American Science & Engineering, Woburn, Mass., as well as Elliot S. Simons [*Electronics*, July 22, p. 124]. Weiner says that the LED current is governed by the phase of the line when the LED is switched on and by how large a portion of the active chip area is conducting during the turn-on transient. "Current is limited only by the bulk resistance of the junction and the equivalent series resistance of the capacitor," he explains. **Localized high-current densities can burn out portions of the active chip area and eventually destroy the entire LED.** He guesses that Miller's success with this circuit may be due to the use of a low-quality capacitor (not an ac type), having either high series inductance or resistance that limited LED current.

More memory in the SR-52 calculator . . .

In Engineer's Newsletter, Philip R. Geffe has already noted [*Electronics*, July 22, p. 124] that Texas Instruments' SR-52 calculator has some 30 extra addressable data registers, at locations 70 through 99. But, says David M. Mackenzie, program manager at Doric Scientific, San Diego, Calif., **locations 60 through 69 can also be used for read/write functions.** Additionally, he notes, data written into locations 70 through 99 can be recorded on the calculator's magnetic program card for later loading into the registers. "At 0.02 to 0.03 cent a bit, the SR-52 is one of the lowest-cost nonvolatile read/write memories going, although somewhat awkward to use," observes Mackenzie.

. . . and some cautions on how to avoid errors

Each of the SR-52's registers at locations 70 through 99 can store about 8.5 program steps, although the space each keystroke occupies depends on the instruction given, says C. J. Mitchell of C.M. Instrumentation Ltd., Bracknell, Berks., England. If a program does not occupy the machine's full 224-stroke capacity, he notes, the unused program stores may be employed as data stores in the program—but with caution. **For example, if registers 93 and up are empty, it's best not to use 93.** Also, the calculator must be in its floating-decimal-point mode when you're recalling registers, since otherwise a register could seem empty though in fact it contained a very small fraction. Mitchell adds another word of advice—it's not possible, through indirect entry and recall, to use registers 100 upwards. For these locations, all but the last two register digits are ignored.

A lasing material that beats neodymium YAG

Looking for a solid-state laser that's easier to use and offers better performance than neodymium-YAG types? A new material being manufactured for the Air Force Materials Laboratory by Lambia-Airtron division of Litton may be just what you want. It's **anisotropic yttrium aluminate doped with neodymium, which sustains smaller thermal losses than conventional lasing materials,** does not require an external component to polarize the laser light, and gives increased energy storage for electro-optical switched lasers. The new material is suitable for linearly polarized continuously pumped lasers, flash-pumped lasers, and Q-switched lasers for aircraft and satellite applications. AFML will loan tested rods to qualified Government agencies and contractors. Direct inquiries to: Air Force Materials Laboratory, Wright-Patterson AFB, Ohio, 45433.

—Lucinda Mattera

Erased any PROMS lately?

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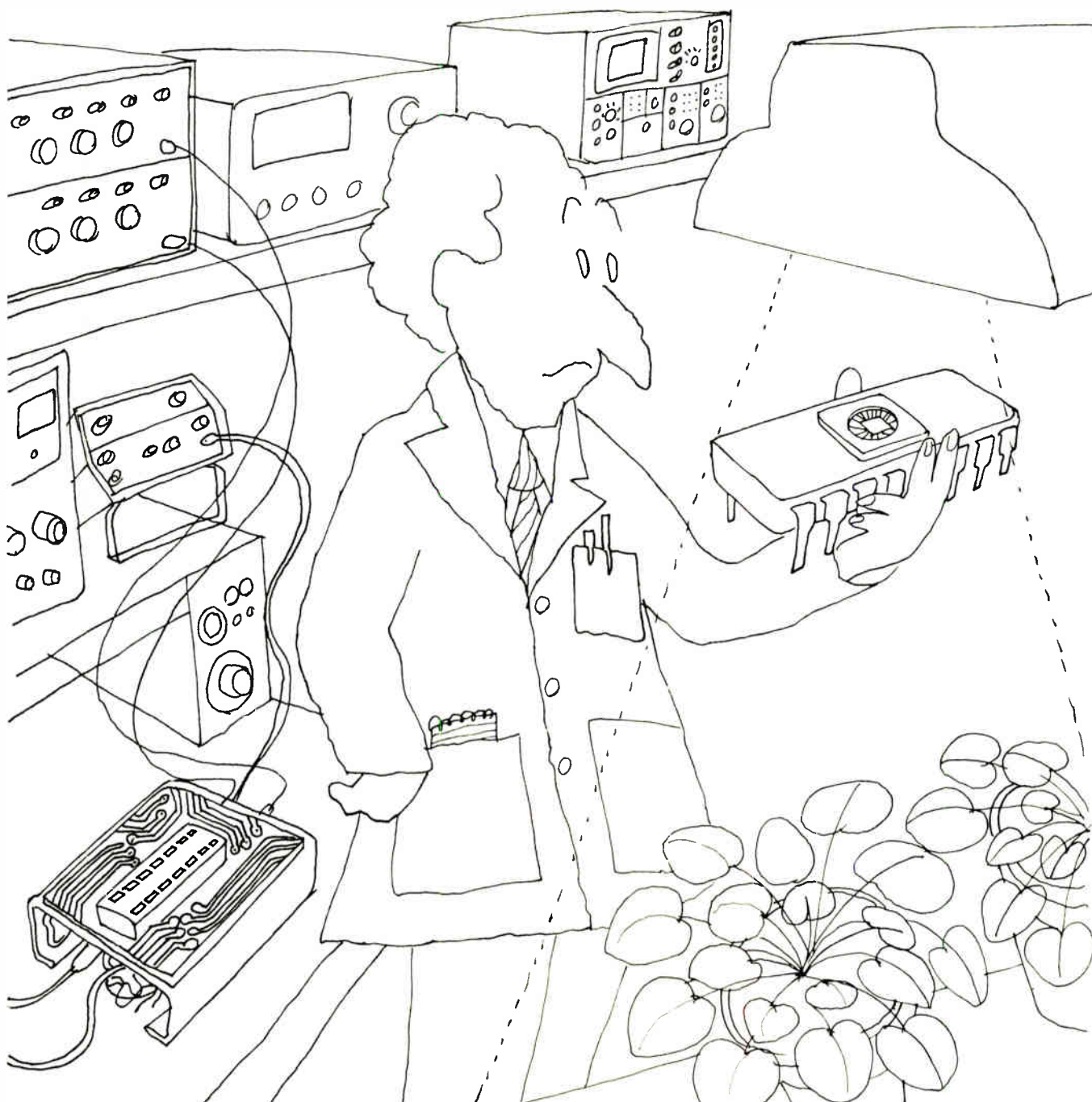
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World Radio History

Multimeter uses 8080 'brain'

Microprocessor controls separate analog and digital data buses that handle a wide variety of measurement and interface options

by Andy Santoni, Instrumentation Editor

When the Fluke 8500A is first turned on, its seven-segment light-emitting-diode displays light up the legend III. That's only the first indication that something's different about this meter.

The 8500A's chassis is a simple, passive frame and motherboard into which plug separate printed-circuit cards for input-signal conditioning, a-d conversion, internal control, input/output interface, power supply, and even the front panel. The instrument's "brain" is an 8080-type microprocessor, mounted on the internal control board, which manages communications among the other boards over analog and digital data buses.

The 8500A is an autoranging 5½-digit multimeter that can be configured for instrument-system applications as well as bench-top laboratory use. It has a fairly simple front panel from which the relatively limited range of bench-top measurement capabilities can be controlled. A greater variety of features can be called up by remote control, as in systems applications.

For example, the 8500A's front-panel sample-rate switch has two

positions—two or eight readings per second. But under remote control, the instrument can be programmed for any of 17 sample rates, from 500 readings per second to one reading every nine minutes.

Upon initial operation or request, after the salutation has appeared for about two seconds, the 8500A displays its model number and variation for about one second, then reads out the options that have been installed. During this interval, the function switches are active and a function and range may be selected. If a range is not selected, the instrument automatically selects the 1,000-volt dc range.

The 8500A employs Fluke's recirculating-remainder analog-to-digital conversion technique with the addition of bidirectional error-correction. In its basic configuration, the 5½-digit 8500A, priced at \$2,395, measures dc voltage on five ranges with resolution up to 1 microvolt. Automatic ranging is under the microprocessor's control.

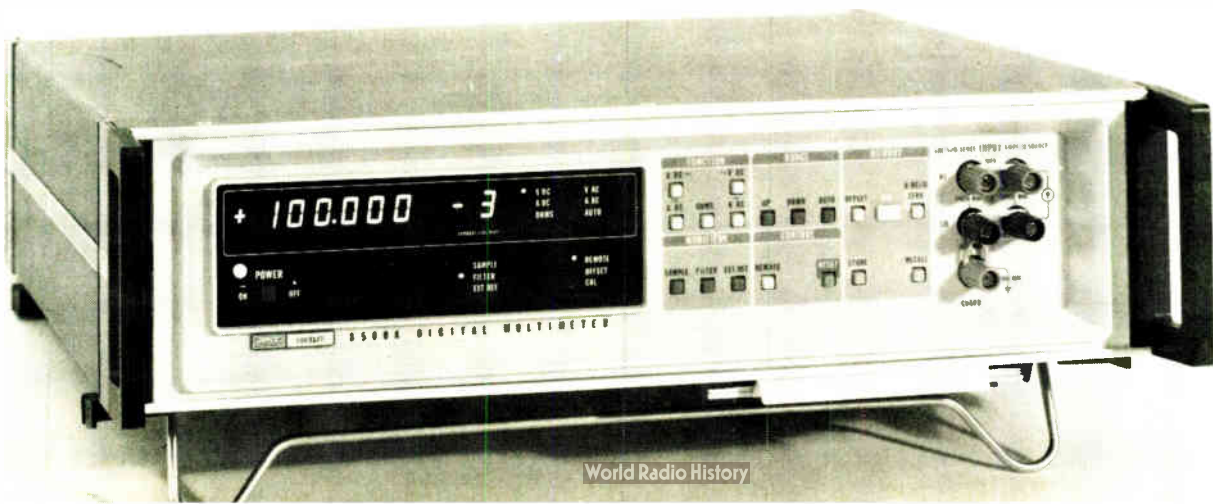
Ratio measurements are made by measuring the input signal at the front panel and the external reference applied to a rear-panel connec-

tor, then calculating the ratio. This eliminates some of the inaccuracies of standard ratio circuits, which substitute the external reference for the voltmeter's internal analog-to-digital-converter reference.

Beyond the basic instrument, a large number of options can be added to tailor the 8500A to many applications. Either of two plug-ins may be chosen for ac-voltage measurements. The averaging converter (option 01), priced at \$450, handles up to 1,000 v on four ranges, with a bandwidth from 10 hertz to 300 kilohertz. Accuracies within $\pm(0.1\% + 15 \text{ digits})$ and resolution up to $10 \mu\text{v}$ are obtainable.

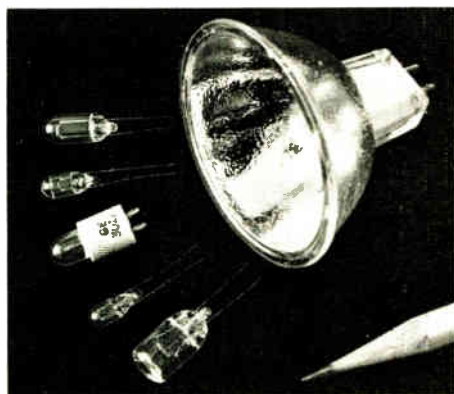
The true-rms converter (option 09), priced at \$475, offers similar specifications. A current module (option 03), priced at \$395, adds current-measurement capability for both dc and, when an ac voltage option is installed, ac signals. Readings on five ranges from 100 microamperes to 1 ampere can be made. Accuracies are within $\pm(0.03\% + 10 \text{ digits})$ with a source impedance of 2 kilohms on dc, within $\pm(0.06\% + 8 \text{ digits})$ on ac.

The resistance-measurement op-



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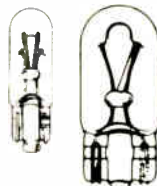
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#3-6254R

Dec. '74 Glow Lamp catalog features 8 pages and 50 changes for 83 Glow Lamp Indicator and Circuit Component lamps.

For up-to-date technical information on any of these items write: General Electric Company, Miniature Lamp Products Department #3382-M, Nela Park, Cleveland, Ohio 44112.

GENERAL ELECTRIC

New products

tion, priced at \$395, offers four-terminal measurements on eight ranges from 10 ohms to 100 megohms.

System options also include measurement isolation, costing \$295, which replaces the jumper printed-circuit board that connects the 8500A's internal analog and digital buses. The module isolates analog signal processing and conversion from digital processing, control, display, and input/output.

The measurement-isolation option is required when any of three available interface options are chosen. The \$395 parallel-interface module, option 07, is a 16-bit duplex register interface that is compatible with many minicomputer systems. The \$295 bit-serial asynchronous interface module, option 06, interfaces the 8500A to systems using either RS232B, RS232C, or current-loop interfaces.

