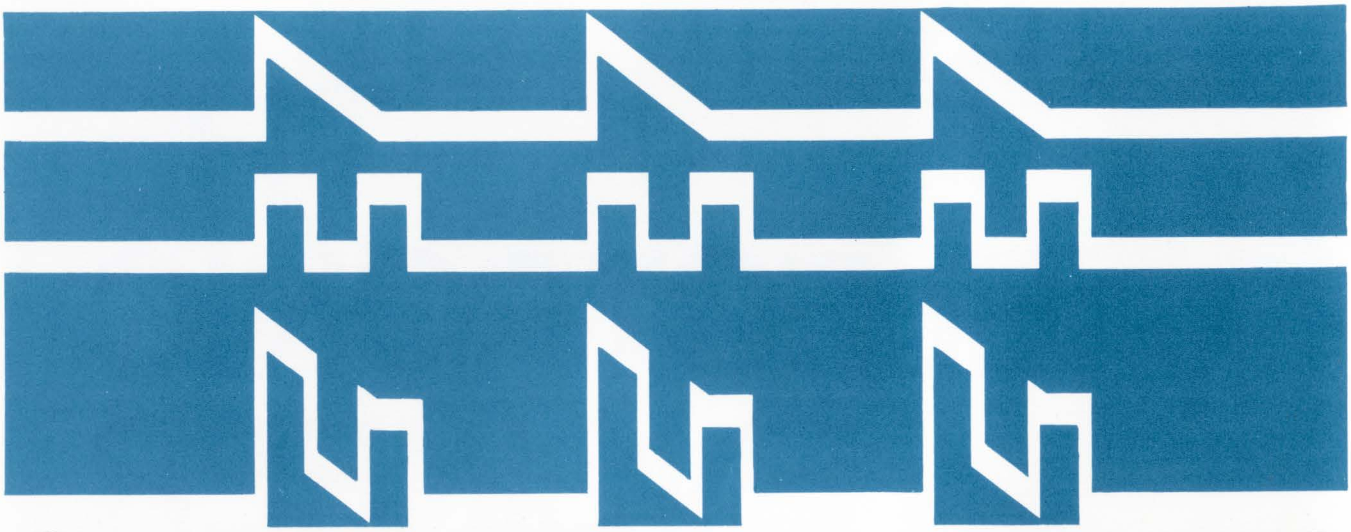
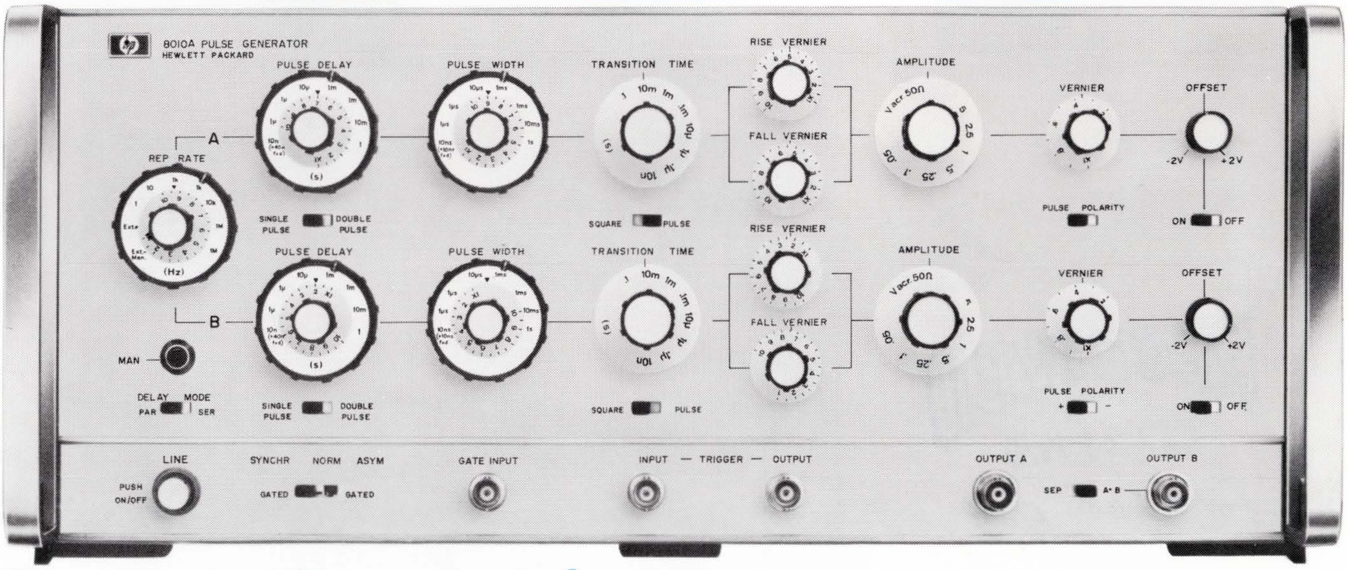
VOL. 29 NO. 9
SEPTEMBER 1970

THE ELECTRONIC ENGINEER

DoD's David Packard talks of falling budgets, rising costs, and you.

Cost of MOS memories
Optoelectronics course—detectors
When not to buy an IC tester





For complex waveforms, a new dual-channel pulser— Top of HP's '8000' line

HP's Model 8010A dual-channel pulse generator is a new top-of-the-line addition to our 8000 series. It gives you the ability to produce **two separate pulses**—to vary them independently in all respects but rep rate—and to **combine them to form complex waveforms, without loss of amplitude.**

The rep rate (common to both channels) can be varied from 1 Hz to 10 MHz. Rise and fall times can be varied independently, on both channels, from less than 10 nanoseconds to 1 second. Pulse width, delay, dc-offset and polarity are also independently variable. **Five volt amplitude of each channel can be combined to form a single-channel 10V output, while maintaining 50Ω source impedance.** In addition, either or both of the two channels can be operated in double-pulse mode (giving an effective rep rate of 20MHz) or in squarewave mode (50% duty cycle).

If you don't need all the capabilities of the 8010A, then one of the other models in the 8000 series is probably just right for you. You can get fixed or variable risetimes (ranging down to 1.5 nanosecond on the 8004A), programmability for low-cost remote-control uses (model 8003A), simultaneous positive and negative outputs (model 8005A), and numerous other capabilities, in various combinations.

We can even give you **digital formatting capabilities,** with our 8006A word generator. Word length can be varied from **2 to 32 bits,** with great versatility in output format. And, it's remotely programmable.

Price of the 8010A is only $1925; other units in the HP 8000 Series of pulse generators begin **as low as $470.** Call your local HP field office to order. For full information on the 8010A, or on the entire 8000 Series, see pages 237-245 in your 1970 HP Catalog, or send for a **free HP 8010A data sheet and brochure on all HP pulse generators.** Hewlett-Packard, Palo Alto, California 94304. In Europe: 1217 Meyrin-Geneva, Switzerland.

080/18

HEWLETT hp PACKARD

SIGNAL SOURCES

Circle 1 on Inquiry Card

PETP FILM CAPACITORS

SIZE & COST: NO BIG THING.

EASIER THAN EVER TO FIT YOUR BOARD & BUDGET.

BROAD LINE GETS BROADER. 8 LOWER CAPACITANCE VALUES (100 pF thru 390 pF @ 200 V).

Type 192P Pacer® Polyester Film Capacitors are mass-produced to beat the space/cost squeeze in commercial and industrial applications. Extended-foil PETP film sections with metal end caps provide best possible non-inductive construction. End caps also act as moisture barriers. Ideal for automatic insertion on printed wiring boards. Expanded line includes capacitance values from 100 pF to .47 μF. Voltage range, 80 to 600vdc. Write for Bulletin 2066C.

Technical Literature Service
Sprague Electric Company
233 Marshall Street
North Adams, Mass. 01247

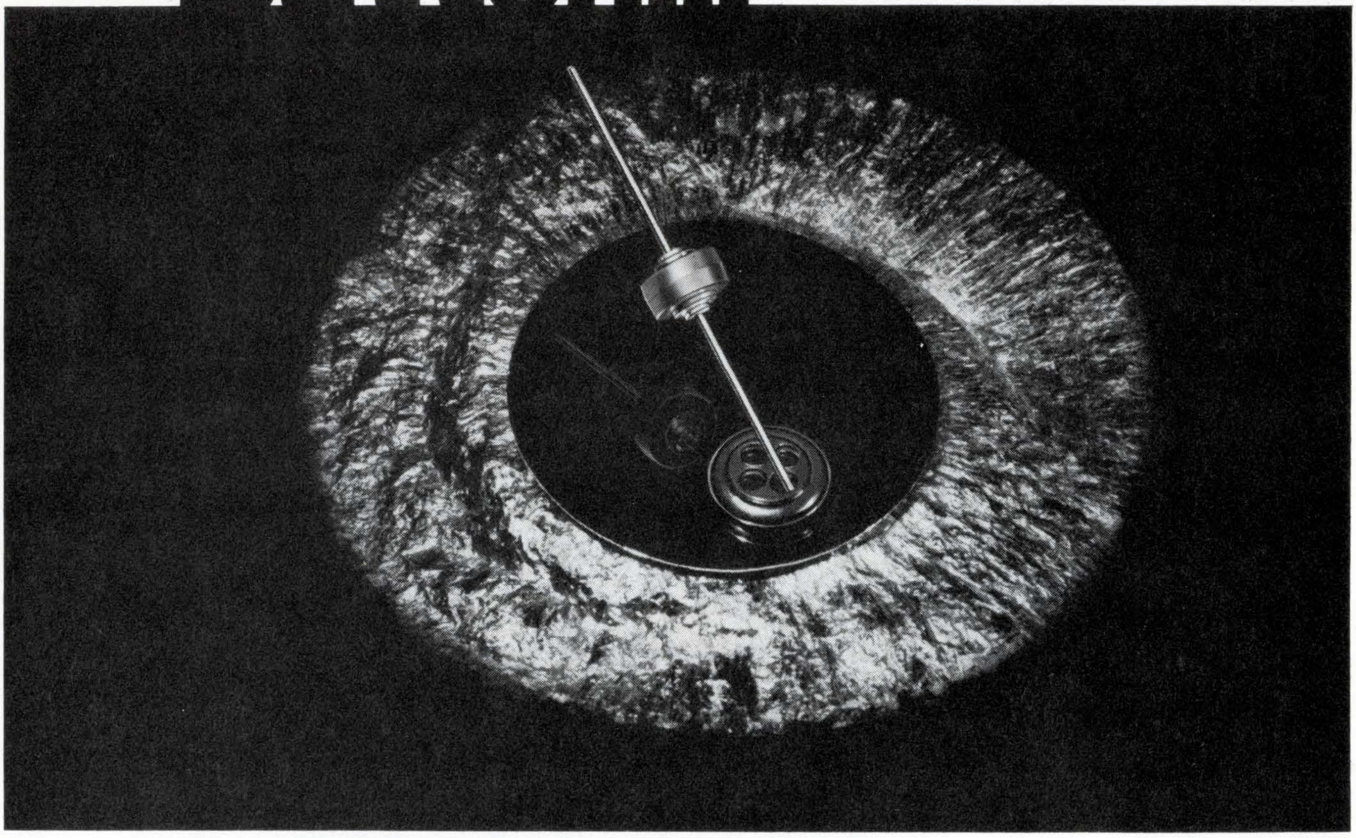
SPRAGUE®
THE MARK OF RELIABILITY

THE BROAD-LINE PRODUCER OF ELECTRONIC PARTS

4SM-0143

Circle 4 on Inquiry Card

Button, Button...



Motorola Rectifiers have it!

. . . And you get *more amps per dollar* from the world's highest-current lead-mounted rectifier — the new MR751 "Button" Series.

If you're getting hot from looking for rectifier savings in dollars and finding only pennies — cool it! Let the industry's first 6-amp axial-lead rectifier save *real money* in your designs by providing more than twice the amps per dollar plus significant mounting and assembly savings.

But the real big savings is in the initial cost.

Compare these MR751 series prices with those of typical stud-packaged 6-amp counterparts:

RECTIFIER TYPE	100-UP PRICES: TYPICAL, 6-A STUD ASP'S	100-UP PRICES: MOTOROLA MR751 SERIES	DEVICE #
$V_R = 100V$	$ .90	**$ .45**	MR751
$V_R = 200V$	1.25	**.49**	MR752
$V_R = 400V$	2.00	**.62**	MR754
$V_R = 600V$	3.75	**.90**	MR756

Compared to stud rectifiers of similar current rating, the silicon MR751 series devices install faster, easier and take less space. And their new, button-shaped, voidless plastic case provides insulation against accidental shorting or grounding.

The MR751 series rectifiers are available in four working peak reverse voltage ratings up to 600 volts and each features a high 600-ampere inrush current surge capacity for increased capacitive-loaded design latitude.

And if you really want to cool it — with a proper heat sink and mounting — this little "button" will handle up to 26 amperes! This and other outstanding characteristics — like forward voltage drop of 0.9V (max) and reverse current at rated dc voltage of 0.25 mA (max) — make the MR751 series rectifiers a real cool buy.

Buttonhole your nearest Motorola representative and ask for evaluation samples — today! Or, write Motorola Semiconductor Products Inc., Box 20912, Phoenix, Arizona 85036.

MOTOROLA POWER
—where the priceless ingredient is care!

CHILTON'S THE ELECTRONIC ENGINEER

September 1970 Vol. 29 No. 9

Departments

COVER

This month's CHALLENGER, David Packard, Deputy Secretary of Defense, speaks candidly of cutbacks in defense spending, spiraling costs, new procurement policies, and how these factors affect the electronic engineer and his design decisions. This new outlook will mean, in many cases, that the cutting edge of technology will be blunted by such variables as increased reliability and reduced costs. (Cover photograph: John DiJoseph, Jr., Wash., D.C.)

FEATURES

Circle 6 on Inquiry Card

THE ELECTRONIC ENGINEER

Vol. 29 No. 9 September 1970

Chilton

Executive and Editorial Offices:
One Decker Square, Bala-Cynwyd, Pa. 19004
Tel. (215) SH 8-2000

Address Mail to: 56th & Chestnut Sts.
Philadelphia, Pa. 19139

Western Offices:
Stephen A. Thompson, 1543 W. Olympic Blvd., Los Angeles, Calif. 90005
Tel. (213) DU 7-1271

Sheldon Z. Edelman, 199 First St. Rm. 335
Los Altos, Calif. 94022
Tel. (415) 941-6655

Monthly publication of Chilton Company, Chestnut & 56th Sts., Phila., Pa. 19139. (Area Code 215) SHerwood 8-2000. Controlled circulation postage paid at Philadelphia, Pa. $1 a copy. Subscription rates U. S. and U. S. Possessions: 1 yr. $12.00; 2 yrs. $20.00. Canada 1 year $14.00; 2 yrs. $25.00. All other countries 1 yr. $20.00; 2 yrs. $35.00.

The Chilton Electronics and Instrumentation Group ● The Electronic Engineer ■ Instruments and Control Systems ■ Instrument & Apparatus News ■ Medical Electronics News ■ Electronic Component News

Circle 7 on Inquiry Card ⟶

Bell & Howell & Recording & How

It's done with oscillographs. We have a bunch, but let's talk about these two. They can handle on-line or off-line test and measurement of any physical happening you might have in mind. From pulse flutters during surgery to whether or not you're refining that crude the same way today as last year.

The one on the bottom is the 5-134. It does everything but talk. It writes to 25,000 Hz. (But with all that speed, it has a data accuracy to ±½%.) And can flip into any one of 10 different servo-controlled speeds.

It's modular, of course, with special refinements. Like the timer, servo control board and galvo all plug in. Individual input connectors as standard. An extremely quiet operation. That type of thing.

Here's a couple more exclusives. You don't have to write out timing line rates. With us, that's taken care of automatically. With a timing ID marked on the edge of the paper. Not only that, the rate can be manually selected or can be automatically synced with paper speed.

And it's got a "jog" feature that allows you to move the paper short distances for initial set up—one hold-down button for on/off.

The smaller box is the 5-135. It weighs in at 35 pounds (a real portable) as compared to the other's 50 pounds. Both boxes share pretty much the same components. It's just that the 5-135 has broader application by more industries across the board because it's not quite so fancy (9 channels versus the 5-134's 18, for instance). Even though it's smaller, it doesn't skimp on performance. It has the largest range of input power options of anybody going. And all that at a lot less money. Not bad, huh?

And one more thing. Just in case you're building a system, we've got a range of other new goodies to complement these graphs: 1-172 amplifier, 8-114 bridge excitation/signal conditioner and the 23-111 paper processor.

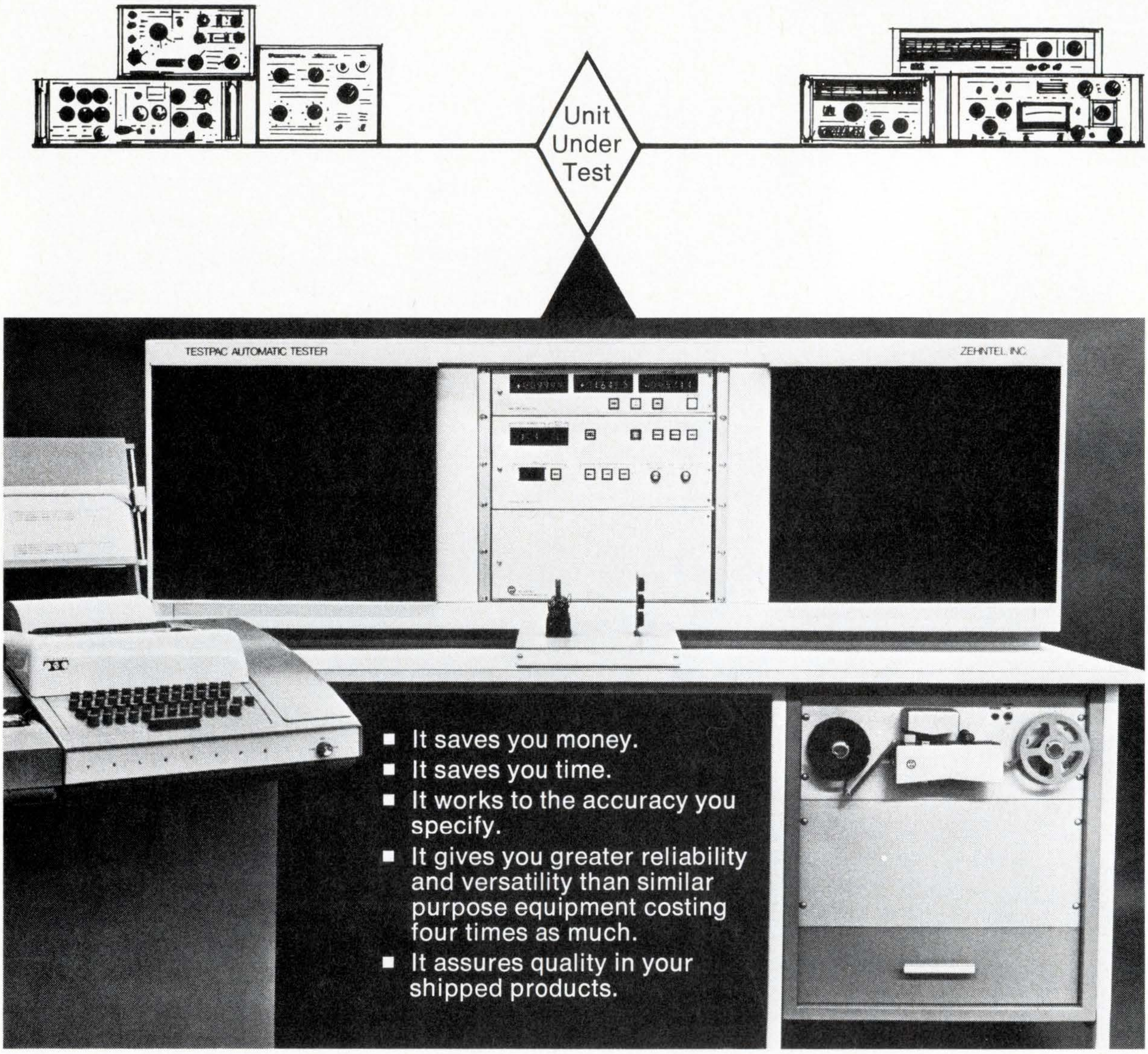
If anything here piques your curiosity, you can get the full package of specs by writing Bell & Howell, Instruments Division, 360 Sierra Madre Villa, Pasadena, California 91109.

INSTRUMENTS DIVISION

BELL & HOWELL

Zehntel's Testpac™

The Complete Checkout Station



It is simple in the sense that it permits you to select the best balance of programmable stimulation and measuring instrumentation using TESTPAC's interface and control equipment.

Zehntel's TESTPAC is designed to accept simple instructions, while it is capable of precise and detailed readout. Ideally suited as a production checkout station, it is also capable of giving you a means of speedy calibration and detailed diagnostic readouts.

TESTPAC is simple enough to be operated by unskilled personnel, yet it is sophisticated enough to let you undertake the most complex, exacting test procedures.

And, while it costs a fraction of comparable equipment it gives you the versatility to eliminate the costly obsolescence of dedicated checkout stations.

For further information contact: Marketing Manager, Zehntel, Inc., 1450 Sixth Street, Berkeley, Ca. 94710 Telephone: (415) 527-5440 TWX 910-366-7047

An affiliate of Electronic Memories & Magnetics Corporation

EDITORIAL

Who speaks for EEs in times of Crisis?

Last month, on August 17, *Electronic News, The Wall Street Journal, The New York Times,* and other papers throughout the country, carried an open letter to President Nixon. Signed by Benjamin Friedman, president of Solitron Devices, Inc., it called President Nixon's attention to a problem we are all painfully aware of. In Mr. Friedman's words, unemployment among "top-ranking scientists, engineers and designers is at an extremely dangerous level for our national well-being . . . Unless immediate action is taken, it will require at least five years to replace this brain power."

Of course, since any electronic engineer already knows this fact, we assume that it is known also in government circles. Indeed it is. As you can read in the CHALLENGE article that appears in this issue, Deputy Secretary of Defense David Packard is very familiar with this situation. After all, the cutbacks that precipitated this crisis started in his Department.

But, does it follow that the President is fully aware of the magnitude and implications of the problem, and that he will decide to establish national priorities that could channel engineering manpower into activities that will allow the U.S., as Mr. Friedman puts it, "to remain number one in the field of technology and not become a second rate power?"

I don't think it does. The President's scientific advisor, Dr. Lee A. DuBridge, has just resigned, and his office has not had a particularly strong voice in the White House. And, unfortunately, no organization in the affected portions of the engineering field has been trying to get the President's ear and advise him. Mr. Friedman's pragmatic approach, then, of writing directly to the President on behalf of the "Technology community," shows sensible and courageous initiative. Who can question his authority to do so? The IEEE, which is barred from lobbying by its own bylaws? The Electronic Industries Association (EIA) which lobbies, but for the industry, not for national technology goals? The Engineers Joint Council? Perhaps. In any case, Mr. Friedman is certainly aware of the situation ("I get 700 resumes a week," he says) and he is far more qualified to speak about it than any Congressman in Washington.

In his open letter, he proposes that the President establish a set of seven national goals—six civilian and one military. These goals are in the fields of communications, transportation (to reduce the major source of pollution), oceanography (to exploit new sources of food), nuclear power generation, defense, health, and education.

Of course, we of the electronic press have written countless editorials and articles on the situation. You will find them in this issue, in many of our recent issues, and in those of most of our colleague magazines. The editorials are fine, they tell us something we already know, and make those engineers who have lost their jobs feel accompanied in their misery. But the problem, as Mr. Friedman points out, transcends the realm of engineering. It may amount to a national calamity if engineers drop out of engineering, and if we slow down our progress to just simmering along while we let (and fund) other nations to zip by past the U.S.

Therefore, since the press speaks to the electronics community, I feel we have an obligation to detect its problems and bring them to the attention of those who hold the key to their solution. To this end, I am inviting our colleagues, the editors of *Computer Design, EDN, EEE, Electronic Design, Electronic News, Electronic Products, Electronics, IEEE Spectrum, Microwave Journal,* and *Microwaves,* to request together an audience with President Nixon, as well as with Congressional leaders, to make them aware of the seriousness of this situation. Will it be called lobbying? It doesn't matter. If that's the name for it, our readers are worth lobbying for.

We will keep you informed of what develops from the pages of this and, hopefully, other magazines. In the meantime, you can help. Mr. Friedman has written to the President. Get a copy of his letter*, or write your own, and send it to your Congressman.

Alberto Socolovsky
Editor

*The open letter ran in the Aug. 17 issues of the following papers: *Boston Globe, Chicago Tribune, Dallas Morning News, Electronic News, Los Angeles Times, Miami Herald, New York Times, Wall Street Journal* and *Washington Post.* Or, you can request a copy directly from Solitron Devices, Inc., 256 Oak Tree Rd., Tappan, N.Y. 10983.


If you're interested in fast delivery, we can produce one million perfect MOS chips a week.
Right now we're shipping 30% of all the 1024-bit-or-under ROM's in the industry, 45% of the counters, and 28% of all shift registers under 100 bits.
Last year alone we expanded production capacity 500% in six months . . . without adding any equipment. What we did add was a tremendous amount of know-how. And that means higher production yield.
Currently, our yield is twice as good as the industry average. Which may explain why your present supplier has delivery problems and we don't.
And since high yield equates with lower cost and higher inherent reliability, you can instantly detect two more very handsome benefits in it for you.
Skeptical? Make us prove it. Ask us to bid on your next buy. Call Bob Simon, MOS Marketing Manager, (215) 646-9100. Or write him at Microelectronics Division, Philco-Ford Corporation, Blue Bell, Pa. 19422.
PHILCO Ford
The better idea people in MOS.

IT HAPPENED LAST MONTH . . .

The editors of THE ELECTRONIC ENGINEER have sifted through the various technical and significant happenings of the past month and selected the items that would be of the most interest or use to you.

Engineer licensing . . . A memorandum issued by the Civil Service Commission Standards Division to its regional offices reminded them of the requirement that certain high level engineers be registered. Professional registration is "essential," according to the memorandum, when public safety is involved. Relax. The memorandum also states that "relatively few engineering positions in the Federal service have duties and responsibilities that would support a requirement for registration." So you probably need not worry—most positions won't require registration.

Light gets brighter . . . Several companies have recently reorganized, or formed new divisions to specialize in the rapidly growing optoelectronics market. One of the latest is RCA, with the formation of the Solid State Optoelectronics Products Dept. The new department combines work with liquid crystals, IR diodes, injection lasers, photocells, and tunnel diodes. RCA expects the optoelectronics market to grow to greater than $200 million by 1974.

Sign of the Times . . . Hewlett-Packard Co. has taken a step to reduce their work schedule without reducing their employee population. Some 11,000 workers will take one day off every two weeks to achieve a 10% cutback in production. Although salaries will be decreased proportionately, President William R. Hewlett states that "We consider the work reduction a more effective and equitable method of reducing costs and inventory than laying people off." The biweekly vacation without pay will continue "until business conditions warrant a return to full production." Domestically, orders are down 6% from a year ago.

No dumping allowed . . . The Electronic Industry Association (EIA) has been after the Treasury Dept. to stop the Japanese from dumping products into the American market at unfair prices. Companies registered complaints about foreign tubes, transformers, and loudspeakers, but with no government action. Finally the EIA went on to complain about tuners and the government stepped in. The Treasury Dept. investigated and indeed found dumping taking place. Since dumping could lead to higher duties in order to protect U.S. manufacturers, EIA considers this action a "landmark decision."

Military purchasing evaluation . . . The Presidential Commission that recently recommended a reorganization of the Defense Dept. also strongly suggested the establishment of an agency within DoD that would test and evaluate weapons the military buys from industry. Such an agency stands a good chance of being created, and it will most certainly assume responsibility for electronic gear. Among the members of the Commission were familiar names in the electronic industry, such as John M. Fluke, president of Fluke Manufacturing Co., and Dr. Ruben F. Mettler, president of TRW Inc.

Pooling of QC in Europe . . . Users of electronic components in Austria, Finland, Norway, and Sweden will pool and exchange data on quality control and testing of electronic components. After a Swedish initiative that started three years ago, the "International **EX**change of **A**uthenticated Electronic **C**omponent Performance **T**est Data," each participating company or institution fills a test report for the components it tests, and sends it to its national EXACT center. The center, in turn makes it available to all contributors. During 1970, the international headquarters of EXACT in Stockholm will be funded by the Swedish government, but as of 1971 it will run on contributions by the subscribers.

Microwave ovens stop pacemakers . . . If you must rely on a heart pacemaker, you might be wise to keep your distance from microwave ovens. Recent tests performed by the Microwave Heating Div., EAS Inc., showed that some models are stopped at a distance of 100 ft. by a microwave oven emitting 30 mW/cm^2 at 5 cm (2 in.). The same unit was stopped at 8 ft. by an oven emitting only 0.2 mW/cm^2 at 5 cm. This figure is 50 times less than the current microwave industry max, and 25 times less than the new government proposed standard. Some units stopped; others increased in pace; and some reverted to a fixed rate. Various brands and types were tested. Further information may be obtained by writing to "Radiation," Box 814, Minneapolis, Minn. 55440, or by calling (612) 521-4608.

Prediction off . . . The 80-million-dollar market originally predicted for digital panel meters has thus far failed to materialize. Apart from the fact that many analog meter users depend on needle movements to show the trend of the measurement, DPM makers cite three reasons for the error in the predicted market size: DPMs are still sophisticated measuring instruments not too easy to reproduce in quantity; they still require field support; and, thus, prices have not dropped as rapidly as anticipated. So look for a shakeout in the ranks; there are now more than 50 DPM manufacturers, of which only a handful have the engineering and marketing resources necessary in this market.

Circle 10 on Inquiry Card⟶

Rate gyro is a vibrating thing

Output is derived from a taut wire vibrating between magnets

A new rate sensor has a predicted life 10 times that of rotating rate gyroscopes. Honeywell's vibrating wire rate sensor (VWRS) has a usable lifetime, without repair, of up to 75,000 hours. It was designed for airborne use.

The VWRS produces a rate of turn output through interaction of a vibrating wire and a pair of magnets. A two-inch beryllium-copper wire is tautly strung within two magnetic fields. One field provides drive impetus, and the other generates an output signal. A second wire, strung at the midpoint of the first wire at right angles, is grounded to separate, electrically, the drive and output signals.

The drive magnet is mounted with its poles in the same plane as the second wire. The signal magnet is mounted with its poles perpendicular to the drive magnet.

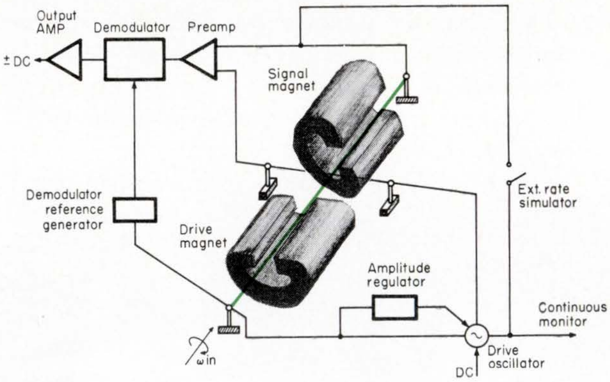
A transistorized oscillator feeds ac to the main portion of the beryllium-copper wire strung through the drive magnet's field. This causes the main portion of the wire to vibrate, inducing sympathetic vibration along the half of the wire strung through the signal magnet's field.

The input axis of the VWRS is along the longitudinal axis of the device. Rotation on the input axis causes Coriolis deflection forces on the vibrating wire to produce an output signal proportional to the input rate.

Some of the device's features are electrical isolation of the output signal; control of wire vibration to prevent signal error; relative insensitivity to temperature and aging; use of latest microcircuitry; ready time of 100 ms; and constant wire frequency vibration.

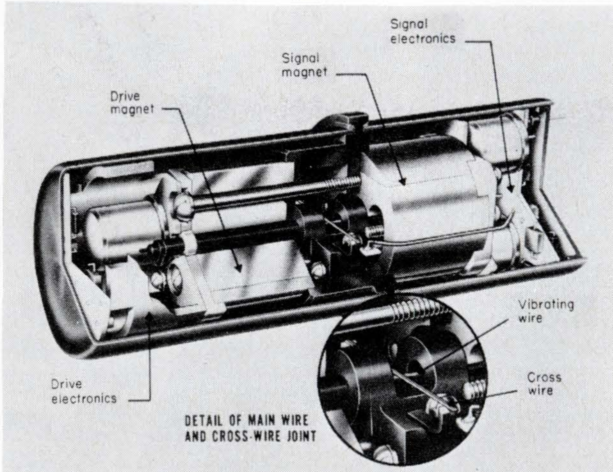
Noise threshold in the output signal is 0.02°/s. Linearity is now 1% with reduction to 0.5% expected. Performance features include a requirement of less than 1 W power, dc input and output signals, easy adjustment of this signal to meet system needs from a shelf-type unit, and no detectable hysteresis effect.

Under development at Honeywell in Minneapolis for five years, the firm has built 36 of these rate sensors for test purposes.



Honeywell's vibrating wire rate sensors. A taut wire vibrates when fed a controlled ac signal. The wire vibrations take place from interaction with the drive magnet. These vibrations, in turn, cause sympathetic vibrations where the wire passes through the signal magnet. Rotation of the axis causes deflection forces on the vibrating wire to produce an output signal proportional to the input.

Here is the VWRS completely packaged. Notice the two wires at 90° to each other. The cross wire is used to isolate drive and output signals.



Circle 11 on Inquiry Card→

Brazen Offer!

If you can come up with a
PC fork and blade plate connector system
that's more versatile than our 5420 system
we'll make your "special"
for the price of our "standard".

A bid like this takes a lot of guts and/or a miniature base plate connector system that's so versatile we're fairly sure we've got ourselves covered.

Our 5420 system has that kind of universality.

First off, consider the 5420's base plate components. Singles. Doubles. Males. Females. .025 square post. All of which can be spaced on .100", .125", or .150" centers. Okay?

Then there're the header components: 5420 has 50 contact headers for IC packages; heat sinked 40 contact headers standardized for SHP's; and modular headers for any other size.

And all the 5420's components provide the metal-to-metal contact required by MIL-E-5400. (No relation.)

If that's still not enough, multiply by the added possibilities of both squared and offset grid patterns.

Now you're beginning to see what makes us so sure that our 5420 system will do the job even for the mcst cunning applications up with which you can come.

They're very much in step with NAFI's standard packaging concept, and versatile enough to take hundreds (make that thousands) of non-standard jobs neatly in their stride.

What we haven't said here we say in our catalog. Write for it. You'll find the 5420 specs on Page 14.
Elco Corporation, Willow Grove, Pennsylvania, 19090,
(215) 659-7000, TWX 510-665-5573.
Or 2200 Park Place, El Segundo,
California, 90245,
(213) 675-3311, TWX 910-325-6602.

ELCO Plate Connectors

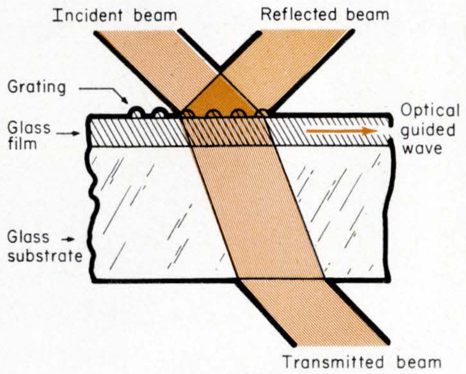
This light-coupling idea is grating

A simple and efficient technique for coupling laser light into a thin-film optical waveguide (lightguide) has been developed by a team at the Research Division of IBM. Using a diffraction grating fabricated directly on a lightguide, the method is compatible with IC technology. To date, the major problem has been getting the light into a lightguide. Two earlier methods have been: the direct passage of a laser beam into a thin-film edge; and the use of a prism to "optically tunnel" light into the film surface. But each has drawbacks. Edge-illumination creates problems in aiming, efficiency, and highly vibration-sensitive circuits. The prism approach, while quite efficient, appears to be incompatible with planar technology.

In IBM's method, the optical waveguide is a dense flint glass film, 0.76 μm thick with a refractive index of 1.73. The lightguide is rf sputtered onto a glass substrate whose refractive index is 1.52.

The diffraction grating is made with a layer of photoresist deposited on the glass film. The pattern is formed by exposure to a 4880 Å laser interferometer fringe pattern, followed by development. The periodicity of the resulting structure is about 0.67 μm. Experiments with 6328 Å laser light shows that up to 40% of the light travels through the lightguide.

As you know, potential information-carrying capacity of light is very high. So is the interest because of better, newer optoelectronic devices. Practical optical communications systems exploiting this capacity would, hopefully, include "integrated optical circuitry" to process light-borne data. Such circuitry might be formed of thin films shaped into miniature lightguide networks with components for modulation, phase shifting, amplification, detection, and a variety of other functions. Replacing optical systems, the circuits could be mass-produced at relatively low cost.



A diffraction grating on the surface of thin film (0.76 μm) has been used at IBM Research to send a laser beam into the film. When the laser beam is incident on the grating at the proper angle, the grating produces a diffracted beam which propagates (see arrow) within the film

Not a fickle finger

A tiny, precise electrical "finger" coupled to a computer streamlines the manufacture of semiconductor devices. The "finger" in Westinghouse's equipment is an electronic probe that automatically measures the resistance of silicon.

Such resistance measurements are then fed to a computer, whose output will indicate the overall quality of the silicon, its uniformity and reliability.

The probe is a thin metal wire about 0.0003 in. in diameter. Its contact on the silicon surface is flat and circular.

As the silicon moves a few thousandths of an inch between each reading, the probe is automatically raised and lowered. The whole stepping action is accurate to 0.000040 in., with readings taken on only one billionth of a cubic inch of silicon at a time.

When done by hand, the measurements are so delicate, tedious and time-consuming that they cannot be applied to a production line. With this new automatic system, millions of measurements can be made on the production line. From this information the essential electrical behavior of devices made with the silicon can be predicted.

When done by hand, measurements take about eight hours. The computer-probe system supplies the information in about 10 minutes.

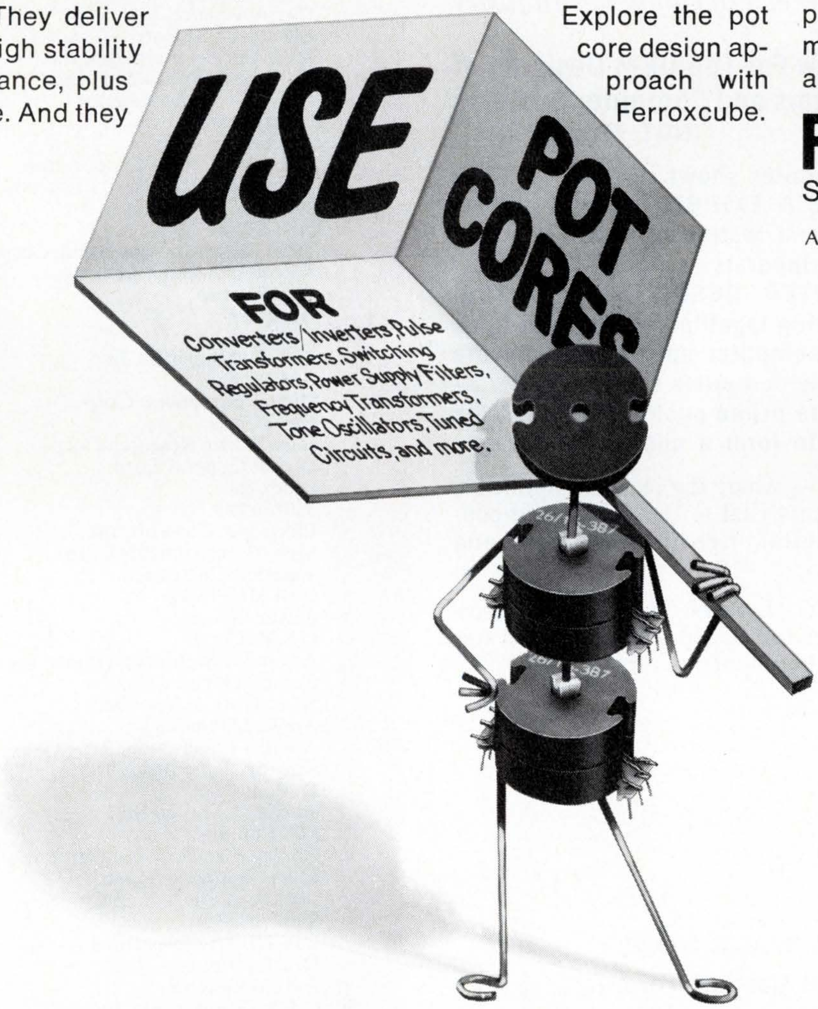
The new probe technique has been installed on several production lines at Westinghouse's Youngwood, Pa., plant where they make power transistors, thyristors and rectifiers.

Save money and get tighter specs.

Still using conventional components in your circuit design? Get out your pencil and start your next design with Ferroxcube ferrite pot cores. Now you can produce circuits that deliver better electrical performance at lower cost.

Here's how. Pot cores are completely self-shielding. They are rugged. They deliver high Q, high stability of inductance, plus small size. And they can meet exceptionally tight tolerances with utter reliability. They come pre-adjusted or adjustable. These characteristics can help you make cost-savings throughout all associated circuitry. Ferroxcube pot cores are ideal for automated production, too, including automatic PC board insertion.

Explore the pot core design approach with Ferroxcube.



It's the broadest line in the industry...97 types in 12 sizes and 5 materials. Plus prototype production quantities off-the-shelf from eight Stocking Centers nationwide. No one else makes pot cores so instantly available.

Send for our latest Linear Ferrite Catalog now. Once you've used pot cores you'll know why so many magnetic component designers are going to pot.

Ferroxcube™
Saugerties, New York
A NORTH AMERICAN PHILIPS COMPANY

STOCKING CENTERS: Boston—(817) 449-1406; **Burbank, Calif.**—(213) 849-6631; **Chicago**—(312) 833-4020; **Dallas**—Gillett Industries, (214) 363-0107; **New York**—Kahgan Sales, (516) 538-2300; **Philadelphia**—Eastern Components, (215) 927-6262; **San Francisco**—Wm. J. Purdy Corp. (415) 347-7701; **Woodstock, N.Y.**—Elna Ferrite Labs, (914) 679-2497; **Toronto, Ont.**—Philips Electron Devices, Ltd., (416) 425-5161.

SALES OFFICES: Baltimore—Eastern Components, (301) 322-1412; **Cedar Rapids, Ia.**,—Thomas & Modricin, (319) 377-6261; **Columbus, Ohio**—Mulligan & Mathias, (614) 486-2976; **Denver**—Wm. J. Purdy Corp., (303) 794-4283; **Huntsville, Ala.**—Cartwright & Bean, (205) 852-7670; **Kansas City**—Thomas & Modricin, (913) 432-2131; **Minneapolis**—(612) 920-1830; **Orlando**—Cartwright & Bean, (305) 425-8284; **Phoenix**—(602) 264-3129; **Rochester, N.Y.**—R. P. Kennedy Co., (716) 271-6322; **Saugerties, N.Y.**—(914) 246-2811; **St. Louis**—Thomas & Modricin, (314) 338-6446.

if you make

Components, Hardware, Instrumentation or Peripherals Required In The Design, Construction, or Testing of Computers and Computer Systems—

JOIN A DISTINGUISHED GROUP OF COMPANIES WHO HAVE ALREADY SIGNED FOR BOOTHS AT THE

CURRENT LIST OF EXHIBITORS

Analog Devices, Inc.
Davidson Optronics Inc.
Howard Industries
Burndy Corp
EG&G Corp
Lambda Electronics Corp
George Risk Industries, Inc.
Electro-Fiber Optics
Motorola Semiconductor Products Inc.
Stratojet Corp
Ferrodyne Corp
Optical Memory Systems
Thomas & Betts
Trompeter Electronics
University Computer Co.
AMCO Engineering Co.
Controls Research Corp
Heinemann Electric Co.

COMPUTER DESIGNER'S CONFERENCE & EXHIBITION

Anaheim Convention Center, January 19, 20, 21, 1971

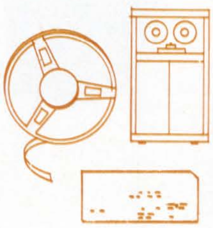
In the heart of the huge Western Computer Industry

The Only Show For The OEM Designer of Computers and Computer Systems (NOT THE USERS!)

In contrast to existing computer shows, the COMPUTER DESIGNER'S CONFERENCE & EXHIBITION will concentrate ONLY on the design and testing of computers and computer systems and peripherals — not on their user applications! The COMPUTER DESIGNER'S CONFERENCE & EXHIBITION will bring together, for the first time, an estimated 15,000 OEM computer specialists who are directly involved in designing computer systems and subsystems . . . the men who are prime customers for all the components that combine to form a computer system.

300-BOOTH EXHIBITION — where the latest components, subsystems, and test instruments vital to the design and construction of all analog, digital, hybrid computers and peripherals will be on display.

WIDE RANGING TECHNICAL PROGRAM — will spotlight current design techniques for all types of computer systems and computer peripheral equipment.



Sponsored by
ELECTRONIC ENGINEER

RESERVE YOUR BOOTH SPACE NOW!

Call or Write For Details and Contract Forms:

INDUSTRIAL AND SCIENTIFIC CONFERENCE MANAGEMENT, INC.

222 West Adams Street, Chicago, Illinois 60606
Phone (312) 263-4866

Borg-Warner
Dynage Inc.
Jonathan Mfg. Co.
Circuit Science, Inc.
Electro-Craft Corp
Mechanical Enterprises, Inc.
R. Howard Strasbaugh, Inc.
Fairchild Semiconductor
Nortronics
Tetra Corp
Data Technology Corporation
Radiation, Inc., Micro Electronic Div.
Vibrac Corporation
NJE Corp
TEC, Transistor Electronic Corp
Talcott Computer Leasing
Quadri Corp
Accuride
Comcet
Pioneer Magnetics, Inc.
AMP Inc.
Digital Equipment Corp
Hepa Corp
Burr-Brown Research Corp
Digital General Corp
Ledex Inc.
Rotron Inc.
Electronic Controls, Inc.
Mobark Instruments Corp
Superior Electric Co.
Gast Mfg. Corp
Pacific Optical
U.S.M. Corp
Advanced Memory Systems, Inc.
Computer Test Corp
W. L. Gore & Associates
Applied Dynamics
Applied Logic Corp
The Birtcher Corporation
DuPont Co.
Alloys Unlimited Inc.
ITT Cannon
Cherry Electrical Products Corp
Eldre Components Inc.
Lockheed Electronics Co.
Signetics Corp
Fabri-Tek Incorporated
Disc Instruments, Inc.
Hybrid Systems
C & K Components, Inc.
Elco Corp
Lipps, Inc.
Sealectro Corp
Electronic Memories & Magnetics Corp.
Nikon Inc.
Sylvania Electric Products, Inc.
Georator Corp
Princeton Electronic Products, Inc.
Westinghouse Electric Corp.

Circle 13 on Inquiry Card →

THE WAVEMAKERS

in every sense of the word

and we'll prove it!

We're challenging you to use our amazing new Model 4200 Test Oscillator in your own lab, on your own projects for 10 days without obligation. We're sure you'll be quick to recognize its superior performance, ease of operation, reliable accuracy, and unmatched value. The consistent half watt power output over the 10 Hz to 10 MHz range plus an internal impedance of 50 ohms means you can drive loads without overloading. Add excellent frequency response of 0.025 db and a distortion factor of 0.1% and you've got a versatile, high performance test oscillator that can't be beat.

Yes, Krohn-Hite, innovators in oscillator design for over twenty years, is making waves again!

KH

First Class
Permit No.
30358
Boston, Mass.

