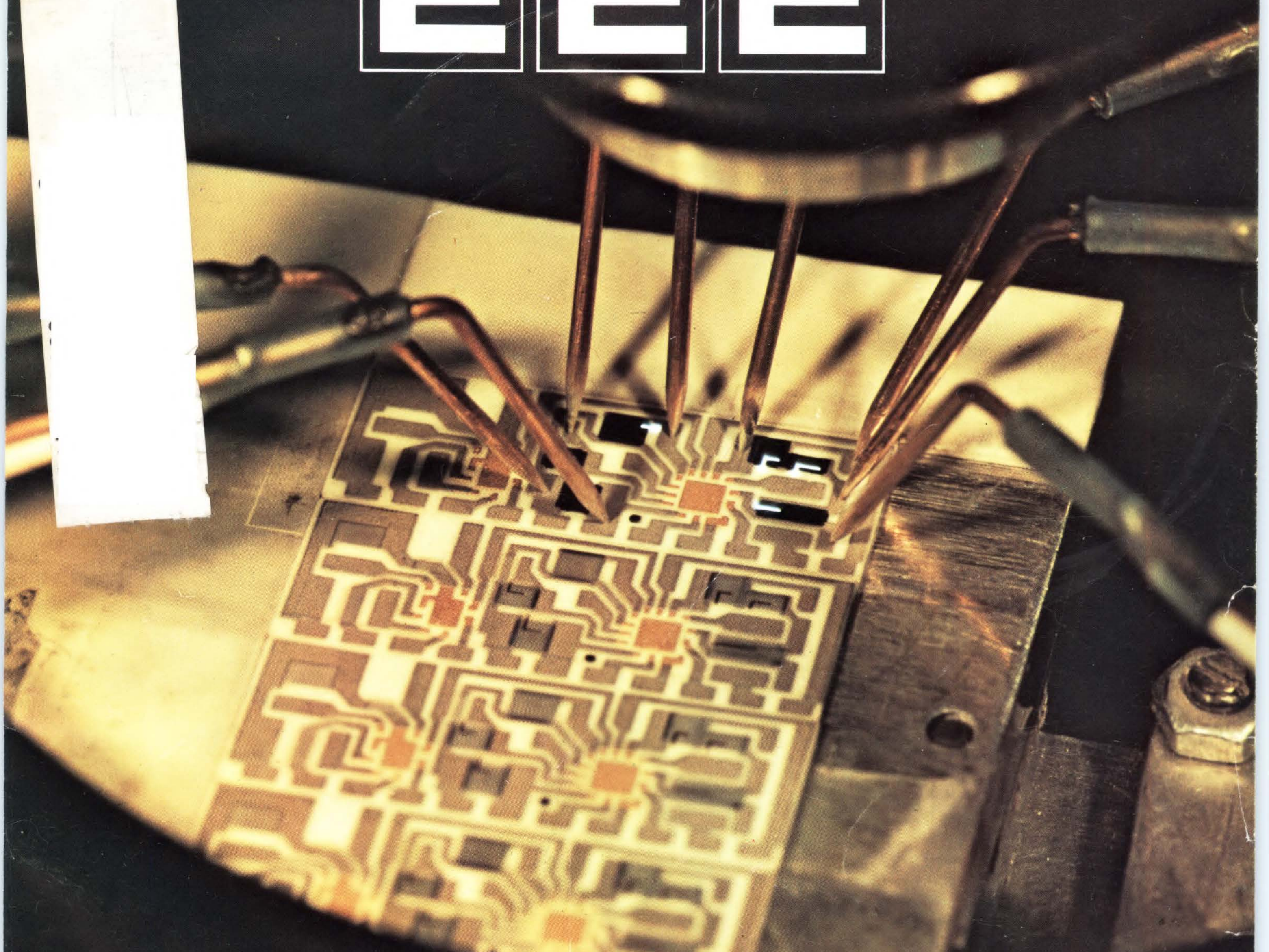
EDN

computer hardware In this Issue

exclusively for designers and design managers in electronics

EEE



Dynamic Laser Trimming

A CAHNERS PUBLICATION

SEPTEMBER 15, 1971

The engineers who designed this electronic tube anode could have given the production men a hard time. It was to be die-drawn from a single piece of copper in three reverse draw planes to a total draw-depth of 12 inches. But conventional, easily drawn copper alloys were out. Conductivity requirements, both electrical and thermal, ruled out most of them. The water cooled anode had to maintain maximum electrical efficiency while dissipating 22.5 kW. Outgassing specifications were even more critical: the anode would operate in a high vacuum and no impurities could be tolerated.

By specifying OFHC copper both the design and manufacturing problems were solved.

Uniform purity was the primary reason. OFHC copper is 99.99+% pure. That meant that production men could accurately predict the performance of the copper and design a drawing process to suit. And, purity eliminated outgassing. In addition AMAX certified conductivity of OFHC at 101% IACS. Good physical strength and good glass-to-metal sealability completed the picture.

OFHC copper may be the solution to your electrical and mechanical problems, too. We have all the data. Draw on it any time.

Specifying ductile copper without sacrificing conductivity and outgassing requirements is easy as OFHC®

It's a story you can draw on. Send for it.

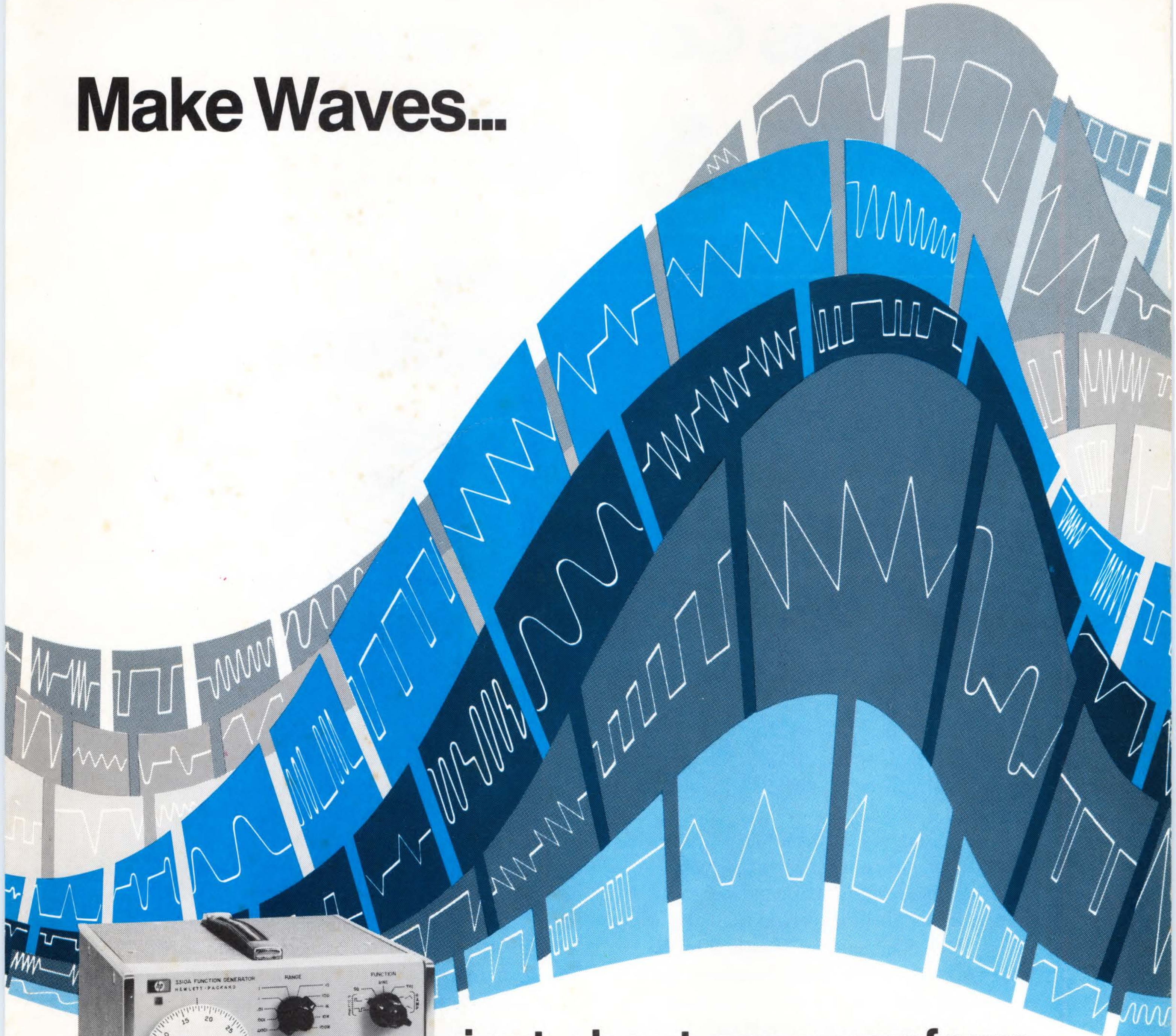
AMAX COPPER, INC.

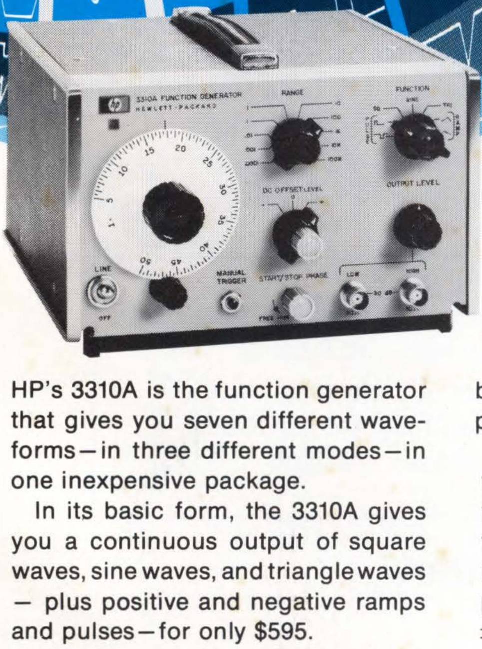
A SUBSIDIARY OF AMERICAN METAL CLIMAX, INC.
1270 AVENUE OF THE AMERICAS, NEW YORK, N.Y 10020

3T

CIRCLE NO. 1

Make Waves...





just about any waveform you can imagine

HP's 3310A is the function generator that gives you seven different waveforms—in three different modes—in one inexpensive package.

In its basic form, the 3310A gives you a continuous output of square waves, sine waves, and triangle waves – plus positive and negative ramps and pulses—for only $595.

And for only $140 more, you can get the 3310B, which lets you generate each of these seven waveforms in two other modes – single-cycle and multiple cycle "bursts." These can be triggered either manually or by an external oscillator; starting-point phase can be varied by $\pm$ 90°.

In either the "A" or "B" version, the 3310 gives you a choice of ten frequency ranges—from 0.0005 Hz to 5 MHz—and an output voltage range from 15 mV pk-pk to 15 V pk-pk into 50Ω load. Dc offset of $\pm$5 V into 50Ω load is also standard.

Both the 3310A and 3310B can be used in frequency-response and transient-response testing, as a waveform converter, for generating phase-coherent waveforms, and as a frequency multiplier or divider, among other things. Applications include testing television and communications systems, radar systems, and analog or digital circuits.

For further information on the 3310A and 3310B, contact your local HP field engineer, or write to Hewlett-Packard, Palo Alto, California 94304. In Europe: 1217 Meyrin-Geneva, Switzerland.

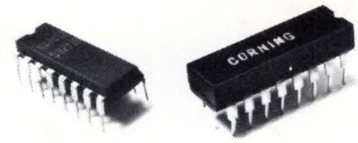
090/41A

HEWLETT hp PACKARD

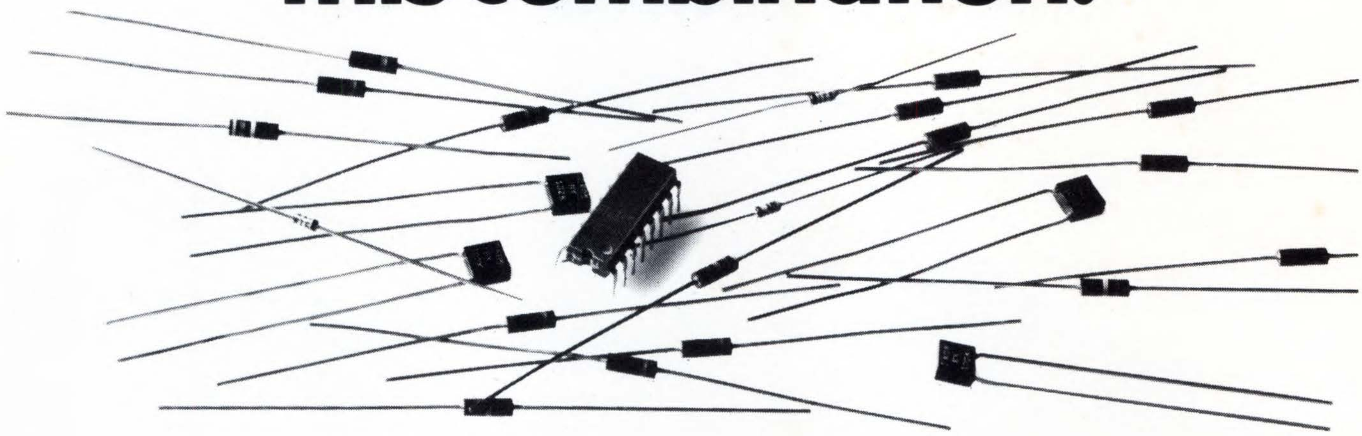
SIGNAL SOURCES

CIRCLE NO. 2

This Combination

Integrated circuit  CORDIP™ Component Network

replaces this combination.



Integrated circuit plus 23 discrete resistors, capacitors, and diodes

Corning's new CORDIP™ component networks take in much of what IC's leave out—outboard discretes.

Unlike screened thick/thin film networks, CORDIP component networks give you custom combinations of discrete resistors, capacitors, and diodes in a dual in-line package.

With combinations of up to 20 components in a standard 14-pin package. Up to 23 in a 16-pin package.

With virtually unlimited circuit complexity. With all inter-connections inside the pretested package.

Which gives you greater reliability and fewer production losses.

Combinations of resistors, capacitors and diodes with different tolerances, temperature coefficients and ratings are available in one package.

Which makes it possible to give you almost any custom combination you specify.

Large orders or small.

And we can make prototypes quickly for you, with almost any combination you specify.

CORDIP component networks are ready to plug in and are fully compatible with IC sequencing and insertion equipment.

CORDIP component networks. You'll save a lot of board space and production costs; you'll gain a lot more reliability and flexibility.

Call or send us your circuit requirements.

Corning Glass Works, Electronic Products Division, Corning, New York 14830.
(607) 962-4444 Ext. 8684.

SPECIFICATIONS

	Resistors	Capacitors	Diodes
Range	10Ω-150K	10-10,000 pF	Low Signal Silicon Planar Types
Tolerance	from 1%	from 5%	
TC	from 50 ppm	+ 2%, −10%	
Ratio	>15,000:1	>1,000:1	

CORDIP™ COMPONENT NETWORKS
From

CORNING
ELECTRONICS

CIRCLE NO. 3

SEPTEMBER 15, 1971
VOLUME 16, NUMBER 18

EDN/EEE

EXCLUSIVELY
FOR DESIGNERS
AND DESIGN MANAGERS
IN ELECTRONICS

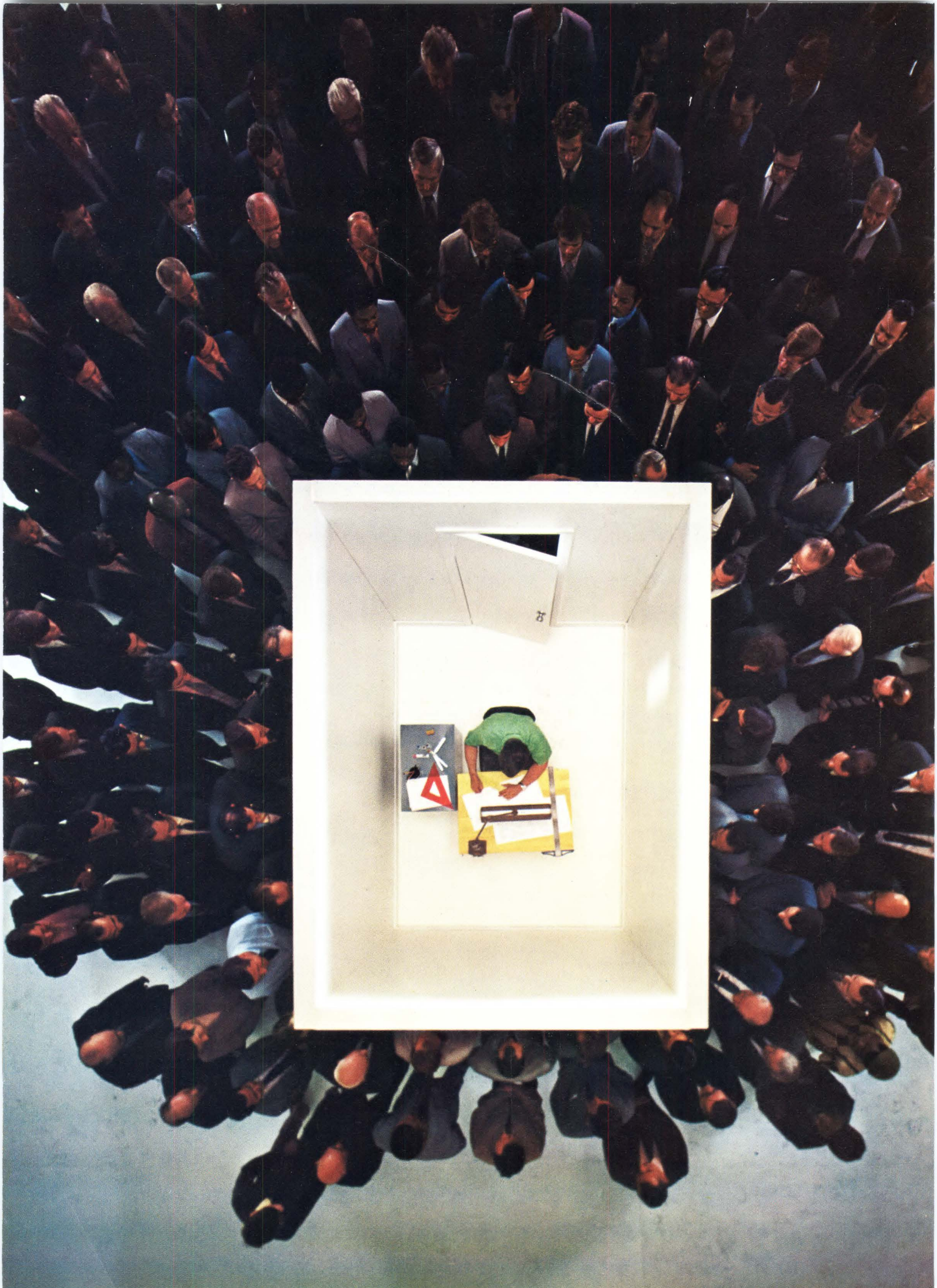
Cover

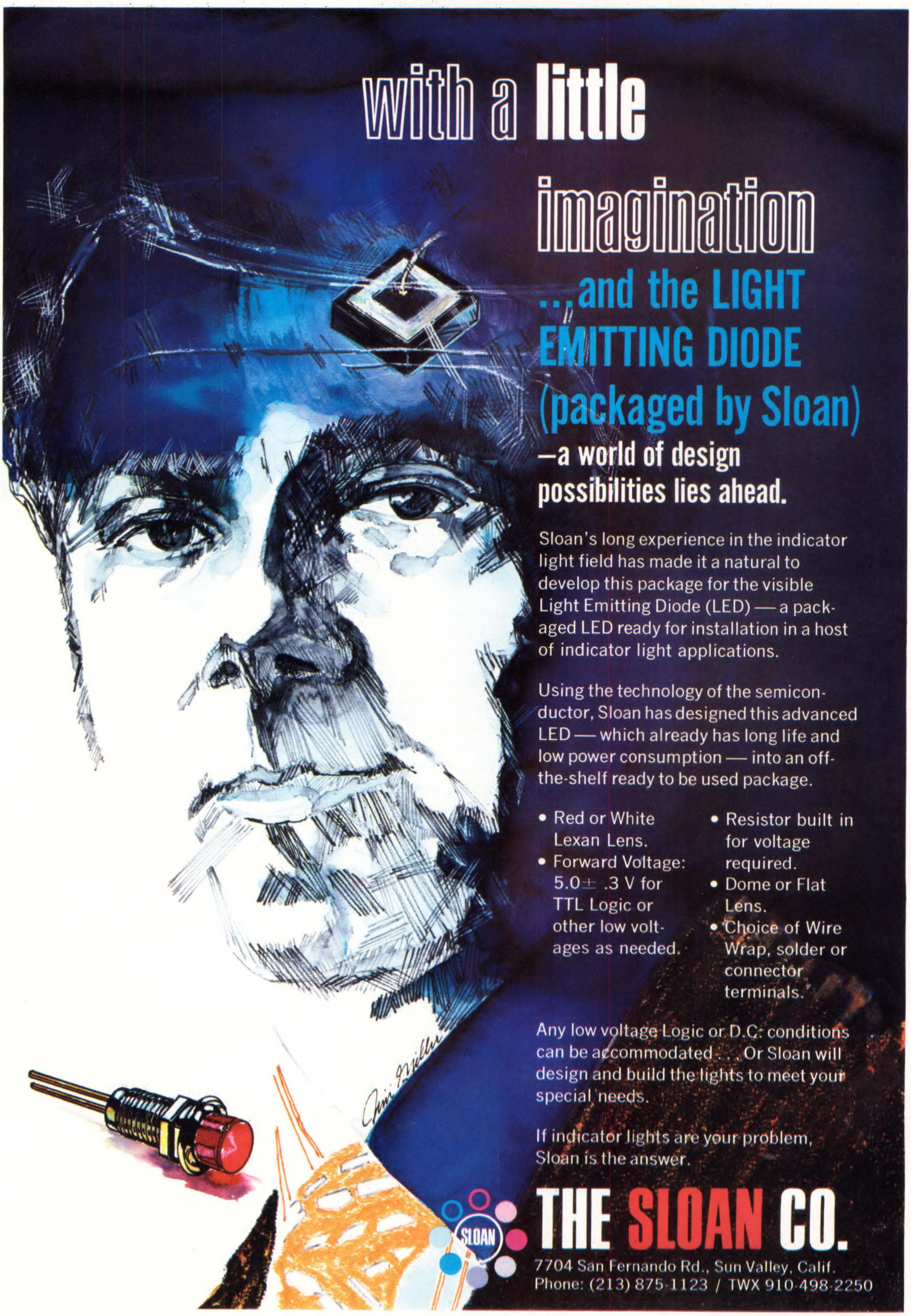
Cover photo from Motorola Semiconductor shows laser trimming of a hybrid IF detector. Both "L" and straight cuts are used, under computer direction. See news story on p. 10.

Speakout—Bob Noyce of Intel Speaks out on the IC Industry, p. 28.

ABP
CP
MCB
BPA
ibpa
International Business Press Associates
DESIGN ELECTRONICS
ELECTRONICS WEEKLY
EDN/EEE
ELEKTRONIK
ELEKTRONIK-ZEITUNG
INTER ELECTRONIQUE

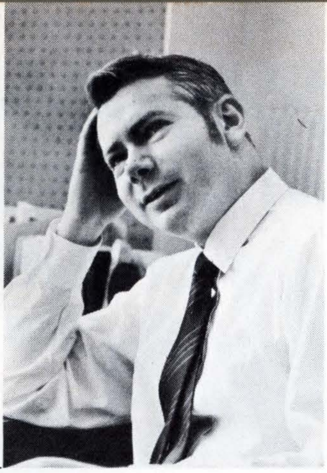
 Norman L. Cahners, Chairman of the Board; Saul Goldweitz, President; H. V. Drumm, Executive Vice President/Magazines; Ned Johnson, Senior Vice President/Magazines. EDN/EEE (formerly Electrical Design News) is published semi-monthly by Rogers Publishing Co., Inc. E. S. Safford, President; T. F. McCormish, Executive V. P.; G. F. Taylor, W. M. Platt, Vice Presidents. Editorial, Advertising, Subscription Offices, 270 St. Paul, Denver, Colo. 80206. Telephone 303 388-4511. Printed at 85 West Harrison St., Chicago, Ill. 60605. Controlled circulation postage paid at Chicago, Ill. Send form 3579 to subscription office. EDN/EEE is circulated to electronic design engineers and engineering managers in electronic original equipment manufacturing industries. Plants having more than twenty employees and manufacturing electronically operated or controlled equipment of their own design are considered part of this industry. Engineers in such plants responsible for specification of components, materials and test equipment for electronic application may receive EDN/EEE without charge. Completed qualification form and company letterhead required. Subscriptions to others in continental United States, $2 per copy. $20 per year. Send requests for qualification forms and change of address to subscription office in Denver, Colo. 80206.




with a little
imagination
...and the LIGHT EMITTING DIODE (packaged by Sloan)
—a world of design possibilities lies ahead.
Sloan's long experience in the indicator light field has made it a natural to develop this package for the visible Light Emitting Diode (LED) — a packaged LED ready for installation in a host of indicator light applications.
Using the technology of the semiconductor, Sloan has designed this advanced LED — which already has long life and low power consumption — into an off-the-shelf ready to be used package.
• Red or White Lexan Lens.
• Forward Voltage: 5.0± .3 V for TTL Logic or other low voltages as needed.
• Resistor built in for voltage required.
• Dome or Flat Lens.
• Choice of Wire Wrap, solder or connector terminals.
Any low voltage Logic or D.C. conditions can be accommodated . . . Or Sloan will design and build the lights to meet your special needs.
If indicator lights are your problem, Sloan is the answer.
SLOAN
THE SLOAN CO.
7704 San Fernando Rd., Sun Valley, Calif.
Phone: (213) 875-1123 / TWX 910-498-2250

CIRCLE NO. 5

Editorial



Design Decision Making In the 1970s

Once upon a time not so long ago, circuit design was considered very basic. People believed that if you gave the same design problem to two different groups of engineers, they would come up with very similar, although independently derived, solutions. Engineers were considered remoras[1] locked to basic circuit/system design procedures set forth by industry standard handbooks and texts.

Today that conservative view of the design engineer is gone. One of the nice things that has happened during the semiconductor era has been the emergence of the design engineer as a respected member of the electronics community.

It's a lot easier for circuit/system designers to move up into top-level positions today than it was 15 years ago. There are many reasons, of course, including easier access to business management courses, better understanding of rapidly moving technology, freedom to innovate and the availability of financial support to start out on their own.

But another major factor has been the changing responsibilities of the design engineer as economics became an increasing consideration in his everyday decision making.

The advent of thick- and thin-film technology helped immeasurably. Hybrid concepts gave the engineer, for the first time, a real choice of techniques to reach a particular goal. Integrated circuits have further expanded the realm of the designer to the point where he evaluates each move from the viewpoint of the present cost of implementation and the likely future cost at the time of production. If once a remora, the design engineer is today in every sense a businessman.

Jerry Eimbinder

Editorial Director

[1] *A remora is a fish with a suction disk by which it attaches itself to sharks, turtles and even ships, contenting itself to ride along wherever its source of transportation decides to go.*

Staff

Publisher
E. Patrick Wiesner

Editorial Director
Jerry Eimbinder

Editorial Staff
Earle Dilatush, *Managing Editor*
Harry Howard, *Senior Editor*
Mike Elphick, *Senior Field Editor*
Bob Cushman, *New York Editor*
Roy Forsberg, *Boston Editor*
Arthur Stapp, *Associate Editor*
Bill Furlow, *Associate Editor*
Tom Rigoli, *Consulting Editor*
Thelma Main, *Editorial Assistant*
Kris Hiester, *Copy Editorial Assistant*

Art Staff
Ray Lewis, *Director*
Edgar Good, *Assistant Director*
Mike Beard, *Illustrator*
Sumi Yamashita, *Illustrator*
Bill Caulfield, *Illustrator*

Production Manager
Wayne Hulitzky

Assistant Production Manager
Constance J. Martin

Circulation Manager
Ron Kinnes

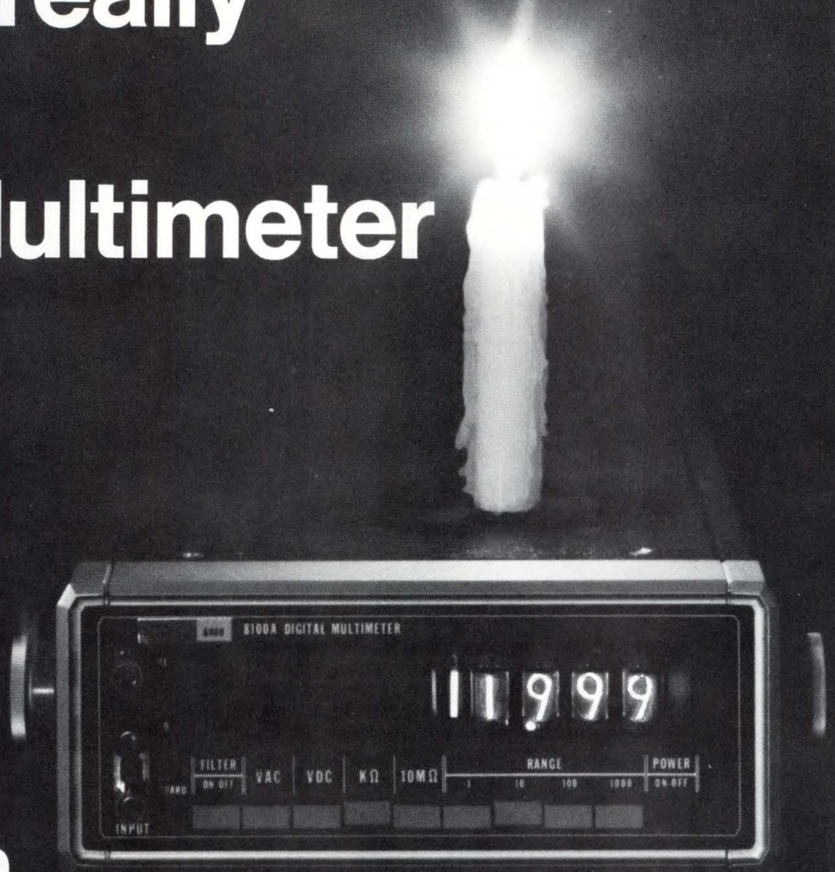
Editorial Consultant
John Peter

Editorial Office Addresses
Executive *(303) 388-4511*
270 St. Paul St.
Denver, Colo. 80206

New York *(212) 689-3250*
205 E. 42nd St.
New York, N.Y. 10017

Boston *(617) 536-7780*
221 Columbus Ave.
Boston, Mass. 02116

When the lights go out, the only really portable Digital Multimeter goes on



...and on.

Run the Fluke 8100A 0.02% digital multimeter anywhere, anytime up to 8 full hours off the rechargeable battery pack. Printer output now available.

There are twenty or thirty digital multimeters around that lay claim to portability. The only one you can move around easily and use without a nearby wall plug is ours. It's the only portable machine that works where you need a portable machine.

True portability is just part of the story. The Fluke 8100A, with an accuracy of 0.02% and a selling price of $795, with rechargeable battery option, gives you nine times the accuracy of three digit instruments for half the price of comparable four digit multimeters. We've used a new A to D technique to give you an instrument with low power drain for eight-hour continuous battery operation without recharging. (line operation only $695)

The Fluke 8100A measures ac and dc volts in four ranges to 1200 volts and ohms in five ranges to twelve megohms. Readout is four full digits plus "1" for 20% overranging. Features include an active 2-pole switchable filter and automatic polarity indicator. All functions are push-button selectable.

Also available are RF and high voltage probes, switched ac-dc current shunts, a ruggedized case, and data output (line operation only).

John Fluke Mfg. Co., Inc., P.O. Box 7428, Seattle, Washington 98133. Phone (206) 774-2211. TWX: 910-449-2850 / In Europe, address Fluke Nederland (N.V.), P.O. Box 5053, Tilburg, Holland. Phone: (04250) 70130. Telex: 884-50237 / In the U.K., address Fluke International Corp., Garnett Close, Watford, WD2 4TT. Phone: Watford, 27769. Telex: 934583.

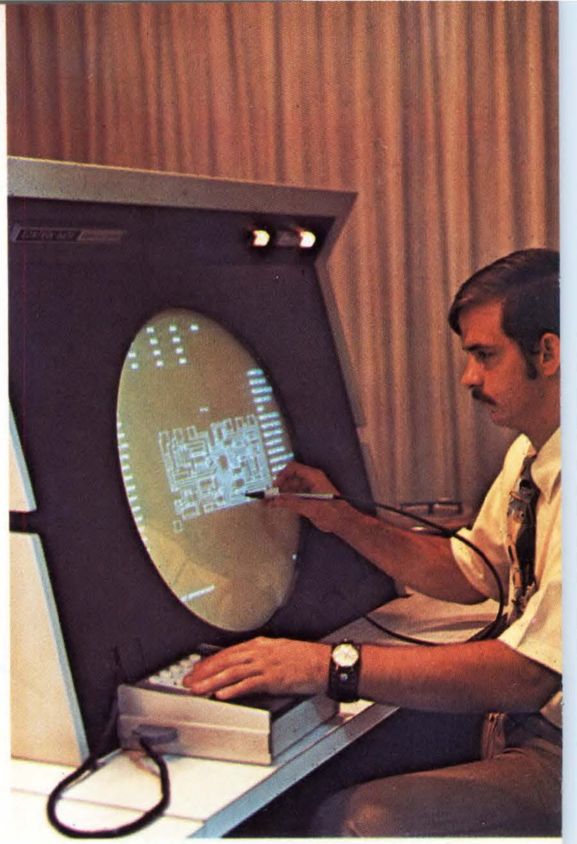
FLUKE®

Automatic Trimming Teams Laser and Computer

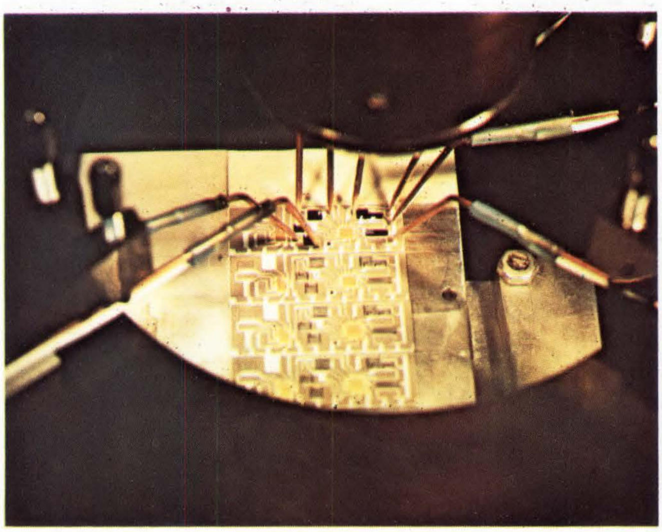
Laser trimming of film resistors continues to make inroads into areas once dominated by air abrasive (sandblasting) systems. The advantages offered by the laser technique—which include accuracy, speed of cut and cleanliness of the finished product—have contributed to the continuing gains being made by these systems.

Motorola Semiconductor, a company that has spent long hours working with laser systems, is a good example to show how one company has brought the laser system to today's point of sophistication. At Motorola it all began with the use of a YAG laser to scribe zener diode wafers. Later, a CO_2 system was added to the hybrid circuit production area for thick-film resistor trimming. And most recently, dynamic trimming is being performed under computer control. In dynamic trimming, resistors are trimmed while the circuit is operational in order to obtain optimized circuit performance. **Fig. 1** shows this technique applied to a practical circuit. This is the automated equivalent of hand selecting one or two components for a critical position in a circuit to get the required performance from that circuit.

With a computer married to a laser trimming system, the statistics for accuracy and speed that accompany such a match are impressive. One indicator of merit is a head traverse speed of 0.06 to 1.0 inches/sec that results in 1 to 2 resistor trims/sec.

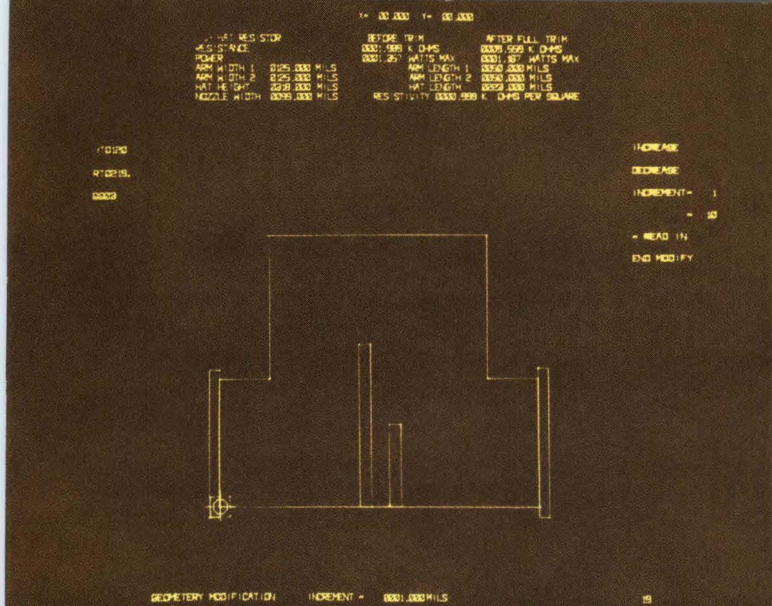


Demonstrating CAD of hybrid circuit. CAD system, consisting of light pen, CRT display and CDC 1700 computer, uses stored "polycell" designs to speed layouts. Computer displays numerical parameters associated with a selected design, such as resistor power dissipation, turn points for L-cut resistor trims, etc.

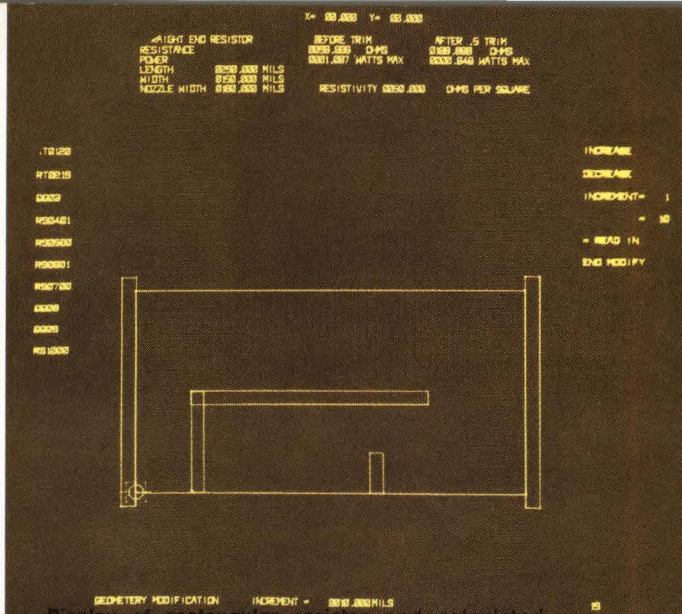


Circuit is hybrid IF detector, part of an automatic paging system. Resistors range from 2 to 150 kΩ with tolerances from 1 to 8%. Trim is passive, and both L and straight-in cuts are used. Two monolithic custom chips later will be bonded onto the substrate. Total trim time is about 5 sec. All resistors are cermet thick film. Kerf is about 2 mils wide and 1.5 mils deep. Resistor sizes range from 30 by 30 mils to 140 by 20 mils. Laser is running at 2.5W, Q switching at 7.5 kHz.

Entire laser/computer resistor trimming system. Laser safety shield normally is in down position, to protect operator from laser light. In photo, protective cover is raised, with laser off. "Teletype", to right, inputs operator instructions to system. Manual control box can be used to operate laser, stage motors, etc., and also contains emergency shutdown button. Left rack cabinet contains controls, interconnection matrices, power supplies and a programmable bridge.



Tophat resistor configuration, displayed on CRT console in CAD center. One or more cuts can be made to bring a resistor within desired tolerance. Bars at either side of tophat are metal circuit connections. Longest cut (left) produces the greatest percentage change in the resistor's value, while shorter cut is used as vernier. After trim, computer calculates resistor values and power handling capability, then displays data to operator.



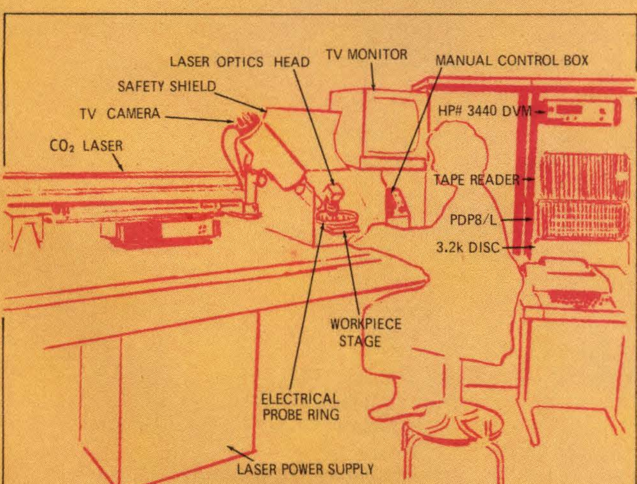
Display of rectangular resistor and calculated parameters. Trim option shown is L-cut, with additional vernier straight-in cut. L-cut offers slower change of resistance as function of cut length (after turn is made) than does straight-in cut. Result is higher accuracy resistor. Straight-in cut (made after L-cut) produces only slight additional increase in resistance.

(Depending on the number of resistors to be trimmed, a complete circuit normally takes about 10 sec for loading, trimming and unloading.) Another indication is that positioning (X-Y) accuracy is achieved to a resolution of ±0.2 mils (±5-mil silk-screened resistor registration is acceptable for successful trimming). Resistor values after trim are accurate to within ±0.1%. This is achieved by various cuts that include straight-in, L and combinations of these. Such a laser trimming system is 10 times faster than its air-abrasive counterpart.

In the Motorola system (shown in the photos), the computer controls both the laser beam and the measurement. It controls the X-Y stage motors, commands the laser to begin or stop and programs the traverse speed of the head which is not constant during a trim.

An off-line, time-shared computer is also called upon for solving field-distribution equations for a particular resistor. This time-shared computer is needed because of the extensive number of computations required. Field equations are solved to assess the effect of making L-cut turns at different points on the resistor.

In the future, Motorola engineers expect to add a rotary table for loading or unloading. This will speed the cycling of parts under the laser head. Laser head motion will probably be increased to 2 inches/sec, and perhaps even faster if mirrors are used. The limitation on speed stems from motor slew rate. As to tolerances, these probably will get down to ±0.05% without the need for major system redesign.



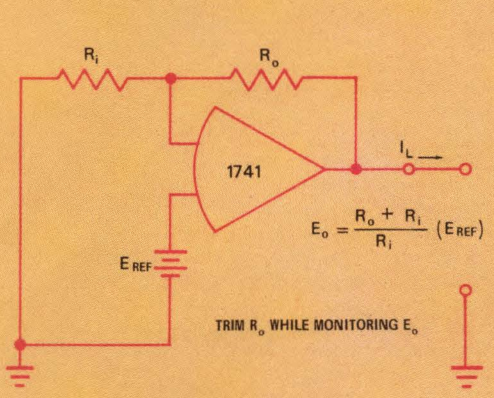


Fig. 1

IC Applications Seminar Planned for Los Angeles

EDN/EEE and approximately 25 IC manufacturers will stage a pair of 2-day seminars in October at the International Hotel, Los Angeles, Calif. Linear ICs will be covered in the first seminar scheduled for Tuesday-Wednesday, Oct. 5-6; Semiconductor Memories will be the topic at the second seminar, planned for Thursday-Friday, Oct. 7-8.

The papers being prepared for the program are applications-oriented —aimed at helping IC users select recently announced ICs and correctly apply them to their particular needs. Application hints and considerations will be stressed.

The tentative program follows:

Linear IC Program (First Day)
Tuesday, Oct. 5, 1971

L1 *"Monolithic D/A and A/D Building Blocks"*
Garth Wilson, Vice President, Engineering,
Precision Monolithics, Santa Clara, Calif.

L2 *"Advanced Bipolar and MOS Linear ICs and Their Applications"*
Merle Hoover, Manager, Linear Integrated Circuits, Applications Engineering,
RCA, Somerville, N. J.

L3 *Topic To Be Announced*
Gus Pfaehler, Linear Applications,
Fairchild Semiconductor, Mountain View, Calif.

L4 *"IC Voltage Regulators"*
Bob Mammano, Chief Engineer,
Silicon General, Westminster, Calif.

L5 *"Designing with Ultralow-Drift Operational Amplifiers"*
Doug Sullivan, President, Nova Devices, Affiliate of Analog Devices, Norwood, Mass.

L6 *"Fast Settling Time Amplifiers"*
Dave Ludwig, Director of Engineering,
Teledyne Philbrick, Dedham, Mass.

L7 *Topic and Speaker To Be Announced*
Teledyne Semiconductor, Palo Alto, Calif.

L8 *"Designing with D/A and A/D Converters"*
Jack Robertson, Executive Vice President,
Zeltex, Concord, Calif.

Linear IC Program (Second Day)
Wednesday, Oct. 6, 1971

L9 *"Applying Digital/Analog Interface Circuits"*
Don Jones, Applications Engineer,
Harris Semiconductor, Melbourne, Fla.

L10 *"Noise In Operational Amplifiers"*
Dave Fullagar, Engineering Manager for Analog Products,
Intersil, Cupertino, Calif.

L11 *"High-Speed Comparators"*
Jim Giles, Director of Engineering, Analog Operations,
Advanced Micro Devices, Sunnyvale, Calif.

L12 *Topic To Be Announced*
Colin Berry, Manager, Linear IC Development,
Signetics, Santa Clara, Calif.

L13 *"Common Problems and Solutions in Using Linear ICs"*
Karl Huehne, Industrial Applications Section Manager,
Motorola, Phoenix, Ariz.

L14 *Topic To Be Announced*
Joel Scheinberg, Linear Applications,
National Semiconductor, Santa Clara, Calif.

L15 *"Applications for Micropower Amplifiers"*
Wayne Folleta, Design Engineer,
Qualidyne, Sunnyvale, Calif.

L16 *"Designing with Micropower Operational Amplifiers"*
Jim Bohorquez, Linear Products Manager,
Solitron Devices, San Diego, Calif.

L17 *"Interface Circuits for Computer Systems"*
Dale Pippenger, Product Engineer,
Texas Instruments Incorporated, Dallas, Texas

Semiconductor Memory Program (First Day)
Thursday, Oct. 7, 1971

M1 *"Field Programming vs Factory Programming of ROMs"*
Marv Pollock, Manager of Applications Engineering,
Unisem, Trevose, Pa.

M2 *Topic and Speaker To Be Announced*
Collins Radio, Newport Beach, Calif.

M3 *"Using Standard Semiconductor Memories"*
Dale Mrazek, Memory Applications Manager,
National Semiconductor, Santa Clara, Calif.

M4 *"Trends in Semiconductor Memories"*
Bob Kressler, Semiconductor Memory Applications Manager,
Texas Instruments Incorporated, Dallas, Texas

M5 *Topic To Be Announced*
Vahe Sarkissian, IC Applications,
Fairchild Semiconductor, Mountain View, Calif.

M6 *"New MOS and Bipolar Semiconductor Memories"*
Sven Simonsen, Director of Engineering, Digital Operations,
Advanced Micro Devices, Sunnyvale, Calif.

M7 *"A Comparison of Various Dynamic RAMs"*
Al Tuszynski, Consultant,
Solitron Devices, San Diego, Calif.

M8 *Topic To Be Announced*
Bud Broeker, Applications Manager,
Motorola, Phoenix, Ariz.

M9 *"Bipolar Read-Only-Memory Applications"*
Joe Rizzi, Vice President, Bipolar Memory Operations,
Intersil, Cupertino, Calif.

Semiconductor Memory Program (Second Day)
Friday, Oct. 8, 1971

M10 *"Memory System Design with MOS RAMs"*
Gordon Hoffman, Applications Engineering Manager,
MOSTEK, Carrollton, Texas

M11 *"New Single-Transistor-Cell MOS RAMs"*
Leo Cohen, Manager, Advanced Product Development,
General Instrument, Hicksville, N.Y.

M12 *"Designing High-Speed Memory Systems with Read-Write Memories"*
Ron Livingston,
Advanced Memory Systems, Sunnyvale, Calif.

M13 *"Using Dynamic Refresh MOS RAMs in Large Memory Systems"*
Mike Markkula, Marketing Manager and Ted Hoff, Manager, Applications Research,
Intel, Santa Clara, Calif.

M14 *"Large-Scale Bipolar Memory Systems"*
H. William Slaymaker, Manager, Applications Engineering,
SEMI, Phoenix, Ariz.

