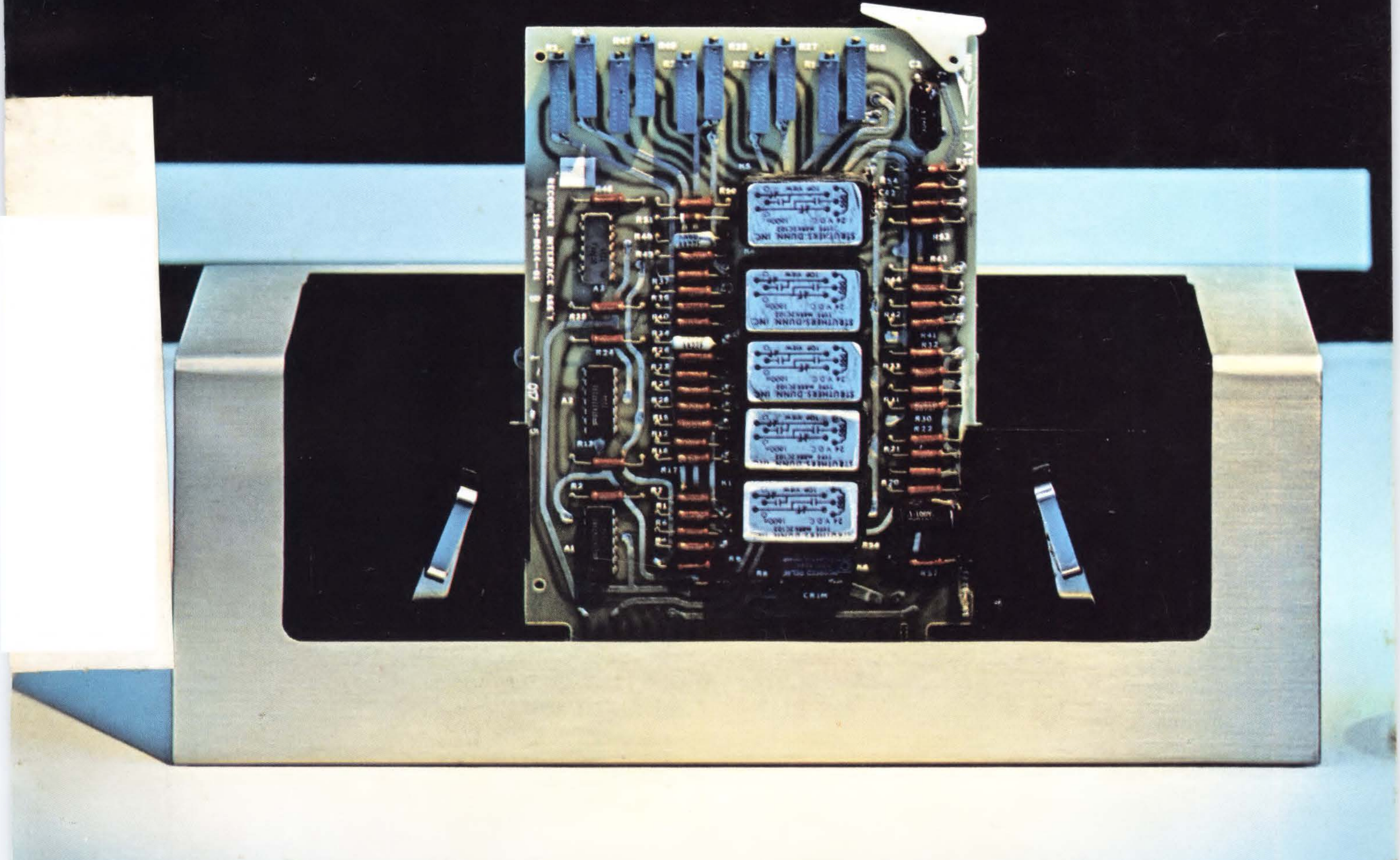
EDN

exclusively for designers and design managers in electronics

EEE

Computer-Controlled Testing



A CAHNERS PUBLICATION

OCTOBER 1, 1971

Leave my power supply system alone!
You can get your own in only 9 days from Acopian.

"I tried struggling through that old power supply system catalog. It was like a jigsaw puzzle, hunting for the pieces I needed for my new power system. There had to be a better way.

"Then I remembered the Acopian hotline. I called it. I told them the DC voltages and currents I wanted. Discussed panel size. Meters. Switches. And other accessories.

"They gave me a firm price. Right on the phone. It was a lot less than I expected. I had our buyer phone in the P.O. And Acopian designed, built, tested and shipped it in nine days. Completely wired.

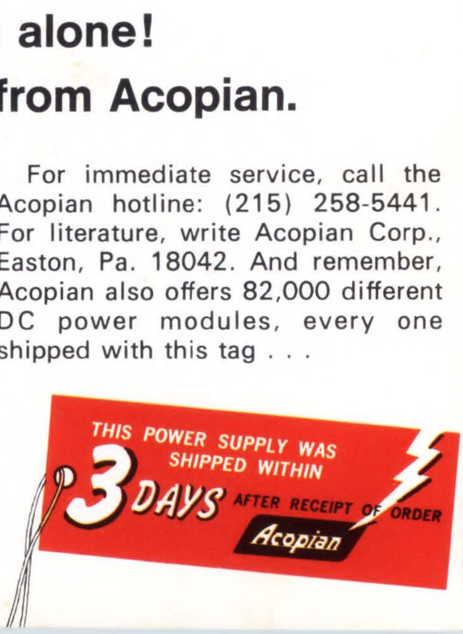
"So go order your own Acopian power system . . . It's easy!"

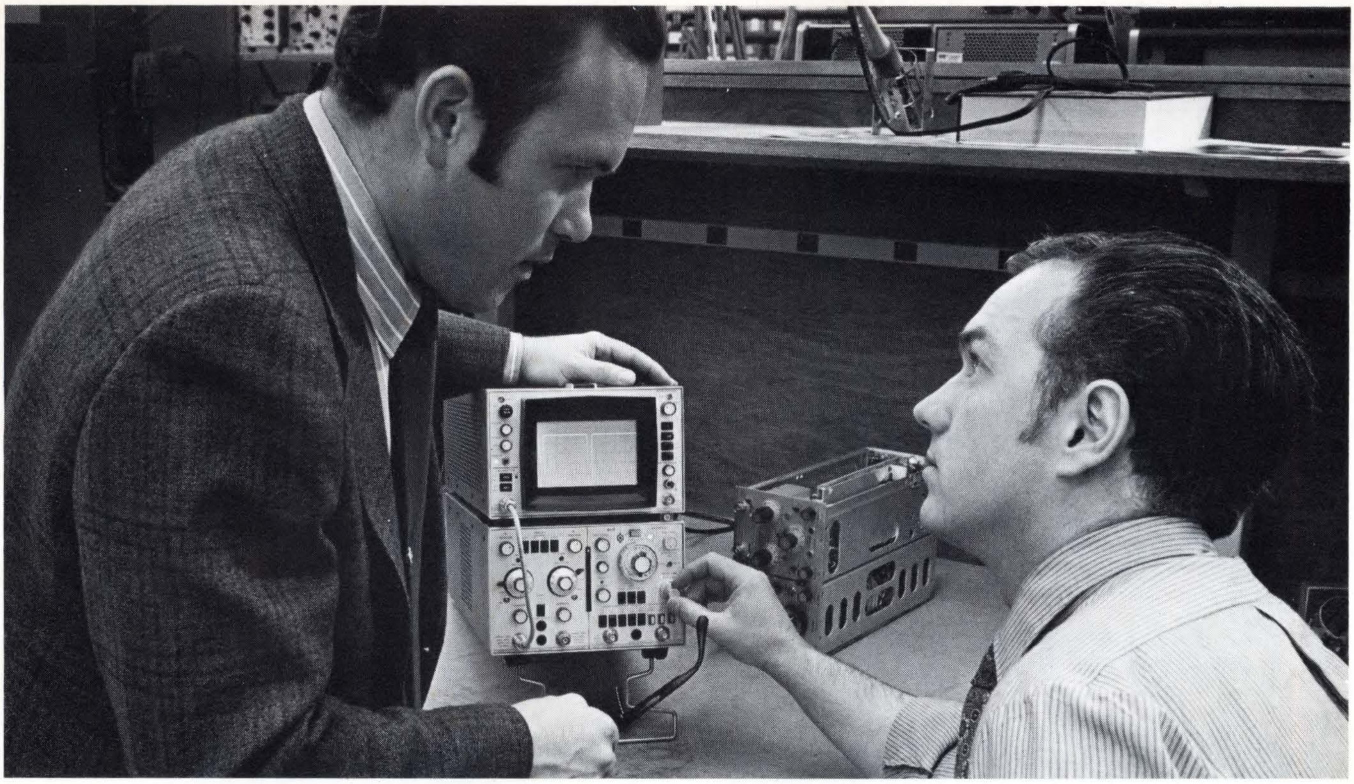
HOW TO ORDER ACOPIAN POWER SYSTEMS

- **Call** Acopian collect
- **Tell us** the outputs and accessories you need
- **Get** a firm price
- **Shipment** of completely wired system will be made in 9 days.

CIRCLE NO. 1

For immediate service, call the Acopian hotline: (215) 258-5441. For literature, write Acopian Corp., Easton, Pa. 18042. And remember, Acopian also offers 82,000 different DC power modules, every one shipped with this tag . . .





HP's 250 MHz 183: Still The Performance Champ! Ask For A Demo.

If you want to look at waveforms in high-speed logic circuits, or to photograph ultra-fast transients—there's still only one general purpose, lab oscilloscope that gives you a real-time window from DC to VHF. It is HP's 183, the 250 MHz 10 mV/div scope (to 600 MHz with direct access plug-in)—**now available for demos on your bench.**

HP pioneered in the development of the first useful, usable high-frequency scope to give you these features: 10 mV sensitivity, 1.5 ns rise time, 4 cm/ns writing speed, negligible distortion from input capacitance. **Balancing price and performance the 183A system is a bargain**—with delayed sweep, \$3900; without delayed sweep, \$3400 (available in either cabinet or 5¼" rack-height versions).

HP's technical leadership, covering a wide area of disciplines, made it all possible. An in-house IC capability produced monolithic transistor arrays for the vertical amplifier—key factor in achieving good transient response with 250 MHz bandwidth and high-fidelity reproduction of waveforms.

HP's step-ahead CRT technology produced a unique CRT to display fast signals. The CRT uses two transmission lines for the vertical deflection system, to provide distributed deflection of the electron beam and to give the CRT **a cutoff frequency well beyond present IC technology.**

Since the 183A mainframe is not limited by hard-wired, internal amplifiers, you have freedom to take advantage of any existing HP 180 Series plug-ins, plus any HP high frequency innovations, as they become available—and higher bandwidth amplifiers are now in HP development labs.

Meanwhile, the HP 183 250 MHz Scope is a deliverable system, **capable of making your measurements, now.** And it's backed by almost two years of successful, in-the-field performance on customer workbenches.

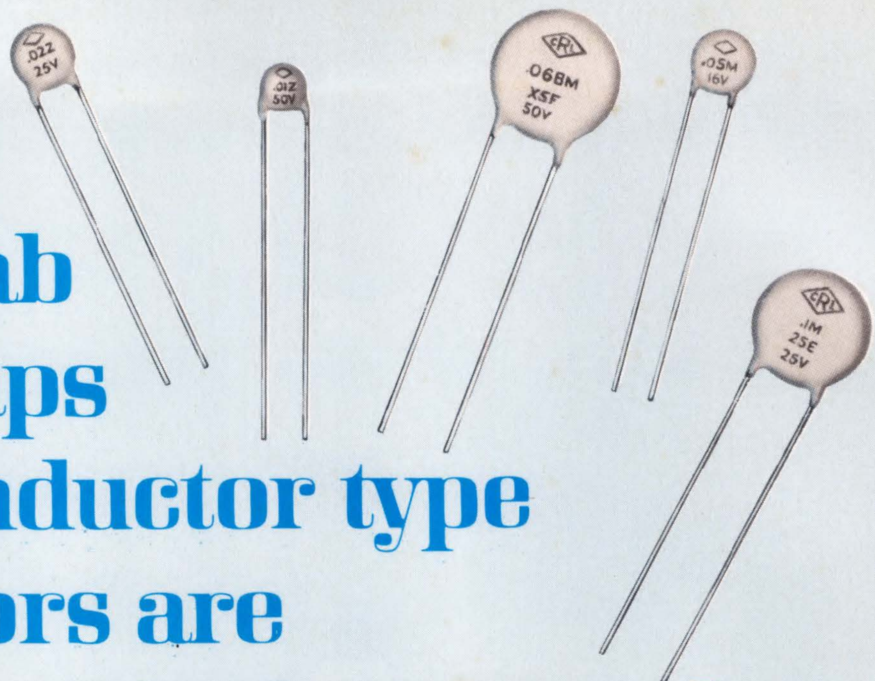
The same step-ahead thinking exemplified in the HP 250 MHz scope also exists in all HP scopes. To find out all about the most exciting new developments in the rapidly changing world of oscilloscopes, ask your HP field engineer to show you the whole HP 180 scope family, including sampling and storage. Or write, Hewlett-Packard, Palo Alto, California 94304. Europe: 1217 Meyrin-Geneva, Switzerland.

Scopes are changing.
Are you?

081/13A

HEWLETT hp PACKARD

CIRCLE NO. 2



Centralab Ultra-Kaps semiconductor type capacitors are an economical approach to miniaturization.

As low as 2½¢ each on quantity orders.

Ultra-Kaps® replace mylar and "Hi-K" ceramic capacitors and you still save space and money. Their reliability has been field tested and proven on millions of circuits. To obtain samples for independent evaluation, write, on your letterhead, to Capacitor Sales Manager, Centralab.

CENTRALAB DELIVERS!