The third interface option, priced at \$450, makes the 8500A compatible with IEEE standard 488 systems. Only one of the three interface options can be installed at one time, but any one can be exchanged when the top cover is removed.

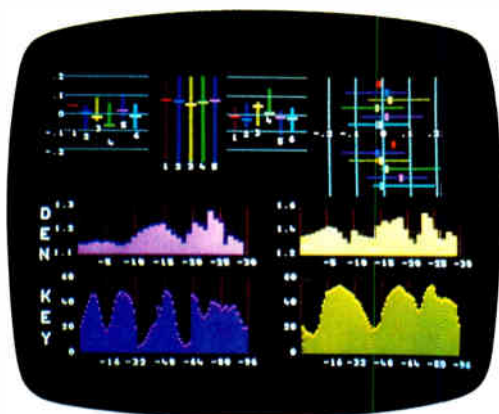
With the \$395 calibration memory installed, correction factors for each range point are derived from a standard input during calibration-mode operations and are stored in a battery-powered nonvolatile memory. This allows the operator to remove power from the instrument, or the system can suffer a power failure, without the loss of automatic-calibration factors.

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CB spawns novel switch designs

Squared-off 40-position binary-output rotary units depart from traditional approach of multiple ganged decks

by Larry Armstrong, Midwest bureau manager

Now that the Federal Communications Commission has approved an expansion of the citizens' band radio service to 40 channels, CB-equipment manufacturers are scrambling to find indexing channel-select switches that can handle the expansion without increasing the size of the set. Several switch suppliers have arrived more or less independently at similar solutions: they've scrapped the traditional multiple-wafer rotary switch and opted for a new rotary design that's derived from the thumb-wheel switch.

Instead of using rotating wipers on

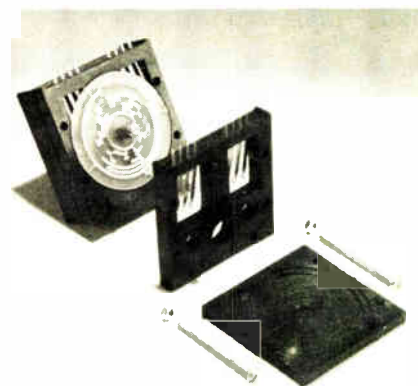
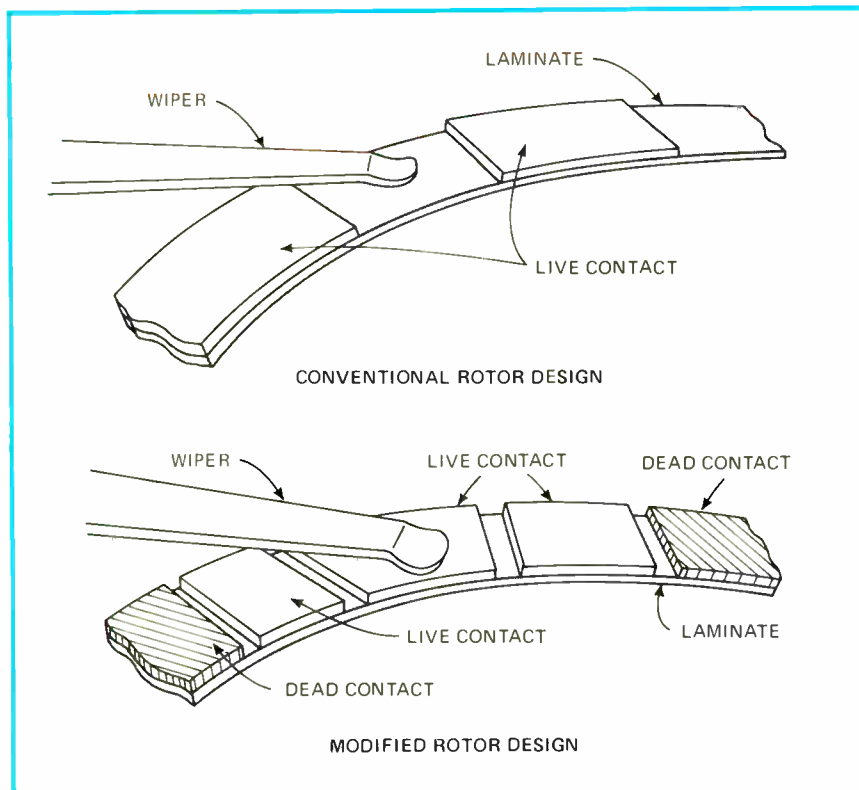
stationary printed-circuit boards, most makers connect a disk-shaped printed-circuit card to the switch's shaft. The board is etched and plated with concentric rings of metal—rings that determine the switching pattern as the board rotates past stationary wipers mounted in the switch housing.

With estimates of domestic CB radio production running as high as 3 million units in the U.S. next year, and perhaps another 18 million to be built in Japan, the CB industry will probably sop up as many switches as the components firms can turn out.

The switches are also suitable for other communications applications, as well as for uses in test and measurement equipment, computer peripherals, office equipment, and vending machines.

But it's the lucrative CB market that has lured a handful of new entrants. In addition to Oak Industries' Switch division, the major U.S. supplier of rotary switches for CB radios, and Standard Grigsby Inc., another traditional supplier, newcomers AMP Inc., Cherry Electrical Products Corp., and Digitran Co. are developing new channel-select switches. And Alps Electric Co., the major supplier of rotaries to Japanese CB firms, has designed its own version to become available in the U.S. through Chicago-based Kanematsu-Gosho USA Inc.

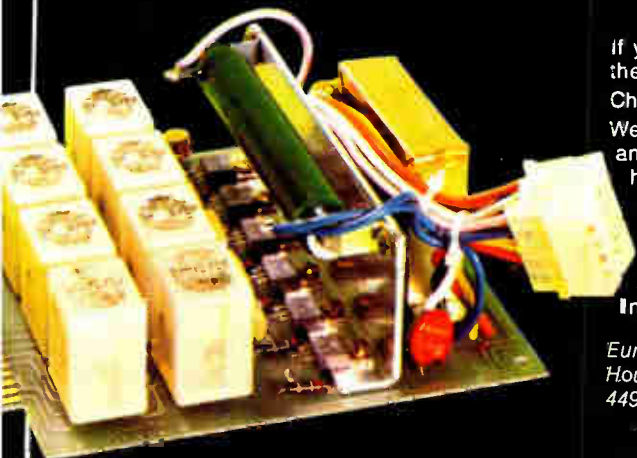
After a few months of grappling, the U.S. suppliers have standardized on a package that measures roughly 1½ inches square by ½ to 1½ in. deep. All have pc terminals coming out of the bottom, and all except Standard Grigsby's have the same



Square rotaries. New breed of rotary switches for CB radio are square, like the one at right from AMP. Internal designs differ, however. For example, most suppliers are using conventional rotor design, while both Oak and Cherry have a modified live/dead-contact version.

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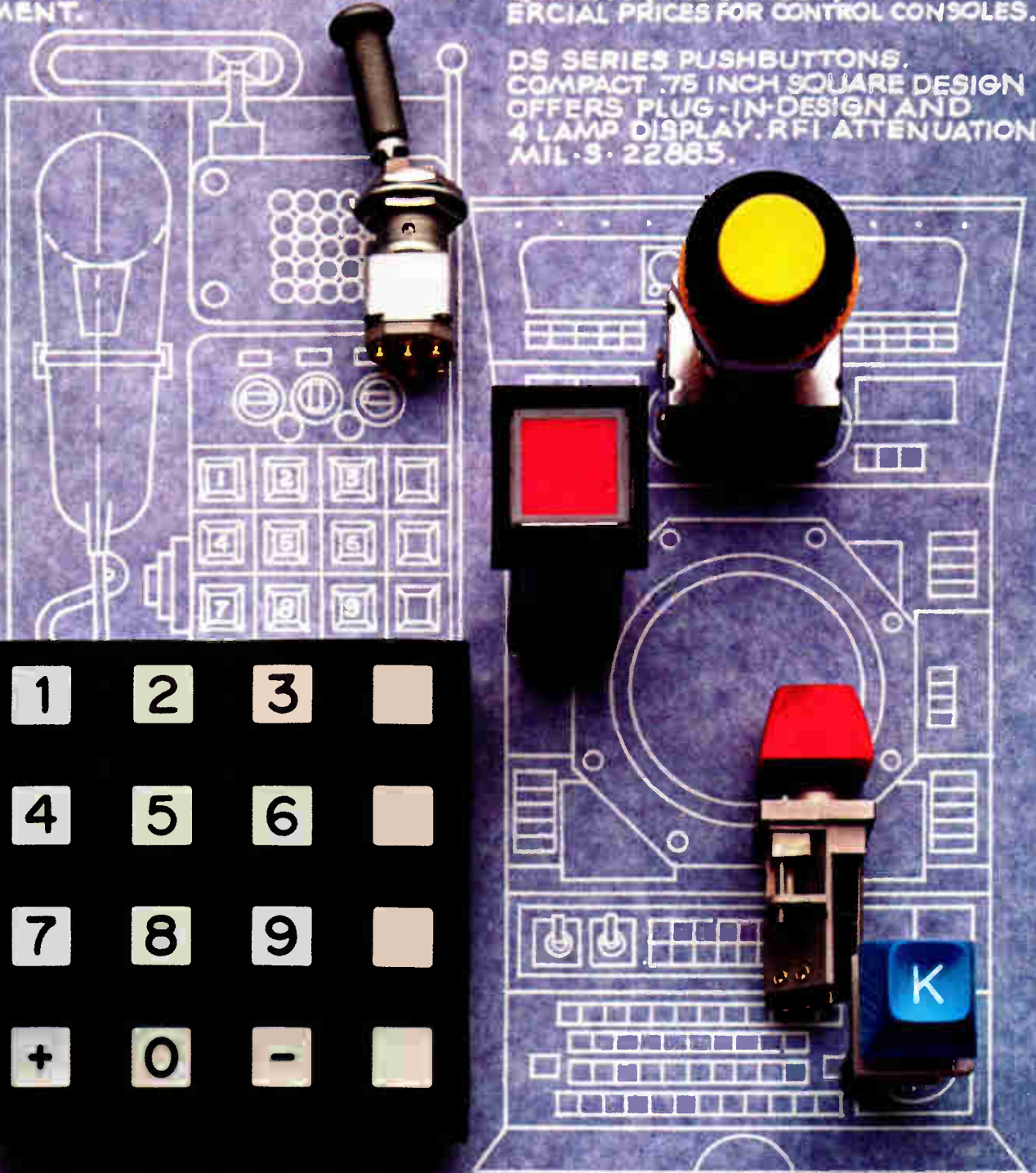
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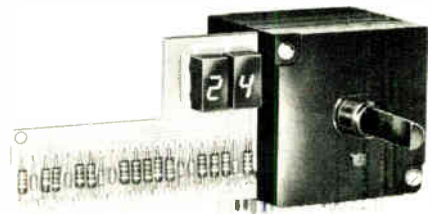
footprint: eight pins per row on 100-mil centers, with rows spaced 200 mils apart. Because the Standard Grigsby P/rel switch is held together with T-struts instead of strut screws, "we can squeeze in two more terminals, and make our disks larger," says Roy Slavin, president. The firm also went to the different footprint to increase reliability: the farther away from the shaft the switching circuitry is, the less critical becomes the alignment between wiper and pe-board metalization, Slavin says.

And the switches have to be reliable. Most CB makers agree that the channel expansion will mean a wholesale change-over from multiple-crystal sets to digitally synthesized transmit and receive channel frequencies from a single reference crystal. The switch generates the binary-coded-decimal number that commands the synthesizer.

The channel expansion will also increase the use of light-emitting-diode channel displays, and since the new rotaries are modular, a second deck can easily be added to drive a pair of seven-segment displays. Cherry, in fact, in addition to its standard Rotocode, is building a custom version (see photo above) that contains a rotating pc board to drive the synthesizer, plus a stationary board with rotating wipers to drive the LEDs and associated components, and an extra pair of pins to bring in the LED-drive voltage. "We can build the whole front end on that board if we're asked," comments Vincent Maida, marketing manager for new products.

Instead of the other suppliers' rotating boards, Digitran uses two fixed, double-sided boards with plated-through-holes—one for the frequency-switching code and one for the LED output. Sandwiched between the two is a notched detent wheel that also carries the wipers.

Contact ratings on all the switches are about 0.125 ampere at 24 or 28 volts dc. Cherry and Digitran use a selective gold plate on contacts and boards; Alps, Oak, and Standard Grigsby use silver; AMP plates bright tin over nickel on the copper contacts and uses electroless nickel



on the rotating boards. Oak and Cherry etch and plate both "on" and "off" areas of the boards—the "off" pads are isolated from the electrical circuit. "The contacts never touch the laminate," says Mike Hassett, Oak marketing vice president. "Precious metal isn't wiped back onto the metal conductors, and the edges of the pads give the switch a self-wiping action."