M15 *Topic and Speaker To Be Announced*
Computer Microtechnology, Sunnyvale, Calif.

M16 *"MOS Arrays in Character Generation and Other Applications"*
Dick Eiler, Director, Product Marketing Engineering,
Electronic Arrays, Mountain View, Calif.

M17 *"Bipolar and MOS Memory System Design"*
George Rigg, Manager, Memory Systems Applications,
Signetics, Sunnyvale, Calif.

CELANESE NYLON IS MADE IN A TOTALLY CONTINUOUS PROCESS. THAT'S ADVANTAGE NO. 1.

Whiteness. We make Celanese nylon in a continuous, patented process—so it has a shorter heat history. That's why it's whiter in the pellet. Whiter in your products. And it's whiter through successive regrinds.

It's one advantage that Buchanan Electrical Products Corporation gets by using Celanese nylon for terminal blocks, connectors—some 30 other electrical parts.

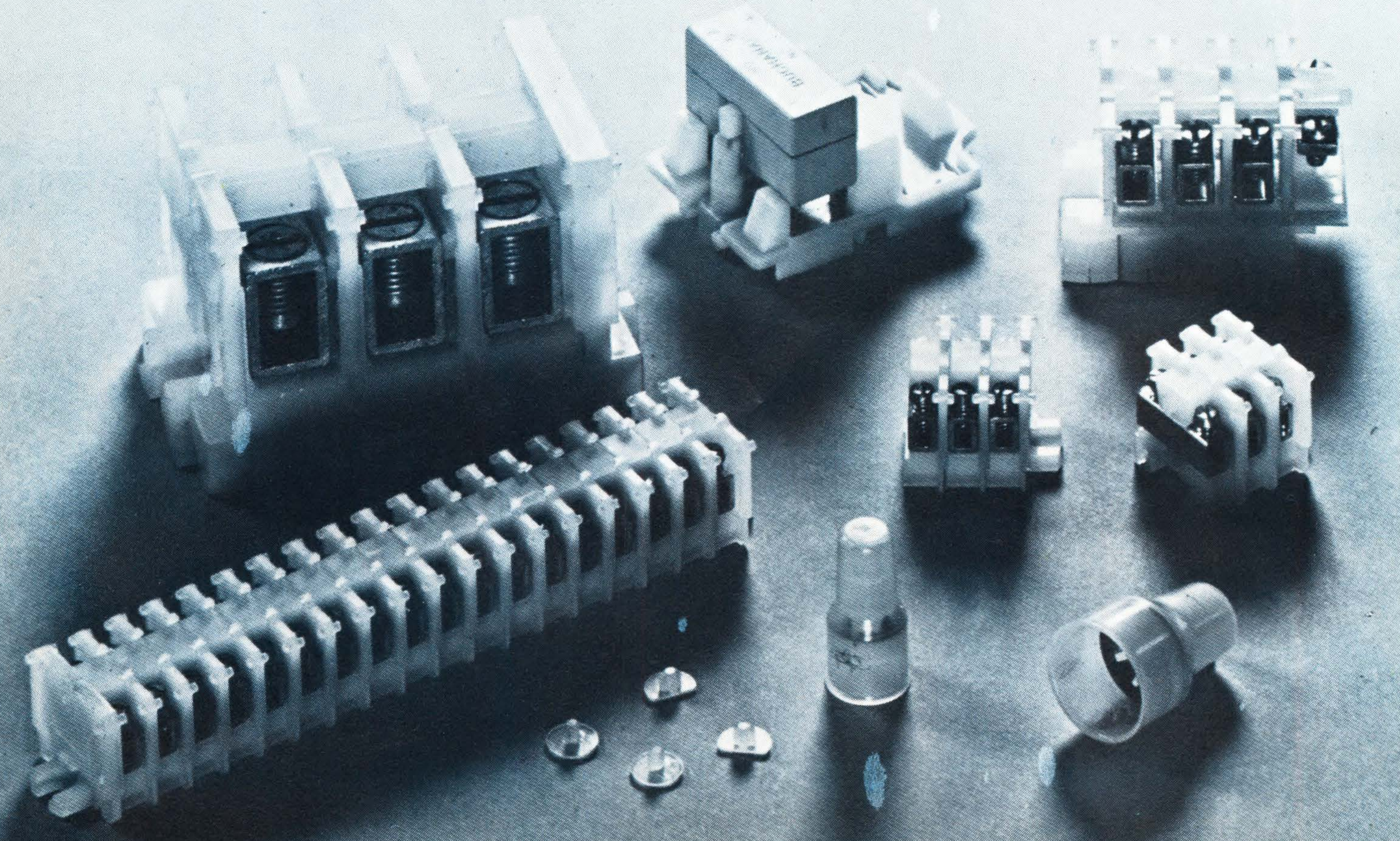
Other reasons for using Celanese nylon include high dielectric properties, which allow thinner walls, more compact units. Great mechanical strength and toughness. Resilience, for parts that have to snap-fit. Hold. Celanese nylon is self-extinguishing. And it has U/L rating on electrical properties of 105°C.

In fact, Celanese nylon has all the best properties you expect in nylon. Without the yellow. Write for a copy of our brochure on electrical applications of Celanese nylon. Also a U/L Yellow Card. Celanese Plastics Company, Dept. N-500, 1090 Lousons Rd., Union, New Jersey 07083.

Celanese Plastics Company is a division of Celanese Corporation. Canadian Affiliate: Chemcell Resources, Ltd. Export: Amcel Co., Inc., and Pan Amcel Co., Inc., 522 Fifth Ave., New York 10036.

CELANESE PLASTICS

CIRCLE NO. 8



More Jobs Predicted for U.S. Engineers Because of 10% Surcharge

The rate at which consumer and commercial equipment design jobs are going offshore should be slowed down by President Nixon's 10% surcharge on imports, according to scattered industry sources. For the most part, these were component makers who have been very conscious of design going abroad. When U.S. engineers aren't doing the full design, component makers have found it much less likely that U.S. components will be used.

"Now U.S. companies won't be so quick to go offshore once their products go into high volume," predicted John Yngve, president of Nortronics Co., Inc., Minneapolis, Minn.—a leading tape-head manufacturer. "All too often in the past we have had the painful experience of helping a U.S. manufacturer through the R&D phase of new product development and investing considerable engineering talent, in the hopes of getting his volume orders once the product goes into full production . . . only to see the product line go offshore and the Japanese and others cash in on the rewards."

"Right now we're worried that the very promising digital cassette products might suddenly go the way of the audio cassettes and be made almost wholly in Japan," Yngve said. "It is the old familiar pattern. There is a lot of new-product development going on in the U.S., but we hear of ominous developments in Europe and Japan. The President's message may have come in the nick of time."

Yngve agreed that U.S. engineers who thought they were in on the ground floor on a new product family have also been "betrayed" in such cases. When the product goes offshore, sooner or later the engineers' jobs go offshore with it.

The effect of the surcharge may be more psychological than absolute, according to Jack Stegenga, Weston, Newark, N. J. "It might take a surcharge as high as 50% to completely stop foreign competition in electronics," Stegenga stated. "Weston has been able to avoid head-on competition from the Japanese because the instruments we make typically sell in 10,000-unit-per-year volume levels, not the million-unit-per-year levels that the Japanese like." Weston is well aware of the effect of Japanese competition, however, from experience with its photographic light meter lines.

"The surcharge will make U.S. manufacturers stop and think before they invest further in offshore sources," reasoned Ron Stannish, U.I.D., Hollywood, Fla. "I think the President made it clear that they will be hurting the U.S. if they do so, and our country can't stand too much more of this sort of harm."

Stannish, who is Marketing Manager for U.I.D., said that all the purchasing agents he has talked to in electronic companies since the President's announcement expect that this 10% surcharge will be around for a long time. But it is causing some interesting situations: "Take the switches we sell U.S. manufacturers—switches that they in turn ship over to Taiwan to be assembled into their products. They know that they can bring U.S.-made components like ours back duty free, while any part they buy over there will cost them 10% extra to bring into the U.S. I think that now we will be more apt to have engineering design and component manufacture remain in the U.S., even when assembly is done offshore. Since offshore assembly labor can be dramatically cheaper than stateside labor, the 10% added to that fraction of the product might not seem too bad for the U.S. manufacturer."

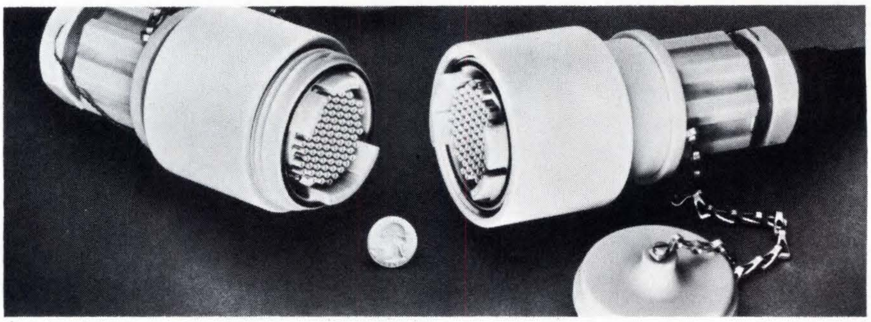
"The problem with Japanese competition in components is that it gets roughest at the highest volumes—just where the real money is," said Walt Jemison, general manager at Michigan Magnetics, Vermontville, Mich.—another tape-head manufacturer that has tilted with the Japanese. "For small-volume orders—under 5000—we are only about 20% higher, and half the time the Japanese won't even bother to quote on these. But for large-volume orders—over 10,000—we are 100 to 150% higher. The Japanese can sell an eight-track automotive cartridge player head for $0.89 while we can't go below $1.65. Obviously, even with the 10% surcharge, they can beat us. However, I agree that the psychological aspect of the President's action will definitely help us. It ought to give courage to those few remaining stateside manufacturers of audio entertainment products, like 3M and VM in the cassette field. They, and others in similar predicaments, will continue to provide jobs for U.S. engineers."

Connector Takes Rough Treatment

Special requirements of the oil industry have prompted the development of a connector that will stand up under extreme environmental conditions.

Subterranean oil deposits are located through analysis of seismic readings obtained by detonating explosive charges in potential oil-bearing terrain. This analysis involves the use of multisection cables containing geophones that pick up seismic vibrations, transform them into electrical impulses and transmit them through the cable to amplifiers and recorders. The patterns thus recorded are then studied for indications of oil deposits.

A standard cable might consist of 48 sections, each section up to 300 feet long, interconnected with a heavy-duty connector. This is where the "RUF-NEK" connector, developed by Hughes Aircraft Company's Connecting Devices Div., Newport Beach, Calif., comes in.



Since the cables are laid on open terrain for distances up to three miles, the connectors must be capable of withstanding rough field handling and all types of weather conditions. Tests of the "RUF-NEK" show that it will remain sealed in up to 100 feet of water, withstand 3000 pounds of tension and even the load of a 39,000-pound truck. Identical halves mate with each other eliminating the need for male and female versions of the connector. With 164 contacts, it meets current and foreseeable needs of the oil industry.

Other potential uses are in mining, portable field recording and instrumentation, utilities, communications and other commercial and military ground equipment cable applications.

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

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

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

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

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

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

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

Celanese Plastics Company is a division of Celanese Corporation. Canadian Affiliate: Chemcell Resources, Ltd. Export: Amcel Co., Inc., and Pan Amcel Co., Inc., 522 Fifth Ave., New York 10036.

CELANESE PLASTICS

CIRCLE NO. 9

Molders: A. L. Hyde Co., Grenloch, N.J., Rapid Tool & Mfg. Co., Newark, N.J.

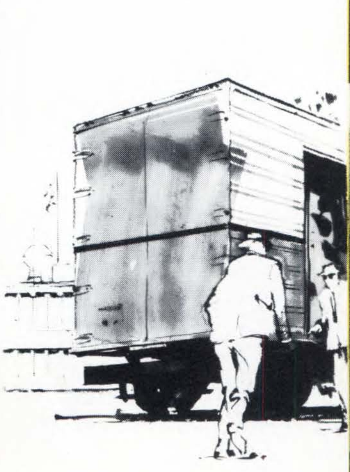
Watch for EDN/EEE's fifth annual Caravan tour, October-November 1971. A traveling exposition of products and ideas visiting leading computer and peripheral equipment manufacturers throughout the U.S.A.

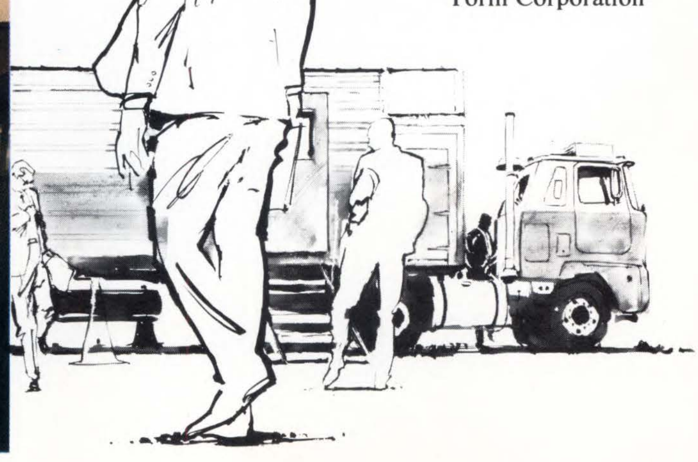
EDN EEE MAGAZINE PRESENTS...

Caravan '71

Featuring new products, ideas and application assistance from:

Advanced Memories Systems, Inc.
Beckman Instruments, Inc.
Belden Corp.
Borden Chemical Mystik Tape Div.
Cinch Mfg. Co.
Cornell-Dubilier Electronics
Dale Electronics, Inc.
Data Products Core Memories, Inc.
Instrument Specialties Co., Inc.
NASA Headquarters
Raychem Corporation
Semiconductor Electronic Memories, Inc.
Torin Corporation





EDN/EEE CARAVAN ROUTING

October 4 - November 5, 1971

DATE / DAY / TIME	AREA	SITE
Monday, Oct. 4		
9:00 - 12:00 noon	Boulder, Colorado	IBM
1:30 - 4:30 p.m.	Loveland, Colorado	Hewlett-Packard
Tuesday, Oct. 5		
9:00 - 11:30 a.m.	Denver, Colorado	Honeywell
2:00 - 4:30 p.m.	Colorado Springs, Colo.	Hewlett-Packard
Friday, Oct. 8		
9:00 - 12:00 noon	Cedar Rapids, Iowa	Collins Radio
Monday, Oct. 11		
9:00 - 11:30 a.m.	Rochester, Minn.	IBM
2:00 - 4:30 p.m.	St. Paul, Minn.	3M
Tuesday, Oct. 12		
9:00 - 12:00 noon	Arden Hills, Minn.	Control Data
1:30 - 4:30 p.m.	Normandale, Minn.	Control Data
Wednesday, Oct. 13		
9:00 - 12:00 noon	Roseville, Minn.	Univac
1:30 - 4:30 p.m.	St. Paul, Minn.	Univac
Friday, Oct. 15		
9:00 - 12:00 noon	Chicago, Ill.	A. B. Dick
1:30 - 4:30 p.m.	Northlake, Ill.	Automatic Electric Labs.
Monday, Oct. 18		
9:00 - 12:00 noon	Lincolnwood, Ill.	Bell & Howell
1:30 - 4:30 p.m.	Skokie, Ill.	Teletype
Tuesday, Oct. 19		
12:00 - 5:00 p.m.	Ft. Wayne, Ind.	Magnavox (Corp. Office 12-1:30 (Bueter Rd. 2-3:30 (Ind. Park 4-5:00
Wednesday, Oct. 20		
9:00 - 11:00 a.m.	Dayton, Ohio	NCR
2:00 - 4:30 p.m.	Galion, Ohio	North Electric
Thursday, Oct. 21		
9:00 - 12:00 noon	Southfield, Mich.	Bendix
1:30 - 4:30 p.m.	Plymouth, Mich.	Burroughs
Friday, Oct. 22		
1:30 - 4:30 p.m.	Cleveland, Ohio	Addressograph-Multigraph
Monday, Oct. 25		
9:00 - 12:00 noon	Rochester, N.Y.	Eastman Kodak
1:30 - 4:30 p.m.	Rochester, N.Y.	Xerox
Tuesday, Oct. 26		
9:00 - 12:00 noon	Owego, N.Y.	IBM/Federal Systems
1:30 - 4:30 p.m.	Endicott, N.Y.	IBM
Wednesday, Oct. 27		
9:00 - 12:00 noon	Binghamton, N.Y.	General Precision/Link
Thursday, Oct. 28		
9:00 - 12:00 noon	Herkimer, N.Y.	Mohawk Data Science
Friday, Oct. 29		
9:00 - 12:00 noon	Kingston, N.Y.	IBM
2:00 - 4:30 p.m.	Poughkeepsie, N.Y.	IBM
Monday, Nov. 1		
9:00 - 11:30 a.m.	Nashua, N.H.	Sanders
1:30 - 4:30 p.m.	Tewksbury, Mass.	Wang Labs.
Tuesday, Nov. 2		
9:00 - 12:00 noon	Maynard, Mass.	Digital Equipment
1:30 - 4:30 p.m.	W. Concord, Mass.	General Radio
Wednesday, Nov. 3		
9:00 - 12:00 noon	Burlington, Mass.	RCA
1:30 - 4:30 p.m.	Needham, Mass.	Sylvania
Thursday, Nov. 4		
9:00 - 11:30 a.m.	Marlboro, Mass.	RCA
1:30 - 4:30 p.m.	Melrose, Mass.	Mohawk Data
Friday, Nov. 5		
9:00 - 12:00 noon	Norwood, Mass.	Raytheon
1:30 - 4:30 p.m.	Framingham, Mass.	Honeywell

EDN/EEE

and

26 IC Manufacturers

will conduct an

IC Applications Seminar

International Hotel, Los Angeles
October 5-8, 1971

Emphasis will be on application hints for maximum effectiveness . . . to help circuit and system designers select and design with new integrated circuits. The seminar will be divided into two programs: linear ICs on October 5-6 and semiconductor memories on October 7-8. Attendees may register for either one or both programs.

All of the papers being prepared for the seminar are new, dealing with fresh approaches to IC applications. The authors represent many years of experience in solving problems relating to ICs and improved circuit, system and equipment designs.

Participating IC Manufacturers: Advanced Memory Systems
Advanced Micro Devices • Analog Devices
Burr-Brown • Computer Microtechnology
Electronic Arrays • Fairchild Semiconductor • General Instrument
Harris Semiconductor • Intel • Intersil • MOSTEK • Motorola
National Semiconductor • Precision Monolithics • Qualidyne • RCA • SEMI
Signetics • Silicon General • Solitron • Teledyne Philbrick
Teledyne Semiconductor • Texas Instruments Incorporated • Unisem • Zeltex

Some Participating Speakers

Bob Mammano: (left) engineering manager at Silicon General since formation of the company in 1969 . . . was previously with ARINC Research . . .

Mike Markkula: recently joined Intel from Fairchild Semiconductor where he was director of IC product marketing . . .

Merle Hoover: manager of linear integrated circuit applications engineering at RCA . . . has 13 microelectronic patents . . .

Jim Bohorquez: linear products manager at Solitron Devices . . . was a senior design engineer with the Union Carbide microcircuit operation when it was purchased by Solitron in 1970 . . .

Leo Cohen: manager of advanced product development at General Instrument . . . is responsible for the development of new MOS arrays . . .

Linear IC Program Speakers: Garth Wilson, Precision Monolithics; Merle Hoover, RCA; Gus Pfaehler, Fairchild Semiconductor; Bob Mammano, Silicon General; Doug Sullivan, Analog Devices; Dave Ludwig, Teledyne Philbrick; Jerry Graeme, Burr-Brown; Jack Robertson, Zeltex; Don Jones, Harris Semiconductor; Dave Fullagar, Intersil; Jim Giles, Advanced Micro Devices; Colin Berry, Signetics; Karl Huehne, Motorola; Joel Scheinberg, National Semiconductor; Wayne Folleta, Qualidyne; Jim Bohorquez, Solitron Devices; Dale Pippenger, Texas Instruments Incorporated; and others to be announced.

Semiconductor Memory Program Speakers: Marv Pollock, Unisem; Dale Mrazek, National Semiconductor; Bob Kressler, Texas Instruments Incorporated; Sven Simonsen, Advanced Micro Devices; Al Tuszynski, Solitron Devices; Bud Broeker, Motorola; Joe Rizzi, Intersil; Gordon Hoffman, MOSTEK; Leo Cohen, General Instrument; Ron Livingston, Advanced Memory Systems; Mike Markkula, Intel; H. William Slaymaker, SEMI; Dick Eiler, Electronic Arrays; George Rigg, Signetics; Vahe Sarkissian, Fairchild Semiconductor; and others to be announced.

Partial List of Linear IC Papers:

- *Monolithic D/A and A/D Building Blocks*
- *Designing with Ultra Low-Drift Operational Amplifiers*
- *Fast Settling Time Amplifiers*
- *Designing with D/A and A/D Converters*
- *Applying Digital/Analog Interface Circuits*
- *Noise in Operational Amplifiers*
- *High Speed Comparators*
- *Applications for Micropower Amplifiers*
- *Designing with Micropower Operational Amplifiers*
- *Interface Circuits for Computer Systems*

Partial List of Semiconductor Memory Papers:

- *Field Programming vs Factory Programming of ROMs*
- *Trends in Semiconductor Memories*
- *New MOS and Bipolar Semiconductor Memories*
- *A Comparison of Various Dynamic RAMs*
- *Bipolar Read-Only-Memory Applications*
- *Memory System Design with MOS RAMs*
- *New Single-Transistor-Cell MOS RAMs*
- *MOS/Bipolar Memory Systems*
- *Using Dynamic Refresh MOS RAMS in Large Memory Systems*
- *Large-Scale Bipolar Memory Systems*

Time:
Programs will run from 9 a.m. to 5 p.m. with coffee break at 8:45, lunch and an afternoon break each day.

Place:
International Hotel,
6211 W. Century Blvd.,
Los Angeles, CA 90045
(213 670-9000).

Registration:
Linear IC Program—$95; Semiconductor Memory Program—$125. The fees include registration, meeting materials, luncheons and refreshments. Tickets will be mailed to registrants unless requested to be held at reception desk.

Seminar Registration

Please register me for:

☐ The Linear IC Applications Program, October 5-6, 1971. Fee: $95

☐ The Semiconductor Memory Applications Program, October 7-8, 1971. Fee: $125

☐ Both Programs. Fee: $220

Note: If you wish to confirm reservations by phone, call (212) 689-3250. Ask for seminar registrar, Ext. 252.

Name________________

Title________________

Company________________

Address________________

City________________

State________________

☐ Check enclosed ☐ Bill me ☐ Bill company

Make checks payable to EDN/EEE Seminars and mail to: 205 E. 42nd St., New York, NY 10017.

There is a place for both ceramic and tantalum chips in miniaturized circuit applications.

And you just found it.

Union Carbide.

Who makes KEMET® chips in both ceramic and solid tantalum. All with the exclusive Solder-Guard copper barrier layer. That enables KEMET chips to withstand the severe temperatures of solder-reflow assembly. With no degradation of performance and electrical characteristics.

The KEMET ceramic chips are available in ratings from 10 through 330,000 picofarads. The KEMET tantalum chips, from 100,000 picofarads through 100 microfarads.

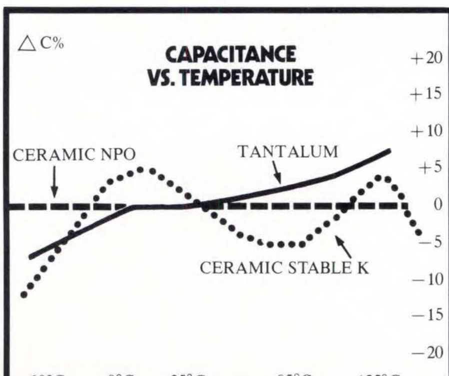
The ceramics will withstand 260° C. for 20 minutes; the tantalums will withstand 300°C. for 3 minutes.

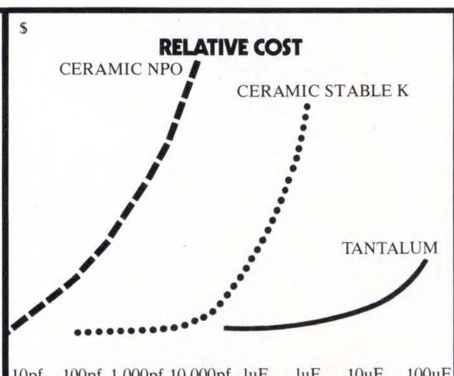
Check the tables below for stability and cost comparisons. Then write for free engineering samples and technical data. At Box 5928, Greenville, S.C. 29606.

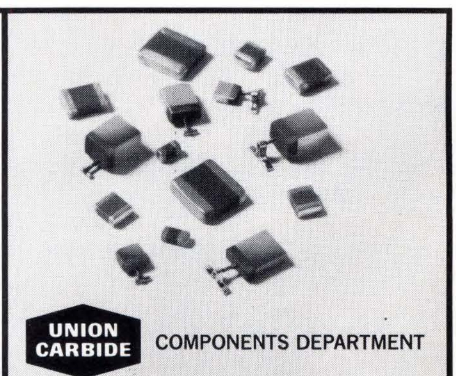
And be glad.

That specifying chips will be easier from now on.

Because one manufacturer has the technology to offer you both kinds.







CIRCLE NO. 11

WHAT'S HAPPENING IN MOS

After seeing what MOS was all about in the last issue, it is time to move ahead and find out what is happening today, what is now available and what to look for in the future.

ROY W. FORSBERG, Boston Editor

In the September 1, 1971 issue of EDN/EEE ("Making Sense Out of the MOS Muddle") we looked at each technology as it is known today, defined terms and placed these terms in their proper perspective. Now we will view the MOS world today and see what's in store for the future.

Which Processes Will Survive?

This is a very important consideration for designers, and a perplexing one for semiconductor manufacturers. To be sure, no one technology is best for all applications so there should be many survivors. Of course, some super breakthrough could upset the thinking of the industry as it is today. It could make one or two processes the best for most applications, but this seems unlikely for the next 5 years at least. It looks as though a number of technologies will become standard in the years to come and be directly related to applications.

High-threshold p-channel <111> will continue for a number of years simply because of its sheer volume in the field and a certain amount of inertia. Most new designs, however, whether cost-conscious or not will use some low-threshold process because many will be cost-competitive very soon. As a matter of fact, Intel claims it can make p-channel silicon gate devices right now at lower costs, General Digital claims it can make them at the same cost and others like Electronic Arrays feel things will be equal by the end of 1971.

Low threshold p-channel <100> will not be a continuing process except as a replacement item in existing products. There are already too many processes such as nitride, ion implant and p-channel silicon gate that are cost-competitive and still offer many performance advantages. The exception here is National Semiconductor which attains high field thresholds and good performance by special processing.

The low-threshold, high-field, p-channel nitride process should become a standard for low-cost, relatively low-speed and medium density applications, and can replace both high-threshold p-channel <111> and low threshold p-channel <100> in these areas. It could be that some form of dielectric comparable in properties to nitride, but easier to handle, will come along—but the basic process will remain.

P-channel silicon gate should become the workhorse for applications requiring high density and medium power, speed and cost. As the process is refined, it will also compete in low-cost applications.

Ion implantation as a processing tool will be used in one way or another by all manufacturers within a few years. Equipment will be refined and become less costly as more suppliers move into this market. Because of its ability to adjust thresholds, make depletion devices, make CMOS devices, etc., it is too useful a tool to ignore. Circuits made by ion implantation will be cost-competitive with most other technologies and offer some performance advantages.

Complementary MOS will also be a standard for many existing and new market areas. Its low power, high speed, wide supply tolerances and high noise immunity place it in a unique position to meet many design needs that can't be solved by other technologies. Its only real competitor in some of these markets will be a single-channel ion-implant process. CMOS will find it difficult to compete with many of the single-channel processes for use in high volume LSI arrays, except for those special needs calling for its low power, high noise immunity, wide operating voltage properties. As the process is refined further, costs could tumble and the features noted could make CMOS a close competitor for MSI and LSI bipolar arrays.

The real sleeper in this whole game could be some form of n-channel device, with silicon gate as the most likely candidate. Processing difficulties have been a real drag to this process and when they are overcome—whether by silicon gates, field shields or other means—n-channel could take over most performance-oriented applications requiring high speed, high densities and

(Continued)

FOR A FREE REPRINT OF THIS ARTICLE, **CIRCLE NO. L61**

MOS (Cont'd)

PROCESS	SILICON ORIENTATION	THRESHOLD VOLTAGE	FIELD OR PARASITIC INVERSION	POWER SUPPLIES	GAIN FACTOR
High-Voltage P-Channel	<111>	3–6	30	20–30	2.5
Low-Voltage P-Channel	<100>	1.5–3	15	10–15 (often +5 & −12)	2.0
Low-Voltage/High Field P-Channel (with channel stops)	<100>	1.5–3	30	10–30	2.0
N-Channel Enchancement	<100>	0.5–2	15	5–15	6
N-Channel Field Shield	<100>	0.4–0.8	∞	5–15	–
N-Channel Depletion	<100>	1–4 (Pinchoff)	15	5–15	8
High-Voltage P-Channel Nitride	<111>	3–6	30	20–30	2.5
Low-Voltage P-Channel Nitride	<100>	1.5–3	15	10–15	2.2
Low-Voltage/High Field P-Channel Nitride	<111>	1.5–3.0	25	10–25	8
SATO	<111>	1.5–2.5	25	10–25	2.5
SATO Si Gate	<111>	1.5–2.5	20 (Si) 45(Al)	10–25	2.5
Low-Voltage Complementary	<100>	1.5–3 (p) 1.5–3 (n)	30 (p) 16 (n)	5–15	2.0 (p) 4.0 (n)
Ultra-Low Voltage Complementary	<100>	0.5–1 (p) 0.5–1 (n)	5 (p) 5 (n)	1–5	2.0 (p) 6.0 (n)
P-Channel Si Gate	<111>	1.5–2.5	15 (Si) 25 (Al)	10–25	2.5
N-Channel Si Gate	<100>	0.5–2	15	5–15	6.0
Low-Voltage Complementary Si Gate	<111>	1.5–2.5 (p) 1.5–2.5 (n)	25 p (Al) 15 n (Al)	5–15	2.5 (p) 4.0 (n)
Ultra-Low Voltage Complementary Si Gate	<100>	0.5–1 (p) 0.5–1 (n)	5 p (Al) 5 n (Al)	1–5	2.0 (p) 6.0 (n)
Ion-Implantation	ANY	In threshold tailoring process, typically adjusted 0-3V from base process value. No change when used only for self-aligned structures	Unchanged from base process	Modified according to threshold voltage	Same as base process

Table I

relatively low costs and power.

If you look at American Micro-systems Inc., the recognized production house of the MOS industry, you will find them either in production or hard at work on almost all of the above processes. AMI is especially enthused over ion implantation as a processing technique.

The use of refractory metals in place of silicon gates offers many advantages. However, the inertia of the drive toward silicon will probably more than offset these advantages and keep refractory metals in the background.

There are still a number of processes similar to those already mentioned but unique to a single company. To the design engineer, they are analogous to some of the other processes as far as performance is concerned and can be interchanged at will. Thus for a particular company, its own process can be the best cost/performance one and be dominant for that company. One that stands out in this category is the SATO process at Texas Instruments Incorporated. There should be no problem at all with this situation, for if all cost/performance requirements are equal, a designer shouldn't be too concerned with which process makes his circuits.

Silicon on sapphire or spinel will not be a reality for 3 to 5 years at least. There are many difficulties to overcome, among them very high cost. If problems are solved, CMOS could really take off. Most feel that today's needs, and those of the near-future, can be adequately met by current technologies without SOS. (See **Table I** for a MOS process summary.)

What to Expect in the Future

More and more MOS in plastic packages, with an attendant cost reduction, is the general byword throughout the industry. The multilevels of metal approach is also seen by many as coming. This could lead to speed and complexity gains as great as 2X in random logic and 40-50% in memories.

Collins expects to produce MOS arrays on chips as large as 250 mils on a side as a result of artwork improvements and new masking techniques.

Hughes and National Semiconductor see high V_T MOS devices in the hundred-volt ranges for driving things like gas displays. National already has as a standard product a neon driver with output capabilities to 115V.

Computer Microtechnology predicts that n-channel silicon gate circuits with depletion loads will be in volume production in 2 years. Devices will have a single 5V supply and could replace some MSI now in TTL.

MOSTEK envisions n-channel devices made by implanting positive ions in the channel until the normally depletion devices become enhancement-mode devices. They also see depletion loads making superior analog circuits which will permit the placement of high-gain amplifiers, differential amplifiers and the like on complex arrays.

Motorola also expects increased mixing of analog and digital devices on the same chip.

Solid State Scientific and Bell Labs anticipate the emergence of many forms of electron beam techniques. For example, applications could be ion-beam photoresist for greater resolution, ion back sputtering for etching (more pure) and ion implant. The significance of this is that all three are done in a vacuum, thus they are very clean and should lead to high yields.

A Word about Depletion Mode Transistors

Not too many people argue against Harry Neil of Intersil when he says that depletion load devices are the designer's dream of the future, much as current sources are used by linear circuit designers.

Depletion-mode devices are used as constant current loads for enhancement-mode drive transistors. This arrangement, similar in a sense to CMOS, makes the circuit insensitive to power supply variations, and allows internal voltage swings equal to the supply without need for a V_{GG} supply. It results in a higher speed/power product, so lower power is needed for equivalent performance. These devices also permit smaller output drivers (see **Fig. 1**) and allow linear operation.

Depletion-mode loads are currently being made by ion implantation, however Texas Instruments Incorporated and others expect to be able to do it by different

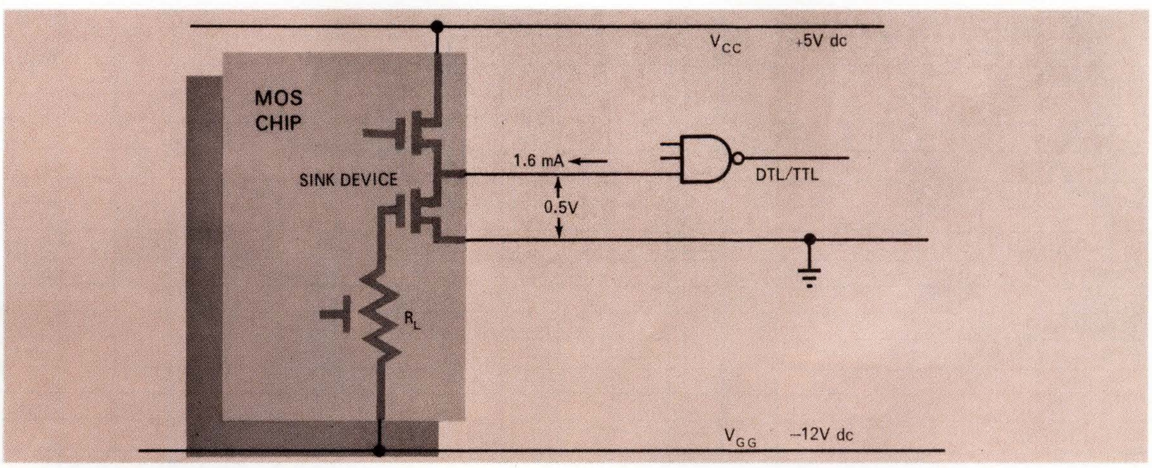


Fig. 1—**MOS Output Buffer Stage.** The output sink device must present an impedance of less than 310Ω which is a function of both device size and gate voltage. When used as R_L, an ion-implanted depletion-mode device provides a much more negative drive for the output device than that from an enhancement-mode (Si-gate) R_L device. Because of this increased drive, size typically is reduced more than 2:1—from perhaps a 130- to a 50-mil² area.

(continued)

means. National Semiconductor uses circuit design tricks to get other devices to act like depletion devices, but at the expense of real-estate. The alternative to enhancement-depletion mode operation is CMOS, with a saving in power but at the cost of space.

Random Thoughts

Be careful when making a decision to use MOS for your new designs. There is a minimum level below which it is neither economical nor efficient to use custom designs. First talk to a number of vendors who can help you pick the right technology. Remember, MOS does not fit all applications efficiently.

Don't go to a vendor and specify a particular technology for your new designs. Talk to more than one, including some who have multiprocess capability. It could very well be that your design can be made cheaper and more efficiently by a process other than the one you had in mind.

Consider carefully the source for your product. It is just as important to evaluate the manufacturer's capability and reliability as it is the process. Make sure that the product is available in adequate quantities and with the qualities needed.

When evaluating different process costs, keep in mind total system costs including cost of power, PC board cost, space, clocks, drivers and decoders and the like.

If you don't need TTL compatibility, don't ask for it. By avoiding it, you may be able to end up with higher-performance, lower-cost circuits.

Be careful about picking a new, unproven, short-history technology. If you do, you'll have to compile your own performance and reliability history.

In specs, watch for guaranteed speeds rather than nominal ones. The question to be answered is: Can the

KEY
P = Production status
N = Lab to pilot production status
* = with silicon gates

	PMOS High V_T ⟨111⟩	PMOS ⟨100⟩	PMOS Thin Oxide	MTNS or MNOS (nitride)	SATO with and without silicon gates	NMOS	PMOS Silicon Gate	NMOS Silicon Gate	Ion Implant (SAG)	Ion Implant - Low V_T	CMOS	NMOS - Field Shield	RMOS	DMOS
Advanced Micro Devices						N	P							
American Micro-Systems Inc.	P	P				N	P			P	N			
Cogar						P								
Collins Radio	P			P					N	N				
Computer Microtechnology		P					P	N						
Electronic Arrays	P							N						
Fairchild Semiconductor	P	P	P				P	N	N*	N				
General Digital	P						P							
General Electric													P	
General Instrument	P			P			P				P			
Hughes Aircraft		P	P						P		P			
Intel							P	N						
Intersil	P						P	N			P*			
MOS Technology	P			P				N		N	N			
Mostek	P							N		P	N			
Motorola	P	P				N	P	N			P*	N	N	
National Semiconductor		P					P							
NCR	P													
Nortec	P	P		P		N	P	P			P			
North American Rockwell	P			P		N	P	N			N			
Ragen Semiconductor											P			
RCA											P			
Signetics	P						P	N		N				N
Solid State Scientific								P			P-N*			
Solitron		P												
Texas Instruments Incorporated	P	P		P	P	N				N	N			
Varadyne				P								P		

Table II shows which processes are being used by each company.

	RAM-Dynamic	RAM-Static	ROM-Dynamic	ROM-Static	Shift Register-Dynamic	Shift Register-Static	Multiplexers	Character Generators	Random Logic	Discrete Logic Gates	Calculator Circuits	Data Communication Circuits	Timing Circuits	Counters	Frequency Dividers	Shift Register Variable Length	Series/Shunt Switch
Advanced Micro Devices	l	l			l												
American Micro-systems inc.	c l	f	c	b f	b c f	b c	b					c					b c
Cogar	n		n														
Collins Radio		b d	d	b	b d		b	d	b d								
Computer Microtechnology	l	b c l			l												
Electronic Arrays	b n		b	b	b	b		b			b					b	
Fairchild Semiconductor	l	b l		b l	b c l	b l	c l	l	b c l	b	b l	l	l	l	l		
General Digital	Custom random logic in combination of RAM, ROM, S/R (b,l)																
General Electric	e				e												
General Instrument	b d l	b d l	b d	b d	b d l	d l	b d	b d		d		d		d	b		
Hughes			c f		c k	k				k				k	k	(Mostly custom)	
Intel	l	l	l		l												
Intersil	l n	l m n	b	b n	b l		l										
MOS Technology		d		d	b d	b d		b d						b			
Mostek	f	f		f				b f									
Motorola	b k	b			b l	b k	b	b	b c	k							
National Semiconductor				c	c	c	c	c		c							c
Nortec	Custom and pre-production (all devices, most processes)																
North American Rockwell	Mostly custom, any circuits including ROM, RAM, S/C etc. (b,d,l,)																
Ragen Semiconductor						k	k									k	
RCA		k			k	k				k				k	k		
Signetics	b l	l	l	b l	b l	b l		l									
Solid State Scientific		k m		k													
Solitron	c	c				c	c	c									
Texas Instruments Incorporated	h i	b d i	d	b d h	bdhi	b d h		b h	d b		b d	b c d			b		b
Varadyne	j																

KEY

b PMOS High V_T ⟨111⟩
c PMOS ⟨100⟩
d MNOS or MTNS
e RMOS
f I^2 Low V_T
g I^2 Self aligned gate
h SATO
i SATO w/silicon gate
j NMOS Field Shield
k CMOS
l PMOS, silicon gate
m NMOS, silicon gate
n NMOS

Table III shows who is making what and by which technologies.

device you buy drive the outside world at the required speed?

When second sourcing, it is usually best to stick with the same process. Although different processes can be used to produce many identical items and meet certain nominal specs, the devices can be different inside and can vary functionally in other areas.

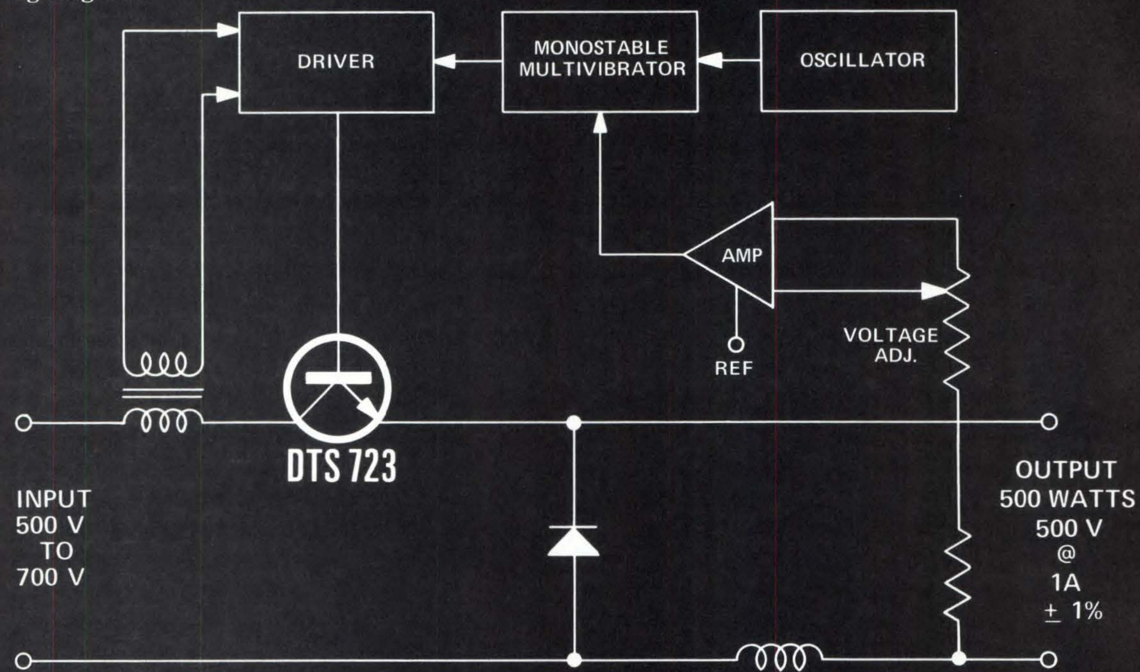
Don't get carried away with tight packing densities. They can bring on large problems, drastically reduce yields and increase costs. □

Many thanks are due the following companies for their valuable assistance in compiling these articles:

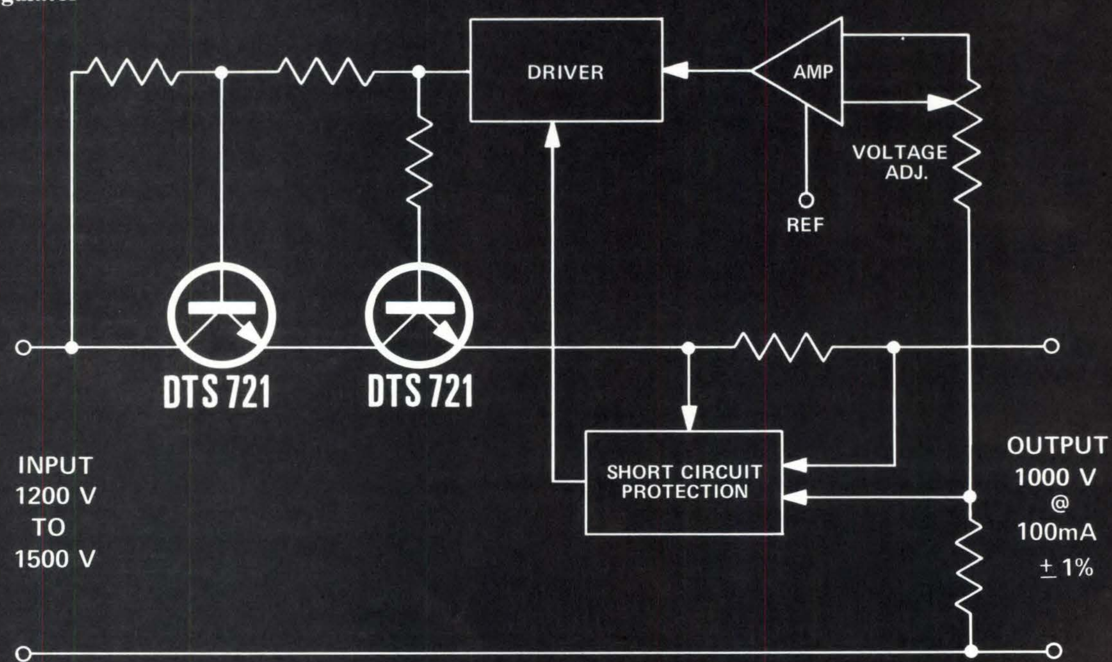
ADVANCED MICRO DEVICES, Sunnyvale, Calif.; AMERICAN MICRO-SYSTEMS, Santa Clara, Calif.; ARTHUR D. LITTLE, Cambridge, Mass.; BELL LABS, Murray Hill, N. J.: COGAR, Wappingers Falls, N.Y.; COLLINS RADIO, Newport Beach, Calif.; COMPUTER MICROTECHNOLOGY, Sunnyvale, Calif.; ELECTRONIC ARRAYS, Mountain View, Calif.; FAIRCHILD SEMICONDUCTOR, Mountain View, Calif.; GENERAL DIGITAL, Newport Beach, Calif.; GENERAL ELECTRIC, Syracuse, N.Y.; GENERAL INSTRUMENT, Hicksville, N.Y.; HUGHES, Newport Beach, Calif.; INTEL, Santa Clara, Calif.; INTERSIL, Cupertino, Calif.; MOS TECHNOLOGY, Valley Forge, Pa.; MOSTEK, Dallas, Tex.; MOTOROLA, Phoenix, Ariz.; NATIONAL SEMICONDUCTOR, Santa Clara, Calif.; NORTEC, Santa Clara, Calif.; NORTH AMERICAN ROCKWELL, Anaheim, Calif.; NCR, San Diego, Calif.; RAGEN SEMICONDUCTOR, Whippany, N. J.; RCA, Somerville, N.J.; SIGNETICS, Sunnyvale, Calif.; SOLID STATE SCIENTIFIC, Montgomeryville, Pa.; SOLITRON, San Diego, Calif.; TEXAS INSTRUMENTS INCORPORATED, Houston, Tex.; VARADYNE, Santa Monica, Calif. Special thanks go to Intel, Nortec and Signetics for artwork they supplied.

High energy silicon for the 70's.

Switching Regulator



DC Regulator



	V_{CEX}	V_{CEO}	V_{CEO} (sus)	I_C (cont)	h_{FE} @I_C min/max $V_{CE}=5.0V$	P_T
DTS-721	1000V	1000V	800	3A	20/60 @ 150 mA	50W
DTS-723	1200V	1000V	750	3A	2 min @ 2.5 A	50W

Bob Noyce of Intel Speaks Out On the Integrated Circuit Industry

You can probably remember back to the days when we thought resistors were cheap. I'm reminding you of that to indicate just how much change really has occurred in our industry.

There was a time when resistors were actually cheaper than transistors; some of you are too young to recall that and may find it hard to believe. In those days the basic concept in designing was to eliminate as many transistors as possible and replace them with resistors. In that era, diodes were also significantly cheaper than transistors and were popular with designers. Today, I doubt if any engineer would seriously think of replacing transistors with diodes, particularly in integrated circuits where there's really no difference in cost.

Also in those days, there was an enormous proliferation of transistor types. As a matter of fact, when the type numbers registered reached the 2N700s, it was decided to assign three-digit suffixes to small-package transistors (such as those in the TO-18 case) and four-digit suffixes to larger package transistors (TO-5 or larger cases). The idea was to keep about 300 type numbers reserved for packages that were too small to accommodate a type number with a four-digit suffix.