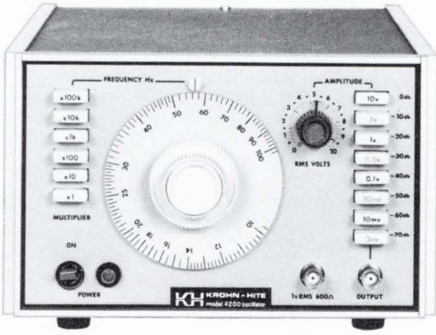
Business Reply Mail

Krohn-Hite Corporation
580 Massachusetts Avenue,
Cambridge, Massachusetts 02139

THE WAVEMAKERS

KROHN-HITE MODEL 4200, 10 Hz TO 10MHz, TEST OSCILLATOR

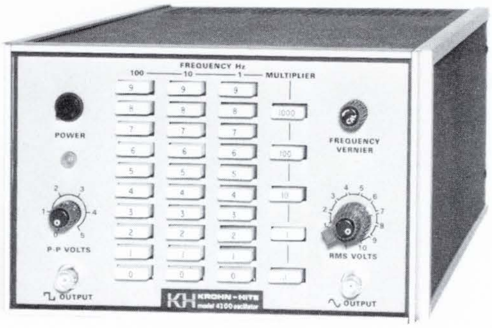
- **Frequency Range: 10 Hz to 10 Mhz**
- **Power Output: ½ watt**
- **Maximum Output: 10 volts rms**
- **Frequency Response: 0.025 db**
- **Harmonic Distortion: 0.1%**
- **Frequency Accuracy: 2%**
- **Internal Impedance: 50 ohms**
- **Auxiliary Output**
- **External Synchronization**
- **Amplitude Stability: 0.02%**



A low priced, solid state laboratory or production signal source featuring unusual flatness and ease of operation normally found in instruments selling at twice the price. The high power output signal of the Model 4200 delivers full voltage to the load over the entire frequency range. An infinite resolution dial and push-button multiplier provide rapid and continuous frequency tuning. In short, the Model 4200 is a broad range, versatile test oscillator destined to set new standards in performance and value.

KROHN-HITE MODEL 4100A, 0.01 Hz TO 1 MHz PUSH-BUTTON OSCILLATOR

- **Frequency Range: 0.01 Hz to 1 MHz**
- **Power Output: ½ watt**
- **Harmonic Distortion: 0.02%**
- **Frequency Accuracy: 0.5%**
- **Amplitude Stability: 0.002%**
- **Frequency Response: ±0.05 db**
- **Internal Impedance: 50 ohms**
- **Square Wave Risetime: 20 ns**
- **External Synchronization**



A medium priced, solid state, general purpose Oscillator that produces sine and square waves simultaneously from 0.01 Hz to 1 MHz with ½ watt of power into 50 ohms. Frequency calibration is within ±0.5% and push-button tuning permits ±0.1% frequency repeatability. 50 ohm internal impedance minimizes output voltage drop due to loading, specifically at higher frequencies where unavoidable capacitive loading limits the usefulness of higher impedance oscillators. The Model 4100A is an ideal laboratory and production instrument for a variety of applications where outstanding performance offers increased measurement speed and accuracy.

Yes, Krohn-Hite, the leader in variable filters, is fast becoming a leader in oscillators. Krohn-Hite has designed and manufactured a complete line of signal generating equipment to meet and, in many cases, exceed your project requirements. Each offers high performance features that you'd normally expect to cost a great deal more. Here's a brief rundown of the soon-to-be famous, never-to-be forgotten Krohn-Hite line. For further information on any of the instruments or complete details on our challenging Free Trial offer, simply fill in the attatched postpaid reply card. We guarantee an answer by return mail.

OSCILLATORS

Frequency Range	Osc. Model*	Freq. Acc. %	Power (mw)	Impedance (ohms)	VRMS (Open Circuit)	Quad. Output	Add'l. Wave-Forms	Freq. Resp. (db)	Dist. %	Approx. Ship. Wt. lbs/kgs	Price
0.001 Hz to 100 kHz	4024	0.5	125	200/600	10	Yes	⊔⊓ ⎍	0.01	0.01	24/11	$1200
0.001 Hz to 100 kHz	4025	0.1	125	200/600	10	Yes	⊔⊓ ⎍	0.01	0.01	24/11	$1950
0.01 Hz to 1 MHz	4100A	0.5	500	50	10		⊔⊓	0.05	0.02	21/10	$ 550
0.1 Hz to 100 kHz	4000	0.5	125	200/600	10	Yes	⊔⊓	0.01	0.01	18/9	$ 850
0.1 Hz to 100 kHz	4001	0.1	125	200/600	10	Yes	⊔⊓	0.01	0.01	18/9	$1450
10 Hz to 10 MHz	4200	2	500	50	10		∼ (FIXED)	0.025	0.1	21/10	$ 350

*Add suffix "R" for rack mounting.

PROGRAMMABLE OSCILLATORS

Frequency Range	Osc. Model	Freq. Acc. %	Max. Volts	Output Impedance	Dist.	Square Wave	Prog. Amp.	Approx. Ship. Wt. lbs/kgs	Price
0.1 Hz to 100 kHz	4030R	0.5	10 RMS	200/600	0.01%	optional	optional	27/13	$1495
0.1 Hz to 100 kHz	4031R	0.1	10 RMS	200/600	0.01%	optional	optional	27/13	$2145
0.1 Hz to 1 MHz	4131R	0.1	10 RMS	50	0.02%	yes	no	30/15	$1375
0.1 Hz to 1 MHz	4141R	0.1	10 RMS	50	0.02%	yes	yes	30/15	$1585
1 Hz to 1 MHz	4130R	0.5	10 RMS	50	0.02%	yes	no	27/13	$1075
1 Hz to 1 MHz	4140R	0.5	10 RMS	50	0.02%	yes	yes	27/13	$1285

☐ Yes, I accept your challenge to try the fabulous Model 4200 Test Oscillator. Send me complete details at once.

☐ Send me complete specifications on Model(s): ____________

☐ Send me a copy of the complete K-H Catalog.

☐ Wow! You've aroused my interest and I can't wait. Please have your representative call me for an appointment.

NAME ____________ TITLE ____________

COMPANY ____________

DIVISION ____________ PHONE ____________

STREET ____________

CITY ____________ STATE ____________ ZIP ____________

Here's your chance to put Krohn-Hite, the Wavemakers, to work for you. Accept our challenge and you'll never settle for less. Just fill in the attached post-paid card and we'll see that you get all the details on the Krohn-Hite Free Trial Offer by return mail. Then, you too can be a wavemaker.

KH

KROHN-HITE CORPORATION

580 Massachusetts Ave., Cambridge, Mass. 02139
Telephone: 617/491-3211 TWX: 710-320-6583

OVERSEAS SALES OFFICES: BELGIUM, C. N. Rood s. a. DENMARK, SC Metric A/S; FRANCE, Antares; GERMANY, Nucletron Vertriebs-GMBH; HOLLAND, C. N. Rood n. v.; ITALY, Dott. Ing. Mario Vianello; SWEDEN, Teleinstrument; ISRAEL, R. D. T. Elect. Eng. Ltd.; JAPAN, Shoshin Shoji Kaisha, Ltd.; AUSTRALIA, Sample Electronics (Vic.) Pty., Ltd.; G. B., B & K Inst. Ltd.

Printed in U.S.A.

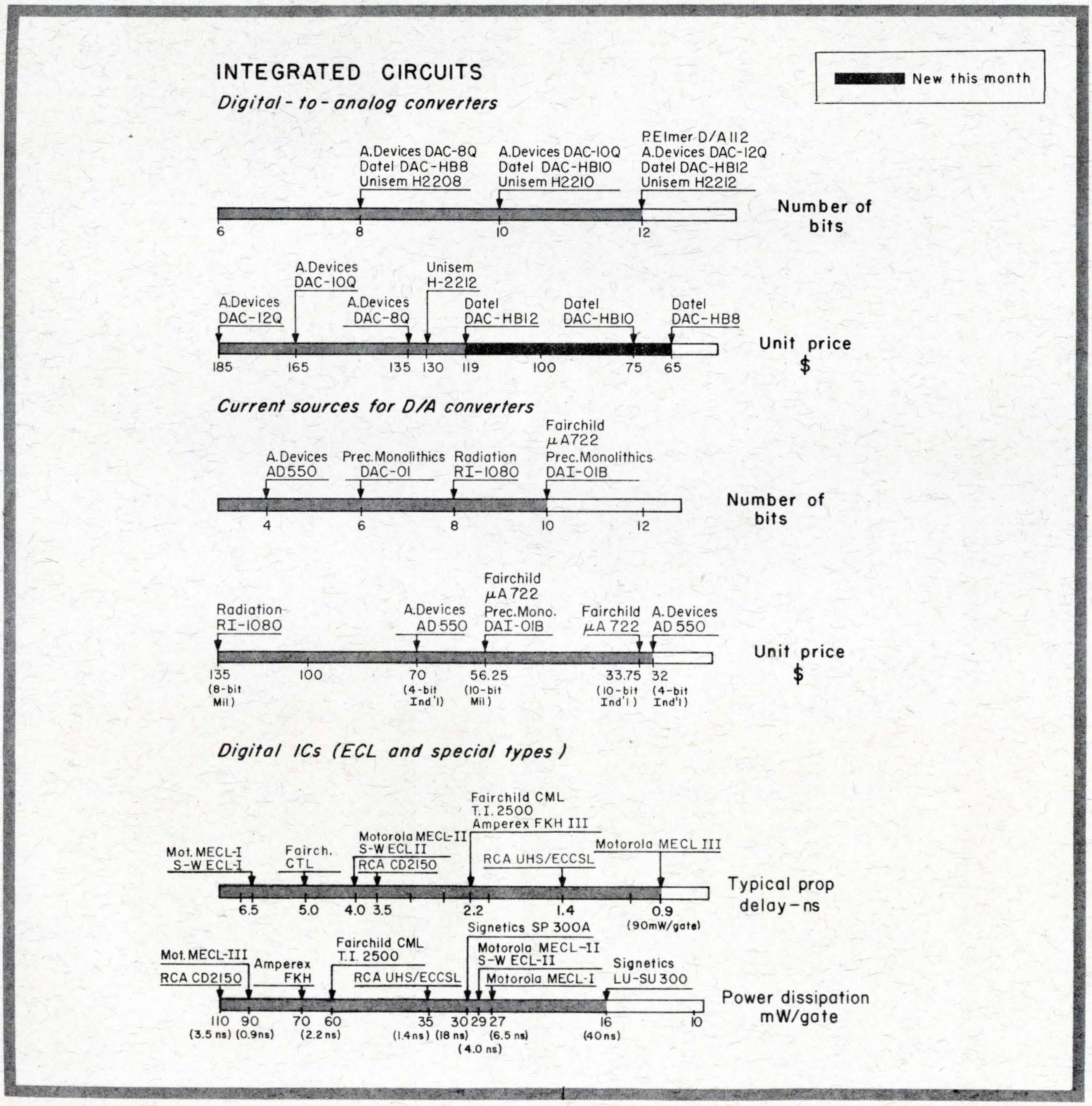
FOREFRONT

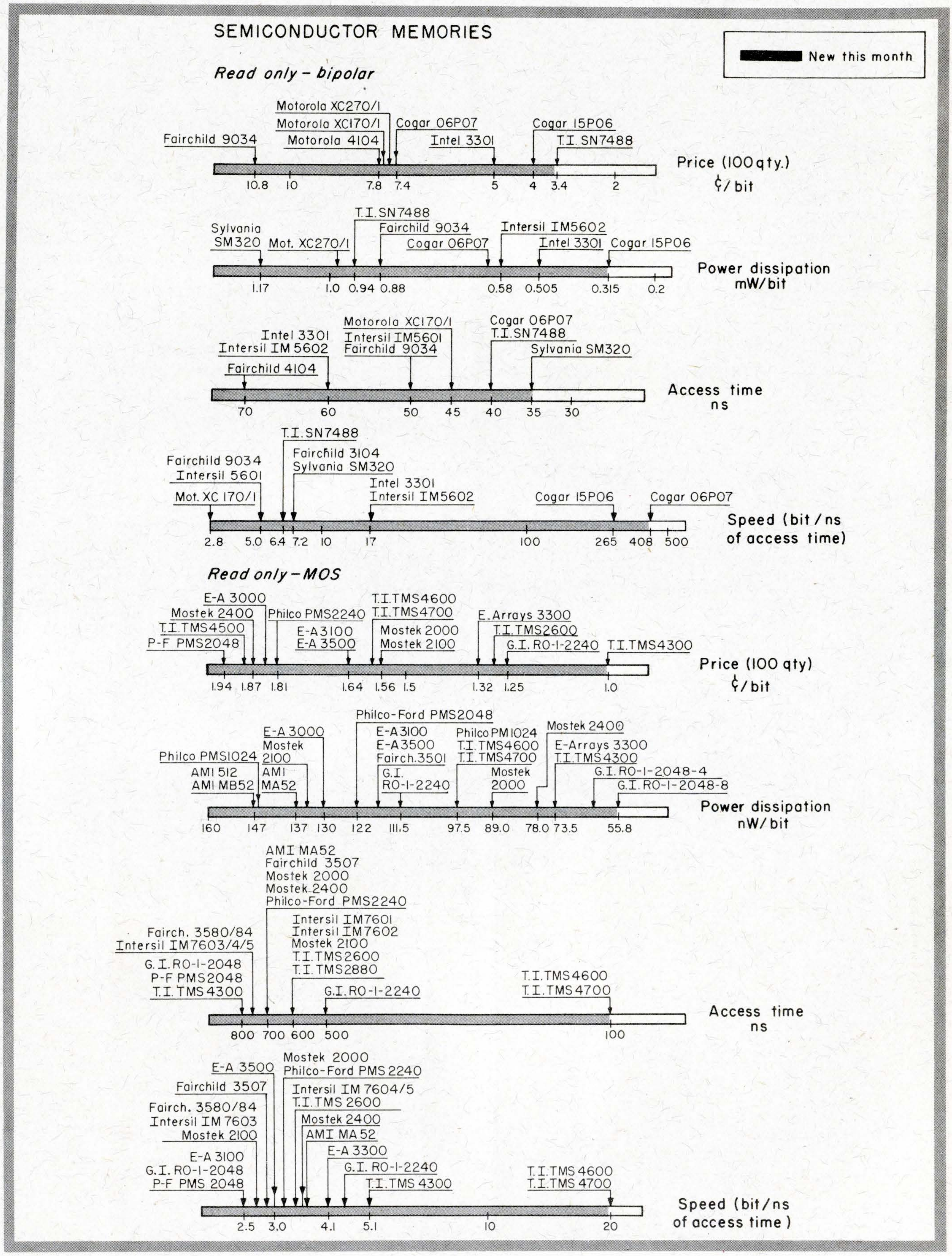
The EE Forefront is a graphical representation of the practical state of the art. You will find here the most advanced components and instruments in their class, classified by the parameter in which they excel.

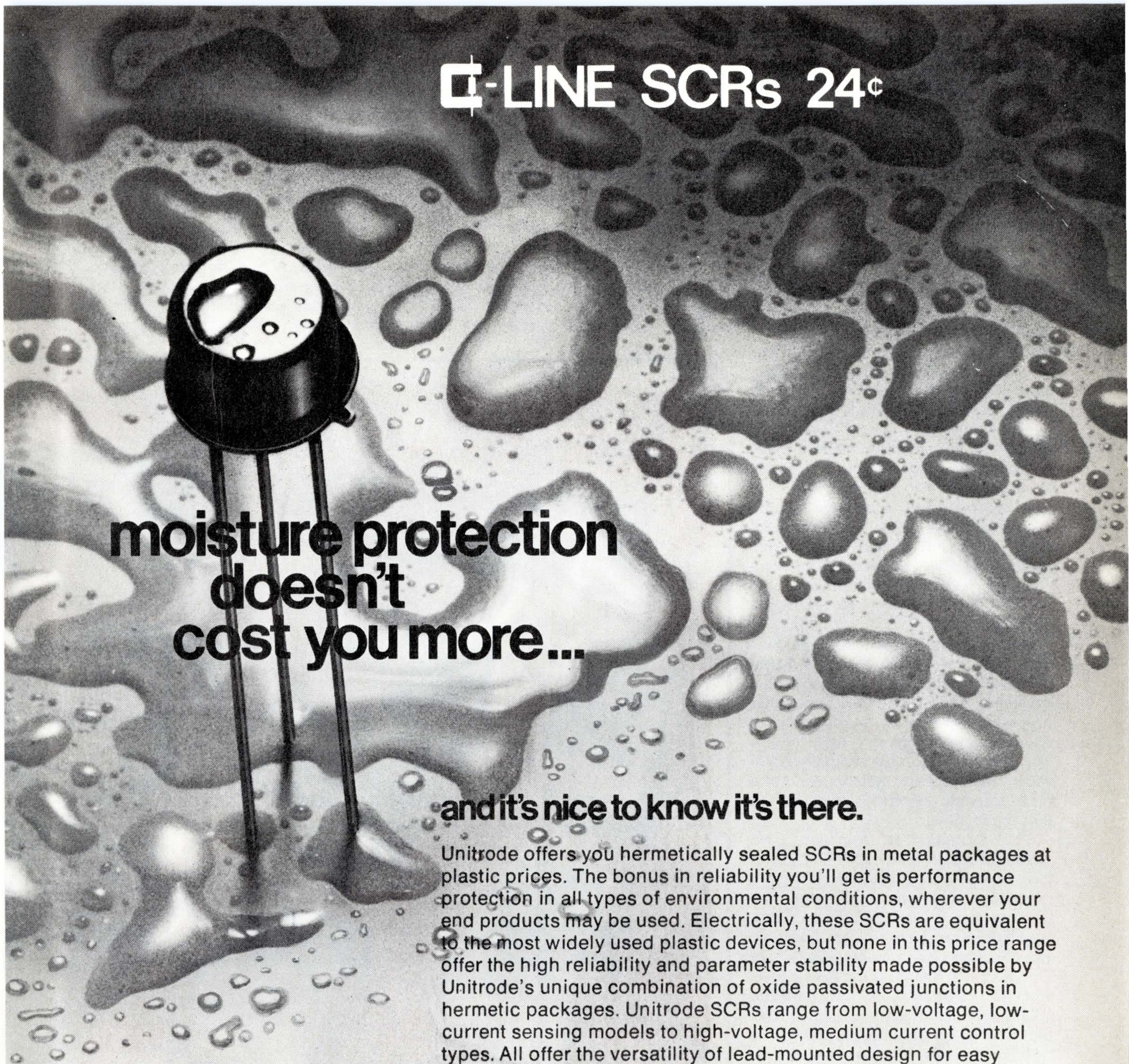
A word of caution

Keep in mind the tradeoffs, since any parameter can be improved at the expense of others. If there is no figure-of-merit available, we either include other significant parameters of the same products, or we provide additional bar graphs for the same products.

Do not use these charts to specify. Get complete specifications first, directly from the manufacturers.




SEMICONDUCTOR MEMORIES
New this month
Read only – bipolar
Motorola XC270/I
Motorola XC170/I
Motorola 4104
Fairchild 9034
Cogar 06P07
Intel 3301
Cogar 15P06
T.I. SN7488
10.8 10 7.8 7.4 5 4 3.4 2
Price (100 qty.) ¢/bit
T.I. SN7488
Sylvania SM320
Mot. XC270/I
Fairchild 9034
Cogar 06P07
Intersil IM5602
Intel 3301
Cogar 15P06
1.17 1.0 0.94 0.88 0.58 0.505 0.315 0.2
Power dissipation mW/bit
Intel 3301
Intersil IM 5602
Fairchild 4104
Motorola XC170/I
Intersil IM5601
Fairchild 9034
Cogar 06P07
T.I. SN7488
Sylvania SM320
70 60 50 45 40 35 30
Access time ns
T.I. SN7488
Fairchild 9034
Intersil 5601
Mot. XC 170/I
Fairchild 3104
Sylvania SM320
Intel 3301
Intersil IM5602
Cogar 15P06
Cogar 06P07
2.8 5.0 6.4 7.2 10 17 100 265 408 500
Speed (bit/ns of access time)
Read only – MOS
E-A 3000
Mostek 2400
T.I. TMS4500
P-F PMS2048
Philco PMS2240
E-A3100
E-A 3500
T.I. TMS4600
T.I. TMS4700
Mostek 2000
Mostek 2100
E. Arrays 3300
T.I. TMS2600
G.I. RO-I-2240
T.I. TMS4300
1.94 1.87 1.81 1.64 1.56 1.5 1.32 1.25 1.0
Price (100 qty) ¢/bit
Philco-Ford PMS2048
E-A 3000
Mostek 2100
Philco PMS1024
AMI 512
AMI MB52
AMI MA52
E-A3100
E-A3500
Fairch. 3501
G.I. RO-I-2240
Philco PM1024
T.I. TMS4600
T.I. TMS4700
Mostek 2000
Mostek 2400
E-Arrays 3300
T.I. TMS4300
G.I. RO-I-2048-4
G.I. RO-I-2048-8
160 147 137 130 122 111.5 97.5 89.0 78.0 73.5 55.8
Power dissipation nW/bit
AMI MA52
Fairchild 3507
Mostek 2000
Mostek 2400
Philco-Ford PMS2240
Fairch. 3580/84
Intersil IM7603/4/5
G.I. RO-I-2048
P-F PMS2048
T.I. TMS 4300
Intersil IM7601
Intersil IM7602
Mostek 2100
T.I. TMS2600
T.I. TMS2880
G.I. RO-I-2240
T.I. TMS4600
T.I. TMS4700
800 700 600 500 100
Access time ns
E-A 3500
Fairchild 3507
Fairch. 3580/84
Intersil IM 7603
Mostek 2100
E-A 3100
G.I. RO-I-2048
P-F PMS 2048
Mostek 2000
Philco-Ford PMS 2240
Intersil IM 7604/5
T.I. TMS 2600
Mostek 2400
AMI MA 52
E-A 3300
G.I. RO-I-2240
T.I. TMS 4300
T.I. TMS 4600
T.I. TMS 4700
2.5 3.0 4.1 5.1 10 20
Speed (bit/ns of access time)



and it's nice to know it's there.

Unitrode offers you hermetically sealed SCRs in metal packages at plastic prices. The bonus in reliability you'll get is performance protection in all types of environmental conditions, wherever your end products may be used. Electrically, these SCRs are equivalent to the most widely used plastic devices, but none in this price range offer the high reliability and parameter stability made possible by Unitrode's unique combination of oxide passivated junctions in hermetic packages. Unitrode SCRs range from low-voltage, low-current sensing models to high-voltage, medium current control types. All offer the versatility of lead-mounted design for easy interchangeability in hundreds of applications. The low-price, high reliability of ₵-line SCRs make them ideal for lamp or relay driving and as sensors, for use in pulse generators, timing circuits, motor controls and process controllers. (Sensing types are as low as 24¢ ea. in 100K lots.) They're in stock now, ready for immediate delivery. Can you afford not to use them? For fast action, call Sales Engineering collect at (617) 926-0404
Unitrode Corporation,
580 Pleasant Street, Watertown, Mass. 02172
Send for your free samples and complete specs today.

UNITRODE quality takes the worry out of paying less.

	ID 100 Series	ID 200 Series	ID 300 Series
Anode current rating	500mA @ 100°C Case	1.6A @ 70°C Case	1.6A @ 70°C Case
Voltage ratings	to 200V	to 200V	to 400V
Max. gate trigger current	200μa	200μa	200μa
Peak On-voltage	1.7V max. @ 1 Amp.	2.2V max. @ 4 Amps.	2.5V max. @ 4 Amps.
Package	TO-18 can, 0.5" leads	TO-5 can, 0.5" leads	TO-5 can, 1.5" leads

WELCOME

This column welcomes new companies or new divisions in the electronics industry.

IC designing can be fun

One of the most time-consuming and burdensome aspects of IC design is the translation of the circuit into a layout of its components and interconnections. An accurate layout is required because it will serve to generate the artwork for the IC's photomasks. At best, layout is a mechanical process in which individual components must be copied and positioned numerous times. The Design Assistant, developed by Dr. Fontaine K. Richardson for Applicon, Inc., is a new computerized interactive graphical system that shortens the development cycle by allowing the design engineer to select the position of components, while the computer keeps track of them and displays the layout on a storage CRT.

Applicon, Inc., located at 83 Second Ave., Burlington, Mass., is a new computer-aided-design company that develops and distributes computer programs and systems, particularly for scientific and engineering applications. The systems are either complete hardware and software systems, or complete software systems, depending on the application.

The founders of Applicon, Inc. were formerly with MIT's Lincoln Lab. where they acquired their CAD experience with the same group that had spawned Digital Equipment Corp. Applicon's president is Dr. Gary D. Hornbuckle; its vice-presidents are Dr. Richard Spann, Dr. Harry Lee, and Dr. Fontaine K. Richardson. While Dr. Hornbuckle frankly gives the reason for forming Applicon as "All companies are in business to make a profit—we're no different," he adds, "We are interested in providing and delivering useful products to end users, to help them solve difficult design problems."

Applicon's Design Assistant is a good example of such a philosophy since it is available as a complete hardware/software system. The hardware consists of a graphics terminal (which includes a Computek storage CRT display, keyboard, and data tablet) and an IBM 1130 computer. No user programming is required, and the software includes interfaces for automatic artwork generation equipment (such as flatbed plotters) and libraries of components that would normally be defined by the user, although they can also be acquired from Applicon. The system can be used for thick- and thin-film hybrids, for MOS, and for the bipolar circuits of LSI complexity. The complete Design Assistant can be leased for $4407/month. Deliveries began in June.

Applicon has also developed electronic programs which are distributed over several time-sharing networks. Such programs include MATCH, a frequency domain analysis program with optimization; MICRONET, for microwave circuit design; and ALICE, a logic simulation program with spike and hazard protection. Price for utilizing the three programs is approximately $30 to $60 per hour.

Circle 499 on Inquiry Card

The modular concept

What does Modular Computer Systems Inc. have to offer the real-time computer systems market? The modular concept. But this is more than just an idea. The new company is approaching a modular system by which you can purchase highly productionized computer and system building blocks as individual products for your specific needs.

Kenneth G. Harple, co-founder and president of the new company, was aware that nobody wants to go to the expense of having to buy all new equipment when his system requirements change. Harple thought that if he could make the modular concept work, he would eliminate the need for custom design for every customer.

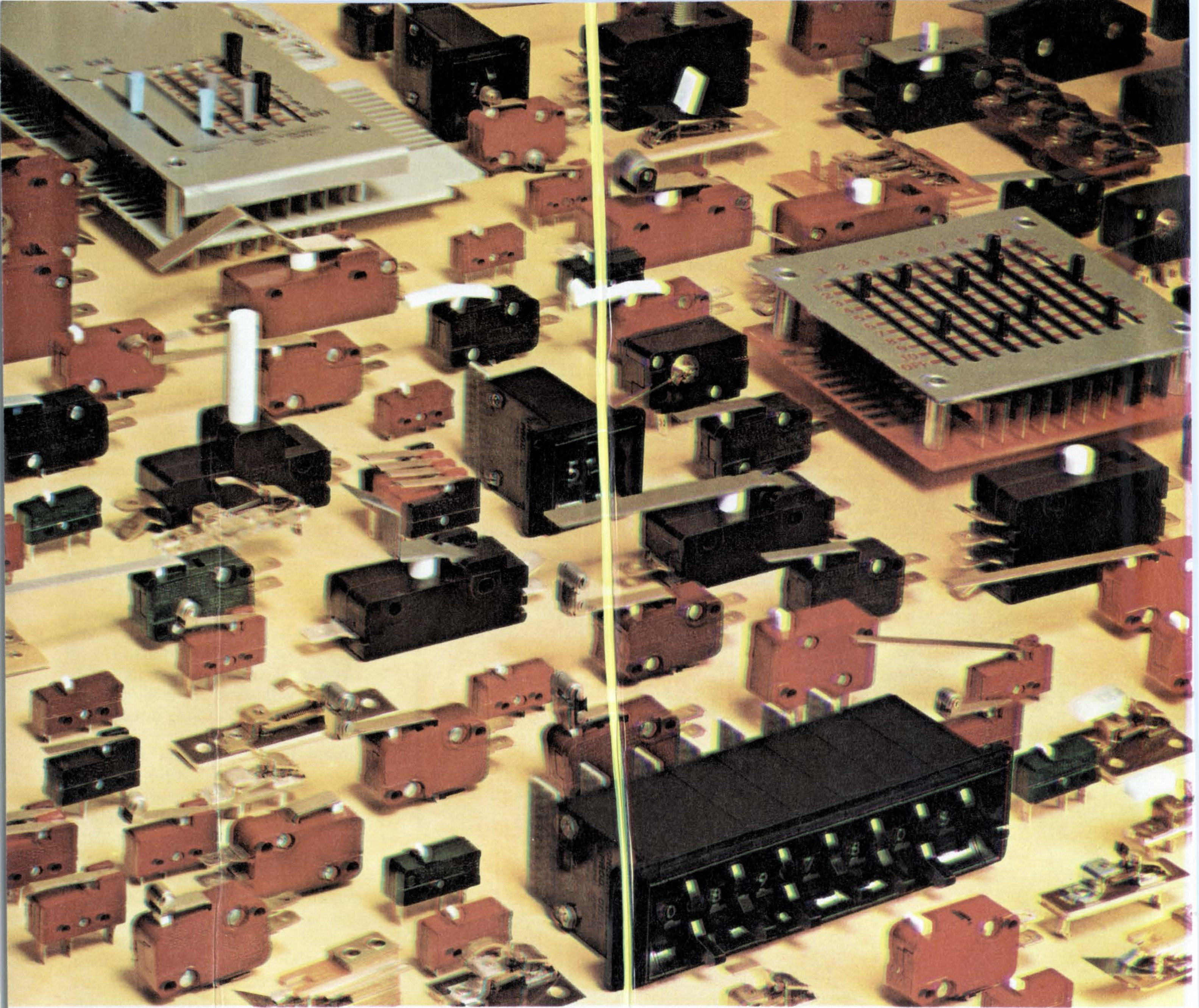
So Harple left his position as executive vice-president at Systems Engineering Labs and, along with several former co-workers, founded Modular Computer Systems. William Landis joined with him and now works as director of finance. Ray Mattson will be director of engineering, and Hugh Abernathy will serve as technical director. Robert DiStefano, director of manufacturing; Raymond Marlatt, marketing director; William Arbuckle, marketing operations director; and Seymour Schwartz, director of programming, were all founders of the new company and formerly with SEL.

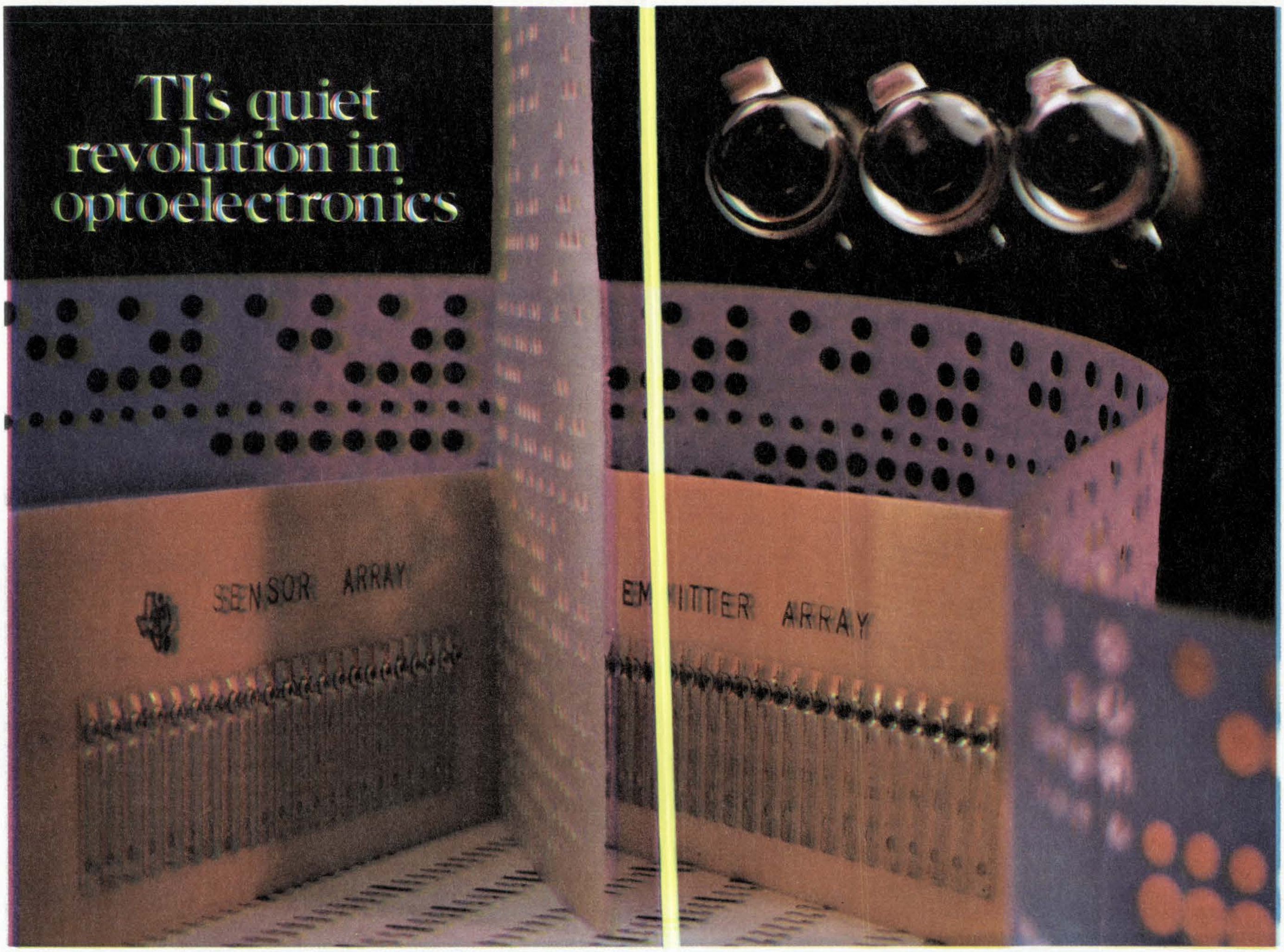
Here's how their modular concept works: the new company will take on complete systems responsibility (including software) by manufacturing a family of computers that can be upgraded without having to rewrite their programs. The availability of economic ICs using medium and large scale integration allows the modular design concept to be applied to computer and system building blocks. This way you can buy a machine to meet your present requirements and simply add from the family of building blocks when your needs expand.

The company, then, is working towards the manufacture of a complete family of real-time computers with all necessary peripheral equipment and software. They will put as much hardware "on the shelf" as possible so they can satisfy your requirements and cut your engineering costs.

The first family of computers to feature this concept are the Modcomp I, II, and III, to be introduced shortly. The company's efforts will be geared towards marketing complete systems for real-time, on-line data acquisition, control and communications.

Circle 500 on Inquiry Card





Now, GaAs emitters and Si sensors for under $5 per channel

TI's emitters are just $2.68 each in 100 quantities.

They're spectrally matched to our LS 600 silicon sensors which are only $2.15 each in 100s.

Pair them up for the most economical channel in solid-state readers today. The $4.83 channel.

Low initial cost. Exceptional system economics, too.

Here's why.

Compared to tungsten and fiber optics, TI's new emitters increase system performance by 10 to 1. You won't need potentiometer adjustment to make them work.

Forget about heat problems, tricky fiber alignment, adverse environments and sudden failures. These emitters have a lifetime 5 times that of comparable tungsten lamps. Better than a 5-year half-life.

TI's P-N emitters put out up to 2 mW for just 50 mA forward current.

Powerful, but small. They're easy to mount at 0.087" center-to-center...as required by new generation card readers. Use them to read tape, credit cards, badges. Also in encoders, speed and position indicators and communication systems.

Tell us what you need. You'll get the benefit of TI's unequaled experience in designing and producing emitter/sensor pairs in standard and custom arrays.

The new TIL 23 and TIL 24 emitters are in stock right now. Call your TI sales office or authorized distributor for fast delivery.

For information, write Texas Instruments Incorporated, PO Box 5012, MS 308, Dallas, Texas 75222.

TEXAS INSTRUMENTS
INCORPORATED

CALENDAR

SEPTEMBER

20	21	22	23	24	25	26
27	28	29	30			

Sept. 21-24: 1970 IEEE International Conference on Engineering in the Ocean Environment, Panama City, Fla. Addtl. Info.—C. B. Koesy, Naval Ship Res.-Dev. Lab., Panama City, Fla.

Sept. 22-24: ASTM Committee F-1 on Materials for Electron Devices and Microelectronics, Stardust Hotel, Las Vegas, Nevada. Addtl. Info.—Hank Hamilton, ASTM, 1916 Race St., Phila., Pa. 19103.

Sept. 23-24: Electron Device Techniques Conference, United Engrg. Ctr., New York, N. Y. Addtl. Info.—Mayden Gallagher, Hughes Res. Labs., 3011 Malibu Canyon Rd., Malibu, Calif. 90265.

Sept. 24-25: 20th Annual Broadcast Symp., Washington-Hilton Hotel, Washington, D.C. Addtl. Info.—Ed L. Shuey, c/o Ampex, 7222-47th St., Chevy Chase, Md. 20015.

OCTOBER

				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Oct. 7-10: International Microwave Power Symp., Hotel Kurhaus, Scheveningen, Holland. Addtl. Info.—Mr. D. J. Goerz, Jr., General Chairman, Bechtel Corp., Fifty Beale St., San Francisco, Calif. 94119.

Oct. 13-15: International Telemetering Conference/ITC USA-70, International Hotel, Los Angeles, Calif. Addtl. Info. —J. Wayne Matthews, Publicity Chairman, ITC/USA '70, c/o Electronic Resources, 4561 Colorado Blvd., Los Angeles, Calif. 90039.

Oct. 16-17: 25th Midwest Conf., American Society for Quality Control, Minnesota Section-Region 12, Minneapolis, Minnesota. Addtl. Info.—Roger Lundmark, 4700-76th Avenue North, Minneapolis, Minn. 55429.

Oct. 21-22: Third Annual Connector Symp., Cherry Hill Inn, Cherry Hill, N.J. Addtl. Info.—Ed Brautigan, Program Chairman, Third Annual Connector Symp., Box 3104, Phila., Pa. 19105.

Oct. 21-23: 1970 IEEE Ultrasonics Symposium, San Francisco, Calif. Mail an original and one good copy of your paper by August 1 to: Dr. W. J. Spencer, Bell Telephone Labs, Inc., 555 Union Blvd., Allentown, Pa. 18103.

Oct. 26-29; 25th Annual ISA Conf., Civic Center in Philadelphia, Pa. Addtl. Info.—Daniel R. Stearn, Public Relations Mgr., ISA, 530 William Penn Place, Pittsburgh, Pa. 15219.

NOVEMBER

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Nov. 4-6: IEEE Northeast Electronics Research and Engineering Meeting (NEREM) Sheraton-Boston Hotel, Boston, Mass. Addtl. Info.—IEEE Boston Office, 31 Channing St., Newton, Mass. 02158.

Nov. 9-11: Fourth International Congress on Microelectronics in Munich, Germany. Addtl. Info.—Dr. Leo Steipe, Electronica 70, Schaltbau GmbH, Munich, GERMANY.

Nov. 15-19: Magnetism & Magnetic Materials Conf., Diplomat Hotel, Hollywood Beach, Fla. Addtl. Info.—J. K. Watson, Univ. of Fla., Gainesville, Fla. 72601.

Nov. 16-18: 1970 Hybrid Microelectronics Symp., Century Plaza, Beverly Hills, Calif. Addtl. Info.—Ronald A. Delaney, Alloys Unlimited, 320 L.I. Expressway So., Melville, N.Y.

Nov. 17-19: Fall Joint Computer Conf., Astro Hall, Houston, Texas. Addtl. Info.—L. E. Axsom, IBM Scientific Ctr., 6900 Fannin, Houston, Texas 77025.

'70 Conference Highlights

NEC—National Electronics Conference, Oct. 26-28; Chicago, Illinois.

NEREM—Northeast Electronics Research Engineering Meeting, Nov. 4-6; Boston, Mass.

Call for Papers

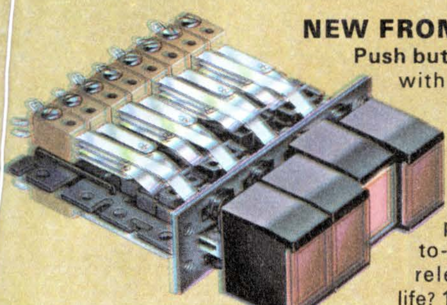
May 18-20: 1971 Spring Joint Computer Conference, Atlantic City. Submit six copies of your abstract (100-150 words), a draft (not exceeding 5,000 words) and rough illustrations by October 9, to Dr. N. Macon, '71 SJCC Technical Program Committee, Box 30130, Bethesda, Md. 20014.

Change your mind at the snap of a cam.

NEW FROM YOUR GUARDIAN ANGEL:
LEVER SWITCHES WITH SNAP-IN CAM INSERTS

This latest miracle from your Guardian Angel lets you change switch actuator positions instantly . . . at any time. Any combination of **off, momentary** or **locked** actuator positions is as easy as inserting a pair of "programmed" molded plastic cam inserts. A snappy little chore that takes maybe 20 seconds.

The new Guardian Lever Switches offer more than versatility. They are available in non-illuminated or illuminated with color coding. Up to 4 pole, double throw per station with switches arranged in any desired form to provide needed circuitry. (**Now** do you believe there's a Guardian Angel watching over Engineers?)



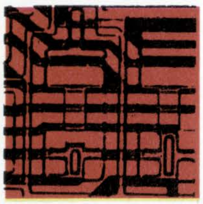
NEW FROM GUARDIAN: **Push button switch banks** with illuminated color coded buttons. Sleek, compact design with interlock, non-lock, all-lock, push-to-lock/push-to-release or solenoid release. Mechanical life? 100,000 operations!

WRITE FOR BULLETIN NO. E-2

GUARDIAN® ELECTRIC
MANUFACTURING COMPANY
1550 W. Carroll Ave., Chicago, Illinois 60607

Circle 17 on Inquiry Card

To make the lowest-cost arithmetic logic unit with carry lookahead built-in,

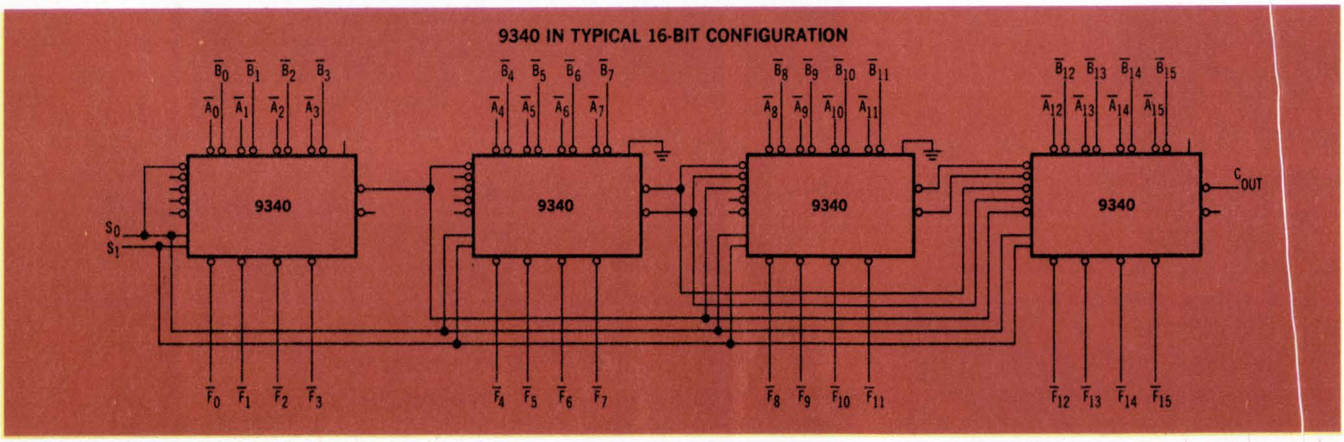


Fairchild's new 9340 is the perfect arithmetic logic unit for almost every application. It's a high-speed device that can perform two arithmetic operations (ADD or SUBTRACT) and any of six logic operations on two 4-bit binary words in parallel. To handle 16 bits, just hook up four 9340s. And nothing else.

The 9340 can ADD two 4-bit words in 28ns and SUBTRACT two 4-bit words in 33ns. The addition of two 16-bit words takes only 42ns.

The new ALU has full internal carry lookahead, and provides either a ripple carry output or carry lookahead outputs. The speed and flexibility of the 9340 make it ideal for other applications like multipliers, dividers and comparators.

Input clamp diodes are used on all inputs to limit high speed termination effects in the 9340. Input/output characteristics provide easy interfacing with all Fairchild DTμL, TTμL and MSI families.



To order the 9340, call your Fairchild Distributor and ask for:

PART NUMBER	PACKAGE	TEMPERATURE RANGE	PRICE (1-24)	(25-99)	(100-999)
U6N934059X	DIP	0°C to + 75°C	$20.90	$16.70	$14.00
U6N934051X	DIP	−55°C to +125°C	41.80	33.40	28.00
U4M934059X	Flat	0°C to + 75°C	23.00	18.40	15.40
U4M934051X	Flat	−55°C to +125°C	46.00	36.80	30.80

you have to get serious about MSI family planning.

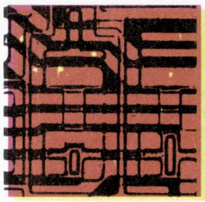
We put together a family plan by taking systems apart. All kinds of digital systems. Thousands of them.

First we looked for functional categories. We found them. Time after time, in a clear and recurrent pattern, seven basic categories popped up: Registers. Decoders and demultiplexers. Counters. Multiplexers. Encoders. Operators. Latches.

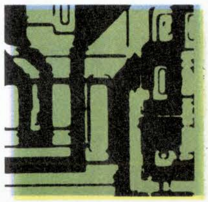
Inside each of the seven categories, we sifted by application. We wanted to design the minimum number of devices that could do the maximum number of things. That's why, for example, Fairchild MSI registers can be used in storage, in shifting, in counting and in conversion applications. And you'll find this sort of versatility throughout our entire MSI line.

Finally, we studied ancillary logic requirements and packed, wherever possible, our MSI devices with input and output decoding, buffering and complementing functions. That's why Fairchild MSI reduces–in many cases eliminates–the need for additional logic packages.

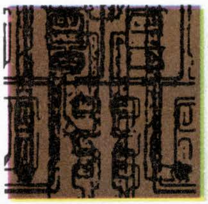
The Fairchild MSI family plan. A new approach to MSI that's as old as the industrial revolution. It started with functional simplicity, extended through multi-use component parts, and concluded with a sharp reduction in add-ons. Simplicity. Versatility. Compatibility. Available now. In military or industrial temperature ranges. In hermetic DIPs and Flatpaks. From any Fairchild Distributor.



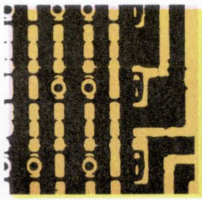
OPERATORS
9304 – Dual Full Adder/Parity Generator
9340 – Arithmetic Logic Unit



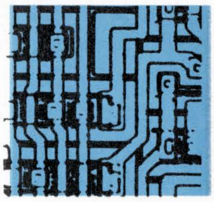
LATCHES
9308 – Dual 4-Bit Latch
9314 – Quad Latch



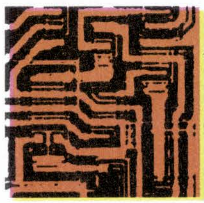
REGISTERS
9300 – 4-Bit Shift Register
9328 – Dual 8-Bit Shift Register



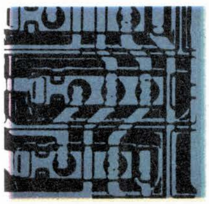
MULTIPLEXERS
9309—Dual 4 Input Digital Multiplexer
9312—8-Input Digital Multiplexer
9322—Quad 2-Input Digital Multiplexer



DECODERS AND DEMULTIPLEXERS
9301 – One-Of-Ten Decoder
9315 – One-Of-Ten Decoder/Driver
9307 – Seven-Segment Decoder
9311 – One-Of-16 Decoder
9317 – Seven-Segment Decoder/Driver
9327 – Seven-Segment Decoder/Driver



COUNTERS
9306 – Decade Up/Down Counter
9310 – Decade Counter
9316 – Hexidecimal Counter



ENCODERS
9318 – Priority 8-Input Encoder

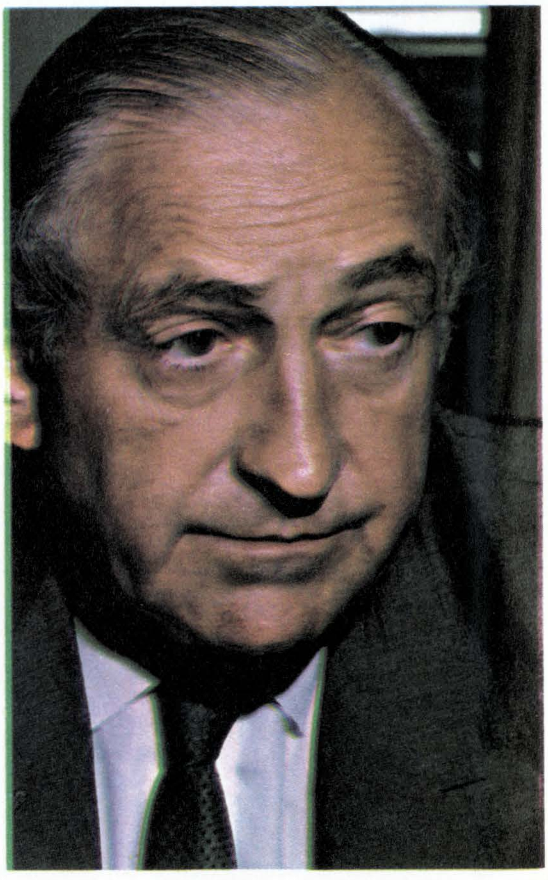
FAIRCHILD
SEMICONDUCTOR

FAIRCHILD SEMICONDUCTOR A Division of Fairchild Camera and Instrument Corporation Mountain View, California 94040, (415) 962-5011 TWX: 910-379-6435

The GLORY DAYS

As usual, DoD means business; but not business as usual.