The other firms etch and plate only the electrical circuits. "We find that filling in the spaces with dead pads is more hazardous," explains Kenneth E. Gookin, product marketing manager at AMP. "The wiper has to step over twice as many edges, leading to contact wear."

Ready to ship. The detents are all different, but all are the star-wheel (notched-wheel) type. Mechanical life is guaranteed for at least 20,000 complete revolutions, and up to 100,000 in some cases. Oak will start shipping its Communicator Series in production volumes this month, followed by Standard Grigsby in September. Alps has started production, and AMP is in pilot production on its 3500 Series. Cherry and Digitran, which have sold samples, expect volume production to begin late this year.

Prices in 100,000 quantities for a two-deck switch range from \$2.25 (Standard Grigsby) to about \$3 (Oak and AMP).

Alps Electric Co. Ltd., 543 W. Algonquin Rd., Arlington Heights, Ill. 60005 [371]

AMP Inc., Industrial Division, Harrisburg, Pa. 17105 [372]

Cherry Electrical Products Corp., 3600 Sunset Ave., Waukegan, Ill. 60085 [373]

Digitran Co., Division of Becton, Dickinson, and Co., 855 So. Arroyo Parkway, Pasadena, Calif. 91105 [374]

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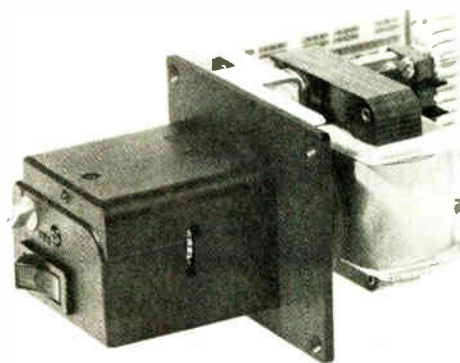
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Multimeter/counter rides on scope

Instrument can be added to Tektronix oscilloscopes including the new 250-megahertz-bandwidth model

by Bernard Cole, San Francisco bureau manager

A current thrust among instrument makers is incorporation of microprocessors to perform calculations and enhance performance. Going counter to this trend, Tektronix is introducing a multimeter/counter "piggyback" option on many of its portable oscilloscopes, including the new model 475A. The add-on, called the DM44, does not include a microprocessor, yet it permits a range of functions—including delta delayed sweep—previously available only on microprocessor-equipped scopes.

Also, earlier techniques used to enhance performance have been limited to more expensive portable and lab-type scopes and added about \$1,000 to their cost. They usually employed a microprocessor, digital-to-analog converter, and two comparators. In addition, a relatively large number of controls was required to operate the processor-based scope.

The DM44 is a simpler, less expensive multimeter/counter (\$410 with temperature probe, \$355 without) that can be added to the medium-price portable scope so indispensable to the maintenance and servicing of digital equipment, according to Soren Vestergaard, portable-instrument marketing manager at Tektronix. The DM44 option does not require a microprocessor nor a d-a converter, and it requires only a single comparator. Only two dials are required to control sweeps, rather than a combination of dials, buttons, and switches. The delay time, he says, can be adjusted continuously rather than in incremental steps, increasing precision. The delta delayed sweep and the time interval are displayed as a

negative quantity, an exclusive feature provided by the DM 44.

The new \$3,300 model 475A scope is a good example of how much power the DM44 option adds, says Vestergaard. Essentially a variation of the earlier model 475 portable oscilloscope, it has a greater bandwidth (250 instead of 200 megahertz), and slightly less sensitivity (5.0 instead of 2.0 millivolts per division) as well as a sweep rate of 1 nanosecond per division. The combination of the 475A scope and the DM44 is priced from \$3,635 to \$3,710.

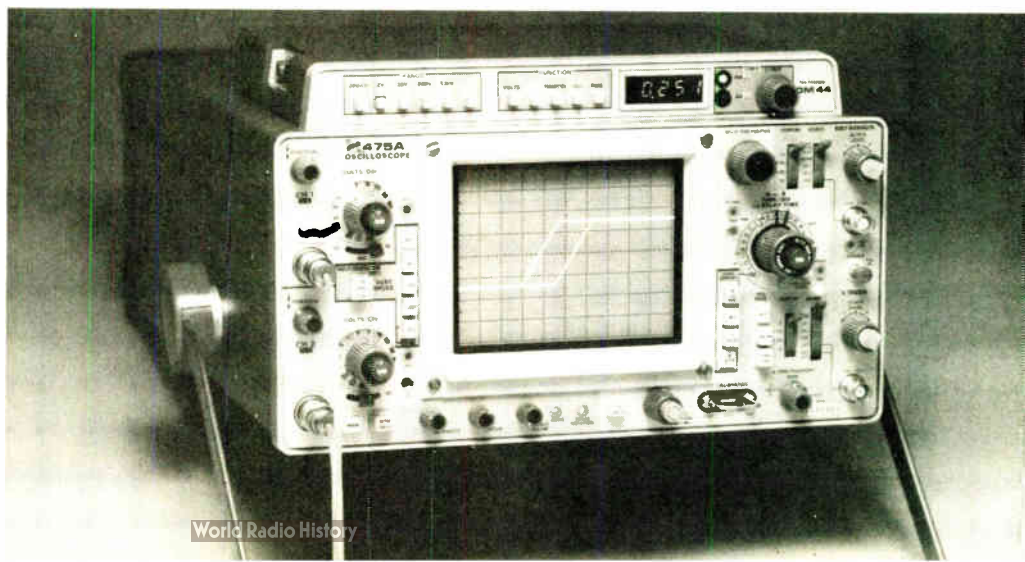
Speeds time measurements. Compared with conventional single delayed-sweep oscilloscopes, a model equipped with the DM44 multimeter/counter makes timing measurements with greater repeatability, speed, ease, and freedom from error, Vestergaard says. To measure a time interval on-screen, the oscilloscope is set for sweep A, intensified by sweep B. Using the oscilloscope's delayed sweep and delay-time controls, the two intensified spots are positioned at the beginning and end of the interval to be measured. At this

point, the time interval is read out on a 3½-digit display on the DM44.

For greater accuracy, says Vestergaard, the oscilloscope is switched to the sweep-B-delayed-by-sweep-A mode, where detailed views of the beginning and end of the time interval are displayed at the same time. Using the delta time control, the end of the interval is superimposed on the beginning to produce a readout of the interval, correct within 1%. By inverting the measured period for waveforms such as clocks, the DM44 also provides frequency measurements.

For still further convenience, the multimeter/counter add-on includes dc voltage measurement that is accurate within 0.1%, resistance measurement that is accurate within 0.25%, and temperature measurement from -55 to +150°C. All these measurements, says Vestergaard, are made independently of the oscilloscope, allowing dc-voltage monitoring or component-temperature monitoring simultaneously with associated waveforms.

Tektronix Inc., P.O. Box 500, Beaverton, Ore. 97077 [340]



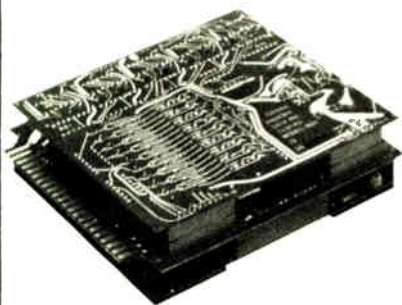
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Display and C-MOS converter hold instrument's power consumption to 300 mW

Because of their low power consumption, liquid-crystal displays are becoming increasingly popular as readouts for portable digital multimeters. Among the latest digital multimeters with an LCD readout is VIZ Manufacturing's model WD-751A.

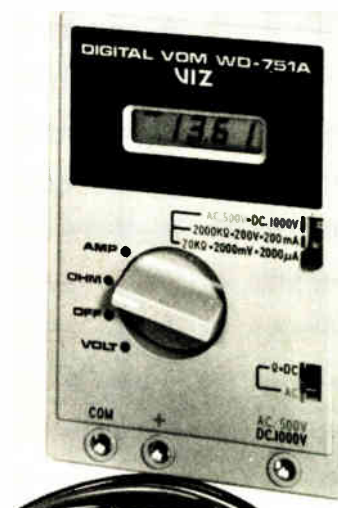
Priced at \$179, the 751A has a 3½-digit (1,999-count) field-effect liquid-crystal display and uses a complementary-MOS large-scale integrated circuit for analog to digital conversion. Between them, these two components keep power consumption down to 300 milliwatts. A set of four alkaline AA cells provides more than 30 hours of continuous use.

The Seiko liquid-crystal display has black numerals against a gold background to maximize contrast.

In operation, the WD-751A is semi-autoranging. A range-selector switch chooses among three positions, each of which covers two automatically selected ranges.

In ac- or dc-voltage ranges, for example, the first switch position covers 200 or 2,000 millivolts full scale, the second position covers 20 or 200 v full scale, and the third position handles 200 or 1,000 v full scale. Input impedance is 5 megohms in either of the two lower ranges and 10 M Ω in the highest range.

Accuracy is within $\pm(0.3\%$ of reading + 0.1% of full scale + 1 digit) on the lowest ranges, $\pm(0.5\%$ or reading + 0.1% of full scale + 1 digit) on the center ranges, and $\pm(1.5\%$ of reading + 0.1% of full scale + 1 digit) on the 1,000-v dc range. Accuracy is within $\pm(0.8\%$ of reading + 0.7% of full scale + 1 digit) from 40 hertz to 1 kHz on the



20-v ac range, for example.

Resistance to overload is especially important in voltmeters designed for portable use. On all but the 1,000-v ranges, the WD-751A can withstand up to 500 v dc or ac for up to 1 minute. On resistance ranges, the instrument can withstand up to 200 v dc or 150 v ac for 1 minute, and on current ranges, it can withstand up to 450 milliamperes ac or dc during a maximum of 1 minute on all but the highest range.

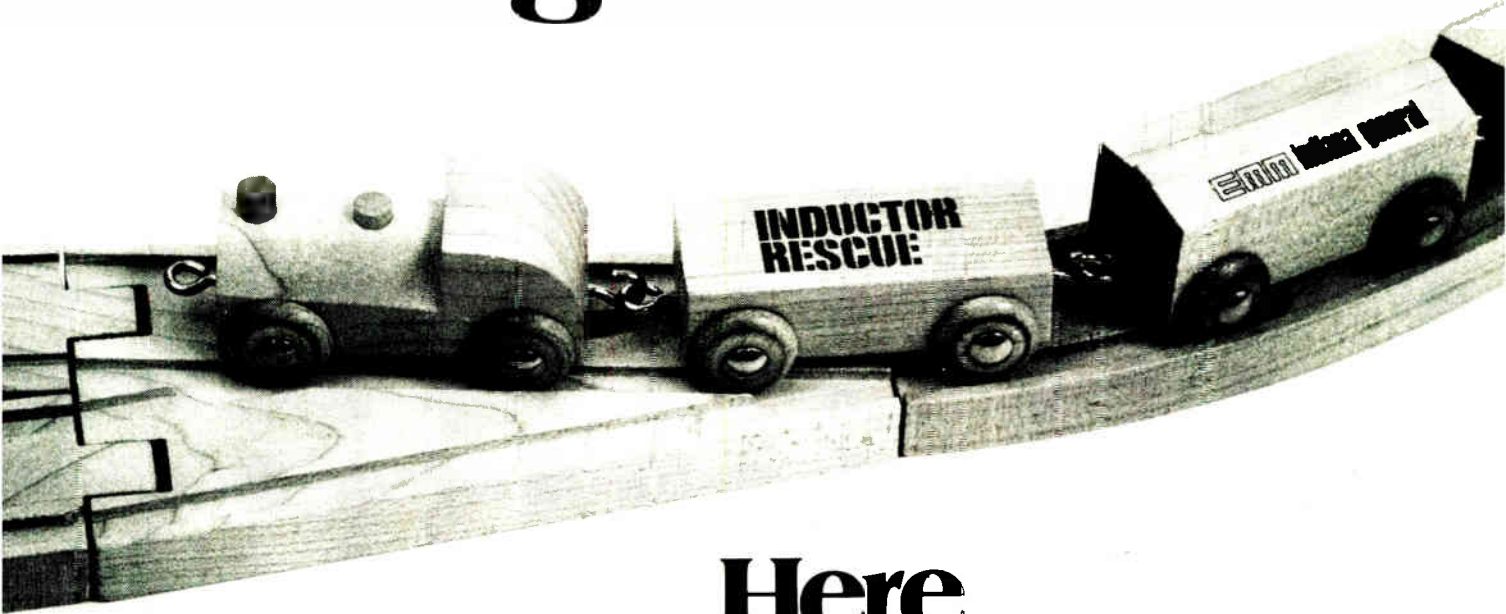
VIZ Manufacturing Co., 335 E. Price St., Philadelphia, Pa. 19144 [351]

Dc-coupled DMM measures voltage, current, and power

Capable of making power measurements at dc and at frequencies from 25 hertz to 1.2 kilohertz, the model 2514-16 is a dc-coupled, true-rms digital instrument that can also make individual measurements of dc and ac voltage and current. When measuring only voltage or current, the instrument's frequency range extends to 2 kilohertz.