Once that decision was made, all new transistors in TO-18 cases received 2N three-digit numbers and all new transistors in TO-5 cases received 2N four-digit numbers. This worked for a while, but because transistors kept coming out so rapidly the system was soon overwhelmed by thousands of type number requirements.

Even with all the thousands of 2N transistor type numbers registered, I doubt if many of you have used more than 20 to 30 of them or are presently using more than 20 or 30 different transistor types.

The number of distinct device types needed by a designer today is significantly reduced from what he needed in past years. This is because the capabilities of individual transistors now are typically far in excess of the requirements of various applications.

Audio amplifiers were designed with 100-kHz transistors in our early days, and RF transistors were operated at 5 MHz. It was considered just fine if an audio transistor got up to 20 kHz, grounded-emitter configuration. Obviously, as the capabilities of transistors have improved, the task of the designer has been simplified.

Of course, the advent of the integrated circuit was to change the life of the designer and revamp every concept of circuit and system design.

Once ICs began to appear, there was a tremendous demand from transistor users to convert their particular needs to monolithic form. I think that for every flip-flop developed by an IC manufacturer

(Continued)

during the period from 1960 to 1964, there were customers coming in and asking for 50 other types. I remember visiting a customer during this time and going into one room where this company had 60 engineers designing logic circuits. But when I visited the same company about 3 years later, only three engineers were employed in the same group.

Now, the other 57 engineers did not all go to work for semiconductor companies; 50 of them probably moved into a higher level of design, but maybe five or six of them actually did go to work for semiconductor manufacturers doing circuit design.

The proliferation of design that took place in the early 1960s resulted in expensive solutions to design problems. It would have been a lot less costly to use fewer devices (perhaps overdesigned for those particular jobs), but thereby achieving larger production runs for each device.

If you can remember when resistors were inexpensive, then you can probably recall the days when system designers were choosing between two-input and three-input gates. If you didn't have three inputs, you used the simpler device—you never had any open inputs. Who would think of doing this today? Now it doesn't cost any more if your devices are designed in excess of actual needs for a particular application—particularly when the "excess needs" may cut down the total part count in other subsequent applications.

When you stop and think about it, the whole real appeal of integrated circuits has been their ability to cut down interconnection costs.

Look at the yield statistics. The cheapest transistor chip to make is the single transistor chip. If there's a defect in it, this means only one transistor has to be thrown out. The only reason a lot of transistors on one chip cost less than individual transistors is the savings in interconnections, both to the user and the semiconductor manufacturer.

Let's consider a circuit requirement somewhere in the middle of the user's system to be hooked up to 40 or 50 transistors within the system. For an integrated circuit, this may be accomplished by eight or ten wires; for transistors, it may call for 140 or 150 wires. That's a big difference in interconnection cost.

We've already reached what appears to be a ridiculous price situation in certain applications (for example in some TTL subsystems) where the component unit costs a fraction of what must be paid to interconnect it. The user's interconnection cost for a TTL gate can run up to $0.50/unit—more than the cost of the gate.

Medium scale integration evolved naturally as a means for cutting the costs of building integrated circuit systems. It started out first as a custom business, but it is evolving into a catalog-item marketplace. A designer can get out his shopping list and say "Okay, I can build this circuit by using two of these and a half dozen of those or I can use three of these with four of those", and so on. Put them all together, they accomplish the desired function and you don't really even have to worry about what's inside or the fact that they can do a lot more than you need to have done. Not only will these standard circuits do what you require, they're as cheap a way as any to get it done.

We've been talking about MSI but we haven't really left the subject of interconnections. Remember, it's the cost of interconnection that was the prime motivation to the evolution of MSI.

This leads us to large scale integration, where the motivation for development has been precisely the same—lowering interconnection costs. It may not be true right now but the time will come when the cost of MSI will become lower than the cost of the boards that it goes on. And today, the interconnection cost for MSI is still significant when compared to the cost to duplicate the same job with LSI.

Again, LSI has started out primarily as a custom business. Most of the LSI products that have been sold have gone to calculator manufacturers—calculators are one place, indeed, where there is large volume usage of a relatively well-standardized circuit. For more achievements of this type, standard LSI circuits must have enough capability to do the desired job and a lot of other jobs as well.

Memory is a good example of an application well suited for standard LSI. The function is well defined, the usage is large and one design can satisfy many different needs.

LSI memories are being proven practical production items. In 1968 and even in 1969, a lot of skeptics said that LSI was at least 5 years away—LSI was something that the IC manufacturers liked to pretend was around the corner, but you wouldn't be able to buy any for at least 5 years.

But LSI did arrive and is available in large quantities. The IC user today is in a position where he can count on LSI deliveries of his design in volume.

Of course, the user still has the problem of getting the design done, and simplification of that problem still has a long way to go. Even with all the automation that has gone into laying out logic circuits, these techniques still can't do the LSI job very well – the individual is a little slower than the computer but it's not possible to do the job cheaper by computer than by hand. The automated approach isn't the answer right now either, unless you're willing to give up something both in production cost and performance of the unit. We're continuing to push ahead but right now most design problems are being worked out by hand.

Back in 1964, Gordon Moore said that in 1971 designers would be able to buy ICs with more than 1000 components in high quantities. In 1965, that sounded to a lot of people like a daydream.

If you look seriously at the way IC technology is moving today, you can extrapolate and come to the conclusion that ICs with one million components will become available in 1980.

This sounds ridiculous but actually it's no more ridiculous than 1000 components on a chip sounded in 1964.

If IC technology really moves along at this pace, what will happen to prices? IC prices have been affected by several factors – increased complexities, improved resolution, improved yields, greater wafer sizes, etc. Increased die sizes have allowed more function per individual die and lower handling costs. Let's see what prices are likely to be by 1980.

One of the big cost factors in the semiconductor business is defect density, which has gone down by a factor of six in the last 10 years. Correctly anticipating the behavior of defect density is one of the critical factors in extrapolating to what will happen in 1980.

The $10/square-inch cost of processing silicon, about where we are now, is probably not going to change much. In order to decrease defect densities, it's going to take even more careful processing than we're now doing, and we aren't going to save much money. I'm also assuming that we will be able to decrease defect densities, since there's nothing inherent in semiconductors that makes it impossible. Most of the defects that are present in integrated circuits are process induced defects – defects that exist only because of mistakes that IC manufacturers make.

It isn't a question of achieving the ultimate in crystal perfection. It's just a question of how dirty your photoengraving operation is, and frankly, that's the cause of 90% of the defects in ICs right now.

In looking to the future, I'm assuming that we'll improve our linear resolution by a factor of three. That's about where I see the industry going from an optical standpoint. We can't go much beyond that until we get into electron-beam processing. I do believe that electron-beam processing will come in before the end of this decade.

I have also assumed that we will see an improvement in efficiency. By that I mean circuit configurations will be designed that will provide more function per circuit element. New device concepts such as the charge-coupled device will enter the picture.

Okay, let's look at the chips IC makers will offer in 1980. The size of the MOS chip will be larger than the bipolar chip because the MOS defect density will be smaller. Why will it be smaller? Because the MOS process uses fewer photoengraving steps, and photoengraving is the major cause of defects.

Typically, we'll be working with 1.5 cm^2 of silicon for MOS circuits, and 0.6 cm^2 for bipolar circuits. Chip cost should be running around $3 for bipolar circuits and $9 for MOS circuits. That's with yield consideration included and estimated at 30%. (If this yield figure is too low, the cost figures that I'm giving you will be too high.)

The number of components per chip will be about one million MOS devices and about 100,000 bipolar devices. If 10 components per memory bit are assumed, then one order of magnitude less bits than the number of components can be obtained.

Let's assume that the cost of packaging is $10. Let's also assume that we only get 50% yield after packaging (and that number shouldn't be that bad).

With these projections, it's likely that the cost of MOS memory will be $0.0003/bit and bipolar cost will be a little under $0.002/bit. To arrive at these costs, I've assumed a 50% cost of sales for the semiconductor companies.

I've based the above figures on semiconductor memory growth; all the technologies involved are applicable to logic as well as memory. However, with logic, we are getting into a different situation.

Interconnections again are a severe problem. We find ourselves interconnection-limited. How much logic can we conceive of putting on one chip? How many gates will be needed for minicomputers? Since the answer for some minicomputers is 1000, by 1980 we may well be capable of putting the equivalent

(Continued)

Speakout

number of gates for 100 minicomputers on one chip.

A big part of the minicomputer market calls for gate requirements in the 5000 range; bigger computer needs run say 30, 40, 50 and up to 100,000 gates. The biggest computers made today have requirements in the 100,000-gate range. This would make it sound as if a superstar computer's needs could be satisfied with about 10 bipolar LSI chips. However, even if the capability exists to put all of a computer's logic on a few chips, this doesn't mean that we'll be able to find a practical design philosophy that will permit us to do it—and that brings us back to the whole interconnection problem again. ▭

About Bob Noyce

Dr. Robert N. Noyce was one of eight employees who left Shockley Semiconductor Labs in 1957 to form Fairchild Semiconductor. He served as Director of Research of the fledgling Fairchild operation, placing major R&D emphasis on mesa and planar silicon transistors.

He became vice president and general manager in 1959, three years before Fairchild Semiconductor became a part of Fairchild Camera & Instrument. Dr. Noyce was appointed Group Vice President for the semiconductor and instrumentation divisions in 1965, a post he held until leaving in 1968. In July 1968, he founded Intel Corp and has served since then as its president.

Dr. Noyce received a bachelor's degree in 1949 from Grinnell College in Iowa, majoring in physics and math. He earned his doctorate in physical electronics at MIT in 1953.

Upon graduation he joined Philco Corp. in Philadelphia, Pa., engaging in semiconductor research. He left Philco to join Shockley Semiconductor Labs in 1956, where he was concerned primarily with research in semiconductor diffusion techniques.

Dr. Noyce finds time for skiing at Squaw Valley and sailing off the Maine Coast. "We have six boats—if you want to count the rowboat—one for each member of the family," he says.

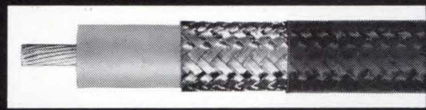
The family consists of Bill 17, Penny 15, Polly 12, Margaret 10 and Betty, Dr. Noyce's wife. They reside in Los Altos, Calif., and also have a seashore home in Maine.

Dr. Noyce is a member of the National Academy of Engineers, a Fellow of the IEEE and a Trustee of Grinnell College.

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

We've put a continuous FEP jacket on our RG-225/U and RG-115A/U that cuts out the cable handling problems that really trouble you. No more fiberglass particles to breathe, to get stuck in clothes and irritate, no more frayed ends making terminations seem like an impossibility, no more wasted time and no more cable failures on critical equipment due to hydraulic oil or coolant penetration damage.

We can provide you with Times FEP-115A



(modified RG-115A/U) with sweep testing for insertion loss from 1 to 12 GHz with a maximum variance of 10% from nominal. Another design improvement this cable features is a "hold-down" layer over the tape dielectric to prevent tape spring-up during termination. Or, Times RG-393/U (replaces RG-225/U) which is also FEP jacketed and has QPL approval. Both fight off seepage that can collect inside of connectors and cause transmission failure.

Send for bulletin TD-3, and our 44 page RF Transmission Catalog and Handbook.

*Fluorinated Ethylene Propylene

TIMES
SUBSIDIARY OF insilco **WIRE AND CABLE COMPANY**
Wallingford, Connecticut 06492. Tel. (203) 269-3381

CIRCLE NO. 14

FEP* jacketed cables cure frayed fiberglass nerves.

Designing Precision Integrators With High Speed Mode Controls

by Paul Yee

■ *The problem of capacitance drift with temperature is well known in the analog electronic integrator. Not so well known is the mechanical drift in the adjustable capacitor favored in these integrators.*

Mr. Yee details a method of minimizing capacitance drift and replacing the adjustable capacitor with a fixed type by using additional circuitry. ■

A new integrator circuit has several advantages over "standard" integrators:

1. The feedback capacitor is calibrated and temperature compensated actively, removing the dual requirements of a regulated temperature chamber and adjustable capacitor. In addition, the fixed capacitor offers improved long-term stability as well as a simpler initial calibration procedure.
2. Large variation of the time scale is possible without a variable capacitor.
3. All-solid-state switches give improved reliability, reduced package size, and submicrosecond mode switching which allows close tracking of mode change among multiple channels of integrators.

The integrator is one of the most commonly used circuit configurations in analog computation, system simulation, in-line process control, etc. The basic components used in an integrator are a solid-state operational amplifier, a feedback capacitor and switching components.

During recent years, the quality of op amps and solid-state switches has improved immensely. However, the performance of capacitors remains essentially unchanged. Today's precision integrators still use yesterday's polystyrene capacitors.

To maintain initial tolerance and temperature stability of, say $\pm 0.01\%$, the polystyrene capacitor must be installed and operated within a well regulated temperature environment. Setting an adjustable capacitor to a desired value can be very time consuming since the device requires quite a long period to establish mechanical equilibrium.

Author: Mr. Yee is product manager at Zeltex in Concord, Calif.

Conventional integrators

In general an integrator has the following functional modes: "operate", "reset", and "hold". These modes can be established by some combination of FET, biopolar, and mechanical switches. For the "hold" mode, a solid-state switch should have a low "on" resistance and an extremely low leakage current. Neither FET nor bipolar units can provide these, so mechanical switches have hitherto been used exclusively in this mode. But a mechanical switch's slow response in the "hold" mode can cause computational error in multiple integrators.

Before we analyze the new integrator, let's examine two conventional precision integrators. In Fig. 1 we use only mechanical switches, while Fig. 2 has solid-state switches with the exception of SW_1. Both circuits suffer from common deficiencies caused by the mechanical "hold" switch and the limitation of the adjustable feedback capacitor. Also, the circuit of Fig. 1 has limited reset speed due to the time constant of RC_f.

Improved circuit

Figure 3 shows a high-speed precision integrator with all MOS FET switches to control operating modes. The feedback capacitor is a fixed-polystyrene type. Initially, the capacitor is set by adjusting the attenuator preceding amplifier A_2, connected as a unity-gain noninverting buffer. No temperature chamber is needed as the capacitor's temperature coefficient is compensated by the thermistor network which regulates the attenuation of P_1. In this circuit, for $(R_i)(C_f) = 1$ second, $R_i = 100$ kΩ and $C_f^* = 10.1$ uF at 25°C, P_1 is set to deliver $0.990\ e_o$.

The circuit of Fig. 3 is used as follows: In the "operate" mode, SW_1, SW_2, and SW_3 are as shown. In the "reset" mode, SW_1, SW_2, and SW_3 take on the opposite positions. In the "hold" mode, SW_3 is as shown, and SW_1 and SW_2 are in the same position as for "reset".

Figure 4 shows a practical circuit in the "operate" mode. In this mode, the desired equivalent capacitance and time scale of the integrator are adjusted by R_s and the temperature compensation of the capacitor is set by R_C and P_A.

Time constant adjustment

The desired time constant of the integrator is R_iC_f as noted in Fig. 3. However the added circuitry takes a slightly larger feedback capacitor C_f^* equal to $C_f\ (1+\Delta)$ to produce the desired equivalent C_f (at 25°C). To adjust the physical capacitance C_f^* to the desired equivalent value (C_f), a precision attenuator consisting of a buffer amplifier and resistive network preceding C_f^* is employed.

With input current, i_i, to C_f^*, the impedance transfer function of Fig. 4 is adjusted to $1/sC_f$ with R_S. For $R_X = R_B$ and $R_C = R_D$ at 25°C, e_A is made equal to e_B or $e_o\ (C_f/C_f^*)$. For correct impedance transfer characteristic, R_S is adjusted such that:

$$\left(\frac{R_C}{2R_S + R_X + R_C}\right) e_o = \left(\frac{R_D}{2R_S + R_X + R_D}\right) e_o$$

$$= \left(\frac{C_f}{C_f^*}\right) e_o = \frac{i_i(s)}{sC_f^*}$$

$$or\ \frac{e_o(s)}{i_i(s)} = \frac{1}{sC_f} \qquad (1)$$

Temperature-coefficient compensation

Over the normal lab temperature environment, the temperature coefficient of fixed polystyrene capacitors is linear and typically −0.01%/°C.

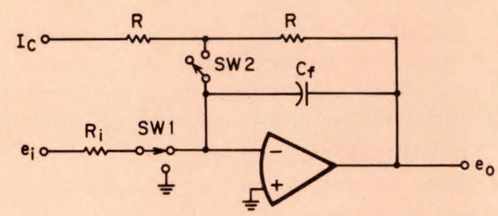


Fig. 1. Three-mode integrator using only mechanical switches.

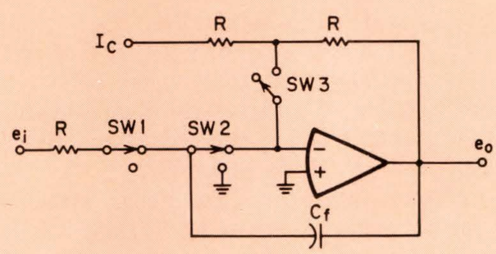


Fig. 2. Three-mode integrator using two solid state and one mechanical switch.

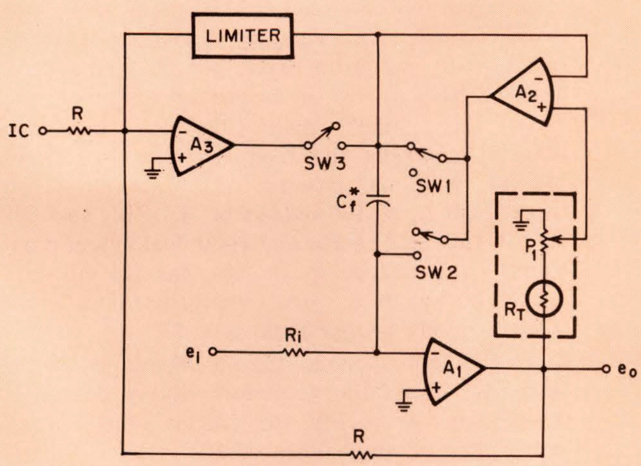


Fig. 3. High-speed precision integrator with MOS FET switches.

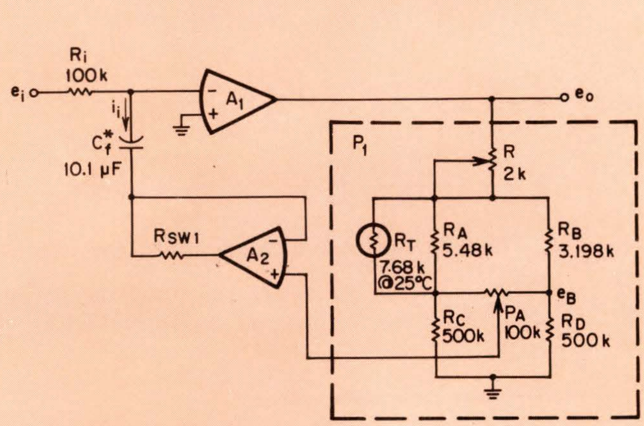


Fig. 4. Prototype circuit in the "operate" mode with $R_X = R_TR_A/R_T + R_A$, $C_f^* = (1+\Delta)C_f$, $R_C = R_D$ and $R_X = R_B$ at 25°C.

To compensate this linear change of capacitance over the range of +15 to +35°C, a thermistor of the proper negative temperature coefficient is introduced into the attenuation network. To linearize the exponential effect of the thermistor, a temperature-stable resistor, R_A, is added in parallel with the thermistor, R_T. The following equations describe R_T and R_X, the parallel resistance of R_T and R_A.

$$R_T = R_{T_o} e^{\beta\left(\frac{1}{T} - \frac{1}{T_o}\right)} \tag{2}$$

$$R_X = \frac{R_A R_T}{R_A + R_T} = \left[\frac{R_A + R_{T_o} e^{\beta\left(\frac{1}{T} - \frac{1}{T_o}\right)}}{R_A + R_{T_o} e^{\beta\left(\frac{1}{T} - \frac{1}{T_o}\right)}}\right] \tag{3}$$

$$\frac{dR_X}{dT} = -\left[\frac{\left(\frac{R_A^2 R_{T_o}}{T^2}\right) e^{\beta\left(\frac{1}{T} - \frac{1}{T_o}\right)}}{\left(R_A + R_{T_o} e^{\beta\left(\frac{1}{T} - \frac{1}{T_o}\right)}\right)^2}\right] \tag{4}$$

Given R_{T_o}, T_o and β, and dR_X/d_T, R_A can be calculated from Eq. 5 as follows:

$$R_A \Big|_{T = T_o} = \frac{\left(\sqrt{\frac{-\frac{dR_X}{dT}}{R_{T_o}\beta}}\right)\left(TR_{T_o}\right)}{1 - \left(\sqrt{\frac{-dR_X/dT}{R_{T_o}\beta}}\right) T} \tag{5}$$

For example, let's take a thermistor of Fenwal C curve with β = 3495±175, R_{T_o} = 7.680 kΩ at T_o=298°K (25°C). For a dR_X/dT *of* -50 ohm/°C, R_A calculated from Eq. 5 equals 5.480 kΩ. Further calculation of R_X over the temperature range of 25°C ±10°C using these data and Eq. 3 yields a dR_X/dT of -50 ±1 ohm/°C.

To maintain close to linear attenuation, C_f^* should not exceed C_f by 1% so that,

$$\frac{R_C}{2R_s + R_X + R_c} = \frac{1}{1+\Delta} \tag{6}$$

can be approximated to within 0.005% accuracy by $(1-\Delta)$. Since

$$\frac{1}{1+\Delta} = \frac{R_c}{2R_s + R_c + R_X} = \frac{1}{1 + \left(\frac{2R_s + R_X}{R_c}\right)}$$

$$\textit{then } (1-\Delta) = 1 - \left(\frac{2R_s + R_X}{R_c}\right)$$

$$\textit{or } \Delta = \left(\frac{2R_s + R_X}{R_c}\right) \tag{7}$$

The term $\frac{1}{1+\Delta}$ can be made linear over 25°C ± 10°C to within ± 2% of the tc of the polystyrene capacitor, if dR_x/dT is linear within ± 1Ω/°C.

Integrator time scale change

The time scale of an integrator is related to $K_2C_f^*$ (C_f/C_f^*) where K_2 is the closed-loop gain of A_2. For a fixed value of C_f^*, a large variation of time-scale changes can be realized by merely controlling the closed-loop gain of A_2 or the attenuation of P_1. For K_2 equal to greater than unity and still maintaining a ±10-V full-scale integrator output, A_2 must have an output voltage range greater than ±10V. For a slower time scale, higher value capacitance can be simulated using an amplifier (A_2) of a higher voltage output.

"Hold" and "reset" mode

With SW_1, SW_2 and SW_3 set for the "hold" mode, C_f^* is connected across the feedback of A_2. The voltage across C_f^* remains essentially constant as long as the input current to the inverting terminal of A_2 is negligible. Meanwhile the input current through R_i is absorbed by the low closed-loop output impedance of A_2. The signal at the output of A_1 due to $e_i(s)$ in the "hold" mode, is approximately equal to $(e_i(s)R_o/K_2(s)\alpha_1R_i)$ where R_o is the open-loop output impedance of A_2, α is the attenuation of P_1 and $K_2(s)$ is the closed loop gain of A_2 at the frequency of interest.

With Fig. 3 in the "reset" mode, the integrator's initial-condition voltage is set by the overall feedback around A_3, A_2 and A_1. The time required to set an initial condition is a function of the current capability of A_3, A_2, SW_2, SW_3 as well as the capacitance of C_f^*.

Critical amplifier and switch characteristics

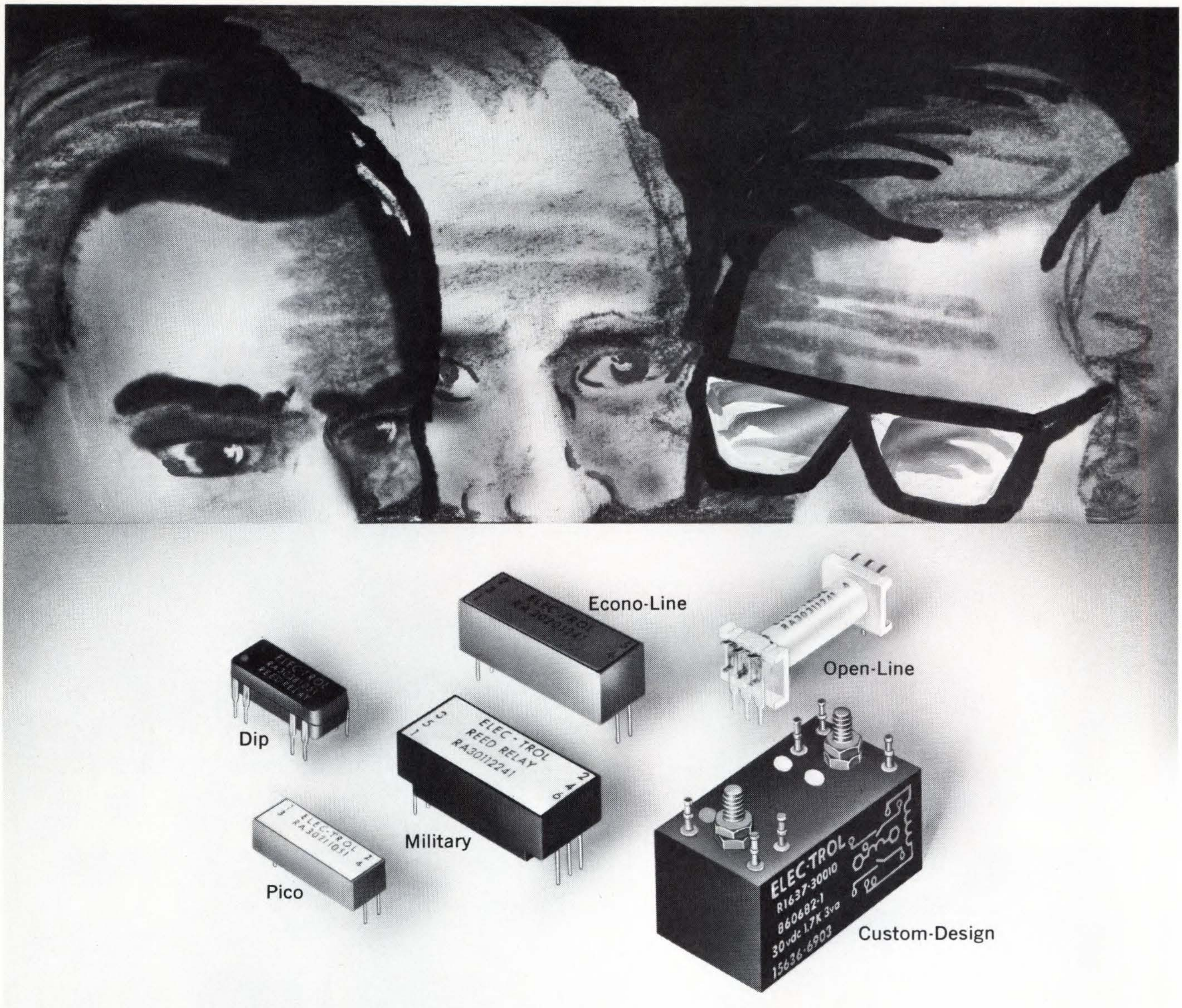
Amplifier A_1 must either be chopper stabilized or have low voltage drift. A_2 requires a FET input with high output-current capability. A_3 should be a general-purpose amplifier with high output capability.

The two important parameters of the MOS FET switches used in this application are on impedance and leakage current. The improved circuit minimizes the effects of both.

In the "operate" mode, the on impedance of SW_1 is not critical since it is inside the feedback loop of A_2. SW_1 must be able to pass the maximum integrand current without saturating A_2. The other two switches are in their "off" state in this mode. The leakage of SW_3 is absorbed by A_2 with negligible error, but the leakage current of SW_2 causes an integrand error.

In the "hold" mode the on impedance of SW_2 connects the feedback capacitor across A_2 as well as passing the integrand current from R_i to the output of A_2. SW_1 and SW_3 are in the "off" state and their leakage currents cause C_f^*'s charge to change, causing an error at the output of A_1 directly proportional to time and inversely proportional to C_f^*.

In the "reset" mode, the on impedance of SW_2 and SW_3 limits the maximum charge current to the capacitor during the initial phase of the cycle. The on impedance of SW_3 and C_f^* determine the reset time constant once A_2 resumes the linear mode of operation. The leakage current of SW_1 is of no consequence in this mode.



Thinking engineers prefer Elec-Trol Reed Relays

Here's why...

Integrity (in-tĕg′ rĭ-tĭ), n., and **Reliability** (re-lī′ ă-bil′ i-tĭ), n., are two key words in Elec-Trol's vocabulary. Nowhere in the industry can you find a more stringent reliability test program than in Elec-Trol Quality Control.

The integrity of our reed switches is unexcelled, for Elec-Trol's reliability test program is concentrated on these switches, which are made by the leading U.S. manufacturers. Our strict tests are applied to each lot prior to their incorporation in relays. A sample of each lot is subjected to microscopic examination and a 5,000,000 operation life test consisting of nine contact loads. The lot is accepted or rejected based on the test results. Data is kept from each lot tested for comparison checks to determine trends in reed switch integrity.

An accepted lot of reed switches following the sample tests is then tested 100% for contact resistance and pick-up sensitivity . . . Only reed switches that have passed this 100% testing program are used in Elec-Trol reed relays.

Superior performance of Elec-Trol reed relays can also be attributed to our conservative design approach. Our relays are purposely designed to operate well within specification limits . . . The safety factor goes beyond our written specs. Excessive heat is never encountered in our coils. An outstanding example of performance is our multiple pole relays, where we match reeds throughout the coil allowing all reeds to operate at nearly the same pick-up voltage.

Elec-Trol has long been famous for its engineering leadership and manufacturing techniques used to protect the reed switch and coil in reed relays, providing the assurance of proper performance throughout the relay's application life. We pioneered the DIP reed relay. The know-how of precise bending of reed lead terminals, all welded internal construction, along with expertise in use of special epoxies that have similar temperature coefficients to the reed switch glass enclosure, are outstanding examples. We have available special packaging techniques to make customized relay configurations.

All Elec-Trol reed relays are 100% tested for operating parameters prior to shipment. Quality control records of inspection are maintained throughout in-process and final inspection.

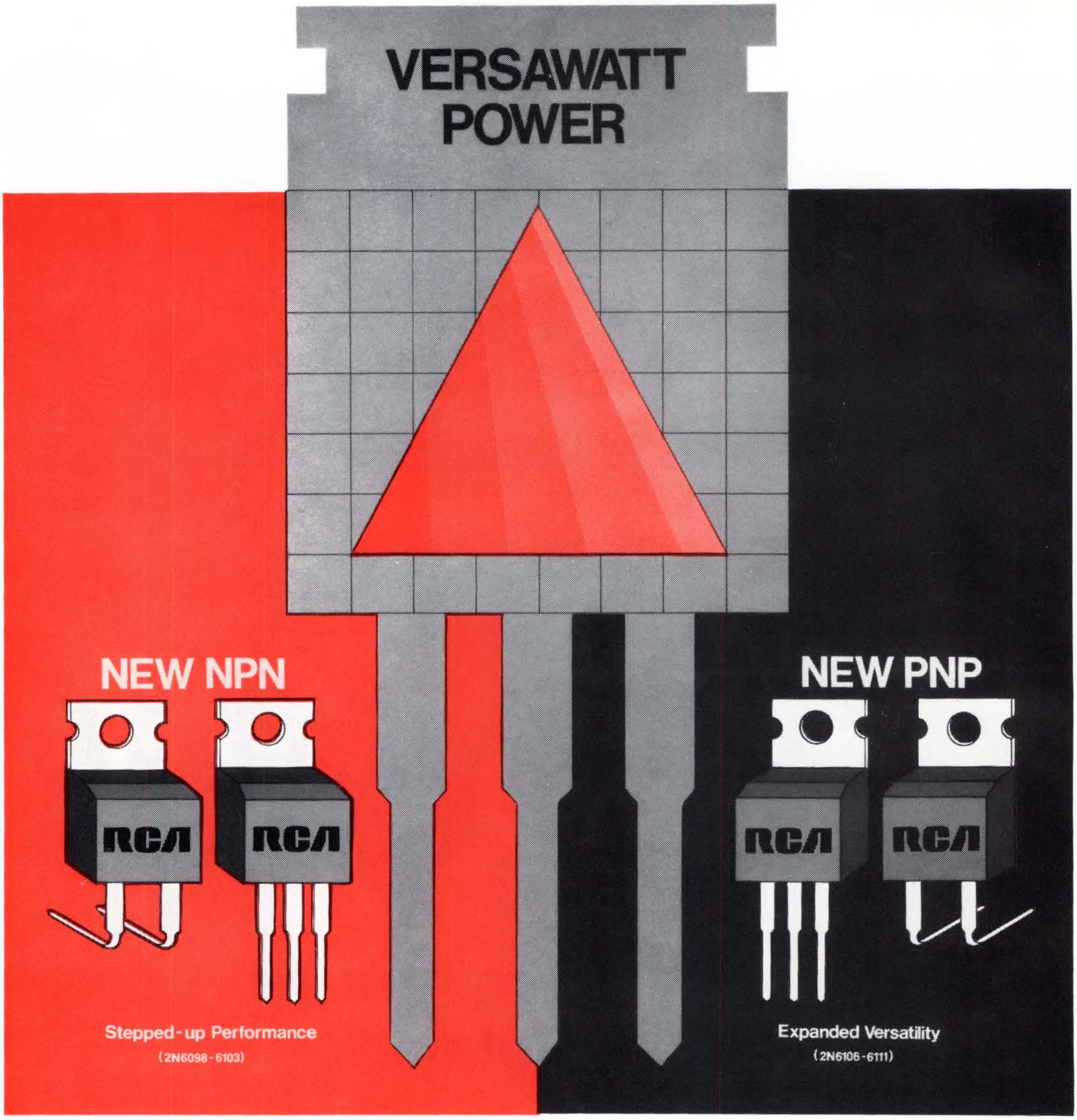
Whether your decision to buy is based on switching speed, long life, light weight, reliability, circuit isolation, power handling, special packaging, or otherwise, one of our five reed relay lines: Econo-line . . . Open-line . . . Dip . . . Pico . . . Military . . . or a customized design is sure to fill the bill. Our automated production line guarantees high performance reed relays at low cost. You can be certain that Elec-Trol is doing a better job.

Write, wire or call us your requirements.

ELEC-TROL, INC.

26477 N. Golden Valley Road
Saugus, California 91350
Phone: (213) 788-7292 • (805) 252-8330
TWX: 910-336-1556

CIRCLE NO. 15



RCA's 2N6103 series is new! It now makes available to designers an extended current capability in the RCA VERSAWATT line—from 0.5 to 8.0 Amp. Utilizing a chip similar to the 2N3055, this silicon power n-p-n family is the next step up from the 2N5298 and 2N5496. You get all the advantages of Hometaxial-base construction, backed by thermal cycle ratings and safe area operating curves. The 1000-unit prices in the family start at 65¢.

The 2N6103 family is recommended for such applications as hammer drivers, series regulators, motor speed controls, inverters, and output stages of audio amplifiers to 40 W.

Also new, the 2N6111 family is another in the series of RCA epitaxial-base p-n-p power transistors, offering designers new p-n-p versatility in the popular VERSAWATT package. Intended for complementary use with 2N5298 and 2N5496, these epitaxial devices are backed by RCA's exclusive thermal cycle ratings and complete safe area operating specifications. The 1000-unit prices in the family start at 70¢.

Ideal in a variety of circuits, the 2N6111 will especially interest those working with audio amplifiers to 25 W, vertical deflection circuitry, high frequency inverters, positive/negative series regulators, and automotive applications.

To be confident of plastic power transistor quality and reliability, look to RCA. We engineer and build our economy-priced plastic power to the exacting standards that have made our hermetic products your bench mark for power transistor dependability.

For more information, see your local RCA Representative or your RCA Distributor. For technical data, write: RCA, Commercial Engineering Section 50I-15/UTL19, Harrison, N.J. 07029. International: RCA, Sunbury-on-Thames, U.K., or P.O. Box 112, Hong Kong.

RCA Solid State

CIRCLE NO. 16

Switching Regulator Designed for Portable Equipment

Here's an IC switching regulator for portable equipment that lets the battery voltage fluctuate over a wide range with no performance degradation. It's all done with low-cost components, too.

EUGENE R. HNATEK and LARRY GOLDSTEIN, National Semiconductor Corp.

Most batteries used in portable field equipment exhibit considerable voltage changes over their discharge cycle. Thus, for the equipment they power to function properly, it is generally necessary to make frequent adjustments with a series rheostat. This way of regulating voltage is inefficient and bothersome—and it shortens battery life.

A circuit was developed that uses an IC voltage regulator in a switching mode (see boxed information) to provide a highly efficient regulated supply voltage. This circuit (**Fig. 1**) makes use of the LM376N positive voltage regulator. It has a maximum output current rating of 25 mA (without external pass transistors), operates from an unregulated input voltage from 9 to 30V and provides load regulation of 0.3%.

This switching regulator combines high efficiency with a unique plus—low cost. Normally, switching regulators require fast-switching diodes and transistors, and a core (choke) with a sharp saturation characteristic to minimize losses. The approach presented here works at relatively high efficiency (87%) yet does not require fast components or sharp saturation cores. Instead, almost any diode, transistor and choke can be used efficiently. In fact, an inexpensive Japanese transformer secondary can be used for the choke, which points up the circuit's low cost, versatility and performance.

Also, the high switching frequency (50 to 100 kHz) generates transients that could be troublesome. However, because of the inherent design of the LM376N (for voltage breakdown ratings of the integrated transistors) and selective filtering employed, spikes are not a problem.

In this circuit (**Fig. 1**), the output voltage need only be set once during the design stage (not every time that the battery voltage decreases). R1 and R2 set the output voltage anywhere between 5 and 27V. A 10-kΩ rheostat was used for R1, though normally a fixed resistor is used. Values for R1 and R2 are obtained from the formulas:

$$V_{out} = 1.72 \frac{R1 + R2}{R2} \text{ V}$$

$$R1 \simeq 1.11\, V_{out}$$

R_{sc} determines the base drive for switch transistor Q1, providing it with enough drive to saturate it with maximum load current. The value of R_{sc} is obtained from

$$R_{sc} = \frac{325 \text{ mV}}{I_{sc(mA)}}$$

where I_{sc} = short current limit.

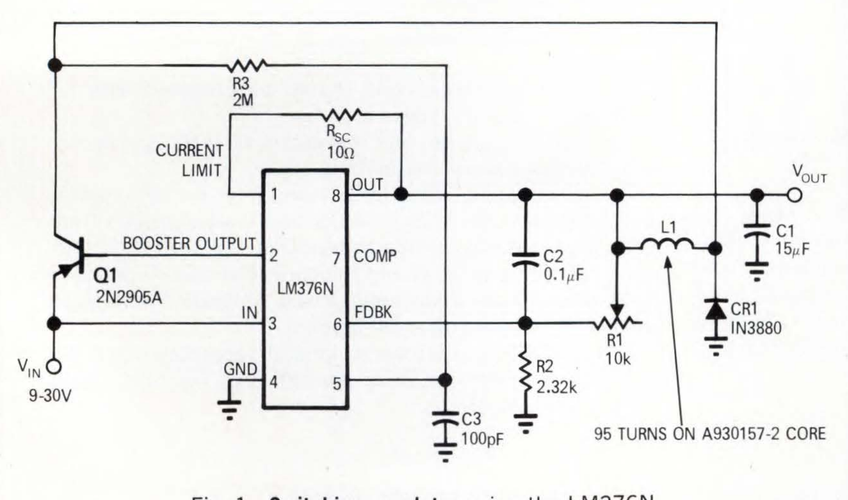


Fig. 1—**Switching regulator** using the LM376N.

Positive feedback at the reference terminal stems from R3, C2 minimizes the output ripple and C3 removes fast risetime transients that would otherwise be coupled into pin 5 through the shunt capacitance of R3. However, C2 must be small enough so that it does not integrate the waveform.

The optimum switching frequency for these regulators has been determined to be between 20 and 100 kHz. At lower frequencies the core for L1 becomes large, and at higher frequencies switching losses in Q1 and CR1 become excessive. A switching frequency of 33 kHz was selected for the circuit of **Fig. 1**.

The regulator was used to drive a

(Continued)

6V, 500-mA tape recorder motor. The input voltage was varied from 7 to 20V without any change in motor speed. Furthermore, the load was varied from 700 mA of starting current to 250 mA of running current, and the output voltage of the regulator remained at 6V. In fact, stalling the motor did not cause any regulating damage (700 mA).

A New Circuit

The regulator circuit of **Fig. 1** is optimized in terms of efficiency and switching waveform, but not for the

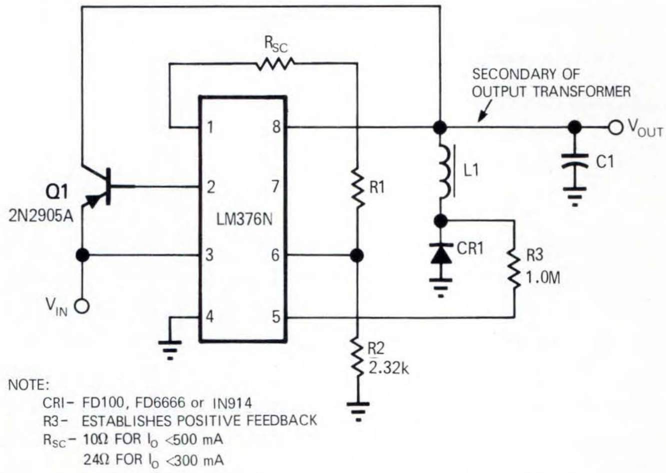


Fig. 2—**Simplified** switching regulator circuit.

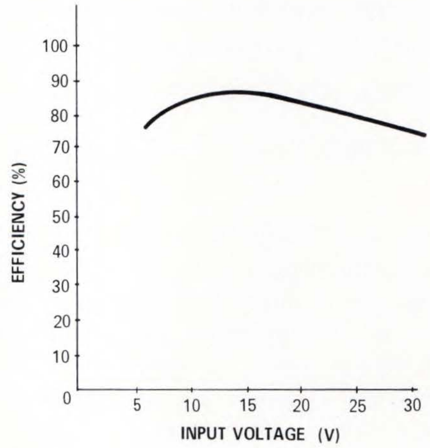
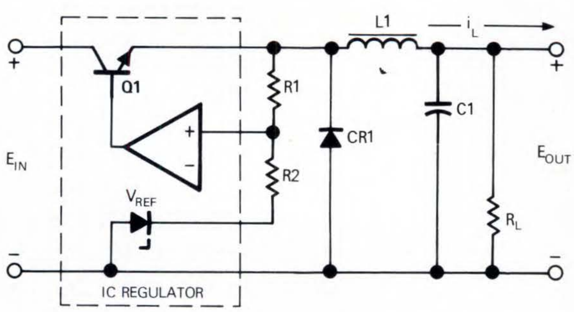


Fig. 3—**Efficiency** vs input voltage.

SWITCHING REGULATORS REVIEWED

Efficiency is the main advantage of a switching regulator over the conventional series type. When compared to series regulators, switching regulators permit the use of smaller components and heat sinks to provide a specified output power capability.

The basic configuration of a switching regulator is shown below.



Regulation is achieved by controlling the duty cycle of Q1.

Transistor Q1 serves as a switch and is either on (saturated) or off, so that power dissipation in it is minimum. Freewheeling diode CR1 conducts during the time that Q1 is cut off, thus maintaining current flow through inductor L1. When Q1 is on, the load current i_L through L1 increases according to the relationship.

$$E_{in} - E_{out} = \mathrm{L1}\,\frac{(\Delta i_L)}{(t_{on})}$$

This current flows through the load and charges capacitor C1.

When E_{out} reaches V_{ref}, a voltage comparator turns Q1 off. Current through L1 then decreases until CR1 is forward biased. At this point the inductor current flows through CR1 decreasing at a rate given by

$$E_0 = \mathrm{L1}\,\frac{(\Delta i_L)}{(t_{off})}$$

When the inductor current falls below the load current, C1 begins to discharge and E_{out} decreases. When E_{out} decreases to slightly less than V_{ref}, the comparator turns Q1 back on and the cycle repeats itself.

The output voltage is given by

$$E_0 = \frac{E_{in} \times t_{on}}{t_{on} + t_{off}}$$

A number of precautions should be observed with all switching regulators. These are:

—Fast switching diodes and transistors must be used to prevent excessive power dissipation.

—The core material used for L1 should have a soft saturation characteristic. This prevents high peak currents from occurring in the switching transistor if the output current becomes high enough to run the core close to saturation.

—Q1 should have a low emitter-base saturation voltage to prevent excessive power dissipation.

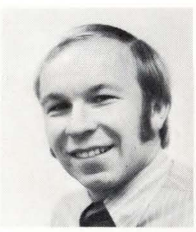
—CR1 should be returned to ground separately from the other parts of the circuit to prevent large transients from occurring in the circuit.

FOR A FREE REPRINT OF THIS ARTICLE, **CIRCLE NO. L64**

minimum number of components. The next step, therefore, was to reduce the number of components but leave circuit performance unchanged (**Fig. 2**).

Almost any type of choke can be used for L1, which gives a significant cost savings. Diode CR1 can be any diode (even a low-frequency type) that can handle the actual load current, and transistor Q1 can be any variety of transistor as long as it can handle the load current and remain within its maximum ratings. Even though the boxed information recommends the use of a fast switching diode, a low-frequency diode will work in the circuit of **Fig. 2**. Efficiency of this circuit relative to input voltage is shown in **Fig. 3**.

Applications for this type of regulator are numerous. It can be used for devices powered from 9, 12 or 18V batteries, or in fact, from any battery in the range of 9 to 30V. Portable instrumentation, motor speed control for radio-controlled boats and portable tape recorders—all are promising applications of this circuit. It should be noted that for most tape recorder applications, a resistor is used in series with the tape drive motor to set the motor voltage. During starting conditions this resistor drops more voltage than when running—the motor needs high starting current. With this IC switching regulator the output voltage is independent of the load current. ▭



Both **Eugene Hnatek** (L) and **Larry Goldstein** (R) have been with National Semiconductor for 2 years. Hnatek is Military/Aerospace Product Manager, responsible for direct linear, digital, hybrid and MOS military product efforts.
Goldstein is Linear IC Testing Manager, responsible for software and hardware developments for testing op amps, regulators, consumer and communications circuits.

CIRCLE NO. 17 ▸

Plagued By Triac Hysteresis?

Hysteresis or snap-on in triac phase control circuits is a common problem usually solved by adding components to the triggering circuit. A new IC trigger does the job neater and cheaper.

ROY W. FORSBERG, Boston Editor

Designers of ac phase control circuits are usually bothered by hysteresis or snap-on effects of simple trigger circuits (**Fig. 1**). Although they desire a smooth transition from full OFF to full ON, what they usually get is a step-type snap-on action as illustrated in **Fig. 2**. This can be very disconcerting in lamp dimmers and motor speed controls for example, and solutions such as those shown in **Fig. 3** are often employed. Such solutions are required regardless of whether the actual trigger device is a neon lamp or a bilateral switch. Unfortunately, these solutions require added discrete parts resulting in greater volume and higher costs, conditions not compatible with lamp dimmers and power tool controls.

IC trigger devices have been tried in the past but because of manufacturing constraints, such as triple diffusions needed to gain isolation, costs have not been competitive with discrete solutions.

What is desired is a triggering device with asymmetrical voltage characteristics to compensate for the undesired phase shift described in **Fig. 2**. A simple zener-bilateral switch arrangement provides these characteristics, but when integrated on a single chip, it either requires lots of area or additional diffusions. However clever circuit design can offset these problems and result in a small, low-cost IC providing characteristics shown in **Fig. 4** and per-

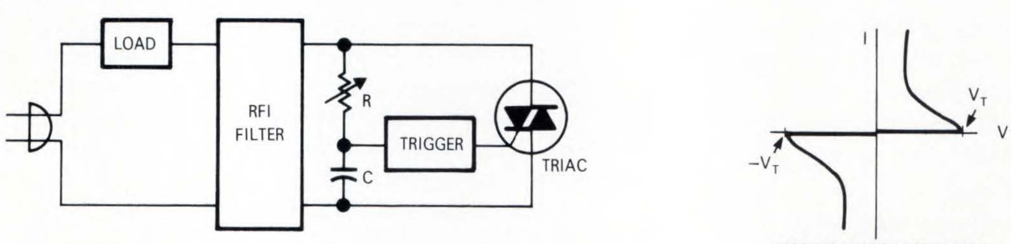


Fig. 1 – Typical triac phase control circuit with hysteresis. Although threshold voltage is symmetrical, actual triggering of the first cycle is non-symmetrical as shown in **Fig. 2**.