DAVID PACKARD
of the Department of Defense



C-130

are over at DoD

By John McNichol, *Assistant Editor*

Like many other organizations this year, it is no longer in a growth phase. Foreign commitments have been cut back; domestically the organization has an image problem; personnel have been laid off; inflation has taken its toll; and the budget has shrunk accordingly.

As the chief administrator of this sprawling enterprise says, "the Department is no longer a growth industry. On the contrary, it is now in the throes of a rather rapid shrinkage."

This large organization in a bear market is the Department of Defense and the chief administrator is David Packard, Deputy Secretary of Defense. In this fiscal year, ending June 30, 1971, military forces will be reduced by 551,000 men and the civilian work force, by 130,000 personnel. The war in Indochina has been roundly denounced across this country and in Europe, with particular heat put on the Pentagon as the symbol of the "military-industrial" complex. The budget for FY 71*, beginning July 1, 1970, is $71.8 billion, down from $77 billion in FY 70 and $78.7 billion in FY 69. Inflation has watered down the buying power of the current budget a further $5.9 billion, leaving an actual $65.9 billion (in 1969 dollars) to spend on DoD needs in Fiscal Year 1971.

Translated, this means that DoD expenditures will decline to 34.6% of total Federal outlays, the lowest level in 20 years. Spending will drop to 7% of the Gross National Product, the lowest level since 1951. As Deputy Secretary of Defense Packard states, "The impact of reductions is already severe. Even if the current dollar level were maintained, inflation would bring procurement expenditures down. This means that DoD has a great incentive to get more for their dollars."

The squeeze is on

Engineer, entrepreneur, cattle rancher, supporter of social and community causes, David Packard is nothing else, if not a good businessman—witness the growth of Hewlett-Packard. And, since January 1969, Packard has tried to bring common-sense business practices to the Department of Defense. This is not an easy job with any organization, especially one that currently

*The government's fiscal year starts on July 1st of the previous calendar year. For example, FY 71 started on July 1, 1970 and will end on June 30, 1971.

AMERICAN SUCCESS STORY

"We saw you looking at IC testers during the last WESCON Show," we told David Packard, who has been Deputy Secretary of Defense since January 1969. "Can you really keep up with electronic instruments?"

A faint smile appears in his face. "The truth is that I can't, much as I want to."

The reason is imprinted in his face. During the last two years, Packard has aged ten. His graying hair has now turned almost white, and the deep furrows on his forehead and under his eyes confirm the combination of long working hours and seemingly unsurmountable problems involved in running the Department that, employing 4.5 million people, and having a budget (for 1971) of $71.8 billion, is charged with safeguarding the Nation's security. As Deputy Secretary, Packard serves as chief administrator and general manager of this imposing operation. When a decision must be made, he is **the** man.

But Packard is not a man to be intimidated by big numbers or a big job. The Deputy Secretary's personal fortune has been estimated at $300 million. The Hewlett-Packard Co., which he and William R. Hewlett co-founded in 1939, has some 16,500 employees and sales of $270 million in 1969.

A big man, who played letter-level football and basketball at Stanford University and was an excellent hurdler until his track career was curtailed by an injury, Packard received both the B.A. and the B.S.E.E. degrees and the Phi Beta Kappa key from the same school, and went on to the University of Colorado for graduate work. His success story is well known to electronic engineers—how he and William R. Hewlett started their company in 1939 with $538, how they developed the "Model 200A" audio oscillator based on Hewlett's patent for using a Wien bridge to stabilize the amplitude of oscillation, and how they parlayed their company into becoming the largest manufacturer of test and measurement instruments in the world.

As a former trustee for Stanford and Colorado College, David Packard is particularly concerned with maintaining the high level of R & D we have come to expect from the U.S. "However," he says, "the cuts in funding for R & D, combined with the prevailing atmosphere on the campuses, will leave little money for university research. We will have to channel R & D projects through in-house and independent research laboratories. It's a shame—this money has meant a great deal to universities." And we get the distinct feeling that, while the Deputy Secretary of Defense must make those decisions, the heart of the former trustee bleeds for the graduate schools whose quality of research will suffer.

Alberto Socolovsky

GOD, MOTHERHOOD AND DOLLARS

In a recent press briefing, Deputy Secretary David Packard gave the thrust of a new memo, entitled "Policy Guidance on Major Weapon System Acquisition." "Actually," he stated, "a good many things that I say in this policy guidance are just plain statements of what good management is; you might say statements supporting God and motherhood, if you want to make it that simple."

Making it simple is what David Packard has been trying to do since he joined the Department, even though this has meant a virtual revamping of the centralized "big daddy" concept DoD of Robert MacNamara. Under this new policy, increased responsibility will be put on the services, with dollar limits given to each service to aid in equipment decisions. As Packard stated, "the services—who are the ones who really implement these programs—are the ones who have to take the major responsibility—in fact, in almost a real sense, a total responsibility—for the implementation." Continuing, he acknowledged that programs had been poorly managed at the DoD level, "we can't sit up here topside, and make decisions, and run the programs, and have it make any sense."

Broken down, the guidelines indicate that DoD will **approve** the policies of the service, **evaluate** its performance and **decide** if the programs should move into the next phase. Some key points that Packard stressed are the following:

Management: Capable program management personnel will be rewarded and assigned to a given program long enough to be effective. The numerous layers of authority that exist at present will be removed. As Packard's memo states, "Put more capable people into program management, give them the responsibility and the authority, and keep them there long enough to get the job done right."

Development: The key consideration here depends "upon making practical trade-offs between the stated operating requirements and engineering design than upon any other factor." Another point stressed is the validity of the schedule which will allow the accomplishment of important task objectives without unnecessary over-

employs 4.5 million people (almost as many as the 30 largest U.S. companies), possesses assets of $200 billion (more than the combined assets of the 75 largest companies), makes possible the employment of over 2 million workers by private industry for DoD contracts, and engages in more than 200,000 purchases of over $10,000 or more a year.

At present, Packard is deeply engaged in trying to avoid the type of procurement problems that plagued the F-111, the C-5A and others, and make DoD more responsive to contract needs. As a first step in revising procurement procedures, he has issued a memo, "Policy Guidance on Major Weapon System Acquisition" (see box, "God, motherhood and dollars" for background) that may become a classic among Government guidelines. This shifts much of the responsibility and authority for programs from the Department of Defense to the military services, in addition to laying down basic guidelines for handling the contractual process.

When asked if there could be a dollar-for-dollar correlation between the value obtained in industry and that in government, Packard replied, "There just can't be a direct comparison because these large systems programs are more difficult to manage. After all, complex systems are different than those found in industrial programs. In evaluating results at the DoD, we have no profit and loss statement, as such, to work against. The weapons we build for defense serve our country best if they never have to be used.

"However, we have gone way overboard on some extras, such as documentation. Investigation has shown that many classes of documentation are wasted effort. One example I'm thinking of is the contract definition stage where teams of high-powered technical people work on defining the proposal. Although this is supposed to bring a competitiveness to the proposal, it usually results in high-calibre people putting out truckloads of paper, and that is really not very efficient. What we are trying to do here is to get more hardware development at this early stage, instead of contract definition. Development must be finished before we start production.

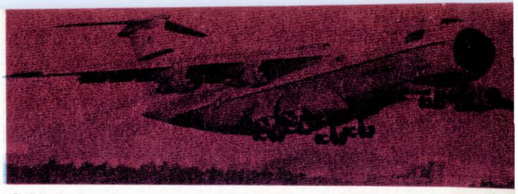
"All this doesn't mean that big companies can reduce the ratio of peripheral services to engineering. For instance, you can't necessarily do the same thing with large companies as with the company I came from.

"The services want more for their procurement dollars. It may sound paradoxical but we believe it will be easier to manage with a tight budget than before."

Implementation

The Deputy Secretary recognizes that the guidelines will not be implemented overnight. "Well," he says, "it does take time for changes to filter down through the system. The important thing is to have it reach the project management level and below. Incidentally, we are making a very strong effort to get men with engineering backgrounds into project management for the services. We're giving more recognition to project management and conducting training courses in it."

Packard went on to elaborate on a new technique that DoD hopes will do much to avoid future C-5A type contracts. Called the "should cost" approach, it is a cooperative effort between the Department of Defense and the contractors to cut costs and arrive at the best design within practical limitations. Defense officials and management sit across a table and try to hammer out an approach that, while it may not be at the forefront of technology, promises a workable implementation with the emphasis on reliability. Obviously on fixed cost contracts, this discussion must take place



C-5A

lapping.

Conceptual development: Technical risk can be minimized by:

- **Risk assessment**
- **System and hardware proofing:** Sufficient engineering design and competent testing must be done at this stage to demonstrate that technical risks have been reduced to a reasonable level.
- **Trade-offs (risk avoidance):** "Trade-offs must be considered not only at the beginning of the program but continually throughout the development stage."

Full-scale development: Assurances must be made that problems encountered in earlier stages have indeed been cleared up. Procedures must be established to handle the invariable problems that will crop up. Support functions, such as maintenance, logistic support, training, etc. should be delayed, as much as possible, until the production stage.

Production: Before entering this phase, the engineering design must be completed, with all major problems resolved, and requirements optimized; this should be demonstrated by actual performance testing.

Contracts: Types of contracts will be chosen according to the situation. DoD prefers **cost-plus-incentive** contracts for both advanced development and full-scale development projects for major systems. These contracts will provide for competitive fixed price subcontracting. **Fixed price** contracts may be selected where risks have been reduced sufficiently to make realistic pricing possible, as in production programs; however, "the contractor's financial ability to absorb losses that might be incurred must be a factor in making the award."

The use of letter contracts will be minimized and change orders will not be authorized unless they have been contractually priced, or until contractual ceilings have been set.

All these steps indicate that Packard meant it when he stated, "Neither the Department of Defense nor the Congress will continue to tolerate large cost overruns which relate to unrealistic pricing at the time of award, or to inadequate management of the job during the contract."

prior to the award of contract.

"How about an example of a good design?" we asked him. "Unfortunately," he answered, "you don't hear about the good things. However, there has been a good deal of satisfactory equipment used in Viet Nam that has been well shaken out. One example is the modification done on the C-130 by the Aeronautical Systems Division of the Air Force Systems Command at Wright-Patterson AFB." (These fixed wing gunships, armed with four 7.62-mm miniguns and four 20-mm cannons, were modified on a production contract by the Greenville Division of LTV Electrosystems for $34.8 million. The gunships, which combine reconnaissance and strike capabilities, are used to hunt the enemy at night, provide close air support, and respond to trouble calls.

"Also," continued Packard, "the initial procurement for the F-15 program, which is not too far along, incorporates some of the principles mentioned in my memo. On this project, we have made a determined effort to improve management by the military and industry."

The F-15 contract, which calls for engineering, design, and fabrication of 20 advanced tactical fighters at a cost of $1,146,385,000, is an example of DoD's new emphasis on holding the cost line. The contract will utilize cost-plus-incentive-fee (CPIF) contracts for engineering and design phases and fixed-price-incentive, successive target (FPIS) for the test aircraft, initial production effort, and subsequent production option quantities. The Air Force is hoping that combining the CPIF and the FPIS with a demonstrable milestone system gives them a fighter offering performance at controlled costs.

The $64 billion question

Following the discussion on the new look at the Department of Defense, we asked Packard if the aerospace industry will ever again return to the golden days. The Secretary's assessment of the situation was that, "The industry has already been very hard hit. I'm afraid in the future that we'll see an even more competitive environment where prospective contractors will fight for less business. We simply must develop ways of working more efficient than those used in the past."

Reinventing the wheel

One of the problems that the Department of Defense faces is the unknown area between the cutting edge of technology and off-the-shelf equipment. Packard is particularly concerned with the problems of this aspect of procurement, having inherited some classic examples of "advanced" hardware that were not necessarily proven. "Let me preface this by saying that I'm not against innovation," he states. "However, I do recognize that there is pressure on industry to innovate, to come up with the most sophisticated design. Also, in the past, the services have tried to squeeze the last ounce from a design. I'm convinced that we're better off when we use a piece of equipment that has proven reliability and which is available. Sure, the military want the best and the contractors want to supply the best, but we have tried to push the state of the art beyond the capabilities of industry—as with the avionics for the C-5A. To prevent this sort of thing from recurring we're encouraging the contracting officers to sit down with the contractors to iron out these details."

The problems that plagued the C-5A were serious enough to have an Ad Hoc committee of the USAF Scientific Advisory Board called to study the radar altimeter, the Attitude and Heading Reference Unit (AHRU), the Multimode Radar (MMR), and MADAR

F-15

DEALING WITH DOD: THE AGONY AND THE ECSTASY

For fiscal year 1969 the Department of Defense issued a statistical breakdown of the top 100 companies and their subsidiaries, classified according to the net value of military prime contract awards. The breakdown showed that the top 100 companies accounted for $25.2 billion, or 3.8% less than in FY 1968. Total awards to all U.S. companies were $36.9 billion, down 5% from the previous year. The total electronic content of these awards has been estimated at $10.3 billion.

Some major defense contractors are listed below:

Company	Rank	FY 1969 (K $)	FY 1968 (K $)	Major Programs
Lockheed	1	2,040	1,870	aircraft (C-5A, Cheyenne, P-3 Orion), missiles (Poseidon)
General Electric	2	1,621	1,489	jet engines (C-5A), ordnance, guidance control (missiles), nuclear propulsion (ships)
General Dynamics	3	1,243	2,239	aircraft (F-111), submarine and missiles
McDonnell Douglas	4	1,070	1,101	aircraft (F-4 Phantom), MOL (cancelled)
United Aircraft	5	997	1,321	aircraft (helicopters), engines and spare parts

(Malfunction Detection, Analysis, and Recording Subsystem). Interestingly enough, Deputy Defense Secretary Packard told Congress at the same time that, "If we agree to pay for additional airframe development, as I conclude we must, I am sure that we will find that some of the avionics requirements, in hindsight, were not needed." He also noted that the plane could make only limited use of the MMR, the automatic flight control system, and inertial doppler navigation package.

A qualified silver lining

Looking into the next two or three years, Secretary Packard sees more of the same, with some exceptions. "Despite the cut in contractual funds," he declared, "we still have a high level of funding for certain programs, which should be of great interest to electronic engineers." Among these projects were the following:

• The Defense Satellite Communications System (DSCS), Stage II, will be a new space system combined with already existing earth terminals to be technically improved. At the same time, new state-of-the-art terminals and equipment will be integrated into the system. TRW will produce the satellites which will be placed in orbit by Titan IIIC at a cost of $145 million. The modification of the existing ground terminals is costed at $40 million. The new ground and shipborne terminals with associated advanced modulation and multiplex equipments is funded for $53 million. (Philco-Ford won the first of a series of contracts for this phase.)

• Standardizing the hardware and software of the World-Wide Military Command and Control System (WWMCCS) and the part of the Intelligence Data Handling System (IDHS) that is integrated into it. Another example of Packard, the businessman in action, is the way he cut the original concept of 34 new computers (with an option for 53 more) down to 15 systems (reported at $42 million) with an option for 20 more.

• TacFire, a tactical fire direction system, is an automatic data-processing storage system for basic artillery functions. Used in Viet Nam, it is designed for target analysis. Worth $35 million to date, the contract was awarded to the Data Systems Division, Litton Industries.

• Infiltration detection is a classified project.

• An anti-submarine plane (S-3A) is being developed by Lockheed Aircraft Corp. Approximately one-half of the $461 million contract is slated for avionics.

Belt tightening

David Packard, the Department of Defense, and that portion of American industry that depends on defense contracts face hard days ahead. No one is more aware of the severe contraction that has taken place and will continue than Packard. As he sees it, "Scientists and engineers that are being released will hopefully be able to find work in non-defense areas. It's a very difficult, a very trying, time, but I'm confident that it can be done." Ironically, much of the funds to ease the transition will have to come from DoD money; preliminary estimates have been tagged at cutbacks of $5-7 billion above the savings from reduced Indochina spending. Beleaguered by Administration critics and handicapped by an unpopular war, greatly overrun contracts, and a declining economy, Packard will need all his considerable skill as an engineer and a businessman to bring some order out of the chaos at DoD.

INFORMATION RETRIEVAL
Careers

Matheson's NEW and BETTER way to etch silicon

Chemically speaking, E-GAS® is Matheson's new, specially prepared gas for etching silicon. It displaces Hydrogen Chloride as the "NOW" etching method. Practically speaking here's why:

E-GAS gives more effective etching. It enables you to etch through oxide holes with no oxide deterioration or etching of back seal. What's more, E-GAS gives a planar etch, forms flat bottom holes, and is ideal for etching junctions prior to mesa passivation and requires a lower operating temperature (200°C. less than HCl).

E-GAS stands for economy. In addition to the many operating economies accrued, only 1/5 as much E-GAS is required to do the job as compared with HCl.

E-GAS is easier and safer to handle. It's nontoxic, noncorrosive and does not contaminate. As a result, there's no equipment damage.

You can order E-GAS in No. 1A or No. 3 cylinders. Because of its high etching rate, E-GAS is also being offered in mixtures for lower etch rate applications such as etching silicon prior to thermal or pyrolytic oxidation. These mixtures have a 10% concentration of E-GAS in a choice of background gases.

Ask to see our etching engineering report! Write Matheson Gas Products, P.O. Box 85, East Rutherford, N. J. 07073

MATHESON GAS PRODUCTS
A Division of Will Ross Inc.
East Rutherford, N. J.; Cucamonga, Calif.;
Gloucester, Mass.; Joliet, Ill.; LaPorte, Texas;
Morrow, Ga.; Newark, Calif.;
Matheson of Canada, Ltd., Whitby, Ont.

10-69GR

Circle 21 on Inquiry Card

Here is your copy of a brand new reference chart sponsored by

ELCO CORP.

CONNECTOR AND TERMINATION SELECTION GUIDE

Tear it out,

NOW

. . . and mount it on your wall

If the chart has been removed, Circle Number 41 on the Inquiry Card for a copy.

COURSES

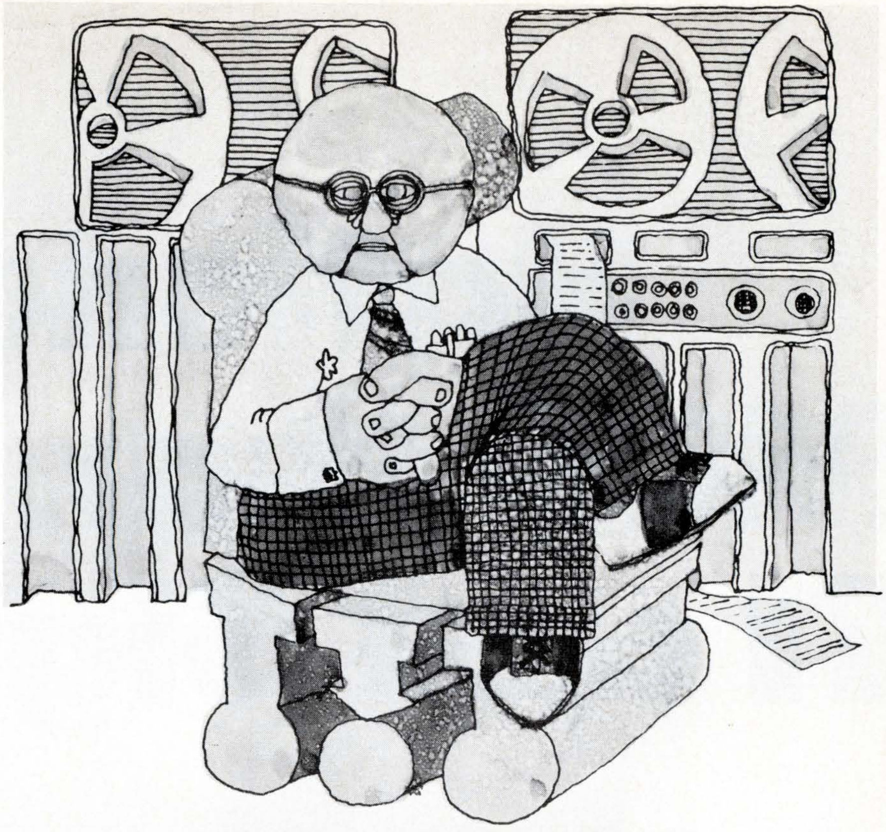
Microelectronic Engineering: Sept. 15-Oct. 20 (Tuesday nights), Los Angeles, $60. Engineers with an interest in the development of micro-electronics in electronic systems applications will find this course useful. The course will cover IC, MOS, and hybrid thick- and thin-film technology. Foundation, California State College, Los Angeles, Calif. 90032.

Design/Fabrication: Sept. 21-Oct. 16, Phoenix, $10,000. Each student will design and make his own bipolar IC using the shallow diffusion process. Designs are brought from schematic, through computer-aided mask making, to processing and finished package. This is an opportunity to design a completely functional circuit meeting specific requirements; all materials and facilities are provided. ICE Corp., 4900 East Indian School Rd., Phoenix, Ariz. 85018.

Data Communications Systems and Applications: Sept. 22-24, Cleveland; Sept. 29-Oct. 1, New York; Oct. 6-8, Washington, D.C.; $350. All forms of data transmission, its application, and typical equipment to handle it are discussed in this seminar. Through an analysis of various systems, problems and potential solutions will be described. Sylvania, 63 Second Ave., Waltham, Mass. 02154.

Electronic Systems Reliability: Oct. 5-6, Madison, $100. Here is a course designed to introduce the primary concepts of effective systems reliability engineering. It will help you to understand the essential management functions and technical decision processes relating to electronic systems reliability. University of Wisconsin, Engineering Extension, 432 N. Lake St., Madison, Wis. 53706.

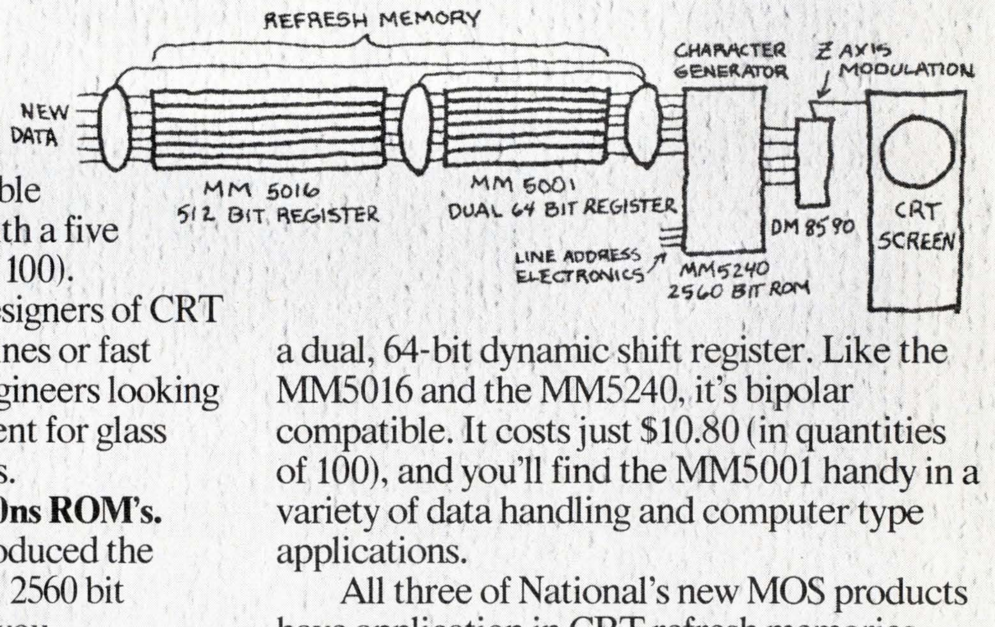
The Mini-Computer—Impact on the 70s: Oct. 5-7, Washington, D.C., $300. Mini-computer applications described in this course will help develop your ability to recognize when mini-computer technology can be applied. The course includes problem sessions and delineates the procedures for mini-computer system design and implementation. Control Data Corp., 5272 River Rd., Washington, D.C. 20016.



National sells MOS than Fairch TI and Signetics

Guess which one is selling shift registers at a penny a bit.

more
ild, Motorola,
combined.



Who else?

National just came out with the MM5016, a bipolar compatible 512-bit dynamic shift register with a five dollar price tag (in quantities of 100). The MM5016 should interest designers of CRT refresh memories, radar delay lines or fast access drum memories. And engineers looking for a small and stable replacement for glass and magnetostrictive delay lines.

Now guess who's selling 600ns ROM's.

National again. We just introduced the MM5240, a bipolar compatible, 2560 bit character generator that offers you off-the-shelf standard fonts in addition to its blazing speed. We've priced the MM5240 at $30.00 (in quantities of 100) and now await orders from people involved in character generation, random logic synthesis, micro-programming and table look-up.

What else?

Well, National recently introduced still another MOS, the MM5001. The MM5001 is a dual, 64-bit dynamic shift register. Like the MM5016 and the MM5240, it's bipolar compatible. It costs just $10.80 (in quantities of 100), and you'll find the MM5001 handy in a variety of data handling and computer type applications.

All three of National's new MOS products have application in CRT refresh memories. We've written an application brief to give you all the details. The brief awaits you now at your National distributor. So do the products. National Semiconductor Corporation, 2900 Semiconductor Drive, Santa Clara, California 95051/Phone (408) 732-5000, TWX (910) 339-9240.

National

Circle 23 on Inquiry Card

MOS Course—Part 5D
Memory costs

Semiconductor memory systems— p. 50
what will they cost?

By **Arthur J. Boyle,** Technical Editor

We have devoted a significant portion of our course on MOS integrated circuits to their use in memories. This installment also deals with memories, but now we get down to the nitty-gritty—their cost.

The memory market is extremely sensitive to cost. Main-frame memories are going to use the technology that provides the lowest cost solution to the data storage problem. For the purposes of our course, we are going to confine our discussions to the established king-of-the-hill—magnetic cores, and the newest challenger —semiconductor memories, both bipolar and MOS.

ICs vs. cores

You will get fairly widespread agreement (even between core and semiconductor manufacturers) that semiconductors will and even now are displacing cores in two areas. The first of these is the high performance memory—those with very fast access and cycle times. The inherent advantages of semiconductors make them a natural for this kind of application.

The second area where semiconductors are running strongly is in small memory modules. In this situation, the drive and sense circuits are the dominant cost of a core memory and semiconductors offer a more economical solution.

Turn your discussions to the large, main-frame type of memory with the same people who agreed above, and you may have a small-scale riot on your hands. The manufacturers of magnetic cores scoff (at least in public) at the notion that the price of ICs will ever come down enough to be a serious challenger. The semiconductor people, on the other hand, point to an impressive history of decreasing prices and say "it's just a matter of time."

The semiconductor people appear to have two aces up their sleeve that lend credence to their predictions of significantly lower prices on the way. We have mentioned before in the course that the price of an integrated circuit is closely related to the silicon area that it occupies. If you can pack more function in a given area, you can get a more complex circuit for practically the same cost. The two areas that promise more circuits per unit area are improvements in the resolution of the photo-processing techniques used by IC manufacturers and process refinements that will improve yields (or allow more complex circuits with the same yield).

In addition to the debate of cores versus semiconductors, there is the question of whether to use bipolar or MOS ICs for memories. Bipolar offers better performance at higher prices while MOS lets you pack more bits in a given size chip. Hybrid structures that combine both bipolar and MOS have developed to take advantage of the strong points of each. Whether there will ever be a clearcut winner is doubtful. A good guess is that each of the technologies will find its own niche in tomorrow's systems.

From all of the discussions of price it is apparent that arriving at the cost of a memory system is more complex than shopping in a supermarket. The article that follows takes a hard look at the cost of memories and shows you where we are now and what you can expect in the future.

Semiconductor memory systems —what will they cost?

Better be sure you consider all the costs before picking a semiconductor memory. Here is a look at some of the ones that are usually "in fine print."

By Thomas W. Hart, Jr. and Donald D. Winstead
Semiconductor Electronic Memories, Inc., Phoenix, Ariz.

The system designer faces a multitude of alternatives, trade-offs, and cost factors when considering semiconductor systems for storage applications. But out of the plethora of competitive claims and counterclaims, he should consider two basic questions of paramount importance.

They are, "When will semiconductor memories be cost competitive with existing storage techniques?" and, "In what form—DIP, module, or plug-in board—should the product be purchased to get the optimum cost in the final system?"

Relating to the initial question, let's take a look at core, MOS, and bipolar systems available in reasonable volume for the second half of 1970. In Fig. 1, the solid lines indicate core memory system prices as quoted by leading manufacturers for delivery of commercial grade systems during the last half of 1970 and the first half of 1971. (The price per bit will vary, of course, with system size and speed of operation.)

Dotted lines in the same graph show quoted prices for several semiconductor memory products and systems, available for delivery now. The dotted lines marked 200 ns and faster represent bipolar semiconductor memory systems. The upper 1500-ns line is an MOS memory with static cell design, while the lower 1500-ns line is the curve for MOS products of dynamic design.

The chart shows at which parameters semiconductor memories become cost competitive. For instance, the MOS static design product is price competitive now with systems of <8k bit density when a cycle time of <1.5 μs is required.

Also, MOS dynamic design is competitive with cores out to 128k bits for cycle time requirements of <1.5 μs. But note, that it is not competitive for <16k-bit applications.

The bipolar memory system is cost competitive now for applications of up to 16k bit density when cycle times of <500 ns are required. At the 250-ns level it is cost competitive out to 256k bits.

Turning to Fig. 2, we find typical projections of price per bit through 1975 of the three basic approaches to high-density semiconductor memories—bipolar, MOS dynamic, and MOS static. These three curves, however, do not tell the entire story since clocking, drive, and interface circuitry varies dramatically from one type to another. Generally speaking, costs for these requirements are much higher for dynamic cell designs than they are for the static cell.

Having established that semiconductor memories can offer cost advantages for many system applications, we can turn to the second basic question regarding the form of the semiconductor product for optimum system cost.

Because economic analysis of semiconductor memory systems does not stop at the point of buying the vendor's product, we should review associated costs at each level of the manufacturing process. By working backwards from final checkout in your system to the original silicon wafer, we can determine "What the system really costs."

At the same time you should consider "At what point should we, the user, enter the fabrication cycle?"

Should it be at the diffusion level? Or perhaps the wafer level or the package level? Many will opt for the plug-in card or system.

And then we come to the design—should it be a custom or standard system, or a combination? Any of these starting points can make sense, depending on your volume requirements, the amount of risk you wish to assume, and your capabilities.

These questions are not easily answered and the decision must rest upon basic economics in individual situations.

There is a wide variety of system needs for memory and a corresponding assortment of means to satisfy those needs. The options available to the user have been placed in broad categories for discussion purposes. In many cases, it is difficult to categorize a particular device. For example, is an LSI chip with 1024 bits of storage including address register, decoding, sensing, and write logic and logic level interface a system in itself or just a component? In any event, we will use five categories for our discussion.

Standard vs custom systems

For our purposes, a standard system or subsystem is one fabricated as a printed-circuit card with multiple packages, a hybrid module with multiple chips, or a larger assembly of multiple cards or modules. There are several vendors who have announced products such as these ranging in size from a hundred bytes of storage to thousands of bytes. The great advantage to the purchaser of a semiconductor memory system in this form is that the engineering is done and, in most cases, there will be little additional effort other than establishing the proper interface. Costs are well defined and there is a low risk associated with use in a system. Of course, some method must be worked out with the vendor to assure the quality of the memory and to establish confidence in the system reliability.

This brings us to one cost of a semiconductor memory system that is often overlooked but which can affect substantially the total cost of any system. Since no system will be completely reliable, some failures will occur and they must be planned for. How will field failures be handled? What will spare parts cost? How rapidly can a system fault be isolated and repaired? What test equipment will be necessary for fault isolation and how much will it cost? What manpower will be needed to make these repairs? A standard system on a plug-in, printed-circuit card has a large advantage in minimizing these costs if the vendor guarantees his product and will replace any defective card. With a large base of users of standard system cards, the vendor can handle this type of service very efficiently.

Another advantage of a standard system is that overall testing costs are minimized and tooling and engineering expenses are amortized over a very large manufacturing volume. There is essentially no duplication of testing or test equipment, both of which can be a substantial portion of the overall cost of a memory system.

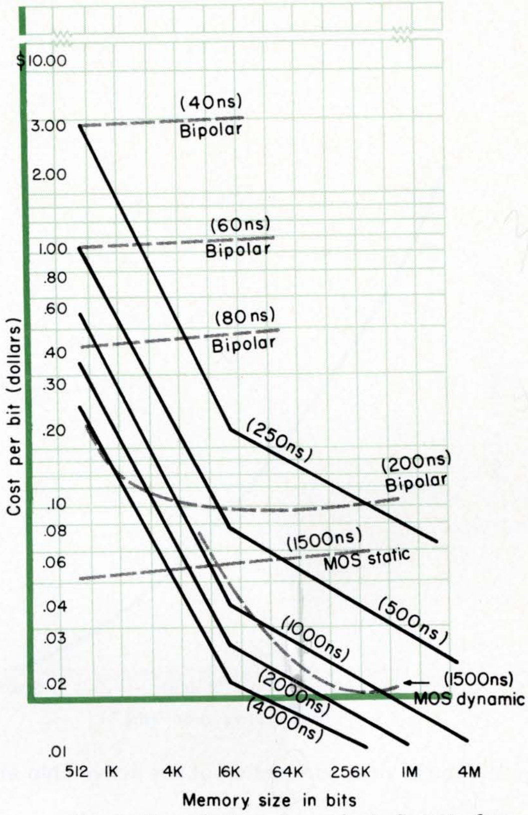


Fig. 1: Manufacturer's projected costs for memory systems available in the second half of 1970. The solid lines indicate core systems while the broken lines are semiconductor memories.

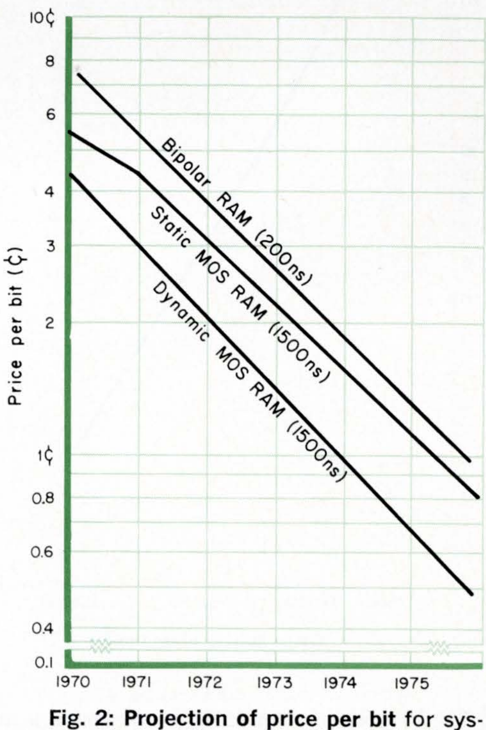


Fig. 2: Projection of price per bit for system bit densities greater than 10k bits.

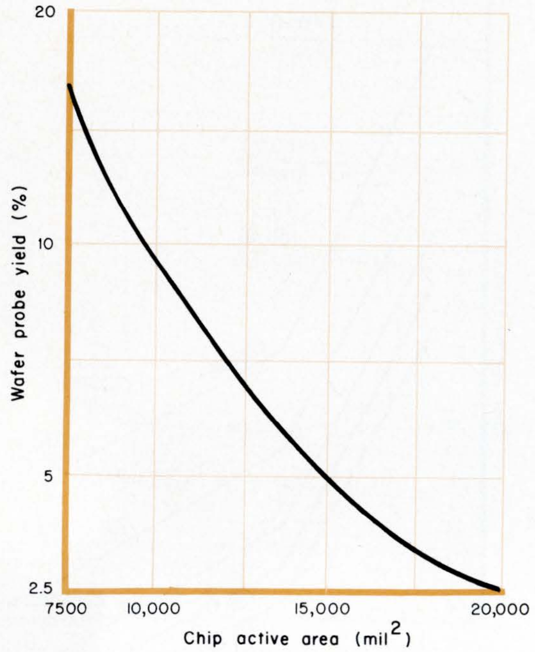


Fig. 3: Typical yield as function of the active chip area.

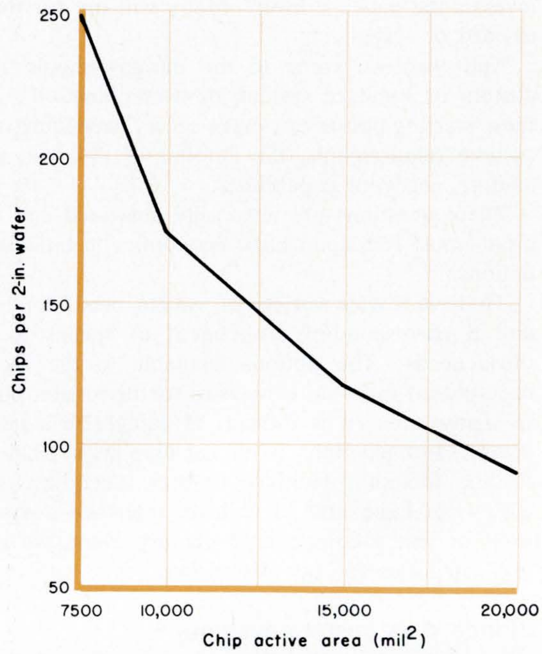


Fig. 4: The number of potentially good chips on a 2-inch wafer plotted as a function of chip area.

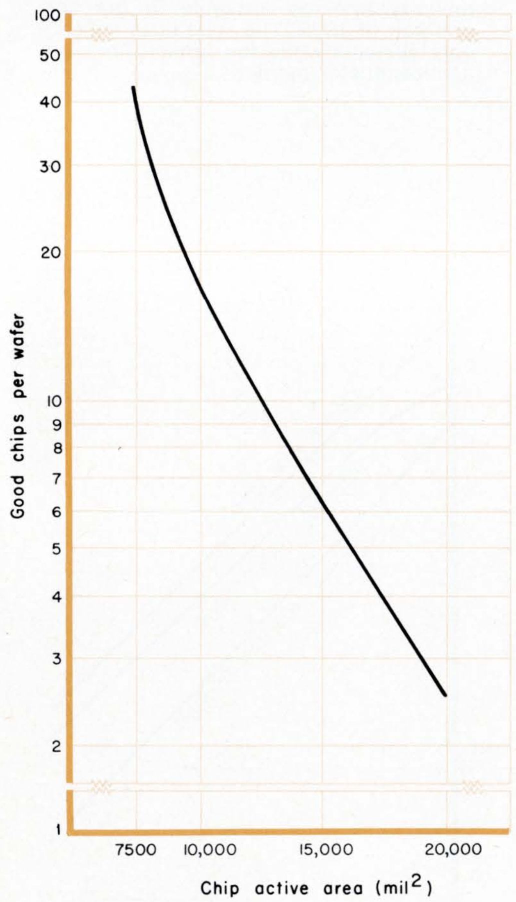


Fig. 5: The number of good chips per wafer as a function of chip area can be obtained from combining Figs. 3 and 4.

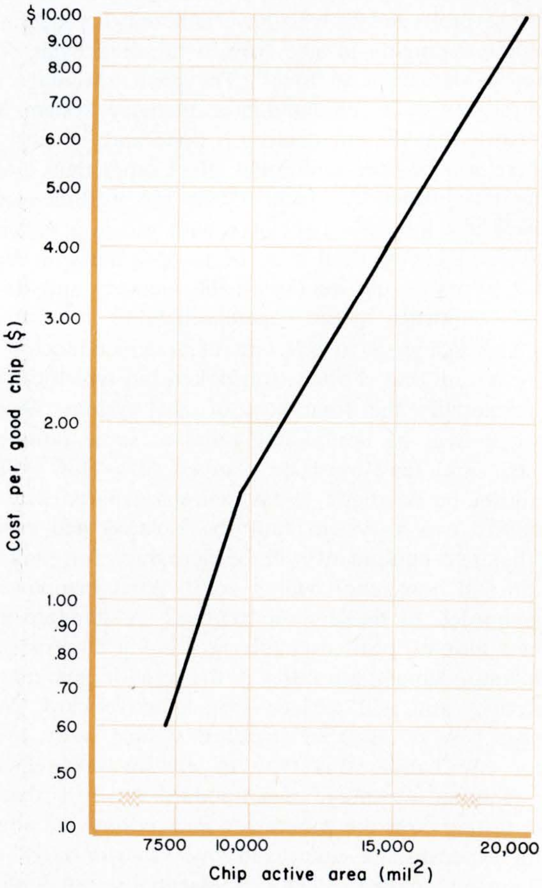


Fig. 6: Cost per good chip based upon an assumed wafer cost of $25.00. The cost varies from $0.58 for a 7500-mil² bipolar chip up to $10.00 for an MOS chip with 20,000 mil² of active area.

The principal disadvantage of any standard system is the possible non-compatibility with the overall system packaging design. This can cause additional costs for the user.

A custom system, on the other hand, is one specified by the user as to mechanical, electrical, and environmental requirements. It is then fabricated by a vendor using his system building blocks. The additional cost factors over a standard system are the vendor's engineering tooling charges amortized over the number of systems to be built and perhaps slightly higher prices per bit. Repair and field maintenance will also become more costly.

The advantages over a standard system are mechanical and electrical system compatibility. The advanges over designing and building it yourself with purchased components are the lowering of engineering risks, engineering expenses, and testing costs.

Standard and custom components

A standard memory component is a package or module which must be assembled and interconnected with other components in order to function as a memory system. A wide spectrum of devices exists ranging from 16 bits to 1024 bits per chip with system performance capabilities in the few tens of nanoseconds cycle/access time to several microseconds. Prices/bit range down to under 2¢/bit in quantity. A wide range of peripheral support electronics is needed for different designs ranging from standard TTL interface to multiphase ac clocking and special sense amplifiers. Power supply requirements also cover a wide spectrum of from two to four different power supplies.

In all cases, there will be additional design engineering costs, prototyping costs, and testing costs. Thus, the advertised cost/bit is only a starting point in evaluating the actual cost of a semiconductor memory that goes out the door in a piece of your equipment. The final system cost/bit can easily be double the price of the purchased part.

A custom memory component is one that you design and/or specify. The additional costs which must be absorbed are the additional engineering costs of the component design and the vendor charges for engineering, mask making, and prototypes. If your volume requirements are not high enough, you will also pay more for devices. These charges might range from $25,000 to $100,000 depending on the complexity of the requirements.

Custom wafer fabrication

Here, you design the memory and the masks around someone's standard process and have them fabricated. MOS wafers can be obtained at under $100 each. Add to the list of costs those of wafer probing, packaging, packaging yield, mask design, and mask fabrication.

This concludes the discussion of the five options. Now, let's examine the cost factors that make up the total cost of a semiconductor memory system.

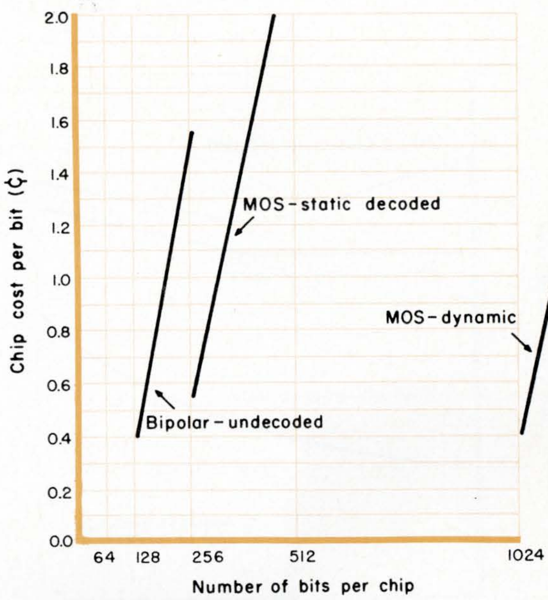


Fig. 7: Cost per bit at the chip level as a function of the number of bits per chip. A point to note is that each of these approaches has very different costs associated with peripheral electronics.

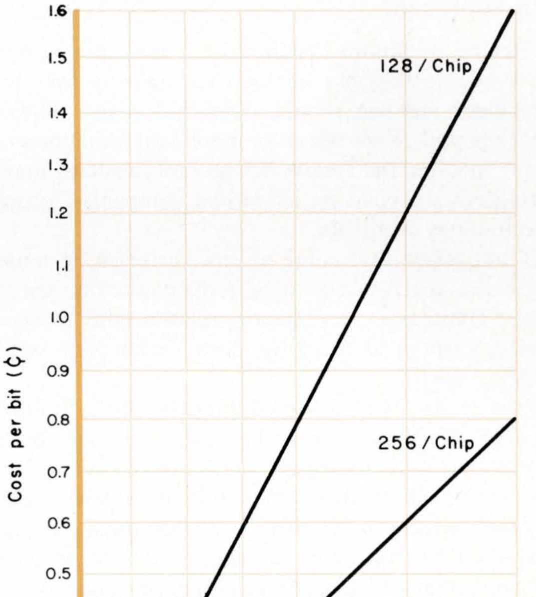


Fig. 8: The contribution that the package makes to the cost per bit of the memory.

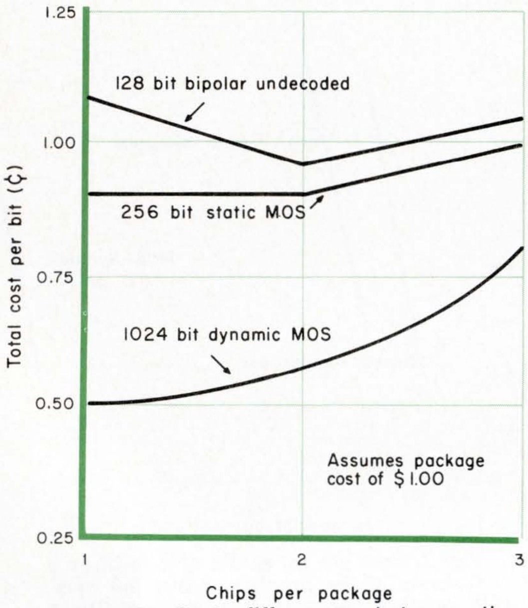


Fig. 9: Cost differences between the three semiconductor memory technologies based on our assumptions.

Which approach?

Achieving minimum system cost is not an easy task. Some fundamentals can be used to logically approach the problem and we should note that many different approaches will make sense in individual situations. In the final analysis, the system design and resultant manufacturing costs depend on individual companies, people, and technology available.

It is important that some of the variables be understood in the cost makeup of a semiconductor memory system. There are very strong relationships between chip size, chip yield, package costs, packaging yields, and testing costs.

With a stable, well designed process and a uniform application of mask layout rules, chip yield will be inversely proportional to some function of the active area. Figure 3 depicts typical yields for chips with active areas ranging from 7500 mils^2 to 20,000 mils^2. Typical devices used for this analysis are, (a) 128-bit undecoded bipolar at 7500 mils^2; (b) 256-bit decoded MOS at 10,000 mils^2; (c) 1024-bit dynamic MOS at 15,000 mils^2.

Since, in addition to the active area of a chip, room must be left for bonding pads and a scribe grid for dicing a wafer into chips, 8 mils are added to each edge of a square chip. The perimeter of a wafer rarely yields any good chips near the edges so these must not be counted as potential die. The number of potentially good chips on a 2-inch wafer is graphed in Fig. 4 for various chip areas.

By combining Figs. 3 and 4, we get a graph of the number of good chips/wafer we can expect versus the active areas of the chip using our yield assumptions. This is shown in Fig. 5.