RANGE CHART

	16 volt		25 volt		50 volt	
Maximum Diameter	Max. Cap. MFD	Min. I.R. Megohms	Max. Cap. MFD	Min. I.R. Megohms	Max. Cap. MFD	Min. I.R. Megohms
.290	.02	5.0	.015	65.0	.01	1000
.390	.033	3.0	.022	45.0	.015	1000
.405	.05	2.0	.033	30.0	—	—
.485	—	—	.05	20.0	.022	1000
.515	.068	1.5	—	—	.033	1000
.590	0.1	1.0	.068	15.0	.047	1000
.690	0.15	0.65	0.1	10.0	.05	1000
.760	—	—	—	—	.068	1000
.820	0.2	0.5	0.15	6.5	—	—
.920	0.3	0.33	0.2	5.0	0.1	1000

Thickness: .156 inches maximum
Temperature Characteristics: 16 and 25 volt: X5R, Y5F, Z5E
50 volt: X5F, Y5F, Z5F

CENTRALAB
Electronics Division
GLOBE-UNION INC.
5757 NORTH GREEN BAY AVENUE
MILWAUKEE, WISCONSIN 53201

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CIRCLE NO. 3

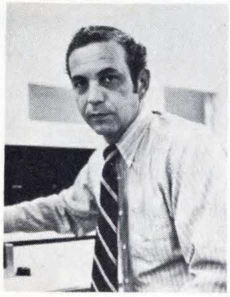
OCTOBER 1, 1971
VOLUME 16, NUMBER 19

EDN/EEE

EXCLUSIVELY
FOR DESIGNERS
AND DESIGN MANAGERS
IN ELECTRONICS

Cover

Cover photo from Instrumentation Engineering Inc. shows a circuit board plugged into the DUT socket of a computer-controlled test system. See p. 24 for a Speakout article on computer-controlled testing by Instrumentation Engineering's president, Paul Giordano. (Photo by Walt Sayer)



Speakout—Paul Giordano of Instrumentation Engrg. Speaks Out on computer—controlled testing. See article on p. 24.

DESIGN ELECTRONICS
ELECTRONICS WEEKLY
EDN/EEE
ELEKTRONIK
ELEKTRONIK-ZEITUNG
INTER ELECTRONIQUE

International Business Press Associates

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Everybody wants your components business.

But we're doing 6 things to earn it.

1 Better components. From ER through industrial, from precision through general purpose—we give you documented reliability. You'll find our tin oxide resistors outperform metal film, wirewounds, carbon comps and metal glaze resistors. And our Glass-K™ capacitors outdistance monolithic ceramic capacitors on all counts.

2 Better prices. And this extra reliability costs you no more. The fact that we've become the country's largest supplier of metal film resistors—including metal glaze—says clearly that we're more than *just* competitive.

3 Better delivery. Our distributors can give you off-the-shelf delivery from an inventory of over 50,000,000 components. And you'll find our "ball parks" are the most accurate and dependable in the industry. You benefit in reduced expediting and inventory costs.

4 Better QC. Enough better so that many of our customers find they can totally eliminate incoming QC testing of our parts. Couple this with our unique product configurations that cut component insertion costs and you'll find it costs you less to do business with Corning even when our per unit price is the same.

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Just let us prove it. Write for full details to: Corning Glass Works, Electronic Products Division, Corning New York 14830. Or call: (607) 962-4444. Ext. 8381.

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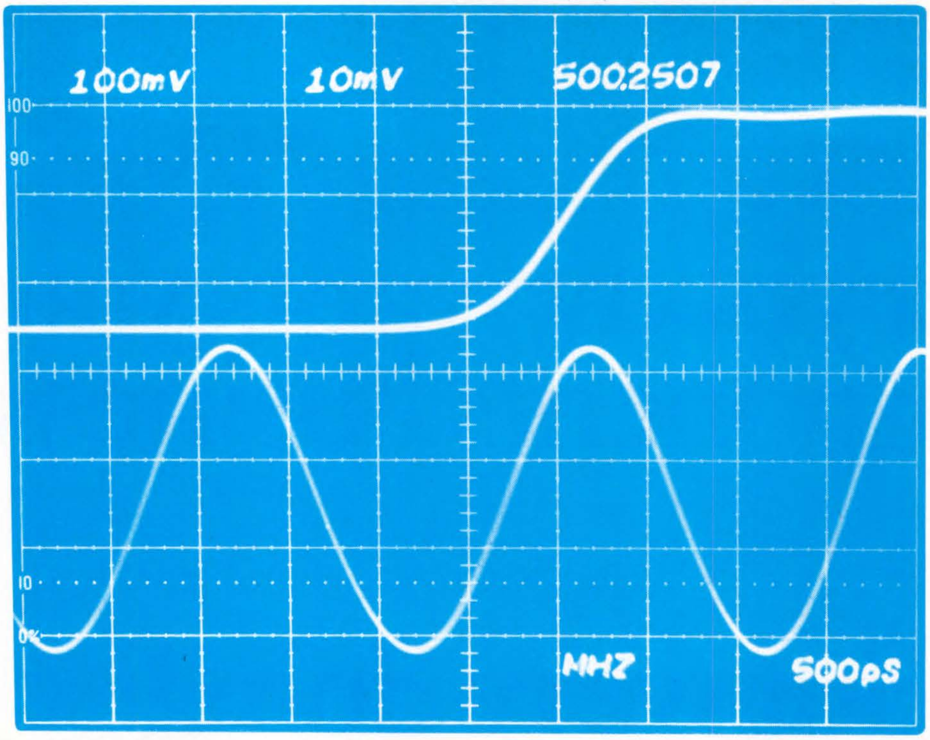
ELECTRONICS

Resistors & Capacitors

for guys who can't stand failures

CIRCLE NO. 4



CRT READOUT

CHAR. SET ABCDEFGHIJKLMNPQRSTUVWXYZ0123456789mμnpd↓</.>Δ+-Ω

Actual Size

TEKTRONIX 7000-Series Oscilloscope Systems

CRT READOUT, unique to the *TEKTRONIX 7000-Series Oscilloscope Systems,* provides a combined display of waveforms, measurement parameters and symbols on the CRT for direct reading.

Wrong answers because of overlooked control settings are now passé. CRT READOUT tells you the full story. Speed, perception and convenience are available because the scale data is printed right on the display. These values are automatically corrected for both probe attenuation and sweep magnification. There are also special symbols for identifying trace position (IDENTIFY), amplifier polarity (↓) and uncalibration (>).

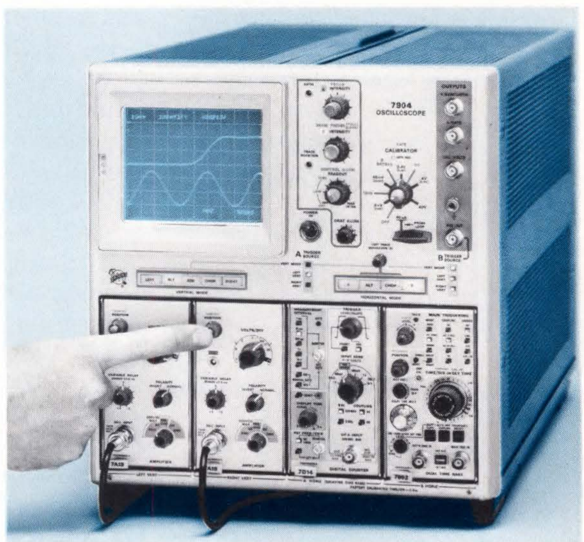
Correct answers are always on your photographs with CRT READOUT. The photos will show the waveforms along with their parameters and symbols — A REAL TIME SAVER.

CRT READOUT is available for 7000-Series plug-ins working in *frequency, time, voltage, current, resistance* and *temperature* domains - - - AND there are MORE coming.

CRT READOUT functions in all 7000-Series mainframes and plug-ins except those having a suffix N (7403N, 7B53N, etc.).

Tektronix, Inc. lease and rental plans are available in the U.S.A. For information, call your local TEKTRONIX Field Engineer or write: Tektronix, Inc., P. O. Box 500, Beaverton, Oregon 97005.

CIRCLE NO. 5

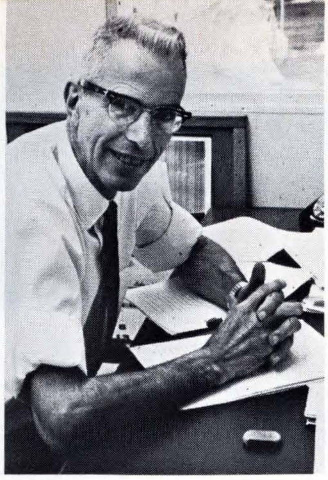


CRT READOUT responding to various functional instructions and generating up to 50 symbols is shown using the 500-MHz 7904, a four-plug-in Oscilloscope with a pair of 500-MHz, 10-mV 7A19 Amplifiers, a 525-MHz 7D14 Digital Counter and a 500-ps/cm 7B92 Dual Time Base.

TEKTRONIX®

committed to technical excellence

Editorial



Involvement and the Designer

One of today's popular buzz words is involvement. All of us are being exhorted to "become involved" in politics, in social welfare and in the task of cleaning up our unhealthy and untidy environment. Corporations are pressured to become concerned about the effects of their activities on community well-being, and to insure that their products offer satisfactory service to the consumer for whose use they were designed.

Electronic engineers are often told that they, personally, should become more concerned about the value to society of their daily labors. For example, those who design consumer goods are being taken to task over the lack of durability of those goods—and about the built-in repair headaches. All such "do this, do that" can become frustrating, particularly when many of us have little actual control over the things we are being urged to change.

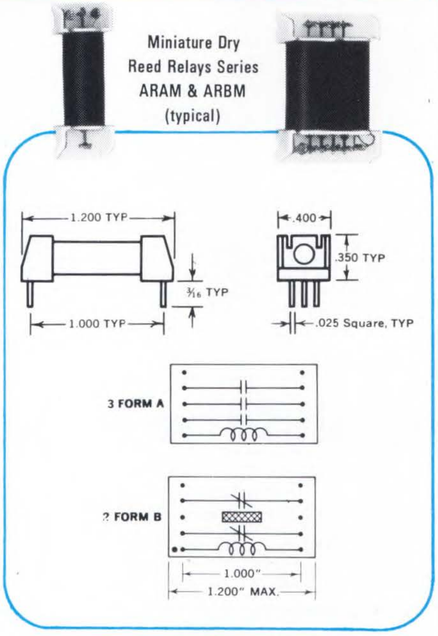
There are, though, some rather basic guidelines we all can use where involvement is concerned. One practical one is to confine our efforts to those things over which we have some control. As an illustration, we can make sure that we design so that servicing is easily accomplished—instead of trying for the ultimate in compactness or cosmetic appeal. Another is to be as conscientious about the work we do for others as we would be if we were doing it for ourselves. Neither is a cure-all for the world's woes, but if we follow both these rules we'll be "involved" in a positive way.

Earle Dilatush

MANAGING EDITOR

ADLAKE DRY REED RELAYS

Quality and reliability are key design parameters built into Adlake's complete line of DRY REED RELAYS. Advanced electrical, mechanical and packaging features qualify these *standard, intermediate,* and *miniature* size devices for an extremely wide range of commercial, industrial, and military switching applications, such as control panels, machine process control instrumentation, and telephone and communications apparatus, to mention just a few.



Miniature Dry Reed Relays Series ARAM & ARBM (typical)

ELECTRICAL DETAILS:

Contact Arrangements:
Up to 4-A or 2-B

Contact Current Ratings:
Switch 0.5 A; carry 3 A
(Miniature & Intermediate)
Switch 1.5 A; carry 6 A (Standard)

Contact Resistance:
Initial—50 milliohms, max.;
end-of-life—2 ohms max.
(Standard)
Initial—200 milliohms max.;
end-of-life—2 ohms max.
(Intermediate & Miniature)

Contact Life:
Rated Loads—20 x 10^6 operations
Dry Circuit—500 x 10^6 operations

Contact Voltage Ratings:
100 VDC or 150 VAC
(Miniature or Intermediate)
150 VDC or 250 VAC (Standard)

Insulation Resistance:
10^{12} ohms (min.)

Operating Speed:
1 to 2.5 ms
(Miniature & Intermediate)
2.5 to 4.5 ms (Standard)
(Varies with sensitivity and number of poles; including contact bounce and coil time)

PACKAGING DETAILS:

Environmental Protection:
Hermetically sealed contacts. Rhodium plating on contacts for higher loads and longer life characteristics.

Shelding:
Magnetic shielding layer

Shock:
200G max. 11 ± 1 ms
(Miniature & Intermediate)
100G max. 11 ± 1 ms (Standard)

Vibration:
30 G max. 0-1700 cps
(Miniature & Intermediate)
0-600 cps (Standard)

Temperature Range:
—55 to 105°C

Choose from 123 cataloged items. Dry Reed Relays with special features are available on special order with surprisingly short delivery times.

MERCURY WETTED CONTACT RELAYS

Low, stable contact resistance and "1-billion-operation" life qualify Sensitive Mercury Wetted Contact Relays for a wide array of switching applications, such as digital and analog computers, telecommunications system, multiplex, industrial control equipment, power control devices. New Series MWK and AWK Sensitive Relays offer contact form K (SPDT, center off)—ideal for multiple channel switching.

MERCURY DISPLACEMENT RELAYS

Time delay and load relays meet the toughest, most demanding switching applications. Non-adjustable time delay relays offer contact forms A and B with delays up to 1 hour, current ratings to 15 amps. Load relays switch from 30 to 100 amps with contact forms A and B.

USE READER SERVICE NUMBER FOR COMPLETE INFORMATION

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THE ADAMS & WESTLAKE *COMPANY*
A SUBSIDIARY OF ALLIED PRODUCTS CORPORATION

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CIRCLE NO. 6

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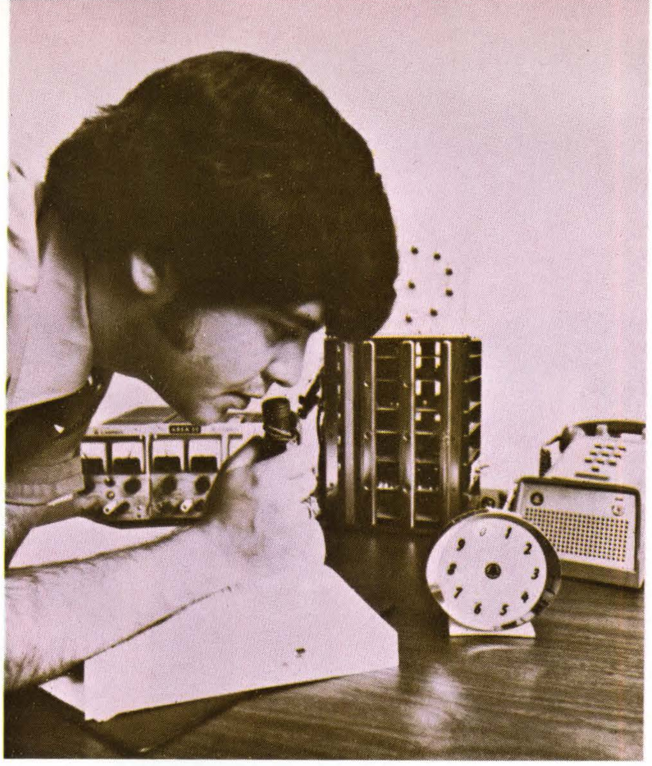
Voice-Controlled Device Dials Telephone



The mention of voice-controlled devices generally conjures up a vision of computers and other elaborate electronic systems. However, engineers at Bell Laboratories, Holmdel, N. J., have created a device that can dial a telephone number on voice command using a simple form of integrated circuitry.