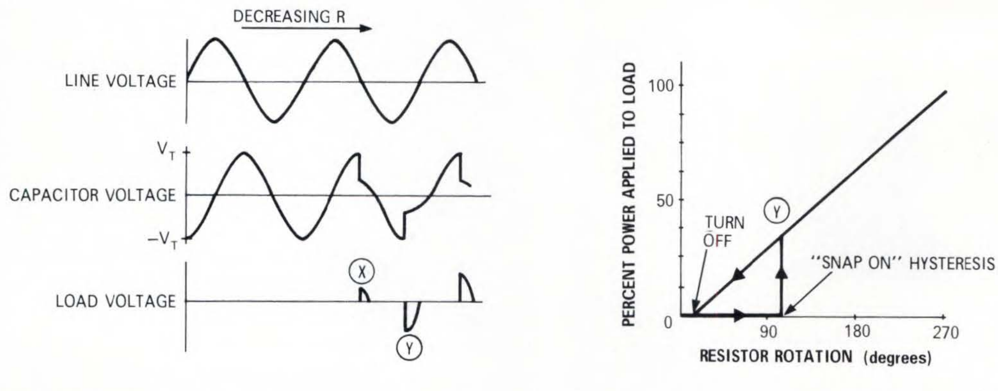


Fig. 2 – Waveforms showing hysteresis effect. Initially, capacitor voltage lags line voltage by about 90° and no triac triggering occurs. As resistance is decreased, this phase relationship changes until the triac first triggers at point 'x'. However, after the first triggering, the charge removed from the capacitor by triggering causes the phase angle to shift further and thus apply more power to the load as at 'y' causing an apparent 'snap-on'.

FOR A FREE REPRINT OF THIS ARTICLE, **CIRCLE NO. L65**

formance shown in **Fig. 5**. **Fig. 4** shows how both threshold triggering and conducting voltages in the negative quadrant are drastically altered in order to compensate for normal phase shift while maintaining a constant threshold current to the triac.

This IC approach results in a single trigger device no larger or more expensive than conventional devices, yet requires no additional circuitry to combat hysteresis or snap-on. It is mounted in a TO-98 plastic 2-lead package. □

This device was presented in a paper at ISSCC '71 by W. H. Sahm III of General Electric Company.

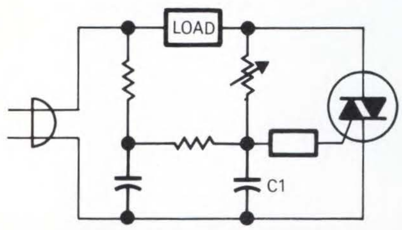


Fig. 3—One approach to combat hysteresis. This is one of many approaches used to solve snap-on problems. The added resistors and capacitor are used to provide a ready charge to C1 immediately after each triggering.

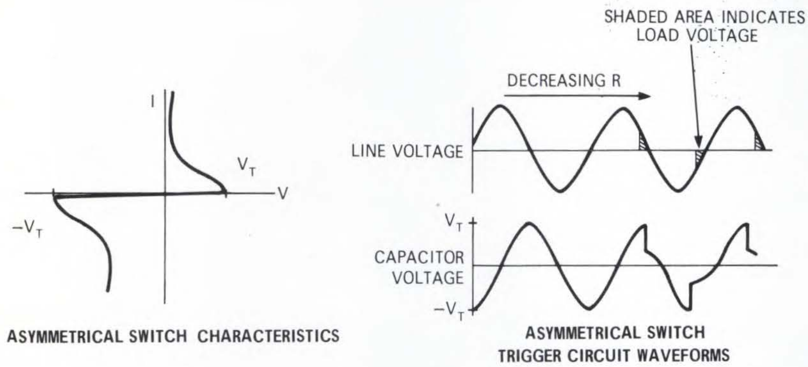


Fig. 4—IC trigger characteristics. By increasing the negative trigger voltage and conducting voltage, the dc value of capacitor voltage is shifted thus preventing any phase shift after first triggering.

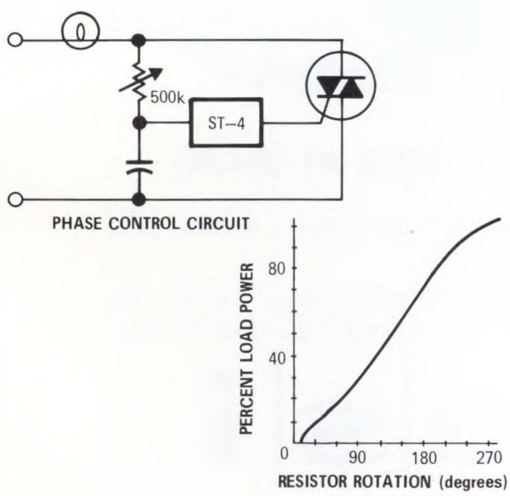
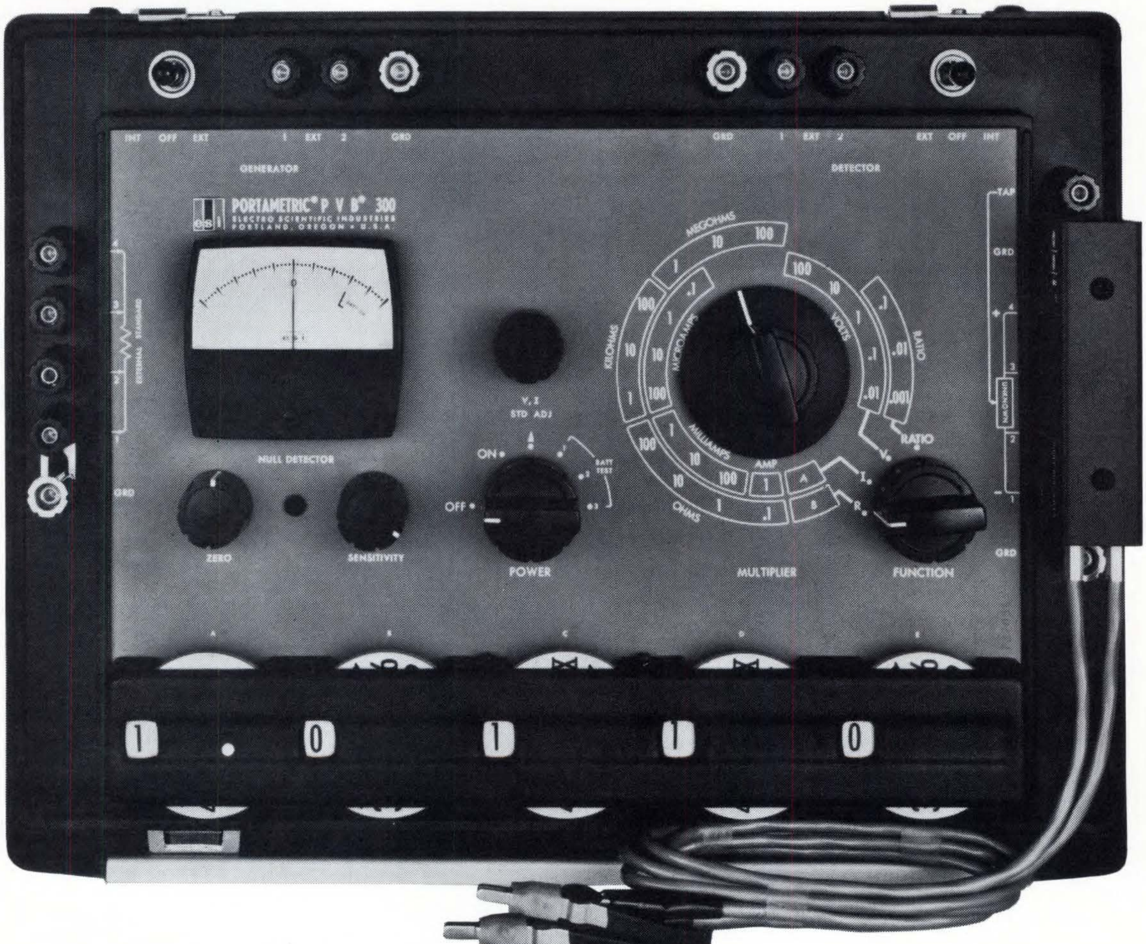


Fig. 5—Circuit performance. The simple control circuit shown at the left using the new IC trigger gives close linear performance from about 3% to over 99% of the available power.

DEAR PRESIDENT NIXON:

We would like to go you one better and lower the price of the world's best portable calibration and test instrument.



Our Model 300 PVB—now $65 less at $930

It's still 6 instruments in one at 0.02% noninflated accuracy (0.01% for another $100). It's a potentiometric voltmeter, standard voltage source, ammeter, resistance bridge, comparison bridge and ratiometer. In addition to the obvious you can measure temperature, pH, high, low and ac voltage with accessory attachments. All are guarded Kelvin 4-terminal measurements warranted for 2 years stability. Exceptional ac rejection. Zener-regulated mercury battery works over 1000 hours.

We agree with the President: It's time the consumer gets a break—so take it away.

esi®

Electro Scientific Industries
13900 N.W. Science Park Dr., Portland, Ore. 97229
Phone 503/646-4141

CIRCLE NO. 65

CIRCUIT DESIGN AWARD PROGRAM

UNUSUAL CIRCUITS □ Designed by readers □ For use by readers □ Voted on by readers.
Your vote determines this issue's winner. All circuits published win a $25 U.S. Savings Bond. All issue winners receive an additional $50 U.S. Savings Bond and become eligible for the annual $1000 U.S. Savings Bond Grand Prize.
VOTE NOW . . . by circling the appropriate number on the reader inquiry card. Submit your own circuit, too. Mail entries to Circuit Design Program Editor, EDN/EEE, 270 St. Paul St., Denver, CO 80206.

Readers have voted William C. Schaefer and Dale B. Chapman winners of the June 1 Savings Bond Award. Their winning circuit design is "Low-Cost, Long-delay Timer." Mr. Schaefer and Mr. Chapman are with IBM Corp., San Jose, Calif.

Proportional oven-temperature controller

To Vote For This Circuit Circle 161

by Robert L. Wilbur
Southwest Research Institute
San Antonio, Texas

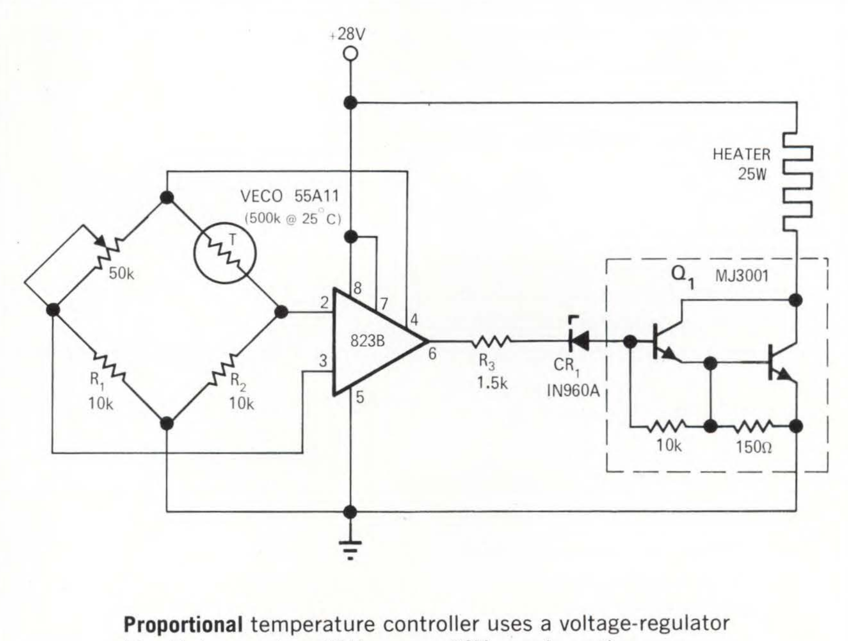
This circuit provides proportional temperature control of an oven to within 1°C for temperatures from 75 to 250°C. The circuit uses an IC voltage regulator, Type 823D, which has a quiescent current of 1.5 mA. This particular IC operates well on the same 28V power source as the oven.

Bridge resistors R_1 and R_2 should be 1% carbon-film versions. To achieve adequate resolution of the temperature setting, the potentiometer should be a ten-turn wirewound type. Since the power transistor Q_1 operates either saturated or almost cut off, no heat sink is required and operational power derating is unnecessary.

The same basic circuit can be used to control temperatures over other operating ranges, and can be easily modified by selecting a suitable thermistor and bridge resistors. Ovens of different power ratings than indicated can be controlled by suitable selection of components R_3 (to provide the correct current drive), CR_1 and Q_1.

Low-power heater elements (where heater current does not exceed 15 mA) can be driven directly from the output (pin 6) of the regulator IC.

This circuit was developed in conjunction with the NASA-sponsored Technology Utilization Program, Contract No. NASW-1867. □



Proportional temperature controller uses a voltage-regulator IC which operates off the same 28V supply as the oven.

Adjustable rectangular-wave oscillator interfaces with IC logic

To Vote For This Circuit
Circle 162

by David E. Manners
Vision Laboratories, Inc.
Oriskany, N.Y.

With this inexpensive rectangular-wave oscillator, the frequency can be adjusted over a wide range and the ON and OFF times of the signal can be independently manipulated. The circuit requires only 5V dc for operation and can therefore operate from conventional logic power supplies. Because the current drain is only about 8 mA, the circuit can also be operated from a zener regulator fed by a higher voltage supply line.

Output levels of the oscillator are compatible with conventional IC logic. The circuit was originally developed to provide an input to a driving stage for low-frequency pulsing of an inductive load.

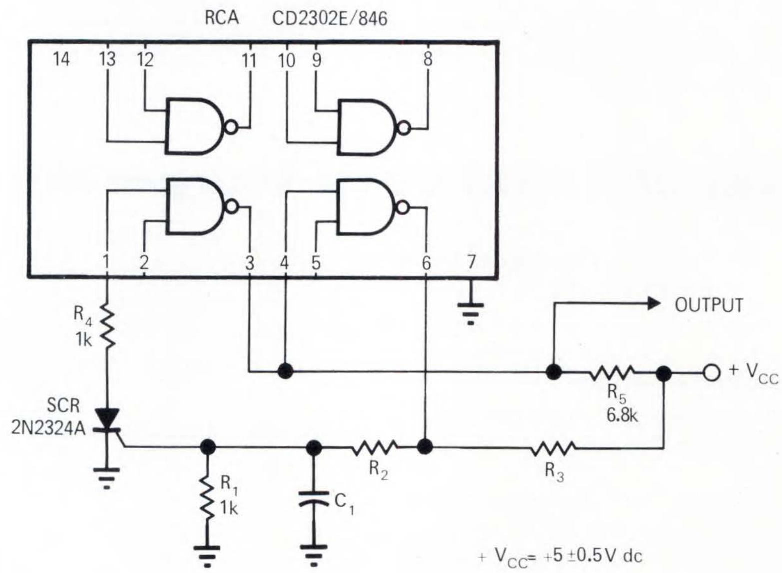
Another useful feature is that terminal 2 of the IC can accept logic signals which serve as an ON/OFF control. When held at logic 0, pin 2 forces the output to be a steady logic 1. If a steady logic-0 output is desired, another NAND gate on the same IC must be used. Removal of the logic 0 from pin 2 allows oscillation to occur. For normal operation, pin 2 is either open circuited or, preferably, connected to 5V dc.

Operation is fairly straightforward. When power is first applied, the SCR is nonconducting. Thus, pin 1 of the IC is presented with a logic-1 level. Pins 3 and 4 are therefore at logic 0. Pin 6, in turn, starts out in a logic-1 condition. This allows C_1 to begin charging from the voltage source via R_2 and R_3, in an attempt to reach a voltage level determined by the divider network formed by resistors R_1, R_2 and R_3. Thus, as the voltage level increases, the SCR is eventually triggered into conduction.

When the SCR starts to conduct, a logic 0 appears at pin 1 of the IC. This causes pins 3 and 4 to go to logic 1, and pin 6 becomes logic 0. The "near ground" on pin 6 causes C_1 to commence discharging through R_2 and also via R_1 and the gate-cathode path of the SCR. The capacitor voltage then decreases until the SCR is again cut off. This occurs because the current through the SCR is limited by R_4 and is always less than the required holding current. After the SCR stops conducting, the operating cycle repeats as described.

The table shows typical frequencies and duty cycles for selected values of C_1, R_2 and R_3. Note that there is a lower limit to practical values for R_3 (6 kΩ in this case) because otherwise the current-sinking capability of the IC NAND gate would be exceeded. Possible values of R_2 and R_3 are limited at the high end by the required gate voltage needed to turn on the SCR.

Total component costs for the circuit shown were about \$8, with the SCR (at \$5.75) contributing the bulk of the cost. Suitable SCRs can now be obtained for around \$2, thus reducing the total parts cost to approximately \$4.25. □



Both the frequency and the mark-space ratio of the output can be determined by suitable choice of component values in this oscillator.

OUTPUT FREQUENCY AND DUTY CYCLE FOR VARIOUS COMPONENT VALUES

C_1 (μF)	0.05	0.1	0.5	10.0	40.0	R_2 (Ω)	R_3 (Ω)	Approx. % ON
Freq. (Hz)	22.2 k	6.84 k	1.67 k	58.3	17.23	1 k	27.0 k	35
	23.6 k	8.62 k	2.08 k	75.7	22.00	1 k	13.5 k	45
	27.8 k	10.00 k	2.50 k	91.0	26.00	1 k	7.3 k	55
	7.8 k	3.92 k	0.96 k	31.2	9.26	2 k	27.0 k	45
	11.9 k	6.25 k	1.54 k	52.1	15.15	2 k	7.3 k	60

multiply your computer output controls

Get up to 240 low-cost control outputs from one I/O channel

Meet HP's new computer-stretcher, the Multiprogrammer . . . ready to help you solve the many problems encountered in designing automatic test and control systems — at minimal cost.

Minicomputers just don't have sufficient I/O channels and adding more is expensive. What's more important, many devices used in automatic test and control systems require control signals in forms other than the computer's binary output. This is why HP designed the Multiprogrammer System. It's a computer-controlled data distributor and converter that allows you to simultaneously or independently control up to 240 analog (or 2,880 digital) outputs . . . from a single computer I/O channel.

The Multiprogrammer houses a variety of plug-in cards that provide programmable resistance, voltage, contact closure, or TTL outputs. You "custom design" your own system by simply plugging in these cards, and you have the ability to change the system any time you want. There's an additional saving with reduced computer programming time. All outputs are automatically set to a safe state at power turn-on. Digital storage on each output card eliminates the need to refresh each output channel. Special circuits simplify event timing and sequencing. And, because you'll be operating the Multiprogrammer in rugged industrial environments, HP designed and built it to eliminate problems with noise transients, ground loops, and broken cables.

You need one master Multiprogrammer, Model 6936A ($1,300), which has 15 channels. You can expand this capability at any time by adding on up to 15 Multiprogrammer Extenders with no changes in computer hardware or operating software. Each Multiprogrammer Extender, Model 6937A ($800), has 15 channels. Programmable output cards now available are: Resistance Output ($345), Low Speed D/A ($385), High Speed D/A ($420), Relay Register ($370), and TTL Output ($200).

A detailed brochure on the **HP MULTIPROGRAMMER SYSTEM** including system description, specifications, and applications is yours for the asking. Just contact one of the 220 HP Sales/Service offices.

HEWLETT hp PACKARD

100 Locust Avenue
Berkeley Heights, N. J. 07922 • (201) 464-1234

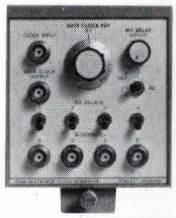
CIRCLE NO. 26

21104

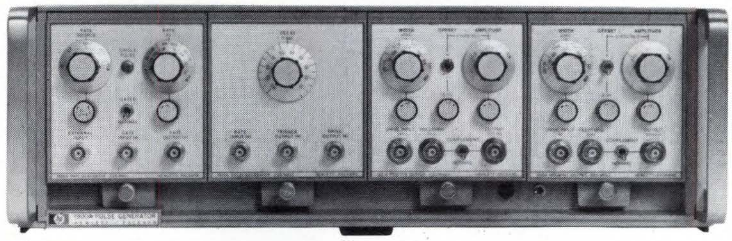

computer hardware
FOR DESIGNERS OF COMPUTER MAINFRAMES, PERIPHERALS AND SYSTEMS
"Firmware" Power
A CAHNERS PUBLICATION / SEPTEMBER 15, 1971


Circuit-Makers.
New DIP Tools from Dale.
DIP TRIMMERS
2600/8600 "Fastpacks". Wirewound model (2600) rated at 1 watt (40°C) over 10-50K ohm range ±10%. T.C. 50 ppm/°C. Film model (8600) rated .75 watt (25°C) over 10Ω-2 Meg. range ±10%, ±20%. T.C. 150 ppm/°C. Sealed cases, .75" long, machine or hand insertable.
85/87 "Fastpacks". Single or multi-turn models rated at .5 watt (25°C) over 10Ω to 1 Meg. range ±20%. T.C. 150 ppm/°. Sealed cases, .265" wide x .28" long. Machine or hand insertable.
DIP RESISTOR NETWORKS
TKR. Molded or coated networks with 14 (T.O. 116) 16, 18 pins. 1/8 watt max. per resistor, 3/4 watt max. at 125°C per package. 10Ω to 1 Meg., ±2.5%, 200 ppm/°C. Available with DIP or P.C. pins on .3" x .1" or .6" x .1" grid (coated only).
WDP/FDP. Film (FDP) networks in 14 and 16 pin packages. Up to 15 elements, .05 watt max. with .5 watt max. per package; 10Ω to 1 Meg. per resistor, ±1%, 10-200 ppm/°C. Wirewound (WDP) networks have up to 7 elements per 14-pin package, .5 watt per element, 3.5 watts max. per package. 1 to 800Ω per resistor, .1%-5%, ±20, ±50 ppm/° C.
DIP PULSE TRANSFORMERS
PT-14/PT-16 with 3 (14-pin) or 4 (16-pin) pulse transformers per package. Inductance 1 μh to 2.0 mh over −55 to +125°C. range. Temperature stability ±10%, tolerance ±20%. Sealed cases with pins on .3" x .1" grid. Machine or hand insertable.
In addition to these standard DIP packages, we're ready to quote on custom RC networks and hybrids with active and passive devices to your specification. Fast turnaround on prototypes. Write for new DIP Brochure or phone our Application Engineering Department, 402—564-3131 today!
DALE ELECTRONICS, INC., 1300 28th Avenue, Columbus, Nebraska 68601
In Canada: Dale Electronics Canada, Ltd. A subsidiary of The Lionel Corporation
CIRCLE NO. 401
DALE®
DALE
C-6363 DALE TKR-90 7116
TKR-38 DALE 7045

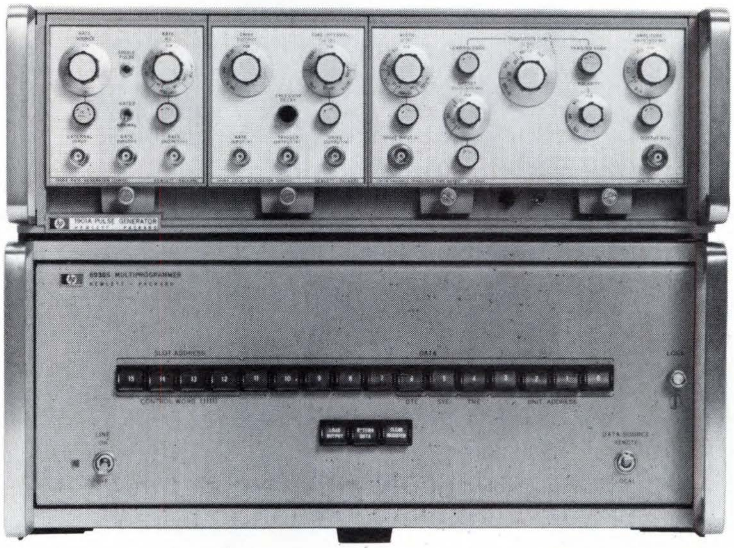
From HP – Three new dimensions in "pulser power"...



1. Multiphase MOS Testing



2. 125 MHz Capability



3. Digital Programmability

Hewlett-Packard's 1900 System, the pacesetter in pulse generation, now has three new capabilities that put it even farther ahead of all competitive pulsers.

1. Multiphase MOS Testing—The new 1934A Multiphase Clock plug-in lets you use the 1900 System to design and test MOS circuits with a minimum of effort. It gives you four-phase outputs to 12.5 MHz, or two-phase to 25 MHz... with variable phase pattern and variable phase overlap. The 1934A can be used with either high-threshold drivers (the 1915A) or low-threshold drivers (the 1917A); but the 1934A's price is strictly low-threshold... only $775.

CIRCLE NO. 416

2. 125 MHz Capability – Now, there are two 1900-System plug-ins that let you generate pulses at rep rates up to 125 MHz. The new 1921A (for positive pulses) and 1922A (negative pulses) are designed for testing fast T^2L and ECL logic—in computers and high-speed digital communications. Both have a fixed transition time of <2 ns, variable amplitude to 5 V, and variable ±5V offset. Both have switch-selectable complement capability, plus feed-through pulse-adding capabilities and pulse shaping capabilities. And both are compatible with other 1900-System plug-ins such as the 1930A PRBS generator. Yet you can get either the 1921A or the 1922A for only $950.

CIRCLE NO. 417

3. Digital Programmability – Now, your 1900 System can be computer-controlled, for high-speed automatic testing applications... thanks to HP's new 6936S Multiprogrammer. Its 16-line parallel input lets you interface your 1900 System to a computer quickly and easily, using only one I/O slot... and the result is a fully programmable pulser system suitable for almost any testing or control purpose.

To tie together your 1900 System and the 6936S, HP provides an interfacing package (Option 005), which includes cables, program cards and software. This lets you assemble the combination of capabilities best suited to your own particular needs. For example, you can get the 1900 with three popular plug-ins (1905A rate generator, 1908A delay generator, and 1917A variable-transition-time output) *plus* the 6936S Multiprogrammer and interfacing option 005, for $5950.

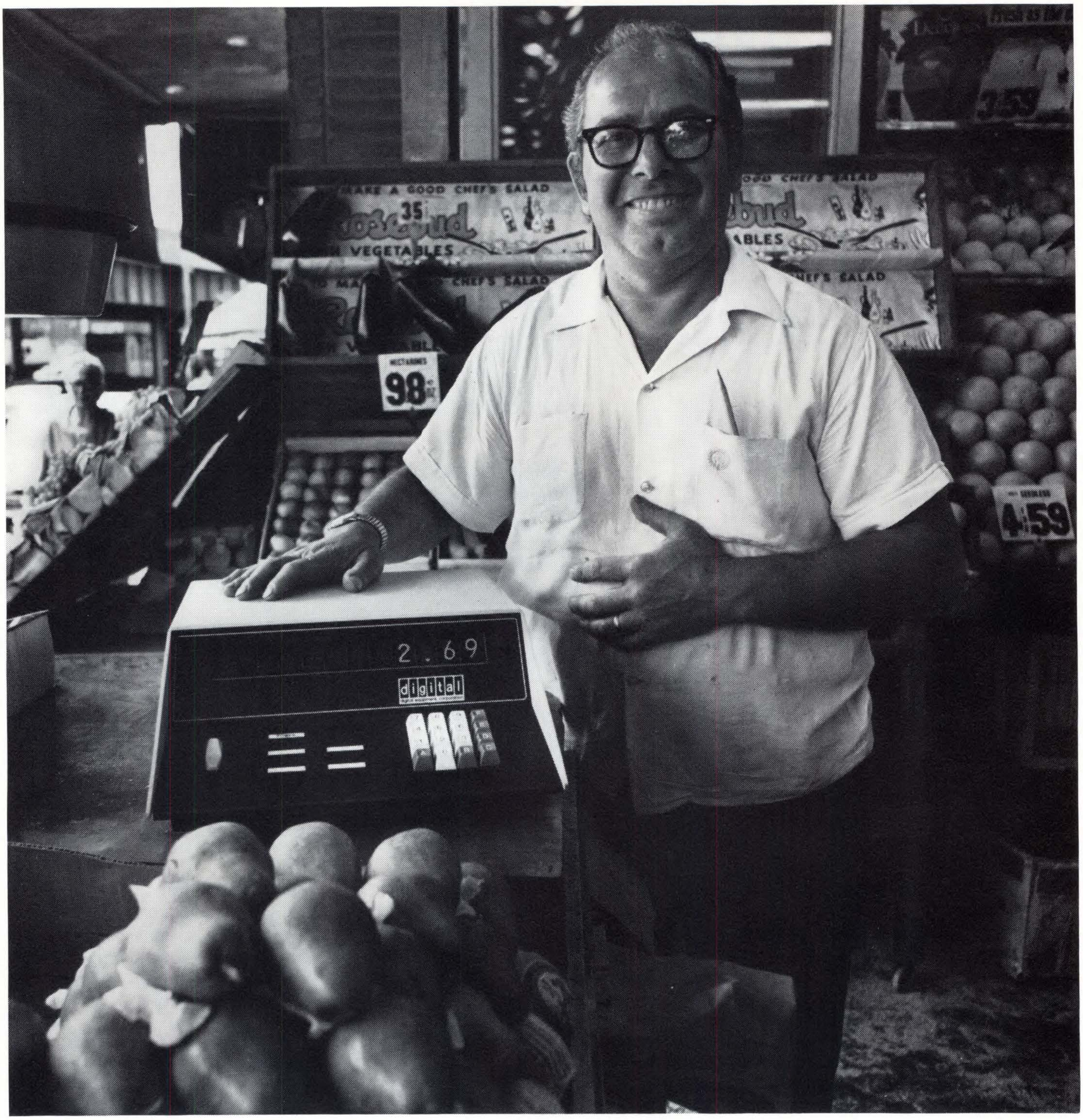
CIRCLE NO. 418

For further information on any aspect of the pace-setting 1900 System, contact your local HP field engineer. Or write Hewlett-Packard, Palo Alto, California 94304. In Europe: 1217 Meyrin-Geneva, Switzerland.

081/15

HEWLETT hp PACKARD

SIGNAL SOURCES



If you thought you couldn't afford remote terminals, you've got another think coming. DEC-link.®

DEC-link brings the cost of remote data entry terminals down to where you can stop thinking about what they cost and start thinking about where you need them.

You could put terminals at office desks for accounting reference, for management information and decision-making, or simply to log job time. Put them at point of sale. Put them in the stock room for inventory purposes, on the production line for QC or workflow monitoring, at security guard posts to keep track of who's coming and going.

DEC-link includes a 16-character keyboard, numeric Nixie* readout, four status indicators to display non-numeric information from your computer, teletype and EIA serial line compatibility. All for between $600 and $1000.

We also have a version without Nixie display for under $500, in quantity.

So start thinking about what DEC-link can do for you. Our brochure will help. Write for it—it's free.

digital

Digital Equipment Corporation
Main Street, Maynard, Mass. 01754
(617) 897-5111

*Registered trademark of Burroughs Corporation

CIRCLE NO. 403

computer hardware

EXCLUSIVELY FOR DESIGNERS OF COMPUTER MAINFRAMES, PERIPHERALS AND SYSTEMS

cover

Microprogramming cover art, supplied by Datapac, Inc., shows a section of braided U-core memory. See article on p. CH 9.

directions

features

events

10 new ways to improve system performance

MECL 10,000 means optimum performance

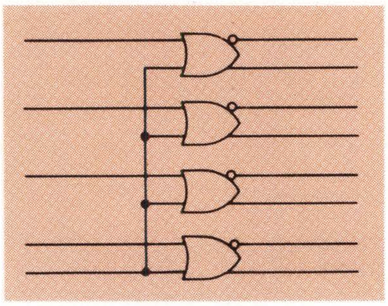
MECL 10,000 improves your system performance 10 ways — actually 16 when you consider devices previously introduced. This new "systems-oriented" logic family combines high speed (typically 2.0 ns propagation delay per gate), with low power (25 mW dissipation per gate), yielding the best speed/power combination available today.

But speed and power are only part of the story. Take a look at the design advantages of MECL 10,000. Features such as collector and emitter dotting on chip allowing multiple functions with only single gate delays. Or open emitter outputs and Hi-Z inputs which permit you to select the optimum termination method for your system.

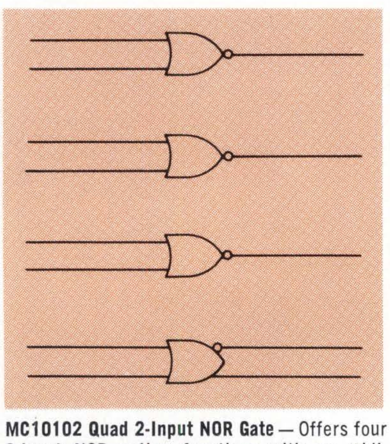
Interested in driving capacity? MECL 10,000 offers 50 Ω to 2 K Ω driving capability. High Z inputs with parallel terminated lines allow "stubbing" off of a line at several points. Popular series terminating and series damping techniques may be used with no loss in noise immunity.

Worried about cooling? Forget it! MECL 10,000 low power gates (25 mW/gate, 52 mW/gate with 50 Ω load) eliminate cooling and power distribution problems and ensure long term reliability. In fact the devices are so low power you can use them in any environment—from still air to specialized cooling.

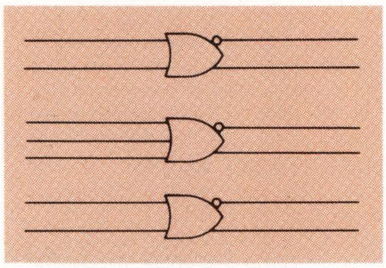
These are only a few reasons for choosing MECL 10,000 — your evaluation will discover the rest.



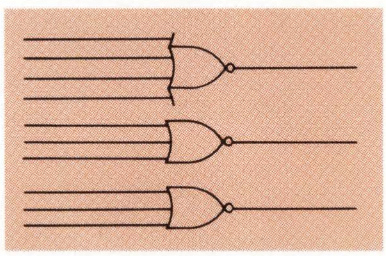
MC10101 Strobed Quad OR/NOR Gate — Very useful for distributing 4 bits of parallel information on or off card. With both OR/NOR outputs available, 4 twisted pair lines may be driven at data rates of 100 megabits/second. Use the single strobe input to gate the data on or off in 2 ns.



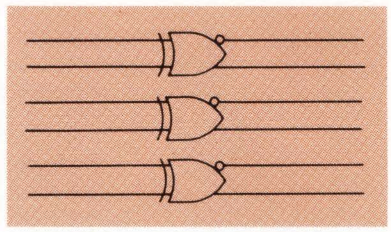
MC10102 Quad 2-Input NOR Gate — Offers four 2-input NOR gating functions with an additional OR output available. Input pulldown resistors on all devices eliminate need to tie unused inputs to an external supply.



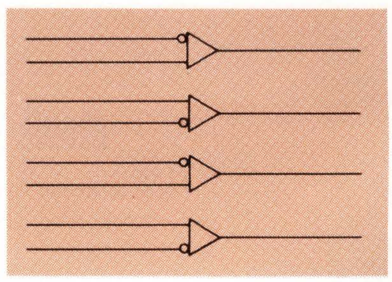
MC10105 Triple 2-3-2 OR/NOR Gate — A system oriented device aimed at reducing package count by providing three OR/NOR gates within one package. This versatile logic element provides manipulation of Boolean functions in typically 2 ns.



MC10106 Triple 4-3-3 Input NOR Gate — Basically a triple 3-input logic NOR function plus an additional input on one gate to provide added design versatility for maximum package use.



MC10107 Triple 2-input Exclusive OR/Exclusive NOR Gate — A three gate array providing the positive logic Exclusive OR and Exclusive NOR functions for high speed applications. Temperature compensated internal bias on 10,000 series devices insures that the threshold point remains in the center of the transition region over temperature.



MC10115 Quad Line Receiver — Useful for receiving 4 bits of differential data transmitted over twisted pair or ribbon cable from the MC10101. Also recommended for MOS to MECL interfacing and is ideal as a sense amplifier equivalent for MOS 1103 type memory translation to MECL.

MECL 10,000...

(of course)

MECL 10,000 — a comprehensive family

Originally designed as a computer-oriented logic family, MECL 10,000 also offers the optimum combination of parameters and flexibility required for high-speed digital communications, telemetry systems, and instrumentation. In addition to these 10 functions, here is a look at the line.

Previously announced and available:

MC10109 Dual 4-5 Input OR/NOR Gate
MC10110 Dual OR 3-Output Gate
MC10111 Dual NOR 3-Output Gate
MC10119 3-3-3-4 Input OR/AND Gate
MC10131 Dual D Flip-Flop
MC10181 4-Bit Arithmetic Unit

These functions will be added in 1971:

Memory Elements

MC10133 Quad D Latch
MC10134 Dual D Latch W/2D Inputs & Select
MC10135 Dual J-K Master Slave Flip-Flop
MC10136 4 Bit Universal Counter
MC10139 256 Bit Fusible Link ROM
MC10140 64 Bit RAM
MC10141 4 Bit Universal Shift Register

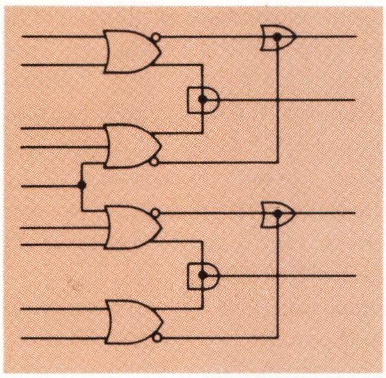
Line Receiver

MC10116 Triple OR/NOR

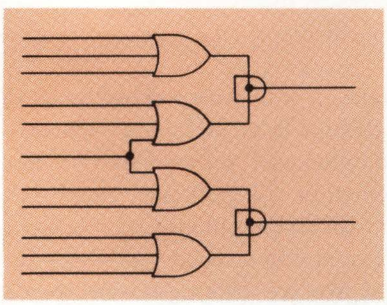
Complex Functions

MC10160 12 Bit Parity Checker/Generator
MC10164 8 Line Multiplexer With Enable
MC10179 Look-Ahead Carry Block
MC10161 Three Bit Decoder w/two Enables
MC10162 Three Bit Decoder w/two Enables

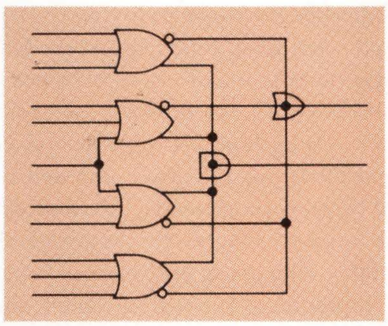
Your local Motorola representative has complete MECL 10,000 data yours for the asking — or write to Motorola Semiconductor Products Inc., P.O. Box 20912, Phoenix, Arizona 85036. And for evaluation call your nearby Motorola distributor.



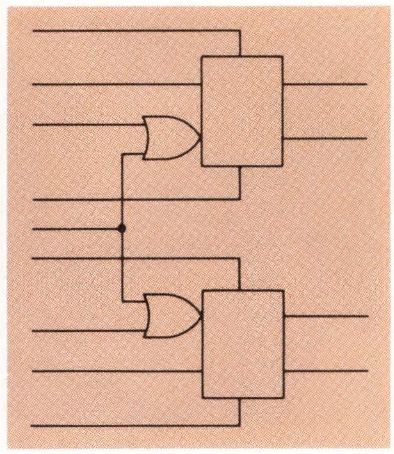
MC10117 Dual 2-Wide OR-AND/OR-AND-INVERT Gate — A powerful logic function featuring the first available OR-AND/OR-AND-INVERT emitter coupled logic gate. The internal collector AND/emitter OR dotted logic gate will perform the OR-AND/OR-AND-INVERT logic function in 2.4 ns. Useful for data multiplexing and data distribution.



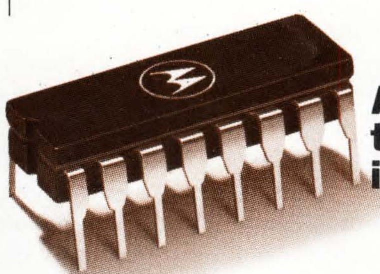
MC10118 Dual 2-Wide 3-Input OR-AND Gate — A highly functional basic building block to provide the OR-AND function. Recommended for digital multiplexing and data control applications.



MC10121 4-Wide OR-AND/OR-AND-INVERT Gate — Another system oriented building block providing the simultaneous OR-AND/OR-AND-INVERT function, a natural for data distribution applications.



MC10130 Dual Latch — A clocked dual D type latch. Each latch may be clocked separately by holding the common clock in the low state, and using the clock enable inputs for the clocking function.



MECL 10,000 eliminates the alternatives. The proof is in the comparison!

MOTOROLA MECL

. . . for faster computers & systems

CIRCLE NO. 404

under new management—a computer—

Recently Varian Associates formed a new division that will manufacture and market a new concept in data systems—computers for the hotel and lodging industry. Already Varian/TALIX has installed a system in the 500-room Hyatt House Hotel in San Jose, Calif. Using a specially developed logic unit, room status is automatically indicated and a minute-by-minute house count of vital data involving occupancy, reservations and check-outs yet to depart is provided. Until now, to disseminate such information was too slow and inaccurate for the modern hotel. Occasionally, these inaccuracies and time lags provoked a whole variety of events that resulted in a nightmare for both customer and manager.

The new system keeps track of all information; it remembers and displays each status report until told to change the status. Each hotel requires a special logic unit. The programs are "hard-wired" and sealed—it is never necessary for hotel personnel to be concerned with this "hands off" feature. The system functions with information received from specially-designed portable data input stations.

Simplicity is the key. The new system is designed to be used by anyone, including non-English-speaking people, and is as simple to operate as an ordinary AM radio.

all a computer needs is an education—

Experiments aimed at giving the computer some of the sensory abilities of humans are being conducted at the Massachusetts Institute of Technology. These experiments make use of an electronic device called a data tablet, manufactured by GTE Sylvania Inc., a subsidiary of General Telephone and Electronics Corp. According to Prof. Nicholas Negroponte of MIT's School of Architecture and Planning, the processing abilities of today's computers are severely limited because they receive information from the real world through so few media or "senses." The goal of this research is to broaden the computer's abilities and enable it to grasp entirely new sets of ideas and concepts.

In addition to the data tablet, the experiment involves two minicomputers and a display tube. Any design sketched on the tablet is transmitted into the computer. A key feature of the data tablet is its transparency, which permits the user to mount the tablet in front of the display and compare the two drawings.

"It has been possible for years to feed drawings into computers via data tablets," said Prof. Negroponte, "so long as the sketches were exact. But we are teaching the computer to interpret data not explicitly stated. The machine must handle sketches that include hastily-drawn lines, inaccuracies, crossed-out mistakes and ambiguities stemming from discrepancies between the user's intention and his execution."

As an example, if the user hastily sketches a wall with wobbly lines, the computer realizes that he probably meant them to be straight and corrects the error. If he slowly and deliberately draws a round wall, the computer assumes that the roundness is intentional. "The computer will no longer require the user to be any more exact with it than he is with another human," Prof. Negroponte continues. "This improvement in the computer's vision will enable it to comprehend pictures it previously could not. We are working toward the day the computer will be able to hear and see the world as we do. We look forward to computers with artificial intelligence that enables them to be as innovative and creative as man."

For immediate assistance, call your nearest

DATASCAN REPRESENTATIVE

N. N. J., MET. N. Y. C.
TECHNICAL MARKETING ASSOC.
Fort Lee, N.J. 07024
201-224-6911

MAINE, VERMONT, N. HAMPSHIRE MASS. CONN., R.I., N.Y. STATE
DANER-BUCHLER CO., INC.
Newton Center, Mass. 02159
617-969-4650 or

Rochester, N.Y. 14617
716-467-5100

N. C., S. C., TENN., GA., ALABAMA, MISS., FLA.
LEE ASSOCIATES, INC.
Orlando, Florida 32803
305-241-4445 or

P.O. Box 1506
Huntsville, Alabama 35805
205-539-0761 or

P.O. Box 906
Winston Salem,N.C. 27101
919-724-2406

W. PA., W. VA.
RUSSELL F. CLARK CO.
Pittsburgh, Pa. 15235
412-242-9500

OHIO, KENTUCKY, INDIANA
BOB HOCKER & ASSOC.
Dayton, Ohio 45419
513-298-8638

MICHIGAN
ANDERSON ELECTRONICS, INC.
Farmington, Michigan 48024
313-476-9161

OKLAHOMA, LOUISIANA, ARK., TEXAS
PACKARD-SPEAIRS CO.
Arlington, Texas 76010
817-261-4424

N. CALIF. & NEVADA
SYSTEMS MARKETING CONSULTANTS
P.O. Box 1376
Los Altos, Calif. 94022
415-941-4777

S. CALIF., ARIZONA
CAIN & COMPANY
Los Angeles, Calif. 90049
213-476-2251

S. IDAHO, WYOMING, UTAH, COLORADO, NEW MEXICO
CROPLEY, INC.
Littleton, Colorado 80122
303-794-4231

N. ILLINOIS, WISC., MINN. N. DAKOTA, S. DAKOTA
DATA ELECTRONICS CO., INC.
Chicago, Illinois 60630
312-774-1452 or

Minneapolis, Minn. 55405
612-377-8383

CANADA
ELECTRODESIGN LIMITED
Ville LaSalle 650, Quebec, Canada
514-363-5120

NEBRASKA, KANSAS, MISSOURI, S. ILLINOIS, IOWA
MC GRAW ENGINEERING
P.O. Box 511
Florissant, Missouri 63033
314-831-0342

VA., MD., DELAWARE, WASH. D.C., S. N.J., E. PA.
SONCO
King of Prussia, Pa. 19406
215-265-3250 or

Wheaton, Maryland 20902
301-942-9420

WASHINGTON, OREGON, N. IDAHO BRITISH COLUMBIA
DEL COM SALES
Seattle, Washington 98146
206-248-0090

Try it for 30 days in your equipment - *AT NO CHARGE!*

We're so sure you'll like the dollar savings and tape reader performance, we would like you to try it for 1 month. There's no obligation during this 30-day trial period. But once you're satisfied that the reader/interface meets your requirements, you'll want to keep it.

* 500 cps punched tape reader and compatible interfaces for PDP-8L, PDP-8I, NOVA, SUPER NOVA and HP2114, 2115 and 2116 computers are available now.

Send for specifications and details.

Datascan
computer products group

Datascan Inc., 1111 Paulison Avenue • Clifton, N. J. 07013 • (201) 478-2800

The one you've talked about and waited for just came onstage. The Eye modestly presents the new EPI Cassette Transport. Totally unique. Extremely low-priced.

Our transport is as simple as it is revolutionary. Retracting idler arms draw tape out of the cassette and against a "flying" write/read head—eliminating skew, flutter and wow.

Utilizing Phase recording techniques, the EPI cassette unit features a storage capacity of 2.4 million bits.

Add to this a block modification capability with its truly remarkable price tag, and you may well be already writing your letter of inquiry.

Do. Our first coup was the EPI-118 mini-computer with 18-bit capacity and a cycle time of 900 nanoseconds. We brought it in for $5,900.

Now, an EPI cassette unit solves all the familiar problems common to other cassette drives. At last, you can write-read-verify. And modify. With absolute fidelity.

The Eye just winked again.

It's happened. A tape cassette drive that writes, reads, verifies and modifies. All in favor say Eye.

CIRCLE NO. 406

CIRCLE NO. 407

ELECTRONIC PROCESSORS, INCORPORATED
A Subsidiary of the Samsonite Corporation
5050 So. Federal Blvd. • Englewood, Colorado 80110 • 303/798-9305 • TWX 910-935-0874

go from software to hardware in one easy lesson

Through "microprogramming", an instruction can be tailor-made to a specific machine. In this way, operational sequences are encoded in hardware and the instructions are executed more rapidly.

Instead of hardwiring a function, use a read-only memory (ROM) to store the routine that performs the function—an intermediate step between software and hardware called "firmware". The user does not know that the function is in the firmware because the computer accepts and executes the instructions either through stored logic in the ROM or directly through hardware.

More and more firmware is appearing in the newer systems—a trend that is likely to continue. This approach permits a computer with stored logic capabilities to be microprogrammed to accept instructions for any other computer without a substantial cost or hardware modification. Also firmware provides a simple means for adding new functions to the equipment, whereas changing the hardware functions can be costly and at times impossible. Attempting to use software may be too slow and cumbersome.

What is Microprogramming? In the 1950s, M.V. Wilkes introduced microprogramming as a systematic alternative for designing the control section of the computer. Other equally important factors are:

—Microprogramming offers an economical approach that grants large instruction sets to the computer systems.

—Maintenance and diagnostic aids can be incorporated, thus providing excellent diagnostic information for the service engineers.

—Emulation of different machines is easily achieved.

—Microprogramming renders a flexible design that allows easy system updating.

Consequently, microprogramming suggests an orderly technique for designing and organizing the control signals that represent the computer states and the orderly transition between these finite states. This can be considered as a direct replacement for the sequential logic control circuits of the second-generation machine.