The instrument's five voltage ranges—30, 60, 100, 150, and 300 v—can be combined with its five current ranges—0.5, 1, 2, 5, and 10 A—to yield power ranges from 15 watts full scale to 3 kilowatts. Maximum error on all ranges is 0.25%. On its most sensitive ranges,

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New products



the 2514-16 can resolve 0.01 volt per digit, 0.1 milliampere per digit, and 0.01 watt per digit.

The meter sells for approximately \$3,300. Its exact price depends upon options such as BCD outputs, programability, etc.

Yokogawa Corp. of America, 5 Westchester Plaza, Elmsford, N.Y. 10523. Phone (914) 592-6767 [353]

Triple-output bench supply has floating outputs

The model MPS 620M power supply is a triple-output bench instrument, but none of its outputs is connected to ground. One output is adjustable from 0 to 6 v dc, and can deliver up to 5 amperes at any voltage setting. The other outputs are a pair of tracking voltages that can be varied from 0 to ± 20 v dc; each output can deliver up to 1 A. The 20-volt outputs can be connected in series to form a 0-to-40-v supply, but they cannot be connected in parallel because they share a common terminal. Line regulation for all outputs is within 0.01%. The 0-to-6-v output also has a load regulation within 0.01% whereas the tracking outputs are regulated to 0.05% or 5 millivolts, whichever is greater. The time



required for the stabilized outputs to recover from a step-load change to within 10 millivolts of the original setting is less than 50 microseconds.

Special features on the 0-to-6-v output include remote error sensing, current limiting, and an adjustable crowbar. The current limiting, which is set to approximately 110% of the maximum rated current, allows the supply to sustain a short circuit indefinitely. The crowbar can be adjusted from 4 to 8v by a screwdriver. The MPS 620M sells for \$475.

Kepeco Inc., 131-38 Sanford Ave., Flushing, N.Y. 11352. Phone Paul Birman at (212) 461-7000 Ext. 742 [354]

1-GHz pulse-generator

system also generates words

An instrument system consisting of a mainframe and six plug-ins may be configured as a 1-gigahertz pulse generator, a 300-megahertz pulse generator, or a 300-MHz generator of 64-bit serial words. The six plug-in modules are a 300-MHz repetition-rate generator, priced at \$795, a



1-GHz rate generator at \$3,145, a 300-MHz output amplifier at \$795, a 1-GHz output amplifier at \$1,585, a word generator at \$2,510, and a combination delay generator/frequency divider at \$2,600. The system mainframe with power supply sells for \$820.

By combining the rep-rate generators with the delay generator/frequency divider and appropriate amplifiers, various single- and dual-channel pulsers can be configured. It should be pointed out that the incredible speed of the 1-GHz unit is

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Parameter	Four 1K Static RAMs (2102 AL-2)	One 4K Dynamic RAM (TMS 4051-1)
Power (max.)		
operating	1368 mW	882 mW
standby	168 mW	101 mW
Access (max.)	250 ns	250 ns
Board area ratio	3.6	1.0
Fully TTL compatible	yes	yes
100 Pc prices	\$20.00	\$12.26

Based on published data

same as the 2102AL-2.

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Applications Help

For your copy of the 4K dynamic RAM Application Note covering simple refresh, contact: Texas Instruments, M/S 669-4K, P.O. Box 1443, Houston, Texas 77001.



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New products

even more costly than appears at first because the 300-MHz output amplifier is a dual-channel unit, whereas the 1-GHz amplifier is a single-channel device. The transition time of the 1-GHz amplifier, however, is less than 300 picoseconds.

The word generator, driven by the 300-MHz rep-rate generator, can put

out words 16, 32, and 64 bits long at rates from 10 Hz to 300 MHz. The format may be return-to-zero or nonreturn-to-zero, and the sequence can be automatic, single, or gated.

Delivery estimates for the 8080A family are six to nine weeks
Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304 [355]

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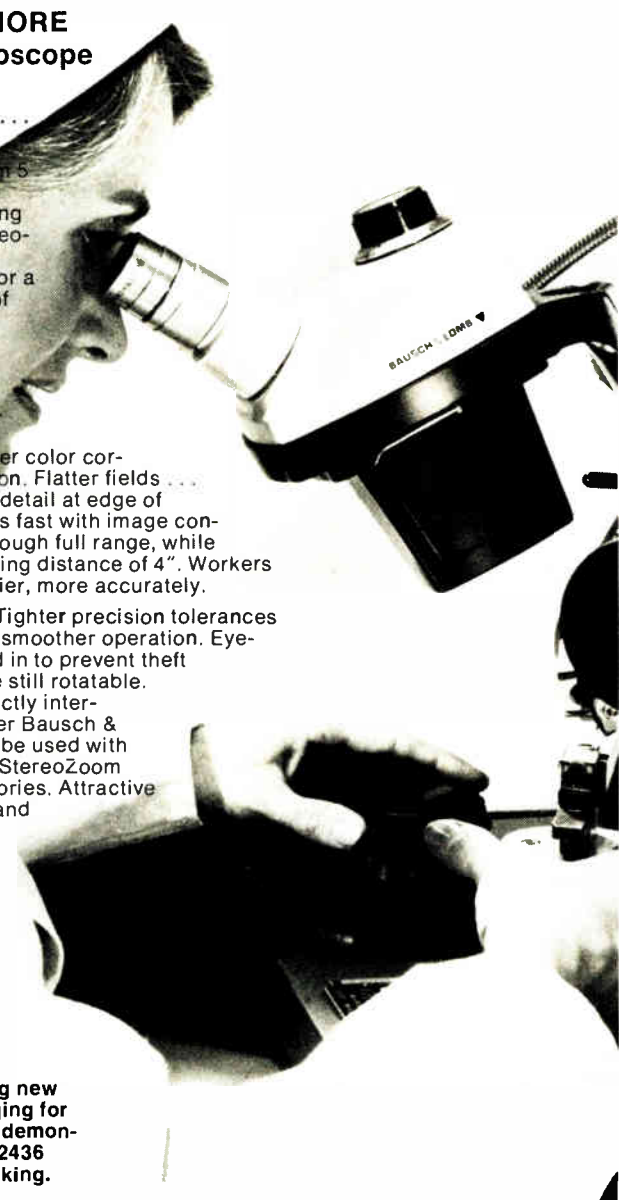
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Three-axis display includes
32 kilobytes of memory

A three-axis display system, the model 7200B, accepts analog or digital inputs, digitizes the analog ones, and stores them in its 32-kilobyte memory for processing and display. Developed originally for government spectrum-surveillance applications, the display, if connected to a suitable receiver or spectrum analyzer, can show how the spectral composition of a signal varies over time. The photo, for example, is a three-axis view of the 10-megahertz signal transmitted by wvv. Frequency-selective fading of the carrier and sidebands is obvious in the 16.8-second time span shown. The width of the frequency axis in the photo is 2 kilohertz, and the amplitude (vertical) calibration is 30 decibels per centimeter.

But the third axis of the system



need not be time. The instrument may be used, for example, to display some property of a silicon wafer as a function of position on the wafer surface. Other potential applications include voice prints and medical equipment such as that used in computerized axial tomography.

The unit, including 32 kilobytes of memory, a high-resolution cathode-ray tube display, and a 64-line scanner, is priced at \$38,000. Options include up to 64 kilobytes of memory, a bigger CRT, and up to 128 scan lines. The unit, of rack width, is 7 inches high and 21 in. deep. It weighs 56 pounds.

Emtel, Division of Develco, 404 Tasman Dr., Sunnyvale, Calif. 94086. Phone (408) 734-5720 [356]

Bausch & Lomb, Scientific Optical Products Division, 30408 N. Goodman St., Rochester, N.Y. 14602
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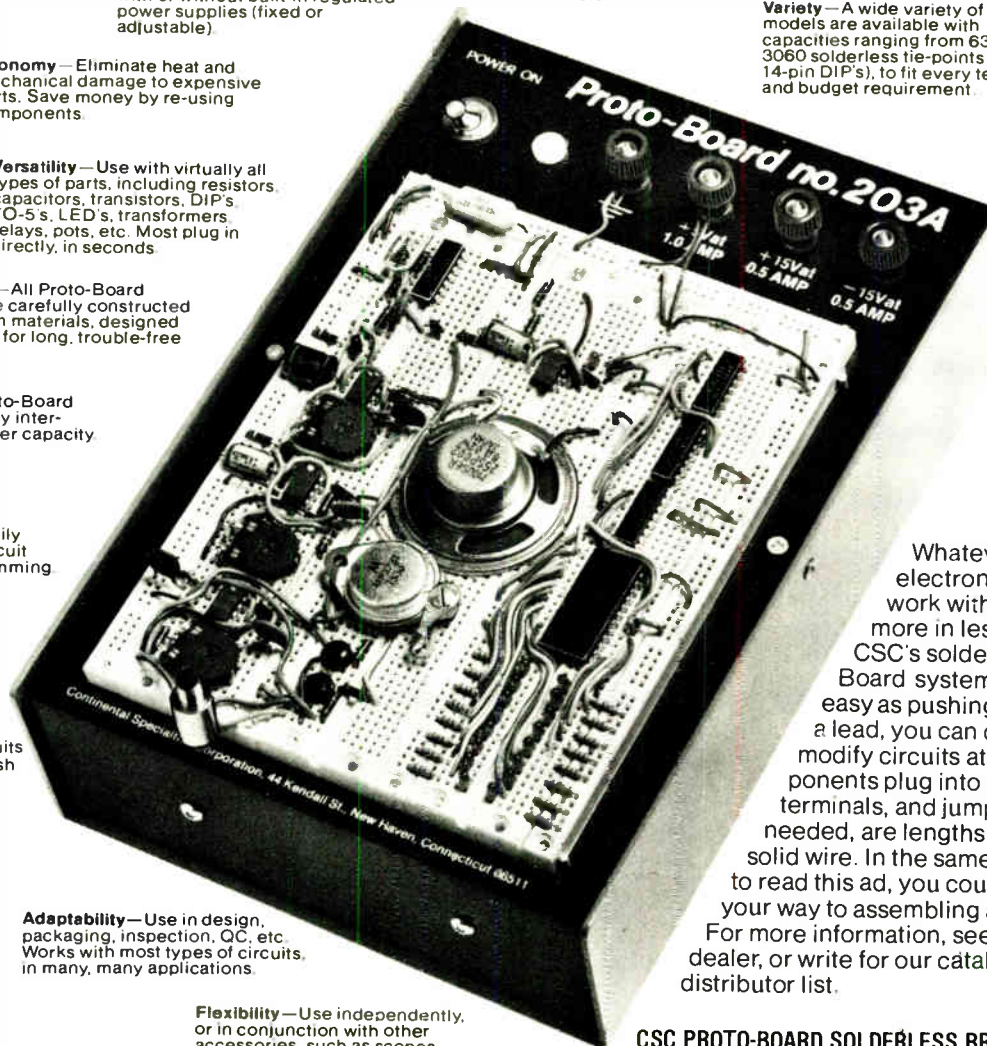
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PB-103	2260	24	59.95	Even larger capacity, only 2.7¢ per tie-point
PB-104	3060	32	79.95	Largest capacity, lowest price per tie-point
PB-203	2260	24	75.00	Built-in 1% regulated 5V, 1A low-ripple power supply
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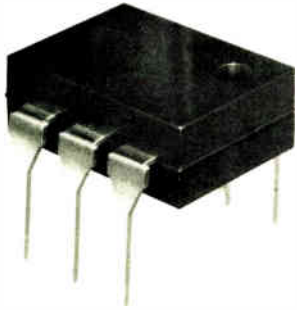


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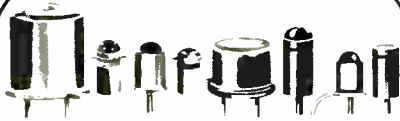
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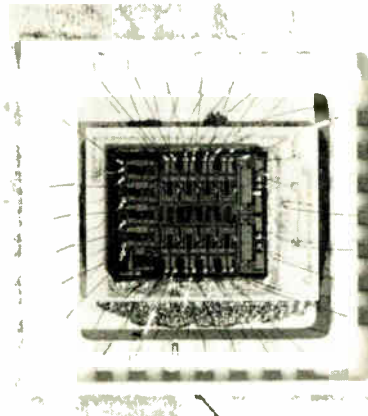
Semiconductors

Data-system components bow

Monolithic multiplexers,
hybrid sample-and-holds
are first in new family

First in a line of components for data-acquisition systems, a pair of 16-channel monolithic multiplexers and two hybrid sample-and-hold circuits developed by Intersil come in plastic packages and carry price tags that the company says are 20% to 30% below those for discrete counterparts.

Skip Osgood, product manager for data-acquisition products, says the two devices are part of a family of low-cost, low-speed, high-accuracy data-system parts that the Cupertino, Calif., company will introduce



over the next year. In quantities of 1,000, the IH5060/5070 multiplexers (a packaged chip is shown above) are priced at \$9.95 each and the IH5110/5111 sample-and-holds at \$3.65 to \$5.95 each.