Assuming a wafer manufacturing cost of $25/wafer, curves for cost per good chip are plotted in Fig. 6. Cost/chip ranges from 58¢ for a bipolar chip with $7.50 mils^2 active area up to $10 for an MOS chip with 20,000 mils^2 active area.

If we look at three different memory cell designs of undecoded bipolar, decoded static MOS, and dynamic MOS, the relative cost/bit at the chip level are plotted as a function of the number of bits/chips in Fig. 7. Each of the designs would have different peripheral electronics costs.

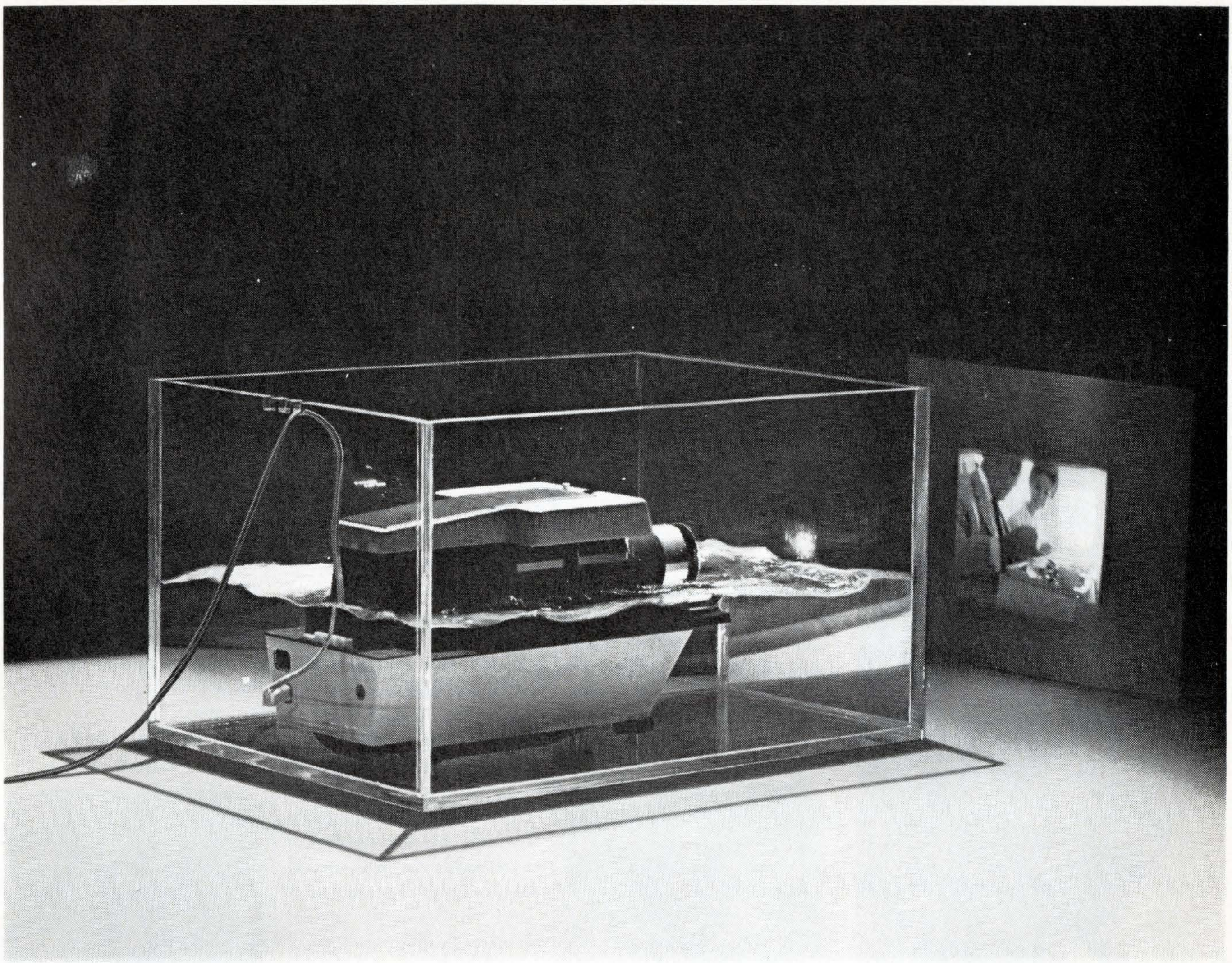
Figure 8 shows cost/bit at the package level for various size memory chips as a function of the package. We can now take our previously generated curves and combine them in an example. From this, we can draw some conclusions. Figure 9 shows the cost/bit at the package level for a 128-bit undecoded bipolar chip, a 256-bit decoded MOS chip, and a 1024-bit dynamic chip as a function of the number of chips/package. Yield loss of 20% is assumed for a two-chip package and 40% yield loss is assumed for a three-chip package.

From this analysis, one can conclude that lower package costs relative to the chip cost will shift the minimum cost to a fewer number of bits/chip while higher package costs relative to the chip costs favor a higher number of bits/chip.

It is very important that an adequate testing job be done at the wafer level. A bad chip committed to a package means that the bad package costs must be amortized over the remaining good ones. Package yield is also extremely important. If yield through packaging is 50%, then costs/bit have doubled. With multi-chip packages, this is even more important. One bad device may render the remaining devices in the package useless unless a good rework technique exists.

From our discussions, it appears that the long awaited advent of cost-competitive semiconductor memories has arrived. Clearly, the entire answer to the most economic approach to a given system design requires more analysis than that which can be derived from the supplier's cost projections. In Fig. 1, there is a three to five times difference between projected prices for the three semiconductor approaches. (The fact that these projections are not supported by Fig. 9 is worthy of further analysis.) The additional questions of ability to test a given product sufficiently to assure reliable performance, and the costs associated with device utilization and maintenance, must be closely scrutinized if the user is to choose the most economic approach.

INFORMATION RETRIEVAL
Integrated circuits, Digital design
Computers and peripherals



Our dry test bath results are completely projectionable.

If ever there was a dry liquid . . . this is it. Stick your hand in, it comes out dry. Not moist but totally dry.

Stick a microelectronic circuit in it and you find out immediately whether it leaks or has other flaws . . . and it comes out dry. Ready to use or ship.

Fluorinert® Brand Electronic Liquids are a whole new generation of testing agents for temperature and gross leak evaluations for all manner of electronic miniature devices.

Wide temperature variations don't affect their performance. They have unique dielectric properties. They don't react with even the most sensitive of component materials. They are inert . . . in the most inclusive sense of the word.

Send the coupon for the whole story. 3M Company, Chemical Division, 3M Center, St. Paul, Minnesota 55101.

What we send you may be dry, but it'll be illuminating.

Fluorinert® Electronic Liquids 3M
BRAND COMPANY

3M Company, Chemical Division, 3M Center
St. Paul, Minn. 55101 KYZ 9-70
Send me all the details about Fluorinert Brand Electronic Liquids.

Name____________________

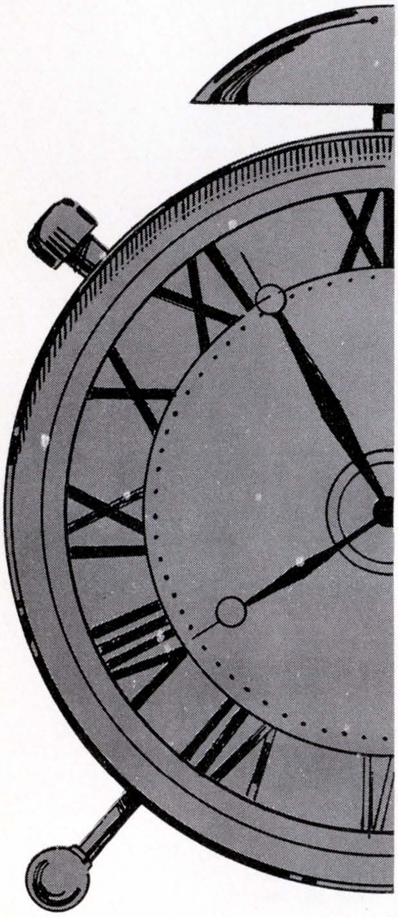
Company__________ Title__________

Address____________________

City________ State______ Zip______

Circle 25 on Inquiry Card

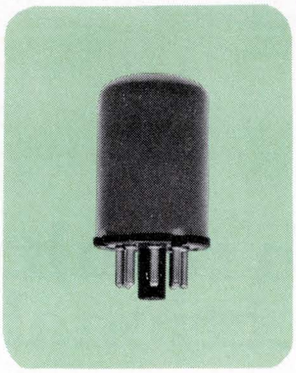
up-to-date "clocking" solves your advanced LOAD TIMING/CONTROL PROBLEMS



Precision timing and control of high current (mercury displacement) load switching requires advanced, reliable components and circuitry. Where nanoseconds, seconds, minutes, or even hours must be controlled, precision solid-state circuitry must be employed to insure maximum dependability. ADLAKE now offers two new timing devices, plus a unique solid-state bistable relay designed for precise and reliable control. These versatile products will find applications in circuits ranging from the most simple electro-mechanical apparatus to highly sophisticated computers.

PULSE LATCH

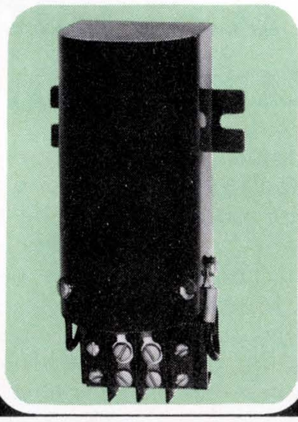
The **Pulse Latch** is a solid-state bistable relay of advance design which controls loads in excess of 3 amps (8-200 Volts). Positive input pulses as narrow as 100 usec. to the same terminal will alternately latch the two outputs. Switching rates as high as 2 kHz are attainable, depending on output loading.



The **Pulse Latch** is unaffected by shock or vibration and is internally supressed against voltage transients. Many standard models are available. **Pulse Latches** to accommodate your particular load, voltage, and switching parameters can be built on special order.

HYBRID TIMER

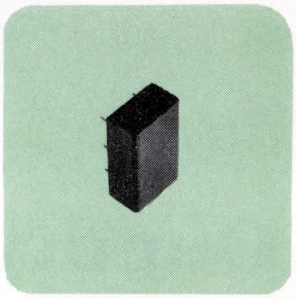
For the first time, an economical timer to handle 35 amp loads for the full timing period (no derating necessary). No need for a costly additional driven relay for high currents. Inputs up to 220 VAC and/or 200 VDC are time delayed from 50 msec. to over 2 minutes. ±5% accuracy under all load conditions in an operating temperature range from −30 to 200°F. Fixed or adjustable timing periods in excess of 15 minutes available special. Wide variety of combinations of "On", "Off", "Delay", "Instant Close or Open", with N.C. or N.O. switching.



DC-DC TRANSFER TIMER

Provides positively controlled, delayed dc output from dc input —timing interval is 10 msec. to 10 minutes. Timing period can be fixed (external resistor) or adjustable (external potentiometer).

Output timing accuracy is within ±2.5% at recycle times as low



as 20 msec. Operating temperature range is −30 to 170°F.

Selection of screw-type, PC, or quick connect-disconnect terminations minimize your production line problems. N.O. delay operate mode standard; N.O. quick operate-delayed release on special order. Solid-state AC or input/output isolation available special.

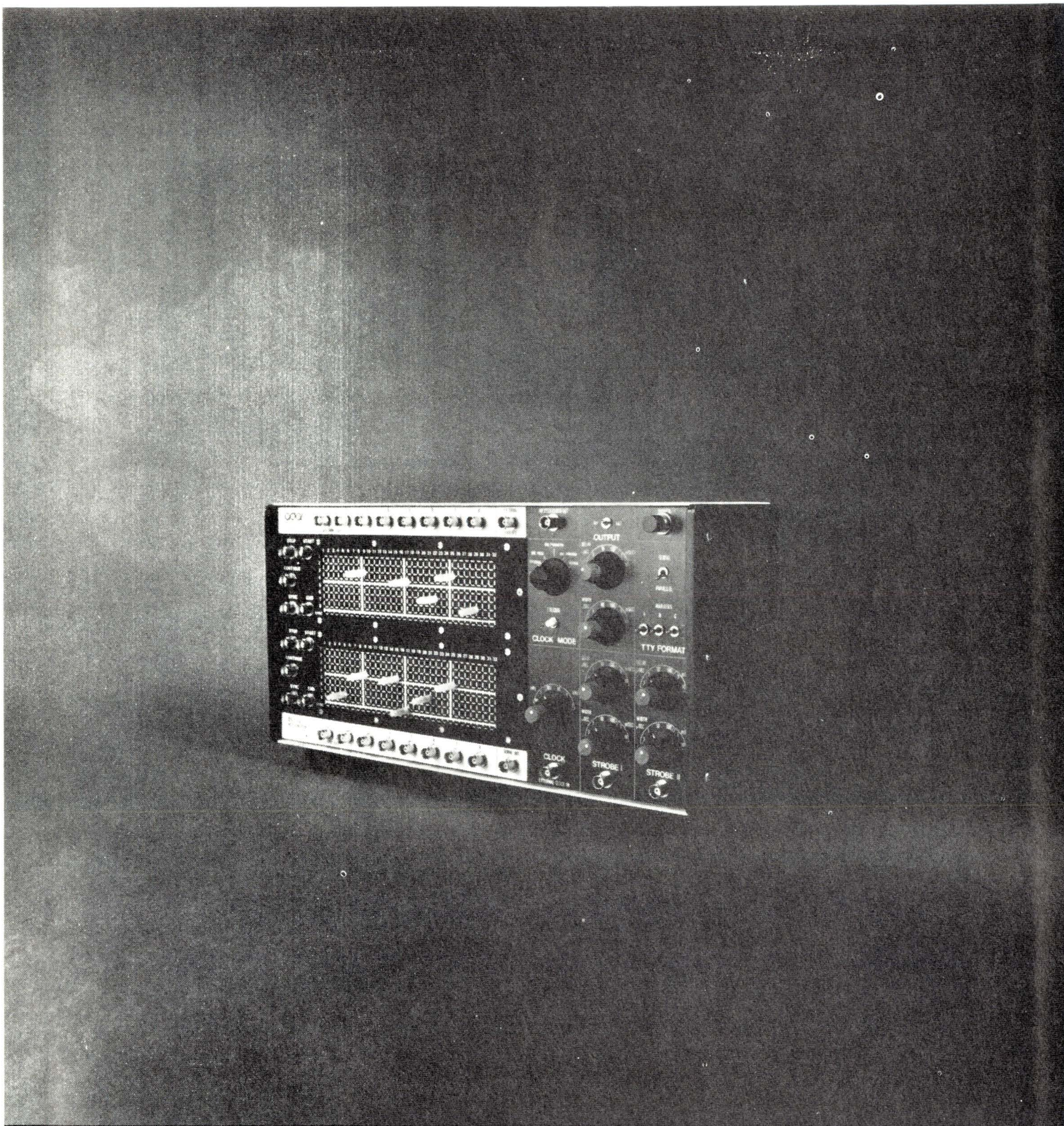
Specify ultra-reliable solid-state ADLAKE Timers and Control components for critical timing and heavy current load switching applications.

Won't you let us help you? Our engineering applications specialists have modern answers to your most frustrating power timing and switching problems.

Adlake SINCE 1857 **THE ADAMS & WESTLAKE** *COMPANY*

A SUBSIDIARY OF **ALLIED** *PRODUCTS CORPORATION*

(219) 264-1141 • TWX 219-522-3102 • TELEX 25-8458 • CABLE ADLAKE 1025 North Michigan Street, Elkhart, Indiana 46514


OUTPUT
CLOCK MODE
TTY FORMAT
CLOCK
STROBE I
STROBE II

TESTING integrated circuits

From minis to maxis, dc to dynamic, you have a wide choice. But, as an IC user, the first decision you must make is: do you need a tester at all?

By Sheldon Edelman
Western Editor, San Francisco

Shopping for an IC tester is a bit like strolling through a carnival midway, with merchants hawking their wares everywhere you look. Most manufacturers claim much for their machines, and often rightly so. Some criticize other makers' efforts, and often not rightly so.

Those of you who contemplate the purchase of a tester and intend to search the market thoroughly had better be prepared for a dizzying—though hopefully, illuminating—experience. Complicating things is the fact that the machine you buy today must satisfy you for at least the next three years—a tough proposition since the next three to five years will see a veritable explosion in MOS/LSI circuits and applications. Furthermore, the chips will be more complex, and will take longer to test, than chips available now.

A growing market

After a fairly slow start, due to the tendency of major IC producers to use more home-grown equipment than outside-purchased gear, the market has only recently begun to take off, having grown at an annual rate of about 8% for the past several years.

The growing sophistication and variety of available testers makes it now increasingly uneconomical for people to build their own. Further, older equipment cannot adequately test the newer, more-than-16-pin MOS/LSI circuits. This factor is a major force in the development of new testers and, while it will further increase the growth rate of the tester industry, it will make your choice of a tester even more agonizing in the near future.

Looking at the leaders

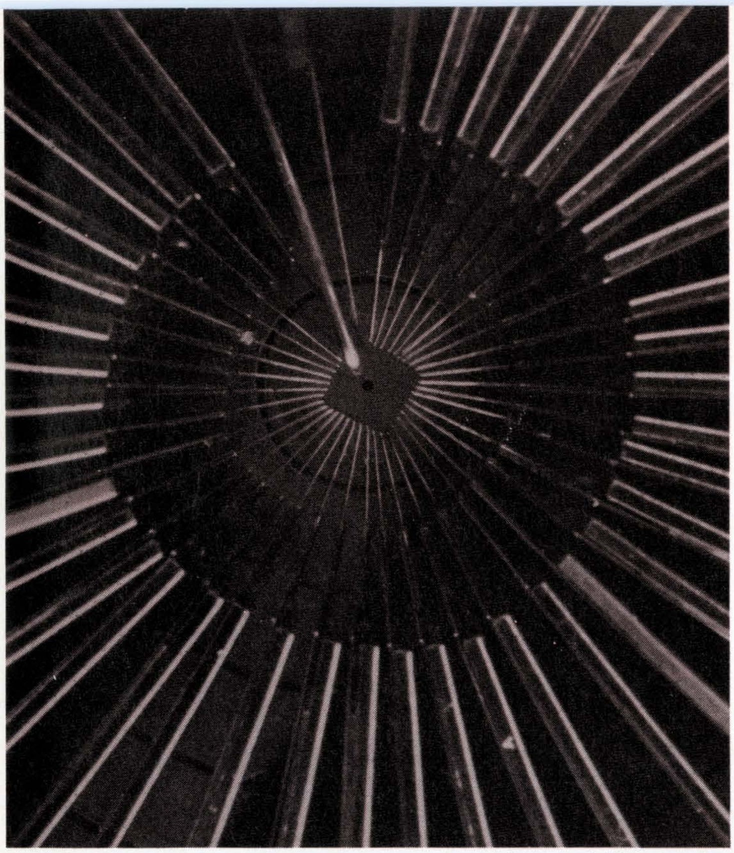
The IC tester market place is rather distinctly divided between the large, often computer-oriented, test systems, and the small, bench-top testers. As of this writing, in dollar volume for large dc/functional testers, Teradyne leads the pack by a small margin over Fairchild Systems, with Redcor placing third. Redcor's share is about a third of that of the two leaders; and although this company dominates the field of MOS testing, even this market is only a small fraction of the total. On the other hand, figures for the bench-top testers show that manufacturers such as Microdyne, Teradyne (again), Beckman, Signetics, Philbrick-Nexus, et al, have a much smaller dollar-share of the total market.

The market for dynamic testers of (primarily bipolar) ICs is split between Tektronix and E-H Research, and stands at a trifle over 6% of the total tester market: two million out of about 30 million dollars.

HOW TO CHOOSE A TESTER

Assuming that you need to purchase a tester, here are some recommendations to help with your decision.

- Take a long, hard look at your test needs, especially from an economic point of view. For example, the crossover point between the use of a small and a large tester is a function of time (in dollars) and throughput rate. If you're going to test strictly for a production line, then go/no-go testing may be sufficient; but engineering and QC will need data logging capabilities of one sort or another.
- Try to evaluate what you will need next year, as well as right now. If you're now working only with bipolar circuits, maybe you will have MOS next year; or you may need dynamic testing later. And multi-pin test



Courtesy of Electroglas, Inc.

The need to test

The IC tester market grows because of the growing need to test ICs. And the reason for that need is: *economics*. You've got to catch failures as early as you can to increase profits and to avoid adding significant value to a defective component, be it a wafer or a finished, packaged IC.

To an IC manufacturer, this means complete analysis (if possible) at the wafer level, plus further checks along the line to the finished circuit. He uses such information to keep tabs on his process. If the process is good, then yields are high; the manufacturer gets a good reputation; and the user gets fairly priced ICs.

How "good" are good ICs? As an IC user, you can expect that, on the average, 2% of your incoming ICs will be bad. Some IC sources show less than 1%, others up to 4%, and these failures are for established IC families. If you are using newly-introduced ICs, don't be surprised at a 10% rejection figure on a given lot. (The majority of these failures will be catastrophic; few will be due to excessive leakage currents or out-of-spec logic thresholds since such malfunctions are, hopefully, weeded out by IC manufacturers.)

Let's see what that 2% failure rate means. Suppose you're building PC boards, each of which holds 50 IC packages (a fairly common figure). Then, one out of every 50 ICs on your boards can be bad. The implication is that you may have to rework every board you make, unless you test *all* ICs prior to board insertion.

And this is why IC tester manufacturers invariably try to hammer home the importance of incoming inspection. They stress the cost of rework, which includes not only replacing the bad part with the consequent possibility of damaging the board (many boards can take only two solderings), but also of finding the bad IC in the board (which may require diagnostics).

On the other hand

Now that we have made the case for incoming inspection, note this: "It ain't necessarily so." And this is one reason why selecting a tester is not the easiest decision to make.

Hewlett-Packard's Cupertino, Calif. division is a case in point. This division builds small computers and interface equipments which use tens of thousands of ICs each month. Most of them end up soldered (no sockets) into complex logic cards of ten to 70 ICs each; 50 ICs per card is typical. Now, remember that key word: *economy*. It turns out that the division does not do incoming inspection. They've found it's cheaper for them to make the first tests on a finished board, with HP's own Model 2060A logic circuit analyzer.

The initial fallout is only about six ICs per 1000, or 0.6%, which is very good. The ICs are well-established

---

sockets may be very useful for your PC board tests.

- Evaluate the companies which make the type of tester you need. Talk to other users to determine the reputation of tester manufacturers. Are measurements repeatable? How long does it take a company to get a machine working? Are service and applications-engineering back-up available?
- In the case of computer-oriented machines, you may want to talk to the system designers to find out what the system will and won't do. Is it suitable for your circuits? Will it solve your problems?
- Keep an eye on true costs: initial purchase price plus what it costs to run the machine in terms of service contracts and downtime; cost of new program cards for small machines; programming-time costs for large machines; and perhaps you should worry more about the protection of the tester, rather than that of the IC under test—you can throw away a lot of ICs for what it may cost you to repair the tester.

In closing, keep in mind that exhaustive lists of machine specifications are not always to the point. They really do not show you how the tester will work for you in your test environment. Very often, what you infer from the specs is not at all what the tester manufacturer intended them to imply. And remember this: what you're after in a tester is a low test-cost-per-IC, which can mean that you may have to keep the tester busy. Can you do it?

logic types purchased outside, and the bad ICs are found very quickly thanks to the automatic card analyzer. Additional testing, all the way through systems' quality assurance (QA), shakes out only another 0.25% (or less) failures.

Other IC users, of course, do rely on incoming inspection; if the detection of bad ICs at incoming inspection saves you money, then the tester pays its own way. The point is that only you can decide whether or not it's right for your operation.

How much is enough?

Exhaustive testing is a substitute for ignorance: ignorance of the device under test, and ignorance of the economics of testing. On the other hand, counting the number of leads on an IC is not much of a test. Also, the nature of the test determines the failure rate; the more severe the test, the more rejects you'll have.

The answer again is tied to economics, and this time probability enters the picture. You must increase the probability of catching bad parts without adding significantly to the cost of your finished product. An IC—or any other component—must perform a function in some piece of equipment, and you must ensure—to some probability level—that it will. At some point in testing, it becomes more economical to assume that the IC is good and proceed with your assembly, than to test more exhaustively.

Now, suppose that you can't tolerate the normal 2% failure rate of non-inspected components. The question is: how much do the various forms of testing buy you? Well, you can reduce your failure rate to about 1% with functional testing only; doing both functional and dc testing, the figure will drop to about 0.1%; and with all three tests—*dc, functional,* and *dynamic*—your failure rate will drop still further to about 0.02%.

So you don't just run out and spend $100,000-plus for a tester with full capabilities. For most ICs and simple MSI circuits, a $5000-or-less tester may meet your economic need for prior-to-assembly sorting. Many users, indeed, find that they are saving money within months of buying such testers.

Probability becomes very significant in testing the newer, complex MOS/LSI ICs. Even with high-speed computerized testers it could take years to test completely all the possible logic combinations of such ICs. All that you can hope to do in this situation is to set a high level of probability that the IC is good. Programming is important here, because through software you optimize the test time to reach an estimated level of probability of acceptable performance.

Another factor to consider is throughput rate, and again this is tied to economics. You've got to test sufficiently to establish confidence in the part, but you can't take forever to do so.

Almost all testers mate with the several automatic handlers on the market. You'll find that, in general, these handlers are slower than the testers, so they will set the limit on throughput rate, even on small, bench-top machines. On the other hand, the real world shows that many users simply do not need a high throughput rate. An operator who manually inserts and removes the ICs can test several thousand each 8-hour working day.

A 2% failure rate among ICs may ruin every PC logic board you make.

Digital ICs—parametric, functional, or dynamic?

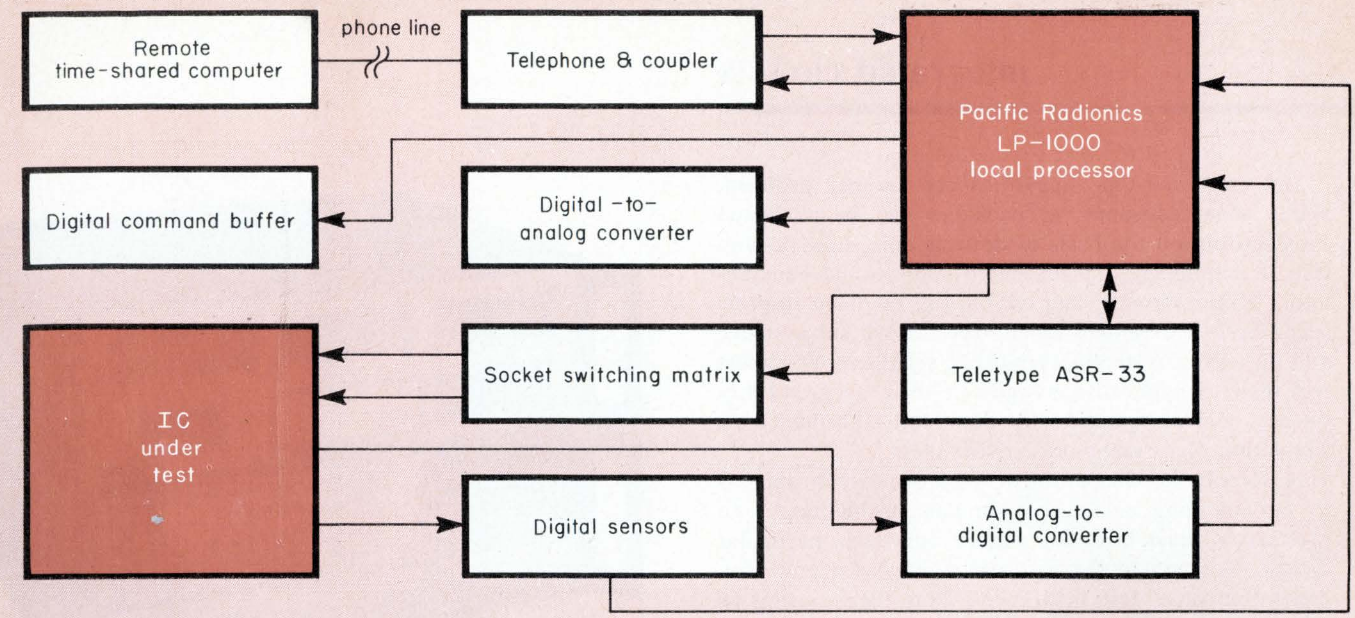
The type of testing that you do depends greatly on how the various parameters of the IC affect your circuit's operation. Briefly, in **parametric** testing you measure the dc, or static, parameters of the IC under test. Such tests include measurements of forward and reverse currents, saturation levels, offset voltages, logical high/low levels, and so forth. In general, the number of dc tests required is more-or-less proportional to the number of pins on the IC package.

Functional testing checks the truth-table operation of a digital IC by means of patterns of ones and zeroes. Because this type of testing logically exercises the paths through the integrated circuit, the necessary number of such tests increases with the IC's internal complexity. And this is why functional testing of large arrays of memory or logic can be a debilitating experience in generating seemingly endless sequences of test patterns; you might be grateful if your tester had a computer.

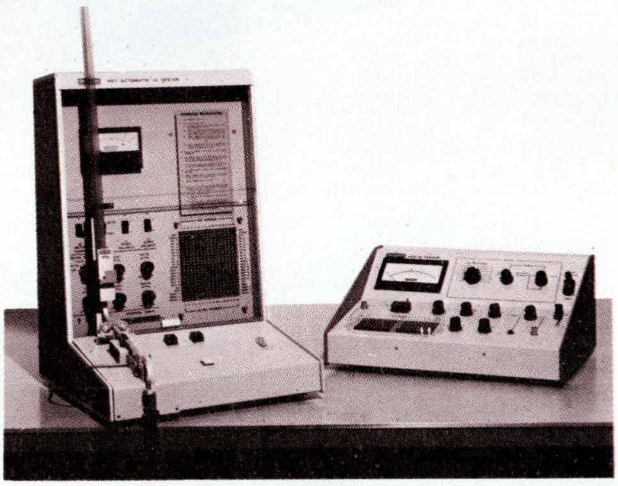
Complicating functional testing somewhat is that there are two types of logic circuits: *combinatorial* and *sequential.* In combinatorial logic circuits, there is a specific logic pattern output for any given input pattern, regardless of the order in which you apply the input patterns. Sequential logic, on the other hand, has internal storage (flip-flops, latches, and so forth). The logic pattern outputs of such circuits are a function of the input test patterns and also of their sequence.

Combinatorial logic is reasonably easy and straightforward to test. If there's an error in one pattern, it has no effect on the following outputs. But in sequential logic an error in a test pattern, or noisy lines that cause an internal element to change state, cause trouble. The sequence of output patterns will not be what it should, and you may reject good ICs.

Dynamic testing checks time-dependent parameters such as rise and fall times, propagation delays, storage times, and so forth. While all testers make dc and functional tests of one sort or another, few perform dynamic tests directly. The reason is that such testing requires special instruments and circuitry (nanosecond pulse/word generators, test fixtures designed for high-speed data handling, and so forth). In contrast, some testers can make limited dynamic tests by means of adapter fixtures which let you test the IC with externally-



Another way. If you're hooked to a computer time-sharing service, you can test small to intermediate quantities of linear and digital ICs without buying a tester. You can use a data coupler, in this case Pacific Radionics' LP-1000, as a test station. The computer stores the test programs, stimulates the IC under test, and records and processes all data. Print-out is via the TTY. The LP-1000 supplies bias voltages, programmed voltages or currents, and can supply commands for logic-function testing.



Package deal. Beckman's Model 997 tests all major families of bipolar, digital ICs with simple, inexpensive programming. The 997 is a dc/functional tester, and runs through 512 steps in less than 100 ms. Beckman has a standing package deal which gives you the 997, the 996 automatic handler (throughput rates well in excess of 10,000 ICs/day), and the 999 diagnostic tester for digitals, all for $3795.

supplied pulses and measure its response with a scope.

To each his own

Parametric, functional, and dynamic testing are complementary techniques in that they tell you different things about the IC under test. And the tests are of varying importance to different people.

Semiconductor manufacturers with well-established and controlled processes often will have only a parametric test capability. Functional testing may or may not be used depending on the complexity of the logic circuit. Further, manufacturers generally do not test dynamically, because they feel that they can guarantee such performance on the basis of the IC's design, and by statistical sample tests.

The point, of course, is that you—the user—had better be careful. If your design performance depends on the ICs' meeting certain specifications, then you should test to these specs yourself. And unless you're willing to pay for it, don't expect a manufacturer to change his test routine just for you.

But also keep in mind that if your circuit or system doesn't work because of a dc or functional failure, you can probably isolate the bad part, and fairly quickly, with ordinary test instruments. However, suppose your system fails dynamically because of, say, an out-of-spec propagation delay somewhere. Now you have a nasty diagnostic problem on your hands. To solve it may require lots of time and money, both of which could have been saved by an earlier, proper decision on what you really needed to test.

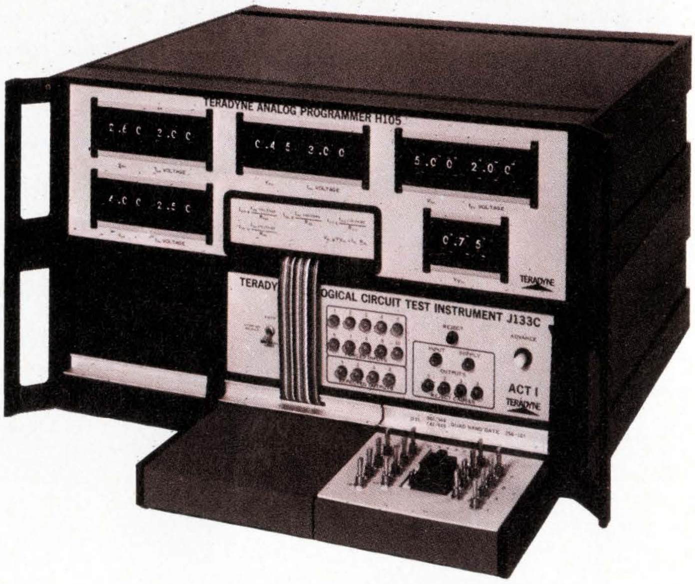
Linear ICs—enter the consumer

Testing of linear ICs differs from that of digital circuits in several ways. First of all, you're dealing with measurements of parameters such as gain, common-mode rejection ratio, slew rate, bandwidth, noise, and so forth. Primarily, you are measuring "continuously variable" quantities, as contrasted to "discrete" parameters such as threshold or switching levels.

Additionally, linear testers must provide an electrically-stable test environment for the circuit under test, and be able to measure very low-level signals. A large number of testers, from small to large, are available to satisfy these demands, and are suitable for testing op amps, sense amplifiers, comparators, and so forth.

But consumer-type linear ICS are another problem. While some consumer IC packages can be evaluated satisfactorily on the basis of dc tests only, how do you test i-f amplifiers, a-m/fm/stereo and chroma demodulators, sweep circuits, and oscillators? In many respects such circuits resemble small, specialized sub-systems, and dc testing is necessary but not sufficient. You must test them dynamically as well—at their operating frequency, and preferably with the circuit embedded in a simulation of its real-world environment.

A solution to this problem, and one which appears to be emerging as the predominant technique, is to provide a black-box test fixture for each particular circuit. You regard the IC tester simply as a powerful, general-purpose, test instrument. This means using its programming power, voltage and current supplies, switching facilities, and measuring capabilities as fully as you can. The fixture box provides all those specialized functions the tester itself doesn't have (such as oscillator circuits). Some users have built such fixtures on their own, and a few IC tester manufacturers have application groups to supply information and adapters.



Dynamically controversial

Dynamic testing is more useful to the user than to the manufacturer of ICS. For instance, you will often need such testing to determine how far you can push an IC in its actual working environment. Or, it may help you in getting rid of a problem through testing (such as minimizing, by measurement and selection, cross talk between pins which were not tied down as they should have been). In short, although the need for dc and functional testing outweighs that for dynamic testing, someone has to verify dynamic parameters, and that someone will generally be the user.

The problem with dynamic measurements is that they can be difficult to make reliably, even with a carefully laid-out bench set-up for just a few ICS, let alone in a large, automatic machine. You are dealing with nanosecond pulses, which will introduce signal-transmission problems. In dynamic testers, therefore, the most critical item is the test-head itself. It must have short signal paths, a well-matched transmission-system approach to signal routing, low and stable capacitances around the test socket, and so forth.

It's no wonder, then, that the earliest entries in the dynamic testing arena came from firms well-established in the fast-pulse field: E-H Research and Tektronix. Unfortunately, their basic approaches to such measurements differed, which has led to today's controversy in dynamic testing: single-shot or sampled?

One pulse does it

E-H Research pioneered the single-shot approach. They (and more recently, also Teradyne Dynamic Systems) feel that a single excitation/response cycle—one pulse in, one pulse out—provides all necessary information about the device under test. It's a sample-and-hold technique in which you sample a single output waveform and hold the measurement information long enough to read it.

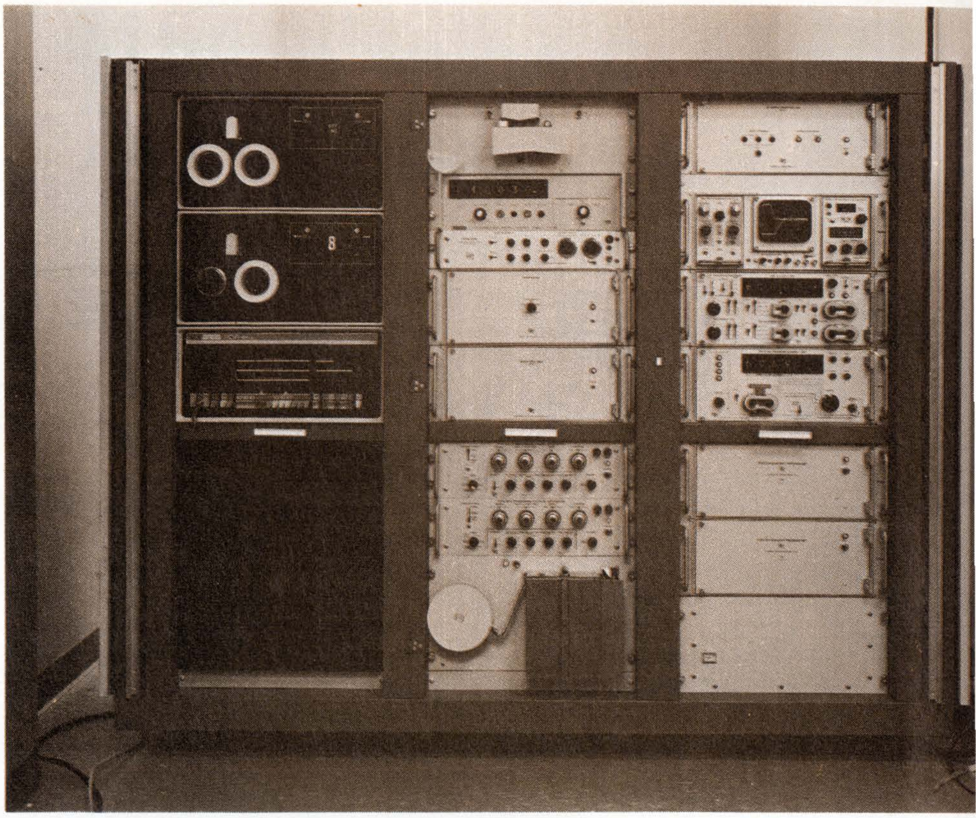
They also claim two major advantages over the sampling approach. One is that measurements are faster because you don't have to wait to sample a string of repetitive outputs: one pulse does it. (The implication is that sampling is useless for all but simple logic.) The second major advantage, according to its adherents, is that single-shot testing does not cause a temperature rise in rep-rate sensitive ICS.

Equal time: the samplers reply

Single-shot testing works; no one denies it. But Tektronix's answer to the critics of sampled data testing is that while its systems do require a repetitive signal, they attain a wider bandwidth than do single-shot (real-time) systems, because they take just a little information from each signal repetition (sampling). And that's what you're after—fast response.

The crux of the test-time question probably centers around a very complex IC, one which would require a great many different input words before giving one output pulse. There is a way to test such a circuit—if one were available to be tested—with a sampling system. You simply find an input sequence which you can apply repetitively, so that the circuit's output transition is forced to occur at a rate above the minimum required by the sampling system (100 Hz is ample for Tektronix's S-3150 test system).

It's true that if you have a circuit which you must clock at a slow rate, one which needs many, many input pulses to give a single output, then sampled measurements would take more time than single-shot measurements. But Tektronix feels that, in the real world, their sampling system can test the vast majority of



◀ **Adaptable.** Many small testers have a multitude of uses. Teradyne's J133C ($4850), for example, is generally considered to be a dc/functional tester for fast, go/no-go production work. But by adding an analog programmer ($2450; top-half of instrument) and an evaluation deck ($385; toggle switches around the test socket), you have an instrument well suited for engineering evaluation studies.

Behind the doors. Dynamic test systems tend to be collections of boxes identifiable with fast-pulse work. This is Tektronix's S-3150, originally a dc/dynamic tester, which showed up at last month's WESCON with a new 50-kHz functional test capability, a 32-pin load board, and environmental test capability as added features.

ICs in milliseconds; and that, in fact, for most circuits, there are no significant test-time differences between sampling and single-shot systems.

With regard to rep-rate sensitive ICs, it is true that sampling systems can heat them up. But the answer to the question as to whether the resulting measurements are or are not valid is rather nebulous. Certainly in some circumstances single-shot is a better method of measurement—for instance, if the IC is clocked only occasionally. But if an IC's inputs are switched rather frequently (as they usually are), then sampling represents perhaps a truer measurement. Dynamic, clocked logic is a very good example of this case.

According to their advocates, sampling systems have a particular advantage over single-shot systems in the presence of noise and jitter. A single-shot system makes one measurement: whatever it gets, that's what it records. But in sampling systems, you can apply smoothing techniques to greatly reduce the effects of noise. Further, you can average the first several samples before actually starting a measurement, to verify that the event really goes the way it's expected to.

The great rate race

Testing MOS ICs differs from the testing of bipolars in three ways: MOS circuits need higher voltages; leakage currents are lower and thus harder to measure; and dynamic-MOS testers must supply multiphase clocks. The MOS manufacturers who must test wafers have an additional problem: the bare wafers are photosensitive.

However, the third item in this list—clocking—is getting most of the attention these days; not the multiphase aspect, but the clock rate for functional testing. The tester manufacturers seem to have entered a great clock-rate race, with most aiming at 2 to 3 MHz, and at least two, as of this writing, at 8 MHz.

Why this race? Because manufacturers and users claim they must test at as high a frequency as their circuits operate, and/or at as high a rate as they can get a tester to run.

Multiphase-clocked, dynamic MOS uses the intrinsic capacitance of the device for temporary storage of data; clocking directs the data flow from gate to gate. Because it takes time to charge the gate capacitances, and because phasing and pulse width are critical in multiphase clocking, only testing at high clock rates can verify the charging time constants of those capacitances, and also the clocking, and thus check whether data can be properly stored and transmitted.

But there is another side to this picture, one which is often ignored. The gate capacitance stores data, but only for so long. The charge ultimately leaks off, which is why there is a frequency below which dynamic MOS circuits will not work. And this, conceivably, could cause problems. There are a great number of MOS applications (such as desk calculators) in which, while it's doubtful that the circuits will ever run at their high-frequency end, it is fairly certain that they will often have slowly-changing conditions.

Doesn't it make sense, then, to be practical and verify the lower-frequency performance that you actually may need, rather than reach for the fastest test rates, which you possibly may not need?

Again, it's a matter of probability. You should do what you can to increase the probability of catching

Continued on page 66

Two Schools of

Today, two schools of thought exist where there is a need for automated measurements.

1 | BUY THE SYSTEM

Buy a fully compatible test system and let the supplier do the systems engineering.

Tektronix offers solutions for each position: ***. . . buy the system . . .***

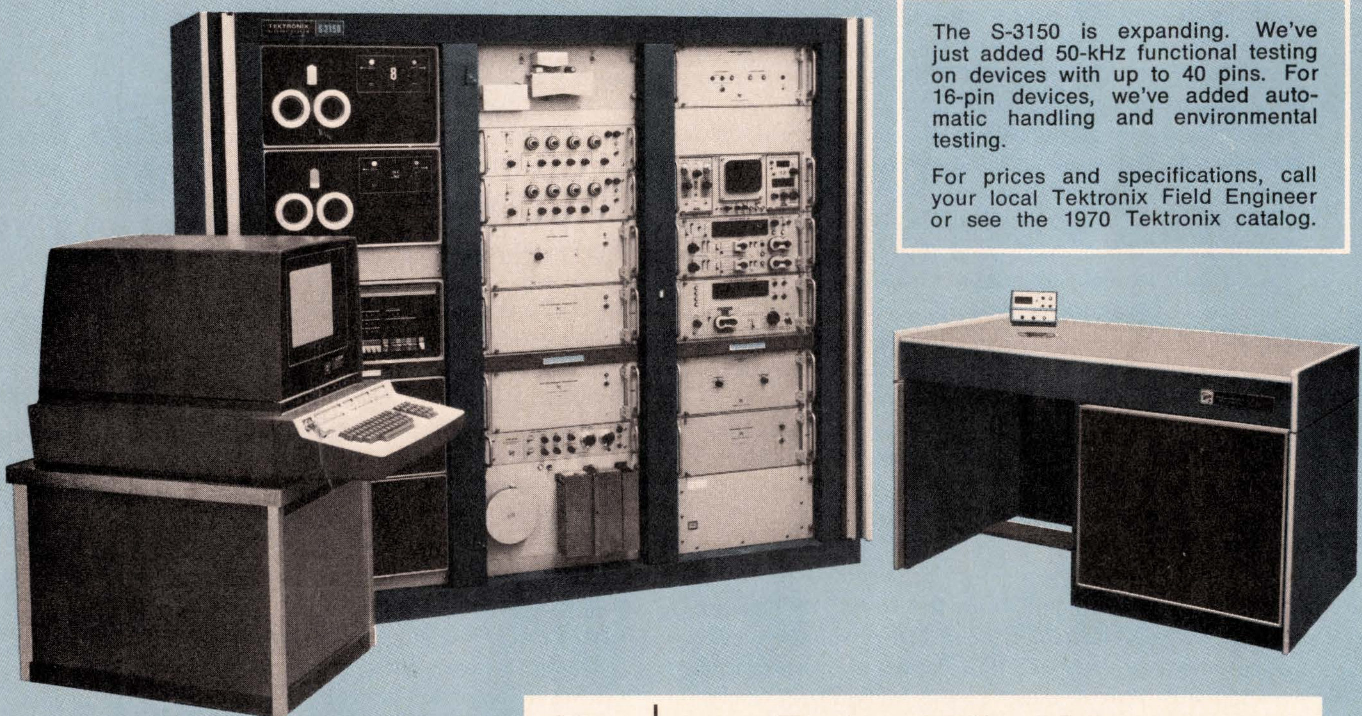
If you're of the "buy the system" group . . . you must decide: Functional, DC or Dynamic tests? The NEW Tektronix S-3150 will do *all three* types of testing on Digital IC's. Our S-3130 will make *dynamic* tests on IC's, transistors, circuit boards, etc. Most suppliers provide DC or Functional test systems . . . Tektronix provides dynamic systems!

A word for dynamic testing: dynamic testing is a powerful tool, enabling you to verify the performance of active devices under operating conditions. If the device has a specified clock frequency of 15 MHz, why perform a DC or Functional test and be left guessing that it will work at 15 MHz . . . test it there! There are nine systems available from Tektronix . . . standard modifications to three of these brings the total to *twelve cataloged dynamic systems.*

We're anxious to discuss the unique applications that can't be served by one of our standard cataloged systems!

The S-3150 is expanding. We've just added 50-kHz functional testing on devices with up to 40 pins. For 16-pin devices, we've added automatic handling and environmental testing.

For prices and specifications, call your local Tektronix Field Engineer or see the 1970 Tektronix catalog.



Tektronix, Inc.

committed to progress in waveform measurement

failures in your test situation. Also, remember that testing at a low frequency does not guarantee operation at the upper frequencies. In some instances, this means a decision between machines of high clock rates but with somewhat limited test capabilities, and those of lower clock rates but with more exhaustive testing.