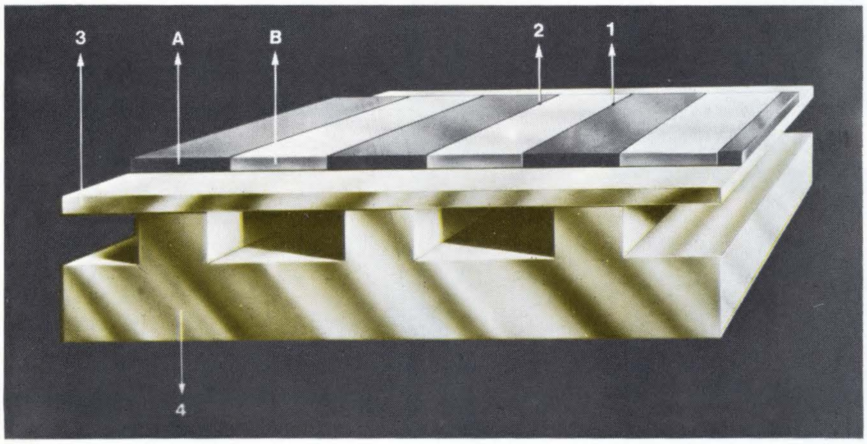
This circuitry converts sound waves into electrical pulses that open and close electromechanical switches necessary for obtaining a dial tone, executing dialing and terminating a call.

Part of the total system is a small circular display of ten lamps labeled zero through nine. These lamps light in sequence and a sound uttered in coincidence with a lighted numeral will activate that number. As the numbers are activated they are stored in a memory. After all the digits of a telephone number are stored, they are transmitted, by special command, as a series of pulses to dialing circuitry.

A telephone number remains in memory even after it is dialed and can be used again. Storing a new number automatically erases the old one from memory.

A similar voice-control device may one day provide "hand-free" telephone service for severely handicapped people. This technique might also be used to operate other electrical equipment or machinery.

Sensitive Thermopiles Based on Thin-Film Techniques



Thermopiles combining high sensitivity and ruggedness have been produced using microelectronic techniques.

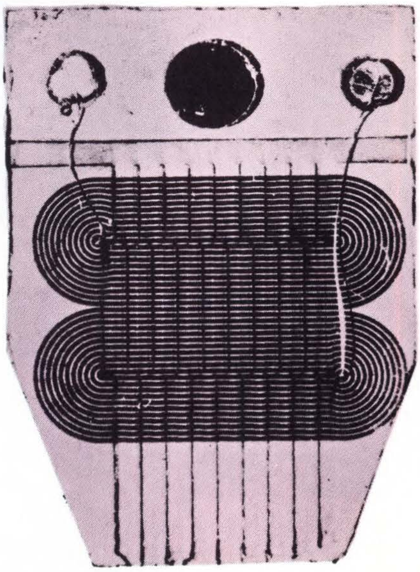
Engineers at the Laboratoires d'Electronique et de Physique Appliquee, Limeil-Brevannes, France, have produced a number of prototype units able to withstand 50G acceleration at vibration frequencies from 20 Hz to 2 kHz. Sensitivity of one type, which has been adapted for the Symphonie satellite project, is 1.65V/W in the IR spectrum as a whole, using 448 junction pairs.

The device consists of a series-connected arrangement of two alternating materials (A and B) which are deposited in thin films on an insulating thin-film substrate (3). This substrate is bonded to a heat-conducting base (4) in such a way that even-numbered junctions have good thermal contact while odd-numbered junctions are insulated from the base.

When the thermopile absorbs radiation, the odd-numbered junctions become warmer than even-numbered junctions and an emf is set up across the terminals of the chain of thermocouples.

Parameters such as resistance, response time-constant and sensitivity depend on the unit's dimensions. Methods of construction make it possible to vary the size and shape to any dimension from 0.2×0.2 mm to 10×10 mm simply by modifying the deposition masks and photomasks.

As a final touch, the unit shown will receive an absorbent coating of black paint to increase sensitivity of the device.



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
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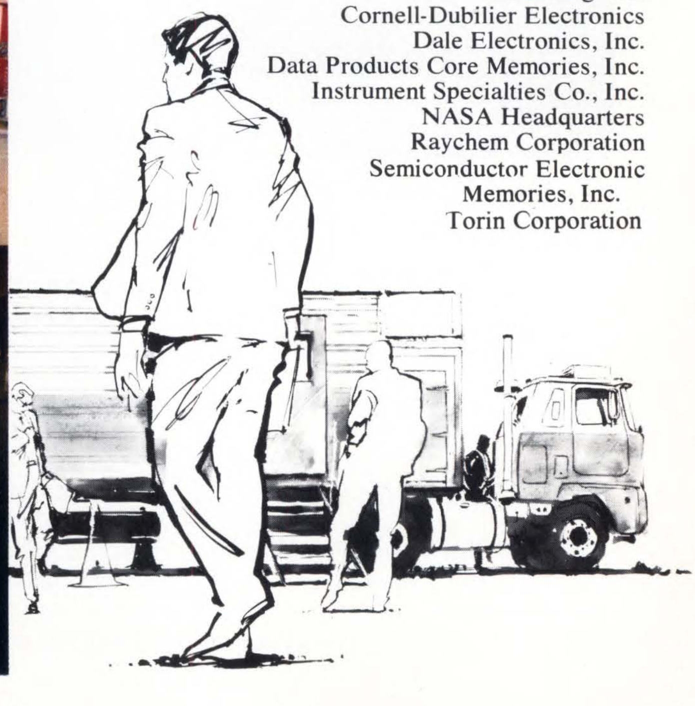
Caravan '71



Featuring new products, ideas and application assistance from:

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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

SCIENCE/SCOPE

High-voltage DC power transmission and control problems are now under study at Hughes' Malibu, Calif. research laboratory. The original research currently being conducted on DC converter valves and circuit breakers stems from the company's earlier ion-propulsion research for NASA. The Electrical Research Council, which represents America's private and public utilities, is partially funding the development of the Hughes DC breaker.

Electric power specialists from 13 countries, who were attending a CIGRE conference in Los Angeles on AC-DC converting equipment, reviewed the work in progress during a visit to the Hughes laboratory recently.

Belgium's Ministry of Defense has ordered preproduction laser tank fire control systems for use in the Belgian Army's Leopard tank. Built by SABCA in collaboration with Hughes, the system incorporates a computer, sensors, a precision mirror-drive assembly, precision optics built by O.I.P. Belgium, and a laser supplied by Eltro GmbH of Germany, a licensee of Hughes. During earlier trials the system demonstrated more than twice the first round hit capability of a classic fire control system. Reaction time to engage a target has been reduced to a few seconds.

A connector for instrument and remote-control cables that can survive the rough handling and rugged environments encountered in geophysical surveying for oil and minerals has been developed by Hughes. Trademarked the RUF-NEK connector, it has 164-contact capacity, enabling it to accommodate up to a 78-trace system with eight spare contacts. A unique contact design provides eight wiping surfaces to assure low circuit noise.

New commercial products from Hughes include: a scan conversion memory unit which is furnished with all circuitry, power supplies, and controls for writing, storage, erasure, and readout. It can be used for computer graphics, medical, document retrieval, CCTV, navigation, fascimile, printer....a compact digital-video converter that provides data equipment manufacturers and users with low-cost video readout of digital information....a 12-volt DC-input He-Ne laser system featuring rugged, weather-proof construction. The power supply typically permits 20 to 40 hours of continuous operation from a fully-charged car storage battery.

Airborne radar transmitter design engineers are needed now at Hughes. Must have specific fire-control-system, doppler, pulse-compression, microwave, and power-supply experience. Also: solid state microwave engineers with experience ranging from UHF to millimeter frequencies, and in the design and use of related circuits. Both positions require accredited degree, 3 years of specific experience, and U.S. citizenship. Write: Mr. Robert A. Martin, Hughes Aerospace Engineering Divisions, 11940 W. Jefferson Blvd., Culver City,CA 90230. An equal opportunity M/F employer.

A patent on pulsed laser holography has been awarded to Hughes. The new illumination technique permits holograms to be recorded in times as short as 30 billionths of a second (an important factor in noisy environments). Earlier continuous-wave gas lasers required long exposure times. Scientists foresee many valuable applications for holography in industry, medicine, dentistry, archeology, and teaching.

Creating a new world with electronics

HUGHES

HUGHES AIRCRAFT COMPANY

CIRCLE NO. 7

Polymer Processing Produces Piezoeffect

Mechanical stress caused by rolling during processing has been found to produce the piezoelectric effect observed in some polymer films.

Scientists experimenting with PVC and PVF sheets at the NBS Institute for Applied Technology, U.S. Department of Commerce, have found that peizocharacteristics can be eliminated by heating and induced by rolling the polymer films.

Piezoresponse of the films is comparable to conventional piezomaterials and is highly antistropic. They may eventually find use in biomedical instrumentation, underwater sound transducers and infrared detectors. Present investigations are directed at still more effective methods of polarizing polymer materials and the creation of other effects, such as pyroelectricity.

Scientists Store 'Cold' For a Hot Day

Thermal energy storage (TES) is an old principle that scientists and engineers at the University of Pennsylvania's National Center for Energy Management and Power laboratories have put to work to help relieve peak electrical power demands.

With the help of grants from the National Science Foundation, engineers and scientists at the Center have fabricated essential parts for air conditioners that "store up coolness" for use when utility circuits get overloaded.

A commercial prototype unit, to be operational by the summer of 1972, will be essentially a conventional air conditioning unit with one major addition – thermal energy storage material. Refrigerant from the evaporator (40-45°F) passes through a thin, lightweight panel of ribbed aluminum and plastic containing eutectic salt hydrates – inexpensive crystals that freeze at 55°F. By running the air conditioner during off-peak nighttime hours, "ice" builds up in the TES panel. During hot periods of the day, the compressor is supplemented by the coolness stored in the TES panel, which temporarily replaces the evaporating unit as the cooling agent. By evening the TES material has melted, the evaporating unit goes back to work again and the cycle resumes.

Air conditioning units of this design are expected to last considerably longer and require 60% less power than standard models. If run on a 24-hour basis, they should save at least 15% in overall power consumption. In addition, a smaller unit will be needed to do the same job. A 3-ton present-day model could be replaced by a 1-1/4-ton TES unit.

AEA Formed to Aid Engineers

A new engineering organization, the American Engineering Association, has been formed and is headquartered near Washington, D. C. Its stated purpose is to improve the professional, social and economic well-being of all engineers.

Immediate concerns of the new organization are improved communication among engineers, development of an astute political awareness among engineers and directed self-involvement of engineers in the improvement of their present employment dilemmas.

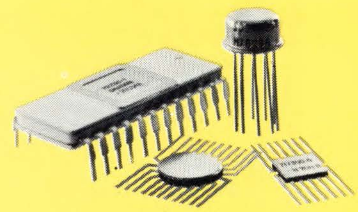
National in scope, the AEA envisions local chapters for effective lobbying on both state and national levels. Employment centers concerned with the employed as well as the underemployed and unemployed are also planned.

Specific problems that the AEA feels need investigation and action include portable pension plans, professionalism in industry, employee retention of patent and publication rights, layoff policies and engineering participation in management and management decisions.

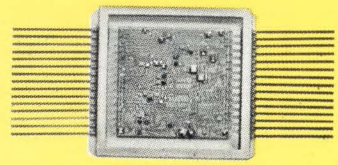
Annual dues are $10 for employed engineers and $2 for students or those unemployed. For more information about this organization, write to Gail D. Smith, Director, American Engineering Association, 6009 Harland St., Lanham, MD 20801.

Hughes is more than just electronic components and equipment.

It's devices too.

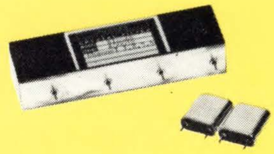


MOS integrated circuits (RS 283)

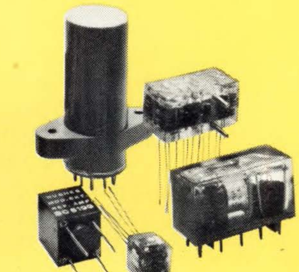


Bipolar and hybrid circuits (RS 284)

Microwave diodes (RS 282)



Frequency control devices (RS 285)



Special assemblies (RS 286)

HUGHES

HUGHES AIRCRAFT COMPANY
INDUSTRIAL ELECTRONICS GROUP
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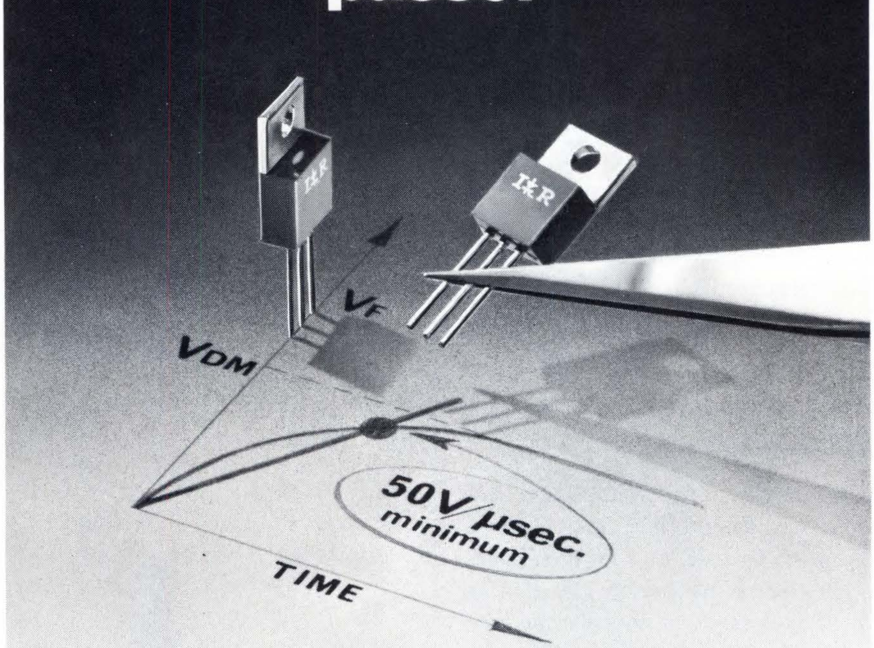
Circle appropriate Reader Service (RS) numbers.