The IH5060 is a complementary-MOS 1-out-of-16 analog multiplexer that is a latch-proof replacement for the Siliconix DG506. Four-line binary decoding is used so that the 16 channels can be controlled by four strobe inputs. A fifth input can be used as a system-enable. When the enable line is at 0 volt, none of the channels can be turned on, and when it's at 5 v, the channels can be

sequenced by the four strobe-line inputs.

The IH5070 is a 2-out-of-16 version of the 5060's differential analog circuit that Osgood says is a replacement for the Siliconix DG507. Three-line binary decoding is used so that the 16 channels can be controlled in pairs by binary inputs. A fourth input is used as a system-enable. Both multiplexers have a ± 15 -v analog signal range, an on resistance of less than 500 ohms over the full signal and temperature range, break-before-make switching, two-tier submultiplexing, and a power-supply quiescent current of less than 100 microamperes.

The 5110 and 5111 are complete sample-and-hold circuits, except for external sampling capacitors. The ICs include an input-buffer amplifier, output-buffer amplifier, and C-MOS logic for switching. The 5111 is primarily designed to operate with any input in the ± 10 -v range, regardless of whether it is ac or dc. The 5110 is designed to switch smaller ac signal amplitudes so as to minimize charge-injection effects, the company says.

After its offset voltage has been zeroed, this unit has a typical error amplitude of 1 to 2 millivolts peak-to-peak, corresponding to 10 to 20% of charge. The drift rate for both parts is specified at a maximum of 10 millivolts per second, which corresponds to a 100-picoampere total leakage into a 0.01-microfarad sampling capacitor. While 10 mv/s is the maximum, more typical readings are about 1 mv/s, making the devices ideal for any application requiring very low drift or droop rates. When combined with Intersil's already introduced 3 $\frac{1}{2}$ -digit integrating dual-slope converter pairs, either the 8052/8053 or the 8052/7101, Osgood says the multiplexer and sample-and-hold devices constitute the heart of a data-acquisition system for a price that is less than \$25.

Other devices planned for the family, Intersil officials report, include six C-MOS digital-to-analog converters ranging in accuracy from

SEVEN NEW PRODUCTS SAY WE'RE IN DIGITAL THERMOMETERS. WITH BOTH FEET.

Last month, we couldn't say it.
Now we can.

As of right now, Fluke offers as full and complete a line of digital thermometers as anyone.

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The 2160A series of panel-mount and portable 1° digital thermometers. And the 2170A series of panel-mount and portable 0.2° digital thermometers.

Both will handle all your thermocouple needs. In fact, we can't think of a single standard thermocouple capability that Fluke digital thermometers can't handle—J, K, E, T, R, S, B and C included. And that's across a temperature range of -200°C to +2327°C or to 3999°F.

And for user convenience, the portable instruments are truly portable and the panel instruments are truly designed for industrial environments. Our bench model is really a bench model, not just an adapted panel meter with legs. And our panel meters conform to DIN Standards.

Ease of use hasn't been forgotten. For example, temperature scale selection (°F or °C) is easily accomplished with a pushbutton on the bench models and front panel access on the panel models. A further convenience is being able to calibrate panel mount instruments in place, without removal from the panel.

Here's a quick look at the new instruments priced from \$299*:

2160A is a panel-mount, 4-digit thermometer capable of resolving 1°C or 1°F over the entire temperature range of any of eight thermocouple types (J, K, E, T, R, S, B, C). 2165A is the portable, bench-top version of the 2160A.

2166A expands the basic capabilities of the 2165A to include monitoring of up to ten thermocouples of the same



We don't go into a new product line halfheartedly.

type with a front panel selection switch.

2168 is another portable, 1° single-point instrument. It can, however, accept any one of eight thermocouple types as input.

2170A is a panel-mount, 4-digit thermometer capable of 0.2° (°F or °C) resolution over a temperature range of

-99.8° to +999.8°, for four thermocouple types (J, K, T, E). 2175A is the portable, bench-top version of the 2170A.

2176A expands the basic capabilities of the 2175A to include monitoring of up to ten thermocouples of the same type with a front panel selection switch.

Options for the new series of instruments include rechargeable battery power, an isolated parallel BCD output, an isolated analog output, a multi-point switch unit, and a Hi-Lo set point comparator.

And if you're wondering what the reaction to these new products has been, well, it's pretty typical.

Users are happy to see Fluke quality and technology in a full line of laboratory and industrial digital thermometers.

And the competition's awfully grumpy.

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Fluke (Nederland) B. V., P.O. Box 5053, Tilburg, The Netherlands.

Phone: (013) 673-973 Telex: 52237

*U.S. price only.



INTRODUCING 2160A/2170A DIGITAL THERMOMETERS. 

For demonstration on 2160A, circle 168
For literature on 2160A, circle 133

For demonstration on 2170A, circle 212
For literature on 2170A, circle 211



Scanbe-gram



RE: THE SOCKET THAT ENGINEERS SWEAR BY

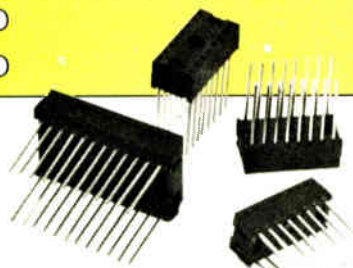
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134 Circle 169 on reader service card

World Radio History

New products

8 to 12 bits, with resolutions of 10 to 12 bits.

Intersil Inc., 10090 N. Tantau Ave., Cupertino, Calif. 95015 [411]

30-kilovolt rectifier
is only 15.2 mm long

Intended for such applications as cathode-ray-tube power supplies, the type TR 30 subminiature silicon rectifier has a 30,000-volt repetitive peak-reverse-voltage rating and a length of only 15.2 millimeters. The device is only 4 mm in diameter, making it possible to encapsulate the rectifier in the flyback transformer in TV sets. Average forward current is 2 milliamperes with a recurrent peak rating of 200 mA.

Electronic Devices Inc., 21 Gray Oaks Ave., Yonkers, N.Y. 10710. Phone (914) 965-4400 [420]

FET performance achieved
by double diffusion

Double diffusion gives field-effect transistors developed by Solitron Devices channel widths of less than 1 micrometer and resultant device-performance characteristics that are said to be otherwise impossible on a production basis. Breakdown voltage of the n-channel enhancement-mode FETs can be nearly independently designed for a given application, the company says.

As part of the family of devices, units in the Solitron SDF8000 series are designed for linear and ultra-high-frequency applications. They have gain as high as 1 gigahertz, a



Electronics/August 19, 1976

HOW THE LEADER IN DIGITAL VOLTMETERS PLANS TO STAY THERE.

A while back, we got a head start on everybody else in DVM's. People bought more of our instruments than they did the competition's.

Nothing has changed.

We still have the lead because we discovered a few things about the test and measurement field. We learned some things about developing new DVM's for the changing electronics industry.

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Six-month calibration cycle	only Fluke
10,000-Hour demonstrated MTBF	only Fluke
Environmental capability specified and defined	only Fluke
Full line of accessories offering HI volts to 40 KV, RF to 500 MHz, current to 600A	only Fluke

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A running start helps.

temperature coefficient. Five ranges each of ac and dc volts to 1200V with 0.02% dc and 0.2% ac accuracy. Five ranges each of ac and dc current to 2A with 0.1% dc and 0.3% ac accuracy. Six ranges of resistance to 20 megohms with 0.1% accuracy. AC bandwidth to 100 kHz.

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And remember, those are conservative specs for the 8600A. At \$549.

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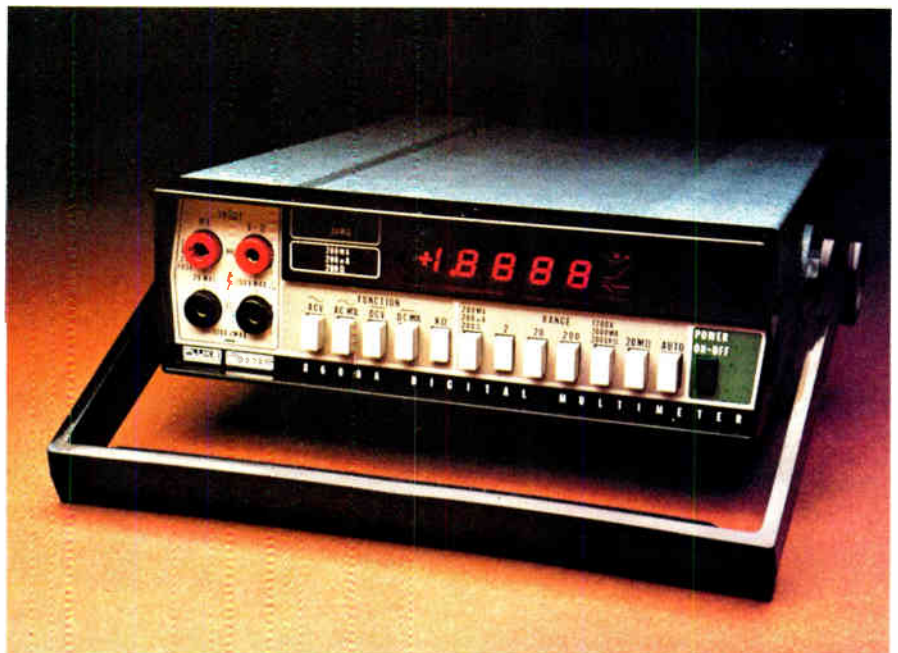
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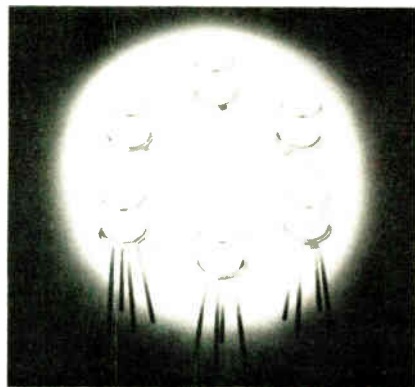
The Solitron SDF 9000 series, designed for high-speed switching applications, has low feedback capacitance, low insertion loss, and low output capacitance.

Solitron Devices Inc., 8808 Balboa Ave., San Diego, Calif. 92123. Phone (714) 278-8780 [413]

Optical couplers provide
1-kilovolt isolation

Built to meet requirements in high-reliability applications, three optically coupled isolators from Optron Inc. replace pulse transformers or mechanical relays in solving such problems as common-mode noise rejection, ground loops and voltage-level translation.

The Jedec-registered types 3N243, 3N244, and 3N245 consist



of a gallium-arsenide infrared transmitter coupled with a silicon phototransistor. They are similar to Optron's OPI 140 standard isolator, and each is available in a hermetically sealed TO-18 package.

All devices in the series offer 1-kilovolt isolation. Guaranteed minimum current-transfer ratios are 15% for the 3N243, which is priced at \$3.35 in quantities of 1,000; 30% for the model 3N244, priced at \$4.31; and 60% for the model 3N245, priced at \$5.83. All are available from stock.

Optron Inc., 1201 Tappan Circle, Carrollton, Texas 75006. Phone (214) 242-6571 [416]

Electronics / August 19, 1976

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JOHNSON

Circle 137 on reader service card 137

New products

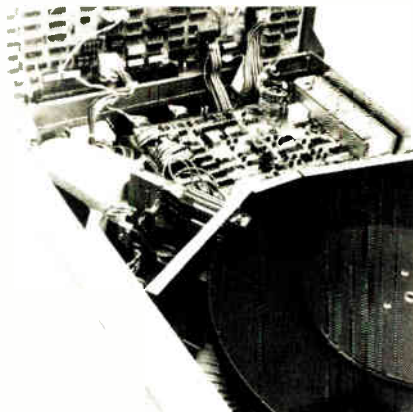
15-by-15-inch printed-circuit cards. Price of the basic system with case, chassis, power supply, front panel and 8 kilobits of memory is \$2,500 in lots of 50 or more. Or the system is available on cards for OEMs.

Computer Division, Monolithic Memories Inc., 1165 East Arques Ave., Sunnyvale, Calif. 94086 [363]

Disk drives offer capacities up to 24 megabytes

Two dual-platter fixed-disk drives, holding 12 and 24 megabytes respectively, have been added to the D1000 family of Pertec Corporation's Peripheral Equipment division. The family of fixed-disk drives provides designers with a range of drive capabilities. Earlier units include the single-platter models D1400 and 1600, with capacities of 6 megabytes and 12 megabytes respectively.

The new 24-megabyte unit, the D1660, has two IBM 3336-type



nonremovable platters. Bit density is 4,400 bits per inch; and track density, 200 tracks/in. The D1660 is available with a data-transfer rate of either 3.12 megahertz at 1,500 revolutions per minute or 5.0 MHz at 2,400 rpm. The 12-megabyte unit, the D1460, has two IBM 2316-type nonremovable platters with a bit density of 2,200 bits/in. and track density of 200 tracks/in. Data-transfer rates are either 1.5625 MHz at 1,500 rpm or 2.5 MHz at 2,400

revolutions per minute.

Prices, in OEM quantities, are about \$2,085 for the D1460 and \$2,710 for the D1660.