Enter the computer

"Systems of two or three years ago were suitable for the ICs of that time. But the new test systems represent a quantum jump in an effort to stay ahead of the IC technology itself," says Vito DiMucci, Director of Systems Engineering for Fairchild Systems Technology. And this neatly sums up what's happening with IC testers today—computer-oriented systems are coming on fast and furiously to keep up with, and hopefully outdistance, the pace of complex IC developments.

Just what are some of the things a computer can do for you? To start with, it can help you write the test program. Hopefully, the dialogue between you and the computer will be an interactive conversation in plain English, and one which requires only that you know how to read an IC data sheet. Another area where the computer helps is data collection; you can command it to collect all test data, or test data on failures only, or what have you.

If you collect test data, then the computer can help you prepare it for display as, say, histograms on a teletypewriter, or parameter distribution curves on a graphic terminal.

Further, you can program-in word-screening to protect the IC under test. If a "no-no" word comes up, the test sequence will be interrupted. Also, if the computer can be run off-line, your company will have available a small general-purpose computer.

But remember this: the larger and more powerful the test system, the more you will depend on it. And the more you depend on it, the more nervous you should be about system failures. If the computer is down, can the test section proper keep going? And, conversely, if the test section fails, is the computer store disturbed? You must carefully consider the fail-safe aspects of any test system of interest to you.

On-line test plan generation

The first automatic IC tester (in which the test program was stored in a disc) required you to write every definition of every test. With computer-oriented machines, on the other hand, you are required to write only those things that change from test to test.

But suppose you could just write a set of instructions which directed the computer to generate the test plan for you, as you go along. You could store such testing in less memory; test planning would take less time; and there would be fewer errors. Gordon Padwick, manager of Teradyne's Western Technical Center in Palo Alto, Calif., feels that such on-line test plan generation is a very important field of work, and one which is not yet very well known or understood in the industry.

Memories, memories

Teradyne's J283—the SLOT machine—uses such on-line test plan generation. To illustrate the power of the approach, consider the testing of a memory. Now, if you think of a semiconductor memory as more than just a replacement for magnetic cores, and more than just a collection of gates, you will want to test it in a certain way: not just with a checkerboard pattern of ones and zeroes, and not just with the usual patterns used to test arrays of gates.

For example, the following test procedure, which is particularly geared to semiconductor memories, gives a reasonable indication that the memory is good:

- Write *zeroes* into every cell.
- Float a *one* through this field of *zeroes* (write a

DIRECTORY OF MANUFACTURERS

For information on the IC testers, diagnostic systems, PC card testers, data couplers for IC testers, and services, circle on the Reader Service card the number shown next to each company.

IC testers	Circle No.
AAI, Box 6767, Baltimore, Md. 21204	201
Adar, 85 Bolton St., Boston, Mass. 02140	202
Beckman Instruments, 2200 Wright Ave., Richmond, Calif. 94804	203
Birtcher, Instrument Div., 1200 Monterey Pass Rd., Monterey Park, Calif. 91754	204
CGS Units, 73 Saginaw Dr., Rochester, N.Y. 14623	205
Datatron, 1562 Reynolds Ave., Santa Ana, Calif. 92707	206
E-H Research, 515 11th St., Box 1289, Oakland, Calif. 94604	207
EL Instruments, 61 First St., Derby, Conn. 06418	208
Fairchild Systems Technology, 974 E. Arques Ave., Sunnyvale, Calif. 94086	209
ITT/Metrix (Advanced Technology & Systems Corp.), 1143 Post Rd., Riverside, Conn. 06878	210
LSI Testing, 2950 S. 133 West, Salt Lake City, Utah 84115	211
Macrodata, 20440 Corisco St., Chatsworth, Calif. 91311	212
Microdyne, 203 Middlesex Tpk. Burlington, Mass. 01803	213
Micro Test, 9000 Winnetka Ave., Northridge, Calif. 91324	214
Monitor Systems, Inc., Industrial Park, Ft. Washington, Pa.	215
Non-Linear Systems, Box N, Del Mar, Calif. 92014	216
North American Electronic Systems (ECC) Sicklerville, N.J. 08081	217
Optimized Devices, 220 Marble Ave., Pleasantville, N.Y. 10570	218
Philbrick-Nexus, 22 Allied Dr. at Rt. 128, Dedham, Mass. 02026	219
Quan-Tech Labs, 435 Jefferson, Whippany, N.J. 07981	200
Redcor, 21200 Victory Blvd., Woodland Hills, Calif. 91364	221
Scientific Measurement Systems, 351 New Albany Rd., Moorestown, N.J. 08057	222
Signetics, Measurement/Data, 341 Moffett Blvd., Mountain View, Calif. 94040	223
Spectrum Dynamics, Box 23699, Ft. Lauderdale, Fla. 33307	224
Tektronix, Box 500, Beaverton, Ore. 97005	225
Teradyne, 183 Essex St., Boston, Mass. 02111	226
Teradyne Dynamic Systems, 9551 Irondale Ave., Chatsworth, Calif. 91311	227
Test Equipment Corp., 2925 Merrell Rd., Dallas, Tex. 75220	228
Texas Instruments, Industrial Products Div., Box 66027, Houston, Tex. 77006	229
Varadyne Instrumentation, 320 Martin Ave., Santa Clara, Calif. 95050	230
Xintel, 20931 Nordhoff St., Box 665, Chatsworth, Calif. 91311	231

Diagnostic computer systems	Circle No.
Digital/General Corp., 11000 Cedar Ave., Cleveland, Ohio 44106	232

Card and system testers	Circle No.
Automation Dynamics, 35 Industrial Pkwy., Northvale, N.J. 07647	233
Dynatronics Operation, Box 2566, Orlando, Fla. 32802	234
General Radio, West Concord, Mass. 01781	235
Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94303	236
Sangamo Electric, Data Systems, Box 3347 Springfield, Ill. 62708	237
Scientific Measurement Systems, 351 New Albany Rd., Moorestown, N.J. 08507	238
Willard Labs, 4221 Redwood Ave., Los Angeles, Calif. 90066	239

Data couplers	Circle No.
Hewlett-Packard, 1501 Page Mill Rd., Palo Alto, Calif. 94303	240
Pacific Radionics, 581 Division St., Campbell, Calif. 95008	241
Sagetec, 20747 Deerborn St., Chatsworth, Calif. 91311	242

Related services	Circle No.
Mellonics, 1001 W. Maude Ave., Sunnyvale, Calif. 94086	243
Telpar, 4300 Sigma Rd., Dallas, Tex. 75234	244
(both of the above companies do logic simulation, test pattern generation and verification, etc.)	
Nova Devices, 829 Woburn St., Wilmington, Mass. 01887. (Linear IC testing)	245

one into the first cell; check it as a *one*; check that all other cells are still *zero*; reset the first cell to *zero*, and write a *one* into the second cell; check that *one;* check all other cells for *zeroes;* and so on through all cells of the memory).

- After floating the *one* through the memory, write a *one* into every cell.
- Float a *zero* through this field of *ones*.

Suppose you wanted to check a 64-bit, read/write RAM in this manner. You'll see that the test procedure involves 8320 separate functional tests $(64 + 64^2 + 64 + 64^2)$. And this doesn't include the necessary dc checks. (A 256-bit memory would need 121,584-plus tests). If you write this long sequence onto a paper tape, or disc, via a teletypewriter keyboard, it will take you quite a long while, and by the time you're finished, there will be several errors. So you go through it again. This is an unrealistic approach.

The next approach is to let a computer write the 8320-step sequence for you. But it still must be stored in the test system memory before it can run the tests. Since core is expensive, disc memories are commonly used for bulk storage, with transfer to core as the test progresses. But disc-to-core transfer is slow (and is the hang-up in several available testers which could otherwise run at faster rates), and it requires extra software.

But now go one step further. You not only let the computer generate the test pattern, but you also let it do so as the test progresses. And this is what SLOT's on-line test plan generation is all about. With it, the 64-bit memory test sequence needs only about 1200 words of memory instead of the 8000-plus. (A 256-bit memory needs very little more than 1200, because the instruction set is basically the same.) And the same principles and savings apply to logic circuits in general.

There's a lot to consider, then, in all that's been said, but if you keep your specific requirements as well as the tester's capabilities in mind, you'll find the tester best suited to your needs.

Many thanks to . . .

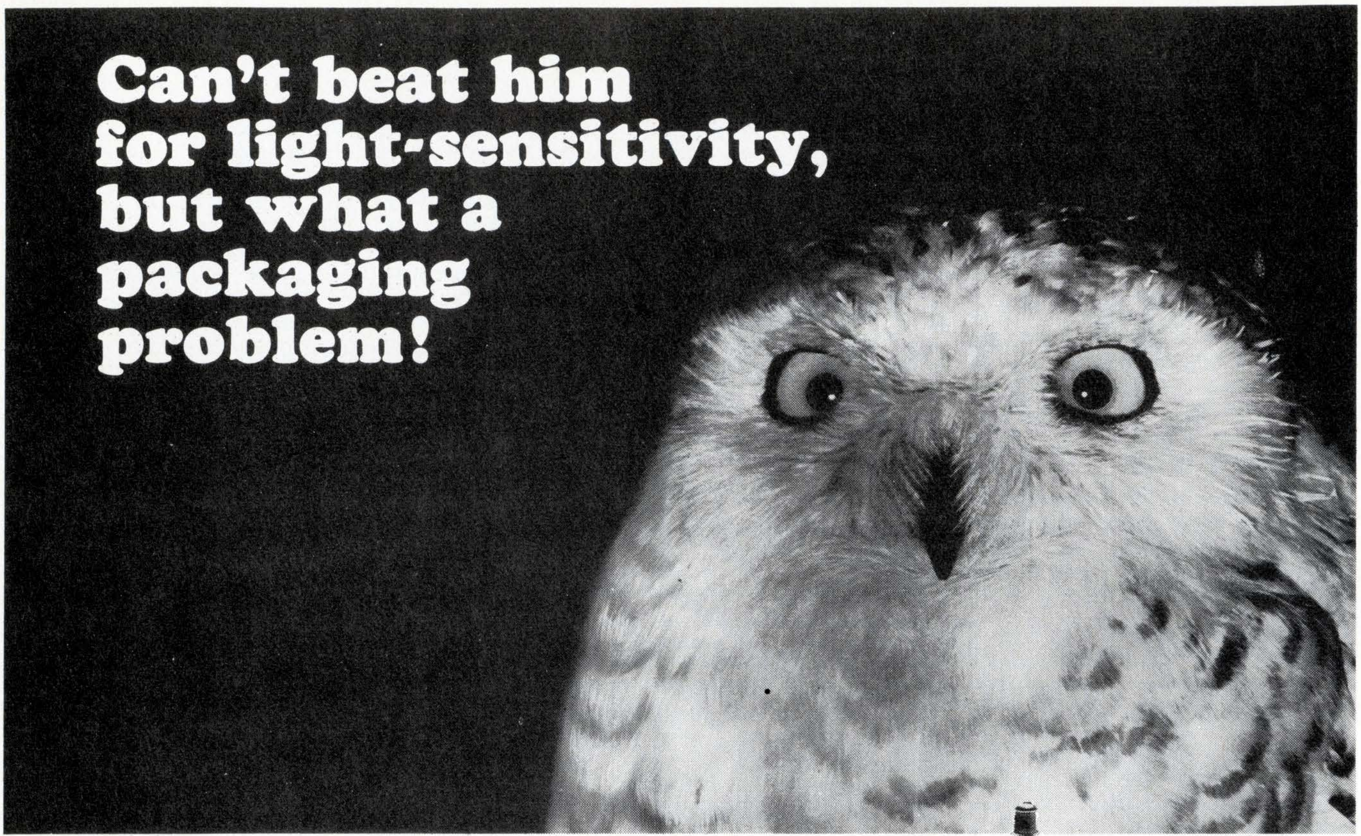
. . . the following gentlemen, who patiently sat through the author's interrogations: Sven Simonsen, *Advanced Micro Devices;* the whole team at *American Micro-Systems* (especially George Avery, Jim McPhail, and Don Richard); Jerry Hartman, *Beckman Instruments;* Bill Boggs, *E-H Research;* Sam Wauchope, *Electronic Arrays;* Vito DiMucci, Bob Schreiner, *Fairchild Systems Technology;* John Kemper, *General Radio;* Hank Doust, *Hewlett-Packard;* Chuck Maxfield, Roger Pfeil, and Ed Thompson, *Lockheed Microelectronics Center;* Bob Prosin, *Microdyne;* Dan Hauer, Rudy Svetal, *Qualidyne;* John Rock, *Quantum Science Corp.;* Gerald Williams, *Signetics Measurement/Data;* Al Zimmerman, *Tektronix;* Gordon Padwick, *Teradyne;* Dale Burton, *Varadyne Instrumentation;* Bill Ackley, John Coons, and Rod Mack, *Xintel.*

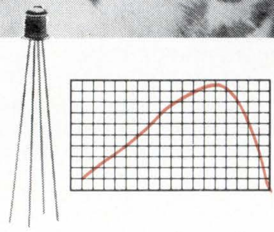
Thanks also to the many others, too numerous to mention here, who took time to send me their thoughts via the mail.

INFORMATION RETRIEVAL

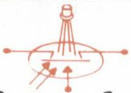
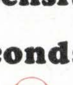
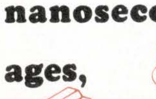
Integrated circuits, Instruments and measurements, Data acquisition and processing.


Electro-optics
technology
from RCA
for your
UV/ visible/ IR
needs





Here's the next best thing . . . FOTOFET®

If you're working on high sensitivity electro-optical light-pens, keyboards, laser detectors, optical communications systems or positioning systems, here's a wise buy . . . FOTOFET.  **This device gives you photomultiplier sensitivity coupled with transistor size and simplicity. FOTOFETs have 1000 times higher sensitivity than phototransistors. Rise and fall times are less than 50 nanoseconds. FOTOFETs are available in lens-equipped transistor packages,**  **in chip form for use in arrays or hybrids,**  **or in lid form.**  **The lids can be spaced as close as 0.05″ on centers, for use in card and tape readers, shaft encoders, and other arrays. FOTOFET spectral response is compatible with GaAs diodes and visible incandescent sources. FOTOFETs are well suited to cryogenic operation.**

TELEDYNE
CRYSTALONICS

147 Sherman St. • Cambridge, Mass. 02140 • TEL: 617-491-1670
1800 N. Highland Ave. • Suite 616 • Hollywood, Calif. 90028 • TEL:213-469-5871

CALL YOUR LOCAL CRYSTALONICS OFFICE FOR DETAILS

(201) 835-0332	(305) 831-1080	(404) 939-7075	(609) 784-5000
(206) 323-5100	(305) 848-4617	(415) 349-6316	(612) 488-0201
(213) 466-6201	(305) 563-6639	(416) 366-2157	(616) 243-8576
(213) 469-5871	(312) 547-6200	(505) 268-0928	(617) 491-1670
(214) 231-6891	(313) 474-0661	(513) 299-4144	(617) 891-4582
(301) 668-4646	(315) 457-1188	(514) 684-2246	(704) 366-6678
(303) 798-8439	(317) 289-6322	(516) 593-2628	(716) 342-1413
	(319) 363-6425	(602) 273-7387	

DEVICES SENSE LIGHT

There are many types of "light detectors." Learn what they are and how they work.

By Lin Wetterau, Millis Miller, & Dr. Robert Haisty
Texas Instruments Incorporated, Dallas, Tex.

The principle of photoconductivity was first observed by Willoughby Smith in 1873 when he noted a decrease in the resistance of a selenium bar resistor upon exposure to light. For many years, this principle was often confused and combined with the photovoltaic effect in which a voltage is generated in a material when exposed to radiation.

Photoconductive and photoresistive components

Generally the term photoconductivity is used to describe a material's change in conductivity during its exposure to light. For our purposes, we will consider photoconductors as components in which the change of resistance value with light intensity is used in optoelectronic circuits (Fig. 1). In such components, the resistance value decreases linearity as light intensity increases.

Any semiconductor may be used as a photoconductor because its electrical conductivity is increased by the absorption of light. When light is absorbed by the photoconductive substance, hole-electron pairs are generated in proportion to the intensity of radiation. For this effect to occur, certain conditions must be met:

• The light must be absorbed—light which is reflected from the substance does not generate hole-electron pairs. This is another way of saying that the light, to be absorbed, must be of an energy equal to or greater than the band-gap of the material.

• The holes and/or electrons, once generated, must have sufficient mobility and lifetime to cause an increased conductivity.

• A field and electrodes must be provided to move the charge carriers within the material and create a current flow.

When the above conditions are satisfied, several processes are in competition, namely recombination, trapping, and thermal creation of free holes or electrons. All of these processes combine to determine the carrier lifetimes and to affect the overall performance of the photoconductor. The extent of recombination and trapping is a function of the material's crystal structure.

The most widely used photoconductive materials are cadmium sulfide (CdS) and cadmium selenide (CdSe). There are devices made of thallous sulfide, lead telluride, and lead sulphide, as well as the special doping of CdS with copper, chlorine, and iodine. Some cells contain a rectifying pn junction or metal barrier contacts and can be considered simple photoresistors. The manufacturing processes and techniques used for photoconductors vary from sintering or firing operations to vapor, chemical, or vacuum deposition techniques. There are many more processing variations for photoconductors than for other semiconductor components.

Photoconductive components are used when applications require large sensitive areas, zero offset voltage, and large light-to-dark ratios, as well as relatively low cost. The speed of response for photoconductors is slow—in the millisecond range. A memory or hysteresis effect may cause problems for some applications. The spectral response peaks sharply at 5500 Å for CdS and at about 7000 Å for CdSe.

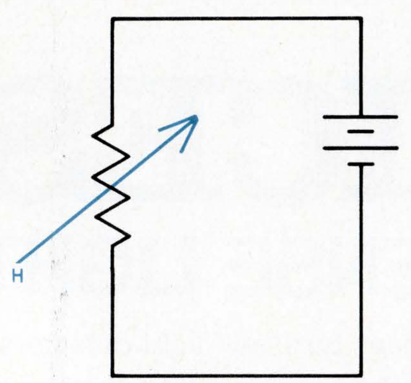


Fig. 1: Here is the circuit equivalent of a photoconductor which functions as a variable resistor, varying according to light intensity (H).

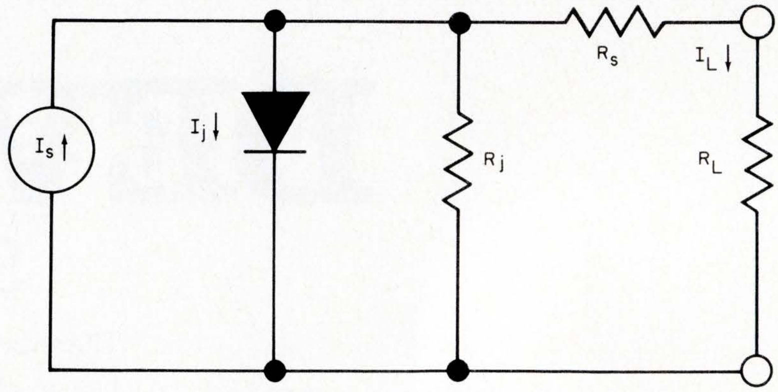


Fig. 2: In this circuit equivalent of a photovoltaic cell, the pn junction, I_j, functions as a current source across the junction resistance, R_j, and also blocks current flow in the opposite direction.

Photovoltaic components

A photovoltaic component differs from a photoconductor in that it generates a voltage when light is absorbed, rather than changing its conductivity. In the photovoltaic cell a pn junction is formed in the semiconductor. This creates a barrier for the separation of the hole-electron pairs. The field at the junction drives the electrons to the n-type side and the holes to the p-type side, thus creating a potential across the junction.

The photovoltaic cell is usually applied in the open circuit voltage mode or with an optimum load impedance for solar cell power applications. The equivalent circuit is shown in Fig. 2, where I_s represents a current generator and I_j is the junction current of the pn junction, R_j and R_s are the junction and series resistances, while R_L is the external load resistor. In practical cells where R_j is much greater than R_s, and R_L is relatively small: then:

$$I_L = I_s - I_j$$

The open circuit voltage of a cell can be expressed by:

$$V_{o/c} = \frac{nkT}{q} \ln \left(\frac{I_s}{I_o} + 1 \right)$$

Where I_o = reverse saturation current of the dark junction,

q = electronic charge (abs),

k = Boltzmann's constant,

and n = factor in diode equation whose value is between 1 and 2.

While photocells can be made from many different materials, such as germanium, cadmium telluride, indium phosphide and gallium arsenide, the most common material is silicon. Generally in the silicon photovoltaic cell a p-type boron diffusion is made into an n-type siilcon to form the pn junction. Solid metal ohmic contacts are fabricated to the n-type side and a grid pattern contact (permitting light absorption) is made to the p-type side. Usually an anti-reflective coating is deposited on the p-type surface to reduce the reflection losses from the surface. The manufacturing processes for these silicon pn photovoltaic devices are well developed. Photovoltaic components convert solar energy to electricity and find use in card-tape readers, cameras, and light sensitive switches.

Photodiode components

A photodiode, like the photovoltaic cell, is a pn junction device designed to work with a reverse bias applied across the junction. The reverse bias increases the field across the junction and the device operates as a current generator. Light absorbed by the cell creates hole-electron pairs which are swept across the junction barrier, giving an excess of carriers. The bias extends the effective junction or depletion region, making the device very efficient in converting photons. A photodiode has a linear change of current with light intensity,

$$I = I_L + I_o$$

where I_L is the load current in the light and I_o is the dark saturation current of the junction. Fig. 3 shows the typical V-I characteristics of a photodiode in light and dark conditions.

In the practical sense, photodiodes are made in a variety of configurations, taking advantage of the properties of the pn junction. As the resistivity of the base

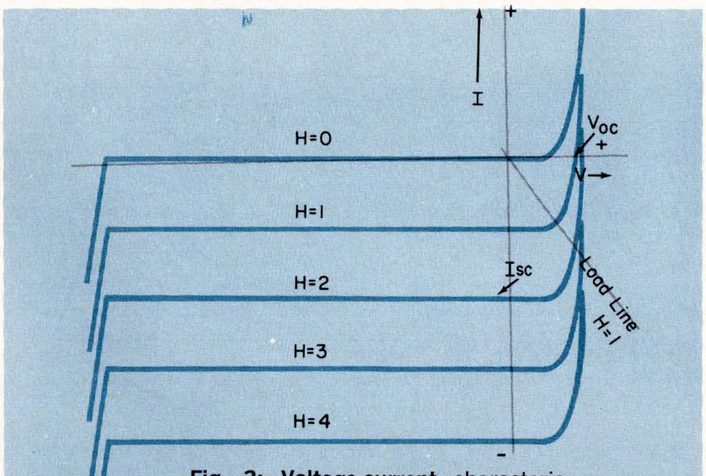


Fig. 3: Voltage-current characteristics of a pn junction diode with various light intensities (H). The photodiode operates in the III quadrant where the reverse current is proportional to H.

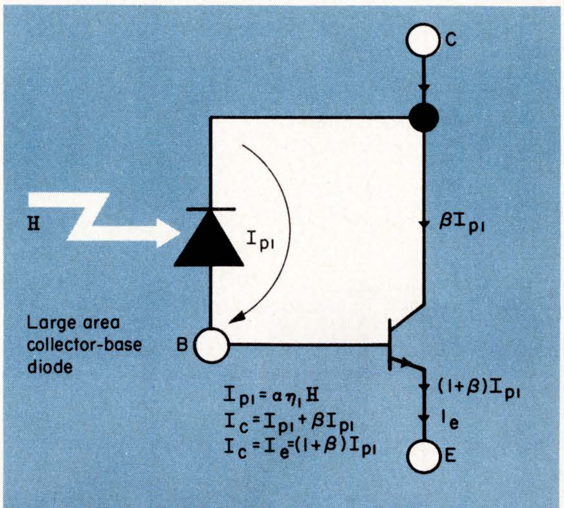


Fig. 4: The circuit equivalent of a phototransistor shows how the large area of the collector-base (diode) functions.

material is changed along with the bias voltages, it is possible to affect the junction characteristics and thereby, the light response of the device.

As the depletion region of the junction is extended deeper into the base material, the holes and electrons have a shorter distance to travel to reach the separation barrier. There is, therefore, less chance for recombination. Also, large depletion regions lead to lower junction capacitances, enabling high speed operation due to the shorter transit time or higher drift velocity.

Photodiodes are also made by taking advantage of the avalanche multiplication factor. As the bias voltage approaches the breakdown voltage, the holes and electrons created by the absorbed photons acquire enough energy to create other electron-hole pairs. As they collide with substrate atoms, these second order electron-hole pairs can then generate further pairs. This characteristic of avalanche photodiodes achieves high speed operation and multiplication of the light current.

Photodiodes can be made of any material in which a pn junction or barrier can be formed, but those most frequently used are silicon and germanium. Normally the junction is formed in a substrate by planar diffusion, and ohmic contacts are made to the n and p regions.

By selecting the initial material characteristics (dopant concentration, lifetime, and mobility), and the diffused impurity type and concentration, it is possible to optimize the photodiode for various characteristics such as speed of response, dark current, efficiency at specific wavelengths, and ac parameters. Photodiodes are also made by the metal barrier technique (Schottky barrier) where the metal-semiconductor interface forms an effective pn junction at the surface. Although many special types of photodiodes are made for specific applications, they are all basically diodes and follow diode theory, being optimized for their photo response.

Phototransistors

The boundary conditions for paper tape and card reading systems were set and standardized before the widespread use of optoelectronics. As a result, hole spacing and shape were set by mechanical limitations of spring contact spacing. The effort to find improved techniques of reading such holes first led to the use of photodiodes in sensing the presence of a hole. The limitations of photodiodes immediately became obvious:

- More output current was needed because the small holes did not let much light through.
- Mechanical spacing limited center-to-center spacing and maximum diode size.
- Electrical noise levels in card handling machinery were usually high, relative to photodiode light currents.

Amplification was required and the obvious question became: Why not use a transistor? Early in their development certain transistors could not be measured under strong illumination, because of light sensitivity. By optimizing this sensitivity, however, we could get effective amplification. A few measurements with light spot probes showed that the exposed collector-base junction was acting as the current generator and supplying the transistor base current.

The equivalent circuit for a phototransistor is approximated in Fig. 4. In this simple form, the base current generator is simply a photodiode as described previously. The transistor collector-base junction and the

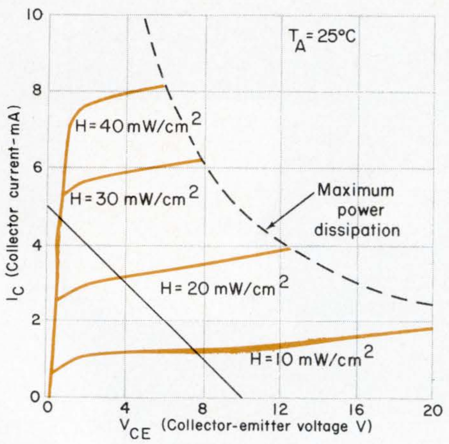


Fig. 5: Here are typical collector characteristics of a phototransistor. Note that H (light intensity) is given in mW/cm². The standard of calibration for light in these terms is a thermopile.

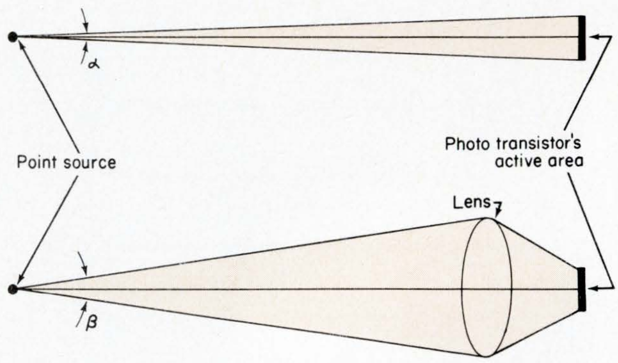


Fig. 6: Optical "gain" is possible in a phototransistor by using a lens. In case 1, the phototransistor intercepts all light in angle α, while in case 2, because of the lens, the same device has a higher collector current, angle β.

photodiode junction are identical, and both operate at the same reverse bias. In practice, the collector-base area is expanded to collect as much light as possible, while the emitter is located as far away as possible.

The collector current of the phototransistor may be expressed as

$$(I_c = I_e = 1 + B)\ I_{pl}$$

The bipolar phototransistor behaves much the same as a normal bipolar device; its h_{FE} decreases at low collector current. The increase in dark current versus temperature is much the same as in most transistors.

A look at the equivalent circuit (Fig. 4) shows that output current can be increased by:

- Making the active collector-base area as large as possible.
- Making the transistor dc h_{FE} value (static forward-current transfer ratio) as high as possible.
- Taking all precautions to enhance the quantum efficiency of the collector-base diode during material processing and assembly.

The long lifetime values in silicon phototransistors lead to the absorption of radiant energy in the entire bulk of the silicon phototransistor. This causes the device to have a relatively long wavelength response, peaking near 0.9 μm—a close spectral match for tungsten light sources or infrared light emitters. A short lifetime material would reduce the amount of long wavelength energy absorbed, causing the device to have lower absolute response with a spectral peak at shorter wavelengths. Filters and optical coatings can also cause the peak relative response to occur at shorter wavelengths. Such spectral response shaping is widely used on phototransistors.

By controlling light input or irradiance, the transistor's light current can be controlled. Varying radiant energy will force the light sensor to provide a current compatible with following circuitry. Fig. 5 illustrates input energy variations and their effects.

Selection of load impedance and light intensity determines the operating point of a phototransistor. Operation of a phototransistor between the logic 0 and logic 1 state is a normal technique for tape and card readers. As an example, the given Transistor of Fig. 5 with a load impedance of 2 kΩ would have its logic 0 level at H = 30 mW/cm² and its logic 1 level at H = 0 mW/cm².

With simple optical lenses phototransistor gain can easily be increased (Fig. 6). The lens, larger than the phototransistor, "collects" light and semifocuses it on the active area. (The light does not have to be in focus on the active area.) Also, device operation is better if the focus is below the plane of the wafer. This way there is no image of the light source on the top surface, where contacts or minor surface blemishes could drastically change the apparent light sensitivity.

The angular response of phototransistors is important. Data stored on paper tape or cards can be spaced relatively close. Because of this, the devices for detecting the data must be selective in their response to light from large off-axis angles. A polar plot of angular response (Fig. 7) illustrates this design constraint. The distinct advantage of lensed detectors becomes evident on the plot. By using a lens, the effective collector-base capacitance of a lensed device could be lower than that of a phototransistor having equivalent light current without a lens.

Silicon is most often chosen for phototransistors. The

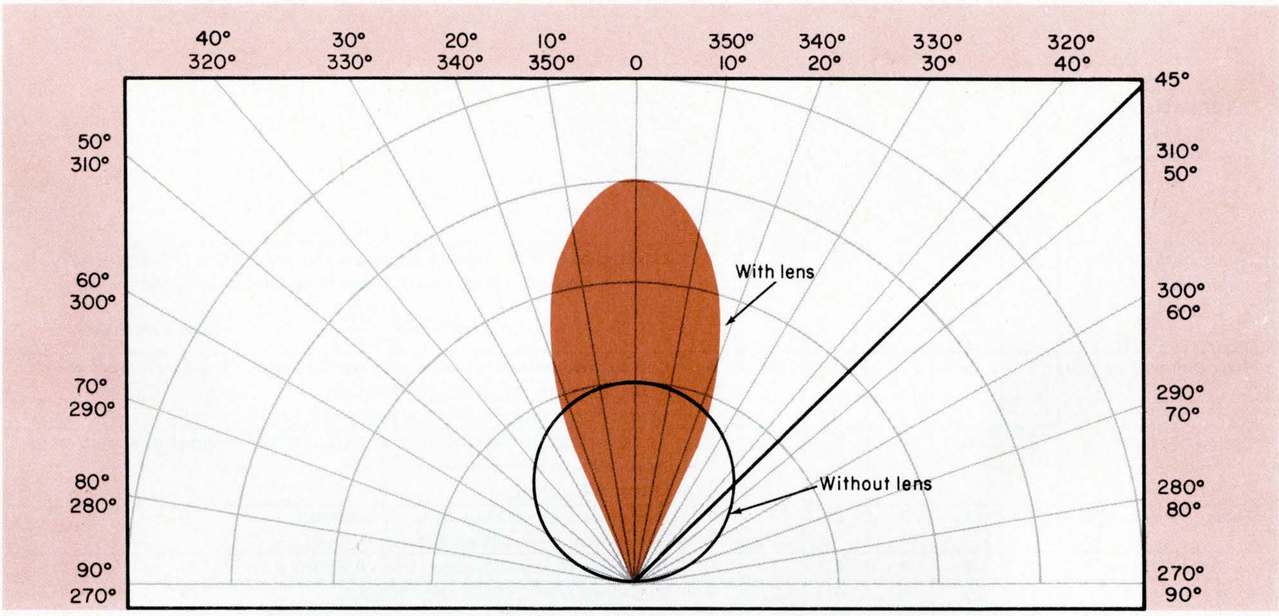


Fig. 7: Along with increased gain as shown in Fig. 6, phototransistors with a lens have a narrower angle of response. As an example, note the difference at 45°.

selection is based on the convenient spectral response as well as the large amount of knowledge gained through experience with transistors and ICs.

Sensitivities in the range of 1 mA collector current for irradiance values of 1 mW/cm² can be obtained. The two-terminal nature of these devices and a selection of sensitivity ranges for matched arrays has greatly simplified their use in computer terminal equipment.

Field-effect transistors

The success of phototransistors led to other amplifying structures for photoresponse. Field-effect-transistors (FETS) are notably light sensitive. The gate junction acts as a photodiode as described earlier. The drain-to-gate junction is normally reversed biased through a gate resistor, R_G (Fig. 8).

By a combination of bias and R_G adjustment, selection of a wide range of FET operation can be obtained. The resulting change in voltage drop from a drain-source becomes

$$V_{DS}\lambda = (I_G\lambda)(R_L)(gm)$$

where I_G is the gate photocurrent. Selection of the proper value for each R_G is required for matched sensitivity in arrays of photo FETS.

Operation with gains of 800 µA/ft-candle have been obtained with 1 kΩ values for R_G.

The mechanical geometry of an FET is not optimum for light sensitivity. Most of the gate junction region is covered by metal source and drain contacts, so care must be taken not to focus a small light source on the surface where it could be blocked by a contact. And again the favorite material is silicon for spectral response and ease of processing through standard operation.

Other devices

Photo pnpn devices are used in a number of industrial control applications. The structures are similar to standard pnpn design with one collector junction expanded so that light triggering may be used. The isolation of the gate function by light is significant in that long strings of these devices may be placed in a series for very high voltage switching applications.

Device sensitivity and trigger characteristics tend to be in the general operating range of phototransistors—1 to 20 mW/cm² equivalent tungsten irradiance. Their temperature sensitivity often makes precise trigger timing a real problem.

Darlington structures have been used for years to achieve high gain. Photo-Darlingtons use phototransistors followed by another transistor to achieve high effective light currents for low input irradiance. The increase in switching time and effective dark current, and saturation voltage are the usual compromise for these structures.

The widespread use of monolithic ICs leads to the obvious question: Why not monolithic photodevices? In general these can be used and are most effective when the light sensitive elements must be placed on very close centers, or very precise sensor placement is a system requirement. The tendency is for monolithic sensors to be custom designed for maximum system use, with little consideration for standard spacing or standard element size. Monolithic arrays, which combine scan-

OPTOELECTRONICS Part 2 B

Comparison of detectors

	Photo emissive	Photo conductive (bulk effect)	Phototransistor	Photovoltaic (junction)	Photo conductive Schottky barrier (junction)	Photo conductive diffused (junction)	
Sensitivity at low light level	1	3	5	3	2	2	Derived as N.E.P. (Noise Equivalent Power) and/or D* characteristics the minimum amount of power that can be detected by the detector. Units: $D^* = \frac{\text{Cm}\sqrt{\text{Hz}},}{\text{watt}}$ NEP = watts
Responsivity	1	3	2	5	4	4	Output per unit input at various wave lengths of the detector, which relates directly to quantum efficiency. Units: R = amps/watt, or $\mu a/\mu w$ or Q.E. in %
Speed	2	6	4	5	1	3	Time for detector to respond to a step function input of radiation from 10% to 90% points. Units: ns, μs, ms.
Near I.R. response	2	4	3	3	2	1	Response from 8000Å thru 1.06 micron. R = $\mu a/\mu w$ or Quantum Efficiency in %.
Visual response	2	1	4	4	1	3	Response thru visual range from 450 nm thru 650 nm.
U.V. response	1	5	4	4	2	4	Response from 2000Å thru 4000 Å.
Overload recovery	3	5	2	2	1	1	Ability to respond to normal inputs after overloads.
Lifetime stability	6	4	4	3	2	1	Stability of responsivity over a period of months or years after initial calibration.
Power consumption	5	3	4	1	2	2	Amount of supply power required for operation.
Multi-element flexibility	5	4	3	2	1	1	Ability to make close spaced arrays with high degree of crosstalk isolation and interelement uniformity.
Ruggedness	4	2	2	1	1	1	Ability to withstand thermal and mechanical shock and vibration.
Linearity	3	4	4	2	1	1	Linearity of output per unit input usually measured in number of decades to remain within 1% non-linearity.

Rating of 1 denotes best detector type for that characteristic.
Two types of devices with the same rating denote equal performance in that characteristic.

Courtesy of United Detector Technology.

Radiation and Illumination sources

The effect of a radiation source on a photo-device is dependent on the device spectral response and the spectral distribution of energy from the source. To discuss such energy, two related sets of terminology are available. The first, radiometric, is a physical system, and the second, photometric, is a physiological system.

The photometric system defines energy relative to its visual effect. As an example, light from a standard 60-W bulb is certainly visible, and as such, has finite photometric quantity, whereas radiant energy from a 60-W resistor is not visible and has zero photometric quantity. Both items have finite radiometric quantity.

The defining factor for the photometric system is the spectral response curve of a standard observer, whereas the defining spectral response of the radiometric system can be imagined as unit response for all wavelengths.—Courtesy of General Electric Co.

Radiometric and photometric terminology

Description	Radiometric	Photometric
Total flux	Radiant Flux, P, in watts	Luminous flux, F, in lumens
Emitted flux density at a source surface	Radiant emittance, W, in watts/cm^2	Luminous emittance, L, in lumens/ft^2 (foot-lamberts), or lumens/cm^2 (Lamberts)
Source intensity (point source)	Radiant intensity, I_r, in watts/steradian	Luminous Intensity, I_L, in lumens/steradian (candela)
Source intensity (area source)	Radiance, Br, in (watts/steradian)/cm^2	Luminance, B_L, in (Lumens/Steradian)/ft^2 (footlambert)
Flux density incident on a receiver source	Irradiance, H, in watts/cm^2	Illuminance, E, in Lumens/ft^2 (footcandle)
Point source relationships		
Point source intensity	I_r, watts/steradian	I_L, lumens/steradian
Incident flux density	H(irradiance) = $\frac{I_r}{r^2}$, watts/distance^2	E(illuminance) = $\frac{I_L}{r^2}$. lumens/distance^2
Total flux output of point source	$P = 4\pi I_r$ watts	$F = 4\pi I_L$ lumens
Design relationships for an area source		
Source intensity	B_r, watts/cm^2/steradian	B_L, lumens/cm^2/steradian
Emitted flux density	$W = \pi B_r$, watts/cm^2	$L = \pi B_L$, lumens/cm^2
Incident flux	$H = \frac{B_r A_s}{r^2 + \left(\frac{d}{2}\right)^2}$, watts/cm^2	$E = \frac{B_L A_S}{r^2 + \left(\frac{d}{2}\right)^2}$, lumens/cm^2

Steradian: The solid equivalent of a radian.

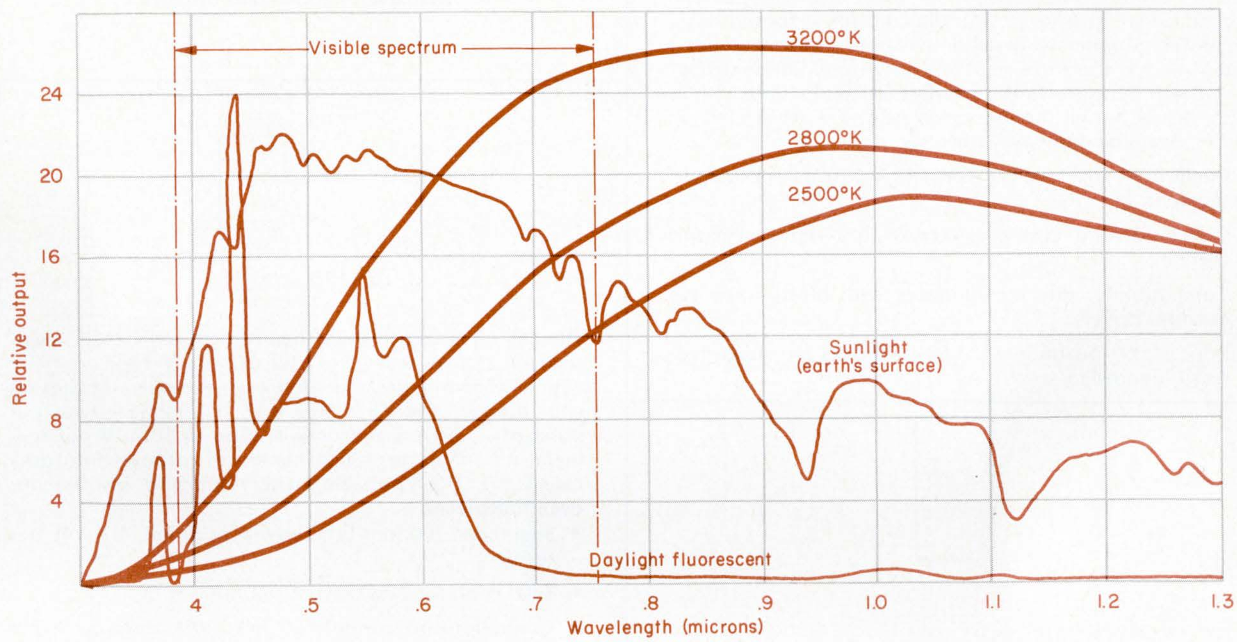


Fig. A: Two common light sources are plotted along with °K curves. (Courtesy of Centralab).

ning generators and photodetectors on the same chip, will probably have use for optical character recognition (OCR).

Monolithic diode array targets have been used for electron beam scanned image tubes. The arrays of over one million diodes achieve high resolution, low lag, and high sensitivity. Targets of both silicon and germanium are made for special system requirements. The electron beam scan provides noiseless switching between diodes in the array, avoiding many problems encountered in all monolithic arrays.

References:

Photoelectronic Materials and Devices, Simon Larach, Editor, D. Van Nostrand Co., Inc., N. J., 1965.

An Introduction to Semiconductors, W. Crawford Dunlap, Jr., John Wiley & Sons, Inc., N. Y., 1957.

Photoconductivity of Solids, Richard H. Bube, John Wiley & Sons, Inc., N. Y., 1960.

Solid State Physical Electronics, Albert VanDerZiel, Prentice-Hall Inc., N. J., 1957.

Considerations of the Solar Cell, D. H. Kleinman, *Bell System Technical Journal* 40, Pages 85-115, 1961.

INFORMATION RETRIEVAL
Optoelectronic devices, Semiconductors

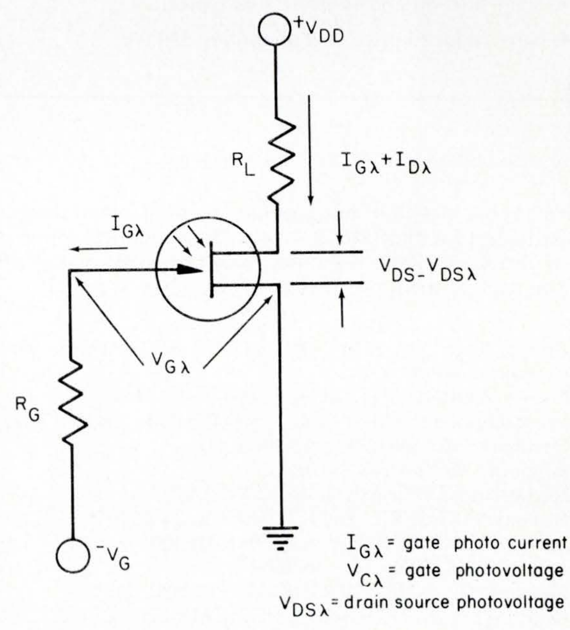


Fig. 8: Bias circuit of a photo-FET.

GaAsLITE Update

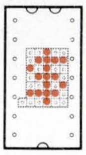
Being a quick and thorough survey of what's available in solid state displays.

The MAN 1:

A seven-segment light-emitting all-semiconductor alphanumeric readout.

Put the attention-demanding red light from electrically excited GaAsP to work in your digital displays for industry, computer peripherals, or avionic/marine instrumentation. Our MAN 1 is shock-resistant and long-lived. Offers styling advantages because it's flat, parallax-free and visible within 150°. Reads out all numbers plus A, C, E, F, H, J, L, O, P and U. Available now. Any quantity.

- Brightness: 350 foot-Lamberts @ I_F=20 mA, 3.4V, per segment.
- Pulsed forward current=100mA, 10% duty cycle/per segment.
- Compatibility: directly interfaces with off-the-shelf IC decoder/drivers.
- Price: 1,000 quantities, $11.00 (all prices are suggested resale figures).



The MAN 2:

An alphanumeric display made up of 36 discrete LEDs which can form 64 ASCII characters and a decimal point.

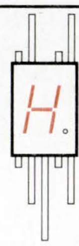
The IC-compatible 5 x 7 X-Y array gives you a bright red (peak emission 6500Å), high contrast display suitable for keyboard verifiers, avionics or computer terminals or other displays. Since the 36 dots can make 2^{36} bits available, the MAN 2 can be very useful in film annotation work.

- Per-diode brightness: 300 foot-Lamberts @ I_F=10 mA, 1.7 volt per diode.
- Pulsed forward current (50 μsec 20% duty cycle) 100 mA
- Light turn-on and turn-off 5 ns typical
- New reduced price: 1–9 quantities, $40.00.

GaAsLITEs are in stock world wide.

You know that all of our products are available in the U.S. through Schweber (516) 334-7474; Semiconductor Specialists (312) 279-1000; K-Tronics (213) 685-5888; or Kierulff. You can get them overseas as easily:

United Kingdom: SEMICONDUCTOR SPECIALISTS, West Drayton 6415
France: YOUNG ELECTRONIC, 604-10-50
West Germany: Alfred Neye, ENATECHNIK, (04106) 4022
Denmark: SCANSUPPLY, AEGIR 5090
Belgium: TECHMATION, 384078
Netherlands: TECHMATION, 020-173727
Norway: ARTHUR F. ULRICHSEN A/S, 21 6510
Switzerland: OMNI RAY A.G., 051-478200
Italy: SILVERSTAR LTD., 46.96.551
Sweden: GP-INGENJOERSFIRMAN, 08/930280
Japan: NEW METALS AND CHEMICALS LTD. CORP., (201) 6585-7
Australia: HAWKER DE HAVILLAND AUSTRALIA PTY., LTD., 93-0221
Israel: MONSEL

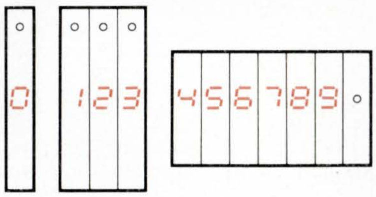


The MAN 3:

The world's first commercially available planar monolithic displav. Low cost, besides!

The MAN 3 is a small (.125" high) bright red GaAsP seven-segment display that gives you extremely good visibility with high density packing; 16 digits need only 3 inches on your display. And since the MAN 3 interfaces with our standard IC drivers and uses as little as 10 mW per segment, it's simple to design numerical readouts into desk calculators, truly portable battery-operated instruments, **even timepieces.**

- Brightness: 200 foot-Lamberts @ I_F=5 mA, 1.7 volt, per segment.
- Total cont. forward current: 80 mA.
- Pulsed forward current=50 mA, 10% duty cycle per segment.
- Price: 1,000 quantities, $7.55.



MPC 1 MPC 2 MPC 3

We've mounted the MAN 3 for you

Our MPC-series are simply the new MAN 3 numerics carefully soldered to NEMA-grade G-10 copper-clad glass/epoxy laminate pc boards.