New 8-Amp economy SCR makes false triggering passé!



Only IR guarantees minimum dv/dt of 50V/µsec. at 110°C (10°C higher than others) that eliminates any chance of erratic "turn-on".

Now you don't have to trade-off reliable performance for price in your economy SCR applications. International Rectifier's new IR122 series gives you all the advantages you wouldn't expect at such low prices. For example, they have the highest minimum dv/dt available (nobody else even specs a minimum), at a full 10°C greater than competitive units. Their characteristics remain stable, even under severe long-term operating conditions, due to IR's advanced passivation techniques. They have round, easily bent leads to simplify mounting. And, you don't have to be concerned about die breakage so often encountered when using the center-mounting-hole packages offered by other suppliers.

They're available now—in 50V, 100V, 200V, 300V and 400V versions—from IR industrial distributors. Contact our local sales office or call factory for details.

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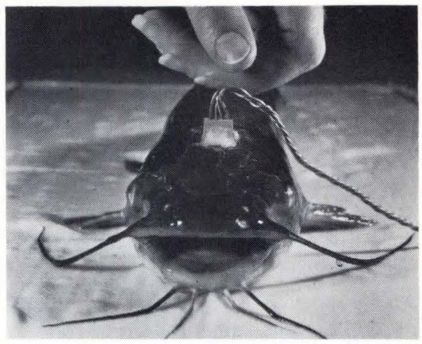
CIRCLE NO. 8

Fish Detect Unpleasant Odors



What's the effect on a fish if you expose it to unpleasant odors?

The electrical activity of its brain suddenly increases, according to a Trinity University psychologist doing research into the olfactory mechanism or sense of smell.

Dr. Vernon Benignus surgically implants tiny electrodes into the brains of catfish. He exposes the fish to very small doses of chemicals such as morphylene, which smells like dirty socks, and ethyl mercaptan, which smells like rotten eggs, and records the resulting electrical activity in their brains.

With no olfactory stimulation, the fish's brain maintains a continuous ac voltage of 50 to 100 μV. When its sense of smell is stimulated, the voltage rises to around 500 μV and there are significant changes in the electrical patterns and frequencies.

An IBM data processing system analyzes the electrical signals and shows patterns caused by the stimulation. It is hoped that by studying the statistical analyses produced by the IBM system it will be possible to determine how the brain codes information from the sense of smell.

Catfish are used because of their highly developed sense of smell as compared to humans, but it is hoped that results of the studies may apply to other senses and to humans as well as lower animals.

According to Dr. Benignus, recent studies have prompted greater interest in the olfactory mechanism because they've shown that the sense of smell may be related to more than the detection of odors. Some researchers suspect that there may be connections between the sense of smell and such traits as learning and behavior.

RCA extends triac capabilities again with this exclusive new 80-amp series.

You can hold down design costs for high power lighting and heating controls, welders, induction motors and other applications, because these new triacs simplify circuitry and heat sinking.

And you save on device costs because the triacs utilize the RCA low cost package with compression seal. Available in press-fit and stud packages. Four modes of gate control add design flexibility. All this means more amps per dollar.

That's why the new 80-amp triac is another example of cost effective simplification from RCA.

Unit prices are $25 to $45 in small quantities. Call your RCA Representative or RCA Distributor. For new RCA catalog write RCA Commercial Engineering, Section50J1/UR12, Harrison, N.J. 07029. International: RCA, Sunbury-on-Thames, U.K., or P.O. Box 112,Hong Kong. RCA Limited, St. Anne deBellevue, 810 Quebec, Canada.

Repetitive Peak Off-State Voltage V_{DROM}

PACKAGE	200 V	400 V	600 V
Press Fit	TA7752	TA7753	TA7754
Stud	TA7755	TA7756	TA7757
Isolated Stud	TA7937	TA7938	TA7939

All types are available with flexible lead attachments.

CIRCLE NO. 9

A full-function digital multimeter + A lab-quality digital AC voltmeter

...both for $595

HP's new 3469A gives you a general-purpose digital multimeter *plus* a lab-quality digital AC voltmeter—for the price of the AC voltmeter alone. Now, you don't have to buy two (or more) instruments to get the capabilities you need—or compromise on quality to stay within your budget.

As a general-purpose multimeter, the 3469A gives you exceptional capabilities. Its 1 Ω range lets you measure low-resistance components and even contact resistances of a few milliohms, with an accuracy of ±0.25% reading ±0.5% range. To make the low range easily useable, a unique offset adjustment lets you compensate for lead resistance. In the higher ranges (100Ω to 10 MΩ), accuracy is ±0.3% reading ±0.2% range. The 3469A also gives you five DC voltage ranges (100 mV to 1000 V) and six DC ampere ranges (1 μA to 100 mA), with accuracy of ±0.2% reading ±0.2% range or better, depending on range.

As an AC voltmeter, the 3469A is unmatched at any price. You get seven voltage scales, ranging from 1000 V full-scale down to 1 mV full-scale—100 times the sensitivity of other digital meters. You also get a 10 MHz bandwidth capability—100 times greater than other digital multimeters—with a basic accuracy of ±0.3% reading ±0.3% range. And you get a bright, ultra-reliable, shaped-character GaAsP display, that's easier to read than tubes or bar-segment numerals.

Compare the 3469A's specs with any other meter's – and you'll agree that there's no better value, at any price. For further information on the 3469A, contact your local HP field engineer, or write Hewlett-Packard, Palo Alto, California 94304. In Europe: 1217 Meyrin-Geneva, Switzerland.

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DIGITAL VOLTMETERS

CIRCLE NO. 10

HOW TO AVOID CUSTOM HYBRID CIRCUIT PITFALLS

The very versatility and flexibility that have made the hybrid circuit so desirable may lead to some costly pitfalls. Here are ten rules for better custom hybrids at lower cost.

GEORGE SMITH, III, Beckman Instruments, Inc.

Custom hybrid circuits, because of their low cost and flexibility, are serving as new tools for system designers. Unfortunately, there are potential pitfalls in their development. In some cases, custom circuits have been designed, only to find that while technically feasible, they are economic disasters. Common sense, along with some simple rules, will help a designer avoid the pitfalls and obtain the hybrid circuit he desires.

Why a Custom Hybrid?

The basic reasons for a custom hybrid are shown in **Table I**. The designer has a problem that is not conveniently solved with off-the-shelf devices. Usually this problem stems from space limitations, performance requirements or form-factor considerations. These factors are usually combined with a requirement for low or intermediate volume. For example, \$20,000 to \$100,000 worth of custom monolithic components is impractical because of the high initial design costs. On the other hand, \$20,000 to \$100,000 is a pretty good order for hybrids because of their lower initial design and production costs.

Then, there are several basic kinds of circuits where hybrid technology performs better. An example is where precision resistor ratios or close temperature tracking are required. These requirements are beyond the limits of monolithic circuits and, except in extremely low volume, they are not economically feasible as discrete component assemblies.

WHY CUSTOM CIRCUITS?

* Limited Space
* Special Form Factors
* Low or Intermediate Volume
* Precision Performance
* Low Cost
* Special Semiconductors
* High Power

Table I

Another reason for custom hybrids is incompatibility of devices in monolithic form. An example is the D/A converter. The use of MOS analog switches requires the switching of very high ladder resistances. Large precision resistors are incompatible with monolithic resistor technology.

Another example is the capability of handling high power. Hybrid devices, because of substrate size and thermal conductivity, are capable of dissipating more power than monolithic devices.

A Future in Packaging

These examples indicate that the custom hybrid manufacturer's future is that of a packager. This revolves around the ability to take the best of several technologies and put them together in a package that achieves the desired function.

A manufacturer's success depends on the technologies with which he is most capable. For a hybrid circuit manufacturer, this means a broad range of capabilities: thick-film, thin-film, plating, etching, cermet resistors, dielectric materials and a variety of substrates. In addition he must be able to handle all types of active devices: individual die, bipolar and MOS ICs, chip carriers and beam-lead devices. In essence, hybrid manufacturers are doing the same thing that the systems house used to do only a few years ago. The difference is that hybrid manufacturers are doing it on a larger scale, faster and with less cost.

Hybrid vs Standard

It's not within this discussion to detail the custom standard hybrid circuit argument, but the effect of a standard product line on the custom circuit business should be noted. A standard product line does two things: 1) It stimulates designers to incorporate known products from known manufacturers into their designs. The user of standard product lines is not likely to challenge the choice of processes and techniques.

(Continued)

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

Custom Hybrid (Cont'd)

2) A standard product line does give a base for some custom work. Modifications of standard circuits form a majority of the custom circuits. This means the designer is not buying a completely untried device, but an assembly of proven devices which achieve particular performance characteristics.

Because of this, standard products should be used whenever possible. However, when there is a true custom circuit requirement, detailed discussions with the hybrid manufacturer can result in improved circuit performance and lower costs.

But it's not all roses. There are a number of pitfalls in custom hybrid design. Designers can easily spend sizable amounts of time with one custom circuit. There are as many approaches to manufacturing a custom hybrid circuit as there are engineers who design them. Given the same end purpose, each engineer might produce entirely different designs to achieve the same results. These differences may lead to dissimilarities in circuit reliability, weight, size, lead-time, delivery, cost or any combination of these variables. The following ten rules are intended to minimize these dissimilarities.

Rule 1: Pin Assignments by Manufacturer

Whenever possible let the hybrid circuit manufacturer determine the pin or lead assignments.

This is a common-sense statement, but it's surprising how few designers give this aspect the consideration it deserves. If the manufacturer can make lead assignments, he can design the circuit for optimum performance while considering all production factors. This results in a better circuit and lower price. The manufacturer doesn't have to incorporate expensive crossovers or long lead runs to get the signals to come out the right place.

On the other hand, the system designer may have absolute pin requirements for certain leads–in the total system, designers often experience the same crossover and lead-length constraints that the hybrid circuit manufacturer experiences in the design of the device. This is where common sense comes in.

If some pin assignments are critical while others are not, the system designer should indicate the critical ones and let the device manufacturer assign the others.

Rule 2: Avoid Large R & C Values

It's difficult to manufacture a hybrid circuit with resistor values in excess of several megohms and capacitor values approaching 1 μF.

One of the major selling points of the hybrid circuit is the practicality of producing resistors that have a very wide range, especially with thick-film technology (**Table II**).

CERMET RESISTOR PERFORMANCE CAPABILITIES

CERMET RESISTORS

Resistance Range	5Ω to 100 MΩ
Resistivity Range	15 to 330 kΩ/sq.
Resistance Tolerance	±0.5% to ±5%
Tempco	
100Ω to 100 kΩ	±200 PPM/° C
10Ω to 100 MΩ	±300 PPM/° C
Voltco	
0 to 100V/inch	0.5 to 1 PPM/V
0 to 1000V/inch	1 to 5 PPM/V
Resistor Noise	
10 to 1000Ω/sq.	-20 dB max
1k to 10 kΩ/sq.	-10 dB max
10k to 330 kΩ/sq.	0 dB max
Power Dissipation	
Precision Resistors	20W/sq.inch
1% Stability	100W/sq. inch
2% Stability	500W/sq.inch

CERMET RESISTOR NETWORKS

Initial Ratio Match (best performance)	
4:1 Ratio	10 PPM
10:1 Ratio	25 PPM
Resistance Ratio Range	1:1 to 10k:1
Ratio Tempco (best performance)	
10:1 Ratio	0.5 PPM/° C
10,000:1 Ratio	5 PPM/° C
Ratio Voltco	0.2 PPM/V/inch

Table II

However, even with good film capability and high value resistors, it is difficult to achieve good performance with a wide range of values on the same substrate. The divider networks in **Fig. 1** are examples of how this problem can be avoided. The lowest value is accomplished by placing many resistors in parallel. Mid-range values are achieved by placing a few sections in parallel while upper values are in series. If this scheme were carried further, because of a broad divider range requirement the problem becomes more difficult. It's not an impossibility, but it is an item of value judgment.

Large capacitors are an obvious taboo. Helipot screens capacitors up to several thousand picofarads and continues with chip capacitors up to 0.1 μF. Circuits with capacitors over 0.1 μF are so difficult that they should be avoided.

Again, it is not that these circuits cannot be manufactured, but that the cost of doing so far exceeds the value of the circuit. It's just not the kind of thing that

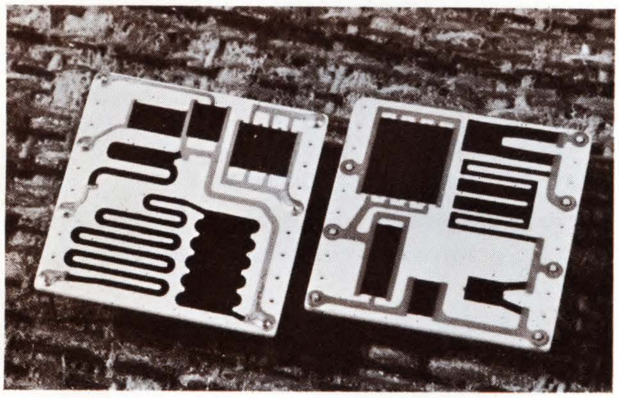

Fig. 1—**Typical divider networks** with wide range of resistor values on a single substrate.

the designer is looking for, and he should redesign the circuit.

An example of this is an amplifier stage with a large shunt capacitor to roll off amplifier gain (**Fig. 2a**). Although the technique is a good one, the capacitor size is difficult to deal with in a hybrid. A successful hybrid approach is indicated in **Fig. 2b**. No additional components are required, and capacitor size is significantly reduced. With the latter approach, a valuable circuit can be produced without the expense of the larger capacitor.

Rule 3:
Power—The Forgotten Parameter

Both the power dissipated in each circuit component and the operating temperature range should be specified.

This should be standard procedure, but it's seldom done. This easily overlooked item seems to stem from the drastic power reduction caused by the use of semiconductors. Where once we dealt in watts, we now deal in milliwatts. In hybrids, however, the concentration of milliwatts on a small substrate can be significant.

A little homework at this point will save many problems in the prototype stage of design. Power ratings and power tolerances of each resistor should be noted, and the specific temperature range of the device must be indicated. The relationship between the dissipated power and the components leads to Rule 4.

Rule 4:
Passive Togetherness Is Important

The ratio tolerance between components is often a more important specification than the tolerances of the individual components.

A standard binary ladder network can be used to illustrate this. With this device, the important consideration is the ratio of one resistor to another and not absolute resistor tolerances.

Often on resistor networks each resistor is specified to 0.01%. It is unlikely that the designer really wants 0.01% resistors; rather the requirement is that the ratios be matched to 0.01%. Guaranteeing ratio tolerances is a completely different requirement from matching absolute value requirements. Under good conditions, Helipot can match resistor ratios to 0.002% and insure that the resistors will track to 1/2 PPM over a nominal temperature range.