Pertec Corp., 9600 Irondale Ave., Chatsworth, Calif. 91311. Phone (213) 882-0030 [368]

Printer operates at 300 lines a minute

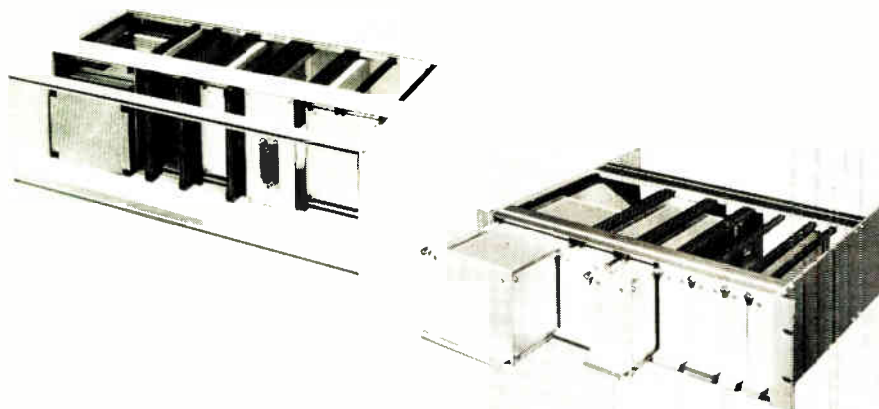
A new member has been added to Teletype Corp.'s model 40 family of teletypewriters—a 132-column, tractor-feed impact printer designed for the original-equipment market. The printer operates at 300 lines per minute, accommodating up to 6-ply standard fanfold from 4 $\frac{1}{8}$ to 15 inches wide and 2 $\frac{1}{2}$ to 22 inches long. It's available with the ASCII monospace set as well as the full 96-character set for upper/lower-case printout. An extended font feature permits character sets of up to 190 characters. Other features include

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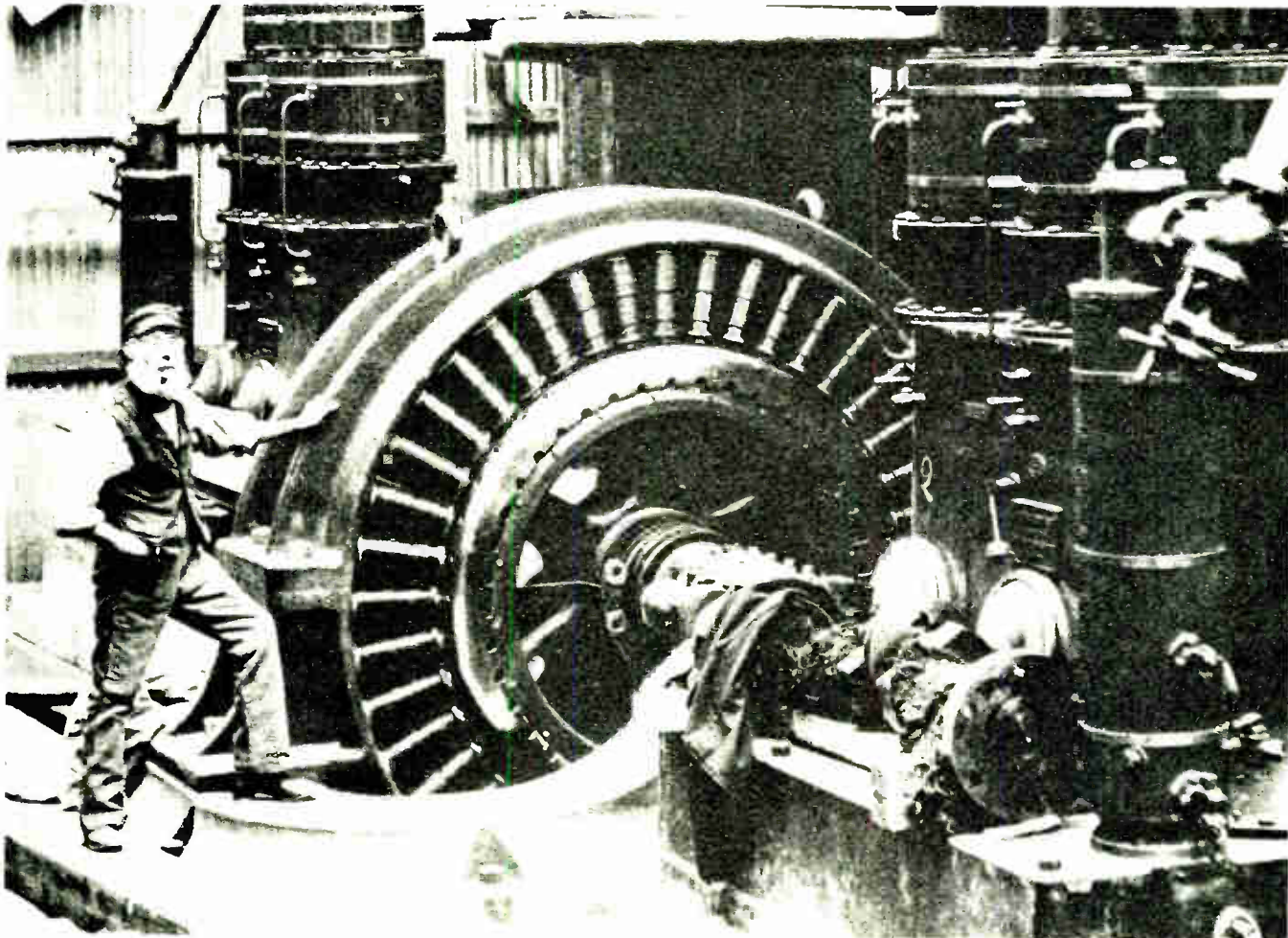
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Circle 140 on reader service card

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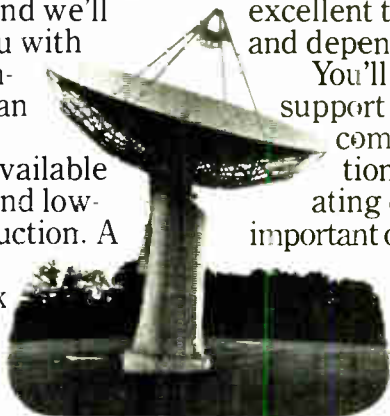
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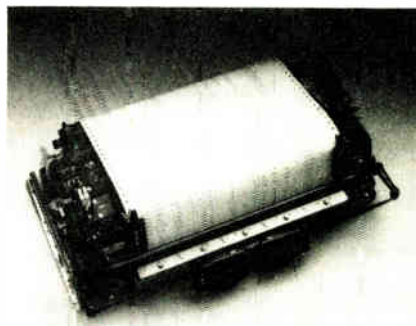
For details, write Eastman Kodak Company, Dept. 412L (48-E), Rochester, N.Y. 14650.

RESULTS COUNT



Kodak micro resist 747

New products



foldover, even or odd parity recognition (optional), automatic new line, and built-in diagnostics. Price is \$2,000.

Sales Headquarters, Teletype Corp., 5555 Touhy Ave., Skokie, Ill. 60076. Phone, 312-982-3134 [364]

Minicomputer tape cartridge said to be error-free

Minicomputer users now can buy what its developers assert is a 100% error-free 1/4-inch data cartridge from Wabash Tape Corp. The four-track cartridge contains Wabash's Quadronix I computer tape, which the company certifies will be free of writing errors. Cartridge-drive elements are protected by a high-impact plastic cover mated to a metal baseplate and by a plastic "door" that automatically closes over the tape-head opening when the cartridge is removed from the transport. The cartridge is interchangeable with others on the market.

Timothy O'Gorman, vice president, marketing, Wabash Tape Corp., 2700 Des Plaines Ave., Des Plaines, Ill. [365]

Matrix printer produces variable-sized characters

Microcomputer-controlled, the IPS-7 Intelligent Printing System is a bidirectional matrix printer designed for OEM and systems applications. Variable-sized alphanumeric characters and bar-code features are optional and permit a user to satisfy present and future needs without a retrofit. Interface options are the

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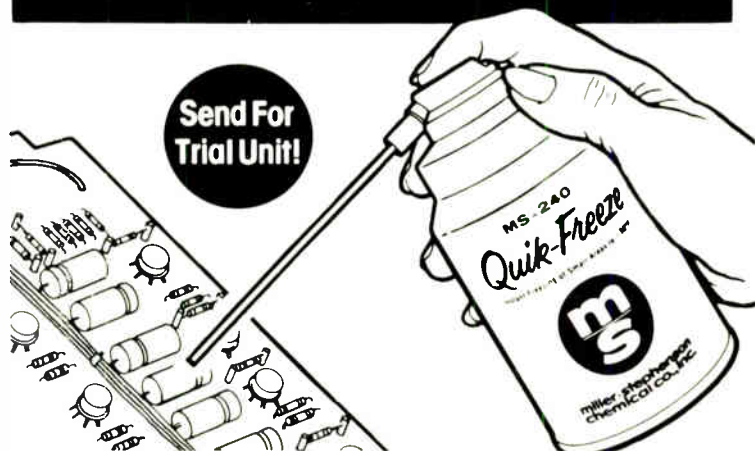
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Dataroyal Inc., Main Dunstable Rd., Nashua, N.H. 03060. Phone (603) 883-4157 [366]

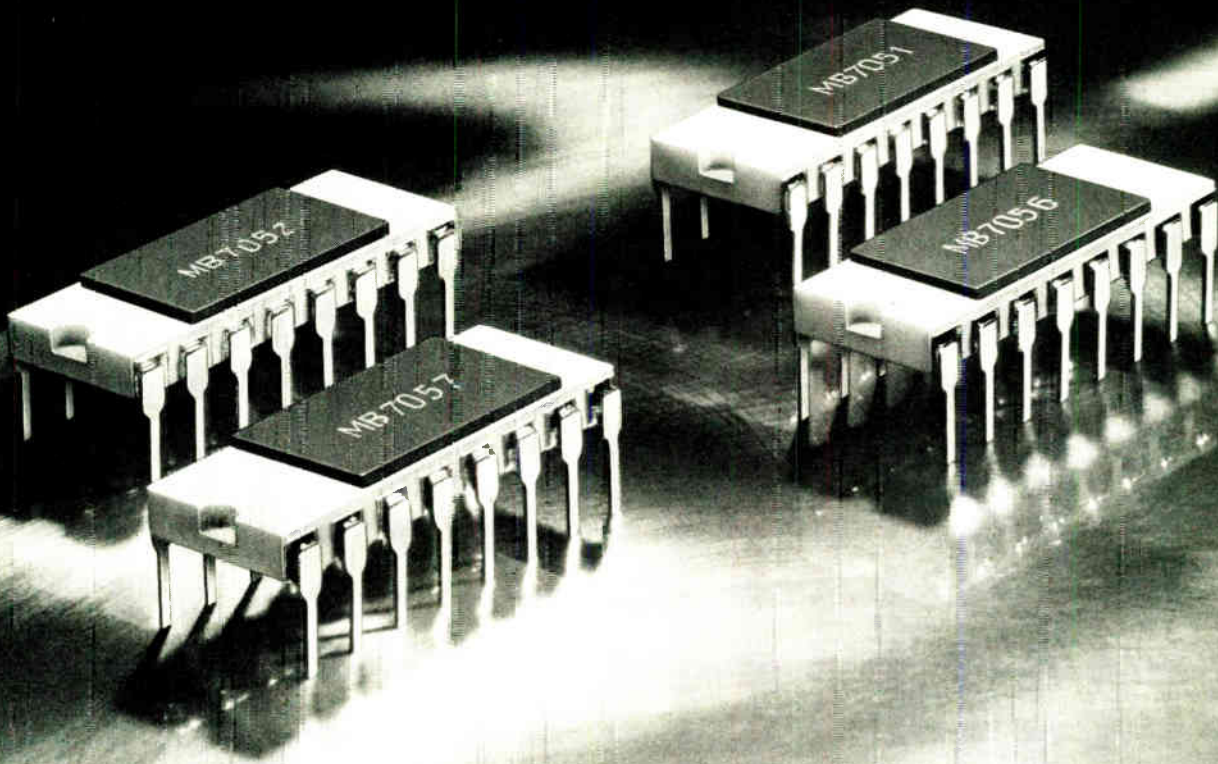
Alphanumeric printer in kit form costs \$250

Designed for do-it-yourselfers, the PR-40 alphanumeric printer comes in kit form. The printer is a 5-by-7-dot-matrix impact type that is similar in operation to the printers offered by Centronics Corp. The PR-40 prints the 64-character upper-case ASCII set with 40 characters per line at a rate of 75 lines per minute on standard 3 7/8-inch-wide rolls of adding-machine paper. Each line is printed from an internal 40-character buffer memory. The kit includes the assembled print mechanism, chassis, circuit boards, 120/240-volt ac, 50-60-hertz power supply, one ribbon, one roll of paper, and assembly instructions. Price of the kit is \$250 in the U.S., with delivery in 30 days.