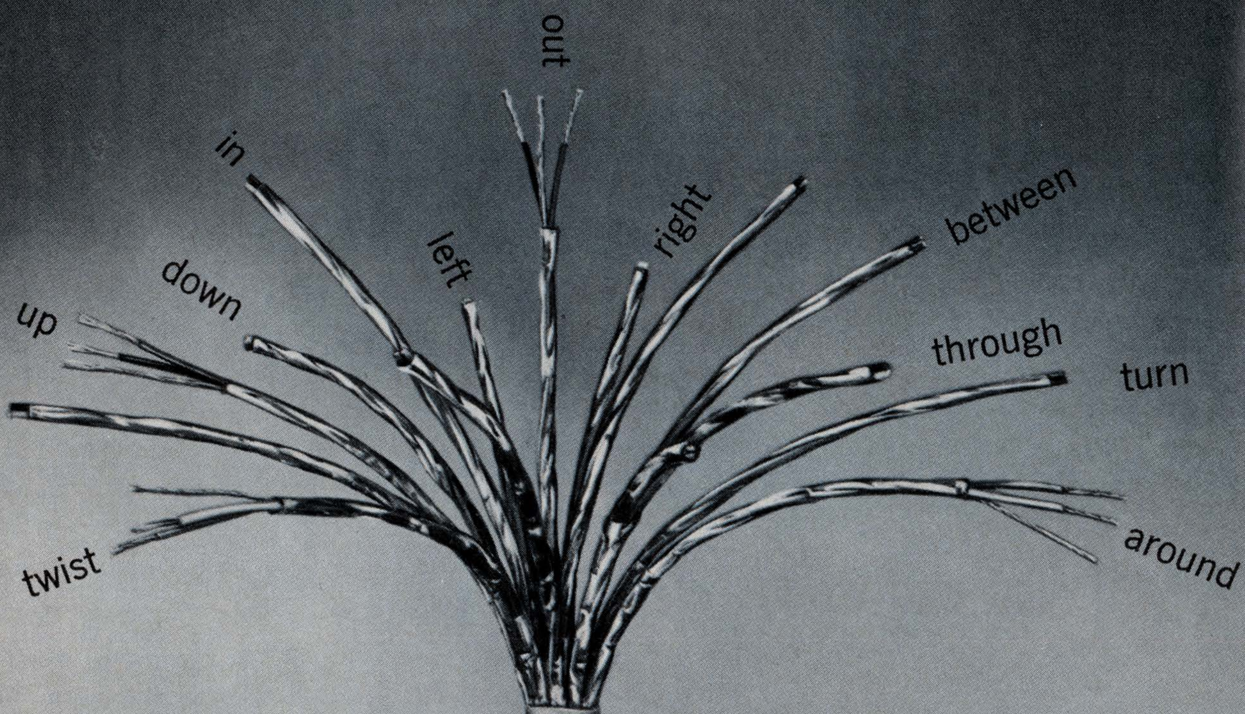
The MPC 1 and MPC 2 boards let you address each segment of the numeric independently. The MPC 3 holds six MAN 3's which are multiplexable (X-Y addressable). There are two major benefits in doing your prototype work with our MPC units:
1) they're a heck of a lot easier to breadboard and 2) you can use them for fast turnaround into full production. Send for complete details. Fast! Price, MPC 2: 1 to 9, $35.80 ea.

Monsanto

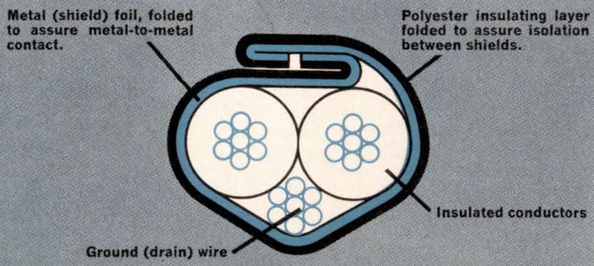
For additional technical information write Monsanto Electronic Special Products, 10131 Bubb Road, Cupertino, California 95014. (408) 257-2140.

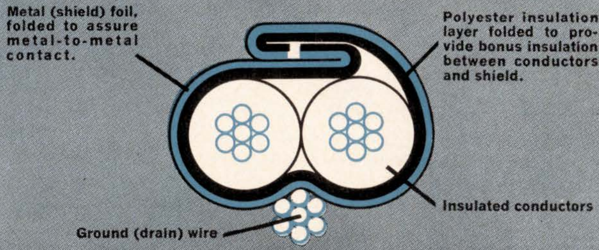
Circle 31 on Inquiry Card

Feel Free To Flex



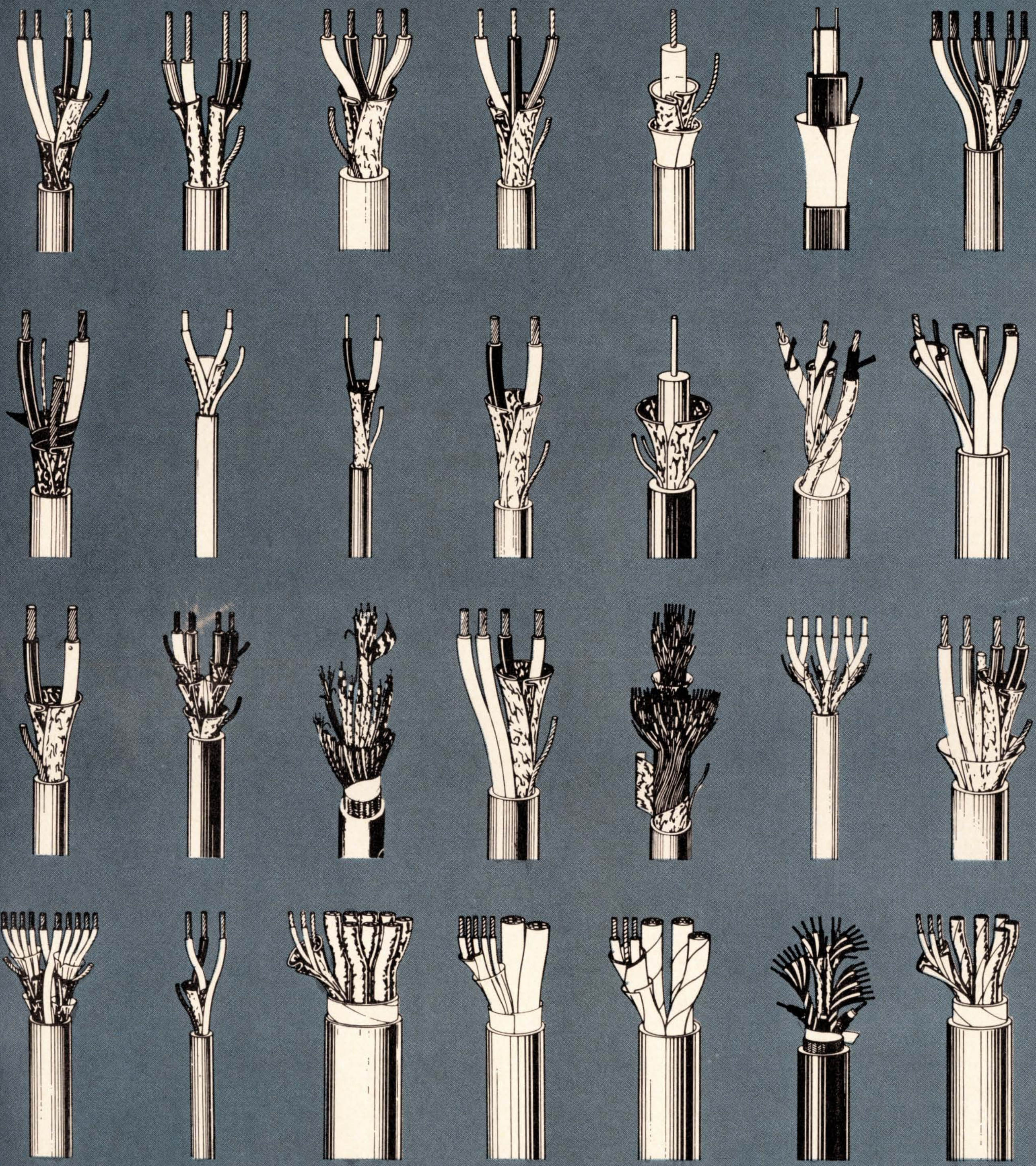
Yes, we know . . . we used to recommend Beldfoil Shielded Cable only for fixed applications. We were too modest. Extended testing proves Beldfoil, even after repeated flexing, provides more physical shield coverage than braided wire or spiral wrapped (served) shields. And greater shield effectiveness. □ Beldfoil is a layer of aluminum foil bonded to a tough polyester film (for insulation and added strength). A Belden invention. We apply it in different ways for different applications. We can even form a unique shield that's like a continuous aluminum tube. This we call ISO-Shield™. □ When new (or in fixed applications) Beldfoil ISO-Shield is extremely effective in limiting crosstalk or interference . . . whether from outside sources or between shielded elements in the same cable. □ Under frequent flexing minor separations may occur in the foil. But special Beldfoil construction features prevent performance from becoming seriously affected. We do, however, recommend that you tell us if cable flexing is to be extreme. We have *special* designs available to meet severe flexing requirements. □ Beldfoil makes possible a small, lightweight cable that terminates easily and is modest in price. Your Belden distributor stocks or can quickly obtain just about any size or type you need . . . from single conductor audio and sound cable up to data cable having 27 individually shielded pairs (more pairs available on special order). Ask him for the latest "Belden Electronic Wire and Cable Catalog." Or for technical information, contact Belden Corporation, P. O. Box 5070-A, Chicago, Illinois 60680; phone (312) 378-1000.





Beldfoil® Shielded Cable

–shield effectiveness remains outstanding



BELDEN

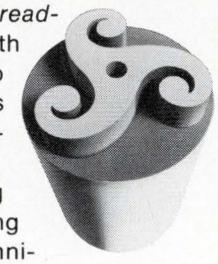
8-5-9A

new ideas for moving electrical energy

Circle 33 on Inquiry Card

The Omniscient Triskelameter talks to computers... 1,000 times a second!

The New HP 3480 DVM — it's so fast you'll want to put racing stripes on it! The HP 3480 DVM is ideally suited for use in your computerized data acquisition or automatic test systems. It gives you 1000 *dc readings* per second with ranges of 100 mV to 1000 V. It also gives you 1000 *ohms readings* per second.



Record-breaking speed isn't everything you get with the Omniscient Triskelameter. You get high accuracy, too — ±(0.01% of reading + 0.01% of range) basic dc accuracy. You get true rms from 1 Hz to 1 MHz (basic speed one reading per second). And, the HP 3480 is the *only* DVM that can measure ac *plus* dc.

All functions are fully programmable so the Omniscient Triskelameter can be easily adapted to your data acquisition system. It can be used with one-way or two-way couplers. If you have an HP 2114, HP 2115 or HP 2116 computer, the HP 11146A interface kit makes it easy to tie-in the 3480 DVM.

With a choice of three plug-ins and a variety of options (including isolated BCD and isolated remote), the HP 3480 DVM can be tailored specifically to fit your system. Find out today how well the Omniscient Triskelameter and your data acquisition system will work together. Contact your local HP field engineer, or write to Hewlett-Packard, Palo Alto, California 94304. In Europe: 1217 Meyrin-Geneva, Switzerland.

Prices range from $1150 for one range of dc to $3375 for multifunction ac, dc, ohms capabilities with isolated BCD and isolated remote control.

090/11

HEWLETT hp PACKARD

DIGITAL VOLTMETERS

IC IDEAS

Vote for the one you like best.

Write the number of the Idea you like best in the box on the Inquiry Card, and send to us.

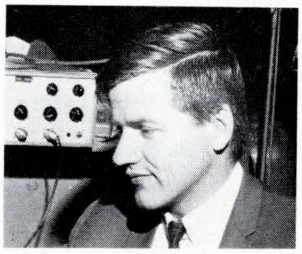
Send us practical, reproducible ideas that are original with you and have been implemented with linear or digital ICs.

- If we publish your idea you win a check for $25.00.
- If our readers vote yours the best of the issue in which it appears, you have your choice of a Simpson 270 or a Triplett 600 multitester.
- After 12 issues our readers will vote on the best idea for all 12 issues. The winner gets his choice of either a Hewlett-Packard 1206A or a Tektronix 310A oscilloscope.

Submit your IC Ideas to:
Alberto Socolovsky
Editor
THE ELECTRONIC ENGINEER
Chestnut & 56th Sts.
Philadelphia, Pa. 19139

Here's how you voted

The winning Idea for the April 1970 issue is, "One-shot triggers on both edges of input."



Ken Erickson, our prize-winning author, is employed as an engineer at Interstate Electronics Corp. in Anaheim, Calif. Mr. Erickson has chosen the Triplett Model 600 TVO as his prize.

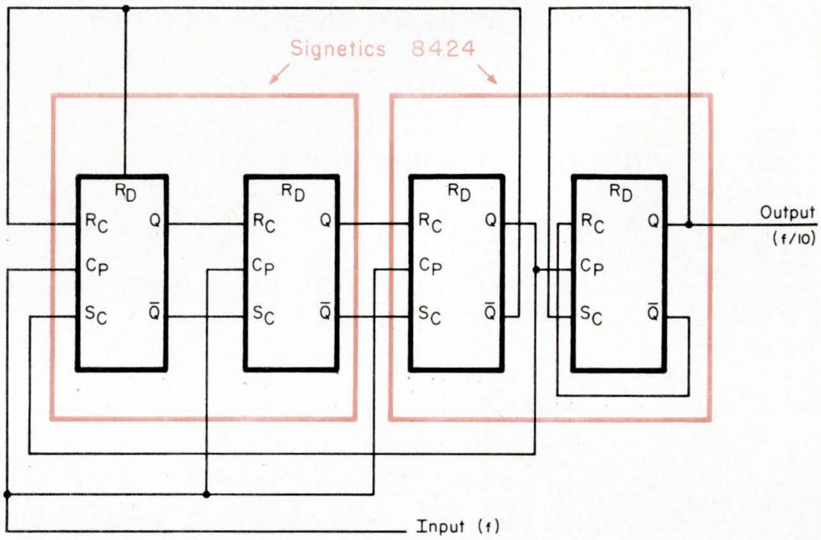
927 Minimum hardware decade counter

M. V. Pitke

Tata Institute of Fundamental Research, Bombay, India

Minimum hardware counters can be built using 4 JK flip-flops with no extra gates or other components. However, if you try to substitute the less expensive RS/T flip-flops, most schemes require extra gates in addition to the flip-flops. This circuit gives you a decade counter with just the flip-flops.

The first three stages look like a divide-by-six counter. However, the addition of the feedback connection to the R_D terminal of the first stage forces the circuit to skip the 111 stage in the counting sequence. The first three stages, therefore, become a divide-by-five circuit. Adding the last stage gives you the decade counter with no additional circuitry.



The feedback connection reduces the maximum operating speed somewhat, but not significantly. The circuit shown has a maximum operating frequency of 10.3 MHz without the feedback. With the feedback connection, it operated reliably up to 9.4 MHz.

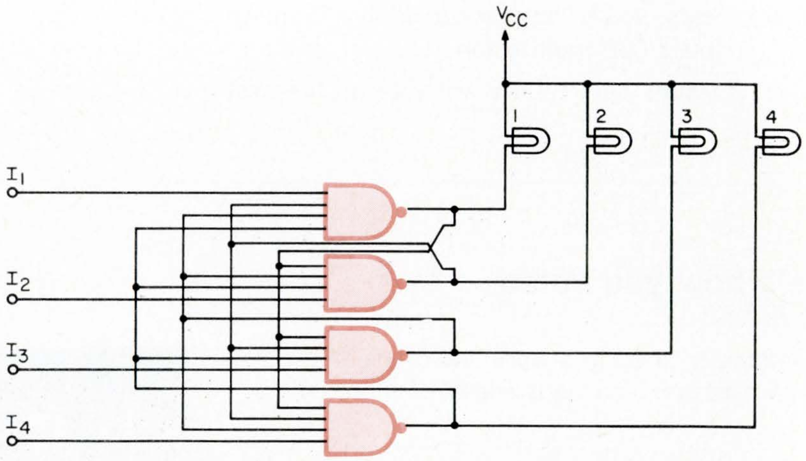
928 Simple priority detector

Bill Wiley Smith

Motorola Semiconductor, Phoenix, Ariz.

This effective priority detector is built as a multiple cross-coupled latch. In the circuit shown, four 4-input NAND gates establish priority among four inputs. You can, however, expand the circuit to any number of inputs. For expansion, the number of inputs per gate and the number of gates must equal the number of inputs.

In the normal or standby state all the inputs are low (0 state). All outputs are, therefore, high and the lamps are off. When one of the inputs goes high, the appropriate lamp comes on and the circuit is insensitive to any further change in input conditions.



The ability of the detector to separate closely spaced pulse signals is not dependent on the gate propagation time. Instead, it is a function of the matching of the propagation delay between all of the gates in the cross-coupled latch. With a random selection of MTTL gates, matching and resolution of the detector has been within 0.5 ns.

Because the resolution is not dependent on gate speed, you can choose the logic family for system compatibility rather than for special priority detector design requirements.

VOTE: for the one you like best.

929 Sine wave oscillator has logic level output

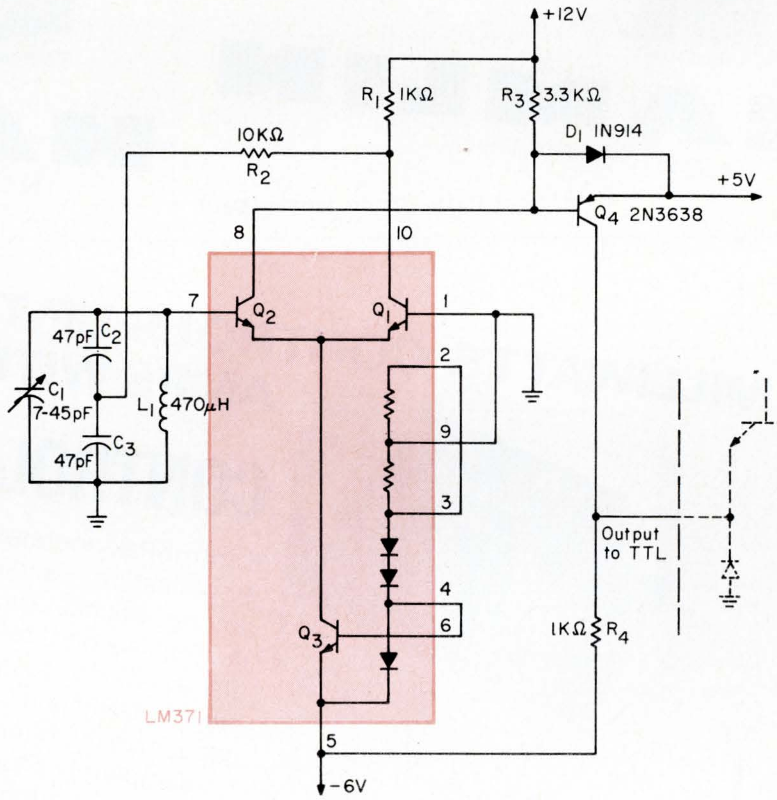
Walter G. Jung

Forest Hill, Maryland

You can use the current mode switching characteristics of an IC differential amplifier to build a sine wave oscillator with a digital output. This combination is attractive because it provides the good frequency stability of an LC oscillator for digital clock applications.

The sine wave oscillator consists of the LM371 diff-amp and the tank circuit L_1, C_1, C_2, C_3, R_1 and R_2. The discrete PNP transistor function as a common emitter level shifter.

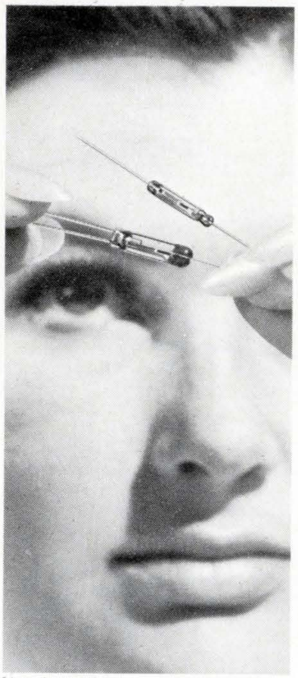
Transistors Q_1 and Q_2 of the LM371, in conjunction with the tank circuit, forms a Colpitts oscillator. Transistor Q_2 operates essentially as an emitter follower, driving Q_1 which operates in a common base configuration. A constant emitter current for the pair is taken from the collector of Q_3, a current source transistor. Since neither Q_1 or Q_2 provide signal inversion, feedback from the collector of Q_1 to the tank circuit is the correct phase to sustain oscillation. With both Q_1 and Q_2 biased from equal dc potentials through low resistances, they statically conduct equal currents because of the close matching of the monolithic pair. As a result, the sine wave oscillations at the base of Q_2 symmetrically switch the Q_1-Q_2 pair between alternate conduction of the current from Q_3. This means that the collector current of Q_1 or Q_2 is a square pulse current at the frequency of oscillation.



By using the output current from Q_2 to drive the Q_4 common emitter stage, the voltage can be clamped about the 5-V logic supply. The current mode drive and the clamping of D_1-Q_4 ensures that the collector of Q_2 does not see large voltage excursions, thereby minimizing interaction with the oscillator.

The output of Q_4 is a 5-V square wave with rise and fall times of less than 100 ns. Because of the high-speed devices inherent to the monolithic process, the non-saturating mode of operation and the short time constants associated with the circuit, you can extend clock rates well into the tens of MHz region.

REED SWITCH SPEEDS WITH NO CONTACT BOUNCE.



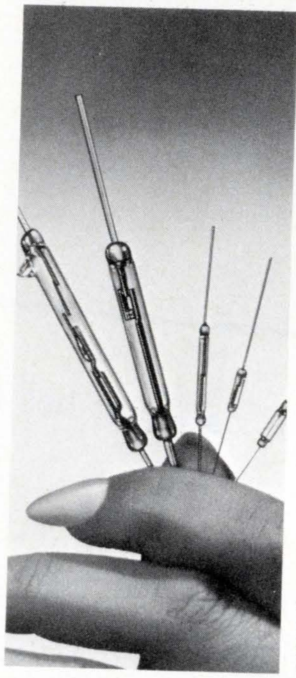
¾ actual size.

Hamlin's miniature, mercury-wetted switches offer all the advantages of high-speed, reed switches with the low contact resistance and high-power capacities of mercury switches. Precise, "on-off" actuation makes mercury-wetted switches ideal for applications where contact bounce cannot be tolerated. Available in form A (100 VDC) and form C (28 VDC). Useable length as low as .835." Write for catalog. Hamlin, Inc., Lake Mills, Wis. 53551. Or call 414/648-2361.

HAMLIN
INCORPORATED

Circle 35 on Inquiry Card

YOU PAY FOR HAMLIN RELIABILITY.



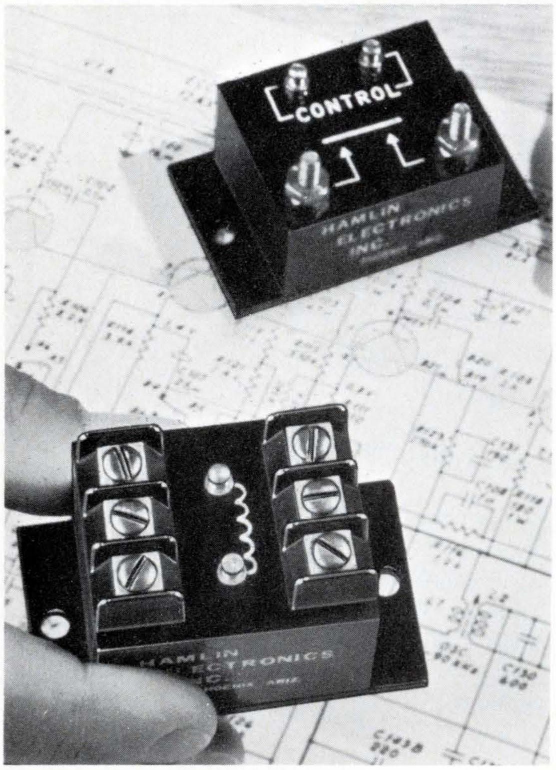
JUST ONCE.

Hamlin reed switches cost a few pennies more. But it pays off. A reed switch failure can cost hundreds of times the price of the switch. Hamlin reduces the chance of failure to almost zero with rhodium contacts, assembly in white rooms, the industry's most effective hermetic seal, 100% electrical inspection—features that will make you glad you specified Hamlin even after millions of closures. You can choose from 2,000 switches—3/10 to 660 watt—and get Hamlin reliability in every one. And you pay for it only once. Write Hamlin, Inc., Lake Mills, Wis. 53551. Or call 414/648-2361.

HAMLIN
INCORPORATED

Circle 36 on Inquiry Card

20 MILLIWATTS CONTROLS UP TO 25 AMPS WITH THE SOLID-STATE



CONTROL-PAK™

Control-Pak operates on I.C. logic without amplification. Handles as much as 25 amps with arcless, bounceless switching. And it's fast—operates in a millisecond, releases within ½ cycle. No noise—electrical or acoustical. Zero switchline for minimum RFI and EMI. Control-Pak controls inductive, capacitive, high-inrush and resistive loads. And it's completely encapsulated. Fumes, dirt and moisture that can ruin ordinary relays can't hurt Control-Pak. It's tough, too—resists shock and vibration—has no moving parts to wear or require replacement. So Control-Pak units keep right on functioning for millions of operations without maintenance. For more information, write Hamlin Electronics, Inc., 3066 West Clarendon, Phoenix, Arizona 85017. Or call, 602/277-4834.

HAMLIN
ELECTRONICS, INC.

Circle 37 on Inquiry Card

Feature article abstracts

**Published information is vital to your job.
To save time in finding this information,
we have abstracted the important technical features
from eight electronic engineering publications.
Should any of these articles interest you, contact the magazine—
names and addresses are listed below.
Reprints of articles with an asterisk are available free.
Save this section for future reference.**

Amplifiers

GHz amplifiers: now they are practical, Robert H. Cushman, N.Y. Regional Ed., "EDN," Vol. 15, No. 14, July 15, 1970, pp. 41-48. Gigahertz semiconductor prices are dropping, and fast and accurate test equipment for the low-GHz range is now available. According to Mr. Cushman, this means that more low-frequency designers will be using GHz design. To help them, Mr. Cushman's report is aimed at familiarizing such designers with some aspects of GHz design, particularly in the areas of construction techniques, Smith-chart use, and matching.

Charts and Nomographs

Time or frequency? John M. Davis Jr., Hughes Aircraft Co., "Electronic Design," Vol. 18, No. 14, July 5, 1970, pp. 56-57. Measurements in both the time-domain and frequency-domain cannot always be made on a particular signal. Conversion from one to the other is possible with graphs that plot modulation index versus the peak power/through power ratio in the time-domain, and modulation index versus the carrier-to-sideband ratio in the frequency-domain. Graphs are provided and examples worked.

Circuit Design

Modified CAD device models can cut down circuit analysis costs, J. R. Greenbaum, General Electric Co., "Electronics," Vol. 43, No. 15, July 20, 1970, pp. 90-93. Expensive computer time can be saved with the proper adjustment of an active device model's critical parameters. Often computers could handle high frequency analysis, but would go into a slow routine for low frequency, say less than 10 kHz. The key is to increase model capacitance to minimize computer time.

Acquisition of shaft-angle data, Jack Heaviside North Atlantic Industries Inc., "EEE," Vol. 18, No. 7, July 1970, pp. 58-66. After reviewing the basic types of transducers that convert angular position and velocity into an electrical signal—potentiometers, shaft encoders, and synchro/resolvers—the author compares their performance characteristics such as speed, resolution, accuracy, reliability (electrical and mechanical), conversion time, and transmission errors. In addition, the article discusses the digital systems required to digitize the transducers' output.

Low-level multiplexing for data-acquisition systems, David D. Yoder, Computer Products, "EEE," Vol. 18, No. 7, July 1970, pp. 67-72. The problem of low-level multiplexing involves the preservation of low-level signals from the measurement point or transducer to the multiplexer, and through the multiplexer itself. Therefore, the author discusses how to reduce noise by shielding and guarding, and compares two multiplexer designs: direct coupling and transformer coupling.

Components

***Optoelectronics course, Part 2B,** Lin Wetterau, Millis Miller, and Dr. Robert Haisty, Texas Instruments, "The Electronic Engineer," Vol. 29, No. 9, Sept. 1970, pp. 71-77. This section of the optoelectronics course covers light sensors/detectors. What are the various types, their advantages, and their disadvantages? This article is your opportunity to learn about these solid state devices and how their capabilities can help you.

Circuit breakers: physical and engineering problems (part I, Fundamentals), W. Rieder, Brown, Boveri & Co., Ltd., "IEEE Spectrum," Vol. 7, No. 7, July 1970, pp. 35-43. Despite their importance, many engineers are not acquainted with switchgear. The first part of a three-section course will deal with current interruptions, arc phenomenons, arc mediums, and testing.

Electronic time delays—relays or systems?, Sidney C. Silver, Associate Editor, "Electronic Products," Vol. 13, No. 2, July 1970, pp. 25-31. The time delay relay has come a long way and here's a look at just how far. This article discusses the operation of the new generation of time delays and also includes a graphic description of the timing options most readily available.

Magazine publishers and their addresses

Computer Design
Computer Design Publishing Corp.
Prof. Bldg., Baker Ave.
W. Concord, Mass. 01781

EDN
Cahners Publishing Company
270 St. Paul Street
Denver, Colo. 80206

EEE
Mactier Publishing Co.
820 Second Avenue
New York, N. Y. 10017

Electronic Design
Hayden Publishing Co.
850 Third Avenue
New York, N. Y. 10022

Electronic Products
United Technical Publications
645 Stewart Avenue
Garden City, N. Y. 11530

Electronics
McGraw-Hill, Inc.
330 W. 42nd Street
New York, N. Y. 10036

IEEE Spectrum
Institute of Electrical & Electronics Engineers
345 East 47th Street
New York, N. Y. 10017

The Electronic Engineer
Chilton Company
56th & Chestnut Streets
Philadelphia, Pa. 19139

*Reprints available free. Request them on your company letterhead.

ABSTRACTS

Computers and Peripherals

Semiconductor memories: make or buy?, Robert Norman, Nortec, "EEE," Vol. 18, No. 7, July 1970, pp. 42-44. Assuming that the **cost** of producing semiconductor memories will be lower (compared with the **price** of core memories) before the end of 1971, and their **price** will be lower sometime in 1974 or 1975, the author analyzes the advantages and risks involved in each option available to the memory buyer. These options are: buying unprocessed semiconductor material and diffusing the memory; buying diffused wafers or dice (packaged or unpackaged); buying modules; or buying the complete memory system.

Low-cost stereo recorders can adapt to digital data, David Newton and Walter Buczek, U. S. Army Electronics Command, "Electronics," Vol. 43, No. 14, July 6, 1970, pp. 90-93. This article describes how you can make use of a stereo tape recorder to record digital data. The 8-track recorder has circuitry added to it in the form of MOS ICs. While originally designed for military applications, the recorder can fill many instrumentation recorder needs.

The big memory battle: semis take on cores, Elizabeth de Atley, "Electronic Design," Vol. 18, No. 15, July 19, 1970, pp. 70-77. Many facets of the semiconductor vs core memory fight are presented along with several graphic predictions of the future costs of each. The areas to be compared are many: cores, bipolar, MOS, ROMs, RAMs, cost, speed, etc., so it is difficult to get an overall picture of the memory market, but this article does present many of the sides.

Program your minicomputer in FOCAL, Richard Merrill, Digital Equipment Corp., "Electronic Design," Vol. 18, No. 15, July 19, 1970, pp. 86-89. FOCAL (FOrmula CALculator) is an easy-to-use conversational language that conserves memory, and so is recommended for minicomputers. Many user-oriented features were conceived in RAND Corp's JOSS language. Several advantages of FOCAL are described.

Digital Design

Computer aids redundant logic search, Dr. Gordon R. Partridge, General Radio, "EDN," Vol. 15, No. 12, June 15, 1970, pp. 35-39. The time needed to reach an optimum logic-circuit design is proportional to the time needed to find redundant conditions in the network. Dr. Partridge first shows how to find redundant circuits manually. He then shows the use of a computer program which drastically reduces the time needed to find optimum NANDgate matrices. If two or more redundant gates show up in the printout, the choice as to which gate to eliminate is left to the designer. Although the program—written in FORTRAN—is not described in his article, Dr. Partridge notes that copies of it are available from General Radio in West Concord, Mass.

Programmable counter exhibits 100-MHz potential, Jon M. DeLaune, Motorola Semiconductor, "EDN," Vol. 15, No. 12, June 15, 1970, pp. 41-45. Mr. DeLaune describes the construction of a counter that accepts any input frequency up to 50 MHz, and divides it by a programmable number from 2 to 999. You can program the divisor with any type of decimal-to-BCD programming device. The circuit uses standard IC packages.

Synthesize logic with exclusive-OR ICs, Bruce A. Twickler, Mitre Corp., "Electronic Design," Vol. 18, No. 14, July 5, 1970, pp. 52-53. Use of exclusive-OR gates can often decrease the IC count enough to perform a given function. Karnaugh maps are difficult to use for synthesizing exclusive-OR logic, but decomposition maps, which are similar, can lead directly to their implementation. Several decomposition maps can be drawn for each function, and all are used. Examples are worked through to illustrate the principle in simple cases.

Reflection and crosstalk in logic circuit interconnections, John A. DeFalco, Honeywell, Inc., "IEEE Spectrum," Vol. 7, No. 7, July 1970, pp. 44-50. The speeds of modern TTL and ECL logic circuits have caused problems at the interconnections. The author offers several techniques for predicting such problem areas as types of reflections and crosstalk.

Integrated Circuits

***Testing integrated circuits,** Sheldon Edelman, Western Editor, "The Electronic Engineer," Vol. 29, No. 9, Sept. 1970, pp. 58-63. What to look for when you're choosing an IC tester is the main concern of this article. You'll learn the advantages and disadvantages of the various types of testers, why one tester is better than another for various applications, and how to decide what testing capabilities are essential to your needs.

***Semiconductor memories—what will they cost?** Thomas W. Hart Jr. and Donald D. Winstead, Semiconductor Electronic Memories Inc., "The Electronic Engineer," Vol. 29, No. 9, Sept. 1970, pp. 49-54. This article addresses itself to answering two questions: when will core and IC memories be cost competitive, and in what form should you buy the memory to get the optimum cost? Cost comparisons are made among bipolar, MOS static and MOS dynamic techniques.

ICs save power, boost efficiency of regulated power supplies, William L. Brown, San Diego State College, "Electronics," Vol. 43, No. 15, July 20, 1970, pp. 94-97. With IC operational amplifiers and low voltage regulators the best advantages of series and shunt regulators can be obtained. Because these ICs are now inexpensive, you can have the desired power supply performance.

Care and feeding of semiconductor "chips," E. W. Callander and L. Merrill Palmer, Centralab Semiconductor Div., "Electronic Products," Vol. 13, No. 2, July 1970, pp. 32-37. With a market of \$20 M in 1970 and a projected growth of 42%, semiconductor manufacturers are paying more attention to the hybrid business. The authors take you through some of the pitfalls of working with IC chips, both from a procurement and handling standpoint.

MOS memory travels in fast bipolar crowd, Edward J. Boleky, Joseph R. Burns, John E. Meyer, and Joseph H. Scott, RCA Corp., "Electronics," Vol. 43, No. 15, July 20, 1970, pp. 82-85. SOS, silicon-on-sapphire, is still getting lots of attention. Under development now is a 256-bit MOS random access memory with access time of 40 ns. This is approximately the speed of some bipolar devices. This article gives you information on the development of this device.

Miscellaneous

***The glory days are over at DoD,** John McNichol, Assistant Editor, "The Electronic Engineer," Vol. 29, No. 9, Sept. 1970, pp. 30-34. David Packard, Deputy Secretary of Defense, assesses the failing aerospace industry, DoD procurement policies, and the electronic engineer's current situation. He emphasizes the need to control costs and the desirability of reliable, tested equipment against more sophisticated untried equipment.

At the crossroads in air-traffic control part I: The view from the ground, Gordon D. Friedlander, Staff Writer, "IEEE Spectrum," Vol. 7, No. 6, June 1970, pp. 26-40. After considering the ominous situation for flight operations, the author discusses the FAA's plan to form an integrated and automated network for 48 contiguous states of the U.S. Summarized are the crowded airport situation, the common IFR (instrument flight rules) room, present and future automated systems, and the problems of air-traffic controllers.

At the crossroads in air-traffic control, Part II: the view from the ground, Gordon D. Friedlander, staff writer, "IEEE Spectrum," Vol. 7, No. 7, July 1970, pp. 69-83. This second installment considers instrument landing systems, automated ground control, en route automation, introduction to collision-avoidance systems, positive-control airspace, improved communications, STOLports, and terminal navigational aids. The FAA has been authorized to spend \$2.5 billion for such air traffic control equipment out of a potential \$5 billion package for airways and airport development. (See CHALLENGE on James Beggs, DoT, May, 1970 **The Electronic Engineer.**)

Packaging

For design flexibility, go hybrid!, Paul Schwartz, General Instrument Corp., "Electronic Design," Vol. 18, No. 15, July 19, 1970, pp. 80-83. Almost any breadboard can be made in hybrid form, defined here as a packaging technique combining monolithic and discrete components. Added circuit flexibility and functions are possible at a cost lower than the straight monolithic approach. Monolithic limitations and the areas of typical beneficial hybrid applications are outlined.

Test and Measurement

The 1970 test equipment selection guide, "Electronic Products," Vol. 13, No. 2, pp. 115-148. This is a roundup of the available features on the most popular test equipment. Included are DVMs, DMMs, oscilloscopes, function generators, IC testers, electronic counters, differential voltmeters, universal impedance bridges, and pulse generators.

Computer, software, p-c cards match up to cut costs in an automatic test system, Don Mactaggart, Canadian Marconi Co., "Electronics," Vol. 43, No. 14, July 6, 1970, pp. 71-75. Automated test systems are expensive. This article suggests ways to beat the cost by building your own, and cheaper than systems normally built by companies for their use. As an example, the author describes a system that his company has built.

Poor packaging produces problems

All of the nice specs that you paid for when buying digital ICs can be lost if your packaging is not properly designed.

By Joseph DiCerto
Sylvania Electric Co., New York, N.Y.

ICs give us very fast switching for computer applications. But, if we are not careful, we can blow the speed through our interconnection system because of several factors working against us.

Packaging problems

Interpackage electrical problems manifest themselves in three ways:

- Propagation delays
- Noise—cross-talk effect (inductive coupling)
- Pulse distortion

Propagation delay is a direct function of distance (the effect of the material used can be disregarded at fast switching rates for very short conductor lengths). Propagation delay, in general, can be considered approximately as one-half the speed of light in free space, or about 2 ns/ft of conductor. The greater the distance between ICs, the greater the propagation delay. Obviously, the solution is to place the IC packages as close as possible on the mounting board. But there are the limitations imposed by heat dissipation capabilities, space needed for routing of conductors, and best location of ICs for their functions.

System **noise** can originate externally or internally. External noise, which can come from numerous sources, will be imposed or induced in the system through the effects of electrostatic or magnetic fields. These fields can only be excluded from a sensitive piece of equipment by extensive and effective shielding. But this is only a small part of the overall noise problem. The strongest source of noise, which is internal to most equipments, comes from conductor coupling effects.

The shorter the rise time of a pulse, the greater will be the intensity of the force field surrounding the conductor, and the greater will be the induced voltage (cross talk) into neighboring conductors. One answer, of course, is to separate conductor lines as much as possible. Referring to Fig. 1 we see that doubling the

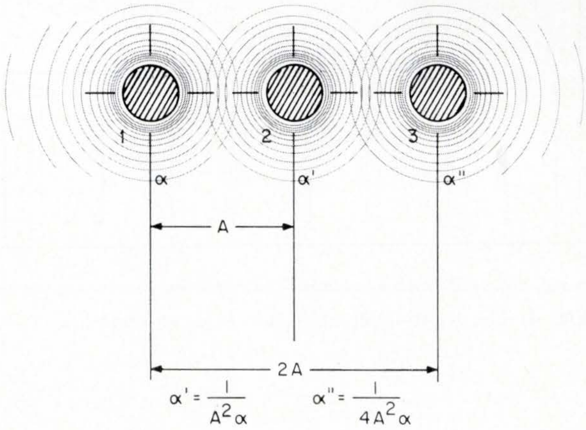


Fig. 1: The induced voltage due to inductive coupling (cross talk) is inversely proportional to the square of the distance between lines. This relationship emphasizes the importance of maximum distance between conductor lines in high-speed switching circuits.

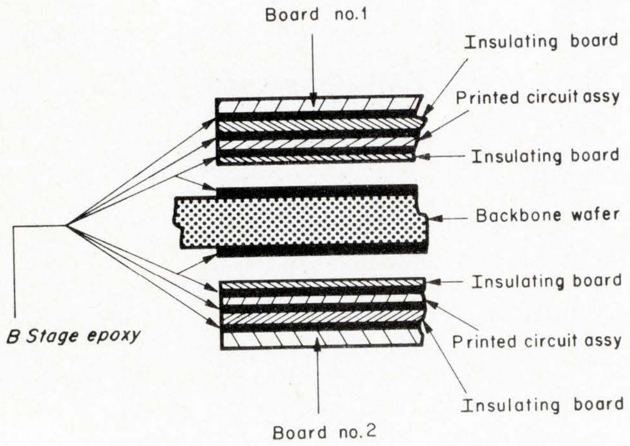


Fig. 2: Construction of double sided multi-layer board containing ground and power planes. The laminated four-conductor planes on each side of the backbone consists of a double-sided power-ground board with two signal layers connected as needed by plated-through holes, and a double-sided power-ground board. The power and ground layers are contacted by the flat-pack leads, which reach through rectangular clearance holes in the top layers. The capacitance between the power and ground layers, 1500 pF per package, provides decoupling. Although the boards are multilayered, no post-lamination plated-through interconnections are used. Each of the package types uses an identical board type on each side of the structure plate.

If needed, electrical connection between the circuit boards on one side of the backbone and the opposite board is accomplished by the connector, the eyelets at the top of the board (also used as test points), or by back panel wiring.

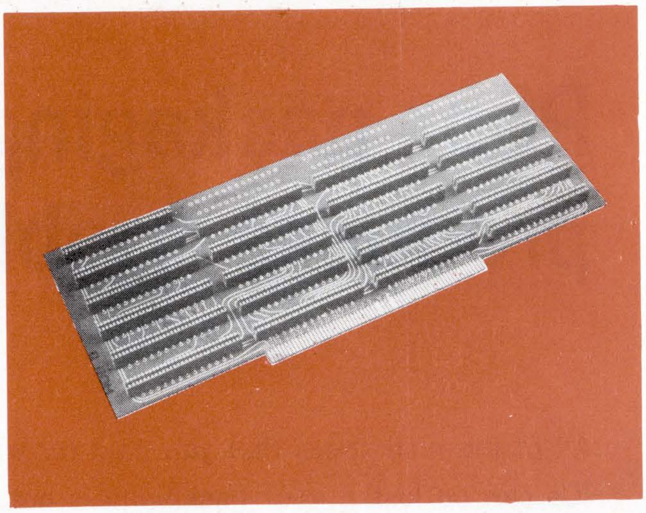


Fig. 3: Mother board can multiply benefits over entire system.

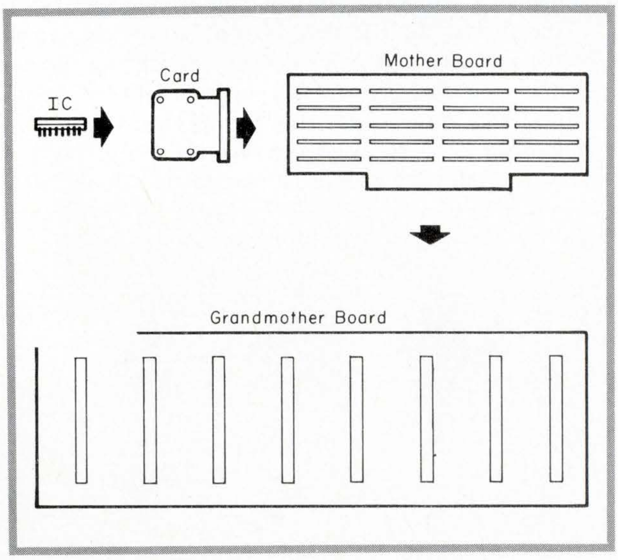


Fig. 4: The multi-layer approach is open-ended.

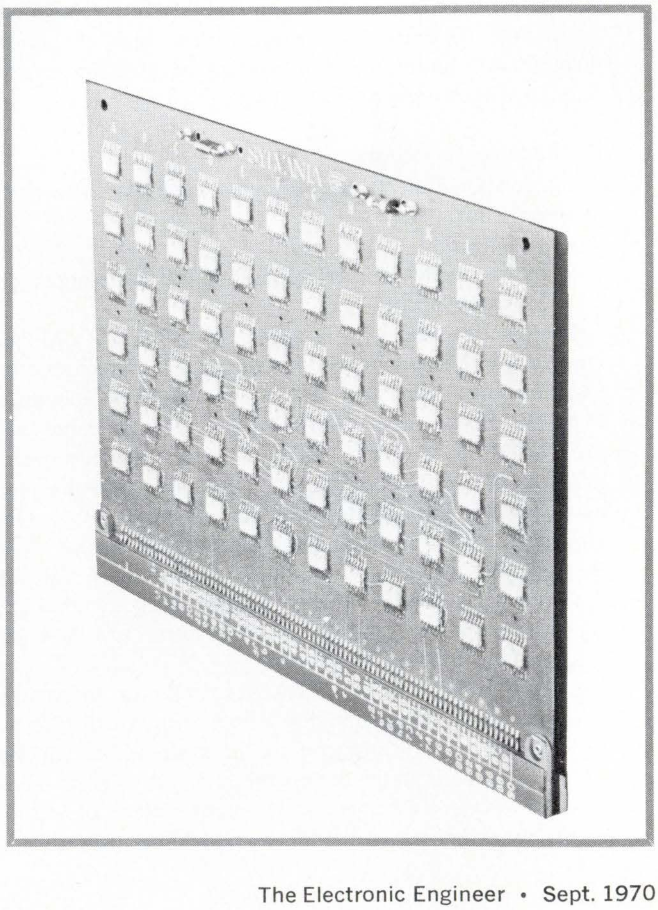


Fig. 5: Multi-layer with 144 IC packages mounted on it eliminates 280 conductor leads. It also provides all necessary decoupling capacitance. Half of the ICs are on the reverse side of board.

distance between conductors reduces the induced voltage to one-quarter of its previous value. This is a considerable reduction when considering the cumulative effects of noise in a large system.

High-speed digital systems have the problem of **pulse distortion.** In the case of high-speed circuits, large amounts of current are required suddenly by the circuits. Because of line inductance and resistance this current demand may not be met. The result of slow current response is the distortion of wave shapes and pulses, and the introduction of spurious signals—in general, the inhibiting of proper and efficient operation.

PC boards to the rescue

Because of the problems just mentioned, we are now faced with a real dilemma! If we separate the IC packages to reduce cross talk, we increase propagation delay. If we place the IC packages closer together to reduce propagation delay, we increase cross talk. Fortunately, there is a partial solution to this seemingly unsolvable problem—multi-layer PC boards.

As an example, let us consider a single printed circuit board upon which are mounted twelve dual in-line IC packages. This means that there could be as many as 168 conductors on the card. However, 24 of these conductors can be eliminated allowing 14% additional area for conductor spacing. The 24 conductors represent the ground and B+ power lead required for each IC. How do we get rid of these 24 conductors—easy. Mount the ICs on the multi-layer boards containing ground and power planes.

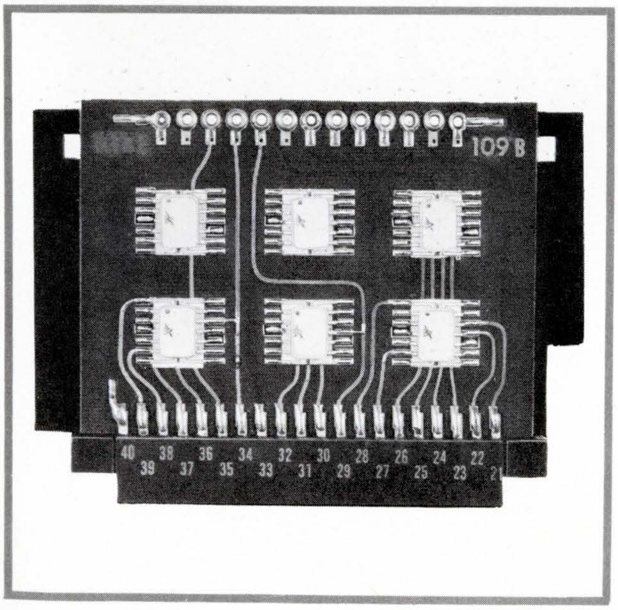
A multi-layer board provides significant advantages to high-speed digital circuits. First, it removes the need for routing separate ground and power leads to each IC package. With ground and power planes available, power and ground sources are no farther away than 1/16 in. With these leads removed, additional space can be allotted between the other conductors without having to move the IC packages farther apart. This results in reduced cross talk without increasing propagation delay. Perhaps even more important is that removal of the 24 leads eliminates 24 noise generating conductors —a big plus for the designer.