A suitable definition (suggested by Samir S. Husson) that sums up microprogramming is:

A technique for designing and implementing the control function of a data processing system as a sequence of control signals to interpret fixed or dynamically changeable data processing functions. These control signals, organized on a word basis and stored in a fixed or dynamically changeable control memory, represent

(Continued)

FOR A FREE REPRINT OF THIS ARTICLE **CIRCLE NO. 480** *the states of the signals that control the information flow between the executing functions and the orderly transition between these two signal states.*

Why Microprogramming?

In a microprogrammed system, small routines, stored in either a ROM, semi-permanent RMM (read-mostly memory) or RAM (random-access memory), specify the actions and the information flow within the computer. At first, the original concept did not excite computer manufacturers because reliable, inexpensive and fast ROMs were not available. Today, the microprogrammed processor enjoys a high degree of popularity attributed to its inherent flexibility and economic superiority over the designs of conventional computer systems.

Basicially, three computer generations exist. They are defined as:

1st Generation – instruction sets were not stored in the memory of the computer.

2nd Generation – instructions and data could be stored in the computer memory.

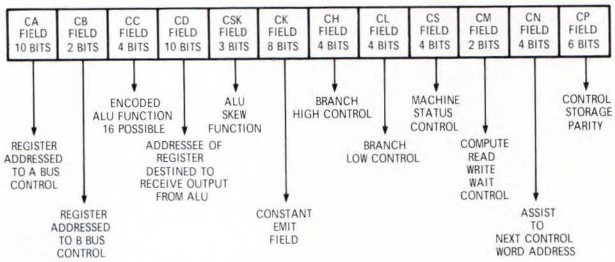
3rd Generation – basic instruction set and data flow are controlled by a microprogram stored in a separate control storage unit. Generally, a third generation computer can emulate any other computer because of its architectural constraints as defined by the microprogram.

With microprogramming, one control word performs many functions. Even with a variety of machine instructions as control words, essentially any control or arithmetic function can be generated. Since the basic machine is under microprogram control, multiple precision algorithms can be used to generate either a byte, word, or double-word oriented machine as seen from the outside world.

When using microprogram for diagnostic checkouts of the hardware, all basic phases of the machine design are evaluated and a printout is provided for the user upon request. These diagnostics can be such that they obtain timing from the central processing unit (CPU) only when the CPU is in a quiescent condition. With concurrently running programs, the diagnostic occurs only when time is available. Therefore, the CPU performance is not degraded with respect to the running program(s).

Software to Hardware.

To understand how a processor can be microprogrammed (see "Generation Gap") assume the following structure for a hypothetical 60-bit control word:



Assume the following instruction:

Transfer main storage word, as addressed by registers SA1, SA2 and SA3 to the A bus. Contents of the GP register are placed upon the B bus. Add contents of A and B busses. Place results into local storage address 45. No skew is rendered to the D bus. No constant is emitted from the control word to the B bus. Branch 4 ways depending upon whether the memory is ready and ST3 = 1. Reset status register bit 5. Designate control word to compute mode. Most-significant-bits of next address are 63.

To perform this operation, a typical microinstruction mnemonic form could be written as follows:

MS + GP → LSAR (combine main storage word (MS) and GP register content and place results into local storage address (LSAR))

CSK = 0 (no skew is rendered to the D bus)

CK = 0 (no constant is emitted from control word to B bus)

CH = Mem Red? (Memory ready?)

CL = ST3 = 1? (check register SA3 contents)

CS = 12 (reset status register ST5)

CM = 0 (compute mode)

CN = (most-significant-bit of next control word address)

CP = control word parity.

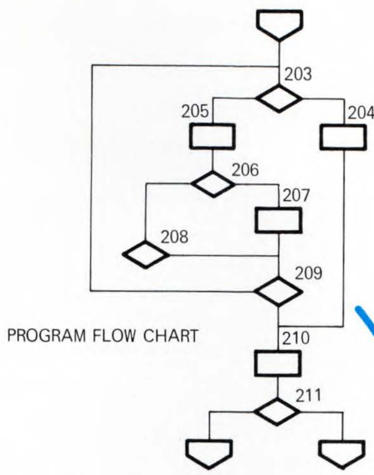
When binary encoded, the microinstruction becomes:

000010010110000000001011010000000000011011011100000110100111

Beakdown of the microinstruction is as follows:

CA = 0000100101 = main storage address MS
CB = 10 = GP register content
CC = 0000 = add command
CD = 0000101101 = local address 45
CSK = 000 = no skew or no shift required
CK = 00000000 = no constant
CH = 0110 = memory ready command
CL = 1101 = check ST3 = 1
CS = 1100 = 12 for resetting register ST5
CM = 00 = compute mode
CN = 0110 = 6 the most-significant-bit of 63
CP = 100111 = parity for control storage.

Several microinstructions, such as the 60-bit control word previously described, make up a microprogram. A typical microprogramming effort begins with a program flow chart and proceeds in the following sequence to the insertion into a ROM.

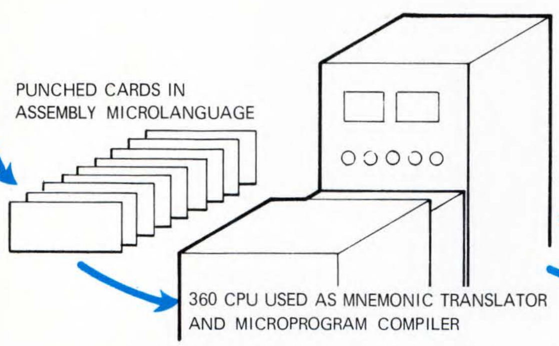


STEP 1. Programmer generates a two-dimensional representation of the problem-solving procedure—the flowchart.

JK+GP	ST,	O ST3,	OP5=1?	OP4=1?	BR
L+NoP	JK,	O ST4,	ST3=1?	ST2=1?	BR
L●GP	W,	O ST1,	ST4=1?	OPS=1?	BR
TU•GP	RS,	NOP,	NOP,	OP4=1?	BR
TU SLPS	GP,	O STS,	ST7=1,	ST6=1	BR

MNEMONIC ENCODING OF MICROPROGRAM

STEP 2. Using the flowchart, the programmer mnemonically encodes the microprogram onto a standard coding sheet.

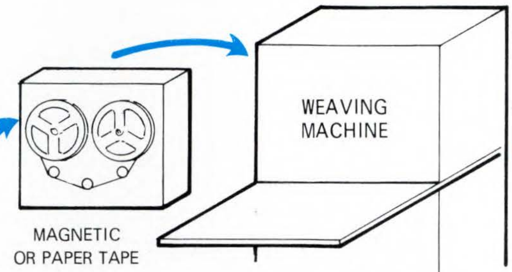


STEP 3. Information on the coding sheets is transferred onto standard IBM cards. These cards are then fed into a computer containing a special compiler and logical description of the final system hardware.

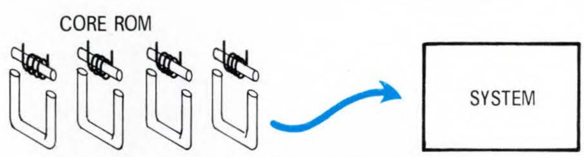
ADDRESS	WORD
203	01100111010101
204	11100110110110
205	0000111010101
206	10001101100111
207	01010111111000
208	11101011010110
209	11001100010000
210	110111111001010
211	011101101011110

BINARY MICROPROGRAM

STEP 4. After the program is compiled and translated, the resultant binary truth table is dumped onto a printout or tab run and the computer memory retains a copy. A special subroutine then interrogates the truth table stored in memory and transfers the encoded microprogram onto magnetic or paper tape.



STEP 5. The tape then controls a special numerical control machine (such as a weaving machine) that is capable of entering the desired microprogram into some type of ROM system.



STEP 6. The final ROM is tested and inserted into the operating system.

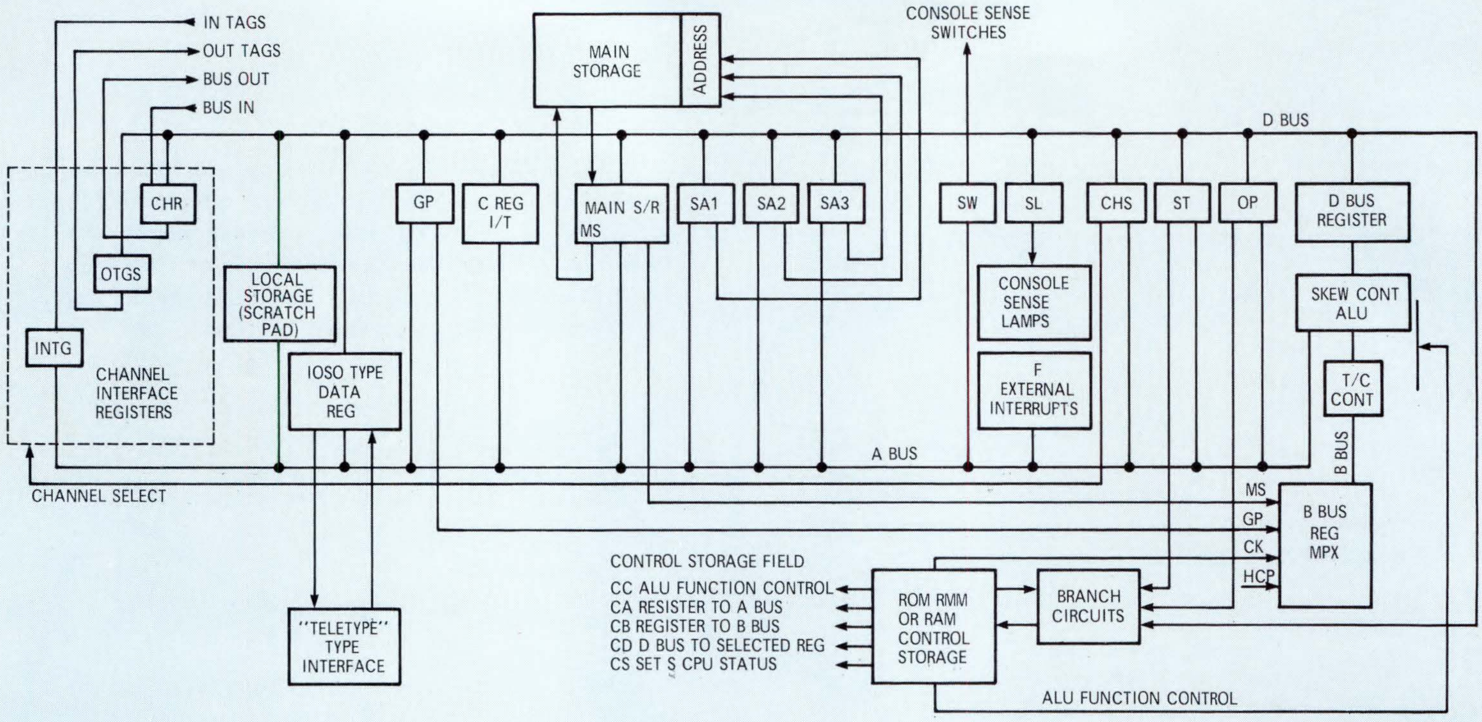
What is the Price? For elementary computing systems, sequential control logic appears to be the easiest design approach. For example, presettable and ring counters can provide all of the necessary control for many systems. In addition, microprogramming techniques may be impractical because of the cost associated with address sequencing and memory selection circuitry regardless of how simple the system is.

There is a great deal of dissension about when it becomes necessary to transcend from sequential logic to microprogramming techniques. Based on past studies, it appears that when the number of sequencing cycles exceed 256, microprogramming is the best approach. When the number exceeds 512, microprogramming is definitely the way to go.

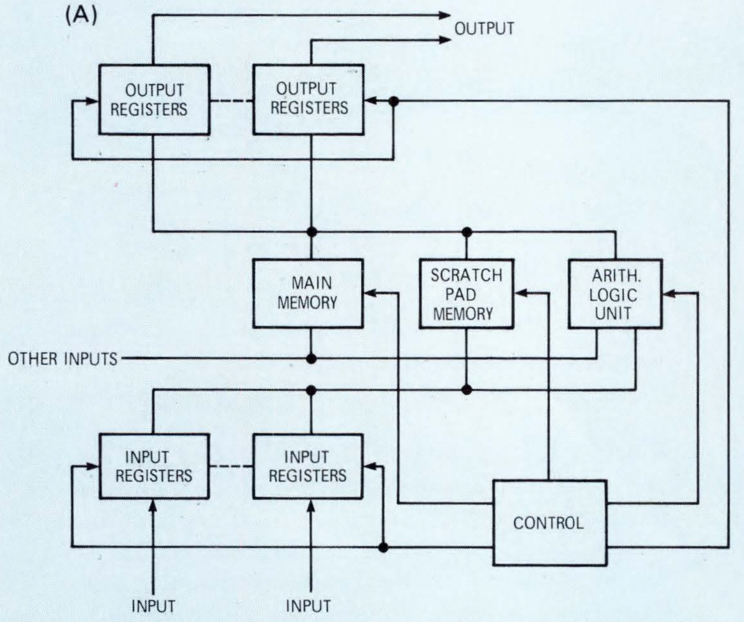
The first large-scale computer to embody microprogramming was the IBM 360. Soon to follow were the System/370 and the RCA Spectra, both based on almost identical machine language. In fact, the similarity is so close that for all practical purposes, the two machines

(Continued)

(B) TYPICAL CPU ARCHITECTURE



(A)



GENERATION GAP

Basic building blocks for any computer are Input, Output, Control, Arithmetic/Logical Unit (ALU) and Memory. Block diagram (**A**) represents both second- and third-generation processors—difference is in the control unit. The second-generation machine uses sequential logic and the third is based on microprogramming.

Diagram (**B**), a third-generation computer, illustrates the methods of interfacing main storage, local storage and I/O devices via standard channels and a method for handling interrupts. Basic data flow through ALU is from the A and B busses to the D (destination bus). Encoded control storage for ALU field specifies the arithmetic or logic function to be performed. Control storage for CA and CB fields specifies the contents of one register to be entered on the A and B busses.

Control storage for CD field selects the register that is to receive the D bus content. A mathematical expression for this operation is $A \otimes B \rightarrow D$ (B operates on A according to function $\otimes$ and results are transferred to D). Typical ALU functions include:

Instruction	Binary Code
0. Add Binary	0000
1. Subtract Binary	0001
2. Multiply Binary	0010
3. Divide Binary	0011
4. Shift Left	0100
5. Shift Right	0101
6. Logical AND	0110
7. Logical OR	0111
8. Exclusive OR	1000
9. Logical NAND	1001
10. Logical NOR	1010
11. Exclusive NOR	1011
12. Add Decimal	1100
13. Subtract Decimal	1101
14. Multiply Decimal	1110
15. Divide Decimal	1111

It can be seen that an ALU function can process the contents of any register and transfer the results to any register.

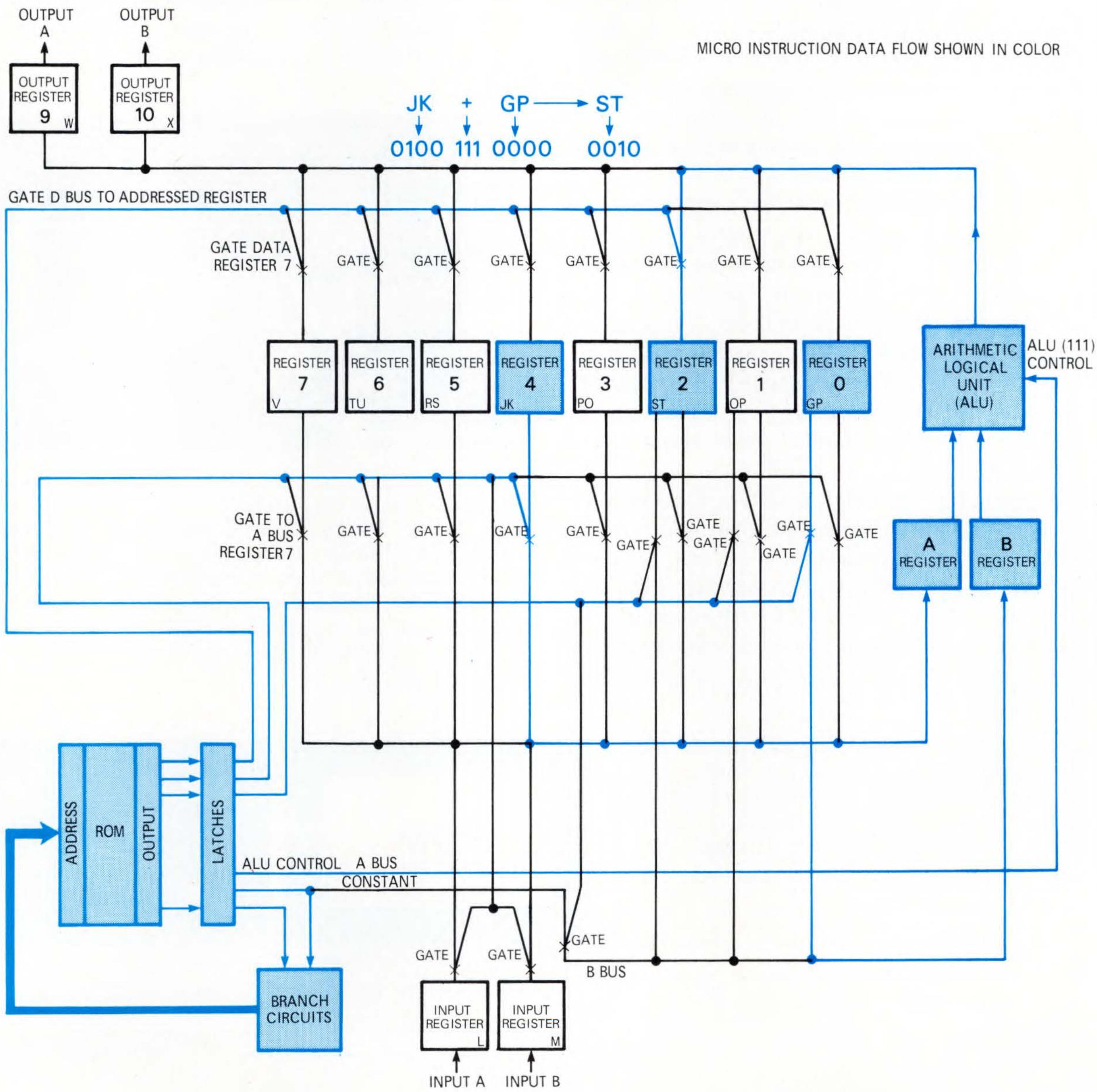
A status register provides flexible branching conditions. This simplifies the generation of standard microsubroutines that can be shared by a variety of microroutines and permits programming redundancies to be removed.

Three discrete registers address the main storage. The word to be accessed or written is processed via MS REGISTER.

Input/output is accomplished through a standard I/O channel—basically four registers:

Input Data Register
Input Tag Line Register
Output Data Register
Output Tag Line Register.

Several identical channels can exist and are selected by the CHS REGISTER. This approach for channel I/O allows IBM-compatible multiplexer, selector and BLOCK multiplexer channels to be programmed. This type of architecture could be microprogrammed for an entire IBM 370 instruction set, including microprogrammed supervisory capability.



MICROINSTRUCTION DATA FLOW

Typical data flow for a microprogrammed minicomputer is depicted above. The computer is comprised of input registers "L" and "M", output registers "W" and "X" and memory or storage registers GP, OP, ST, PO, JK, RS, TU and V. Contents of any register connected to the "A" bus are transferred to the A register via the A bus under control of the ROM. This also applies to the B bus and register. Encoded ALU function, provided by the control storage, combines the contents of the A and B register. ALU output is transposed to the D bus and gated to the register specified by the control storage. Branch circuits determine the microinstruction to be executed.

To illustrate an operation, the data flow for an assumed instruction JK + GP → ST is indicated in color. Binary word and its derivation are shown below:

Mnemonic:	JK	+	GP	→ ST
Numeric:	4	7	0	2
Binary:	0100	111	0000	0010

Microinstruction: 010011100000010

Portion of the control storage associated with branching is not indicated.

(Continued)

can be considered compatible – a very important feature so that one microprogrammed processor can emulate another. The following list tabulates the advantages of the third-generation computer architecture compared to the nonmicroprogrammed machines.

EMULATION – Ability of one computer, when properly microprogrammed, to perform a task that is fully compatible with another.

STANDARD ARCHITECTURE – All third-generation computer architectures are similar.

DIAGNOSTICS – It is possible to have diagnostic routines as part of the resident microprogram.

GENERAL CHARACTERISTICS – Truly general purpose is the nature of the third-generation machines, thus they can be microprogrammed as central processors or peripheral controllers.

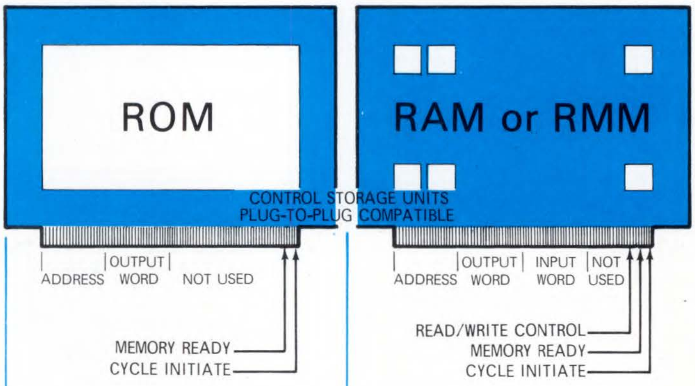
FIELD MODIFICATIONS – Core ROMs permit easy word alterations in the field.

EXPANDING PERFORMANCE ECONOMY – Addition of new features to a system can be simple.

Fourth-generation computers have not been previously mentioned because they operate with third-generation hardware. Basically, fourth-generation machines possess more sophisticated microprogramming to attain features such as virtual systems, virtual memory and paging. In general, one might conclude that for medium to large systems, dedicated or not, a third-generation or a microprogrammed technique appears to be the best approach.

Coauthors of this article are **J. Kjell Hovik** and **Winston W. Hodge** of Datapac, Inc., Costa Mesa, Calif. Mr. Hovik, president, received his B.S.E.E. and M.S.E.E. from the Norwegian Institute of Technology. His past experience includes the position of manager of memory development at Varian Data Machines. Mr. Hodge, director, Systems Architecture, holds three patents. He received his B.S.E.E. from Chapman College and is presently doing graduate work at UCLA and California State College.

Plug-to-plug ROMs and RAMs provide control storage for third-generation computers. Writable control storage is preferred for prototype work; read only is much more cost effective and is preferred in production systems. The table compares these two types of storage.



	READ ONLY CONTROL STORAGE (ROM)	WRITABLE CONTROL STORAGE (RMM, RAM)
COST	ROM is cheaper than RMM, RAM	A large percentage of RTP's can be built with microcode
TAILORABILITY	Modifications of control storage create problems in maintaining compatibility with existing software. Since software should be standardized, emulations are not generally desirable. However, core ROM is easy to alter.	Provides capability for very large numbers of distinct system emulations in one mainframe. Difficult to maintain compatibility between various pieces of equipment from the same product line.
DIAGNOSTICS	Only a portion of ROM generally contains diagnostic microprograms. Only a limited number of diagnostic microprograms can be accommodated.	Diagnostic programs can be loaded into the writable control storage as required. Virtually no limit exists to the number of diagnostic microprograms that can be accommodated.
ENGINEERING CHANGES	Easily accommodated.	More easily accommodated.
VOLATILITY	Nonvolatile.	Volatile.
PACKAGING	Greater bit density than RAM and RMM.	Not as high bit density as ROM.
MAJOR APPLICATION	Production systems.	Prototype systems.

FOR A FREE REPRINT OF THIS ARTICLE **CIRCLE NO. 480**

dipole concept improves readback analysis

Effects of the gap variation between the read head and the surface of a magnetic memory drum can be unpredictable. Using a magnetic dipole concept, a designer attains a better understanding of the readback process without degradation to the accuracy of his design prediction.

An exact analysis of magnetic circuits usually leads to complicated calculations. For engineering purposes, however, selecting the appropriate mathematical model permits the derivation of a relationship that can be effectively applied to design predictions. One of these idealizations is the "magnetic dipole." Employing this concept, an order-of-magnitude value for the amplitude of the readback signals from a magnetic memory drum can be defined.

Basically, a memory drum is a rotating cylinder driven by a synchronous motor. The recording medium is a magnetic material, such as red iron oxide (Fe_2O_3), that is generally placed in a series of grooves parallel to the drum rotational axis.

On the drum periphery, a set of recording heads is mounted. These heads write or read information from the drum surface either by magnetizing small areas or by sensing the magnetization of areas where information has been previously recorded. For this discussion, it will be assumed that the medium directly under the head is in saturation. Strength of the magnetization depends upon the retentivity of the medium, and the write-head current establishes the direction that determines the recorded information. Thus, each bit of information on the drum surface is essentially a small piece of magnetic material as shown in **Fig. 1**. These bits are assumed to be sufficiently spaced not to interact with each other.

For calculating the magnetic flux density distribution in the vicinity of the magnetized oxide, an equivalent magnetic dipole of length "L" will represent a bit. However, since the transversal dimensions "l" and "h" of the equivalent magnet in **Fig. 1** are not negligible when compared to "L", the magnetic flux density amplitude should be corrected to account for the physical shape of the real oxide bit. By comparing the flux densities created by the ideal magnetic dipole discussed in **Fig. 2** and the physical magnet in **Fig. 1**, the required correction factor can be determined as illustrated in **Fig. 3**.

Putting the Theory to Work To demonstrate how to use the magnetic bipole concept, assume a drum system with the following parameters:

On the drum surface, a small magnet with the following dimensions represents each bit of information: L = 0.0045 inch, l = 0.050 inch and h = 0.0015 inch.

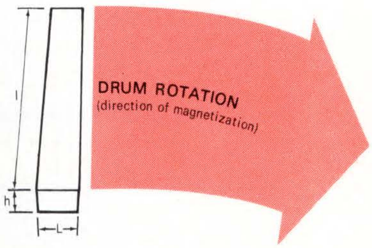


Fig. 1—**Each data bit** on the memory drum surface consists of a small piece of magnetic material. Depth of the magnetic medium is "h", the write head defines the transversal dimension "l" and "L" is the length of an equivalent magnetic dipole for each bit.

Retentivity of the recording medium is $B_r = 450 \times 10^{-4}$ Wb/m². From **Eq. (2-4)**, the magnetic moment is $M = 4.16 \times 10^{-8}$ A × m². Applying **Eqs. (2-5)** and **(3-9)** to OP = x = L = 0.0045 inch yields the correction factor k. **Eq. (2-5)** defines the magnetic flux density induced in P by the magnetic dipole or $B = 12.7 \times 10^{-4}$ Wb/m². For the case of the real magnet, **Eq. (3-9)** determines B in P or $B = 2.55 \times 10^{-4}$ Wb/m². The ratio of the two calculated flux densities represents the correction factor or $k = 5$.

The magnetic flux density component normal to the drum surface is evaluated for specific positions using **Eq. (3-10)**. To illustrate, the results for two consecutive bits magnetized in the same direction are tabulated and plotted in **Fig. 4**.

Readback Voltage Calculation For evaluating the readback signal amplitude, some additional parameters will be defined and introduced where needed in the calculation. In **Fig. 5**, the assumed read-head-drum gap is H = 0.001 inch. If the read-head pole area is A, the expression for the magnetic flux in the head is:

$$\phi = A\,|\vec{B}_n|\ \text{Wb}$$

Applying Lenz's Law, the voltage induced in the head is:

$$V = \frac{\Delta\phi}{\Delta t} = \frac{AN\,\Delta\,|\vec{B}_N|}{\Delta t}$$

where N is the number of turns of the read-head winding.

Referring to **Fig. 4** and using linear approximation, the magnetic flux density varies from circa 0 to 3.84×10^{-3} Wb/m² between points A and B, and from 3.84×10^{-3} to 0 Wb/m² between points B and C.

$$\Delta\,|\vec{B}_N| = 3.84 \times 10^{-3}\ \text{Wb/m}^2$$

If Δt_1 and Δt_2 represent the time required for the read head to travel from points A to B and B to C, respectively, then

$$V_{pk\text{-}pk} = AN\left(\Delta\,|\vec{B}_N|\right)\left(\frac{1}{\Delta t_1} + \frac{1}{\Delta t_2}\right)$$

(Continued)

dipole concept (Cont'd)

Assume the following parameters:

$$A = 0.48 \times 10^{-3} \text{ sq inches}$$

$$A = \frac{4.80 \times 10^{-4}}{1550} \text{ sq meters}$$

$$N = 600 \text{ turns}$$

$$\text{Drum diam} = 4.5 \text{ inches}$$

$$\text{Drum speed} = 100 \text{ rps}$$

$$\Delta t_1 = \frac{0.0043}{\pi \times 4.5 \times 100 \times 2} \text{ sec}$$

$$\Delta t_2 = \frac{0.0045}{\pi \times 4.5 \times 100 \times 2} \text{ sec}$$

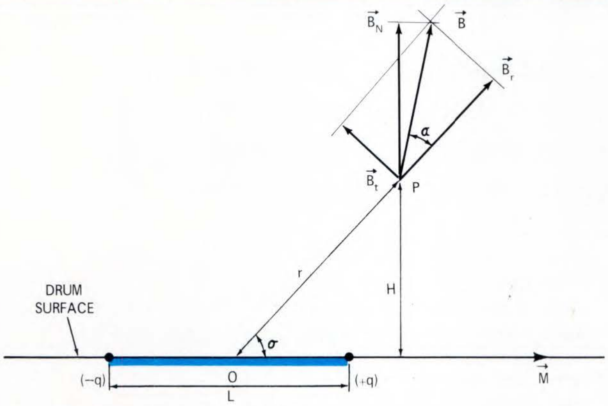


Fig. 2—**Magnetic moment** $q\vec{L} = \vec{M}$ characterizes equivalent magnetic dipole of length "L" where "q" is pole strength. Magnetic flux density in "P" located at "r" distance from the dipole center "O" is $\vec{B}$.

Components $\vec{B}_r$ and $\vec{B}_t$ make up $\vec{B}$ and are defined as:

$$|\vec{B}_r| = \frac{\mu o}{2\pi} \frac{M}{r^3} \cos \sigma \tag{2-1}$$

$$|\vec{B}_t| = \frac{\mu o}{4\pi} \frac{M}{r^3} \sin \sigma \tag{2-2}$$

where $\mu o = 4\pi \times 10^{-7}$ is the permeability of free space.

Magnetic oxide compound specifications usually provide retentivity B_l (Wb/m²) of the coating following saturation. Applying **Eq. (2-1)** at the positive tip of the magnetic dipole yields:

$$|\vec{B}_r| = \frac{\mu o}{2\pi} \frac{M}{\left(\frac{L}{2}\right)^3} = B_l \tag{2-3}$$

and

$$M = \frac{B_l}{\mu o} \times \frac{\pi L^3}{4} \tag{2-4}$$

Combining **Eqs. (2-1), (2-2)** and **(2-4)** yields:

$$|\vec{B}_r| = \frac{B_l L^3}{8\, r^3} \cos \sigma \tag{2-5}$$

$$|\vec{B}_t| = \frac{B_l L^3}{16\, r^3} \sin \sigma \tag{2-6}$$

Components $|\vec{B}_r|$ and $|\vec{B}_t|$ can be expressed in terms of H—distance between point P and the drum surface:

$$H = r \sin \sigma \tag{2-7}$$

Then **Eqs. (2-5), (2-6)** and **(2-7)** give:

$$|\vec{B}_r| = \frac{B_l L^3}{8 \dfrac{H^3}{\sin^3\sigma}} \cos \sigma = \frac{B_l}{8} \left(\frac{L}{H}\right)^3 \sin^3\sigma \cos \sigma \tag{2-8}$$

$$|\vec{B}_t| = \frac{B_l L^3}{16 \dfrac{H^3}{\sin^3\sigma}} \sin \sigma = \frac{B_l}{16} \left(\frac{L}{H}\right)^3 \sin^4\sigma \tag{2-9}$$

Modulus of $\vec{B}$ at point P is:

$$|\vec{B}| = \sqrt{|\vec{B}_t|^2 + |\vec{B}_r|^2}$$

$$|\vec{B}| = \frac{B_l}{8} \left(\frac{L}{H}\right)^3 \sin^3\sigma \sqrt{\cos^2\sigma + \frac{\sin^2\sigma}{4}}. \tag{2-10}$$

Another component of $\vec{B}$ used in evaluating readback signal is the projection $\vec{B}_N$ of $\vec{B}$ on the normal to the drum surface:

$$|\vec{B}_N| = |\vec{B}| \cos \left[\frac{\pi}{2} - (\sigma + \alpha)\right] \tag{2-11}$$

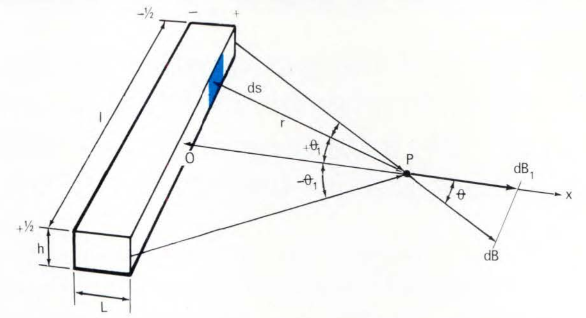


Fig. 3—**Magnet transversal dimensions** affect the magnetic flux density created at any point in the proximity of the oxide bit. A correction factor *k* compares the magnetic flux densities induced by the real magnet (**Fig. 1**) and the equivalent dipole (**Fig. 2**). Since the ideal magnetic dipole and the oxide bit were assumed to be equivalent for calculating **Eq. (2-11)** in **Fig. 2**, their magnetic moments **M** are equal. With reference to the diagram, the small area dS on the magnet's positive end bears a magnetic charge I dS where I is the magnetization constant defined by

$$I = \frac{M}{V} \tag{3-1}$$

and where V = (h) (1) (L) or the equivalent magnet volume.

Coulomb's Law gives the magnetic flux density created at point P by I dS:

$$dB = \frac{\mu o}{4\pi} \frac{I\, dS}{r^2} \tag{3-2}$$

Resultant of two symmetrical elements dS is along axis O-x. Thus:

$$dB_1 = dB \cos \sigma = \frac{\mu o}{4\pi} \frac{I\, dS \cos \theta}{r^2} \tag{3-3}$$

Or because dS = h dl,

$$dB_1 = \frac{\mu o}{4\pi} \frac{I\, hdl}{r^2} \cos \theta \tag{3-4}$$

Eq. (3-4) can be rewritten in function of OP = x = r cos θ:

$$dB_1 = \frac{\mu o}{4\pi} \frac{I\, hdl}{x^2} \cos^3 \theta \tag{3-5}$$

Finally, because $\tan \theta = \frac{1}{x}$:

$$\frac{d\theta}{\cos^2 \theta} = \frac{dl}{x} \qquad \text{Or} \qquad dl = \frac{x}{\cos^2 \theta} d\theta$$

Eq. (3-5) becomes:

$$dB_1 = \frac{\mu o}{4\pi} \frac{Ih}{x} \cos \theta \, d\theta \tag{3-6}$$

Integration of **Eq. (3-6)** over the entire positive face of the magnet yields:

$$B_1 = \frac{\mu o\, Ih}{4\pi\, x} \int_{-\theta_1}^{+\theta_1} \cos \theta \, d\theta = \frac{\mu o\, Ih}{2\pi\, x} \sin \theta_1 \tag{3-7}$$

Using similar calculations, the contribution of the magnet negative face to the flux density at point P is:

$$B_2 = \frac{\mu o\, Ih}{2\pi\, (x + L)} \sin \theta_2 \tag{3-8}$$

Therefore, the total flux density at point P equals:

$$B = B_1 - B_2 = \frac{\mu o\, Ih}{2\pi} \left(\frac{\sin \theta_1}{x} - \frac{\sin \theta_2}{x + L}\right) \tag{3-9}$$

Correction factor *k* is the ratio of the two flux density values at point P. Ratio between **Eqs. (2-5)** and **(3-9)** serves as the correction factor for the flux density amplitude given by **Eq. (2-11)**. Therefore, the flux density distribution around the magnetized bit is:

$$|\vec{B}_N| = \frac{1}{k} |\vec{B}| \cos \left[\frac{\pi}{2} - (\sigma + \alpha)\right] \tag{3-10}$$

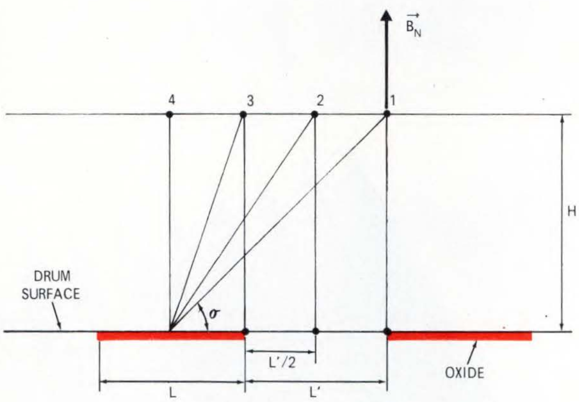
Therefore, the readback voltage pk-pk is:

$$V_{pk\text{-}pk} = \frac{4.8 \times 10^{-4} \times 600 \times 3.84 \times 10^{-3}}{1550} \left[\frac{2\pi \times 4.5 \times 100}{0.0043} + \frac{2\pi \times 4.5 \times 100}{0.0045}\right]$$

$$V_{pk\text{-}pk} = 0.9\text{V}$$

Empirical Results and Conclusions This analysis was successfully used to estimate the effect of the read-head-drum gap variation on the readback amplitude. Actual measurements made on related hardware indicated maximum readback signals of 800 to 900 mV, averaging generally 600 to 700 mV. The fact that the calculated readback signal is on the high side, compared to the empirical results, is because of the idealized models used in the analysis. When combined with experimental measurements, the equations discussed provide a better understanding of the magnetic drum readback process without too greatly reducing the accuracy of the design predictions.

Charles Benet is a senior engineer with Singer/Kearfott Div., where he has project responsibility for the Centaur guidance computer. In France, Charles received an Engineering Diploma from the Institut Superieur d'Electronique du Nord and an M.S. in Physics from Lille University. He has held various engineering positions in France, Switzerland and the United States.



POSITION	ANGLE σ	$\vec{B}_N$	Wb/m²
1	9°	0.086	10^{-3}
2	12°	0.296	10^{-3}
3	24°	3.84	10^{-3}
4	90°	0	

TABLE I

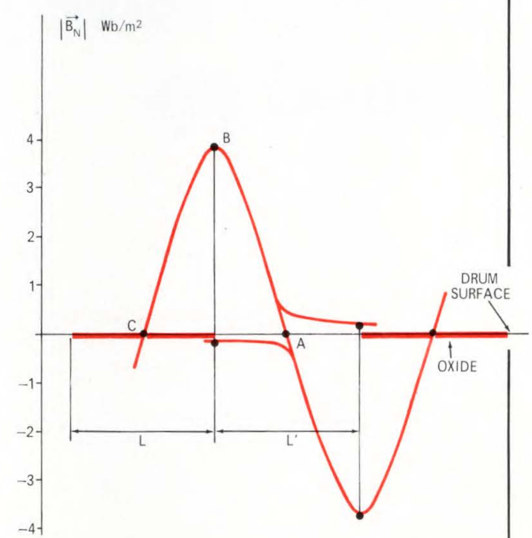
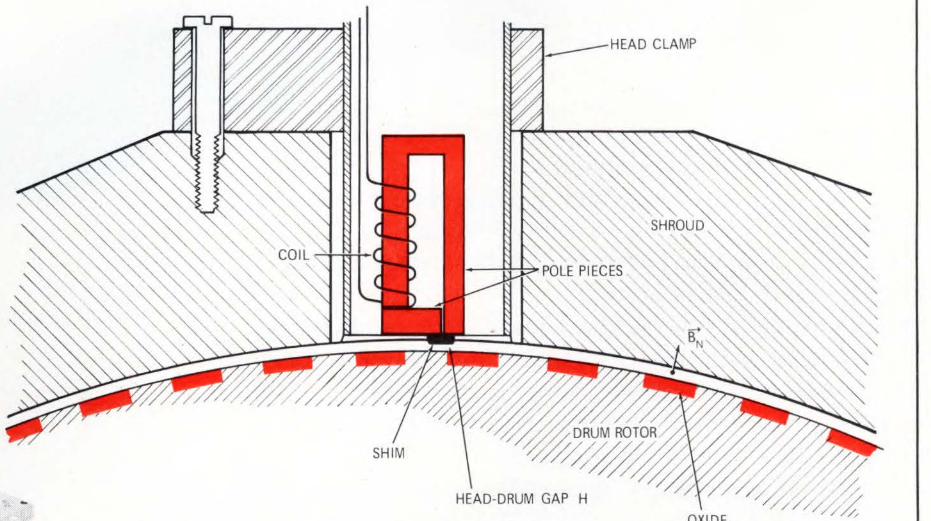


Fig. 4—**Magnetic flux** density component normal to the drum surface is evaluated for four specific positions using **Eq. (3-10)** with H = 0.001 inch and L′ = 0.0043 inch. Results tabulated in **Table I** are used to generate the curve.



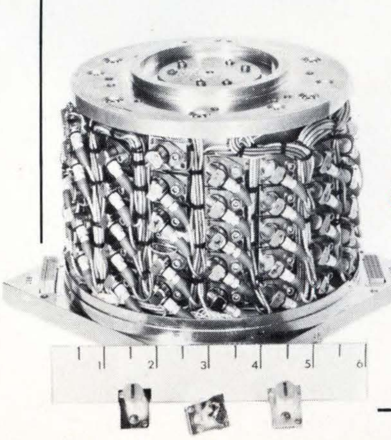


Fig. 5—**Cross-sectional view** shows the shroud, head and rotor arrangement of a magnetic memory drum. Photo depicts read/write head arrangement.

When you come to us for connectors, you could have your whole job wrapped up.

In the old days, we made connectors only to your specifications. We still do. But now we've gone a lot further.

We added off-the-shelf connectors. And now we'll mount either type to your specifications. And we'll have them wrapped to your specifications.

In short, we'll give you a connector or a complete wired backpanel assembly. Or anything else in between.

You save time, money and aggravation, because you don't have to set up an in-house operation.

And we can probably do it at lower cost because we make our own plastic bodies, form our own contacts, and assemble our own connectors. We even draw our own wire for wrapping.

It used to be you could only come to us for connectors.

Now you can throw the whole wrap at us.

To find out what we really can do, call Russ Sanders at 814-723-2000 or write him at GTE Sylvania, Precision Materials Group, Parts Division, Warren, Pennsylvania 16365.

GTE SYLVANIA

CIRCLE NO. 408

ROM/RAM merger forms a strong team

An electrically alterable ROM is an ideal means for storing microprograms. A semiconductor concept combines a RAM with a reprogrammable ROM.

Because biax and plated-wire memories are essentially electrically alterable read-only memories (ROMs), they have been an obvious choice for a microprogrammed system in the past few years. Cost and availability of these systems, however, have been generally unsatisfactory for the gain in system performance. In the search for a low-cost microprogrammed system with high reliability, braided wire ROMs, diode matrices and resistor matrices have also been considered.

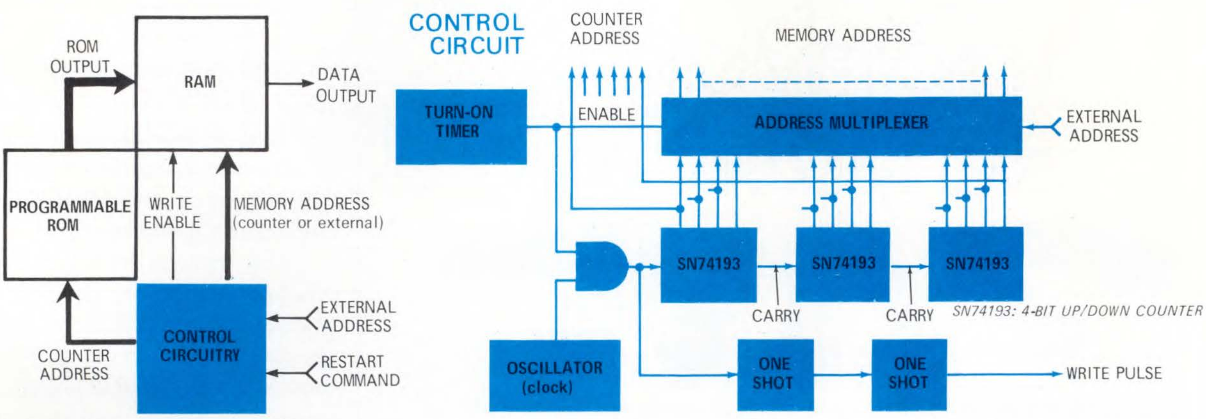
More recently semiconductor ROMs have been well received because of size, cost and power requirements and improved performance. But access time is important. In many cases, the 500- to 1000-nsec MOS devices are too slow. Bipolar, on the other hand, is expensive, but offers the necessary access time. Both MOS and bipolar ROMs lack ease of alterability, however—once an element is programmed it is permanent.

Now, solid-state reprogrammable ROMs are available with access times of 700 nsec—again too slow for most applications. However, the combination of a high-speed RAM with a reprogrammable ROM offers an excellent vehicle for those in need of a high-speed microprogram store. Such a system is easily changed either by changing the system, changing the plug-in MOS elements or by reprogramming the elements and replacing them in the system.

The block diagram illustrates a system that contains a reprogrammable ROM, a bipolar RAM and a control section. When the system is turned ON, the contents of the ROM are transferred to the RAM. The unit then provides output data on a 75-nsec access time basis from a stable address input.

This system is especially useful for debugging microprograms requiring bipolar speeds and applications needing frequent program changes of the ROM. Because the ROM is reprogrammable, the cost of a program change is only the time required to erase and reload new information.

Hugh DeVries, one of the founders and vice president of engineering of Monolithic Systems Corp., Denver, Colo., previously was chief engineer for the Denver Systems Div. of Ferroxcube where he directed memory and computer system design. DeVries received his B.S.E.E. from the University of Nebraska. He has two patents pending and is a member of IEEE.



System block diagram illustrates the signal flow between the reprogrammable ROM, the bipolar RAM and the control circuitry. Control section consists of multiplexing and timing circuits, up/down counters, an oscillator (clock) and a turn-on timer. When the system is turned ON, the ROM contents, under control of the oscillator and counters, are transferred to a location in the RAM, indicated by *Memory Address*. Timer permits external addressing of the bipolar RAM, thus providing high-speed access.

A microprogram instruction may require several ROM words because of bit lengths. For example, if the ROM words are only 8 bits in length, 12 ROM words will be transferred into the RAM for a 96-bit instruction. The unit then provides the output data on a 75-nsec access time basis from a stable address input.

A workable system was developed that is TTL compatible and requires 5 and −12V dc. Word sizes were 256, 512, 1k and 2k with bit lengths up to 96 bits (256-word system). The system is packaged on a 9.75- by 15- by 0.4-inch PC board that has two 70-pin edge connectors on the 9.75-inch side.

coming soon...

1971 IEEE INTERNATIONAL COMPUTER SOCIETY CONFERENCE, Sept. 22-24, Boston, Mass. All topics relate to the development and the use of quantitative methods for designing and evaluating computer systems. The presentations will focus on the computer component, be it hardware, software, firmware or a combination.

Conference keynote speaker is Edgar D. Mitchell, Apollo 14 Lunar Module pilot, and the luncheon guest speaker is Robert C. Townsend—author of *Up the Organization*. Registration fees that cover the technical sessions (total of 26) and a copy of the conference proceedings are: $35 (advance) and $45 (at conference) for members; $45 (advance) and $55 (at conference) for nonmembers; free for IEEE students and $2 for non-IEEE students (sessions only). Students must purchase the proceedings and luncheon tickets separately. For advance registration, contact: *1971 IEEE Computer Conference, General Delivery, Kendall Square Post Office, Cambridge, MA 02142.*

INPUT/OUTPUT SYSTEMS SEMINAR 1971, Oct. 12-14, Chicago, Ill. This 3-day seminar is dedicated to the total systems concept and will include presentations by major manufacturers of input/output equipment.

Presentations on Oct. 12 will include card oriented peripheral equipment and output EDP printers, both impact and nonimpact. The second day will be devoted to plastic card terminal equipment with applications in such fields as banking, health/welfare, industrial, retail and others, plus memory products including perforated tape and key-input data entry.

OCR/OMR equipment and applications will be covered on the final day. Two evening sessions will deal with plastic card security and EDP supplies.