Southwest Technical Products, Corp., 219 W. Rhapsody, San Antonio, Texas 78216. Phone (512) 344-0241 [367]

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MB7051/52/56/57

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Circle 145 on reader service card

FF101A FF101B FF101C



New products

Microwave

GaAs FET puts out 25 mW

At 10 GHz, unpackaged chip
holds noise to 3.6 dB
for gain of 6.9 dB

No longer simply developmental devices, gallium-arsenide field-effect transistors are coming on strong for microwave applications. Initially, Japanese firms dominated this product area, but U.S. manufacturers have been steadily closing the gap. Now, the Microwave Semiconductor division of Hewlett-Packard is offering its first GaAs FET. The device, says Dave Struthers, marketing communications manager, provides wider dynamic range and higher power output than existing units.

Currently available as an unpackaged chip, the HFET-1000 typically delivers 25 milliwatts of linear output power at 10 gigahertz. For this frequency, noise figure is 3.6 decibels typical at an associated gain

of 6.9 dB. The maximum available gain is nominally 11 dB at 10 GHz, while the output power at 1-dB compression is typically 14.5 dBm at 10 GHz.

The HFET-1000 is intended for use in the first and second stages of broadband, as well as narrow-band, low-noise amplifiers operating in the range of 2 to 12 GHz. Applications, notes Struthers, include telecommunications, radar, and electronic-warfare amplifiers.

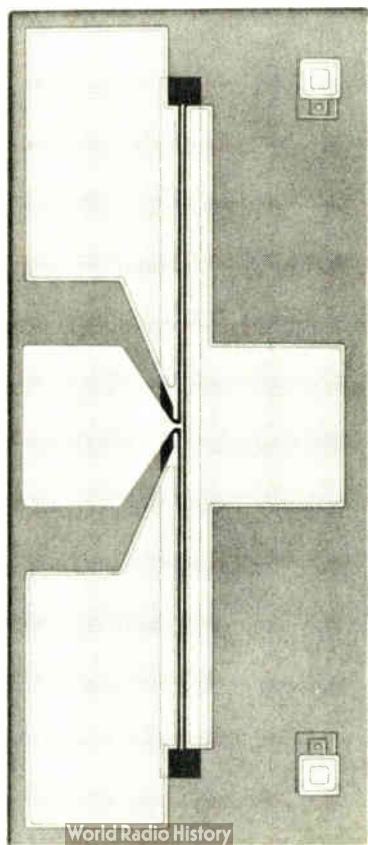
The chip itself measures 26 by 11 by 5 mils; the gate region alone is merely 1 by 500 micrometers. A scratch- and dust-resistant protective layer covers the entire active area of the chip, making it rugged enough for easy wire bonding and die attachment, says Struthers. A packaged version of the chip will be announced shortly, he adds.

Maximum available gain for the HFET-1000 is 13 dB typical, decreasing to 9.5 dB at 12 GHz. At a frequency of 8 GHz, noise figure is typically 2.9 dB for an associated gain of 8.9 dB. At 12 GHz, the typical noise figure is 4.1 dB for a gain of 4.3 dB. What's more, points out Struthers, the device's s-parameters are very consistent across its entire operating frequency range.

Initial reliability projections place the unit's mean time before failure at an estimated 1,250,000 hours for an operating temperature of 80°C.

In quantities of one to nine, price is \$135 each, dropping to \$105 each in lots of 10 to 24. Availability is from stock.

Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304. Phone (415) 493-1501 (401)



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Available in calibrated or uncalibrated versions, two sets of 50-ohm coaxial BNC attenuators from Elcom Systems offer accuracy within 0.5 decibel from dc to 1,000 megahertz and within 1 dB from 1,000 to 1,500 MHz. VSWR is less than 1.35 at 1,500 MHz, and it averages 1.2 over the

Electronics / August 19, 1976

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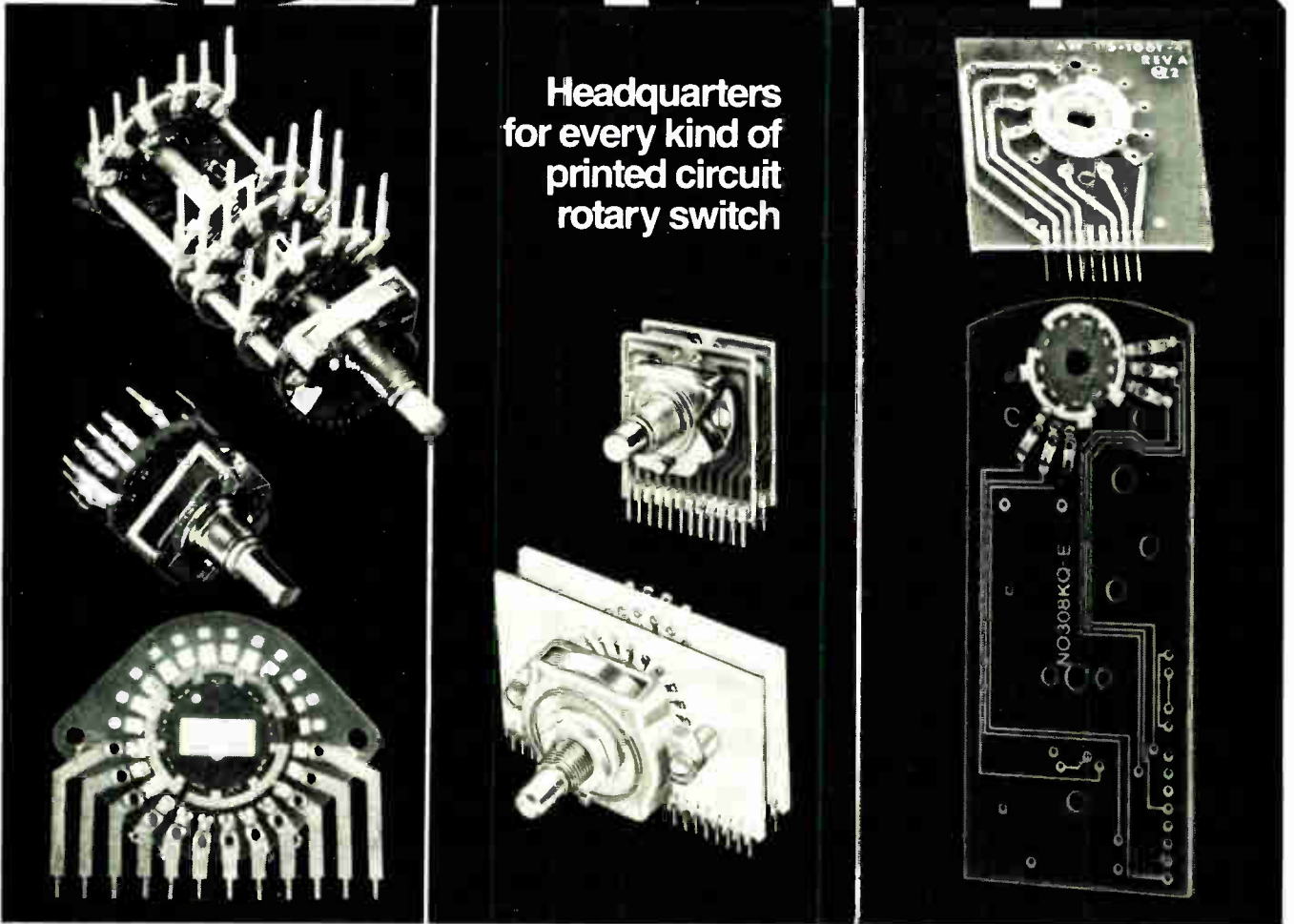
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New products



band. The attenuators can dissipate 0.5 watt in continuous operation or 1 kilowatt of peak power.

Each of the two sets contains 3-, 6-, 10-, and 20-dB attenuators in a plastic case. The calibrated set, model AT-50, is priced at \$40, and the uncalibrated set, model AT-51, at \$36. Delivery time is stock to 30 days. The attenuators are also available with type TNC, N, and SMA connectors, and with impedances of 75 Ω or 90 Ω . They are suitable for

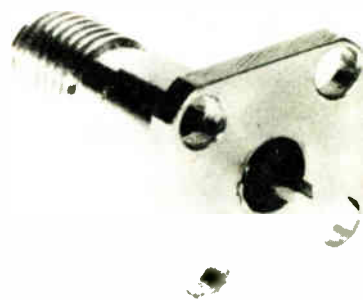
breadboarding applications.

Elcom Systems Inc., 127F Brook Ave., Deer Park, N.Y. 11729. Phone Leonard Pollachek at (516) 667-5800 [403]

Connectors use built-in capacitors to suppress rfi

Eliminating the need for external suppression devices, 3-millimeter coaxial connectors from Tek-wave Inc. use built-in capacitors to suppress electromagnetic and radio-frequency interference. This not only lowers system costs, but also makes assembly and disassembly easier in system applications.

Connectors in the series, called the 24-20010210, use four-hole, flange-mounted bodies and are designed for nonhermetic applications that conform to MIL-C-39012. Bodies are built of passivated corrosion-resist-



ant steel. Center conductors are heat-treated beryllium copper set in a special low-viscosity, high-strength epoxy.

Frequency range of the connectors is 0.1 to 10 gigahertz. The typical minimum insertion loss is 50 decibels, for example, from 0.2 to 10 GHz.

Tek-wave Inc., Subsidiary of Frequency Electronics Inc., 3 Delaware Dr., New Hyde Park, N.Y. 11040 [405]

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Magnetron puts out peak of 3 megawatts at 2.9 gigahertz

A pulsed coaxial magnetron from Varian offers peak power output of 3.0 megawatts at 2.9 gigahertz. The major application for the tube is in long-range, ground-based radar. The VMS-1143 provides frequency stability, long operating life, and a typical efficiency of 60%. It can serve as a retrofit for the model 6410

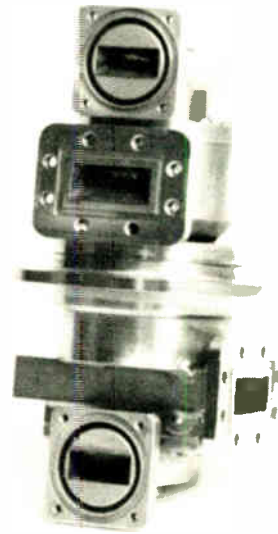


magnetron in FPS-6/89/90 and MPS-14 height-finder radars systems.

Varian, Beverly Division, Salem Rd., Beverly, Mass. 01915 Phone (617) 922-6000 [404]

Dual-channel rotary joint operates in X band

A dual-channel X-band rotary joint, the model 17-2000, operates over the frequency bands of 7.25 to 7.75 and 7.9 to 8.4 gigahertz. Channel 1, 7.25 to 7.75 GHz, is a receive channel that has a maximum VSWR of 1.15, a maximum insertion loss of 0.15 dB, and a maximum wow (variation in VSWR due to rotation) of 1.05. Channel 2 is designed to carry 12.5 kilowatts continuous wave when pressurized at 30 pounds per square inch. It has a maximum VSWR of 1.10, a maximum insertion loss of



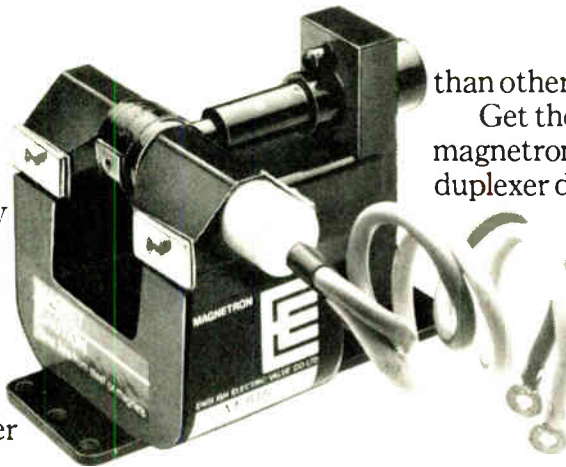
0.1 dB, and a maximum wow of 1.03. The silver-plated aluminum joint weighs 12 pounds. Unit price is

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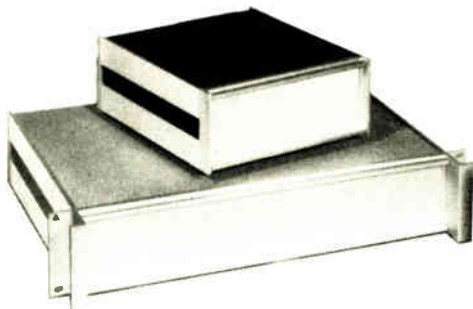
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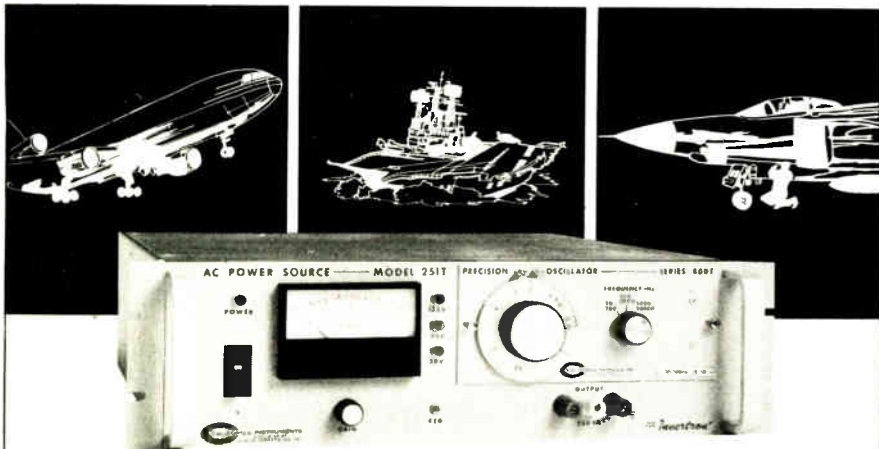
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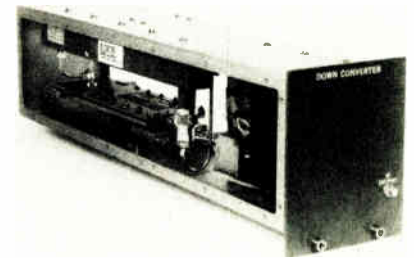
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Eastern Microwave Corp., 4 Gill St., Woburn, Mass. 01801. [406]

Satellite station converters
use pretuned frequencies

Designed for three-across, side-by-side mounting, models UC4-1 and DC4-1 up- and down-converters are pretuned, slide-in frequency converters for dedicated carriers at satellite earth stations. Operating bands are



5,925 to 6,425 megahertz for the up-link and 3,700 to 4,200 MHz for the down-link.