Good ground eliminates noise

Circuit grounding is of utmost importance when considering generation of noise in digital systems. Noise spikes on the ground line can easily exceed the system noise threshold. An effective ground loop is the way to beat this problem. Obviously the quality of grounding junctions becomes more critical as system operating frequencies increase.

If a full ground plane is not practical, the grounding path (strap or strip or bus) should be made as wide as possible. It may require varying the width of the ground path. Also, the ground path should be routed completely around the circuit board. Both ends of the PC ground path should be routed through separate pins to the system ground. As shown in Fig. 2, the two-sided board is constructed with full size ground and power planes, sandwiched between insulating layers. A double-sided signal board provides a more complex conductor pattern (cross talk between conductors on opposite sides of the signal board can be controlled by varying the thickness of the board material). Reach-through holes in the signal board provide access for the ICs to the opposite side of the signal board, and the power and ground planes.

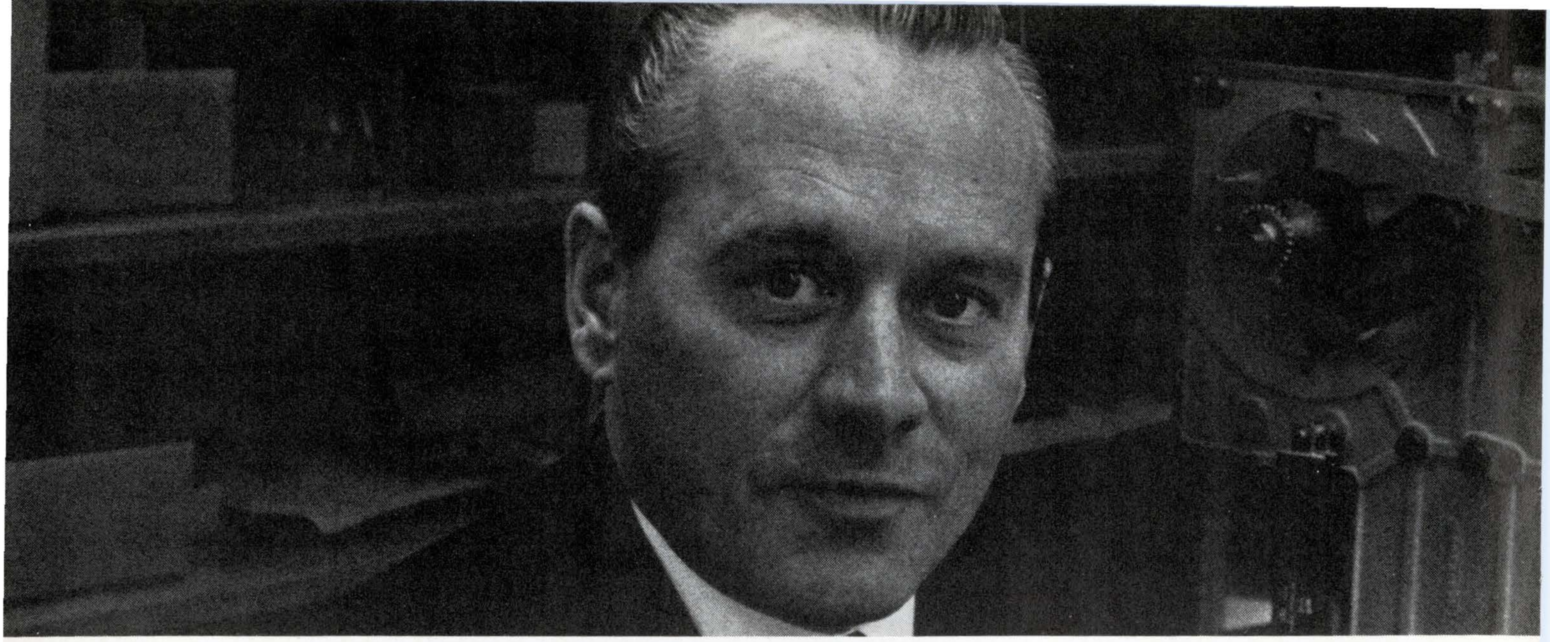
The problems of external noise, reflections, cross talk, propagation delay, and decoupling capacitance requirements, also exist in the system wiring between PC boards. Here again the multi-layer technique can come to the engineer's assistance. "Mother boards" as they are referred to (see Figs. 3 and 4) are constructed so that smaller boards can be plugged directly into them. The mother boards, constructed similarly to the smaller multi-layer boards, further help to reduce propagation delay and cross talk, besides the significant savings in weight they offer—as much as a 7 to 1 reduction. Figure 5 illustrates increasingly larger multi-layer boards used as an entire digital system with a minimum of wiring.



Multi-layer board containing ground and power planes eliminates 24 conductor leads, reducing cross talk. The inherent high circuit-noise threshold (1 V at 25°C and 450 mV at +125°C), combined with a card designed to provide switching noise protection, a well-designed power distribution system, and an excellent quiet system ground insures an equipment implementation with an extremely large noise margin over all temperature and loading ranges.

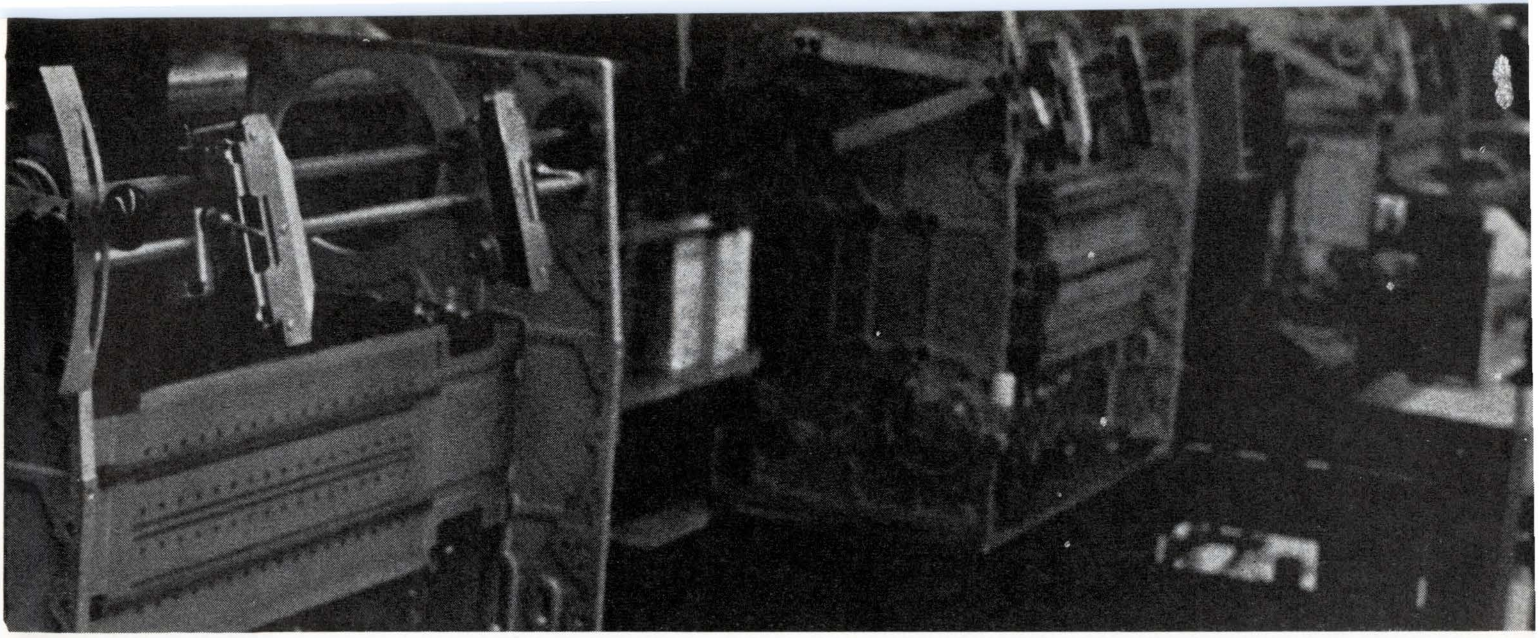
For more information on the printed circuit boards and PC systems, please Circle No. 282 on Inquiry Card.

INFORMATIONAL RETRIEVAL
Printed circuit boards



"No one made a small, quiet, medium-speed chain printer for $9500. So Mohawk did."

George C. Hohl, OEM Marketing Director, discusses a new product.



"We saw a gap in the printer field. Either you paid a lot of money to get a lot of speed and sophistication, or you could pay a little and get very little in return. We decided to aim our printer somewhere in between.

"Chain printers are mechanically simpler, easier to maintain, less expensive. Their flat face characters give good print characteristics, too.

"Our design requirements were rough. We wanted 300 lines- per-minute with such niceties as easily changeable fonts, and yet we wanted to sell it for less than $10K. It had to be small, and yet we couldn't lose accessibility. The design engineers grumbled, but they made it.

"The changeable font cartridge is great—an operator can quickly switch the font chain—and we're offering fonts from 16 to 128 characters.

"We designed a disposable ribbon cartridge to make ribbon changes quick and clean. Paper handling is enclosed to stay clean, too. And everything that could be modularized, was modularized.

"We considered noise reduction vital—anyone who has worked in a printer room knows why. Well, compared to other printers, you'd hardly know this one was working.

"We're selling the printer for $9500 in OEM quantities, and some variations cost even less. So you get a lot of performance in a very little printer—for very little money."

Mohawk Data Sciences Corp.
Herkimer, New York

MDS

OEM MARKETING CENTERS: CORPORATE (315) 867-6475; NORTHEAST (617) 891-5870; SOUTHEAST (404) 631-3443; CENTRAL (312) 298-4141; WEST COAST (213) 685-5165.

WATT'S NEW?
A 2000 WATT LINEAR POWER AMPLIFIER FOR 10¢ A WATT!

We came through, again!

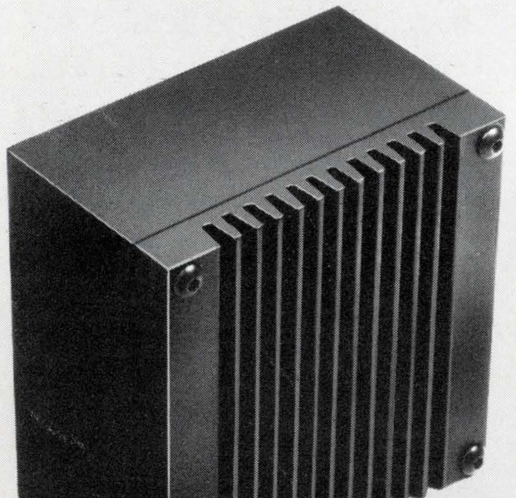
Our customers have long recognized Control Systems Research as their very best source for low cost, high performance, transistorized DC servo amplifiers. Frankly, they weren't overly surprised when we told them about this exciting new breakthrough. They've come to expect this sort of thing from CSR.

But we wanted *YOU* to know that CSR is introducing the PFM SERIES of DC servo amplifiers for high volume servo applications like tape drives, film drives, machine tool drives, and other servo motor applications. This new generation of amplifiers utilizes a unique combination of pulse width and frequency modulation techniques to achieve a linear bipolar output — at a cost of LESS THAN 10¢ PER WATT.

The new PFM SERIES of amplifiers is available in a variety of continuous voltage and current ratings from ±60 VDC and ±40 amps on down. We review your amplifier requirements with the aid of a computer and supply an amplifier with the exact voltage and current your require.

Our OEM customers also like the fact that the PFM SERIES operates from a unipolar, non-regulated power supply and not the old-fashioned bipolar supplies. (That's why we designed it that way.)

You might be wondering how we can get 2000 watts of continuous power out of a 3⅛ x 3⅛ x 1½ module at less than 10¢/watt — especially with internal power dissipation and the like. Call us today! We'd like to tell you all about it.



CSR

CONTROL SYSTEMS RESEARCH, INC.
1811 Main Street, Pittsburgh, Pa. 15215
412-781-1887

70SA1

Oscilloscope + plug-ins = test system

Three more plug-ins and two more mainframes have been added to Tektronix's one-year-old 7000-series oscilloscope line.

Two of the plug-ins—a digital multimeter and a digital counter—combined with the 7000's standard alphanumeric readout on the CRT give you a test system with more measuring capability than is normally associated with an oscilloscope. For instance, across the top of the CRT screen you can read the vertical deflection factor; ohms, dc voltage or current, temperature, or frequency; and horizontal scale factor.

Eight digits, 500 MHz

Model 7D14 plug-in is a gated frequency-counter operating directly to 500 MHz without prescaling. Thus, there is no resolution loss due to a prescaler's division ratio. Further, the gated approach lets you count single events; and such a capability is frequently desirable in rapid burst measurements.

The 7D14 has a gated operating mode. If you place the counter in one of the vertical-plug-in slots of the oscilloscope, and operate the scope in a delayed-sweep mode, the delayed sweep can drive the counter gate. This means that you can display a waveform on the CRT and simultaneously measure its frequency to 0.00005% accuracy.

Should circuit loading be a factor, you can locate the 7D14 in one of the mainframe's horizontal slots. Vertical-input signals will be internally routed to the counter. As a matter of fact, you can use all of the 7000-series vertical plug-ins as signal conditioners for the counter.

Model 7D14 has an 8-digit readout (on the CRT face) with leading-zero supression, 100-mV pk-pk sensitivity, and 50-Ω and 1-MΩ inputs. It sells for $1400.

V, I, Ω, and T: 3½ digits

A second plug-in of major interest is the Model 7D13 digital multimeter. It measures dc voltage to 1000 V with an accuracy of ±0.1%; dc current to 2 A, at ±0.5%; and resistance to 2 MΩ, also at ±0.5%. And because the 7D13's input circuit can be floated to 1000 V above chassis potential, you can also measure circuit parameters that have a high common-mode voltage.

Besides the normal multimeter functions, the 7D13 measures temperature from −55 to 150°C. A temperature/voltage probe uses a transistor as the temperature sensing element ($\Delta V_{BE} \approx f[T]$). The plug-in also supplies a 10-mV/°C output signal suitable for driving an analog chart recorder.

Model 7D13 has a 3½-digit readout on the CRT, which automatically shows the correct symbols for voltage, current, resistance, and temperature. You can buy this plug-in for $560, or $495 without the probe.

The third new plug-in is the Model 7A15. This one has calibrated deflection factors from 5 mV/div. to 5 V/div. Bandwidth is 75 MHz in the 7704 and R7704 mainframes, and 60 MHz in the 7503, 7504, and 7514 mainframes. It sells for $250.

Mainframes

Also new to the 7000-series is the Model 7514, a four-plug-in, split-screen storage oscilloscope. This scope features Tektronix's new WRITE THRU mode of operation. This mode allows both stored and conventional displays in the same area of the CRT, and lets you precisely compare waveforms.

Until now, storage scopes used in the conventional (non-store) mode usually were lacking in brightness and writing speed. But the 7514 uses an 18-kV accelerating potential on the CRT, which gives you a 450-cm/µs writing speed. Tektronix claims this to be faster than any other known storage scope.

The 7514, which sells for $3200, also features automatic focusing. You do not have to refocus as the display changes in intensity.

A second mainframe addition is the R7704, a 150-MHz, rack-mounted, four-plug-in oscilloscope. This model costs $2600 and, like the 7514, features the AUTO SCALE-FACTOR READOUT CRT display, and uses all 17 7000-series plug-ins. Advertising Dept., Tektronix, Inc., Box 500, Beaverton, Ore. 97005. (503) 644-0161.

Circle 342 on Inquiry Card

Electrically programmable C-MOS ROM

Here's a device that is unique in that it is a complementary MOS read-only memory that you can program yourself. Up to now, the manufacturer programmed the desired pattern in a MOS ROM by means of a custom masking step. The SCL5510 however, contains all 1's when you get it and by opening a fusable link you yourself program the O's in the desired locations.

The fusable link technique has previously been limited to bipolar ROMS (see **The Electronic Engineer,** Aug. 1970, p. 75) because the high impedance levels in MOS circuits prevented passing enough current to cause the link to open. With the SCL5510, the links open with as little as 16 mA and the manufacturer, Solid State Scientific Inc., says the MOS devices on the chip will pass the current.

A 45 V potential across the memory array converts the link from a conductor to an insulator through a combination of oxidation and electromigration processes. The effects of opening the link are confined within 0.3 mil of the open and no material is either ejected or evaporated during the process. Solid State considers the actual link material as proprietary.

The ROM itself is organized as 16 words by 1 bit and uses an X-Y select addressing scheme. It can be made TTL/DTL compatible and you get the option of voltage or current sensing for readout. Typical characteristics include a 400-ns cycle time and a static power dissipation of 50 nW at 10 V. By using current sensing schemes, you can reduce the cycle time to less than 100 ns.

The SCL5510 is available in a 16-lead, ceramic, dual-in-line and in quantities of 100 it sells for $25. Solid State Scientific Inc., Montgomeryville, Pa. 18936. (215) 855-8400.

Circle 343 on Inquiry Card

Phase-locked loops go digital

Motorola Semiconductor is marketing two new TTL circuits that expand the world of digital circuits into the area of phase-locked loops (PLL). Fig. 1 shows the basic loop using the new circuits along with Motorola's entry into the Modulo-n divider derby.

A PPL uses feedback techniques to generate an output frequency that is an integral multiple and in phase with a reference frequency. The Frequency-Phase Detector and Voltage Controlled Multivibrator (VCM) could have been put into one package, but Motorola expects to introduce other compatible VCMs, which may have to be shielded at high frequencies.

The MC4044 Digital Frequency-Phase Detector accepts TTL pulse trains on its two inputs, one from a reference oscillator and one from the feedback loop. The circuit achieves zero phase error by locking negative edges of the input pulses, and it is insensitive to duty cycle. A digital phase detector and an analog charge pump circuit convert the inputs into a dc voltage level for use in frequency discrimination and PLL applications. A phase difference between the input waveforms alters the dc voltage to the VCM, which changes its operating frequency until an in-phase condition results.

The MC4024 VCM generates a digital output waveform whose frequency range is linearly dependent upon the variation in dc input voltage between +3 and +5 V. Output frequency is variable over a 3.5 to 1 operating range; the center frequency of which is determined by an external capacitor. See Fig. 2. The VCM will operate between 10 kHz and 30 MHz and dissipates 150 mW.

These units are intended as frequency synthesizers for communication, instrumentation, and computer applications. Digital programming of the VCM output in multiples of the reference frequency is accomplished by changing the value of N in the Divide-by-N package in the feedback loop. Conventional synthesizers comparable to the system in Fig. 1 use 6 to 10 crystals and a lot of functional logic.

Applications are expected in tuners, frequency synthesizers, FM detection, synchronization, timing, and A/D conversion. In aircraft radios, banks of crystals and a mechanical movement costing \$80-\$100 can be replaced for about \$40, and prices could drop to about \$20 in a year. In quantities of 100, the two PLL circuits shown cost: MC4044P—\$7.00, MC4024P—\$5.50. Prices are for DIP plastic packages. DIP ceramic packages and ceramic flat-packs are also available.

Motorola Semiconductor Products Inc., Box 20912, Phoenix, Ariz. 85036.

Circle 344 on Inquiry Card

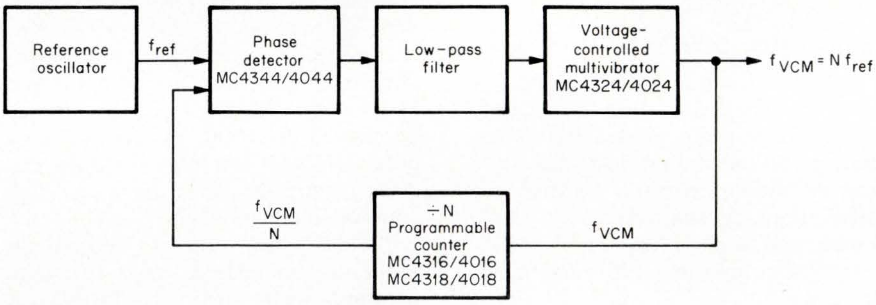


Fig. 1: Digital phase-locked, frequency synthesizer loop. This loop generates output frequencies that are multiples of the reference frequency. When N is changed, or the phase detector senses a phase difference on its inputs, it changes the dc voltage to the VCM which changes its output frequency until an in-phase condition is restored.

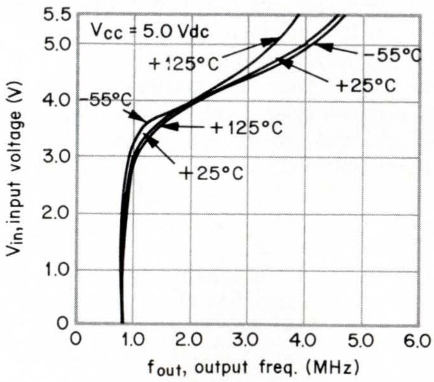


Fig. 2: Operating characteristic of the VCM with a 100 pF feedback capacitor. Output frequency is altered when the input voltage changes between +3 and +5 V. The value of the external control capacitor, C, in μF, can be found from the relationships: $C = 500/f_{max}$ or $C = 100/f_{min}$.

TERMINAL MEMORY UNIT

Uses a magnetic-tape cassette.

Designed to replace paper tape equipment, this unit uses std. C-60 cassettes to provide you with erase capability, as well as storage and handling conveniences not available with paper-tape equipment. The basic TerMIcorder can be ordered either fully interfaced or as a basic deck with write/read electronics and either fast start/stop synchronous or incremental write / synchronous read capability. Midwestern Instruments/Telex, 41st/Sheriden, Tulsa, Okla. (918) 627-1111.

Circle 345 on Inquiry Card

COMMUNICATION COMPUTER

With programmable I/O controller.

New computer accepts and delivers data to and from as many as 253 various types of communications devices simultaneously. Almost any type of remote terminal—displays, keyboards, printers, plotters and other computers—may be used with the Devonshire. It handles pre-processing, concentration, data direction, message switching, remote terminal operations and other communications jobs. Devonshire Computer Corp., 377 Elliot St., Newton, Mass. 02164. (617) 969-0650.

Circle 346 on Inquiry Card

KEYBOARD

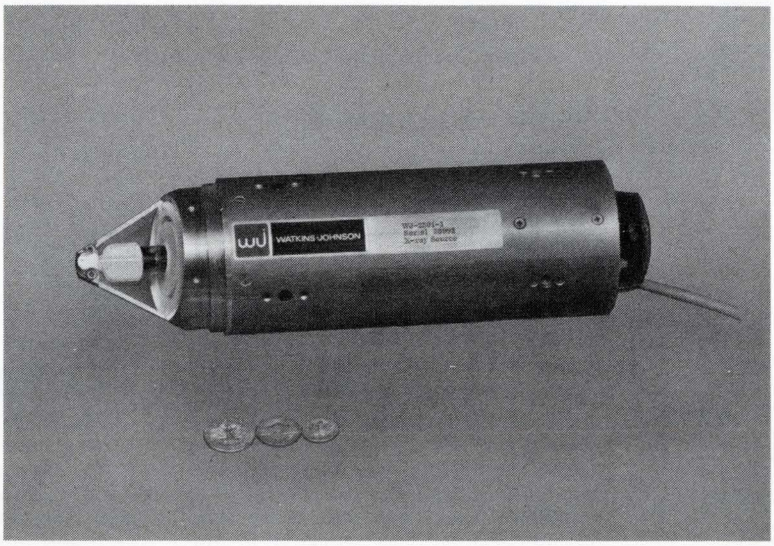
Standard off-the-shelf item.

Model DC-303 has 10 discrete function outputs in addition to the most commonly used USASCII codes. A switching module generates the strobe to the fully buffered outputs. The all-ss design eliminates mechanical linkages and electromechanical parts, providing bounce and noise free operation. Physical arrangement of this keyboard is fixed; however, any key or group of keys may be omitted at your option. \$350. Mark Hild, Inc., 11760 Wilshire Blvd., Los Angeles, Calif. 90025. (213) 478-0996.

Circle 347 on Inquiry Card

Announcing...

A NEW CONCEPT in MINIATURE X-RAY SOURCES



Operating from 28 Vdc with a capability for handling 400 mA at 40,000 volts, the WJ-2301-1 with integral power supply meets the severe shock and vibration requirements of MIL-E-5400. An extremely high x-ray intensity-to-size ratio, particularly under pulse operation, is featured. The tube provides large pulse emission levels at one-tenth the power required for tungsten filaments.

Watkins-Johnson recently delivered x-ray units to these specifications for use in a military application. If you are looking for x-ray tube performance demanding miniature components built to withstand extremely rugged environmental conditions, contact our local representative or Watkins-Johnson Applications Engineering.

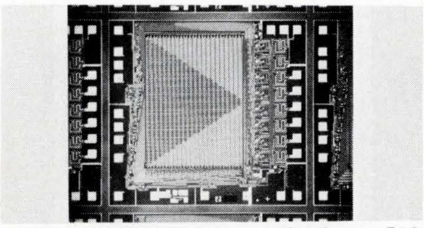
WATKINS-JOHNSON

3333 HILLVIEW AVE., STANFORD INDUSTRIAL PARK, PALO ALTO, CALIF. 94304 • (415) 326-8830

Circle 42 on Inquiry Card

READ ONLY MEMORY

Mos device has 4096 bits.

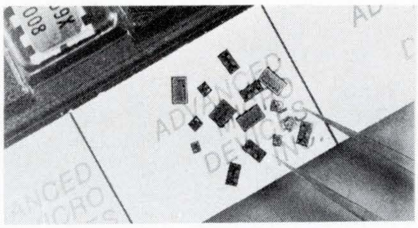


The EA3310 is organized as 512 words with 8 bits/word. Two output inhibit controls allow operation as a 1024 word, 4 bits/word array and also lets you use them in a wire-OR'd configuration. About $60 ea in lots of 25. Electronic Arrays, Inc., 501 Ellis St., Mountain View, Calif. 94040. (415) 964-4321.

Circle 288 on Inquiry Card

DIGITAL AND LINEAR DICE

Fully tested.

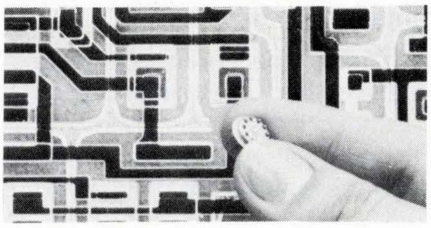


All of the manufacturer's MSI and linear products are available in die form. The devices, which are provided in 100-unit carriers, are subjected to complete functional and parametric testing, and can be supplied in the full military temp. range. Advanced Micro Devices Inc., 901 Thompson Place, Sunnyvale; Calif. 94086. (408) 732-2400.

Circle 289 on Inquiry Card

PHASE-LOCKED LOOP ICs

From subaudio to vhf.

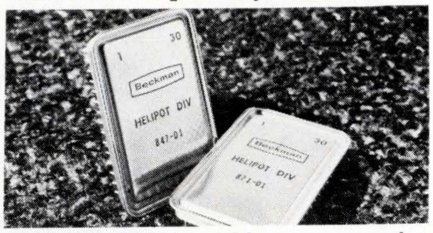


These units can multiply, divide, and fractionalize frequencies. Operating range of the 562, a model fabricated with a dielectric isolation process, is 0.1 Hz to more than 50 MHz. The 565, made with standard processing, operates from 0.1 Hz to 500 kHz. In 100 piece quantities the 562 is $18.00 and the 565 is $6.35. Signetics Corp., 811 E. Arques Ave., Sunnyvale, Calif. 94086.

Circle 290 on Inquiry Card

A/D AND D/A CONVERTERS

With MOS compatibility.

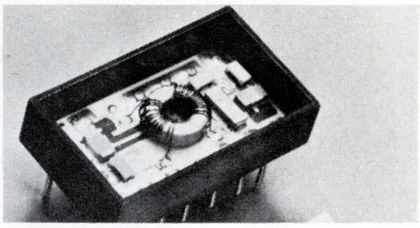


Model 871 is a binary, successive approximation A/D converter. A digital input gives you external control of the converted word length. Model 847 is a 10-bit D/A unit with serial or parallel input capability. Technical Information Section, Helipot Div., Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, Calif. 92634.

Circle 291 on Inquiry Card

INTERFACE CIRCUIT

Needs no external dc power.

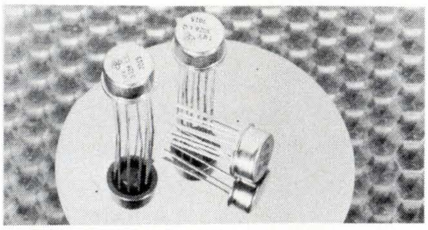


The FTI-2001 data filter operates at data rates from dc to 2.5 MHz and is TTL, DTL and HTL compatible. Features include input/output transformer isolation, faithful pulse restoration and tolerance to high common mode noise. Unit price is $19.85 in 100 lots. Fabri-Tek Micro-Systems, Inc., 1150 N.W. 70th St., Ft. Lauderdale, Fla. 33309. (305) 933-9351.

Circle 292 on Inquiry Card

SHIFT REGISTER

Dual 128-bit unit.



The TMS3028LR can operate from dc to 1 MHz. Two power supplies (−14 and −28 V) and one external clock are required for operation, and three clocks are generated in each 128-bit section. Available in a 10-lead TO-100 package, it is $20.00 ea. in 1 to 24 pc. lots. Texas Instruments Incorporated, Inquiry Answering Service, Box 5012, M/S 308, Dallas, Tex. 75222. (214) 238-3741.

Circle 293 on Inquiry Card

←Circle 43 on Inquiry Card

Bell & Howell & Jon Wells & The Simple Folk

Some people asked our guys how come we didn't turn out a recorder/reproducer that simple folk could use. At a simple price. Something that was production line oriented for a bunch of industries across the board.

We bounced that problem to Jon Wells who just recently came up with the remarkable, hi-rel VR3700B series.

Back Jon came with a little number called the VR3500. Although it's not as esoteric as the B model, it does have a lot of its features.

He used a modular concept with functions being grouped according to use. Linear IC's to get the bulk down. And large cards so any trouble shooting that needed to be done could be done fast.

Transport and electronics are set up so they can be easily repaired or modified. There's a closed loop tape path so you get real accuracy. Bi-directional speeds for versatility. A fail-safe phase lock DC capstan drive so you won't lose a smidgen of information. And very gentle tape handling.

As far as time base error and dynamic skew and flutter, they're fantastically low.

And so's the price.

Another thing. You don't have to be an engineer to run it. The how-to's are decaled right on the equipment.

That's the VR3500. An industrial recorder/reproducer. Brand new. And ready.

For all the specs, write its father, Jon Wells, Bell & Howell, Instruments Division, 360 Sierra Madre Villa, Pasadena, California 91109.

INSTRUMENTS DIVISION

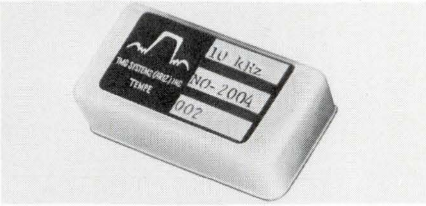
BELL & HOWELL

Circle 44 on Inquiry Card

MICROWORLD PRODUCTS

IC CRYSTAL OSCILLATOR

With ranges of 1 kHz to 5 MHz.



The XO-2004 provides a stability of ±0.005% from 0 to 60°C and ±0.01% from −50 to 100°C. Input power is +5 Vdc ±10% while providing a square wave output capable of driving TTL. Prototypes are available in 2-3 weeks at $62.00 ea. TMC Systems (Arizona) Inc., 930 W. 23rd St., Tempe, Ariz. 85281.

Circle 294 on Inquiry Card

WIDE BANDWIDTH OP AMP

Unity gain crossover is 35 MHz.

The RA-2620 has a typical bias and offset currents of 2 nA, input resistance of 100 MΩ min. and max. offset voltage of 4 mV (adjustable to zero). As an amplifier, the device is internally compensated for closed loop gains greater than three. The commercial version is $10.70 ea. (100-999 pcs). Radiation Microelectronics Div., Melbourne, Fla. 32901.

Circle 295 on Inquiry Card

THICK-FILM AMPLIFIER

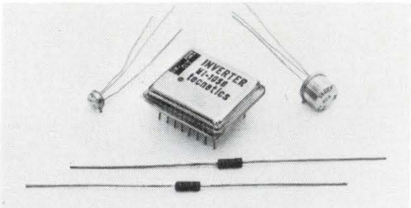
Total weight is under 1 oz.

This unit has a 1 dB bandwidth of 20 MHz centered on 60 MHz with a noise figure of 2 dB. The gain is 32 dB, and the unit contains two output ports with 25 dB isolation between the ports. Matched sets can be supplied within ±2° in phase and ±5 dB in gain. They are priced at $185.00 ea. in medium quantities. Optimax, Inc., Box 106, Colmar, Pa. 18915.

Circle 296 on Inquiry Card

HYBRID INVERTER

With 3 W power output.



This series of dc-ac square wave inverters includes 16 different models with center-tapped outputs from 5 to 300 V pk-pk. Efficiency at full lead is 80% typ. By adding appropriate filters, you can use them to generate sine-waves, sawtooth, pulses or other specialized functions. Tecnetics Inc., Boulder Industrial Park, Boulder, Colo. 80302. (303) 442-3837.

Circle 297 on Inquiry Card

MOS READ ONLY MEMORY

Bipolar compatible even in worst case situations.

The UC6525 can handle both input and output logic levels of any DTL or TTL device without external resistors or translators. This 1024 bit static ROM has a logic 1 input of 2.4 V min. and a logic zero input of 0.4 V max. Four different memory organizations are available and four programmable chip-select inputs allow word expansion and memory arrangement without the need for external decoders. Access time is 500 ns. Solitron Devices, Box 1416, San Diego, Calif. 92112.

Circle 298 on Inquiry Card

SINGLE CHARACTER GENERATOR

Features 500 ns character access time.

The RO-1-2240 is a one-package character generator with horizontal output using ASCII coding. The one-unit generator replaces conventional multi-unit devices, thereby reducing size and memory system requirements as well as cost. One of the benefits of this character generator is its acceptance of ASCII coded inputs for 5 x 7 character selection. The device also features asynchronous operation and output buffers for TTL/DTL interfacing. It is available in 24-lead dual-in-line packages. The price in 100-piece lots is $28 ea. General Instrument Corp., 600 W. John St., Hicksville, N.Y. 11802. (516) 733-3000.

Circle 299 on Inquiry Card

MORE NEW MICROWORLD PRODUCTS

Here are some more products just announced. For more information, please use the circle number indicated.

DIGITAL ICs

COS/MOS counter/divider. The CD4017D from RCA converts binary code to a decimal number. Circle 275

MOS shift registers. The MM5016, a 512-bit, and the MM5006, a dual 100-bit register. From National. Circle 276

Up/down counters. Advanced Micro Devices announces the 8284 and 8285 with 20 MHz clocks. Circle 277

Complex function decoders. Motorola's new circuits convert BCD or excess three to decimal or seven-segment. Circle 278

LINEAR ICs

Dual, monolithic op-amps. Transitron's TOA7747 and TOA8747 feature Darlington inputs for μV sensitivity. Circle 279

Fm limiting i-f amp. The MFC6010 from Motorola, is a monolithic fm limiting 10.7 MHz i-f amplifier. Circle 280

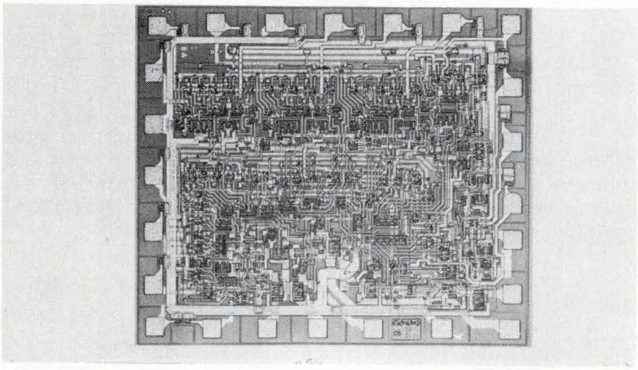
Voltage regulator. Transitron's TVR2000 series maintains 0 to 38 V within ±5.5 mV. Circle 281

Circle 46 on Inquiry Card

NEW MICROWORLD PRODUCTS

ARITHMETIC LOGIC UNIT

Achieves high speed with carry lookahead.

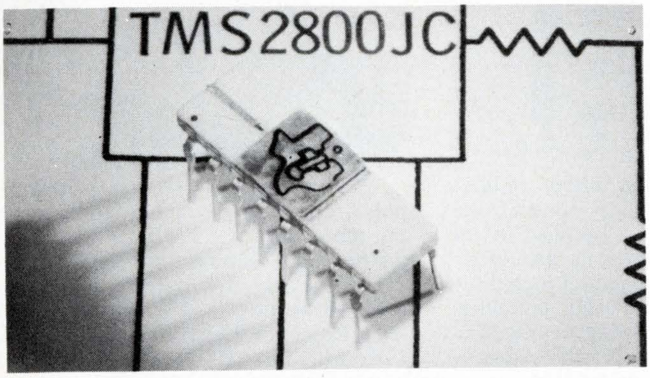


The 9340 is a TTL/MSI circuit that can perform two arithmetic operations (add or subtract) and any of six logic operations based on combinations of A and B inputs. The device accepts two 4-bit binary words in parallel, performing addition in 28 ns and subtraction in 33 ns. It accepts carry lookahead outputs from three other 9340's, producing a full 16-bit arithmetic logic unit without additional gates. The resulting addition time for two 16-bit words is 42 ns. It comes in 24-lead DIPs and ceramic flatpacks in both the military and commercial temp. ranges. Prices (1-24 pcs) range from $20.90 to $46. Fairchild Semiconductor, 313 Fairchild Dr., Mountain View, Calif. 94040. (415) 962-3563.

Circle 300 on Inquiry Card

MOS/LSI READ ONLY MEMORY

Has 1024 bits in a 256 x 4 organization.



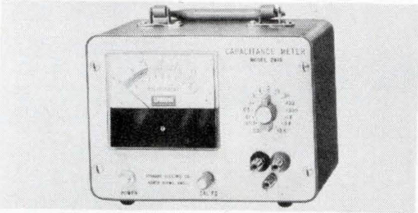
This static ROM, the TM2800JC, has less than 1 μs max. access time. Two types of output buffers are available, the single-ended one for driving TTL which has one MOS device with its drain at the output and its source at chip ground; the other one is a double-ended version for driving inputs to other MOS ICs and devices. It has its own MOS load resistor internally and requires no external circuitry. Non-recurring mask costs are $1000 for the min. 25-piece quantities and $500 for 100 to 249 pcs. On orders for 1000 or more pieces, there is no charge for the mask. Texas Instruments Incorporated, Inquiry Answering Service, Box 5012, M/S 308, Dallas, Tex. 75222.

Circle 301 on Inquiry Card

NEW LAB INSTRUMENTS

CAPACITANCE METER

Uses test voltage of only 1 V.



Model 2W1A gives direct indication of capacitances in 15 ranges from 100 pF to 10,000 μF. Because of its low test voltage, you can use it to check all types of capacitors including low-voltage aluminum and tantalum electrolytic units. Sprague Electric Co., Marshall St., North Adams, Mass. 01247. (413) 664-4411.

Circle 317 on Inquiry Card

SCOPE PREAMPLIFIER

Model 108 has fixed gains of 10 and 100. Input impedance is 1 MΩ and 47 pF and the input noise is less than 10 μV rms. The unit will accept standard probes and will drive VOM's and recorders as well as scopes. Price is $189 with 30 day delivery. Artec Electronics, Box 356, Cupertino, Calif. 95014.

Circle 318 on Inquiry Card

PULSE GENERATOR

With 5 ns rise and fall times.

This unit, the G 710, has a 50 MHz pulse repetition frequency and an amplitude of up to ±5 V into 50 Ω. The instrument features a duty factor >50%, external triggering and waveform distortion <5% pk-pk. $395. E-H Research Laboratories, Inc., 515 11th St., Box 1289, Oakland, Calif. 94604. (415) 834-3030.

Circle 319 on Inquiry Card

RESISTANCE BRIDGE

The Model 520 is a self-contained resistance bridge that provides 0.1% accuracy while dissipating only nW's in the unknown. It is suitable for resistance thermometry, particularly carbon and germanium thermometry at cryogenic temperatures. $995. Keithley Instruments Inc., 28775 Aurora Rd., Cleveland, Ohio 44139.

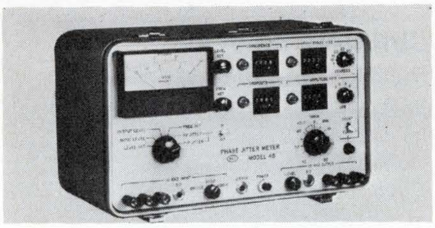
Circle 320 on Inquiry Card

RF POWER AMPLIFIER
With 20 W of output power.

Model 320L operates over the frequency range of 250 kHz to 110 MHz. A highly linear class A design, the unit will amplify inputs of a-m, fm, ssb, pulse and other complex modulations, with minimum distortion. Electronic Navigation Industries Inc., 1337 Main St. E., Rochester, N.Y. 14609. (716) 288-2420.

Circle 321 on Inquiry Card

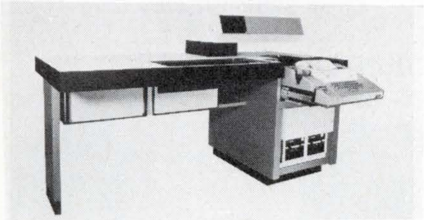
PHASE JITTER METER
For data communication circuits.



Model 45 measures pk-pk and average phase jitter up to 30° with ±1° accuracy. You can also measure phase hits up to 45° in 5° increments. Gain hits of ±1, 2, 3, or 6 dB, coincident phase/gain hits and line dropouts are also detected and totalized. $2,610. Hekimian Laboratories, Inc., 322 N. Stonesstreet Ave., Rockville, Md. 20850. (301) 424-3160.

Circle 322 on Inquiry Card

LOGIC CIRCUIT ANALYZER
Features increased memory.



The new memory for the Model 1790 consists of two tape-cassette transports. These add a capacity of greater than 150,000, 12-bit words to the analyzer's capability. One transport is normally used as storage for system programs, while the other provides storage for existing test programs. General Radio Co., 300 Baker Ave., West Concord, Mass. 01781.

Circle 323 on Inquiry Card

NEW LAB INSTRUMENTS

DIGITAL MULTIMETER

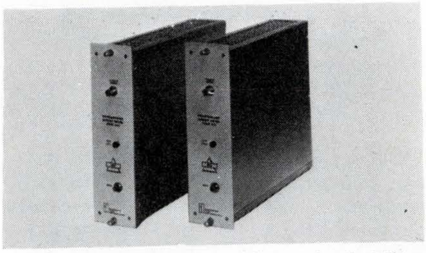
Battery or ac operation.

The Type 341 eliminates zero adjusting and circuit loading, the two major causes of error in multimeter operation. A new input amplifier technique does away with circuit loading throughout the test function. $445 ea. without batteries. Diglin, Inc., 6533 San Fernando Rd., Glendale, Calif. 91201. (213) 245-6754.

Circle 324 on Inquiry Card

CURRENT DRIVERS

Digitally programmable.

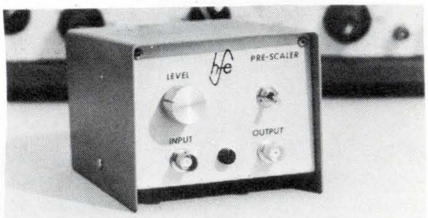


Models 5561 (positive) and 5562 (negative), are designed for special memory test systems, general purpose automatic memory test systems and testing of non-memory components, such as non-linear ferrites, tapewound cores and testing MOS semiconductor memories. Computer Test Corporation, 3 Computer Dr., Cherry Hill, N.J. (609) 424-2400.

Circle 325 on Inquiry Card

COUNTER PRE-SCALER

Extends range to 280 MHz.

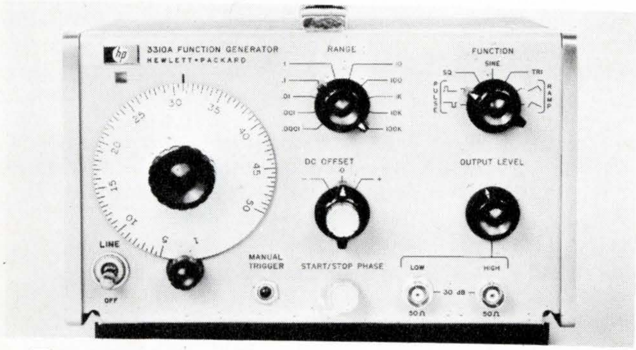


Model 280 HFE is capable of driving any known digital counter and extends the range at a cost substantially below that of an extended-range counter. The unit is available in a bench-top enclosure, in a NIM (nuclear instrument module), or as an IC board alone. High Frequency Engineering Co., 123 Santa Maria Ave., Portola Valley, Calif. 94025.

Circle 326 on Inquiry Card

FUNCTION GENERATOR

With single and multiple cycle modes.

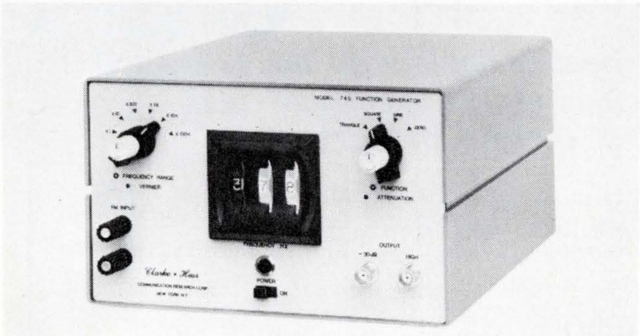


The HP Model 3310A Opt. H10, offers single cycle, multiple cycle, or free run operation. You get single or multiple cycle output with either manual or external triggering. The instrument has an amplitude range from 15 mV pk-pk to 15 V pk-pk into a 50Ω load. Dc offset is ±5 V into 50Ω and an external signal can be used to fm the output frequency. Typical applications include frequency and transient response testing, as a waveform converter, for generating coherent waveforms and as a frequency multiplier or divider. Price is $735.00 and delivery currently is 1 week. Inquiries Mgr., Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304.

Circle 327 on Inquiry Card

FUNCTION GENERATOR

Digitally adjustable.



Model 745 offers 6099 digitally adjustable frequencies from 0.01 Hz to 1.099 MHz. In addition to 10% overlap between ranges, digital readout of freq. and digitally resettable frequencies, it also offers Tone Burst, Synchronization, and fm capabilities for its Sine, Square and Triangular outputs. 20 V pk-pk is available open circuit from two isolated 50 Ω output terminals (75 or 600 Ω also available). It has three digit control of freq. from 1 Hz to 1.099 MHz. A low freq. expand switch allows two digit control between 0.10 and 0.99 Hz and one digit control from 0.01 to 0.09 Hz. A freq. vernier permits operation down to 0.001 Hz, as well as permitting settings between any two digitally selected freqs. $425.00. Clarke-Hess Communication Research Corp., 43 W. 16th St., New York, N.Y. 10011. (212) 255-2940.

Circle 328 on Inquiry Card

VOLTAGE COMPARATOR

With built-in time delay.

Built-in time delay of the Model 560 Voltsensor is adjustable from 5 to 100 ms with automatic reset. The 560 will sense a 1 mV change within 95% of full voltage range (+/−24 V) with no discontinuity through zero. It has repeatability better than 4 mV, hysteresis < 50 mV, input Z > 100kΩ and an output of about 80% of supply voltage. $58.00 ea. FOB factory. California Electronic Mfg. Co., Inc., Box 555, Alamo, Calif. 94507. (415) 932-3911.

Circle 302 on Inquiry Card

GUNN DIODES

Low fm/am noise characteristics.