For further information contact:

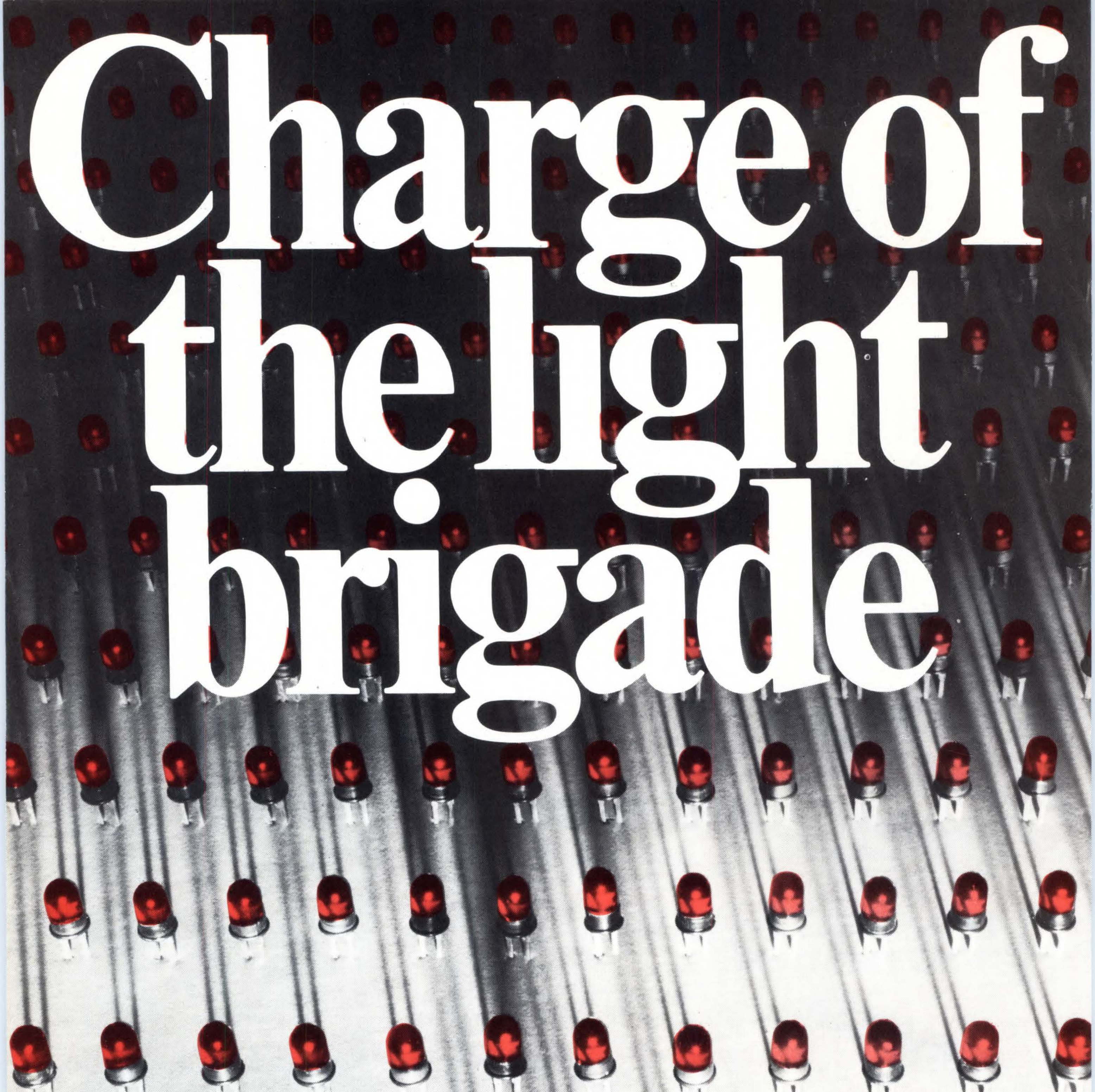
events

C. A. Greathouse, Data Processing Supplies Association, Box 1333, Stamford, CT 06904.

AUERBACH DATA COMMUNICATIONS CONFERENCE, Oct. 5-6, New York, N.Y. The 2-day program will provide executives with information on planning and fianancing a data communications system, emphasizing the use of information as an operational and management resource. Registration fee for all events and work material is $300. Advance registration for one or more individuals may be made on company letterhead, accompanied by a check made out to Auerbach Data Communications Conference or with approval to bill the registrant's company. For further information and advance registration, contact: *Auerbach Data Communications Conference, 9th Floor, 300 Madison Ave., New York, N.Y. 10017. Telephone: (212) 986-1270.*

coming courses . . .

COMMUNICATIONS TECHNIQUES FOR TELEPROCESSING, Oct. 10-13, St. Charles, Ill. Participants will become acquainted with the fundamental concepts and constraints of communication techniques for teleprocessing. They will learn telecommunications fundamentals, become exposed to today's communication techniques and evaluate current services, systems and products. Topics to be discussed include communication network concepts and economics, modulation concepts and modems, time-shared and batch terminal characteristics, error detection and protection, multiplexing, message switching and data concentration. The latest terminal equipment will be demonstrated, including alphanumerical CRT, graphics and facsimile. For 10 sessions, the cost is $390. For further information, contact: *National Electronics Conference, Inc., Oakbrook Executive Plaza, Suite 629, 1211 W. 22nd St., Oak Brook, IL 60521.*



Here are the LEDs you can order by the brigade full. HP's indicator lights—unbeatable for brightness and wideangle visibility. Use them on circuit boards—their tough leads will keep them firmly in place. Or mount them on a front panel; they just clip on. In fact, you can put them anywhere you want a small, tough bulb that needs only 2 volts DC to light the way.

Price? 65¢ in 10 K quantities. And they're available in any quantity you want. Call your local HP office for the exact figures and specs on the 5082-4440. Or write Hewlett-Packard, Palo Alto, California 94304; Europe: 1217 Meyrin-Geneva, Switzerland.

HEWLETT hp PACKARD

SOLID STATE DEVICES

CIRCLE NO. 415

01105

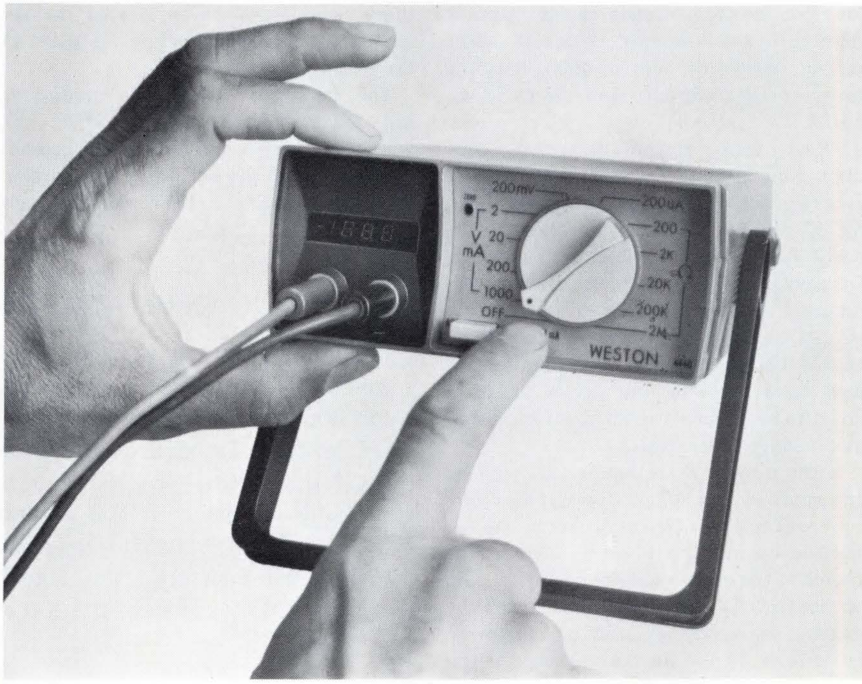
Progress in Products

LSI and LEDs Produce Truly Portable Digital Multimeter

PROGRESS IN INSTRUMENTATION

Seventeen ranges at 3-1/2-digit resolution are delivered by a little 2-1/4-lb multimeter being introduced by Weston. The Weston 4440 joins the Honeywell 500 multimeter (imported from France) in giving engineers and technicians nearly bench-type accuracy and measuring versatility in a package that can be carried anywhere. The cost of the Weston 4440 is in the same $300 range as the Honeywell 500 (both with batteries). However, the Weston "minimultimeter" carries its batteries as an integral part of itself and has automatic polarity switching.

The 4440 is a timely addition to the Weston 1240 family of semiportable, bench-type digital multimeters. One 24-pin MOS LSI DIP in the 4440 (made by a well-known MOS vendor) replaces 18 bipolar DIPs (some MSI) used in the 1240. One little plug-in card mounts 3-1/2 digits worth of Monsanto LED segments in the 4440, replacing the 3-1/2 "Nixie" tubes used in the 1240. Both these advances help the 4440 save PC board space and power. They are part of the reason that the 4440 can run 8 to 12 hours continuously off four C cells, while the 1240, like some other bench instruments, can only run approximately 6 hours off much larger and more expensive add-on battery packs. (The 1240 pack uses 12V Globe "gel/cells.") However, the 4440 does not have quite all the ranges of the 1240, nor does its 0.3% accuracy quite match the 0.1% of the 1240.



Less than $300 buys this little multimeter which can read ac and dc voltages and currents and measure ohms, all with 3-1/2-digit resolution. It is a beautiful example of how various aspects of modern technology—MOS LSI, GaAs LEDs, high-performance IC op amps, PC-mountable switches, injection-molded cases—can work together to produce considerable "progress." These photos are of the prototype; production version will have a battery-test position on the front panel rotary switch and won't have transistor sockets and the PC boards.

LSI-Controlled Dual Slope

The 4440 uses the same continuously self-adjusting type of dual-slope analog-to-digital conversion as the 1240. Rotary and pushbutton switches on the front panel (see photos) connect the two leads directly to the A/D converter in the instrument's basic dc mode (going by way of an attenuator on the higher ranges, of course). The A/D converter consists of a "free-running" IC op amp integrator with a 2-μF polyester feedback capacitor. It charges up and down under control of the logic on the LSI chip, counting out the digital result in the process.

The dc voltage being measured is transformed into the current that charges the 2-μF feedback capacitor by the op amp's input resistor, after the usual manner of operational integrators. Charging continues until a four-decade master timing counter on the LSI chip reaches 9999 and overflows, going to 0000. This happens five times a second because of the fixed frequency of a driving clock on the LSI chip. Then the chip logic causes the correct polarity of the reference current to be applied to the op amp integrator to "overpower" the dc input being measured. The capacitor now discharges.

During the discharge, the master timing counter on the chip is counting up from zero, also performing the function of a measuring counter. A high-gain threshold-sensing amplifier detects when the 2-μF capacitor has been discharged and causes the master timer's count to be copied into a buffer register. It is this buffer register's contents that are displayed without visible blinking on the LED readout. Obviously, the higher the dc voltages being converted, the longer it will take the given reference current to counteract the input and discharge the 2-μF capacitor, and the higher will be the count displayed by the LEDs.

To complete the cycle, the threshold amplifier also causes the reference current to be turned off. Then the dc input, acting alone, starts to recharge the 2-μF capacitor. But the four-decade master timing counter has not stopped. When it again reaches 9999 and goes to 0000, it again turns on the reference and the cycle repeats.

This version of the now universally-popular dual-slope A/D converter (Weston owns the patents and charges others about 3% of sales for their use) is well suited to battery-operated instruments. The clock frequency can drift without affecting the accuracy as long as it does so slowly, for it is just the short-term ratio of the periods that is being measured. But this version does take three or four cycles to settle down to an accurate reading after a large step change of the input.

If the measured voltage is too large for the manually-set range, the reference current will not be able to discharge the capacitor during the 0000 to 9999 count period of the master timing counter. Logic on the LSI chip automatically detects this, causing the overrange "one" and the proper polarity sign to flash a warning. At the same time, meaningless additional digits are blanked to save power.

The LED segments are driven hard ON at 125-Hz strobe rate, both to time share the numeral pattern encoding and to produce short, high-current duty cycles that push the LED diodes towards improved electrical-to-optical conversion. It will be noted from the photo that discrete transistors must be used between the LSI chip and the LED display to provide this high-current driving.

A Truly Miniature Power Supply

The ability to operate all this elegant circuitry for over 8 hours on just four Ni-Cad C cells results from very careful power budgeting, according to designer Irwin Munt. "We power the LEDs and the operational rectifier used for conditioning ac inputs and most of the MOS chip right off the 5V from the cells," he said. "We purposely chose ion-implanted MOS processing to be able to run the LSI off this low a voltage."

The integrating op amp and the reference currents, however, do need a precision ±12V. For this, Munt incorporated a small 100-kHz dc-to-dc converter followed by a zener regulator. The photo shows how small this could be made.

Tooled for Low Labor

"Weston is situated in one of the highest-cost labor markets in the U.S., so our designers have had to become adept at tooling products for low-labor-contact," Jack Stegenga, manager of new products, stated. "But we need to be confident that there is a 10,000-units-per-year market for a product like this before we invest in the tooling."

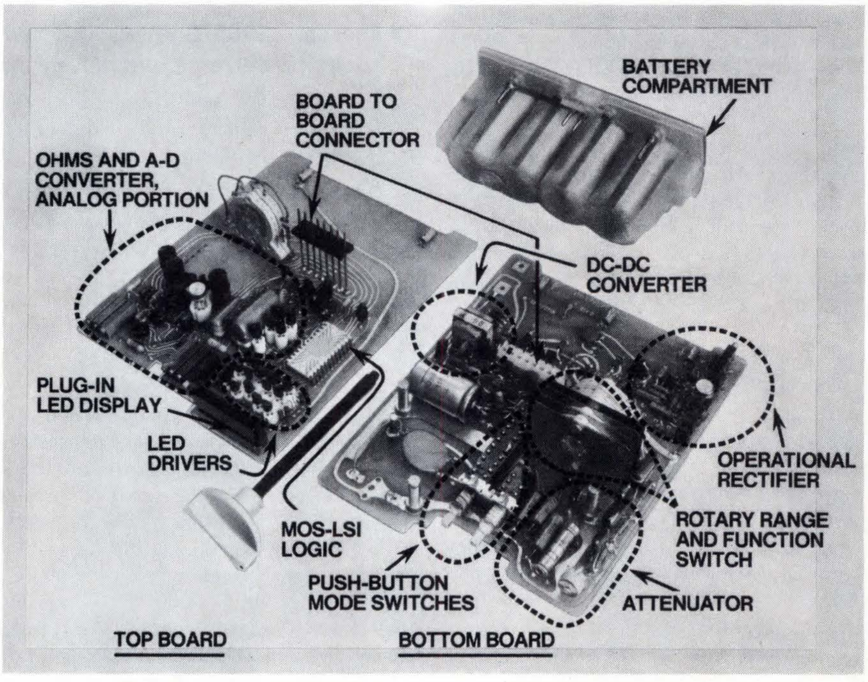
The tooling in this little product is impressive. It starts with the MOS chip, which is a proprietary design worked out by Weston and the semiconductor vendor. It carries through in the way all the parts are mounted on two PC boards with no hand soldering. It is completed by the sophisticated plastic cases for the instrument and the batteries.

Weston has been a pioneer in using the latest innovations in rugged, injection-moldable thermoplastics (see *EDN/EEE* Aug. 15, p. 14). An examination of these parts reveals such clever details as molded-in holes for spare fuses in the battery case and molded-in slides for holding the PC boards in the main instrument housing. They have even molded in additional grooves for future improvements—a thermal print-out being one possibility.

Weston Instrument Corp., 619 Frelinghuysen Ave., Newark, N J 07114. **359**

Model 4440 Specifications

DC Voltage: Will measure from 0.1 mV to 1 kV with 0.3% accuracy (see photo of instrument face for scales). Input impedance is 10 MΩ except on 200 mV and 2V scales, where it is 50 and 500 MΩ.
AC Voltage: Same as dc except accuracy is 0.5%.
AC frequency range is 40 Hz to over 10 kHz.
DC Current: Range is 100 μA and accuracy is ±5 digits.
AC Current: Same as dc except accuracy is 0.7% of reading, ±3 digits.
Ohms: Will measure from 1Ω to 2 MΩ.
Price: $285 (approaching $200 in OEM quantities).



Miniature Capacitor First With Multilayer Dielectric

PROGRESS IN COMPONENTS

Nearly 14 years of research effort have culminated in the introduction by Industrial Condenser Corporation, Chicago, of the first commercial, multilayer dielectric, miniature metallized capacitors. The new polypropylene molded units, designated Type LALZ "Multifilm" and available in values from 0.2 to 7μF, feature four individually-applied and polymerized layers of a plastic lacquer dielectric totalling no more than 2.5 microns in thickness.

The capacitors match the physical size of conventional single-film, thin-layer, miniature metallized types with identical rating, and are substantially smaller than metallized "Mylar" units. More significantly, they offer higher reliability than conventional film designs and, surprisingly, cost less to manufacture, resulting in a lower price tag.

For the future, the company reports that even thinner multiple-layer dielectric films are under development, which should permit the production of the smallest plastic-film capacitors ever marketed.

Why a Multilayer Dielectric?

The electronics industry has long desired a multilayer, miniature plastic film capacitor, but until now no one has been to commercially produce such a device whose total dielectric thickness did not surpass the thinnest single-layer cast or extruded films incorporated in conventional designs.

As a leading manufacturer of single-film, miniature metallized capacitors, Industrial Condenser has long recognized that a multilayer dielectric would inherently offer greater reliability for the simple reason that pinholes or other imperfections would extend only as far through the dielectric as the thickness of one layer, rather than extending through the entire dielectric as in single-film types. The probability of pinholes in four layers lining up is virtually nonexistent. (Paper capacitors always contain multiple layers because of the relatively large number of pinholes in paper compared to plastic film.)

In theory, multilayer miniature capacitors could be produced using several thicknesses of extremely thin, discrete sheets of cast or extruded film similar to that used in conventional capacitors. The problem is that such film is extremely costly and difficult to handle. The lacquer film generation technique has proven to be the more practical answer.

Higher Reliability

The virtual elimination of through-dielectric pinholes and other imperfections in the new "Multifilm" capacitors should substantially reduce the occurrence of catastrophic failures and instantaneous faults and clearings. Freedom from the latter is especially important in applications where circuit energy is insufficient to clear faults or where the circuit disruptions of instantaneous fault/clearing cannot be tolerated.

An ongoing reliability test program recently passed the 1,300,000 capacitor hours mark at 85°C without a single dead short, significant loss of capacitance or change in other characteristics.

Extensive testing is also underway to provide data on instantaneous faults and clearing. To date, these test results indicate that the number of instantaneous faults and clearings is insignificant and considerably lower than that of commonly used metallized film dielectrics.

A further tremendous advantage is that the "Multifilm" plastic is generated, metallized, wound, processed and completed all in one plant, leading to complete control of quality from start to finish, whereas the production of metallized film capacitors in general involves one manufacturer producing the film, another metallizing the film and another producing the capacitor.

Cost Advantage Too

Reliability tells only part of the story. Production economies permit the new "Multifilm" capacitors to be marketed at prices substantially below comparable single-film miniature metallized units and also below the larger metallized "Mylar" components. For instance, a 1-μF "Multifilm" sells for \$0.23 versus \$0.60 for a comparable thin-layer design and \$0.35 for metallized "Mylar". In the 4-μF size, a "Multifilm" unit is about \$0.54 versus \$1 for metallized "Mylar"; in the 7-μF size, about \$0.87 versus \$1.60.

Prospective Applications

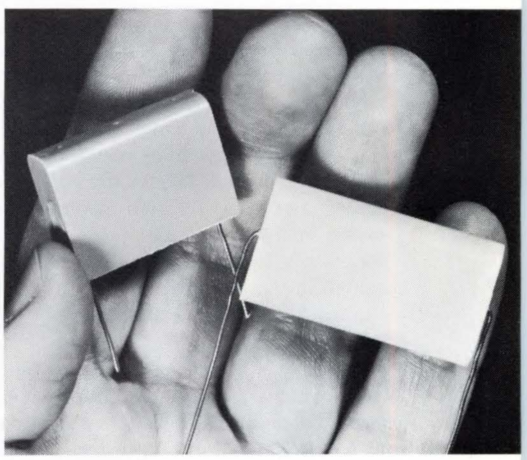
Industrial Condenser foresees that its new capacitors will replace aluminum and

Performance Characteristics

- Non-polar
- Non-inductive
- Operating Temperature Range: −40 to 85° C
- DC Working Volts: 50vdc
- AC Working Volts: up to 120 Hz - 35 V rms (AC Operating Voltage at higher frequencies available on request)
- Surge Volts: 75 V dc
- Test Voltage: 100 V dc - 2 sec
- Pulse Circuit Operation available on request
- Insulation Resistance 25° C at rated voltage:
  1μF and greater:250 M$\Omega\mu$F minimum
  Under 1μF: 750 MΩ minimum
- Power Factor 25° C 60Hz- 0.75% max.
  1kHz - 1.75% max.
- Also available for special applications:
  10 Volt Rating - 20,000 Megohm μF
  20 Volt Rating - 15,000 Megohm μF
- Std. Cap. Tolerance: Under 1μF±20%
  1 μF and greater ±10%
- Non standard tolerance: available to ±5%
- Leads: tinned copper for PC board soldering
- Enclosure: Molded in high temperature polypropylene
- Note: Under development is an additional series of these capacitors having higher insulation resistance.

Use below 5 V dc presently under study – request specific application data if intended use is below this level.

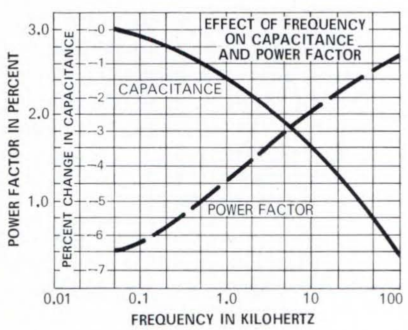
New compact 7-μF "Multifilm" capacitor on left; conventional 7-μF metallized "Mylar" unit on right.



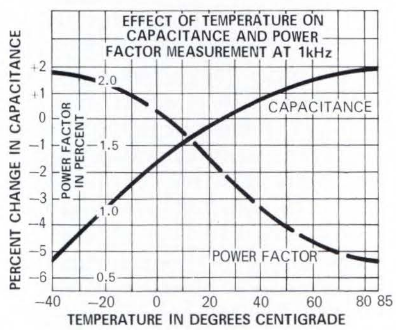
tantalum electrolytics in many applications, in addition to making substantial inroads into markets typically served by plastic film capacitors. Compared to electrolytics, the "Multifilm" units offer very competitive capacitance-to-size ratios (especially in the smaller sizes), lower costs and more stable characteristics. Additionally, they have unlimited shelf life, offer better high-frequency characteristics and are unaffected by voltage reversals.

Industrial Condenser Corp., 3243 N. California Ave., Chicago, IL 60618. **360**

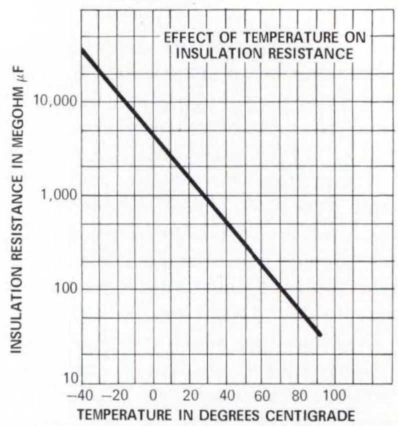
Performance Curves



The relatively small change in capacitance and power factor makes these capacitors applicable over a wide range of frequencies.



These capacitors can be used in many AC applications because of their low power factor which decreases with increasing temperature. Good capacitance stability over a wide range of operating temperatures is also a "Multifilm" feature.



Typical temperature-insulation resistance characteristics for 50V rating. Note: Typical 25° C insulation resistance is four times specified minimum.

Second-Source Log Amps with a Difference

PROGRESS IN PACKAGED CIRCUITS

Intech has introduced a pair of logarithmic amplifier modules that have the same model numbers as an earlier pair of log amps from Teledyne Philbrick. But, although the new Intech log amps (Models A-4350 and A-4351) are interchangeable with the Philbrick versions in many applications, there are also some important differences.

Size vs Versatility

Intech offers smaller packages and lower costs for its versions, whereas Philbrick offers greater versatility. Thus Intech's A-4350 has package dimensions of 1.5 by 1.5 by 0.5 inch, while Philbrick's 4350 is 2.7 by 2.7 by 0.5 inch. In quantities of 1-9, the Intech modules cost $85, compared with a price of $98 for the Philbrick modules. But the Philbrick modules can also be operated in the antilog mode, whereas the Intech versions can only be operated in the log mode.

Philbrick's product manager, Skip Osgood, points out that there would be no advantage in eliminating the antilog function from his company's modules because the same amount of circuitry is needed for both functions—only the interconnections change. Intech, however, used a completely different circuit approach and thus was able to achieve economies by dispensing with antilog capabilities, according to Walter Kaelin, chief engineer. While the internal circuits are different, the pairs of log amps are pin compatible in the logarithmic mode, though Philbrick provides extra terminals for antilog operation.

Positive or Negative

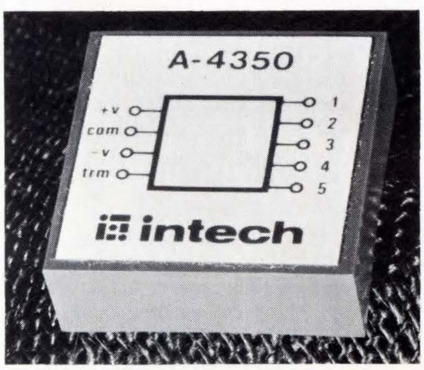
Both companies offer two versions of their log amps—one to provide the log of a positive voltage or current (4350) and the other for use with negative inputs (4351).

Performance of the Philbrick and Intech units is quite similar in most respects. Both versions amplify input currents from 10^{-9} to 10^{-3}A or input voltages from 1 mV to 10V. Both can be strapped to provide slopes of 2/3, 1 or 2V per decade. Both have temperature coefficients of $\pm 0.04\%/^\circ$C over operating temperature ranges of -25 to 85°C. Offset voltage drift (15V/°C) and input offset current (50 pA) are identical for the two pairs.

The two companies differ slightly, however, in the way they specify conformity. Intech specifies accuracy (deviation from best straight line) as $\pm 1\%$ with 1V/decade scaling) over the whole input current range. Philbrick has a similar $\pm 1\%$ conformity spec for the same current range but guarantees a tighter conformity of $\pm 0.5\%$ for the reduced current range of 10^{-8} to 10^{-4}A. Intech engineers also claim that their units have better accuracies in the middle of the current range.

Intech Inc., 1220 Coleman Ave., Santa Clara, CA 95050. **361**

Teledyne Philbrick, Allied Dr. at Rte. 128, Dedham, MA 02026. **362**



Intech's compact new log-amp module is only 1.5 by 1.5 by 0.5 inch. A similar unit from Teledyne Philbrick is larger but can also be operated in the antilog mode.

Hewlett-Packard believes that design engineers doing digital IC work should have a scope that's **intended** for digital IC work. You shouldn't have to face a makeshift adaptation of a scope that doesn't really "have what it takes," or an "overkill" unit with lots of capabilities you don't need and can't afford.

That's why we've developed two new additions to the HP 180 Scope System.

The first is a new mainframe, the 180 C/D. Like our 180 A/AR, it's compatible with all 180-System plug-ins to 100 MHz real time, plus the easy-to-use 1 GHz sampling plug-in and the 12.4 GHz sampling/TDR plug-in.

In addition, the 180 C/D incorporates new circuitry advances that allow optimized CRT performance. A 15 kV accelerating potential now gives you greater brightness and higher writing speed. Thus, photographic writing speed is several times faster—1500 div/μs (1 cm/div) with the standard P31 phosphor. These advanced capabilities make the 180 C/D fully compatible in single-shot response with the 180 System's fastest plug-ins.

The second bright idea is a new 75-MHz vertical plug-in—the 1808A. This bandwidth capability makes the 1808A ideal for testing digital circuits using T^2L or ECL, yet saves you a healthy amount in comparison with a 100-MHz system.

As you'd expect, the 1808A gives you the usual selection capabilities found in scopes of this class—deflection sensitivity (5mV/div to 5 V/div) and polarity. In addition, however, the 1808A also gives you a new first—selectable input impedance (50 Ω and 1 MΩ)!

And despite all these advantages, both 180 C/D and the 1808A are priced very competitively. The 180C is under $1,000; the rack-version 180D is slightly higher. The 1808A is $880—$800 without probes. Compatible time bases range from $450 to $700.

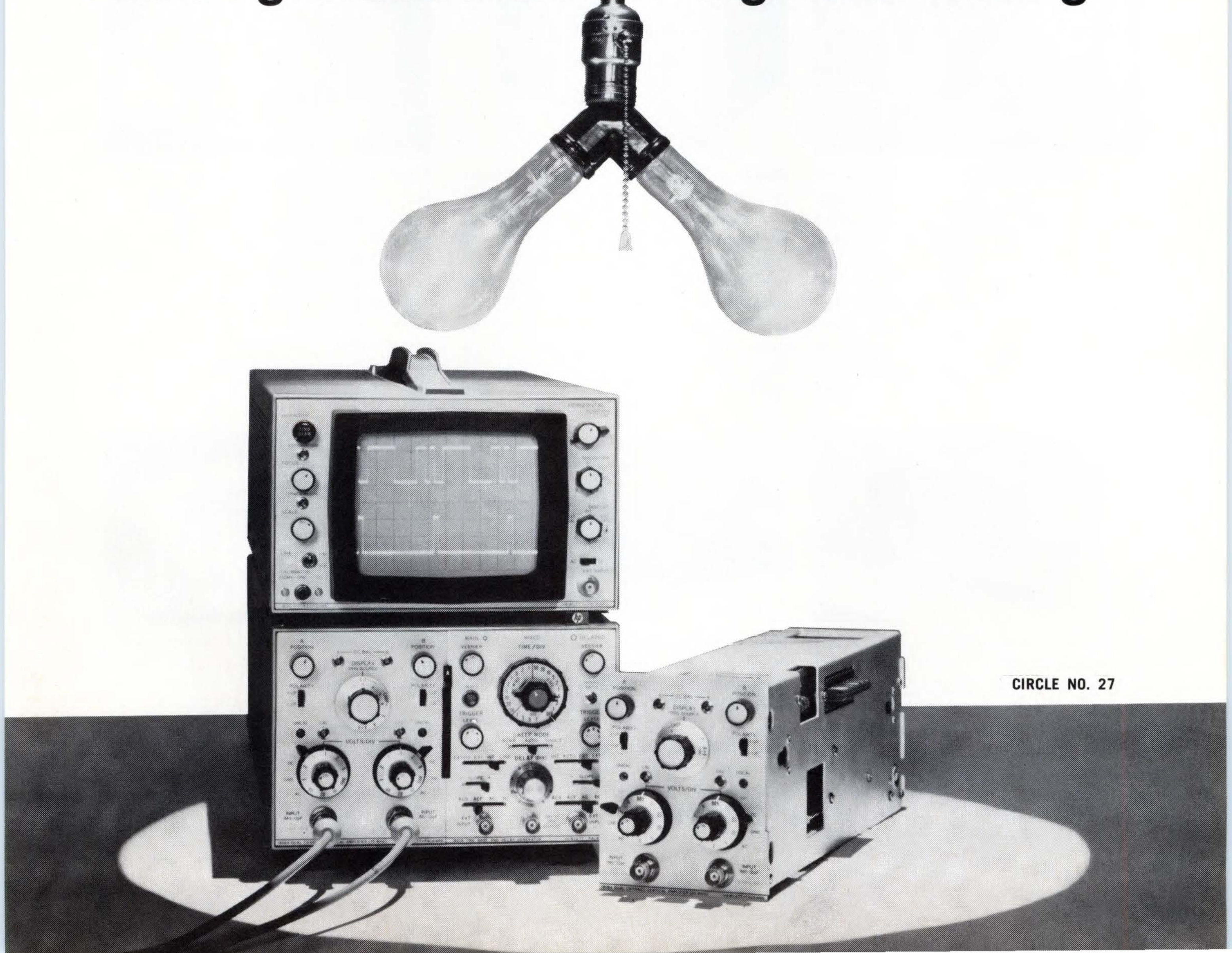
For further information on either of these new additions to the "more-to-come" HP 180 System, contact your local HP field engineer. Write Hewlett-Packard, Palo Alto, California 94304, for data sheets. In Europe: 1217 Meyrin-Geneva, Switzerland.

Scopes are changing.
Are You?

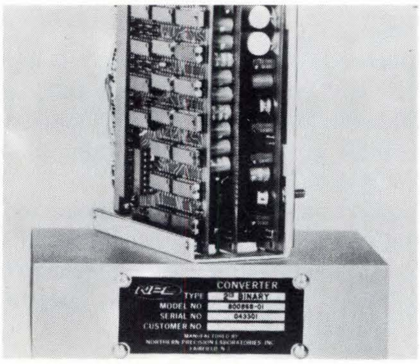
081/17

HEWLETT hp PACKARD

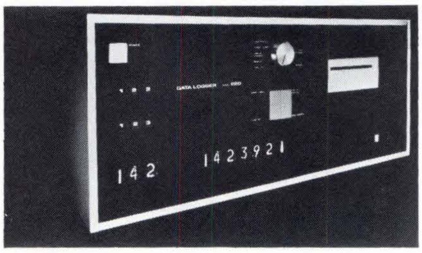
Two bright new ideas in digital IC testing



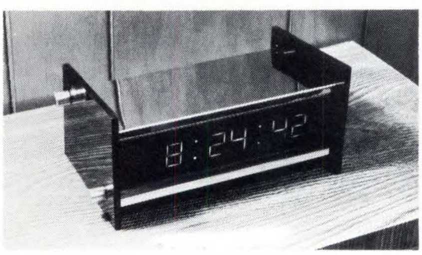
CIRCLE NO. 27



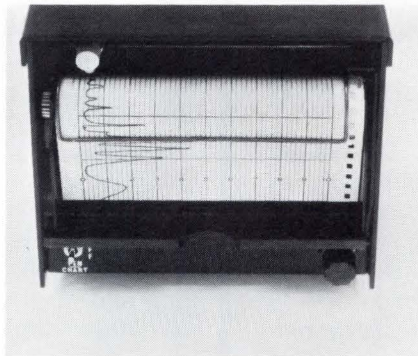
Synchro/resolver to digital converter handles either 11.8, 26 or 90V input signals. Conversion accuracy and resolution is ±1 bit and conversion time is 500 μsec. Overall dimensions are 5.5 by 4.25 by 1.75 inches. Power requirements are ±15V dc ±2% at 100 mA and 5V dc ±2% at 500 mA. Northern Precision Laboratories, Inc., 202 Fairfield Rd., Fairfield, N J 07006. **202**



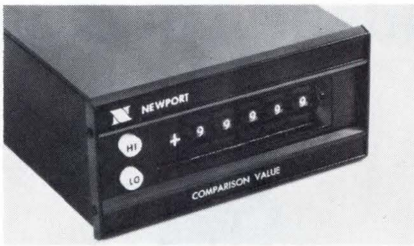
Digital data logger Model 210, features reference junctions, solid-state FET scanning, automatic zero drift correction and a periodic timer for unattended operation. Three function programming allows two thermocouple types and a linear mV range. Basic 10-point system is expandable to 100 points in the same chassis. Exhibiting ±0.01% accuracy, the price is $2000. Doric Scientific Corp., 7601 Convoy Ct., San Diego, CA 92111. **203**



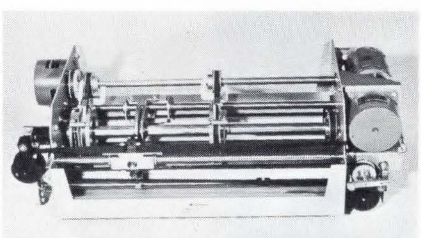
Digital clock, designated "Digicator," is a do-it-yourself item available in either kit form or assembled. Complete schematic and bill of materials are furnished. The unit displays time as hours, minutes and seconds on 7-segment incandescent readouts. Time may be displayed on either 12- or 24-hour basis. Cabinet is also available. Discon Corp., 2820 N.E. 4th Ave., Pompano Beach, FL 33064. **204**



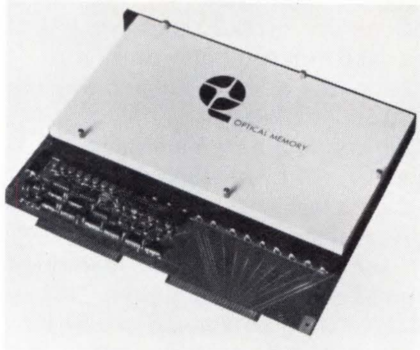
Strip chart recorder Model 701, is a 4-inch chart width unit with a span ranging from 1 mV to 1V full scale. Other features include 20 ips pen response, ±0.5% accuracy and wide selection of single and dual chart speeds. Combination of floating inputs and zero adjust permit recording of positive or negative signals. Price is $225. Precision Standards Corp., 1701 Reynolds, Santa Ana, CA 92505. **205**



Digital comparators, Series 270, provide instantaneous warning signals or process control feedbacks whenever preset limits are exceeded. Models are available with front panel limit selection of 3- to 6-digit unipolar or 3- to 5-digit bipolar inputs or remote limit selection of 3- to 6-digit bipolar. Price for the 2.5- by 5.25- by 7.75-inch unit starts at $135. Newport Laboratories, 630 E. Young St., Santa Ana, CA 92705. **206**

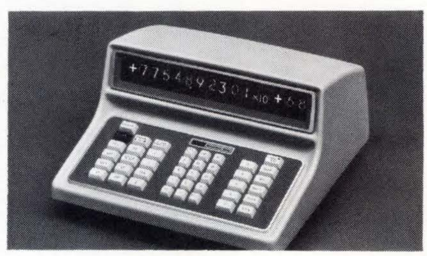


Impact printer mechanism DPM-30 is a 30-cps unit that provides all 94 standard USASCII characters including upper and lower case alphabet, numerals, symbols and space. It accepts standard fanfold, sprocket-fed paper in widths from 4 to 15 inches and can handle single or multiple copies – up to four carbons. Unit OEM price is $750. Typagraph Corp., 7547 Convoy Ct., San Diego, CA 92111. **207**



Optical ROM system, Model 401-22, uses fiber optics rather than the complex and delicate lens systems normally employed, and offers storage capacities of up to 50k bits mounted on an 11- by 13-inch PC board. Standard access time is 150 to 200 nsec. The unit offers rapid and simple field alterability, and can be dot ORed to any desired capacity. Quadri Corp., 2950 W. Fairmont, Phoenix, AZ 85017. **208**

Touch-tone terminal T-500 features a 49-key alphanumeric keyboard, which includes special characters for data entry via an audio response system. Special circuitry restricts the terminal from sending valid frequencies if more than one key is depressed simultaneously. Unit dimensions are 14.3 by 4 by 10.5 inches, and weight is 5 lb. Price is $700. Wavetek Data Communications, 9045 Balboa Ave., San Diego, CA 92112. **209**



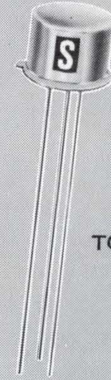
Desk-top calculator Model 909-01 speaks the universal language of mathematics bypassing the need for computer languages. All keys are programmable, thus reducing programming efforts. As a higher-performance replacement for the Scientist 909, this offers 256 program steps and 26 storage registers. Base price is $3200. Tektronix, Inc., Box 500, Beaverton, OR 97005. **210**

Fast Switching

5 AMP and 10 AMP POWER TRANSISTORS

FEATURING: Turn-on Time Less than 10 nanoseconds
• Planar Construction • Typically 500 MH_z, f_t

Solitron's ultra-fast switching SDT 6100 Series is now immediately available at new low prices. These NPN power devices are the fastest switching 5 Amp and 10 Amp transistors in the industry. Order today.



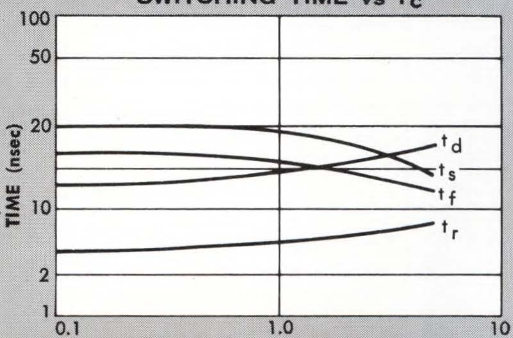
5 Amp Series

Type Number TO-5	Type Number TO-60	BV_{CBO}	BV_{CEO}	t_{ON} max.	t_{OFF} max.
SDT6101	SDT6104	65	30	50 ns	50 ns
SDT6102	SDT6105	65	40	50 ns	50 ns
SDT6103	SDT6106	65	50	50 ns	50 ns

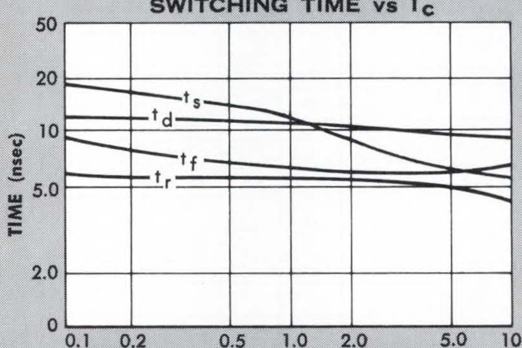
10 Amp Series

Type Number TO-5	Type Number TO-60	BV_{CBO}	BV_{CEO}	t_{ON} max.	t_{OFF} max.
SDT6110	SDT6113	65	30	65 ns	65 ns
SDT6111	SDT6114	65	40	65 ns	65 ns
SDT6112	SDT6115	65	50	65 ns	65 ns

5 Amp Series
SWITCHING TIME vs I_C



10 Amp Series
SWITCHING TIME vs I_C



For complete information, prices and engineering application assistance, dial toll-free 1-800-327-3243. Or write:

Solitron DEVICES, INC.

1177 BLUE HERON BLVD. / RIVIERA BEACH, FLORIDA / (305) 848-4311
TWX: (510) 952-7610

SAN DIEGO, CAL.
8808 Balboa Avenue
FET & Dual FET Transistors
MOS/FET Devices
MOS Memory Arrays
Shift Registers
Monolithic IC's
Small Signal Transistors

RIVIERA BEACH, FLA.
1177 Blue Heron Blvd.
Hi-Rel Power Transistors
SI & Ge. Power Transistors
Hi-Rel Power Hybrids
PNP-NPN Industrial Transistors

PORT SALERNO, FLA.
Cove Road
Microwave Connectors
Plaxial (R) Cable
Precision RF Coaxial

JUPITER, FLA.
1440 W. Indiantown Rd.
Microwave Stripline Components
Microwave Semiconductor
RF Semiconductor
Microwave Integrated Circuits

TAPPAN, N. Y.
256 Oak Tree Road
Diodes & Rectifiers
Zeners
High Voltage Assemblies
Power Rectifiers
Thick Film Hybrid Circuits
Ferrite & Ferrite Devices
Film Resistors

KENT, ENGLAND
Tubbs Hill House
London Road, Sevenoaks
Solidev, Ltd.
Full line of Solitron devices

BEN BARAQ, ISRAEL
51 Hayarkon Street
AEL Israel, Ltd.
Full line of Solitron devices

TOKYO 105, JAPAN
No. 5, 3-Chome
Shibahamamatsu-Cho
Minato-Ku
Matsushita Electric Trading
Full line of Soltiron devices

CIRCLE NO. 28

Computer Products

Plastic card punch, Model 625, converts any properly prepared CR-80 credit/identification card into a dialer card. The machine punches at a rate of 10 cps both data and sprocket holes per Western Electric Specification A-590456 into either embossed or nonembossed cards. Datron Systems, Inc., 100 Route 46, Mountain Lakes, N J 07046. **211**

Memory unit, Model 639, accomplishes input/output signal conditioning, control, scan conversion and storage functions. Using a single-ended scan converter tube, input signals are processed and stored for driving TV displays, printers and other devices. Hughes Display Systems, 2020 Oceanside Blvd., Oceanside, CA 92054. **212**

Portable trend recording system C-750 monitors and continuously records the speed of a section or the speed differences between sections of an operating process. Recorder uses a 20-division strip chart 3 inches wide at a standard chart speed of 3 inches/hr (up to 90 inches/hr is available). The Louis Allis Co., Div. of Litton Industries, Dept. P, 427 E. Stewart St., Milwaukee, WI 53201. **213**

Plated-wire add-on memory for the PDP-11 minicomputer, NM-8000 Series, has a total system capability of 64k 16-bit words. The memory is enclosed in a 20- by 12.25- by 19-inch cabinet. Systems may be purchased with either 4 or 8k modules and are field expandable. Nemonic Data Systems, Inc., 1301 W. 3rd Ave., Denver, CO 80223. **214**

Miniature data recorder combines three proven components. Series 7701 bidirectional totalizer offers up to 7-decade displays including sign. The 13-column high-speed printer, Series 7703, has 16 characters/column and uses standard 3-1/2-inch paper tape. A bidirectional rotary pulse generator, Series 1848, has electro optics capable of producing from 1 to 1200 pulses/revolution. Veeder-Root, 70 Sargeant St., Hartford, CT 06102. **215**

Two moving-head disc cartridge drives, Models 4047A and 4047B, provide high performance mass storage for NOVA computers. The 4047A contains one removable cartridge (1.247×10^6 16-bit words/cartridge) and two 2200-bpi moving heads. The 4047B contains both fixed and removable discs and has four 2200-bpi moving heads. Data General Corp., Southboro, MA 01772. **216**

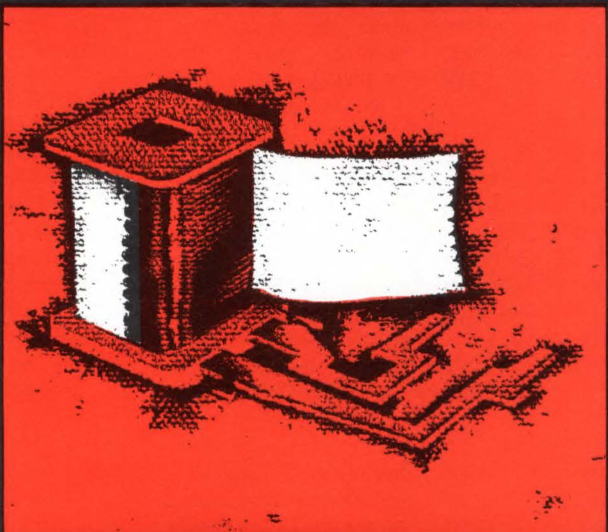
From 3M...

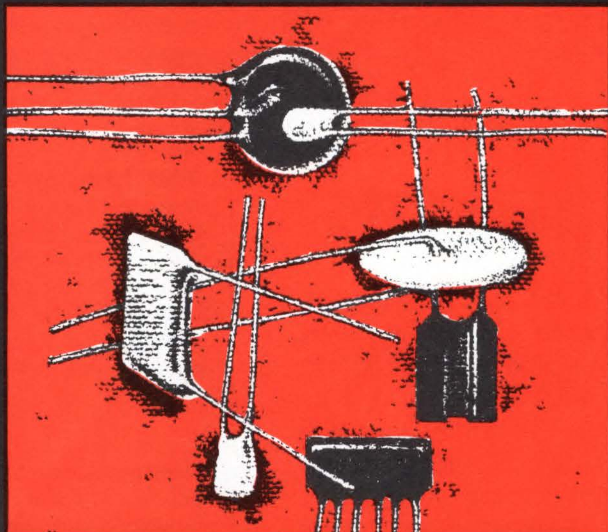
Flammability protection

New flame retardant materials for insulation safety.

"SCOTCH" BRAND FLAME RETARDANT TAPE NO. X-1266.
Resin-fiber construction with flame-retardant pressure-sensitive thermosetting adhesive for 130°C use. Excellent conformability. Handles like conventional paper or acetate cloth tapes. Flame-out in 3 seconds or less (ASTM-D1000-70 test). Meets UL flame retardancy requirements for SE-O materials, as well as UL Standard 492.

"SCOTCHCAST" BRAND FLAME RETARDANT RESIN NO. XR-5217.
For radial and axial lead components — thermistors, resistors, RC networks, film foil, ceramic, tantalum, diced chip and mica capacitors. Suited for semi-automatic or automated production equipment. Coats at 300°-350°F. Fast cure time: 2 min. at 350° to 30 min. at 275°F. Meets flame retardancy requirements of UL Standard 492.





Check these other flame retardant materials.

"SCOTCH" BRAND TAPES.
No. 69 — glass cloth, thermosetting silicone adhesive.
No. 66 — vinyl, UL recognized 105°C meets MIL-1-7798-A.
No. X-1264 — epoxy web solvent-resistant wire and cable ID tape.
"Temflex" Brand No. 2585 — non-adhesive vinyl plastic, flexible, self-extinguishing.