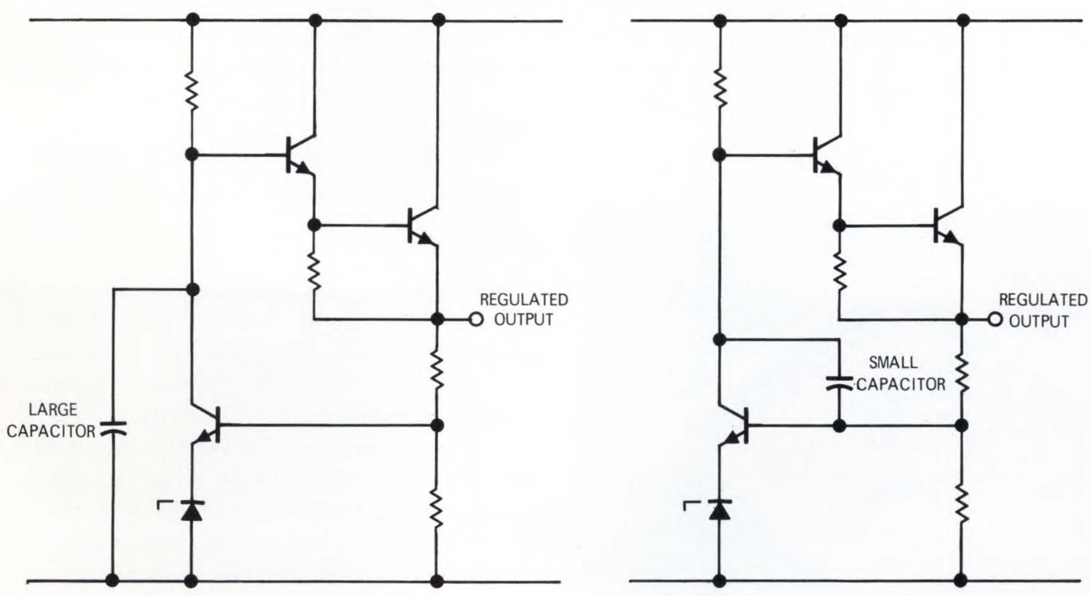

Fig. 2—**Alternative circuit** to reduce capacitor size.

(Continued)

Custom Hybrid *(Cont'd)*

This same truth translates to an RC network. To the designer it is the time constant that is usually important. The hybrid circuit lends itself well to consistent time constants. The designer is much better off if he specifies TC product vs temperature rather than temperature performance of the resistor and capacitor separately. So far these rules concern passive components, but active component needs result in similar rules.

Rule 5: Give More Than JEDEC Numbers

When specifying active devices, indicate critical performance parameters in addition to the JEDEC part numbers.

In many instances a designer may specify a device like a 2N2219, but omit the information that the device is performing with a V_{sat} different from normal. Or the breadboard may have used a device that had selected characteristics.

The hybrid manufacturer usually purchases chips with normal statistical distribution unless told that the devices have additional critical parameters. This results in the manufacturer working with one device, the customer with another—even though both devices have the same JEDEC number. This information is very critical.

An example of this type of problem can be illustrated by the energy detector shown in **Fig. 3**. This circuit uses Schottky diodes which typically have very fast response and a low forward drop. Only two manufacturers make acceptable Schottky diodes, and one of the suppliers manufactures in Hong Kong. In this instance, the designer did detail the critical parameters so that the hybrid manufacturer was able to exercise judgment concerning vendor selection and part procurement.

The key here is that special parameter information given early can result in reduced manufacturing costs and on-time delivery.

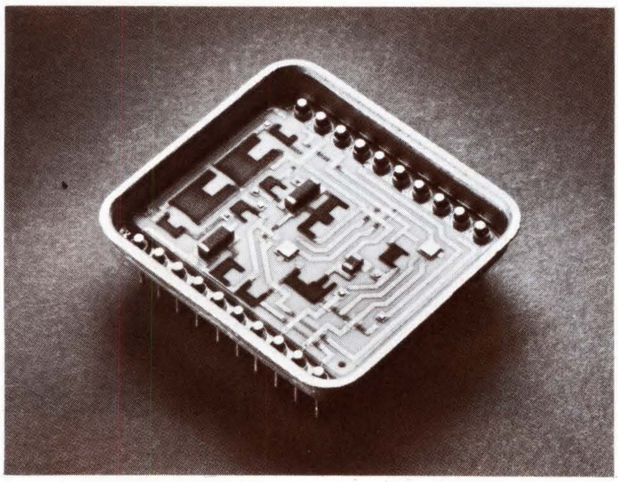

Fig. 3—**Hybrid** energy detector.

Rule 6: Worst-Case Analysis Rather Than Worst Devices

Perform a worst-case design circuit analysis prior to writing a hybrid specification. Detailed test specifications help.

The importance of this rule can't be emphasized enough. A worst-case analysis indicates that the designer has considered the device sufficiently in relation to his own requirement. Helipot has actually been asked to quote on the basis of a sketch prepared on the back of a napkin during lunch!

Often procurement specifications are in the same category as the sketch on the napkin. Many designers write procurement specs without ever building a circuit. As a result, many of the circuits just don't work, although the designer thinks that they do. To compensate for initial design omissions, Helipot does not put anything into production unless it has been breadboarded, built as a hybrid prototype and tested.

Testing is important. The most valuable piece of information that the hybrid manufacturer can obtain is a well-done test specification. Designers will write procurement specifications without building a circuit, but seldom will they write a test specification unless they have a good, clear idea of what they want. To develop a meaningful test specification, the designer usually has to breadboard the circuit.

Fig. 4 indicates a very sophisticated breadboard circuit. The circuit is complex, and considerable effort is necessary to make the transition from a discrete component breadboard to a prototype hybrid circuit.

Rule 7: Don't Hide Breadboard Peculiarities

All circuit peculiarities should be carefully noted and brought to the attention of the hybrid manufacturer.

While this sounds perfectly obvious, it is often not done. What it really means is that if the designer knows about some idiosyncracies, he should tell the manufacturer about them because this improves the chances of success and saves money.

A recent example involved the layout of a state-variable active filter. Along with his circuit specifications, the customer noted that the circuit could not stand capacitance between the output of the first amplifier and the noninverting input of the second amplifier. He had run into trouble with the capacitance both on his breadboard and in a previous attempt to hybridize the filter. The information was incorporated into the layout, resulting in excellent success and early

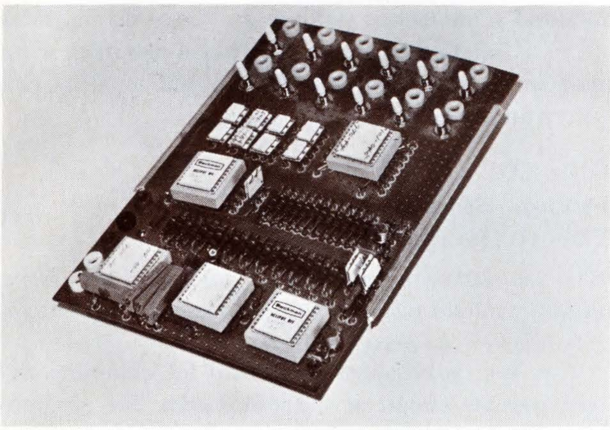

Fig. 4—**Typical breadboard of hybrid** circuit using discrete components.

delivery of parts since only one layout was required.

Some other breadboard peculiarities might be: required selection of components, interaction of components, oscillation or just tricky circuits. Whatever the reason, it is important for the manufacturer to know what went on during the breadboard stage.

Rule 8: Understand Black-Box Specifications

Black-box specifications effectively transfer both design and production responsibilities to the hybrid manufacturer.

At this point it is worthwhile to comment on black-box specifications as opposed to custom circuits specified by the designer. With black-box specifications, the designer indicates certain end results and leaves the internal configuration of the circuit to the manufacturer.

The manufacturer then utilizes his knowledge of hybrid circuits to achieve the desired results. Often he is able to use standard components to optimize the device.

Sometimes the designer will suggest a circuit that might work. If the circuit that "might work" is breadboarded and tested, and then looks pretty good, both the customer and the manufacturer benefit. If the circuit doesn't work, negotiations beyond technology are often involved. Experience has shown that a good customer-manufacturer relationship together with a thorough understanding of the application are essential to a successful hybrid design. This cannot be overstated.

Rule 9: Think Testable

The systems designer should think about partitioning his hybrid system into logical parts that are individually testable.

It is entirely possible that some circuit designer could conceive a circuit with a thousand leads on a side to give a one-million-point matrix. It could be built, but testing would take years.

This, of course, is ridiculous because the designer wants the circuit in the first place or he wouldn't have ordered it. The manufacturer wants to deliver it or he wouldn't have sold it.

What the designer really wants is some kind of device in a form that makes it easiest to buy it in one piece, plug it in and have it work. Hybrid technology lends itself to this concept and that is why it is growing. But the economical limit of testing must never be forgotten.

The point is not how complex the device is internally, but how it can be partitioned for easy testing.

Fig. 5 illustrates this point. A major manufacturer has contracted for substrates on which it will mount its own beam-lead devices. Helipot is manufacturing the substrates because of an ability to screen very fine lines with very fine spacing. The point to be illustrated here is that this is one kind of system which has been partitioned for easy testing. A simple specification was written and each of these units can be tested simply.

To permit ease of testing, the system must be par-

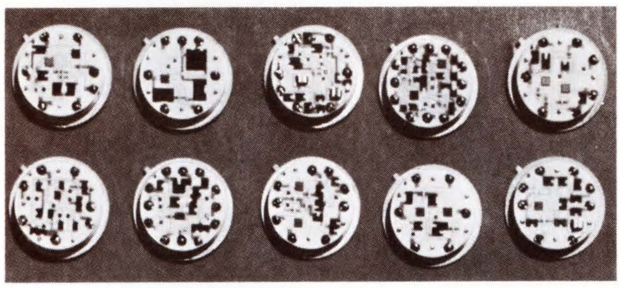

Fig. 5—**Hybrids using circuit partitioning** techniques and designed for attachment of beam-lead devices.

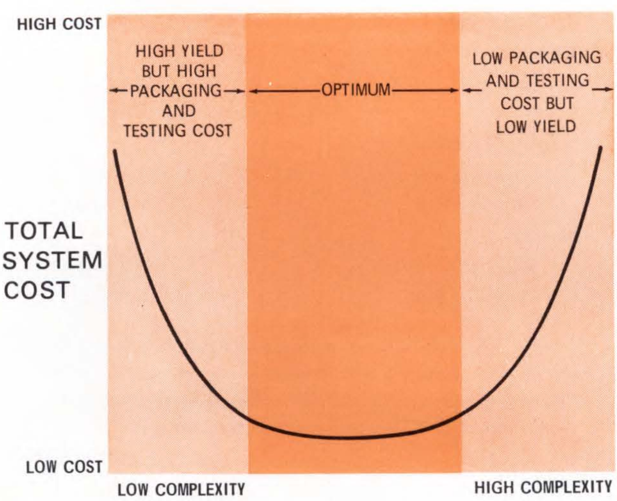

Fig. 6—**System cost** vs block complexity.

(Continued)

titioned into functional testable blocks that represent the best tradeoff between block complexity and yield. The optimum block complexity must ultimately be worked out with the manufacturer to find the low point on the curve of **Fig. 6**.

As a practical rule of thumb, the optimum range of complexity for hybrids is somewhere under 100 lead bonds/substrate. A transistor has two lead bonds and an IC has somewhere between five and 14. Using these figures gives a nice range of complexity. The 100-lead-bond rule is not completely universal, however, for it takes a lot of space to mount 50 diodes or transistors. From another practical standpoint, substrates larger than 1-1/2 inch by 1 inch tend to be uneconomical. **Table III** illustrates a fast way of estimating the substrate area required for a given circuit. The components listed have areas assigned in arbitrary units that are scaled using a density factor. To find the required area, count each component and multiply by the appropriate weight. Sum the weights and multiply by the density factor to find total required area.

There is a minimum limit to the size of hybrid circuits. Consider a custom circuit that consists of two DTL 946 gates. The manufacturer can add so little value to the circuit that it would be easier for the designer to buy the two separate packages and install them himself. On the other hand, if the same circuit required a number of pull-up or ratio resistors, then it might be attractive from the hybrid manufacturing standpoint. It all comes back to how functional the circuit is and how easily it can be tested.

TYPICAL COMPONENT AREAS

COMPONENT	
Capacitors:	
Screened Capacitors	270 pF/unit
Chip Capacitors (High K)	2.0 units
Transistors:	
Switching	0.5 units
General Purpose	0.5 units
High Current	1.0 units
Diodes:	
Switching	0.5 units
Zener	0.5 units
Integrated Circuits:	
Linear Elements	2.0 units
Logic Elements	4.0 units
Resistors:	
Precision	2.0 units
General Purpose	1.0 units

For thick film hybrid circuits, a density factor of 0.015 inch^2/unit will generally produce a good layout providing the manufacturer has the freedom to design pins. Using fineline screening techniques, density factors of 0.006 inch^2/unit have been achieved.

Table III

Rule 10: Please, Before You Freeze, Talk to the Manufacturer

Both the custom hybrid manufacturer and the system designer should review the final hybrid circuit configuration before the design is frozen.

This step is absolutely essential for obtaining the best possible circuit at the lowest cost. The progress from circuit design to breadboard with discretes, translation to a prototype hybrid and commitment to hybrid production involves many small compromises that may be overlooked unless a final evaluation is performed.

The designer should enter into the final evaluation with an open mind—which may be difficult. For example, in the process of prototyping, the performance specifications may be improved. Initially, 12% output-pulse droop may have been specified, but because of good materials and constant resistors 5% can be obtained.

On the other hand, original specifications may not be conveniently accomplished. During the final circuit evaluation, it might be discovered that the specs are not as rigorous as initially envisioned. By reducing the requirements, the designer may benefit by reduced costs. None of these benefits can be accomplished if the final procurement specification is prepared before the final prototype and production hybrid circuits are developed.

To Wrap It Up

These ten rules are not magic, but common sense. What they add up to is that it takes a good working relationship between the system designer and the hybrid manufacturer to insure that both sides benefit from the contractual agreements. If followed, these rules should greatly increase the probability that the designer will obtain the circuit he needs at a price he can afford. ▭

George W. Smith, III, has been with Beckman Instruments, Inc. for 14 years. He is manager of research and development in microcircuits and responsible for the development of materials and products in the hybrid microcircuit area. Mr. Smith has a B.S.E.E. from California State College, Long Beach, and is a member of ISEE and ISHM.