X-band GaAs Gunn diodes which operated through bulk negative resistance, accomplish a one step conversion from dc-to-microwave energy from a single low voltage supply. Characteristic of this series is the MA-49107 diode which operates over the 8.0 to 12.4 freq. band with output power of 100 mW and typical operating bias current of 500 mAdc. Microwave Associates, Burlington, Mass. 01803. (617) 272-3000.

Circle 303 on Inquiry Card

AC TO DC CONVERTER

With ±0.05% regulation.

Model R15 converts 115 Vac, 50-420 Hz power to any output from 5 to 17 Vdc and 15 A. Load transient recovery time is < 75 μs. Ripple has been reduced to 0.02% or 5 mV rms, whichever is greater. Output voltage is adjustable to about 10% of nom. by means of an externally accessible pot. As low as $149 (1) or $136 ea. (2-4) f.o.b. Los Angeles. Abbott Transistor Laboratories, Inc., 5200 W. Jefferson Blvd., Los Angeles, Calif. 90016. (213) 936-8185.

Circle 304 on Inquiry Card

POWER PACKAGE

It's IC regulated.

Designated the LCS-A series, this all silicon, convection-cooled dc supply is available in 19 fixed voltage single-output models from 3 to 150 Vdc and up to 3 A; and 5 wide-range, single output models from 0-120 Vdc and up to 2 A. Regulation is 0.01% +1 mV. Input range is 105-132 Vac, 57-63 Hz. $99.00 and up. Lambda Electronics Corp., 515 Broad Hollow Rd., Melville, N.Y. 11746. (516) 694-4200.

Circle 305 on Inquiry Card

CONVEYOR FURNACE

Controlled atmosphere.

Designed for reflow soldering, this furnace is specially suited to hybrid circuit assembly because the assemblies are exposed to the reflow temp. for <60 s. Belt speed control accuracy is ±½%. The furnace has three zones of preheat, a stabilizing zone, a high heat zone, and a cooling zone. Maximum operating temp. is 600°C, controlled to within ±3°C. Watkins-Johnson, Stewart Div., 440 Mt. Hermon Rd., Scotts Valley, Calif. 95060. (408) 438-2100.

Circle 306 on Inquiry Card

PC CONNECTORS

With solderless wrap tails.

New 225 series bifurcated bellows PC connectors have 0.025 in.[2] contact tails for wrapping 26 to 30 gauge wire. Contact center-to-center spacings are 0.100 and 0.125 in. The tail also permits flow soldering to multilayer boards with enough tail length thru the board to provide supplemental wrapping operations. Amphenol Industrial Div., The Bunker-Ramo Corp., 1830 S. 54th Ave., Chicago, Ill. 60650.

Circle 307 on Inquiry Card

This new **INCENTIVE MONEY** *works harder than cash!*

Actual size samples of S&H Green Stamp Incentive Award Certificates

it's an award for accomplishment!

EMPLOYEES and SALESMEN try harder. They develop strong reasons for reaching and exceeding incentive objectives when S&H Award Certificates are offered. It's because these awards are actually S&H Green Stamps, produced in a convenient form for use by business and industry. They extend their influence through each incentive participant to reach, involve and reward their entire families.

With S&H Green Stamp Certificates, you tap the motivational force of the most popular and most stimulating incentive system in America. You can achieve greater sales — (locally or nationally); cost reduction, quality control, better attendance, improved safety, or better job performance. These versatile award certificates can give your program a "quick start", permit exciting promotions and produce fast action. And, participants can personally select the prizes of their choice at any of over 800 S&H redemption stores throughout the U.S.

Act right now! Send in the coupon and learn how to use this unusual force for accomplishment. Thousands of business and industrial executives have. Why not you?

S&H INCENTIVE DIVISION

The Sperry and Hutchinson Company
330 Madison Avenue, New York, N.Y. 10017

Circle 61 on Inquiry Card

On-the-job accomplishments bring more and more certificates. Winners select from over 2000 top-quality prizes.

CHECK THE AREAS OF YOUR INTEREST

- ☐ Increased Sales
- ☐ New Accounts
- ☐ Trade Incentives
- ☐ Better Attendance
- ☐ Suggestions
- ☐ Cost Reduction
- ☐ Quality Control
- ☐ Improved Safety
- ☐ Driver/Fleet Safety
- ☐ Job Performance

FREE: *S&H PRIZE AWARD BOOK — plus . . .*
Information on the use of S&H Prize Award Certificates

S&H Incentive Division • 330 Madison Avenue • New York, N.Y. 10017

C-11

Name ____________________

Title ____________________

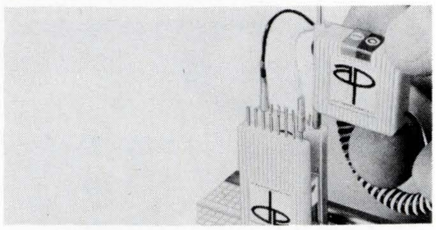
Company ____________________

Address ____________________

City ____________ State ________ Zip ________

NEW PRODUCTS

DIGITAL TEST PROBE



This probe indicates true logic levels and prevents ambiguous readings. It permits hands-free testing of DTL, TTL and other logic systems. A green indicator light indicates "0" level from 0 to 0.6 V. A red light indicates logic "1" level at 2.4 V and above. There is a guaranteed no-indication dead band between 1.0 V and 2.0 V. A P Inc., 72 Corwin Dr., Painesville (Cleveland), Ohio 44077. (216) 357-5597.

Circle 308 on Inquiry Card

ELECTROLYTIC CAPACITORS

Designed to meet special requirements for high volt-microfarad capacity units, the 92 F and 88 F lines are well suited for use in high current dc power supplies and energy storage applications in computers, industrial control equipment, and so forth. Standard units of both lines are available in 21 case sizes with a total of more than 400 ratings, which range from 5 to 150 V and 170 to 180,000 μF at −40° to 85°C. Electronic Capacitor and Battery Dept., General Electric Co., Box 158, Irmo, S.C. 29063.

Circle 309 on Inquiry Card

CHOKES

These epoxy roll-coated chokes meet requirements of Mil-C-15305D. The special epoxy conformal coating provides physical and environmental qualities equal to molded parts—at a price comparable to lacquer-coated models. There are 13 models available in a range from 0.10 μH to 1.00 μH (±10% tol.). Self-resonant freqs. range from 680 MHz to 240 MHz. Dale Electronics, Inc., Dept. 860, Box 609, Columbus, Nebr. 68601.

Circle 310 on Inquiry Card

SINGLE-CARD D/A CONVERTER

Input codes in the DAC-12Q can be binary, offset binary, BCD, or 2's complement. Either unipolar or bipolar outputs are available. It has a TC of ±7 ppm/°C, monolithic current switches and a 12-bit thin film resistor network. Conversion speed is 2.5 μs to <0.01% (fast amp); 20/μs to <0.1% (medium speed amp). Slewing rate is 50 V/μs and 0.5 V/μs respectively. Linearity and FS accuracy are both better than ½ LSB at 25°. Analog Devices, 385 Elliot St., Newton Upper Falls, Mass. 02164. (617) 332-2131.

Circle 311 on Inquiry Card

OSCILLATOR

Five new models of this temp. compensated oscillator cover the freq. range of 1 MHz to 10 MHz. Designated OSC 37 series, they warm up instantly, drawing typ. 15 mA at 12 Vdc. Frequency stabilities of up to ±1 ppm over the range of −5° to +60°C are offered. Output is TTL compatible 1¾ x 1¾ x ¾ in. Ovenaire, Inc., 706 Forrest St., Charlottesville, Va. 22901. (703) 293-5148.

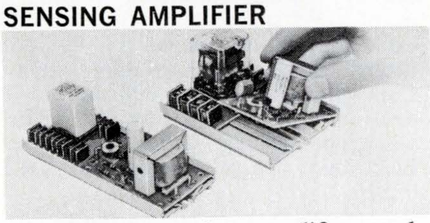
Circle 312 on Inquiry Card

PANEL METERS

These meters feature std. 1% FS accuracy, high sensitivity and 1-s full-scale response time. Model 503-E uses a ss amplifier circuit with chopper input to amplify input signals. Voltmeter sens. is 1 mΩ/V. Ammeter sens. is expected as 10 mV drop. Scales read both Fahrenheit and Centigrade. API Instruments Co., Chesterland, Ohio. 44026.

Circle 313 on Inquiry Card

SENSING AMPLIFIER



Resistance sensing amplifier module snaps vertically into prepunched mounting tracks. It can be used for liquid level, photoelectric or temp. control, or any other function related to detection of resistance changes. Detectable and adj. range is 0-100,000 Ω. $6.40, including track, in lots of 100. Curtis Development & Mfg. Co., 3250 N. 33rd St., Milwaukee, Wis. 53216.

Circle 314 on Inquiry Card

TAPE/HEAD CLEANER

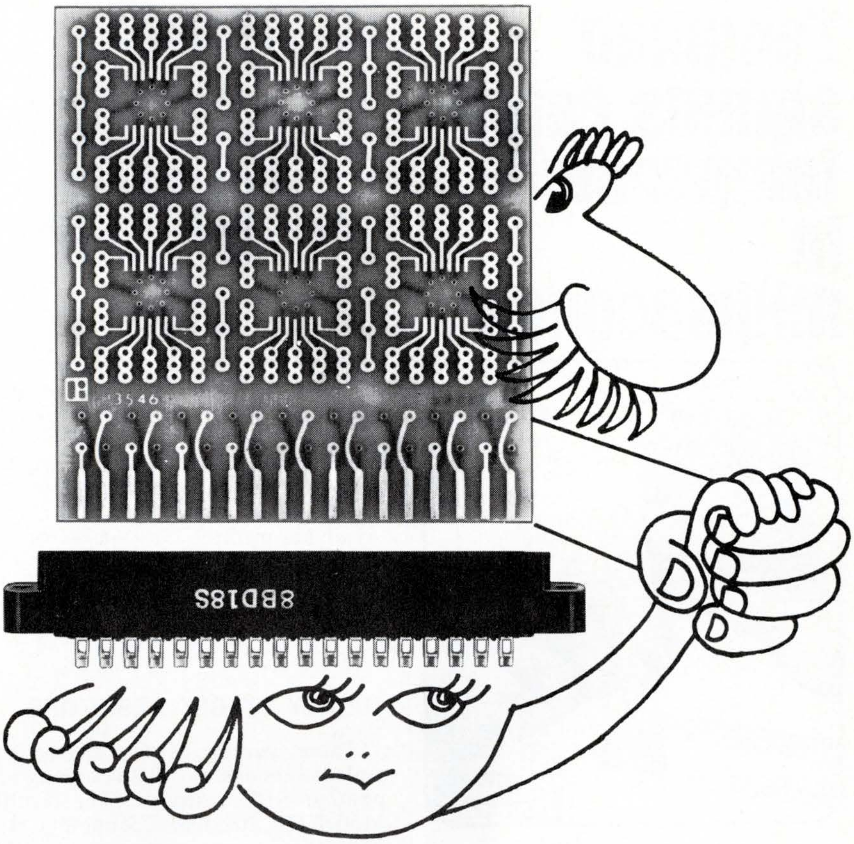
This cleaner is for VTR, audio heads, magnetic tape and photo film. It can be used on cassette and cartridge tape recorders as well as normal reel-to-reel equipment. It eliminates accumulated dirt, film, and oxides. Silicone free, it can also be used to clean guide parts, capstans, and pinch rollers. Nortronics Distributor Div., 6140 Wayzata Blvd., Minneapolis, Minn. 55416.

Circle 315 on Inquiry Card

SAMPLE & HOLD MODULE

Sampac™ buffered sample & hold features 10^{11} Ω input Z, with acquisition uncertainty <50 ns, yet hold decay is <15 μV/ms. DTL/T²L compatible circuity offers good offset and noise characteristics. It operates from ±15 V @ 12 mA. Analogic Corp., Audubon Rd., Wakefield, Mass. 01880. (617) 246-0300.

Circle 316 on Inquiry Card



We call them an engaging couple

Get acquainted with this well-matched pair. No need to look further for the right connector to use with Triad's versatile line of integrated and universal circuit cards. If you put a "CO" prefix ahead of the card number, you'll get the applicable Winchester connector in the same package with the card — ready for you to put together.

Triad has many low-cost, fast-delivery cards for breadboarding and testing use: cards for flat packs, TO-5's and dual in-line packages — with or without connectors; plug-in terminal cards, extender cards, solder training cards.

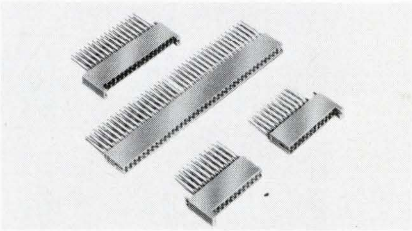
So, if you want to meet an engaging couple, call your nearest Triad distributor. He can also help on your transformer, inductor and filter requirements — we're big in these components, too. Triad Distributor Division, 305 North Briant Street, Huntington, Indiana 46750.

Triad Distributor Division of Litton Industries

Circle 63 on Inquiry Card

NEW PRODUCTS

METAL PLATE CONNECTOR



Used in metal plate connector assemblies, Series 6315 card-edge receptacles are for programmed solderless wrapping terminations. Supporting both voltage and ground plane connections, they use dual-readout contacts spaced on a 0.125 in. grid. Available in three basic insulator sizes (24, 34, or 78 contacts). Elco Corp., Willow Grove, Pa. 19090. (215) 659-7000.

Circle 329 on Inquiry Card

HIGHLY STABLE RESISTORS

These resistors are hermetically sealed versions of the company's 25 ppm/yr S102 resistors. The resulting Model HP 202 has a 5 ppm/yr stab., and tol. accuracy down to $\pm 0.001\%$. It also has ± 1 ppm/°C TC, tracking to $\pm \frac{1}{2}$ ppm/°C for all values, and 1 ns rise time. Resistance values from 30 Ω to 50 kΩ. Vishay Resistor Products, 63 Lincoln Hwy., Malvern, Pa. 19355.

Circle 330 on Inquiry Card

DIP-COMPATIBLE CLOCK

Model 21-OSC crystal-controlled clock contains a two-stage synchronous divider and plugs into a 14-pin DIP socket. It operates from +5 V and is DTL/TTL-compatible with a freq. range from 1 MHz to 10 MHz and an accuracy of $\pm 0.002\%$ over a range of 0° to 70°C. Prices start at $65.00. Standard Logic Inc., 1630 S. Lyon St., Santa Ana, Calif. 72705. (714) 835-5466.

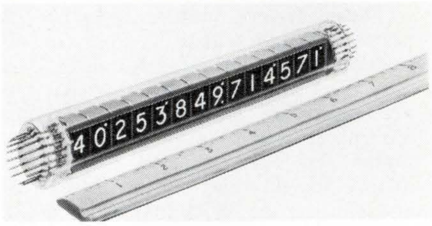
Circle 331 on Inquiry Card

ATTENUATOR

The PA-54 digitally programmable attenuator covers dc to 1000 MHz with a total attenuation range of 0 to 127 dB in 1 dB steps. A control voltage of 26.5 Vdc applied at the inputs of the 1, 2, 4, 8, 16, 32 or 64 dB positions sets attenuation with a switching speed of 4 ms. $795.00. Texscan Corp., 2466 N. Shadeland Ave., Indianapolis, Ind. 46219. (317) 357-8781.

Circle 332 on Inquiry Card

14-DECADE INDICATOR



ZM1200 Pandicon™, a gas-filled, cold-cathode numerical indicator tube, displays 14-digit numbers in only 7 in. of panel space. It requires only 27 ext. connections instead of the 168 needed for a normal 14-digit display. Compatible with IC equipment, it consumes only 1.5 to 2 W for the full 14-decade display. $27.00. Amperex Electronic Corp., Slatersville, R.I. 02876.

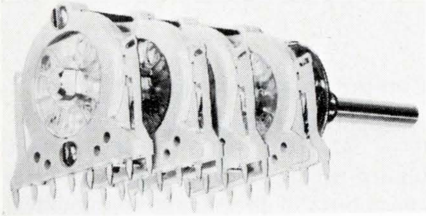
Circle 333 on Inquiry Card

CONTACTLESS RELAY

This relay features complete isolation between input circuit (coil excitation) and output (switching elements), high operating speeds (micro- to nano-seconds), and absence of contacts and other moving parts. It responds to dc inputs as well as to pulses up to 20 kHz. Normal load current is 200 mA. Ebeko Electronik, West Germany. Dr. E. Wolff, U.S. Distributor, 1241 Welsh Rd., Huntingdon Valley, Pa. 19006.

Circle 334 on Inquiry Card

SELECTOR SWITCH WAFER



New selector switch wafer assures fast, easy insertion to PC boards. It is interchangeable with the older 6-terminal "T-Bird" wafer having a 7/8 in. "Y" dimension. CTS 212 wafer assemblies are rated 1/2 A at 28 Vdc; 3/4 A at 115 Vac. Circuit resistance ranges from 0.008 to 0.010 Ω. CTS of Elkhart Div., 1142 W. Beardsley Ave., Elkhart, Ind. 46514. (219) 523-0210.

Circle 335 on Inquiry Card

EVALUATOR/CLEANER

The Inspector is an off-line computer tape cleaner/evaluator which gives you quality control over your tapes. It cleans and evaluates a 2400 ft. reel of std. 1/2 in. computer tape in 5.3 min. It controls tape tension by vacuum pressure. Thus, tension isn't affected by tape speed. Graham Magnetics, Inc., Graham, Tex. 76046.

Circle 336 on Inquiry Card

MOS CAPACITOR CHIPS

This new line of MOS chips for hybrid circuit applications comes in six different geometries of single and dual units. Capacitances are 0.5 to 220 pF and working voltages are 25 to 75 V. Chip sizes range from 20 to 45 mils square, 6 mils thick. Dionics Inc., 65 Rushmore St., Westbury, N.Y. 11590. (516) 997-7474.

Circle 337 on Inquiry Card

200 A/300 V PWR. TRANSISTOR

New 200 A/300 V npn silicon planar power transistor, the SDT-9650, has usable h_{FE} at 200 A, V_{CEO} up to 300 V, saturation voltage at 200 A <1.0 V and I_{CBO} <100 μA at 150 V V_{CB}. Solitron Devices, Inc., 1177 Blue Heron Blvd., Riviera Beach, Fla. 33404.

Circle 338 on Inquiry Card

MOLDED CHOKE

Series 8, rf molded choke is 0.080 x 0.200 in. with 13 RTMA values ranging from 1.0-10.0 μH. Q values 36-60 at 7.9 MHz. Gowanda Electronics Corp., Dept. G-7, 179 Broadway Rd., Gowanda, N.Y. 14070.

Circle 339 on Inquiry Card

SCIENTIFIC CALCULATORS

These new 1600 series electronic calculators, two display models and two printing models, have 10 data storage registers and provide std. decimal and scientific decimal notation. In addition, functions such as log, a^x, sine, cosine, radians to degrees and others are calculated with single key depressions. Use of MOS/LSI technology provides a compact unit only 13 x 13 1/2 x 6 1/2 in. Monroe Div., Litton Industries, 550 Central Ave., Orange, N.J. 07050. (201) OR-3-6600.

Circle 340 on Inquiry Card

CIRCUIT PATTERNS

Circuit Zaps® are copper component patterns, pads, and conductor paths which eliminate the art, photography, photoprinting, touch up, etching, stripping, and other time-consuming and expensive steps in prototype board and test circuit development. They were developed to make printed wiring boards and test circuits—directly from designer's schematic or component placement layout—in one quick, continuous operation. Bishop Graphics, Inc., 7300 Radford Ave., North Hollywood, Calif. 91605. (213) DU 5-1769.

Circle 341 on Inquiry Card

Circle 66 on Inquiry Card

LITERATURE

Connectors and components

There's a lot of information stored in this 152-page catalog. Almost any type of connector you can think of is listed here, including a full coverage of microwave miniature coaxial connectors and components. And, of course, receptacles and terminations are included, too. A selection of assembly tools and a cable selection guide are provided and will save you time with your selection. Americon Microwave Ind. Inc., 87 Rumford Ave., Waltham, Mass. 02154.

Circle 361 on Inquiry Card

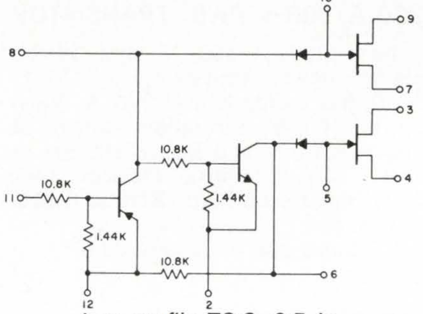
Delay lines

A range of standard electromagnetic delay lines for digital circuitry applications are illustrated in an 8-pager. Delays ranging from 7 ns to 1000 ns with impedance of approximately 100 Ω are discussed with schematics included for each. ESC Electronics, 534 Bergen Blvd., Palisades Park, N.J. 07650.

Circle 362 on Inquiry Card

ICs for 1970

A 1970 version of an IC catalog covers voltage regulators, clock drivers, ladder switches, amplifiers, hybrid switches, and power amplifiers. The 20-pager includes schematics, tables of characteristics, and descriptions for



Low profile TO-8, 0.5 in.

each device. This listing represents a complete summary of the company's line of hybrid products. General Instrument Corp., Integrated Circuits Div., 600 W. John St., Hicksville, N.Y. 11802.

Circle 363 on Inquiry Card

Computer applications

Application sheets (15 so far) have been compiled into an applications library to familiarize you with the capabilities of this computing counter. One sheet, for instance, covers time interval jitter and explains how the counter measures propagation delays and time uncertainties introduced by ICs. Other notes explain phase measurements, crystal oscillator calibration, and high resolution voltage measurements. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304.

Circle 364 on Inquiry Card

IC testers

The company's complete line of digital and linear IC testers is described in this 4-page brochure. It provides basic information on 6 models, including 4 digital IC testers, 1 linear IC tester, and 1 functional test module. Microdyne Instruments Inc., 203 Middlesex Tpk., Burlington, Mass. 01803.

Circle 365 on Inquiry Card

Circle 67 on Inquiry Card

Circle 68 on Inquiry Card

LITERATURE

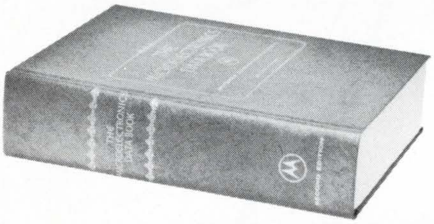
Interconnection devices

Nearly 2,000 connectors, terminal blocks, and sockets are listed in a 28-page catalog of interconnection devices available through the company's distributors. Technical data and specs are provided for all products. In addition you'll find information on a line of test jacks and banana plugs. Cinch Distributor Products, 1501 Morse Ave., Elk Grove Village, Ill. 60007.

Circle 366 on Inquiry Card

The microelectronics data book

Motorola has published a 2000-page data book on ICS, just as well organized as their earlier Semiconductor Data Book. Just as the earlier book started with a listing of all EIA types, the microelectronics data book starts with a very useful and inclusive list of Motorola's direct replacements for ICS made by all other American manufacturers. Since Motorola has the most comprehensive line of ICS in



the industry, including ECL in digital ICS and multipliers, modulators and detectors in linear ICS, this book can be considered almost an all-industry reference. In addition there are 21 excellent application notes at the end. You can get a copy of the Microelectronics Data book for $4.95 from Motorola distributors or directly from Motorola Semiconductor Products Inc., Box 20924, Phoenix, Ariz. 85036.

RAM data sheet

Preliminary data for the RAM series, a family ranging in size from 1024 to 9216 bits, is offered in this 8-page foldout data sheet. You'll find absolute maximum ratings, standard operating conditions, access times, and cycle times. System terminology is defined; mechanical data is given through illustrations; and diagrams illustrate ac test measurements and timing features. You'll also find descriptions of system usage and of operation and timing considerations. Semiconductor Electronic Memories Inc., 3883 N. 28th Ave., Phoenix, Ariz. 85017.

Circle 367 on Inquiry Card

LITERATURE

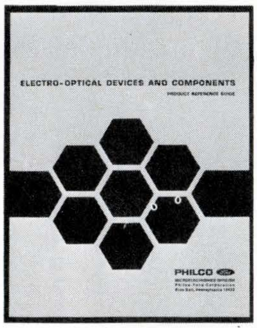
Linear ICs

Here's another pocket-size catalog brought to you by Fairchild. This time it's a linear IC condensed catalog (88 pages) providing key information and pin diagrams for 31 linear IC products. Perhaps the most important feature is its sneak preview of linear products to be introduced later this year—advanced circuits designed for memory interface, A/D interface, communications systems, and consumer applications. Fairchild Semiconductor, Box 880 A, Mountain View, Calif. 94040.

Circle 368 on Inquiry Card

Electro-optical devices

Single-crystal infrared detectors and electro-optical devices and components are the subject of this 16-page catalog. Composed of gallium arsenide, silicon, germanium, indium arsenide, indium antimonide, and gold-, mercury-, and copper-doped germanium crystals, the products range from 0.4 to 3 μm. Package outlines follow the product descriptions. A helpful "extra" is the bibliography which lists the electro-optical literature that you can get from the company. Philco-Ford Corp., Microelectronics Div., Blue Bell, Pa. 19422.



Circle 369 on Inquiry Card

RTS program library

The RTS time-sharing system combines third-generation computing and software designed for conversational usage from remote terminals. Included in the RTS program library are such engineering application programs as ECAP, WYRE, LOGIC, and NASAP. And so you can see the proposed advantages of such a system, this 10-page booklet provides schematics and a printout of a sample problem — a dc analysis of a simple common emitter amplifier. ITT Data Services, Route 17 & Garden State Pkwy., Paramus, N.J. 07652.

Circle 370 on Inquiry Card

P&B solid state relay hybrids advance the art of switching

These six new devices expand dramatically your range of switching options. Now, you can conveniently interface semiconductor logic circuits with inductive loads such as motors, solenoids, or relays. Inputs as low as 5 microwatts can be used to switch 7 ampere loads, for example. Many millions of times, too.

Input/output isolation normally associated with relays is maintained. Installation is conventional, too . . . direct onto printed circuit boards or in a wide choice of sockets. These new products represent a happy melding of semiconductors and relays to enhance the qualities of both.

Information is available from your P&B representative or contact the factory. Potter & Brumfield Division AMF Incorporated, Princeton, Indiana 47570. 812/385-5251.

① **JDA AMPLIFIER-DRIVEN RELAYS** Will operate on signals as low as 25 microwatts. Two dry reed contact forms are available: 2 Form A and 4 Form A. In the 2 Form A configuration, input voltages range from 5 to 24 VDC. In the 4 Form A package, from 12 to 24 VDC. This series permits 0.5" centers for printed circuit.

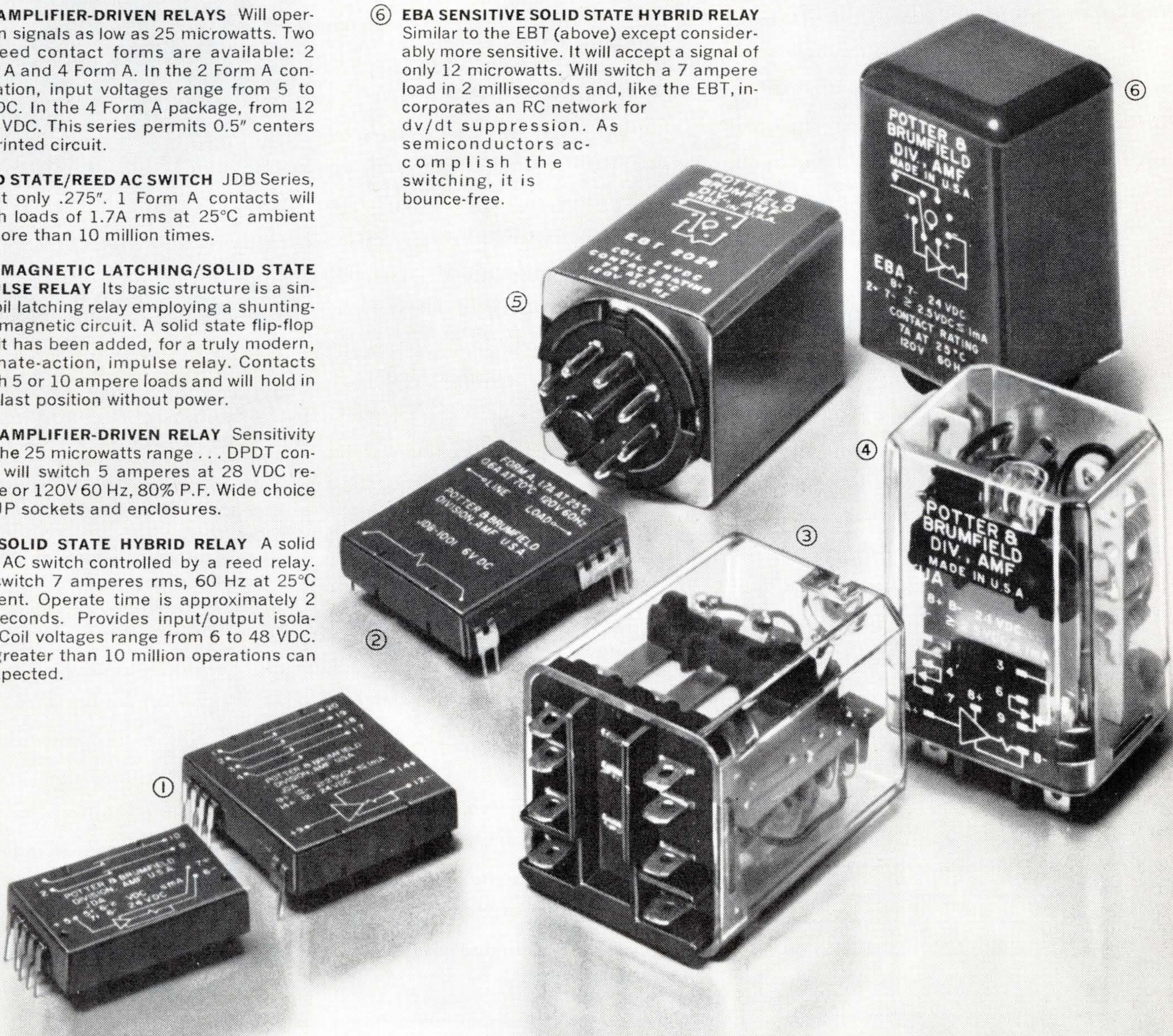
② **SOLID STATE/REED AC SWITCH** JDB Series, height only .275". 1 Form A contacts will switch loads of 1.7A rms at 25°C ambient for more than 10 million times.

③ **KUR MAGNETIC LATCHING/SOLID STATE IMPULSE RELAY** Its basic structure is a single coil latching relay employing a shunting-type magnetic circuit. A solid state flip-flop circuit has been added, for a truly modern, alternate-action, impulse relay. Contacts switch 5 or 10 ampere loads and will hold in their last position without power.

④ **KUA AMPLIFIER-DRIVEN RELAY** Sensitivity is in the 25 microwatts range . . . DPDT contacts will switch 5 amperes at 28 VDC resistive or 120V 60 Hz, 80% P.F. Wide choice of KUP sockets and enclosures.

⑤ **EBT SOLID STATE HYBRID RELAY** A solid state AC switch controlled by a reed relay. Will switch 7 amperes rms, 60 Hz at 25°C ambient. Operate time is approximately 2 milliseconds. Provides input/output isolation. Coil voltages range from 6 to 48 VDC. Life greater than 10 million operations can be expected.

⑥ **EBA SENSITIVE SOLID STATE HYBRID RELAY** Similar to the EBT (above) except considerably more sensitive. It will accept a signal of only 12 microwatts. Will switch a 7 ampere load in 2 milliseconds and, like the EBT, incorporates an RC network for dv/dt suppression. As semiconductors accomplish the switching, it is bounce-free.



AMF | POTTER & BRUMFIELD

LITERATURE

Interface IC

The subject of this 6-page application note is the SN75450 peripheral interface integrated circuit. Altogether, 23 separate applications are listed, and eight of these are covered in detail. A functional block diagram and a package configuration are included, and schematics illustrate, among others, such applications as the dual driver, the film memory digit driver, and the dual TTL to MOS and MOS to TTL drivers. Texas Instruments Inc., Box 5012, M/S 308, Dallas, Tex. 75222.

Circle 371 on Inquiry Card

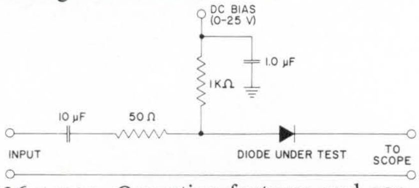
Component reliability

A brochure on the economics of reliability covers both discrete components and ICs. It discusses the economical feasibility of screening and supports its point of view with examples presented on computers and television. STL Electronics Inc., 2821 Ladybird La., Dallas, Tex. 75220.

Circle 372 on Inquiry Card

Components compendium

Solid-state microwave products including diodes, rf frequency multipliers, power sources, Impatt and Gunn effect oscillators, and high power waveguide limiters are discussed in a



36-pager. Operating features and general characteristics are provided for each of the products in this comprehensive company catalog, as are schematics. Varian, Solid State Div., Salem Rd., Beverly, Mass. 01915.

Circle 373 on Inquiry Card

Non-linear circuits chart

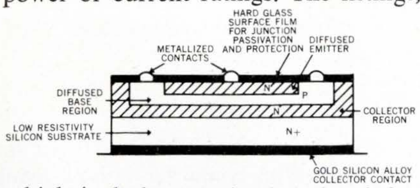
If you'd like another copy of the non-linear circuits chart that appeared in our June issue, here is your opportunity to get one. The wall chart describes wide dynamic range, curve fitting, computing, and modulator/demodulator circuits. You'll find information on basic non-linear functions and schematics to illustrate everything the chart describes. And the chart is brought to you with the compliments of Teledyne Philbrick Nexus, Allied Dr. at Route 128, Dedham, Mass. 02026.

Circle 374 on Inquiry Card

LITERATURE

Rectifiers and diodes

Thyristors and transistors are listed in this 32-page catalog as well as rectifiers, diodes, bridges, and stacks. Each product is listed within a general category (zener diodes, rectifiers, etc.) which, in turn, is subdivided into power or current ratings. The listings,



which include specs and design information, are followed by application data and outline drawings. "General Information" describes the performance and reliability of the major product groups. Unitrode Corp., 580 Pleasant St., Watertown, Mass. 02172.

Circle 375 on Inquiry Card

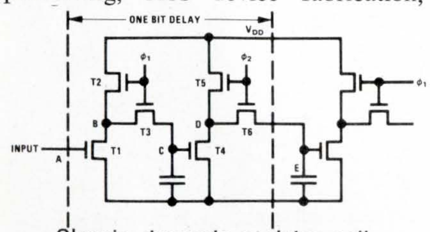
Circuit component patterns

Copper circuit component patterns, pads, and conductor paths are precision-etched on 3.5-mil glass epoxy base material and backed with a pressure-sensitive adhesive. Prototype PC boards and test circuits may be made directly from the schematic. This 4-page bulletin gives you step-by-step instructions and illustrations for this process. Bishop Graphics Inc., 7300 Radford Ave., North Hollywood, Calif. 91605.

Circle 376 on Inquiry Card

MOS reliability

Recent test results of a quality and reliability program reported 1,479,000 life test device hours with zero failures. This 20-page reliability report explains these tests and covers the basic principles of MOS, production processing, MOS device fabrication,



Classic dynamic register cell

and methods used to assure the quality and reliability of the end product. Tables and charts illustrate the various phases of the tests and test results. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, Calif. 95051.

Circle 377 on Inquiry Card

ENGINEERING DATA

LITERATURE

Connectors

The subject of this 16-page catalog is a new line of modular design concept connectors. Construction and application data, typical designs, base plates, grid systems, bushing and contact notes, and available tools for both the Snap-Wrap® and Mini-Wrap® families are included. Details on bushings and contacts are offered for the first time. Constructed on a modular basis, contacts are inserted into .nylon bushings, and the bushings are sealed into punched holes in an aluminum plate. Amphenol Industrial Div., Bunker-Ramo Corp., 1830 S. 54th Ave., Chicago, Ill. 60650.

Circle 378 on Inquiry Card

Dielectric materials charts

Two charts which have been designed for wall mounting show the dielectric constant and loss tangent at microwave frequencies of a variety of dielectric materials. Suggested for finding the right dielectric for a given application, the charts list over 300 materials. Emerson & Cuming Inc., Canton, Mass. 02021.

Circle 379 on Inquiry Card

Cradle relays

A 14-page brochure has been designed to simplify specifying and selecting a line of cradle relays. Application information, dimensions, wiring diagrams, and chassis layout for each terminal type are included, as are details for sockets. Allied Control Co., Inc., 100 Relay Rd., Plantsville, Conn. 06479.

Circle 380 on Inquiry Card

Systems manual

A 660-page systems manual for the Raytheon 706 computer is now available to our readers. It provides the basic information required for programming and using the computer. It features detailed information on the computer's organization, addressing, instruction repertoire and classes, software, and specs. Features of the processor and the use of the more than 400 programs and subroutines available are fully explained and illustrated with photos, diagrams, and tables. Raytheon Computer, 2700 S. Fairview St., Santa Ana, Calif. 92704.

Circle 381 on Inquiry Card

Advertisers—September 1970

**No liability is assumed for errors or omissions.
This index is published for a convenience.**

THE ELECTRONIC ENGINEER

DISTRICT SALES MANAGERS

EDWARD G. SHAUD
BALA-CYNWYD, (Pa.) 19004
One Decker Square
(Area Code 215) SHerwood 8-2000

JOSEPH DRUCKER
NEW YORK 10017—100 East 42nd St.
(Area Code 212) OXford 7-3400

JOHN W. BERNHARDT
CHICAGO 60606—120 S. Riverside Plaza
(Area Code 312) 782-1400

G. T. ALFANO
NEEDHAM HEIGHTS, MASS. 02194—
570 Hillside Ave.
(Area Code 617) 444-0010

TERRENCE D. BUCKLEY
THOMAS R. BORIS
LOS ANGELES 90005 3727 W. Sixth St. #202
(Area Code 213) DUnkirk 7-1271

RALPH PETERSEN
LOS ALTOS (San Francisco) 94022
199 First St., Room 335
(Area Code 415) 941-6655

RICHARD DUTE
CLEVELAND 44114—601 Rockwell Ave
(Area Code 216) SUperior 1-2860

NEWTON B. COLLINSON
ATLANTA 30309—1776 Peachtree St. N.W.
(Area Code 404) 872-4723

HAROLD E. MOTT
MICHAEL D. CORLEY
DALLAS 75206—Meadows Bldg
Expressway at Milton
(Area Code 214) EMerson 3-6426

BRENT GILBERT
Houston 77027
4151 Southwest Freeway
Suite 735
(Area Code 713) 621-7550

INTERNATIONAL BUSINESS OFFICES

London, S W 1 .... Max F Holsinger
67 68 Jermyn St , St James's — Dir European Sales
TRA 6318 9 — Roy V C Hall, A Berg
Cables — WHIP LONDON S W 1

Manchester 22 .... D I Goulden
Haletop, Wythenshawe Civic Centre — MERcury 329

4 Dusseldorf-Rath .... E Hillerbrand, R Schomburg, W Heckelmann
Eitelstrasse 32
Dusseldorf 632031
Cables — WHIP DUSSELDORF

Paris, 8e .... S Brown-Joussard
70 Rue de Ponthieu — ELYsees 65-77
Cables — UIIP PARIS 16e

Tokyo .... C T Sakaguchi
Room 814, Togin Bldg Marunouchi
CPO Box No 1572 — Tel: 211-3506-3509
Cables — CLARENCESAKA TOKYO

BUSINESS STAFF

K. ROBERT BRINK
Publisher
JOHN E. JAENISCH
Advertising Sales Manager
DENNIS J. PERKINS
Promotion Manager
MARK R. WERTH
Marketing Services Manager
PAT KAUFFMAN
Production Manager
WILLIAM M. COFFEY
Circulation Director
JAMES F. NAGY
Circulation Manager
JOSEPH P. BABCOCK
Reader Service Manager
JOHN H. KOFRON
Chilton Research Services
C. R. WILHIDE
Washington Vice-President

Index to Product Information

Listed below are all products and new literature that appear in this issue, along with the page number they appear on and their Reader Service Numbers (RSN). For more information, see the appropriate page and circle the corresponding number on the reader service card.

10 microvolt sensitivity with a lot of numbers.

40,000 to be precise.

Our latest bi-polar Model 1294 packs more numbers than any other into industry's smallest package! And it reads them with a sensitivity of *10 microvolts!* The 1294 is a true bi-polar 4½-digit instrument with a display capability of 19999 and out-of-range indication. Its state-of-the-art electronics utilizes T^2L logic and unique time-sharing circuitry that cuts power consumption to less than six watts. BCD output is optional.

Input impedance is high: 10 megohms on the 100 millivolt range. Reading rate is 5 per second. Response time is well under one second. Accuracy is .05% of reading, ±1 digit.

Housed in the same 7 sq. in. front-panel-mountable case as our five other DPM's, the 1294 offers all the features that have distinguished this line . . . Weston's patented dual slope* integration, plug-in Nixie** tubes, repairable (non-potted) circuit boards, and ten standard voltage and current ranges.

If you're sensitive about your numbers, Weston Model 1294 provides the ultimate at a reasonable price. See how the 1294 complements industry's broadest DPM line. Write for details from the DPM originators.

WESTON INSTRUMENTS DIVISION, Weston Instruments, Inc., Newark, N.J. 07114

a Schlumberger company

WESTON®

*U.S. Pat. #3,051,939

**Registered trademark, Burroughs Corp.

Circle 2 on Inquiry Card

Here's important news for every cost-conscious designer—RCA's COS/MOS line in dual-in-line plastic packages, at prices you can't afford to overlook.

This new COS/MOS line, RCA's CD4000E series, offers a broad range of gate-level and MSI devices with the low-power, high-noise-immunity features of hermetically packaged COS/MOS devices. And this plastic package gives you a broad operating temperature range and built-in reliability for industrial, commercial, and consumer applications. Look into RCA's CD4000E series for automotive systems, appliances, avionics applications, alarm systems, communications equipment, computers, industrial controls, and instrumentation.

This new low-cost, high-performance COS/MOS line offers you wide design flexibility in 19 application-oriented devices in 14- or 16-lead dual-in-line plastic packages. Check them now... and check our reliability report (listed below). Here are some important CD4000E series highlights:

☐ Wide operating-temperature range: −40°C to +85°C (−65°C to +150°C storage)

☐ Ultra-low quiescent-power dissipation—
Gates—$P_T = 50$ nW/pkg. (typ) @ $V_{DD} = 10$ V
MSI circuits—$P_T = 10$ μW/pkg. (typ) @ $V_{DD} = 10$ V

☐ Operation from single unregulated voltage supply: 5 to 15 V range

☐ Excellent dc and dynamic noise immunity—gate level and MSI circuits—
4.5 V (typ) @ $V_{DD} = 10$ V over full operating-temperature range

☐ Speed
Gates—propagation delay (t_{pd}) = 50 ns (typ) @ $V_{DD} = 10$ V, $C_L = 15$ pF
MSI circuits—clock pulse frequency (f_{CL}) = 2.5 MHz (typ) @ $V_{DD} = 10$ V

☐ Single phase clock

☐ Clock voltage equal to supply voltage

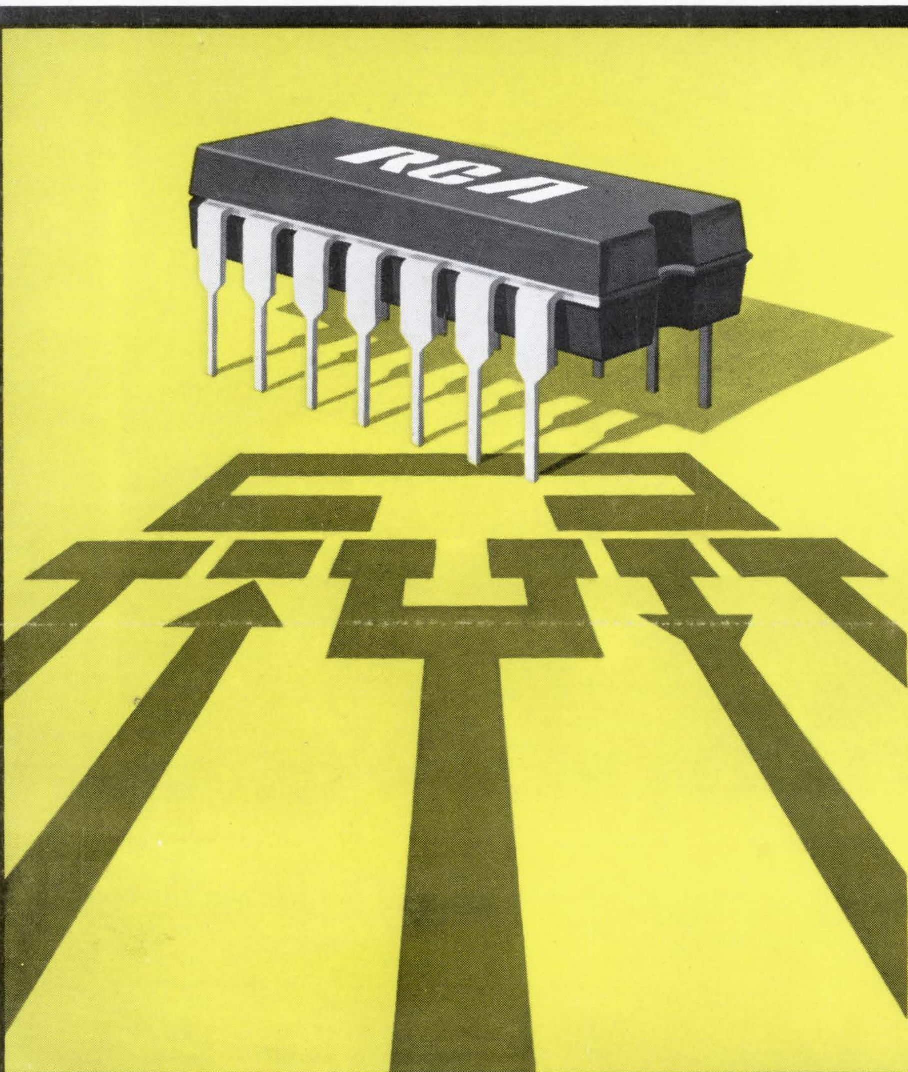
☐ Compatible gate level and MSI functions

☐ Protected inputs and outputs

For further information, see your local RC Representative or RCA Distributor. Ask for tech nical bulletin File No. 445, and the followin publications: "RCA CD4000E Series COS/MO IC Reliability Data," RIC 103; "Counters an Registers," ST-4166; "Noise Immunity," ICAN 6176; "Astable and Monostable Oscillator De signs," ICAN-6267. Or write: RCA, Commercia Engineering, Section 591/CD47, Harrison, Nev Jersey 07029. International: RCA, 2-4 rue d Lièvre, 1227 Geneva, Switzerland, or P.O. Bo 112, Hong Kong.

Now! COS/MOS Goes Plastic for a Brand New Approach to Logic Circuits at Low Cost.

Circle 3 on Inquiry Card



TYPE	DESCRIPTION	PRICE (1000 Unit level)
Gates		
CD4000E	Dual 3-input NOR plus inverter	$2.20
CD4001E	Quad 2-input NOR	2.30
CD4002E	Dual 4-input NOR	2.50
CD4007E	Dual complementary pair plus inverter	2.30
CD4011E	Quad 2-input NAND	2.30
CD4012E	Dual 4-input NAND	2.50
CD4019E	Quad AND-OR select gate	3.70
Flip-Flops		
CD4013E	Dual "D" with set/reset capability	3.30
Hex Buffers/Logic-Level Converters		
CD4009E	Inverting	3.60
CD4010E	Non-inverting	3.60
Multiplexer		
CD4016E	Quad bilateral switch	3.30
Static-Shift Registers—MSI		
CD4006E	18-stage register	7.75
CD4014E	8-stage synchronous parallel or serial-input/serial-output	7.75
CD4015E	Dual 4-stage serial-input/parallel-output	7.75
Counters—MSI		
CD4004E	7-stage ripple counter/frequency divider	5.60
CD4017E	Decade counter/divider with 10 decoded outputs	8.00
CD4018E	Presettable divide-by "N" counter	7.00
CD4020E	14-stage ripple-carry binary counter/divider	9.50
Adder—MSI		
CD4008E	4-bit binary full-adder with parallel carry-out	7.50

RCA

Integrated Circuits