"SCOTCHCAST" BRAND RESINS.
No. XR-5192 — arc and track-resistant 130°C, liquid epoxy.
No. XR-5126 — room-curing two-part epoxy, 130°C, semi-flexible.
No. 255 — thermal and mechanical shock-resistant, 130°C, meets MIL-1-16923E.

TUBINGS.
"3M" Brand 3001, 3002, 3003, 3008 — extruded vinyl, general purpose, 105°C rated.
"Scotchtite" No. 3028 — heat shrinkable, clear or colors, thin wall. UL recognized 105°C, meets MIL-1-631 and MIL-1-23053B.

COPPER CLAD.
"Cuflex" Brand Flexible Laminate 6540 — copper-clad epoxy polyester web for printed wiring.

MICA.
"Isomica" Brand — silicone bonded mica for high temperature use.

For complete information, write: 3M Co., DM&S Div., 224-64, St. Paul, Minn. 55101.

Dielectric Materials & Systems Division 3M COMPANY

CIRCLE NO. 30

Computer Products

Seven-inch reel magnetic tape transport, 7000 Series, has a tape velocity of 18.75 ips and comes in a rack 8.75 inches high. An unusual tape loading feature eliminates the need of a take-up reel, thus simplifing loading and handling operations. Peripheral Equipment Corp., 9600 Irondale Ave., Chatsworth, CA 91311. **217**

Pair of modules, Types 16 and 17, provide signal handling and control logic required for operation of "OMNIGRAPHIC" 3000 strip chart and 4000 T-Y recorders as point plotters. Distances between successive points are 0.025, 0.05, 0.075 and 0.1 inch, selected from the front panel. Houston Instrument, Div. of Bausch & Lomb, Inc., 4950 Terminal Ave., Bellaire, TX 77401. **218**

X-Y position indicator, Model 60-228, detects the center of a laser beam at distances up to 30m with an accuracy of ± 4 μrad (± 0.1 mm at 25m) in each of two axes. Price is $175. Metrologic Instruments, Inc., 143 Harding Ave., Bellmawr, N J 08030. **219**

Digital logic trainer 2010 permits experiments to be performed in Boolean algebra, counters, registers, arithmetic circuits and other computer functions. Each type of circuit is represented on the front panel using MIL-STD symbols. Price, including software and training manual, is $395. Digiac Corp., Ames Ct., Plainview, NY 11803. **220**

Multiconductor cables for connecting computers and peripheral equipment may be ordered in bulk, cut to length or complete with specified connectors at one or both ends. Also available are cables for connecting CRT terminals with display control units. Anixter Wiring Systems, 325 S. Union St., Aurora, IL 60505. **221**

Option 121 for Series 2000 X-Y plotters, plug compatible with TTY or CRT terminals, permits hard-copy graphic plots. Using the terminal keyboard as an input, the operator inserts the program based on plotter control characters. Printout, identical to the data used for the plot, verifies the operator's program. Valtec Corp., 17751 Sky Park Circle, Irvine, CA 92664. **222**

Tightly-sealed cartridge, compatible with IBM 2420/3420 tape drives, reduces tape mounting time to seconds and increases reliability and operating efficiency. Human hands never touch the tape because threading is completely automatic. Memorex Corp., Computer Media, 1200 Memorex Dr., Santa Clara, CA 95052. **223**

Optical rotary encoders, MOD-CODER/R, come as complete "do-it-yourself" assembly kits that include incremental encoders with direction sensing and zero indexing, tachometers up to 5000 cycles/rev, rugged all metal construction and plug-in lamp modules with 100,000-hour life. In quantity, price is $50 each. Sequential Information Systems, Inc., 249 N. Saw Mill River Rd., Elmsford, NY 10523. **224**

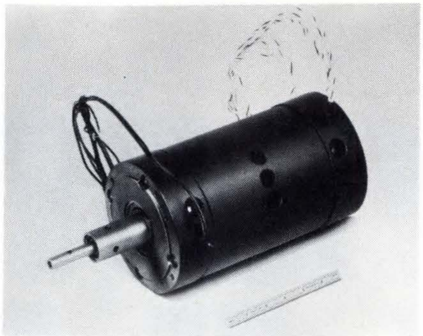
Paper-tape readers, Models 5101 and 5401, continuously adjust slewing speed from 300 to 625 cps and/or operate from a 50 to 400 Hz ac input. Controller mounts inside the reader chassis. Chalco Engineering, 15126 S. Broadway, Gardena, CA 90247. **225**

Modular data acquisition system, Model 7100, is a general-purpose data logger with a full range of optional accessories to scan, digitize and record up to 100 analog inputs. With an optional acoustical or hardwired coupler, the built-in teleprinter operates as a computer terminal. Monitor Labs, Inc., 10451 Roselle St., San Diego, CA 92121. **226**

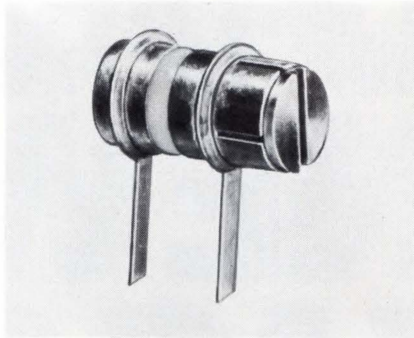
Console card reader M 1200 fills the need for an economical high-speed large-capacity punched card reader for standard 80-column EIA cards. Reading speed is 1200 cpm and hopper and stacker capacity is approximately 2250 cards. Documation, Inc., 841 E. New Haven Ave., Melbourne, FL 32901. **227**

Microfilm print head for a computer output consists of a 5- or 9-inch precision CRT, deflection driver, high-speed stroke-type character generator and page systems. Configured for OEM usage, the unit has spot sizes from 0.001 to 0.004 inches. Character set and fonts are available per customer request. Kratos Display Div., 7825 Deering Ave., Canoga Park, CA 91304. **228**

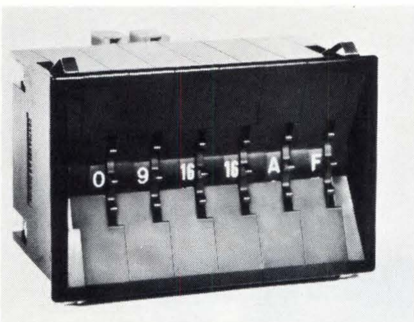
Socket pins are designed for PC board mounting of bi-pin incandescent lamps, indicator lights and LEDs. Component replacement can be done with no additional soldering with the SP-202 pins. Price is $0.05/pair in quantity. General Illumination, Inc., 2233 University Ave., St. Paul, MN 55114. **229**



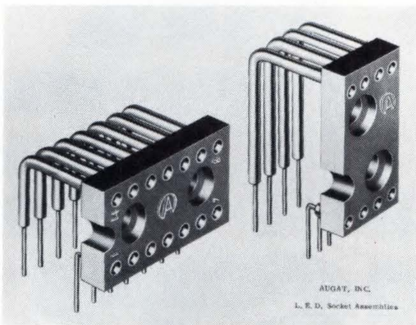
Two dc torque motors in a single housing – each driving a separate shaft – provide a compact tape or reel drive unit. Each motor has a peak torque of 1200 oz-in. Model H5500-1000 can be modified to customer requirements. Magnetic Technology, Div of Vernitron Corp., 21001 Kittridge St., Canoga Park, CA 91303. **232**



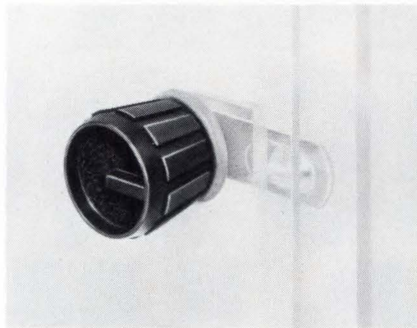
Variable capacitor, Model 7271, features low-loss ceramic dielectrics for fine tuning of crystal oscillators from kHz to GHz frequencies. Range is 0.6 to 4.5 pF with a Q of >2000 at 250 MHz. Price is $7 to $1.50 each. Johanson Manufacturing Corp., 400 Rockaway Valley Rd., Boonton, N J 07005. **235**



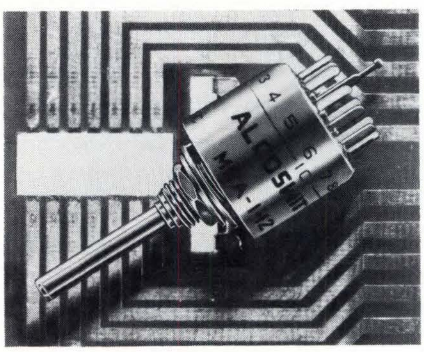
Thumbwheel switches are available in 11, 12 and 16 positions with replaceable code discs. The Type B switch has nine contact springs that wipe across the PCB code disc, and provides up to 9 output lines. Interswitch, 770 Airport Blvd., Burlingame, CA 94010. **230**



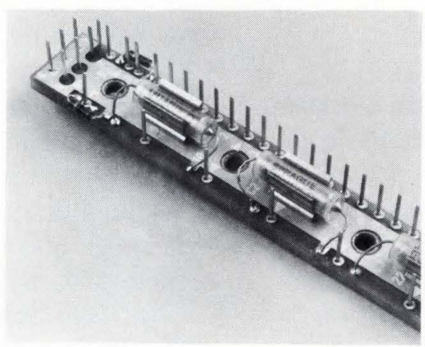
LED socket assemblies for 8- and 14-lead displays are made of glass-filled nylon with mounting holes and polarization notch. Single units are standard for printed circuit or chassis mounting. Multi patterns are available. Augat Inc., 33 Perry Ave., Attleboro, MA 02703. **233**



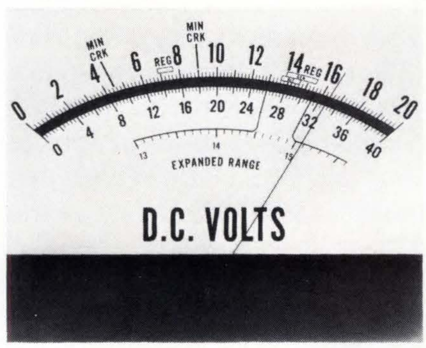
Cabinet latch installs in seconds with a push-on clip and a positioning set screw. Pawl position is shown by a styled knob that indicates latched or unlatched position at a glance. Southco, Inc., 200 Industrial Highway, Lester, PA 19113. **236**



Subminiature rotary switch with 1/2-inch diam is designed for PC mounting. Models are available in 1, 2, 3 and 4 poles on a single deck with a maximum of ten positions. Prices start at $2.97 each in 100 lots. Alcoswitch, Div. of Alco Electronic Products, Inc., 8 Marblehead St., North Andover, MA 01845. **231**



Power/clock-pulse distribution bar includes four 13Ω timing-pulse distribution paths, a ground and three voltage distribution lines. Each timing-pulse line is provided with solder eyelets for mounting termination resistors. CAPITRON, Div. of AMP Inc., Elizabethtown, PA 17022. **234**



Panel meter features input impedance of 10 MΩ. Optional memory capability holds the last-taken meter reading within an accuracy of 1%. Various meter styles are available, with prices ranging from $25 to $30 in 100-unit quantities. Ideal Precision Meter Co., Inc., 214 Franklin St., Brooklyn, NY 11222. **237**

Components

Nylon rivets can be easily installed in electrical panel boards with a low-cost hand tool for inserting rivets and driving the center post through the rivet body. Price is \$3.50. Taylor Industries, Inc., Fisher Rd., Howell, MI 48443. **238**

Electropneumatic sensor can detect deviations or movements as small as 0.0001 inch with repeatability to 0.00002 inch. Basic sensor module is priced at \$20 in lots of 100. Landis & Gyr, Inc., 4 Westchester Plaza, Elmsford, NY 10523. **239**

Cooler for vertical mounting of plastic power devices will accommodate most single mounting tab and hole-through-case configurations. For thermal matching, the 6025 will accommodate two devices, one on each side. Prices vary from \$0.14 to \$0.35 depending on quantity and finish. Thermalloy Co., 8717 Diplomacy Row, Dallas, TX 75247. **240**

"Pee Wee Ductor" is a shielded inductor for micro-miniature hybrid circuits that measures approximately 1/8 inch between its leads. Inductance values range from 0.10 to 1000 μH, ±10%. Nytronics, Inc., Orange St., Darlington, SC 29532. **241**

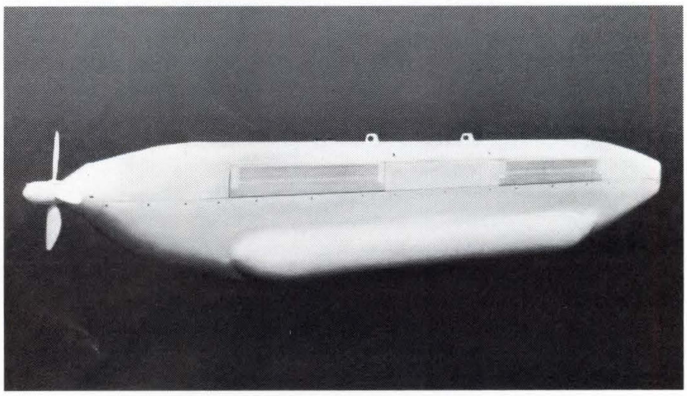
One-part epoxy coating powder for fast packaging, Novaloy 6521, processes as low as 120°C and coats as fast as 1 sec at higher temperatures. Rogers Corp., Rogers, CT 06263. **242**

Miniature variable autotransformers operate at 50 to 2000 Hz with an output voltage from 0 to line voltage or 10% above. Ratings are 2A for 201 Series and 3A for 291 Series. Staco, Inc., 2240 E. Third St., Dayton, OH 45403. **243**

Stepping motor features high torque output and fast response. Designed for use with computer peripheral equipment, the Model SM-024-0035-AA has a step angle of 15° and step accuracy of ±15 min. maximum non-cumulative error. Price is \$35 in quantities of 1000. Motion Control Systems Div., Warner Electric Brake & Clutch Co., 449 Gardner St., Beloit, WI 53511. **244**

AiResearch electronic cooling systems are built into the F-14.

We have designed and built complete electronic cooling systems for hundreds of airborne applications —both on board and pod mounted. In fact, a Garrett AiResearch built electronic cooling system is on board the Grumman F-14 air-superiority fighter. □ Whatever your specific airborne electronic cooling requirement, come to Garrett AiResearch for total system optimization.



Garrett AiResearch enclosures are also cooling the pod mounted ALQ-76 and ALQ-99 electronic countermeasures systems. The enclosure in the ALQ-99 pod (shown above) for the EA-6B utilizes surface heat exchangers as the ultimate heat sink.

GARRETT

AiResearch Manufacturing Co.
9851 Sepulveda Boulevard, Los Angeles, Calif. 90009
one of The Signal Companies

CIRCLE NO. 35

Components

Mildly activated liquid rosin flux is non-spattering and low fuming for microelectronic soldering. Microflux No. 5004 exhibits good bonding to passivated surfaces and eliminates the possibility of corrosion after bonding. Alpha Metals, Inc., 56 Water St., Jersey City, N J 07304. **245**

Aluminum magnet-wire conductor called "Hytek-20" possesses high conductivity with improved mechanical properties in the annealed state. It is available in a wide range of magnet wire insulations and sizes. Anaconda Wire and Cable Co., 9501 W. Devon Ave., Des Plaines, IL 60018. **246**

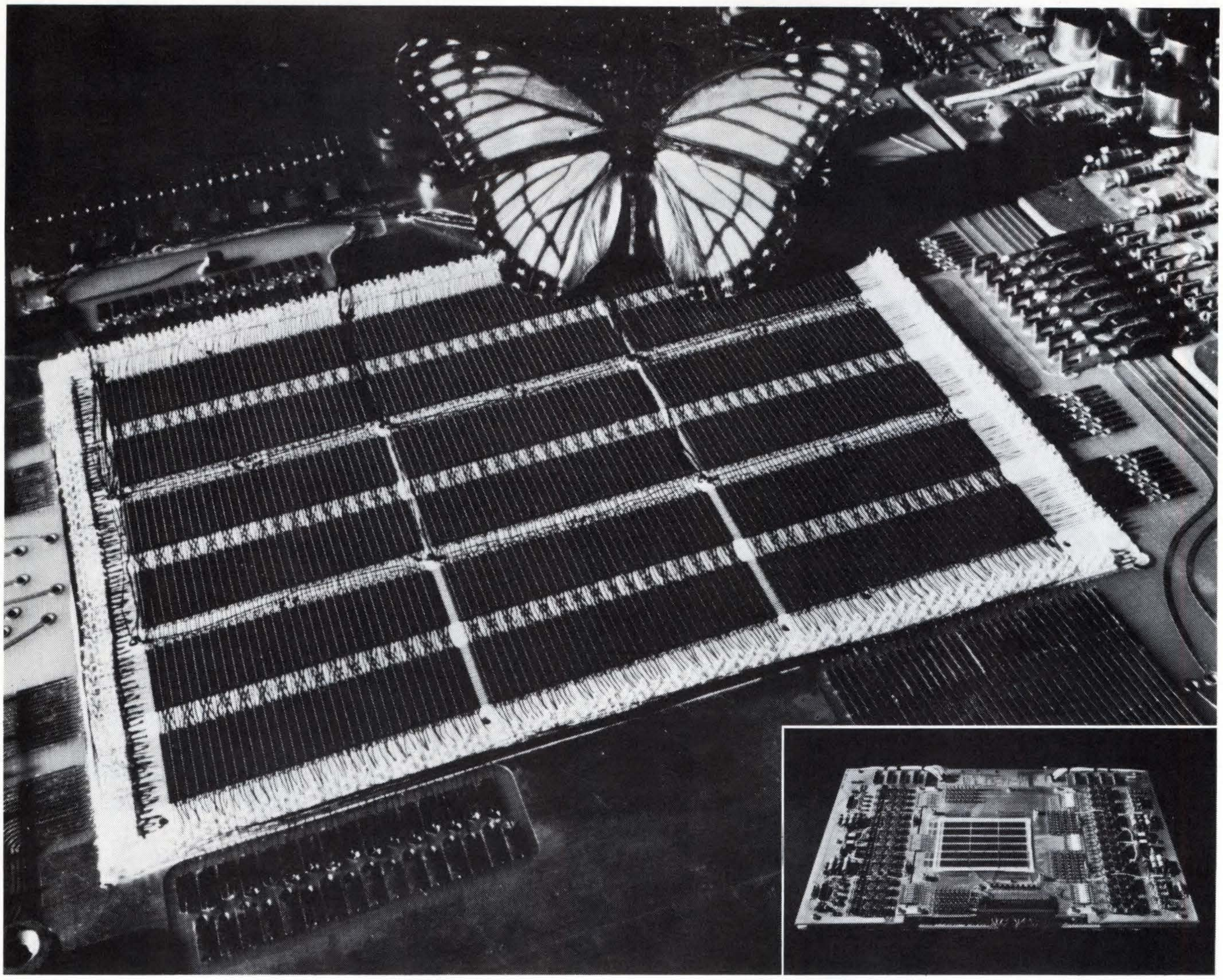
Cermet trimming potentiometers are 3/8-inch square single-turn units compatible with wave soldering practices and board washing techniques. Prices of the Series 72 are $0.70 in 1 to 9 quantities and $0.49 for 1000 quantities. Helipot Div., Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, CA 92634. **247**

Metal hybrid cases are available in 17 standard sizes to accommodate substrate areas of 0.375 by 0.5 inch through 1.125 in^2. Tekform Products Co., 2780 Coronado St., Anaheim, CA 92806. **248**

PC board mounting kit consists of a 15-pin connector and screw terminals mounted on a small PC board that provides interconnection. Priced at $10 each, the Model 2005 is ideal for installations where soldering is inconvenient or impractical. California Electronic Mfg. Co., Box 555, Alamo, CA 94507. **249**

Electrically conductive silicone elastomer has a nominal volume resistivity of 1.0 ohm-cm. "SC-Consil" has a temperature range of -75 to 400°F and 65 ± 5 durometer Shore A. Tecknit, 129 Dermody St., Cranford, N J 07016. **250**

Compact optical shaft encoder features solid-state light source. Measuring 1.5 inch in diam by 1.2 inch long, the "Rotaswitch" 860 Series is available with a sine- or square-wave output at various pulse rates and in unidirectional or bidirectional versions. Standard version price is approximately $125 in single quantity. Disc Instruments, Inc., 2701 S. Halladay St., Santa Ana, CA 92705. **251**



Our new planar memory: a thing of beauty

The Store/233 core memory system stands out in a crowd. It's modular, fast, low in cost, and reliable. These features lift it out of the "plain" planar category, and onto a new plateau of its own. Start with modularity: a basic 4K x 18 matrix on one planar board. Extend it to 16K x 18 in 4K increments, to 64K x 18 in four parallel units. Look at speed: a cycle time of 650 nanoseconds and an access time of 275 ns. This makes it a natural, for example, as a minicomputer add-on memory. Check the low cost: about a penny a bit in OEM quantities. Semiconductor-memory components alone cost that much. And the 2-board planar design slashes spares inventory and makes maintenance easier. Look at reliability: the same basic circuitry as its predecessor, the Store/33, which is operating in more than 400 installations. The not-so-plain 233 uses low-cost cores fabricated at our Core Memories Division with our exclusive roll/cut process. And if you need more speed, ask us about our new 500-nanosecond option using our 14-mil cores. For delivery information, telephone one of our OEM Marketing offices listed below. See our memory products in the EDN Caravan.

DATA PRODUCTS technology gives your computer the edge

DATA PRODUCTS
OEM marketing 16055 Ventura Blvd., Suite 419, Encino, California 91316

Boston, Massachusetts (617) 237-1950; Bethesda, Maryland (301) 652-8120; Cherry Hill, New Jersey (609) 667-7555; Dallas, Texas (214) 231-2240; Southfield, Michigan (313) 354-5858; Los Altos, California (415) 941-5485; Los Angeles, California (213) 981-9600; Minneapolis, Minnesota (612) 927-8747; Amsterdam, The Netherlands 020-452-457; Tokyo, Japan 493-6451; London, England 01-579-2917; Vienna, Austria 34 53 61, 34 44 16

CIRCLE NO. 37

Components

Cadmium-mercury batteries feature long life and operating temperature range from −65 to 200°F. Estimated shelf life at room temperature is 25 years. ESB Inc., 5 Penn Center Plaza, Philadelphia, PA 19103. **252**

Edgeboard connector with bifurcated bellows contacts on 0.156-inch centers is designed for use on 1/16-inch circuit boards. Available with single or double readout and 6 to 22 contact positions, the EB7 will adapt to variations in thickness from 0.050 to 0.071 inch. Dale Electronics, Inc., Box 609, Columbus, NE 68601. **253**

Solid-state proximity switch senses metallic material at preset distances from 0.0005 to 0.15 inch. Weighing less than 0.5 oz, the Model 630801 operates from −65 to 250°F. Dynasciences Corp., 9601 Canoga Ave., Chatsworth, CA 91311. **254**

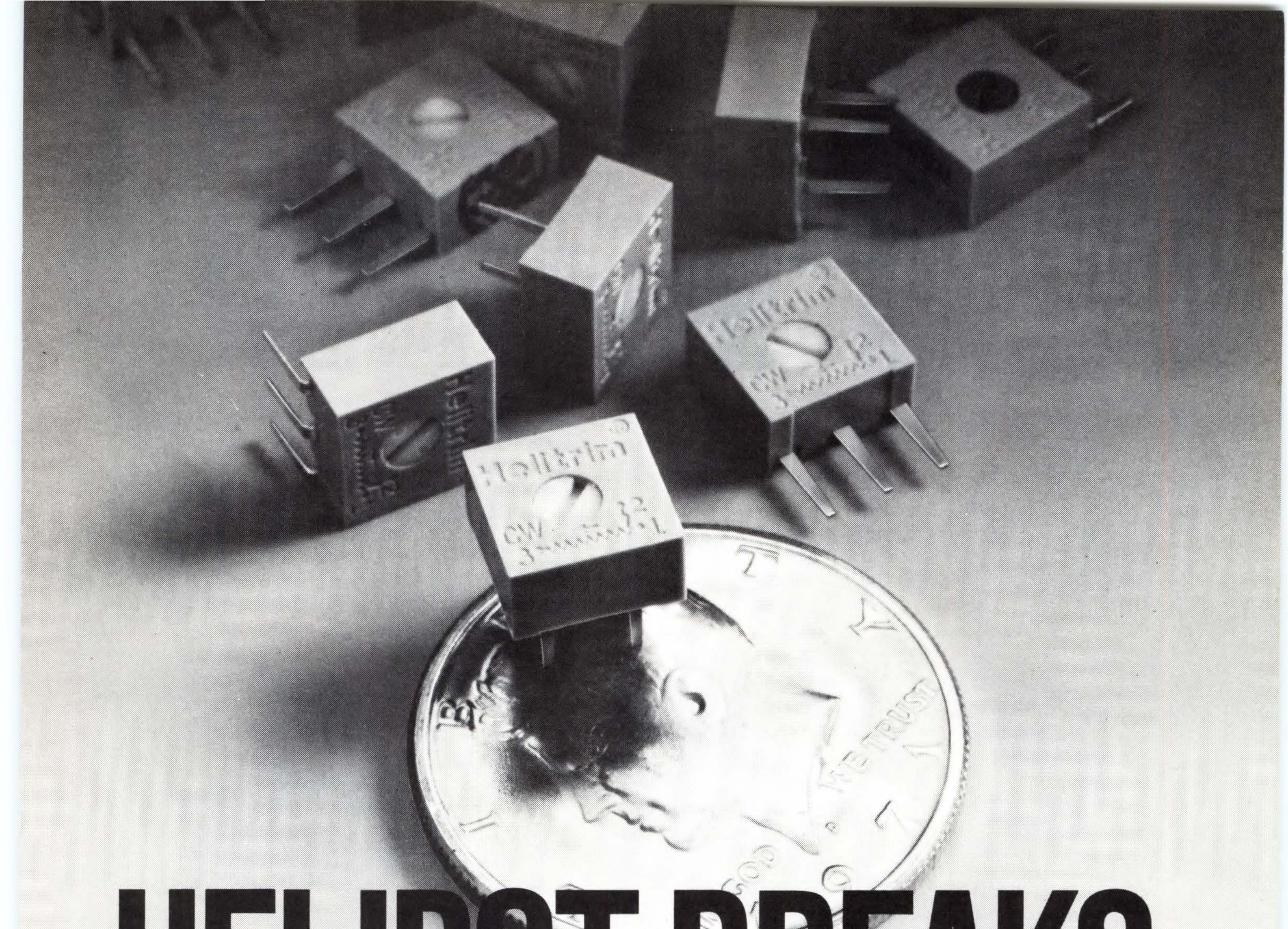
"Tinnerman" wire-harness clamp with adhesive back is made from PVC extrusion. Retaining leg can be locked or unlocked for easy wire or hose insertion and removal. Various sizes are available. Eaton Corp., 25 Charles Ave., Massillon, OH 44646. **255**

Taut-band movement panel meter features a 250° scale. Accuracy of the Model 1105 is ±2%. Price for 1-mA meter in 1000 quantity is $4.55 each. Faria Meter Corp., Uncasville, CT 06382. **256**

Sealed pushbutton switches are "O"-ring sealed, bushing-to-panel and plunger-to-bushing, eliminating the need for external boots or other sealing means. Prices range from $1.50 to $2.52 in 100-piece quantities. Grayhill, Inc., 555 Hillgrove Ave., La Grange, IL 60525. **257**

Moving-coil motor features "ironless" armature for extremely high acceleration capability. Acceleration of up to 850,000 rad/sec^2 is achieved in the low-cost M-1030. Electro-Craft Corp., 1600 Second St. S., Hopkins, MN 55343. **258**

Brushless dc tachometer-generator incorporates an entirely new commutation principle to produce an output of 2V/1000 rpm with maximum ac ripple of 2% pk-pk, unfiltered. Life expectancy of Model TG-140 is over 50,000 hours. Linearity curve essentially goes through the zero point. Dynetics Corp., 8740 49th Ave. N., Minneapolis, MN 55428. **259**



HELIPOT BREAKS THE HALF-BUCK BARRIER.

Here they are: the best buys. Our new Series 72 single-turn ⅜" cermet trimmers at an eye-opening 49¢ each in the 1,000 quantity. They're equally well-priced in other quantities, too. One alone costs just 70¢.

But there's also that dependable Helipot quality and performance, plus things you don't get elsewhere. Like our resistance and slider stability ... change is less than 0.5% in the first 1,000 operation hours, progressively less thereafter. Impressive, when the life expectancy exceeds five years' continuous duty under full-rated power. And the Series 72 sealing — compatible with wave soldering, low-viscosity potting, and board washing even with chlorinated solvents.

Add the wide range of values, ±100 ppm/°C tempco, and off-the-shelf availability from 17 nationwide stocking points and what have you got? The best reasons in the world for requesting complete specs and data on this breakthrough line of Helipot cermet trimmers. Do it now — it won't cost you a cent.

Beckman®

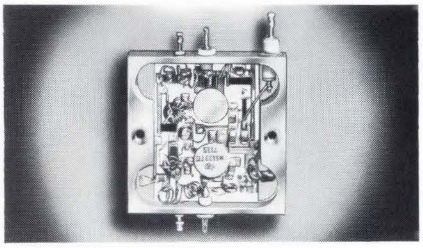
INSTRUMENTS, INC.

HELIPOT DIVISION

FULLERTON, CALIFORNIA

HELPING SCIENCE AND INDUSTRY IMPROVE THE QUALITY OF LIFE.

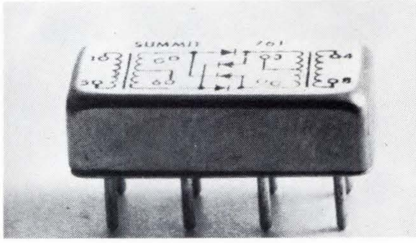
CIRCLE NO. 39



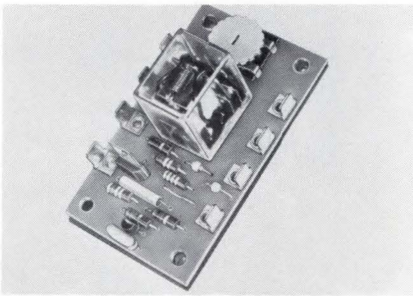
Thick-film hybrid IF amplifier, Model AL-1014, has an operating center frequency of 440 MHz and a maximum noise figure of 2.5 dB. Maximum input VSWR is 1.5:1 and maximum output VSWR is 1.7:1. Minimum gain is 25 dB across the entire 120 MHz bandwidth with gain stability across the band of ±0.5 dB. Input and output impedance is 50Ω. Optimax, Inc., Colmar, PA 18915. **277**

YIG-tuned multipliers WJ-799 provide selected harmonic power over the 2 to 12.4 GHz frequency range. These units exhibit up to 3 mW of power delivered at 12.4-GHz output frequency with power available from 1 to 18 GHz. Inputs may range from 100 MHz to 2 GHz and be fixed-tuned or broadband. Up to 60 dB rejection of unwanted adjacent harmonics is available as an option. Watkins-Johnson Co., 3333 Hillview Ave., Stanford Industrial Park, Palo Alto, CA 94304. **278**

Eight-bit D/A converter DAC 329 comes complete with internal reference, output amplifier, resistor ladder and switches. The unit may be ordered with either 8-bit binary or two decades BCD coding. Full-scale output current is 2 mA. A high-speed (400 nsec settling) current output version designated DAC 329-1 is also available. Price for 1 to 9 quantity is $29 each. Hybrid Systems Corp., 95 Terrace Hall Ave., Burlington MA 01803. **279**

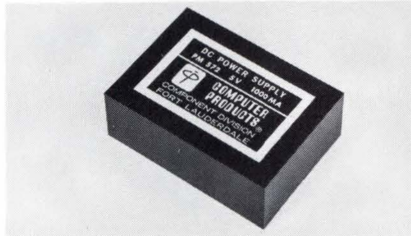


Double-balanced mixer, Model 761, has a broadband characteristic that permits HF, VHF and UHF operation. Dimensions of the 8-pin hermetically sealed package are 0.785 by 0.39 by 0.235 inch. Maximum isolation specifications range from 40 to 45 dB (3 to 100 MHz) and 25 to 30 dB (100 to 1000 MHz). Price for 1 to 4 units is $50 each. Summit Engineering Corp., 1820 S. 7th Ave., Bozeman, MT 59715. **280**

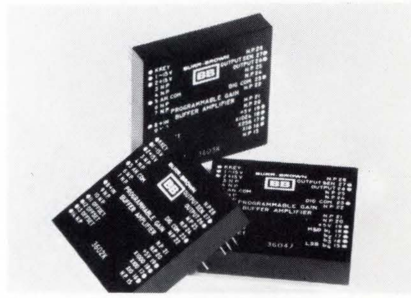


Solid-state time delay relay, Series MOR, comes with either factory-fixed or six adjustable delays that range from 0.5 sec to 5 min. Other features include 5A output contacts, built-in transient protection, temperature and voltage stability from −10° to 65°C and DPDT output configuration. Eight 0.25-inch quick-connect terminals provide the required interface. Prices range from $8.70 to $5.50. Omnetics, Inc., Box 113, Syracuse, NY 13211. **281**

Differential op amp, Model 46, features a slewing rate of 1000V/μsec with settling time to 0.1% in 100 nsec. Common mode rejection is 2000:1 for ±10V input. Other features include a 6 dB/octave frequency roll off and 40-MHz bandwidth. Two versions are available, depending on the voltage drift required. Prices are as low as $62 each in lots of 100. Analog Devices, Inc., Route 1 Industrial Park, Box 280, Norwood, MA 02062. **282**



Encapsulated power supply PM 572 provides 5V dc at 1A and can be mounted directly on a PC board. Input requirement is 115 ±10V ac, 47 to 400 Hz. Other features for the 3.5 by 2.5 by 1.25 inch module include ±0.4% load regulation, ±0.2% line regulation, TC of 0.03%/°C and 1 mV rms ripple and noise. Unit price is $58.95. Computer Products, 1400 N.W. 70th St., Box 23849, Fort Lauderdale, FL 33307. **283**



Programmable instrumentation amplifiers, Models 3602K, 3603K and 3604K, are encapsulated 2- by 2- by 0.4-inch units for PC board mounting. Models 3602 and 3603 each have four gain steps of 1, 10, 100 and 1000 and 1, 16, 256, 1024, respectively. For logic inputs, the unit is programmed in gain steps of 1 through 16, thus providing binary or BCD gain programming. Price is $115 each. Burr-Brown Research Corp., International Airport Industrial Park, Tucson, AZ 85706. **284**

Encapsulated power supply produces 200V at 25 mA from 115V, 50 to 400 Hz or 220V, 50/60 Hz. Designed primarily as a power source for cold cathode displays, the 3.5- by 2.5- by 1.25-inch unit can be mounted directly on a PC board or used with mating socket. Ripple and noise is 2V pk-pk and operating temperature range is −25 to 70°C. Single quantity price is $18. Instrument Displays Inc., Granite St., Haverhill, MA 10830. **285**

RAYTHEON SEMICONDUCTOR. OUR OP AMPS HAVE PARAMETERS WITH TEETH.

Our new products are taking a chunk out of the operational amplifier market with parameters that are easy on designers and tough on competition. All of our dc parameters are specified over the entire voltage range — with no fall-off.

The new RM4131. It's unique in bipolar IC's, with input offset voltage of 2 mV maximum and 0.7 mV typical. Input offset current of 10 namp maximum and 2 namp typical. This high gain op amp has slew rates four times that of 709's and 741's. Typically 2 volts per microsecond with unity gain bandwidth of 4 MHz. And if low current drain at 20 V of 1.6 milliamps maximum is still not enough to put the RM4131 on your purchase order the large voltage signal gain should. It's typically 106 db from 3 to 20 volts.

The new RM4132. It cuts power dissipation by two orders of magnitude and needs no external bias or compensation. This proprietary micropower op amp has typical current drain as low as 22 μA. At maximum, 35 μA. Input offset current is reduced to 0.7 namp. It maintains unity gain bandwidth of 150 KHz. And it means further perfection in your battery operated circuits.

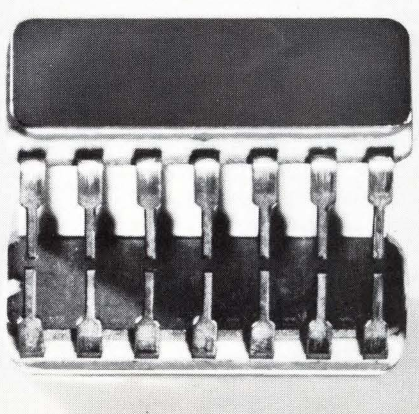
Proprietary linear circuits is one of our great strengths. But it's not our only strength. We're rapidly adding to our extensive line of off-the-shelf linear circuits as well. We provide the tightest parameter specs you can get in monolithic op amps, differential and dual comparators, voltage regulators, line receivers, and sense amplifiers. All available now at franchised Raytheon Semiconductor distributors.

Raytheon Semiconductor has changed. We have a new technical team. And new development programs providing new design tools. We're working on things like new digital analog interfacing that allow active switching and amplifying. Greater integration of external parts in voltage regulators. Greater circuit stability from improvements in temperature tracking. And we're going beyond the parameters established for slew rates, offset voltage, noise, bias current and offset current.

If you haven't been keeping up with us lately you've got a surprise coming. Write for our complete IC catalog and see. Raytheon Semiconductor, 350 Ellis Street, Mountain View, California 94040. (415) 968-9211.

RAYTHEON

CHOMP!



CIRCLE NO. 40

EMI/RFI filters incorporate special IEC connector and conform to European market requirements. Designed for 115 or 230V ac, 50 to 400 Hz power lines, the units filter both sides of power line thus eliminating the need for two filters. Price is $9.75 to $4.95. Components Corp., 2857 N. Halsted St., Chicago, IL 60657. **290**

Wideband amplifier, Model 725, has a range of 50 kHz to 500 MHz with a gain of 27 dB. Gain flatness is ±3 dB. Dimensions are 7.75 by 4.75 by 2.25 inches. Price is $150 each. Measurement Specialties Laboratory Inc., Box 3654, Santa Monica, CA 90403. **291**

Miniature thermal relay, Model 180, features <1 μV offset, fully guarded contacts and <0.01 pF direct capacitance between contacts and coil. Dimensions are 1.375 by 0.562 by 0.5 inch. Price for 1-9 quantity is $8.50 each. Multitech Automation Products, 583 Monterey Pass Rd., Monterey Park, CA 91754. **327**

Noise generator cards, Series 3600B, cover the 10 Hz to 5 MHz range with an output level of 3V rms open circuit. A dynamic range of 3.5 to 1 pk-to-rms is provided. Price is from $154 to $521 each. Elgenco, Inc., 1550 Euclid St., Santa Monica, CA 90404. **293**

Operational amplifier, Model VDA-100, exhibits the following characteristics: <60 nsec settling time, >100 MHz bandwidth, 1 V/nsec slew rate, ±10V at 100 mA output and <0.16 nA/°C drift. Valid Data Corp., Box 441, Calabasas, CA 91302. **294**

Voltage isolator SVI completely separates a low voltage source from its load. Unit accepts 0 to 5V dc. Field accuracy is ±0.2% full scale from 0 to 55°C and from 105 to 125 line volts. Halmar Electronics, Inc., 1544 W. Mound St., Columbus, OH 43223. **295**

Three-in-one infrared detector features a windowless pyroelectric crystal with a wide operating temperature range – no repoling is required for average power inputs as high as 0.4W. A three-position switch permits selection of response times as short as 5 nsec or responsivities as high as 20 V/W into a 50Ω load. Molectron Corp., 930 Thompson Pl., Sunnyvale, CA 94086. **296**

Varactor-tuned transistor oscillator WJ-2800 provides 20 mW minimum microwave power in the 4 to 8 GHz frequency range. Two transistors in a push-pull configuration generate output power at the second harmonic of the fundamental oscillator frequency. Watkins-Johnson Co., 3333 Hillview Ave., Stanford Industrial Park, Palo Alto, CA 94304. **292**

Clock oscillator CO-231L drives 10 TTL loads within the 200 kHz to 30 MHz range. Only 0.3 inch high, the stability is better than ±0.0025% over 0 to 70°C. Price range is from $20 to $90. Vectron Laboratories, Inc., 121 Water St., Norwalk, CT 06854. **328**

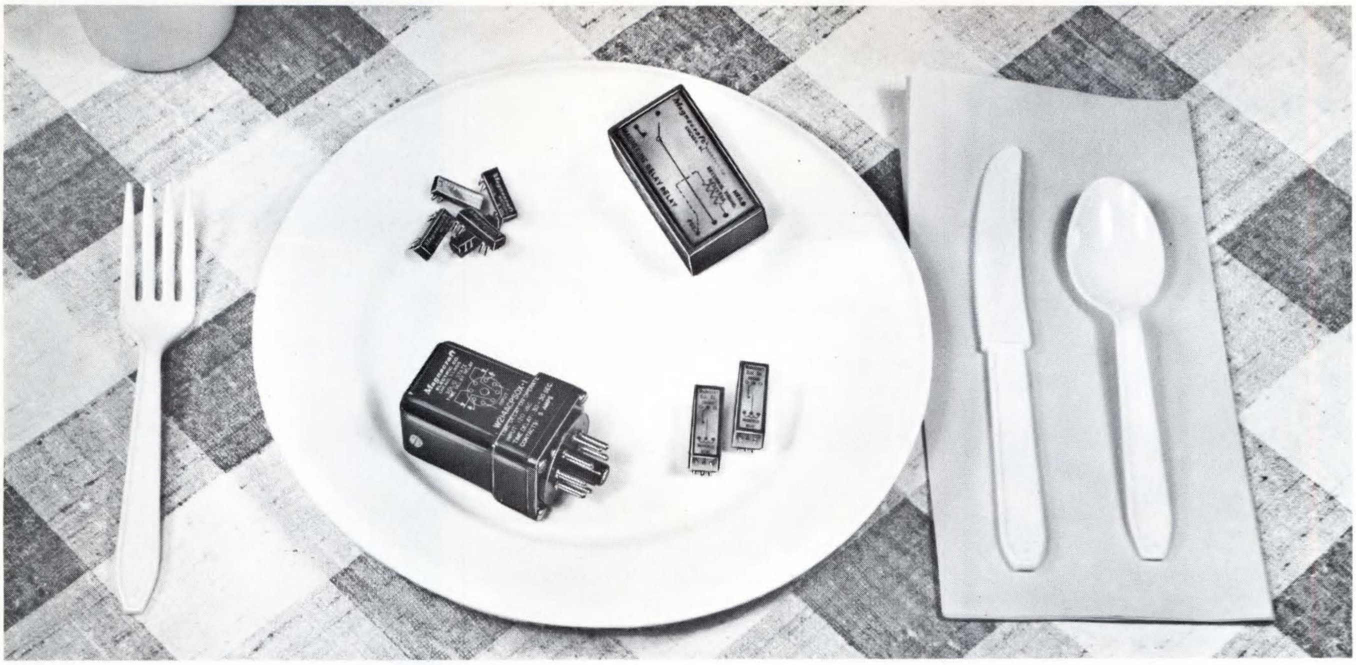
Three-phase bridge rectifiers, B-20 Series, are rated at 35A average dc current at 55°C and have a single-cycle surge rating of 400A at continuous load. Package dimensions are 0.75 by 2.25 inches. Tung-Sol Div., Wagner Electric Corp., 630 W. Mt. Pleasant Ave., Livingston, N J 07039. **329**

Modular power supplies, T27 Series, provide the three most popular voltages: 5, ±15 and 24V dc. Also three classes of regulation are available – 0.01% (T27), ±1% (T27X) and 10% (T27Z). Modular Power Inc., 15302 Oak Canyon Rd., Poway, CA 92064. **330**

High-voltage, high-current driver supplies 10A at 60V (pulsed). The dual circuit is housed in a 12-pin, TO-8 hermetic package. Unit price is $10.32. Micropac Industries, Inc., 905 E. Walnut St., Garland, TX 75040. **331**

High-voltage bridge rectifiers are chassis mounted and fully insulated. Dimensions are 0.75 by 0.75 by 0.25 inch and the peak inverse voltage is 1 to 6 kV, rated at 50 mA. True rms voltage is 700 to 4200V. Computer Diode Corp., Pollitt Dr. S., Fair Lawn, N J 07410. **332**

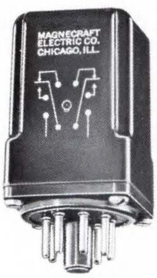
Voltage sensor, Model 551 "Voltsensor Controller", detects low and high points of an analog signal generated by a transducer. Set points can be set independently for a trip point range of ±25V, or with separate trip point voltage reference up to ±150V. For 100 pieces, price is as low as $47.60 each. California Electronic Mfg. Co., Inc., Box 555, Alamo, CA 94507. **333**



designers will have a **PICNIC** with these new relays

NON-POSITION SENSITIVE MINIATURE MERCURY WETTED REED RELAY CLASS 137MPC—This amazing new relay represents a significant state-of-the-art advancement in relay technology. The low-profile miniature PC-mounting mercury wetted reed relay offers bounce-free operation in any position. Now circuit designers will have new freedom of design. Further, the relay is only 1.12 x .40 x .375 inches, requiring minimal area on printed circuit boards. This relay features stable contact resistance of 100 milliohms over its long life of over 20 million bounce-free operations with diode suppressed coil.

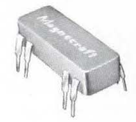
CIRCLE NO. 22



SOLID STATE (HYBRID) TIME DELAY RELAY CLASS 214CP—Magnecraft takes great pride in announcing this new time delay relay. Proven hinge-pin reliability designed into the output relay driven by a solid state circuit used in thousands of our timers, gives you the best low cost small size timing relay on the market. Operate delay timing ranges are offered between 3 hundred milliseconds and 4 minutes with ±5% repeatability and input supply of 115VAC.

We are sure you will share our enthusiasm in this new product when you apply the small size and cost savings to your circuit designs. The body of the timer is only 1.4 x 1.4 x 2.1 inches, the size of our 88 general purpose relay case. The adusting potentiometer gives full range timing control and the very popular octal socket pins extend just a bit beyond the body of the time delay relay to an overall height of 2.3 inches.

CIRCLE NO. 23



DUAL-INLINE-PACKAGED REED RELAYS CLASS 107DIP, 108DIP, 117DIP AND 118-DIP—Magnecraft is proud to announce its new DIP (dual-inline-package) line of 8-pin reed relays. These new relays are designed not only to be compatible with the standard packaging developed for integrated circuits, but to offer Magnecraft quality at a lost cost. This unique design gives further savings by offering the user the optimum in automated insertion and other economical installation techniques associated with printed circuit applications.

These fantastic new epoxy molded reed relays are ideal for use in circuits where high density packaging is essential. The 5VDC IC compatible versions of these relays will operate directly from TTL or DTL circuits.

Other standard coil voltages are available from stock in 6, 12, and 24 VDC as well as contact configurations in 1 form A, 2 form A, 1 form B, and 1 form C. Most versions are also offered with a choice of an internal clamping diode. The size of this device is a tiny .750 x .300 x .210 inches.

CIRCLE NO. 24

SOLID STATE (HYBRID) PRINTED CIRCUIT TIME DELAY RELAYS CLASS 502PCSR AND CLASS 503PCSR—These new time delay relays make use of hybrid circuitry combining a monolithic silicon structure in the control function with a dry reed relay performing isolated circuit switching. Two fully adjustable timing ranges are afforded by using a remote pot or fixed resistor giving 0.2 to 100 seconds or 1 to 300 seconds each with ± 2% repeatability. Standard coil voltages are available from stock in 12 and 24VDC as well as contact configurations in 1 form A rated at 1 amp and 1 form C at 0.5 amp. The size of this time delay relay is a mere 2.25" x 1.25" x .75".