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CIRCLE NO. 11

Paul Giordano Of Instrumentation Engineering Speaks Out on Computer-Controlled Testing

Computer-controlled circuit testing hasn't, so far, achieved the wildfire acceptance that many forecasters expected. The technology is here, and the need is here, but sales of automatic test systems generally have been sluggish.

There seem to be two major reasons for this lack of acceptance. On one side, the manufacturers of these new test systems have tended to overlook many of the customer's very particular test requirements and his own experience in the testing field. And on the other side, design engineers who specify or use test systems are often too hardware-oriented, and simply won't take the time to learn the essentials of software and data processing.

All the elements for effective, economical, computer-controlled circuit testing are already available. We have a wide selection of minicomputers to choose from. Instrument makers are offering an ever-widening range of measurement and stimulus equipment which can be controlled by computers. And modern technology has devised ingenious ways of interfacing computers, instruments and items under test.

Certainly the need exists. Sky-rocketing labor costs and complex set-up problems have made automatic testing economically attractive.

In situations where circuit and component technology have grown incredibly complex, automatic testing is the only practical way to go—that is unless the manufacturer has endless hours or even days to waste on testing. Hence there is a growing list of electronic manufacturers and test facilities in dire need of automatic test systems.

Many people blame the current economic recession for the lag in automatic test systems. This may be true in isolated cases, but it is certainly not universally so. Automatic testing is actually a cost-saving vehicle for most companies, and with the broad range of leasing arrangements currently available, the payback can be measured on a real-time basis.

Thanks to unique methods of designing modular hardware with proper software, versatile computer-controlled test systems are just now coming into vogue. But the engineer who wants to really exploit these new systems must still learn the basic fundamentals of software. Otherwise he'll be like the music lover who knows only how to turn up the volume-control knob on his elaborate stereo set.

Until recently, the potential customer for automatic test systems had very little to choose from. Therefore, he usually resorted to the same remedy he used in the 1950s and 1960s—he built his own systems.

The in-house test system, jerry-rigged from instruments and equipment lying around the shop, was dedicated to the user's specific application.

These systems were not designed for outside marketing, and therefore were not universally acceptable. Each of these specialized testers actually contributed little to the commercial state-of-the-art.

This is not to say that the man who builds his own system isn't capable of excellent innovations in test-equipment design. Many of these engineers have fine technical backgrounds, and based on this early experience, often wind up working for test-equipment manufacturers. But within the user environment, they cannot be expected to do more than put together a tester that will get the particular job done within a tight budget.

The in-house testing specialist is a sophisticated user. Often he would like to buy a complete system, but he has been conditioned to building it himself. Herein lies one of the basic problems for the test-system manufacturer. Even after top management at a company has been convinced of the economics of automated testing, that company's test-equipment specialist must still be persuaded that the equipment is more useful than that which he could build himself.

The manufacturers of automatic test systems have usually underestimated the knowledge of the in-house specialist, and have tried to sell him sys-

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(Continued)

tems that don't have the features he needs. Too often, the customer has been told in effect that if he buys System A he can perform functional testing, but with the same system he cannot readily do analog testing. Or he can get System B and do all his back-plane continuity and leakage testing, but no functional testing. Or he can buy System C and do IC testing, but PC board testing will require complex interface modifications. System D doesn't interface with a CRT terminal, and System E requires patch cords and adapters more complex than the actual unit he wants to test. System F does have the CRT but no cassette storage. System G uses a disc but System H does not. And so on.

Because of past experience with his own automatic test systems, the potential customer's testing specialist usually asks about available software.

Will the new system allow the user to program and debug on-line? Can he operate the system in object code? Is there an easy-to-learn user language? Does the software make allowances for future hardware expansion? Is complete software documentation available?

Until recently, answers to these questions—or lack of answers—combined with frustrations over available hardware, led the test-system user to build in-house. Perhaps a very few go out for competitive bids—and are hit immediately with a large system development cost or a list of exceptions. With considerable patience and persistence, and a good deal of luck, one or two responses may be close enough to the customer's specifications, and a sale is made. But for everyone involved, this is a hard way to do business.

Now is the time to take automatic test systems out of the custom category and turn them into a real business.

The necessary changes in approach for this market will require some original thinking. System vendors will have to look at both the customer and the systems in a different way.

First, let's give the customer credit for knowing his business. He already knows how he must test his devices and products. What he really needs is a testing tool which he can use for specific types of functional and dynamic measurements. For this purpose, he wants to be able to use the best available instruments. And he wants to be sure that his new, expensive test system will accommodate tomorrow's test problems as well as today's.

Second, he doesn't want to be told that he will get "packaged programs" or "applications first aid." His demand is for a stand-alone test system that can be easily and quickly programmed, using a test language that is truly user-oriented and supported by a compiler that really works.

Third, the customer must be helped to overcome his relative lack of knowledge of software. He must understand that new computer-controlled test systems are built around software which need not be altered regardless of the addition or subtraction of various pieces of hardware. This makes the system easy to operate and eliminates arduous and time-consuming mechanical modifications. Modern automatic test systems include English-language programming, a special interactive language used to control certain special functions such as debugging editing and data logging, and the machine language which enables the computer to control test functions.

Finally, the customer must grow to understand the true meaning and value of "hardware modularity" when applied to the test system. The word "modularity" is so overused these days that most engineers are suspicious of it. Yet modularity is the key to anti-obsolescence in test systems.

As instrument makers continue to build more accurate measuring equipment and equipment with new functions, the automatic test system must be capable of incorporating these instruments. Or if a customer finds that his next job requires 200 connections vs 100 and several pulse generators—a capacity which he did not initially need—then he must be able to add on to his test system without drastic interface or cost problems.

True modularity in automatic test systems means a lot more than simple hardware interfacing—it means that the system software must be designed to accommodate all state-of-the-art instruments plus those which will be forthcoming in the years ahead.

The real test of modularity is whether all field modifications can be completed within one working shift.

Here is one example of how a new instrument can be added to an automatic test system in the field—assuming that the system has the required degree of true modularity.

Consider a user who wants to add a programmable ac signal source. First, he finds an empty space in the test system cabinet and physically inserts the ac signal source. This accomplished, he performs the following steps:

A single circuit board, containing the device controller for the signal source, is added to an empty slot in the device controller board file. (The input/output bus of the computer is already wired to every slot in the file.) Then a single cable linking the device controller and the ac signal source is added. The two wires of the analog output of the signal source are connected to the switching system.

As a final step, using the Teletypewriter, the operating software system is informed of the input/output bus address of the device controller and the address of the analog output of the signal source in the switching system.

No other steps are required, and the updated test system is ready to operate within 2 to 4 hours.

"Flexibility" is really the key word for computer-controlled test systems. Today's systems must be easily and economically adaptable to the test requirements of tomorrow. This capability can be illustrated by describing some of the features of a type of test system that is only now becoming available.

Let us say that a customer needs a high-speed computer-controlled system that can handle functional testing of analog and digital integrated circuits and printed circuit boards. Our company would offer him a basic system that provides tests at rates up to 10 MHz and that includes, as one of its key peripherals, a digital word generator/receiver. The system is controlled by a minicomputer with a 32k mass memory, simple English-language test programming, an input/output terminal and two magnetic tape cassettes. The software can control, via a switching and routing section, a selection of stimuli and measurement peripheral devices, including devices that the customer may want to add on later.

For example, the user may want to do dc parametric testing. All he has to do is add an analog-to-digital converter, a series of seven power supplies and hardware interface devices, and he has his expanded system with absolutely no software changes.

Or he may want to use his test system for ac parametric testing. This can be accomplished by adding two programmable pulse generators, a time-interval meter and hardware interface devices.

With these additions, the user can already perform static testing of MOS devices, but at a later time he may want to do dynamic MOS tests. He can achieve this capability simply by adding a four-phase programmable clock and a hardware interface device.

As he becomes more familiar with the use of the computer in controlling the instruments and stimuli devices, the user may want to take full advantage of this technology for such activities as rapid debugging, printing and data logging. He can accomplish this by removing the Teletypewriter and adding a CRT-keyboard-printer terminal, a second magnetic tape cassette unit and hardware interface devices. If he wishes, he can also add a visual display panel.

With the new breed of test system, hardware changes are made quickly and easily. No changes in software are required.

Test systems that feature powerful and flexible software packages and very versatile hardware switching are rapidly emerging as commercial products. But they cannot approach their true market potential unless the customer specialist overcomes his earlier suspicions and becomes oriented to the close marriage of hardware and software technologies in the newest automatic test systems.

The test systems manufacturer must develop and debug the software package, switching systems and hardware interfaces so that his customer received a turn-key test system. When the specific requirements of the user are available "off-the-shelf," the test-system business will have finally emerged from its long incubation.

So the cry is back to the drafting boards. There is plenty of room in the test-systems business for companies willing to devote the time and resources necessary to develop a full line of interfaces that will give the sophisticated user a good selection of peripherals. The key steps in this development include defining the hardware-software tradeoffs for each interface, followed by development and debugging of a compatible software system and design of a flexible switching system that permits the user to take full advantage of the latest hardware technology.

The market for test systems does exist and the technology to serve that market has been with us for years. All we have to do is recognize the real needs of the customer and adapt our hardware and software technology to serve his best interests. ▭

Who is Paul Giordano?

Paul Giordano is president of Instrumentation Engineering, Inc., a young and growing company in Franklin Lakes, N. J., that specializes in the development and manufacture of automatic test systems. Previously, he was employed as head of advanced studies for the System Management Division of Sperry Rand Corp., and was vice president of systems for Bradford Computer & Systems Corp.

After graduation from CCNY in 1952, Mr. Giordano served for 14 years as a civilian consultant with the U.S. Navy. His principal concern was systems engineering applications involving complex electronics systems. During the Korean conflict, he was called to active Army duty, and designed automatic test systems at Edgewood Arsenal. For the past three years, he has been a guest lecturer on the "Real World of Systems Engineering" for the Senior Seminar at Webb Institute of Naval Architecture, Glen Cove, N.Y.

Mr. Giordano lives at Lake Mohawk, Sparta, N. J., with his wife Connie and their four children. The whole family enjoys the variety of summer and winter sports available at the lake. According to Connie, Paul's favorite weekends are those when the house is crowded with friends.

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DESIGNING WITH FAST RECOVERY RECTIFIERS

Designing with fast recovery rectifiers can improve your circuit efficiency, but beware of reverse recovery characteristics that can cripple the design. Here—with the facts—are a test circuit and some practical hints to help you to know exactly what fast rectifiers are all about.

VINCENT A. FALVO, Westinghouse Electric Corp.

Ideally, a semiconductor diode should block reverse voltage the instant a reverse bias voltage is applied following forward conduction. In reality, however, this does not always occur. In the low kilohertz frequency range, a conventional power silicon diode will conduct a high reverse current for a period of time before it regains its ability to block reverse voltage. This reverse recovery time phenomena causes the diode to become less efficient with increased frequency, until at some point the device fails because of excessive heating or does not turn off at all.

Reverse recovery current is the result of the effective minority carrier lifetime (τ), i.e., the time required for a carrier to recombine and form an electron-hole combination that no longer contributes to current flow. In order to shorten lifetime, traps are introduced into the silicon which "capture" the excess holes and electrons sooner than they would normally recombine. These traps are formed by either gold doping, quenching or particle radiation of the prepared pn junction. A great deal has been written about gold doping methods, which at this time seem to be prevalent in the manufacture of the power class of fast recovery diodes.

Characteristic Trade-Offs

Device recovery time is not constant and varies with temperature, di/dt of the forward current source, magnitude of peak forward current (I_{FM}) and the ratio of $I_{FM}/I_{R(Rec)}$.

Some trade-offs must be made when the carrier lifetime is altered by gold diffusion: forward drop, reverse blocking voltage range, reverse current levels and operating junction temperature.

For very low forward current densities, where the recombination current is the major component, the forward voltage drop of the gold diffused device will be lower than that of the comparable standard device. At high current densities, however, the gold-doped device will exhibit a higher forward drop than the standard device.

To compensate for some of the added forward resistance effects and to minimize the resultant power losses at a given current rating, the device designer goes to a thinner base width which results in a lower reverse blocking voltage for the otherwise similar silicon characteristics.

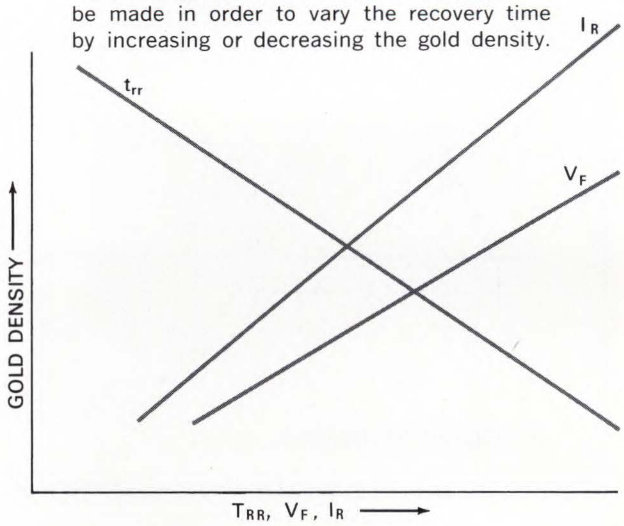
An increase in reverse current level also occurs with the addition of gold to the pn junction. **Fig. 1** relates these electrical characteristics to the density of gold atoms.

Thermal Runaway

Because of higher initial reverse current, the increased reverse power losses added to the forward losses cause the gold-doped units to reach thermal runaway much more rapidly than conventional devices. With increasing junction temperature, and the subsequent exponential increase of reverse current, its safe junction operating temperature is below that of a comparable conventional diode.

Reverse recovery time varies with temperature and circuit parameters. The value of recovery time is therefore a function of the test circuit as well as the device lifetime characteristics of the junction.

Fig. 1—**Graph showing the trade-offs** which must be made in order to vary the recovery time by increasing or decreasing the gold density.