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The UC4-1 and DC4-1, which weigh 10 pounds each, interface at the CCIR standard intermediate frequency, 70 MHz. Bandwidth is 40 MHz, and in-band ripple is less than 0.5 dB. Nominal overall gain is 20 dB. Dimensions of both models are 5.7 inches high by 4.5 in. wide by 18 in. deep. A frame with automatic switchover and alarm is available, providing one-for-one or one-for-two redundancy in critical standby applications. The frame is 7 inches high by 19 in. wide by 22 in. deep.

LNR Communications Inc., 180 Marcus Blvd., Hauppauge, N.Y. 11787. Phone (516) 273-7111 [408]

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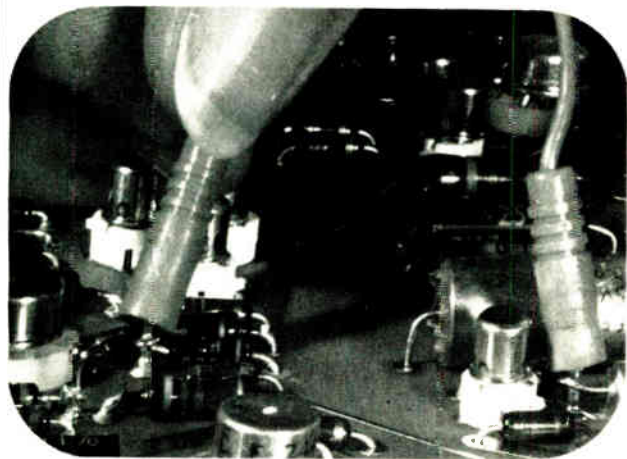
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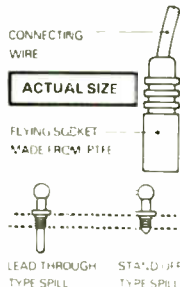
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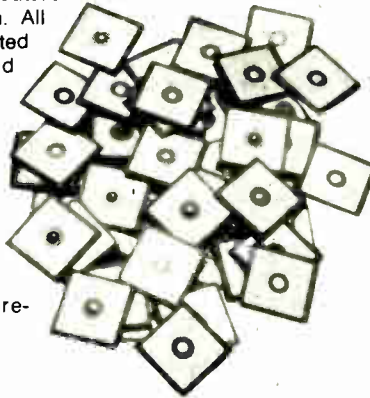
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New literature

Transient suppressors. Two types of devices for suppression of transient voltages are compared in an eight-page report published by General Semiconductor Industries Inc., 2001 West Tenth Pl., Tempe, Ariz. 85281. The brochure, entitled, "A Comparison Report on TransZorbs versus Metal Oxide Varistors," provides comparative data on published specifications plus data from tests. TransZorbs is General Semiconductor's name for its silicon pn-junction devices used in transient suppression. For a copy of the report, circle 422 on the reader service card.

Shielding foils. A four-page technical bulleting covers the MagnaShield line of electromagnetic and electrostatic shielding foils made by SGL Electronics, 300 Harvard Ave.,



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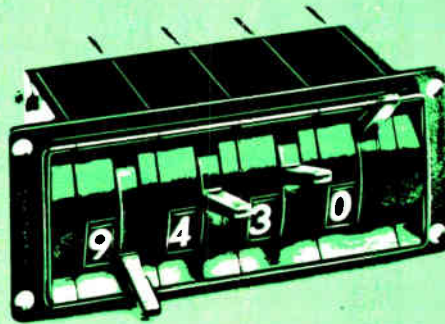
Westville, N.J. 08093. The bulletin describes an empirical method for determining the proper shielding type and placement. Also included are charts covering the technical and performance specifications of the three types of MagnaShield foil—low nickel, high nickel, and silicon steel. [423]

Resistive components. The second issue of "Trimpot Digest," a periodical about the technology and applications of resistive components, has been published by Bourns Trimpot Products division. The content of the current issue centers on unusual applications, material and design

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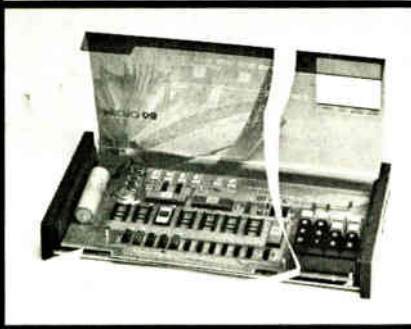


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MICRO68 Microprocessor



The MICRO-68 is a completely assembled computer, for only \$430. Built around the Motorola/AMI/Hitachi 6800 microprocessor, MICRO-68 has its own integral power supply, 16 button keyboard, six digit LED display, and 128 words of RAM. The 512 word MON-1 PROM contains the service routines necessary to load programs, inspect and edit, insert break points for debugging, and execute. Memory expansion to 64K and full I/O can be obtained with convenient edge connectors.

The MICRO-68 can be expanded with a complete line of EPA peripherals, resulting in the power to accomplish the most demanding applications.

EPA Electronic Product Associates, Inc.
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(714) 276-8911

New literature



performance characteristics, performance suggestions, and design aids. In addition, a review of the new McGraw-Hill publication, The Potentiometer Handbook, is included. A copy of the "Trimpot Digest" can be obtained by writing Digest—Bourns Inc., 1200 Columbia Ave., Riverside, Calif. 92507 [424]

Optical components. Low-cost plastic lenses, prisms, mirrors, light pipes, and other specialty optical components are described in a six-page two-color technical bulletin. The publication discusses user advantages of plastic optics, including light-weight, high-visible-light transmittance, resistance to chipping and breakage, and low cost. Applied Products Corp., Horsham Valley Industrial Center, Horsham, Pa. 19044 [427]

Capacitors. As part of its 28-page capacitor catalog, Paktron includes a foldout comparison chart for quick selection of the appropriate device.



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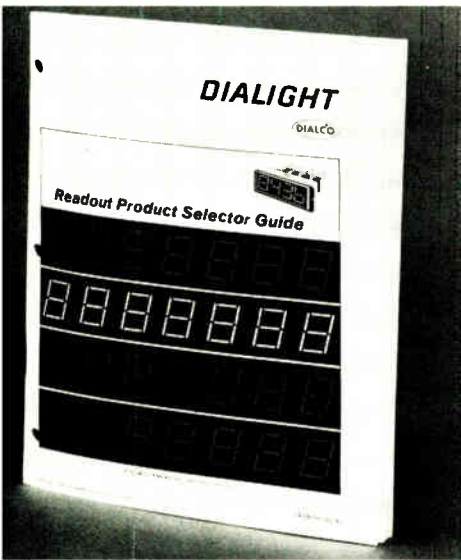
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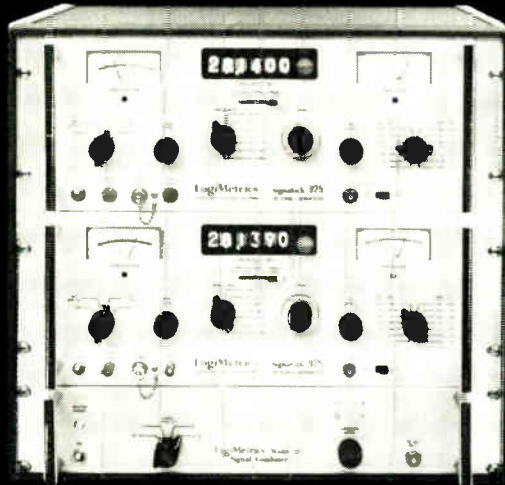


ican Philips company. The 56-page catalog, designated the SG743, describes and illustrates modules that are available as individual components, as integrated systems complete with associated decoder-driver circuitry, and as packages with bezel assembly or panel bracket. Write to Dialight, 203 Harrison Pl., Brooklyn, N.Y. 11237 [425]

Testing technique. Use of gel-permeation chromatography to test epoxy resin, one of the raw materials in the manufacture of printed-circuit boards, is described in a publication from Waters Associates. The case study, entitled Polymer Testing Saves Money in Electronics, tells how two IBM researchers used GPC to reduce the company's reject rates in pc boards. A free copy of publication H66 is available from Waters Associates Inc., Maple St., Milford, Mass. 01757 [429]

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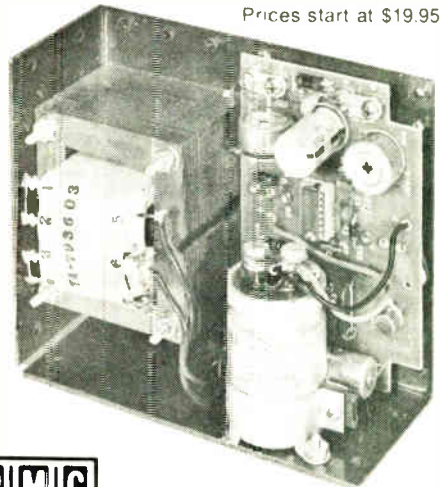
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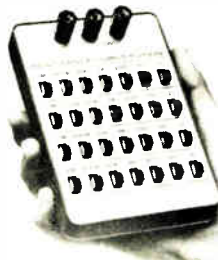
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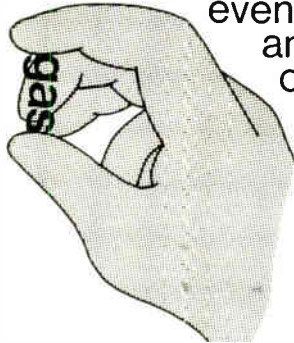


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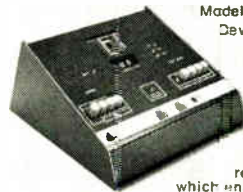
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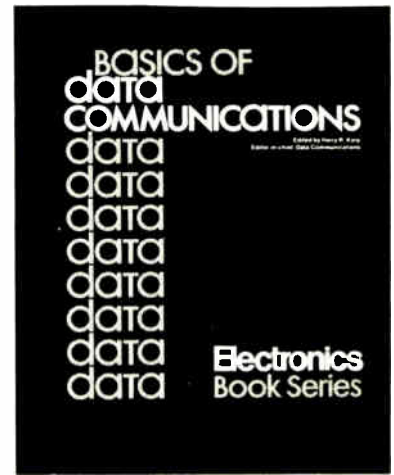
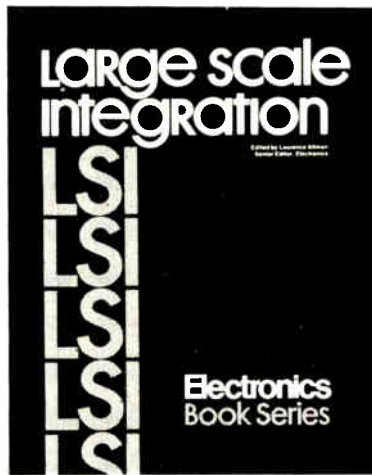
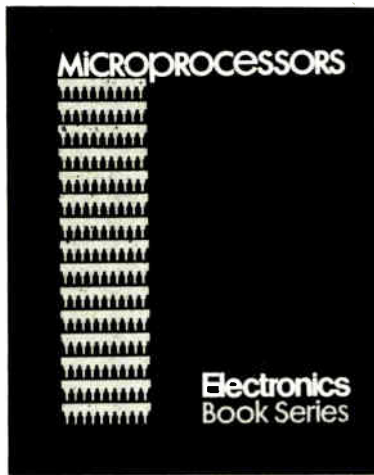


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