CIRCLE NO. 25

Magnecraft® ELECTRIC COMPANY

5575 NORTH LYNCH AVENUE • CHICAGO, ILLINOIS 60630 • 312 • 282-5500 • TWX-910-221-5221

See you at I.S.A. Booth 658

Circuits

Secondary lightning arrester, Model 1250-02, is a one-pole, two-wire device, rated 0 to 175V rms, that has a hermetically sealed spark gap plus silicon-carbide series element. Joslyn Electronic Systems, Div. of Joslyn Mfg. & Supply Co., Box 817, Santa Barbara Research Park, Goleta, CA 93017. **269**

Repeat cycle timers for periods as long as 1 month are available in special low power versions for battery operated systems. Power is only 100 μW. Prices for the "B" series modules are under \$30 in 1000 quantities. Gould Ionics Inc., Box 1377, Canoga Park, CA 91304. **270**

Frequency multiplier accepts an input signal at 0 dBm in the 74.8- to 78.4-MHz band and provides 30 mW of CW power in the 2095- to 2195-MHz band. No tuning is required, and spurious signals are held at least 60 dB below the output signal level. Model 5001-00 is contained in a 23-inch^3 housing and requires 160 mA drive at +28V. Zeta Laboratories, Inc., 616 National Ave., Mountain View, CA 94040. **286**

High power hybrid assemblies of the "PACE/pak" Series contain passivated assembled circuit elements. Current handling capacity is up to 50A and such elements as SCRs, diodes, FETs, and others are contained in the single packages. Semiconductor Div., International Rectifier Corp., 233 Kansas St., El Segundo, CA 90245. **287**

Automatic dialing telephone module handles either local or long-distance phone numbers and eliminates the need for special lines. Price of model 904 138 is <\$100 each in quantity. G-V Controls Div., 101 Okner Pkwy., Livingston, N J 07039. **288**

Broadband microwave IC power amplifiers cover the frequency range of 1.4 to 2.4 GHz with 1-dB bandwidths of 200 to 300 MHz. All units of the PA1100 Series operate from 24V dc. Power outputs of 0.5 to 5W are available with power gains of 10 to 20 dB and efficiencies greater than 25%. Prices range from \$625 to \$975 each. TRW Semiconductor Div., 14520 Aviation Blvd., Lawndale, CA 90260. **289**

Heath/Schlumberger?

That's right . . . Heath/Schlumberger. A new name in design-quality, factory assembled and calibrated instruments.

The "Heath" part of our name comes from being a division of that well known manufacturer of kits. But we don't make kits. In fact, Heath/Schlumberger is an entirely separate operation.

The "Schlumberger" (pronounced Shlum-bear-zhay) part of our name comes from being a member of that world-wide corporation devoted to measurements of many kinds. Schlumberger is one of the leading European manufacturers of electronic instrumentation.

With that background, you can see why we are producing state-of-the-art, ready-to-use, instrumentation . . . comparable to some of the best in performance . . . but with better performance/price ratios.

So when you are ready to buy electronic instruments, check the growing Heath/Schlumberger line.

We're the group to watch.

To order or receive additional information, write Dept. 520-23.

HEATH
Schlumberger

Heath/Schlumberger
Scientific Instruments
Benton Harbor,
Michigan 49022

A. SM-104A 80 MHz counter. BCD output. 1 MHz TCXO with 1 ppm/yr. stability. $500.

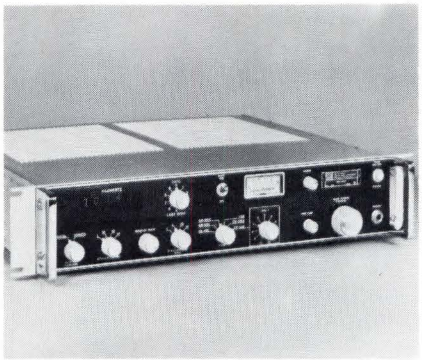
B. EU-205B solid-state strip chart recorder. 23 speeds, 30 in/min. to 0.2 in/hr.; 18 calibrated ranges, 1 mV to 500 V full scale. 0.5 sec. pen response. 0.1% tracking accuracy and linearity. Completely programmable. $675.

C. EU-70A solid-state dual trace scope. DC-15 MHz. Complete dual trace capability. Triggered sweep. 18 calibrated time bases. X-Y capability. $595.

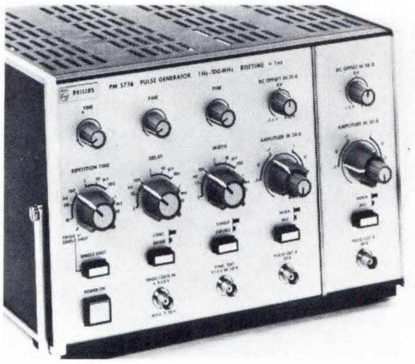
D. SM-105A 80 MHz counter. Same as SM-104A above but without BCD output and uses a 1 MHz crystal with ±10 ppm/yr. stability. $350.

E. EU-81A function generator. Sine, square and triangle wave output. 0.1 Hz to 1 MHz. Linear dial. External voltage control. $245.

EK-308



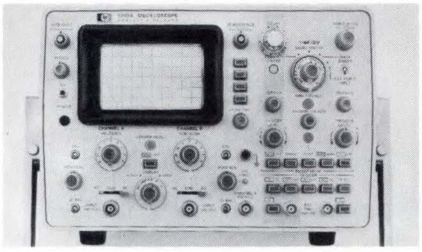
Voltage-tuned receiver covers from 1 to 900 kHz, provides AM, FM and CW detection modes and has selectable IF bandwidths of 1.6, 20 and 50 kHz. Frequency is displayed on a 5-digit LED readout to an accuracy of ±10 Hz. Digital AFC permits locking of the WJ-340's local oscillator in 10-Hz increments over the entire tuning range. Watkins-Johnson Co., 6006 Executive Blvd., Rockville, MD 20852. **260**



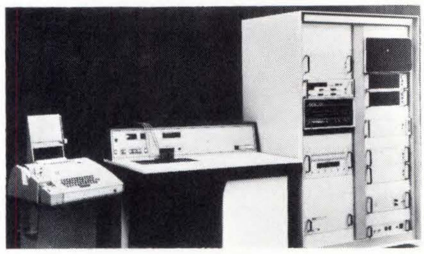
Pulse generators offer repetition rates from 1 Hz to 100 MHz with amplitude adjustable from 0.3 to 3V. Rise/fall times are less than 1 nsec. Model PM 5775 provides a single positive or negative output, while Model PM 5776 provides two outputs. Pulse widths are adjustable from 5 nsec to 100 msec. Philips Electronic Instruments, 750 S. Fulton Ave., Mount Vernon, NY 10550. **263**

Transient voltmeter, the "Peaklok", senses and displays the highest positive or negative peak value of any ac or dc voltage within the range from 0.1 to 1000V full scale. It responds to peaks as short as 1 μsec in duration and holds the reading until reset. Meter accuracy is 1.5% of full scale. Pioneer/Instrumentation, 4800 E. 131st St., Cleveland, OH 44105. **266**

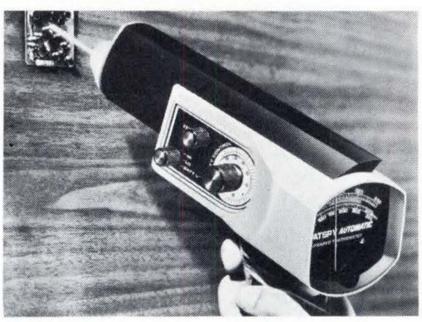
DMM measures ac and dc voltage, ac and dc current and resistance, yet sells for $385. Model 3301 provides five ranges each for both ac and dc voltage and current and seven for resistance. Features include automatic zeroing, 3-1/2 digit nonblinking display, autopolarity, and flashing out-of-range indication. Options include battery pack and BCD output. Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, OH 44108. **261**



Portable dual-channel oscilloscope has dc to 35 MHz frequency response, deflection factors to 10 mV/div, sweep speeds to 10 nsec/div and delayed sweep. Operating modes include storage, variable persistence and normal. On storage, the Model 1703A can retain a waveform for more than an hour. Tentative price is $2700 (Model 1702A without delayed sweep—$2350). Hewlett-Packard Co., 1601 California Ave., Palo Alto, CA 94304. **264**

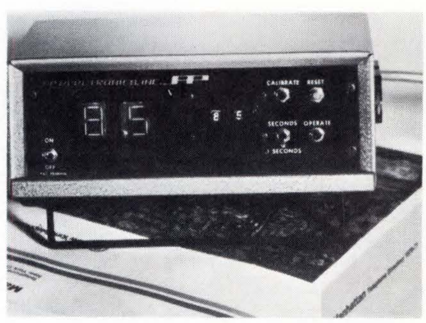


Expandable test system for MOS uses the pulser-per-pin approach. Software includes a machine-oriented program that translates functional commands into operational commands for each system unit, and an operator-oriented program to translate the operator's test requirements into functional commands to the system. System price range is from $115,000 to $300,000. E-H Research Laboratories, Inc., Box 1289, Oakland, CA 94604. **267**



Infrared thermometer makes non-contact surface temperature measurements of components as small as 0.1 inch to an accuracy of ±1%. Model HSA-8E measures over a range of 0 to 600°F. The target area is defined by a light beam. Heat Spy Div., William Wahl Corp., 12908 Panama St., Los Angeles, CA 90066. **262**

Digital test probe, priced at $59.95, operates from the 5 or 6V dc supply of the system under test. Logic levels are detected and defined by colored indicators. The "Dy-Nos-Stick" is individually available from stock. Nu-Concept Computer Co., 306 W. Logan St., Norristown, PA 19401. **265**



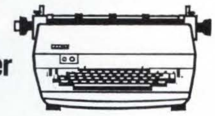
Solid-state timer with digital readout is offered in 2- or 3-digit versions, with the price starting under $200 for a 2-digit unit. The end of the count is indicated by either an output signal or triggering of an ON/OFF control. AP Electronics, Inc., Industrial Rd., Alpha, N J 08865. **268**

There are holes in the type bar.

A phototransistor unit detects code holes in each type bar to provide photoelectric readout. This is a unique sensing method and enables you to make:

■ Parity checking right from the source ■ Type bar velocity check ■ Echo check

There is further interesting information on the new Facit 3851 in this publication.



Facit 3851 - the conventional typewriter with input/output

For further information, contact
in US: Facit-Odhner Inc., 501 Winsor Drive, SECAUCUS, New Jersey
outside US: Facit AB, Albygatan 102, 171 84 Solna, Sweden

CIRCLE NO. 45

SPERRY RAND™

Compare:

Price
Delivery
Performance

you'll choose:

SPERRY

BRUSHLESS DC TORQUER

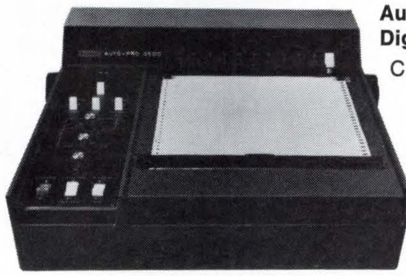
- Built to your specifications
- With 10 years brushless motor experience

SPERRY

MARINE SYSTEMS DIVISION
BRUSHLESS DC MOTOR DEPT.
CHARLOTTESVILLE, VIRGINIA 22901
(703) 973-3371

CIRCLE NO. 46

Beckman simplifies time-sharing, data acquisition and display.

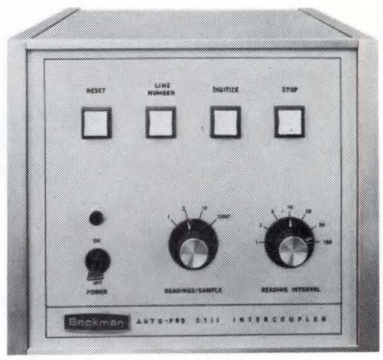


Auto-Pro 3500 Digital Plotter

Costing about $1000 less than most other plotters and designed for the scientific user, the AP-3500 is simple to use with either time-share or small computers. The combination of a digital-to-analog converter Y axis and an incremental stepper-driven X axis removes paper size restrictions and affords complete capability for 90% of all plotting/recording applications. The AP-3500 displays computer-calculated digital data or analog information directly. As a time-share plotter, information is accepted serially in ASCII arrangement at either standard or high-speed rates; as a minicomputer peripheral, data is accepted in bit parallel form, permitting even higher plotting speeds.

Plotting is in continuous form — forward or reverse — on roll chart paper, with only one data word and control character required to uniquely position the pen. Usable with modern high-speed data terminals, the AP-3500 plotter has overall accuracy of better than ±0.25% and is an ideal analytical tool in most scientific applications, ranging from biochemistry to circuit design. Request Bulletin AP-2402 for complete details.

Auto-Pro Intercouplers



Designed as a complete data system, Beckman's AP-3111 Intercoupler takes an analog input, converts the information to digital form, then prints and punches the data on an ASR-33 teletypewriter. Companion unit to the AP-3111 is Beckman's Auto-Pro 3109 which accepts up to 16 BCD data bits in place of the analog input. Paper tape outputs of both instruments are directly time-share compatible and include automatic line number update and special control characters. Other features are local or remote control; preselectable reading interval and number of readings per sample. Request Bulletins AP-2400 and AP-2401 for complete details.

Beckman®

INSTRUMENTS, INC.
AUTOMATION PRODUCTS ACTIVITY
2500 Harbor Blvd., Fullerton, Calif. 92634
HELPING SCIENCE AND INDUSTRY IMPROVE THE QUALITY OF LIFE

CIRCLE NO. 47

NEW from TECHNIPOWER, INC.®

LOW COST, HIGH PERFORMANCE POWER SUPPLIES
NOW IN SINGLE AND DUAL OUTPUT MODELS

"THE PRACTICALS"... they make systems engineers cost-efficiency experts!

Out Specs All Comparatively Priced Units

AC-DC Regulated Power Supplies

Specifications:

Input voltage range: 105-125 volts.
Input frequency range: 47-420 Hz.
Regulation-Line and Load Combined: ±.5%
Ripple (RMS): (with either positive or negative terminal grounded): 10 mv.
Temperature Coefficient: (TYP.) 0.05%°C or 5 mv/°C whichever is greater.
Polarity: May be used positive or negative.
Output voltage and current: See model listings.
Output adjustment range: See model listings.
Short circuit protection: Automatic circuit protects the power supply if the output is shorted continuously. Automatic return upon removal of short circuit.
Remote sensing: Provisions are made for remote sensing to eliminate effects of lead resistance on dc regulation.
Operating temperature: 0°C to +55°C for current ratings specified in model listings.
Storage temperature: −20°C to +85°C.
Recovery time: (TYP.) Less than 50 μsec, ½ L to FL.
Ambient temperature rated: To 55°C.

Length - 8½"
Width - 3⅛"
Height - 2⅝"

SINGLE OUTPUT SERIES DESIGNED FOR BROAD COMMERCIAL APPLICATIONS

$39.75 All Models 10 or more combined units

VOLTAGE AND CURRENT RATINGS

ADJUSTABLE OUTPUT VOLTAGE	OUTPUT CURRENT	STANDARD MODEL NO.	PRICE 1-4 UNITS	PRICE 5-9 UNITS
5.0±5%	5.0	LP5.0-5.0	$49.75	$44.75
6.0±5%	4.5	LP6.0-4.5	49.75	44.75
12.0±5%	2.5	LP12.0-2.5	49.75	44.75.
15.0±5%	2.0	LP15.0-2.0	49.75	44.75
24.0±5%	1.5	LP24.0-1.5	49.75	44.75
28.0±5%	1.2	LP28.0-1.2	49.75	44.75

All models available with overvoltage protection, add $5.00. Prices for large quantities quoted upon request. Custom specifications to order.

DUAL OUTPUT TRACKING SERIES DESIGNED FOR OP-AMP AND OTHER COMMERCIAL APPLICATIONS

$74.75 All Models 10 or more combined units

VOLTAGE AND CURRENT RATINGS

ADJUSTABLE OUTPUT VOLTAGE	OUTPUT CURRENT	STANDARD MODEL NO.	PRICE 1.4 UNITS	PRICE 5-9 UNITS
±12.0±5%	1.2	LPDT-12.0-1.2	$89.75	$79.75
±15.0±5%	1.0	LPDT-15.0-1.0	89.75	79.75

Modification of standard output voltages can be provided over the range of ±5 to ±28 volts at slight additional cost. Voltages below ±7 volts not available in Tracking models.
Independent output adjustment provided at slight additional cost.

BOTH MODELS BACKED BY TECHNIPOWER 5-YEAR WARRANTY

Mr. Arthur Riley, Vice-President, Technipower, Inc.
Benrus Center, Ridgefield, Conn. 06877

- ☐ Please have your representative call.
- ☐ Please send me your complete power supplies Catalog and Data Book No. 701.

Name____
Title____
Company____
Address____
City____ State____ Zip____

EP-1-71

See our product in the 1970/71 EEM/Electronic Engineers Master Pages 1231-1255

CIRCLE NO. 38

Programmable 500-MHz universal counter/timer has an 8-digit in-line "Nixie" display. Measurements are referenced to an internal 10-MHz crystal oscillator with aging rate less than 0.3 PPM for 30 days. Price is $1595. Eldorado Electrodata Corp., 601 Chalomar Rd., Concord, CA 94520. **315**

Varactor capacitance ratio meter, Model 172A, provides rapid, simultaneous measurements of the capacitance ratio of varactors at pre-selected upper and lower bias voltages and of their capacitance at chosen bias level. Available in December, it will be priced at $2700. Boonton Electronics Corp., Rte. 287 at Smith Rd., Parsippany, N J 07054. **316**

Programmable test fixture for use with Tektronix 576 curve tracer permits programming of up to 11 sequential tests without manual setting of the 576 controls. A variable rate control allows the operator to select the test sequence rate. Fixture price is $1400. Tektronix, Inc., Box 500, Beaverton, OR 97005. **317**

Variable rise- and fall-time pulse generator, Model 116, is a 50-MHz unit priced at $850. Rise and fall times are linear and independently variable from less than 5 nsec to greater than 0.5 sec. Systron-Donner Corp., Datapulse Div., 10150 W. Jefferson Blvd., Culver City, CA 90230. **318**

Repeat cycle timer covers from 0.02 to 300 seconds in seven timing ranges with repeat accuracy of ±1% of dial setting. Model TM101 is all solid-state, operates on 115V, 50/60 Hz (+10% or −15%), and is guaranteed for 500 million operations or 5 years. Price is $42 each in lots of 100. Regent Controls, Inc., Harvard Ave., Stamford, CT 06902. **319**

DVM/Multimeter, Model 7004, uses bipolar integration. There are five ranges each of dc and ac volts, dc and ac current and resistance. Price is $650 for the 4-1/2-digit multimeter, $95 extra for 12V battery pack if desired. Systron-Donner Corp., 888 Galindo St., Concord, CA 94520. **320**

AC level converter for monitoring and recording ac voltage or current levels, Model 11-5201-18, has 15 msec response to a step input, which allows accurate recording of transients less than one cycle in duration on 50- or 60-Hz power lines. Measurement range is from 50 mV to 700V rms or 0.5 to 10A full-scale. Frequency response is flat from 50 to 5000 Hz. Gould Inc., Brush Div., 3631 Perkins Ave., Cleveland, OH 44114. **321**

High power pulse generator delivers over 31 kW of peak power at 1.5% duty factor. The output of the Model 360 is continuously variable to 2500V. Price each is $4990. Velonex, A Varian Div., 560 Robert Ave., Santa Clara, CA 95050. **322**

Solid state wattmeter, Model M1/SC1, measures true rms voltage, current and electrical power over the frequency range of 5 to 100 kHz. Power range is 20W to 20 kW full scale. Price complete with recorder output is $495. Wave Energy Systems Inc., Newtown Commons, Newtown, PA 18940. **323**

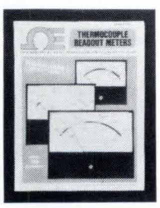
Series LV thermal control units accommodate up to 2 kW of dissipation by semiconductors mounted on heat sinks clamped to a temperature-controlled pipe. They accommodate up to 40 TO-3 transistors, and will maintain heat sink temperatures within ±2°C over the range from 60 to 200°C. Units are sold either as complete systems or modules. Wakefield Engrg., Inc., Systems Div., Audubon Rd., Wakefield, MA 01880. **324**

Sonic tester, for detecting voids in any material, Model 301, operates at 13.4 kHz with power demand of 4W from either 115V ac or battery. Model 301 weighs only 6 lb and measures 9 by 6 by 6 inches. Tek Tran, Box 460, Newark, OH 43055. **325**

Modular photomicrographic attachment camera system, Model PM-10, features both automatic and manual camera bodies that use interchangeable film backs, holders and other accessories. The Model PM-10 system adapts to existing microscopes of all makes. Olympus Corp. of America, 2 Nevada Dr., New Hyde Park, NY 11040. **326**

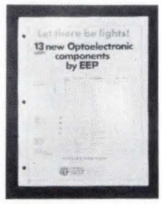
Digital repeater for synchro-to-digital conversion is described in six-page Bulletin 67-11B. Theory of operation, applications and full specifications are included. Theta Instrument Corp., 22 Speilman Rd., Fairfield, N J 07006. **297**

Selector switches are described in a 16-page catalog with complete electrical and mechanical specifications for the CTS 223 Series. Detailed printed circuit switch mounts for both perpendicular and parallel terminal mount styles are included. CTS Corp., 1142 W. Beardsley Ave., Elkhart, IN 46514. **298**



Thermocouple meters and pyrometers are the subjects of this four-page brochure that details the Series 7000 meters and a new low-cost electronic readout meter. Dimensions, various options and prices are included. Omega Engineering Inc., Box 4047, Stamford, CT 06907. **299**

"A Unique Concept in Printed Circuit Relays" is the title of an eight-page catalog describing printed circuit relay that plugs directly into a PC board without sockets or soldering. Information concerning PC board preparation and prototype testing is included. Printact Relay Div., Executone, Inc., 29-10 Thomson Ave., Long Island City, NY 11101. **300**



Optoelectronic components including displays, LEDs, IR emitting diodes and phototransistor opto-isolators are described in this 12-page catalog. European Electronic Products Corp., 10150 W. Jefferson Blvd., Culver City, CA 90230. **301**

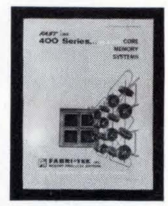
Capacitors, filters and microcircuits are featured in this 228-page product specifier. Capabilities in thin and thick films, hybrid microcircuits, chip arrays and DIPs are discussed along with technical data on capacitors and filters. Copies are available by letterhead request to AVX/Aerovox, New Bedford, MA 12741.

Microelectronic packages are covered in this 16-page illustrated catalog with dimensional drawings of 45 standard configurations and construction details of over 100 standard packages. Sealox Div., National Beryllia Corp., Greenwood Ave., Haskell, N J 07420. **302**

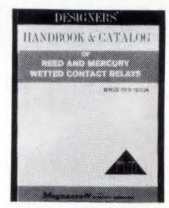
Electrical/electronic measurement system is described in an eight-page catalog. Basic components are arranged to provide Wheatstone, Kelvin, inductance or capacitance bridges; differential voltmeters; millivolt potentiometers; ac/dc transfer unit; and others. Laboratory Systems Research, Inc., 2732 29th St., Boulder, CO 80303. **303**

Electromagnetic delay lines are featured in Catalog No. 10, a 20-page booklet giving specifications and descriptions for a broad range of delay lines. ESC Electronics Corp., 534 Bergen Blvd., Palisades Park, N J 07650. **304**

Electronic keyboard system utilizing a scanning technique is described with a diagram, specifications and a listing of standard and optional features. Also included is a six-page keyboard designer's specification sheet to aid in keyboard design. Cherry Electrical Products Corp., 3600 Sunset Ave., Waukegan, IL 60085. **305**



Core memory systems are introduced in a catalog describing the 400 Series with storage capacity from 4k × 9 bits to 65k × 36 bits. Fabri-Tek, Inc., 5901 S. County Rd. 18, Minneapolis, MN 55436. **306**



Designer's handbook of reed and mercury-wetted contact relays is available in the fifth edition. It contains a glossary of terms, principles of operation, applications, design requirements, specifying and testing data and new product information. Copies are available by letterhead request to Magnecraft Electric Co., 5575 N. Lynch Ave., Chicago, IL 60630.

Literature

"Optogram" is a monthly technical bulletin describing customer applications, new products and exciting activities in the optical and laser field. A. D. Jones Optical Works, Inc., 64 Cambridge St., Burlington, MA 01803. **307**

Indicator lights, light-emitting diodes and incandescent lamps are completely described in an eight-page catalog. General Illumination, Inc., 2233 University Ave., St. Paul, MN 55114. **308**

Data sets and modems are the subject of a 12-page brochure describing the Series 1300 transmitter/receiver units that greatly improve the efficiency of dial-up data systems even where telephone line performance is seriously deteriorated. Several pages of the brochure are devoted to design features and circuitry that make this high-performance possible. Dataserv, 770 Airport Blvd., Burlingame, CA 94010. **309**

FET-input op amp with fractional picoamp bias current is described in a two-page data sheet with specifications, prices and application information. Analog Devices, Inc., Box 280, Norwood, MA 02062. **310**

Multiple-output power supplies are described in a catalog containing condensed data on modular units and custom units for computer CRT terminals, card reader and digital cassette OEM applications. Also included is information on MIL-spec custom units and a four-output lab supply. Astro-Space Labs., Inc., Research Park, Huntsville, AL 35806. **311**

Thin-film resistor networks for D/A and A/D converters feature utmost temperature stability and tracking, and are covered in a data sheet describing three models and various packaging options. Analog Devices, Inc., Pastoriza Div., Box 280, Norwood, MA 02062. **312**

Conductive coatings are covered in this six-page booklet from Acheson Colloids Co., Box 288, Port Huron, MI 48060. **313**

Single-ended CATV amplifiers are discussed in a position paper which reviews basic CATV amplifier designs. Pro and con aspects of push-pull, split-band, distributed and single-ended amplifiers are considered. AEL Communications Corp., Box 507, Lansdale, PA 19446. **314**

Literature

Spectrum analyzers, sweep generators, programmable attenuators and lumped-component miniature low-pass and band-pass filters are featured in a 20-page illustrated catalog with physical and electrical characteristics, applications and prices. Texscan Corp., 2446 N. Shadeland Ave., Indianapolis, IN 46219. **334**

Panel-mounted accumulator that totalizes events occurring during a programmed interval at rates up to 1 MHz is described in Bulletin 2457. Electronic Instruments Div., Beckman Instruments, Inc., 3900 River Rd., Schiller Park, IL 60176. **335**

Precision components catalog contains 446 pages with over 35,000 electrical and mechanical components in this 35th edition. PIC Design Corp., Box 335, Benrus Center, Ridgefield, CT 06877. **336**

Solid-state pushbutton module featuring a magnetically actuated Hall effect integrated circuit chip is described in Product Sheet 101SN1. Micro Switch, Div. of Honeywell Inc., 11 W. Spring St., Freeport, IL 61032. **337**

"A Reliable Plastic Power Transistor Family Aimed at the Heart of Television Applications" is the title of Publication 1CE-406 which describes the procedures that produce the mean-time-before-failure of 275,000 hours for RCA-2N6177 family transistors. RCA Commercial Engineering, Harrison, N J 07029. **338**

Solid tantalum capacitors of the ENS Series, with values ranging from 0.0047 to 330 μF and ratings from 6 to 100V, are covered in Bulletin 830. National Components Industries, Inc., 5900 Voss Rd., West Palm Beach, FL 33407. **339**

Switch catalog has 28 pages providing a guide to the basic criteria for switch selection, and complete specifications and ordering information for a variety of switches. Tech Labs, Inc., Bergen and Edsall Blvds., Palisades Park, N J 07650. **340**

Chip capacitor data sheet, CZ5B, features hundreds of "Vee Jem" values and includes suggested mounting methods, detailed specifications and close-up photos. Vitramon, Inc., Box 544, Bridgeport, CT 06601. **341**

"Lock-In Amplifier Versatility" is the title of a 12-page specification and application guide which describes many different lock-in systems that can be created at minimum cost by the addition of special purpose plug-in modules. Ithaco, Inc., 735 W. Clinton St., Ithaca, NY 14850. **342**

Drafting aids catalog contains eight pages describing unique drafting and engineering aids, including zero center scale and "Decimal Keeper" slide rule. Devonics Inc., 1515 Chatsworth Blvd., San Diego, CA 92107. **343**

Digital audio signal delay unit, Model 101, is described with illustrations and applications in a six-page brochure. Gotham Audio Corp., 2 West 46th St., New York, NY 10036. **344**

Solid-state time code generator module is the subject of Bulletin CG526 which includes specifications, dimensional data and information on a 7-segment LED time display. A. W. Haydon Co., 232 N. Elm St., Waterbury, CT 06720. **345**

System 390 universal card tester for automatically testing digital, analog and hybrid PC boards, modules and components is described in a 16-page brochure. The system is discussed in general terms and specific details. Instrumentation Engineering, Inc., 769 Susquehanna Ave., Franklin Lakes, N J 07417. **346**

Test report on the MD53 and RMD53 high-density, multi-pin series connectors has eight pages showing tests performed, MIL spec requirements and results. Connector Div., Microdot Inc., 220 Pasadena Ave., South Pasadena, CA 91030. **347**

Digital head selector for Datum-Series 1/2-inch IBM-compatible recording heads is designed in the form of a circular slide rule and provides essential technical data on the company's line of tape heads. Nortronics Company, Inc., 8101 Tenth Ave. N., Minneapolis, MN 55427. **348**

Digital panel meters, a limit set comparator and a digital multimeter are described, along with pertinent specifications and prices, in a four-page short-form catalog. Digilin, Inc., 1007 Air Way, Glendale, CA 91201. **349**

NEVER-SEEZ®

ANTI-SEIZE AND LUBRICATING COMPOUND

HERE'S THE ANSWER TO COSTLY MAINTENANCE

- Prevent seizure to 2000°F.
- Eliminate galling, pitting and corrosion
- Reduce repair time

NEVER-SEEZ is easily applied for uniform parts coverage to assure absolute parts protection. Speeds assembly and disassembly. Available in 8 oz. brush top cans, ¼ and 1 lb. applicator top plastic squeeze bottles, 16 oz. aerosol spray container and ¼ lb. to 425 lb. standard metal containers.

WRITE FOR FREE 16 PAGE CATALOG

NEVER-SEEZ COMPOUND CORPORATION
2914-24 S. 18th Avenue, Broadview, Illinois 60153

CIRCLE NO. 48

photo controls for every need

51 sketches showing photo controls for

• conveyors • cut-off • automation • counting • die-protection • jam-up • inspection • limit • measuring • orientation • positioning • processing • packaging • registration • smoke detection • sorting • tension • traffic control • weighing • winding • many, many others.

NEW Catalog 71

297 pre-engineered photo controls including retro-reflective, specular reflective, fiber optic and solid state; ON/OFF and Timing Controls; tremendous selection of photo sensors and light sources. Proximity Controls. Counting Eyes. Bin level, smoke, current surge and impact controls. All illustrated, described and priced.

See the AUTOTRON MAN in your area or send for Catalog 71 NOW

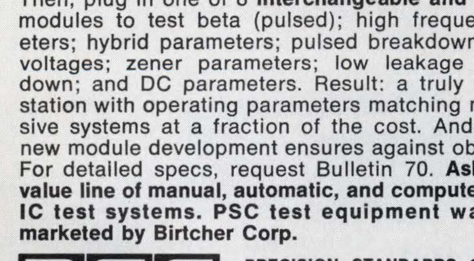
AUTOTRON, INC. 3627 N. Vermilion, Danville, Ill. 61832
Ph 217-446-0650 TWX 910-244-1455

CIRCLE NO. 49

Test any semiconductor with just one test set. (Only $695 for mainframe)

You start with Precision Standards' Model 70 mainframe containing power supplies and basic metering circuitry. Then, plug in one of 8 **interchangeable and ultrareliable** modules to test beta (pulsed); high frequency parameters; hybrid parameters; pulsed breakdown; saturation voltages; zener parameters; low leakage and breakdown; and DC parameters. Result: a truly flexible test station with operating parameters matching more expensive systems at a fraction of the cost. And, continuing new module development ensures against obsolescence. For detailed specs, request Bulletin 70. **Ask about our value line of manual, automatic, and computer controlled IC test systems. PSC test equipment was formerly marketed by Birtcher Corp.**

PSC **PRECISION STANDARDS CORPORATION**
1701 Reynolds, Santa Ana, Calif. 92705 • 714/546-0431



Interchangeable modules plug in here. Module prices range from $595 to $795 each.

CIRCLE NO. 50

COMPACT MULTIPOLE ROTARY SWITCHES for INDUSTRIAL CONTROL APPLICATIONS

SERIES 31
(Illustrated above)

- 15 amps continuous
- 1 to 20 poles
- 1 to 10 sections
- Wide range of circuits & options
- UL and CSA Listed

Other Switches? You can order literally *hundreds* of types *from stock*...or specify a *special* assembled from *millions* of components off-the-shelf! Specs range from 1/2 to 200 amps...from one to 75 poles per switch...push-button, rotary, cam, detent and snap action types.

Send for Bulletin C-1...our "catalog of available catalogs"!

ELECTRO SWITCH CORP.
Weymouth • Massachusetts 02188
Telephone: 617/335/5200 TWX: 710/388/0377

CIRCLE NO. 51

Additional "–Right and Wrong Ways to Design MOS Systems"

After complimenting Evelyn Berezin on her article on MOS systems (July 1 EDN/EEE), Rob Walker, manager of Micromosaic Engineering, Fairchild Semiconductor, contributed these additional points on MOS design:

"1. Digital simulation is of great aid in verifying a design; for example, worst case combinations of gate delays are hard to analyze on a breadboard. Some types of dynamic logic are essentially impossible to breadboard, and simulation is the only answer. Digital simulation is also helpful for test pattern generation.
2. An advantage of breadboarding the MOS design (after partitioning) relates to system checkout. Chances are all arrays won't be completed simultaneously, and will dribble in to the customer one at a time. By proper impedance and voltage matching, the LSI array may replace breadboard components one at a time, shortening checkout time.
3. Part of the extra engineering cost of LSI goes into a very complete analysis of the design. Timing, critical delays and worst case tolerances are studied in greater detail than normally afforded conventional designs. We are all aware of the high cost of field modifications required because of incomplete or careless analysis. To some extent then, the conversion cost of LSI is partly an investment in customer satisfaction."

Gentlemen:

Recently, while making a technical inquiry about silicon rubber wire (to General Electric), a secretary referred me to their semiconductor department with this quip: "They make silicone transistors there."

Thought this might be good for the Signals & Noise Dept.

Dale E. Barbour
Systems Engineer
Magnavox Research Labs
Torrance, CA 90503

"Higgins has come up with something which will make thermal runaway a thing of the past!"

Earth

"A planet doesn't explode of itself," said drily the Martian astronomer gazing off into the air. "That they were able to do it is proof that highly intelligent beings must have been living there."

—John Hall Wheelock

EDN

EEE

Sales Offices

E. Patrick Wiesner
Publisher
270 St. Paul St.
Denver, Colorado 80206
(303) 388-4511

Hugh R. Roome
National Sales Director
205 E. 42nd St.
New York City, New York 10017
(212) 689-3250

NEW YORK CITY 10017
Gerry Hoberman, District Manager
Richard Millar, District Manager
205 E. 42nd St.
(212) 689-3250

BOSTON 02116
Richard Parker, District Manager
Hal Short, District Manager
221 Columbus Ave.
(617) 536-7780

PHILADELPHIA 19103
Steve Farkas, District Manager
Penn Towers
1819 John F. Kennedy Blvd.
(215) 569-2424

CHICAGO
John Huff, Regional Manager
Terry McDermott, District Manager
15 Spinning Wheel Rd.
Hinsdale, Illinois 60521
(312) 654-2390

DENVER 80206
John Huff, Regional Manager
270 St. Paul St.
(303) 388-4511

SAN FRANCISCO 94103
William J. Healey, District Manager
1111 Hearst Building
(415) 362-8547

LOS ANGELES 90036
Ed Schrader, Regional Manager
Harry Fisher, District Manager
5670 Wilshire Blvd.
(213) 933-9525

Bold face type denotes advertisers in this current issue.

Application Notes

Motor and gearmotor overspecification is the subject discussed in the "Chief Engineers Handbook" section of *Motorgram* (Vol. 51, No. 3). Relationships between custom specifications, performance and cost are discussed. Bodine Electric Co., 2500 W. Bradley Pl., Chicago, IL 60618. **350**

Tape recorder Handbook 1330 is a practical guide for users of instrumentation tape recorders. This 43-page handbook contains an introduction to magnetic tape systems, a glossary of instrumentation terms and a concise explanation of how magnetic heads work. Bell & Howell Co., 360 Sierra Madre Villa, Pasadena, CA 91109. **351**

"Testing for Forward-Bias Second Breakdown in Power Transistors" is the title of Application Note AN-4573. This six-page note describes a non-destructive test circuit that determines the forward-bias second-breakdown safe operating locus for power transistors. Test circuit diagrams, typcial waveforms and figures illustrating the physical process of second breakdown are included. RCA Commercial Engineering, Harrison, N J 07029. **352**

"What Every Temperature Chamber User Should Know About CO_2" is a booklet intended to help users get better utilization of the product. Techniques are described that can save engineering time, improve safety, reduce chamber maintenance and cut down on CO_2 consumption. Vacon, 2946 Adams Ave., San Diego, CA 92116. **353**

IC voltage regulators, Types 723 and 823, are described in a 17-page application note including information on parameters and a discussion of bias limitations, ripple rejection, external sensing, thermal effects, current limiting, current capability and special applications. Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94040. **354**

"Primer of Plant Noise Measurement and Hearing Testing" is a 24-page booklet which gives a capsule analysis of current government regulations enacted to protect the hearing of nearly everyone exposed to industrial noise hazards and describes the techniques and equipment used to measure plant noise and monitor employee hearing as required by the new statute. General Radio, 300 Baker Ave., Concord, MA 01742. **355**

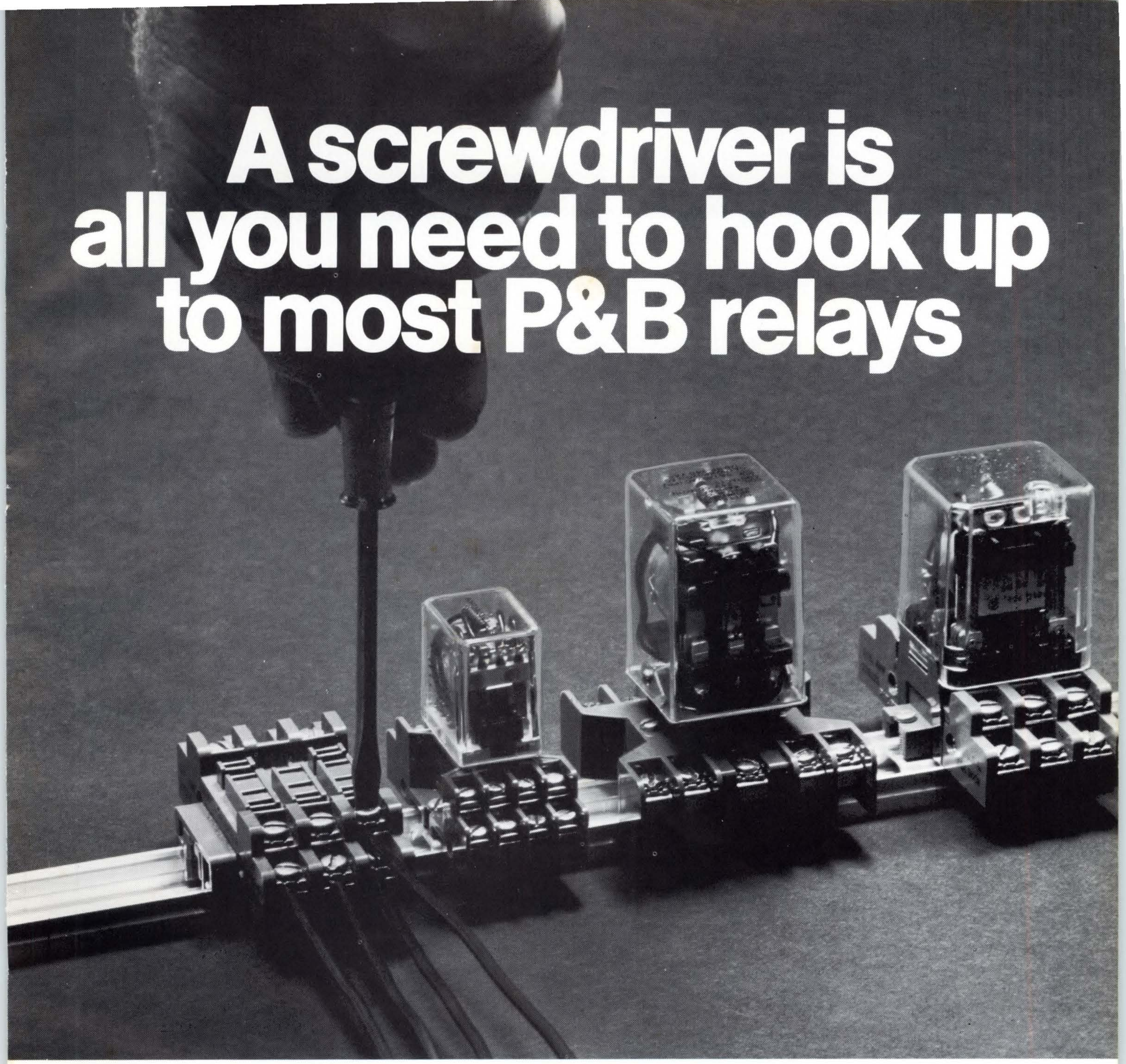
"Thyristor Selection and Calculations for Pulse Applications" is the first title in a new series of "Tech Tips" articles on the selection, application and use of discrete power semiconductors and subsystems. Westinghouse Electric Corp., Semiconductor Div. Marketing Services, Youngwood, PA 15697. **356**

Low-noise FETs are compared with low-noise bipolar transistors in a five-page application note discussing noise relationships. Included are basic definitions, how to determine noise figures, test procedures and information on the use of equivalent noise and current sources. Teledyne Semiconductor, 1300 Terra Bella Ave., Mountain View, CA 94040. **357**

"Analog Dialogue", in a 16 page issue, covers such technical topics as a review of the AD504 1 $\mu V/°C$ monolithic IC op amp, a note for the designer of 12- and 16-bit D/A converters, floating differential instrumentation, design of a data-acquisition system to protect a 128-MW dc power supply and some tips on short cuts to mental arithmetic. Analog Devices, Inc., Rte. 1 Industrial Park, Box 280, Norwood, MA 02062. **358**

Reprints Available

in this issue are offered as follows:



The new Potter & Brumfield socket system with screw terminals gives you a whole new world of relays to choose from.

How?

By converting octal and quick-disconnect tab termination relays to screw terminals.

Quickly. Simply.

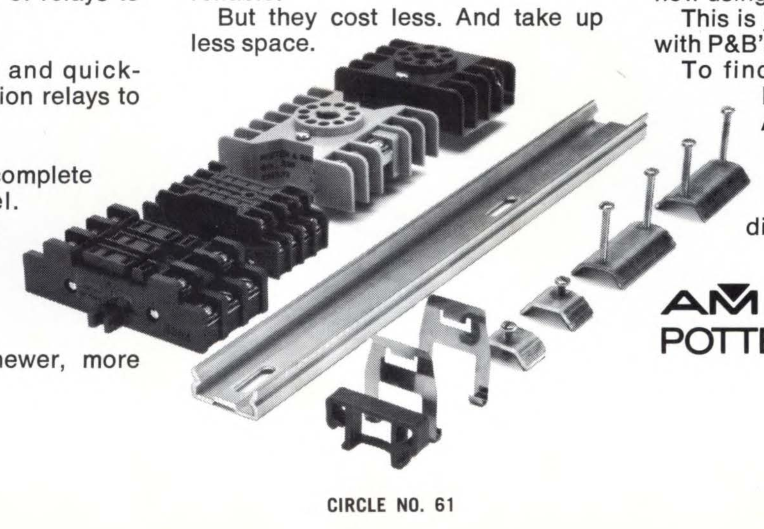
Our system comes complete with mounting channel. Brackets. Retainers. Spacers. And sockets made of virtually indestructible Lexan.

Think of it!

Now you can use newer, more sophisticated relays.

Just as compatible as the ones you've been using. And every bit as reliable.

But they cost less. And take up less space.



(You probably can save as much as 75 percent of the space you're now using.)

This is just part of what's possible with P&B's new socket system.

To find out more, write or call Potter & Brumfield Division, AMF Incorporated. Princeton, Indiana 47670, (812) 385-5251.

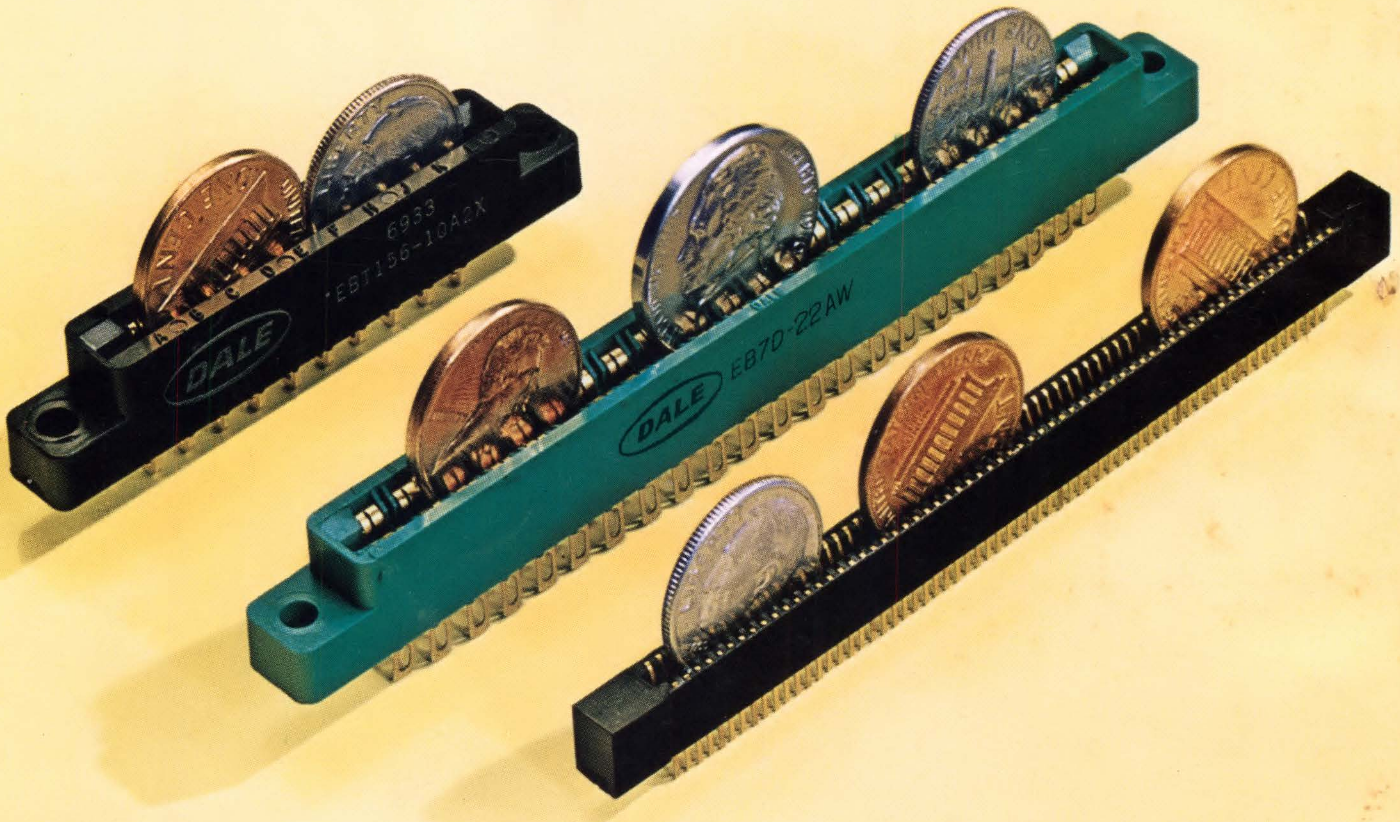
Or talk to your local P&B distributor or representative.

AMF
POTTER & BRUMFIELD

CIRCLE NO. 61

Interchange.

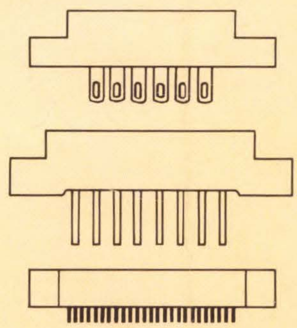
...and get change!



Specify Dale Edgeboards

Dale is ready to deliver your choice of three of the industry's most popular edgeboard connectors...very well made...very interchangeable...very competitively priced. If you're looking for an edge in meeting production schedules and holding the line on costs, contact Dale today.

Get your edge by calling 605–665-9301



EB 7 New .156″ model with reliable bifurcated bellows contacts. Single row (6, 10, 15, 18, 22 contacts). Double row (12, 20, 30, 36, 44 contacts). Solder eye terminals. For 1/16″ board.

EBT 156 Top-selling .156″ model with rugged tuning fork contacts (8, 10, 12, 15, 18, 22). Dip, solder eye or wrap terminals. For 1/16″ boards.

EBTL 050 Industry's thinnest .050″ model. Only .158″ thick for 1/32″ boards; .190″ thick for 1/16″ boards. Cantilever-style contacts (8, 16, 20, 25, 32, 50, 64 per side).

DALE®

DALE ELECTRONICS, INC.

East Highway 50, Yankton, South Dakota 57078. In Canada: Dale Electronics Canada, Ltd., *A subsidiary of The Lionel Corporation*

CIRCLE NO. 62