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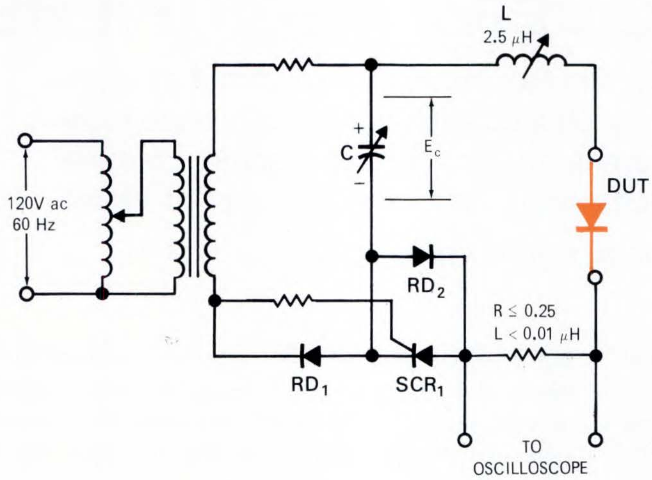
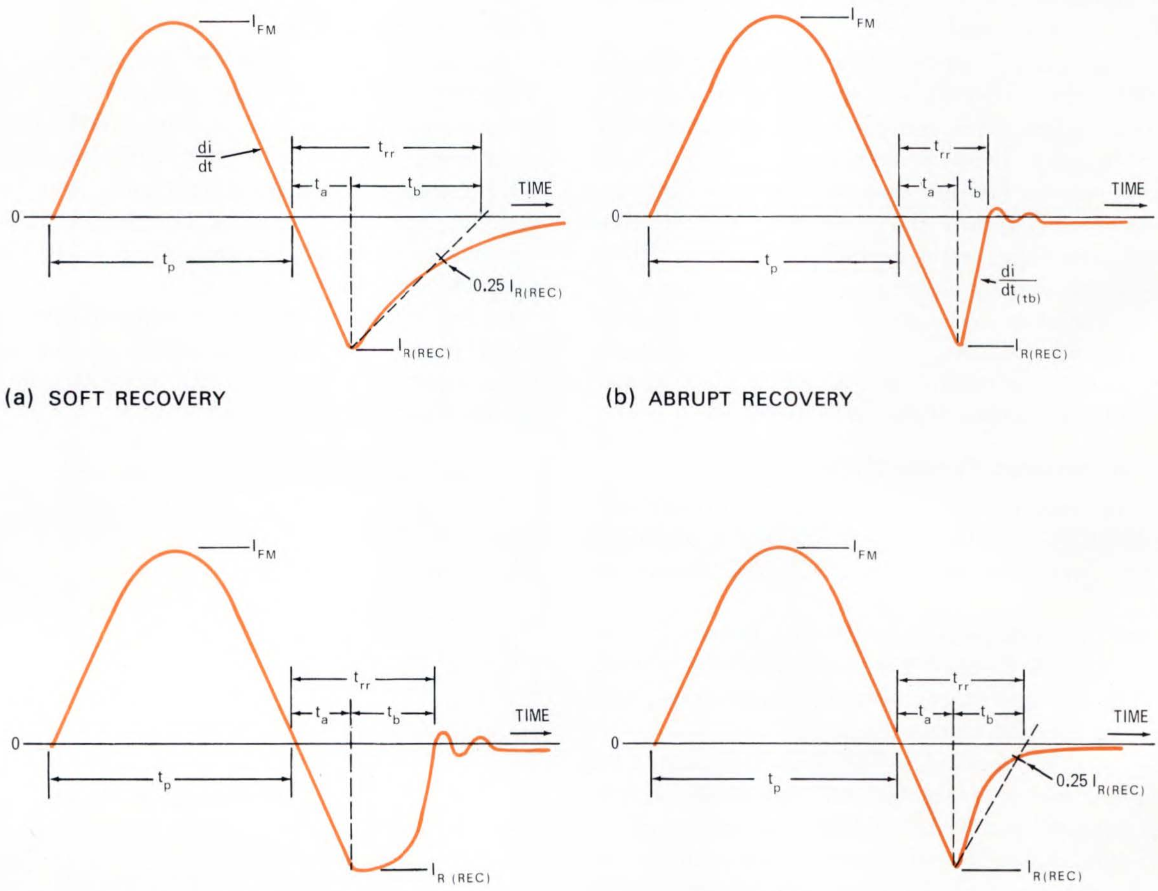


Fig. 2—**JEDEC recovery time test circuit** operates at 60-pps repetition rate with about 2% duty cycle. Circuit resistance, wire size and spacing may affect circuit operation because of test waveform frequency. Current sensing resistor should be low in resistance (0.01 to 0.1Ω) and as noninductive as possible. Commercially available probes such as those from T & M Research Products work well. The 2.5-μH inductor may be wound on a 3/4-inch-diam air core using 30 turns of No. 14 wire tapped at 6, 18 and 30 turns. For testing high current devices, 60 turns of No. 22 wire on a 3/4-inch air core tapped at 12-turn intervals will provide better control of I_{FM} and di/dt at higher currents.

Peak current is approximately $V/\sqrt{L/C}$ and di/dt is about V/L, where V is voltage across C. Length of forward current pulse is controlled by L and C (time period): $t_p = \pi\sqrt{LC}$ (μsec). Use external trigger for improved stability.



(a) SOFT RECOVERY

(b) ABRUPT RECOVERY

(c) ABRUPT RECOVERY

(d) SOFT RECOVERY

Fig. 3—**Recovery characteristic** current waveforms for various types of rectifier diodes as tested in the JEDEC circuit.

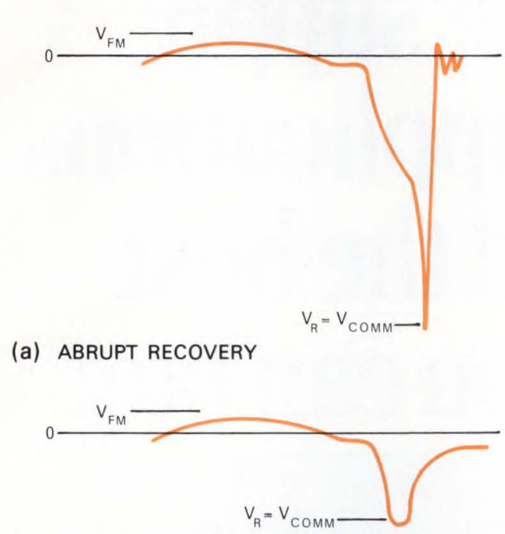


Fig. 4—**Commutation voltage spikes** caused by high di/dt of abrupt recovery characteristic.

Recovery Time Test Method

For a given application, a value of recovery time must be correlated with a specific test circuit and test conditions. **Fig. 2** shows the JEDEC standard test circuit that will be used to characterize all future fast recovery silicon diodes.

Various test current waveforms that may be encountered with the circuit are shown in **Fig. 3**.

Recovery Time Types

Basically, there are two types of recovery characteristics—soft and abrupt. The recovery time for an abrupt recovery device is measured from the point where the device current goes negative to the point where the waveform again crosses the zero current axis (see **Figs. 3b** and **3c**). Recovery time for a soft recovery device is measured in a similar manner, except that termination of the recovery time is measured to the point on the zero current axis where it is intersected by a line drawn from the peak recovery current $I_{R(REC)}$ through the 0.25 $I_{R(Rec)}$ point on the waveform (see **Figs. 3a** and **3d**). In addition, the recovery current is broken down into two parts, t_a and t_b, which may be used to further characterize the waveform. The first portion t_a is measured from zero to $I_{R(Rec)}$, and the t_b portion is measured from $I_{R(Rec)}$ to where the waveform (or the extrapolated line in the case of a "soft" recovery) again crosses the zero axis. Thus, the sum of $t_a + t_b = t_{rr}$.

For acceptance testing and line testing of soft recovery devices, the 0.25 $I_{R(Rec)}$ point should be made a constant. Probably 0.25 of the registered $I_{R(Rec)}$ value will be used by most manufacturers for final testing purposes because of the time consuming process of calculating 0.25 $I_{R(Rec)}$ value for each individual device.

Recovery Characteristic Effects

In most applications, a soft recovery characteristic is less likely to cause trouble. Abrupt characteristics can product a high di/dt when the reverse current snaps back to full recovery from $I_{R(Rec)}$. This high di/dt coupled with the circuit inductance can produce a commutation voltage spike that may exceed the diode reverse voltage rating

$$V_{comm} = L\ di/dt_{(t_b)} \text{ (see \textbf{Fig. 4})}$$

Compensation networks may be required across the circuit inductance to reduce the commutation voltage spike to a safe value.

The reverse recovery time phenomena and the variations in the recovery time characteristics between devices made by different processes or by different manufacturers may seriously affect an application. It is recommended that:

—The circuit output be checked for losses in efficiency.
—Each device be checked in the actual circuit for commutation voltage spikes in new designs, or when evaluating a replacement device in an existing application.
—The designer keep in mind the trade-offs of V_F, I_R, V_R and t_{rr}. It's usually not economical to specify any parameter to be tighter than your application requires.

Efficiency problems can be overcome through the use of "fast recovery" diodes that have had their reverse recovery time shortened by some process such as the gold diffusion method.

Commutation voltage spikes may be reduced by the application of external clamping circuits, compensation networks or through the selection of a soft recovery characteristic.

In either of the above cases and in the general characterization of devices, the JEDEC reverse recovery time circuit is a simple method of correlating device characteristics to the application requirements. □

Vincent A. Falvo is a senior design engineer for the Semiconductor Div. of Westinghouse Electric where he has been employed for 11 years, primarily in rectifier applications. Mr. Falvo's present responsibilities include transistor rating and reliability. He holds a B.S.E.E. from the University of Pittsburgh.

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CIRCLE NO. 13

Look, No Contacts

Man's primary means of communication with the machine is through his fingers. Thus, a reliable, efficient and economical keyboard assembly is a must.

Roger D. Story, Hewlett-Packard

Successive fingering of the keys translates the operator's desires into a language that is understandable to the computing equipment. A two-dimensional array of keys comprises a keyboard, and keyboards continue to be the fundamental means of communicating with these machines. Desirable properties of a key include no electrical contact, minimum noise, positive action upon depression, compatible key structure with printed-circuit board assembly, low cost and long operating life. One keyboard possessing these properties is made of an array of printed-circuit transformers.

The primary and secondary windings of each transformer are interlaced in a spiral coil etched on a printed-circuit board, illustrated in **Fig. 1**. All secondary windings tied in series form this sense line and primaries are arranged in separate pairs. Essentially, the transformers

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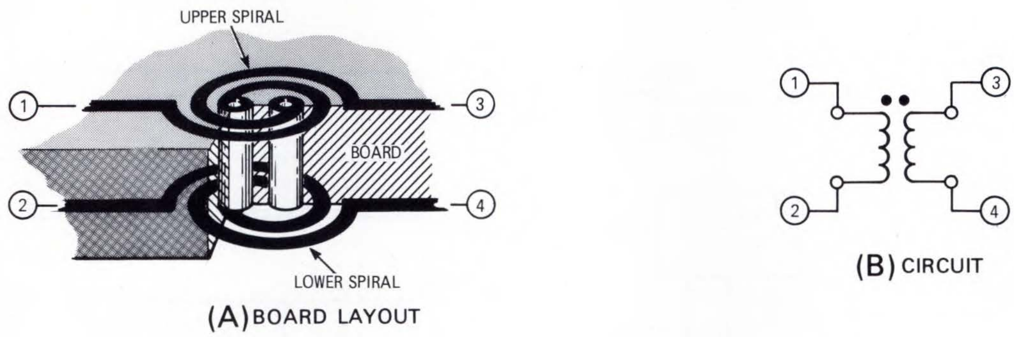

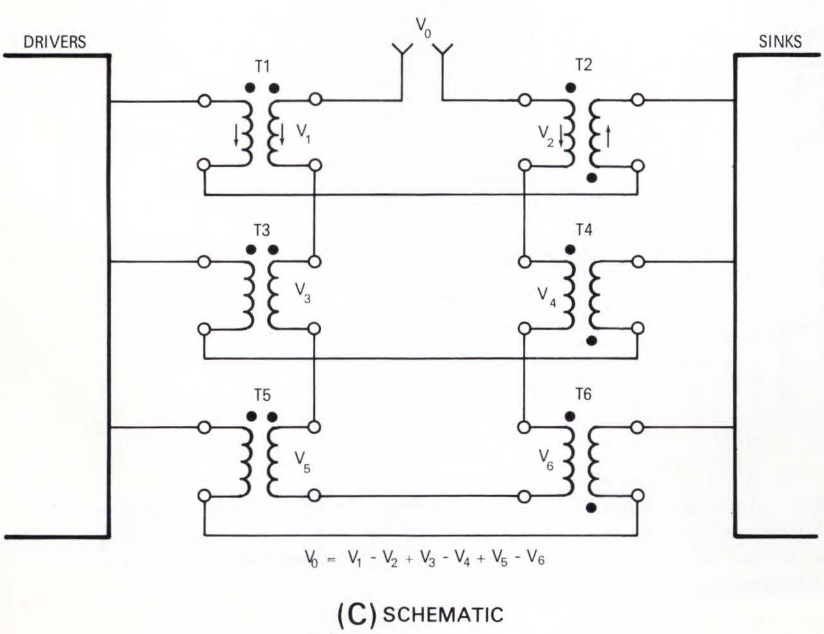

Fig. 1—**Diagrams illustrate** "contactless" key concept developed by Dave Cochran at the Hewlett-Packard electronic research laboratories, Palo Alto, Calif. Diagram (A) shows the printed-circuit layout as it appears on a PC board, with (B) illustrating the equivalent electrical circuit of this layout. When the key is depressed, an aluminum disc magnetically shorts out the upper coil—in effect, a partial magnetic short in the transformer windings.

For keyboard operation, the transformers are grouped in balanced pairs and connected as shown in (C). Magnitude of the output voltage is:

$$V_0 = V_1 - V_2 + V_3 - V_4 + V_5 - V_6$$

When there are no keys selected, $V_0 = 0$. An output is generated when a pair of transformers is in an unbalanced condition because of a key partially magnetic shorting the windings of a transformer.

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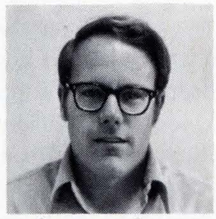
are connected in pairs with their outputs in series but reversed in polarity. For the keyboard to operate, each pair must be balanced. In other words, any drive current applied to the transformer pairs generates a zero output because of the reversed polarity. If this balance condition is altered by either increasing or decreasing the permeability of the transformer, an output signal will be generated.

Centered above each coil is an aluminum disc mounted on the end of the key shaft. When the key is depressed, the disc, simulating a shorted turn, reduces the coupling of the coil—unbalancing a specific pair of transformers. In effect, the permeability of one transformer is reduced causing the other to produce an output.

Every transformer pair has a drive and a sense line that are selected and driven under control of a scanner or ripple counter (**Fig. 2**). An unbalanced pair of transformers generates a plus or a minus signal that is applied to a comparator. Polarity for the unbalance condition is sensed by one of two comparators when the transformer output is greater than the reference level. The least-significant bit of the scanner enables the required comparator. In turn, the comparator triggers a one shot that stops the scanner and lowers the reference level of the comparator. The scanner remains at its present state, which corresponds to the drive and sink line of the selected key.

When the key is released, a spring retracts the key and disc. The transformers return to a balanced condition, thus generating a zero output. Since this zero condition will now be less than the reference level, the comparator "turns off" and the scanner begins to search for the next key. This concept of two bias or reference levels applied to the comparator gives the key a simulated mechanical hysteresis. □



Roger D. Story is a design engineer for Hewlett Packard's Calculator Products Div., Loveland, Colo. Story has been involved with computer hardware design for several years. He received a B.S.E.E. and an M.S.E.E. from Colorado State University.

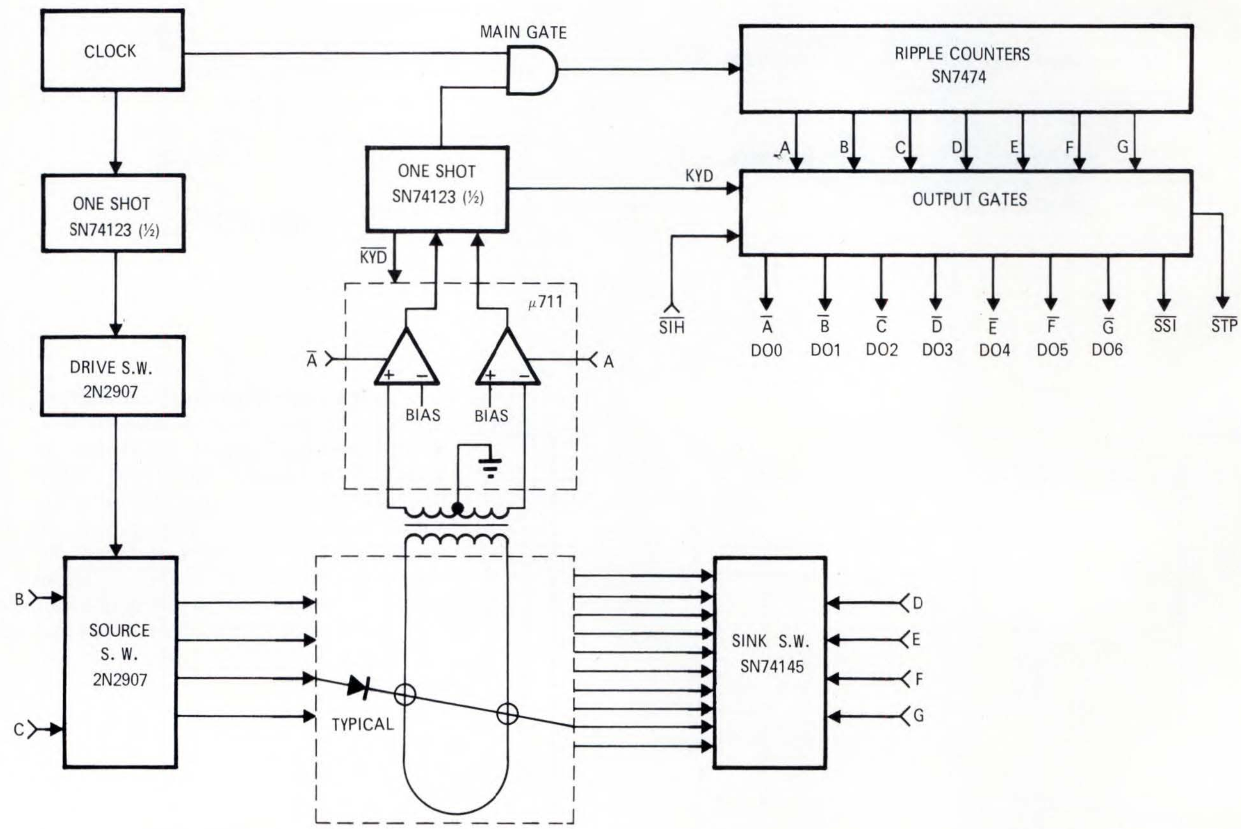


Fig. 2—**Block diagram** illustrates the keyboard interface within Hewlett-Packard's 9800 Series Model 10 calculator. An octal address represents each key location. When a key is selected, the comparator output triggers a one shot that stops the counter operation. Counter output will be the octal address of the selected key. This output addresses a ROM containing the microinstructions required to perform the key function.

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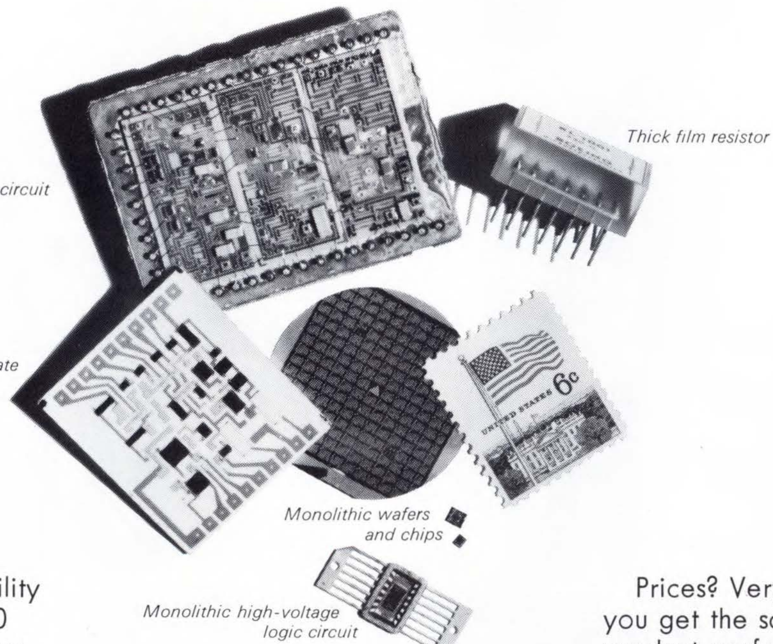

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Versatile Inexpensive Pulse Generator

Easy-to-build pulse generator provides 1 Hz to 1 MHz range with adjustable pulse width.

CARL BROGADO, Univ. of Colo. Medical Center

By combining two ICs and a handful of discrete components, a very wide range pulse generator can be built for about $40, including the chassis and all associated components.

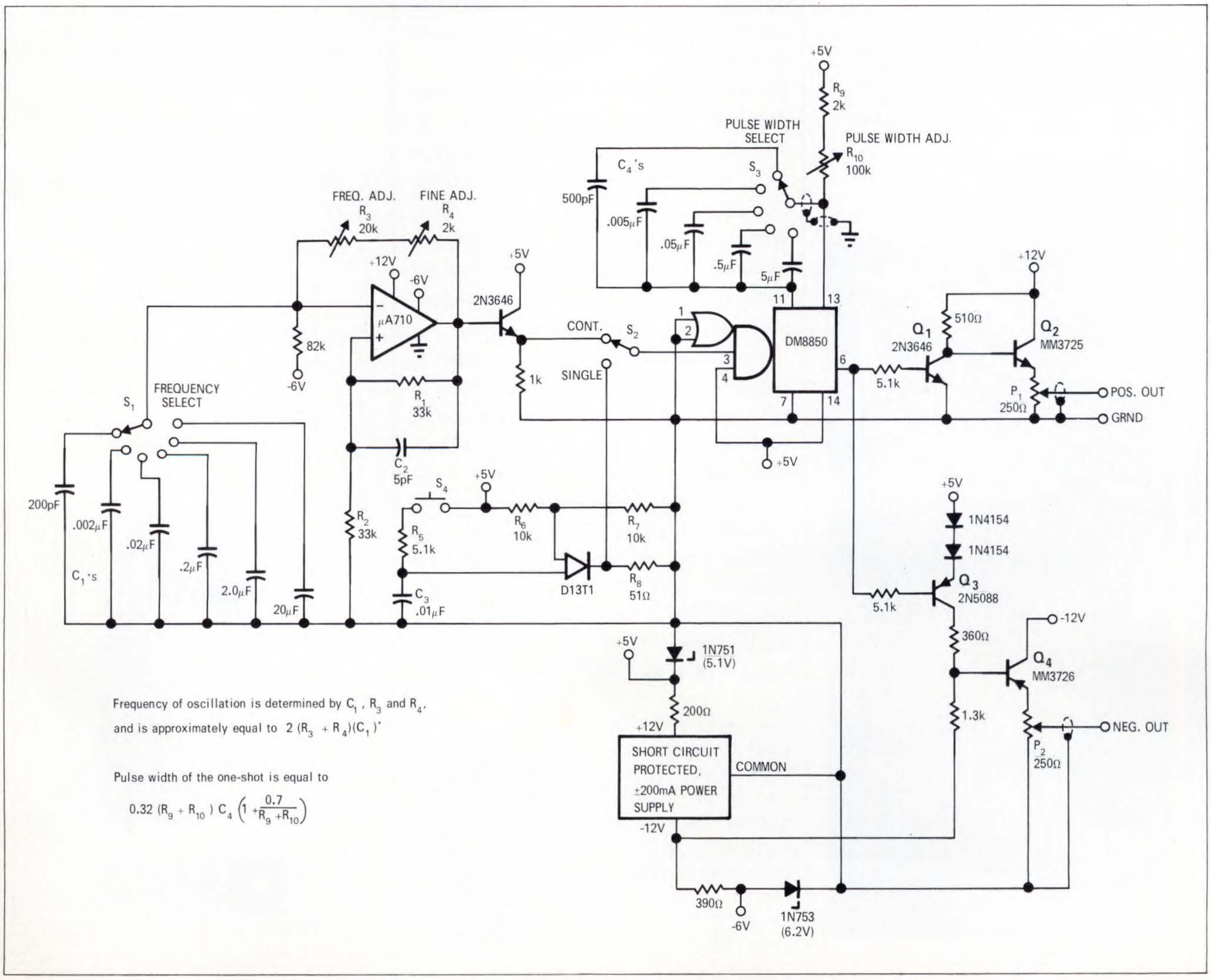
The generator's frequency range is from 1 Hz to 1.0 MHz, with pulse widths from 1 μsec to 100 msec. Frequency and pulse width are selected in decade steps with separate rotary switches. Vernier controls provide fine tuning and allow for a 20% overlap in each range. Rise and fall times are 100 nsec or better throughout the operational range.

Both positive and negative outputs are provided. The positive output gives pulses from an adjustable level as high as 10V to 0V and the negative output gives pulses from 0V to as low as −10V.

A toggle switch selects either continuous or single-pulse mode operation, and a pushbutton provides single-pulse outputs. Two ICs make up the heart of the instrument. A μA710 comparator which is connected to operate as an astable multi provides the trigger inputs to a DM8850 retriggerable one-shot. Circuitry that provides for both positive and negative output is driven from the output of the one-shot. A programmable unijunction transistor triggers the one-shot for single-pulse operation. For good stable operation, a tightly regulated, short-circuit protected power supply, rated at ±12V ±200 mA, is used.

The circuit operates as follows: Resistors R_1 and R_2 provide negative feedback for the μA710, biasing it in the center of its operating region. This insures self-starting for astable operation. R_4 is a fine frequency

(Continued)



Frequency of oscillation is determined by C_1, R_3 and R_4, and is approximately equal to $2(R_3 + R_4)(C_1)$.

Pulse width of the one-shot is equal to

$$0.32\,(R_9 + R_{10})\,C_4\left(1 + \frac{0.7}{R_9 + R_{10}}\right)$$

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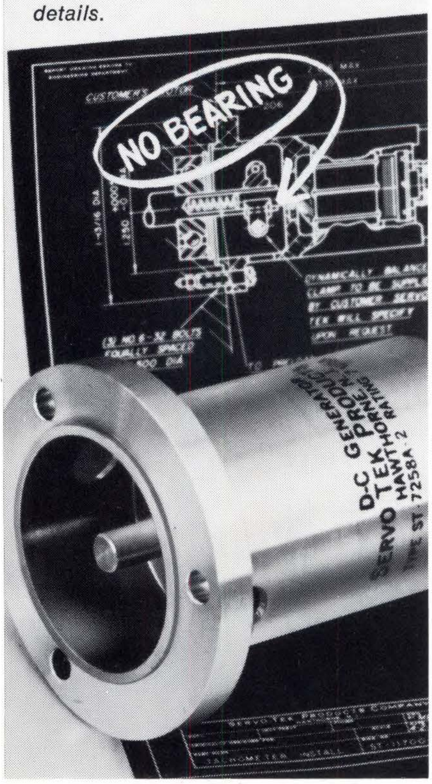

CIRCLE NO. 16

Generator (Cont'd)

adjustment for obtaining the desired overlap in each frequency range. Capacitor C_2 improves the high frequency response. The leading edge of the astable output triggers the one-shot. If the pulse width of the one-shot is longer than the repetition rate of the astable, no output pulses will occur.

Q_1 amplifies the plus 4V pulses from the one-shot. The amplified pulses are passed by emitter-follower Q_2 which prevents loading down Q_1's collector. The positive voltage outputs are taken from the wiper arm of P_1, which adjusts the reference level from 0 to 10V. Q_3 converts the positive pulses from the one-shot to negative pulses. These pulses are passed by emitter-follower Q_4 to P_2, which adjusts the negative pulses from 0 to −10V.

The input of the retriggerable one-shot is connected to the arm of switch S_2. This switch selects either continuous or single-pulse operation. In the single-pulse mode, S_4 is depressed, which causes R_5 to rapidly charge C_3. When the charge exceeds by a diode drop the voltage established by R_6 and R_7, the PUT will fire only once until S_4 is released—insured by biasing the PUT in its saturated operating region with R_5. This scheme makes it totally immune to contact bounce from S_4. The positive output pulse at R_8 triggers the one-shot.

For proper operation, care must be taken when wiring the capacitors to rotary switch S_3. The capacitors must be located as close as possible to the one-shot. R_9 should be located at the V_{cc} line that supplies the one-shot. Finally, shielded cabling is used as shown, with all shields tied together directly back to the power supply ground. These steps are very important in that they help to minimize noise pick-up and stray capacitance. ☐

Carl Brogado is an engineering technician in the Bioengineering Dept. of the University of Colorado Medical Center, Denver, Colo. He is the author of six previous EDN articles.

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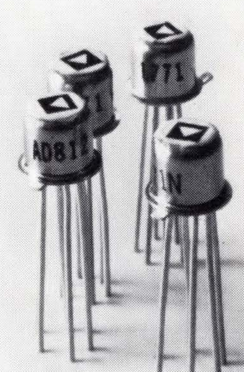
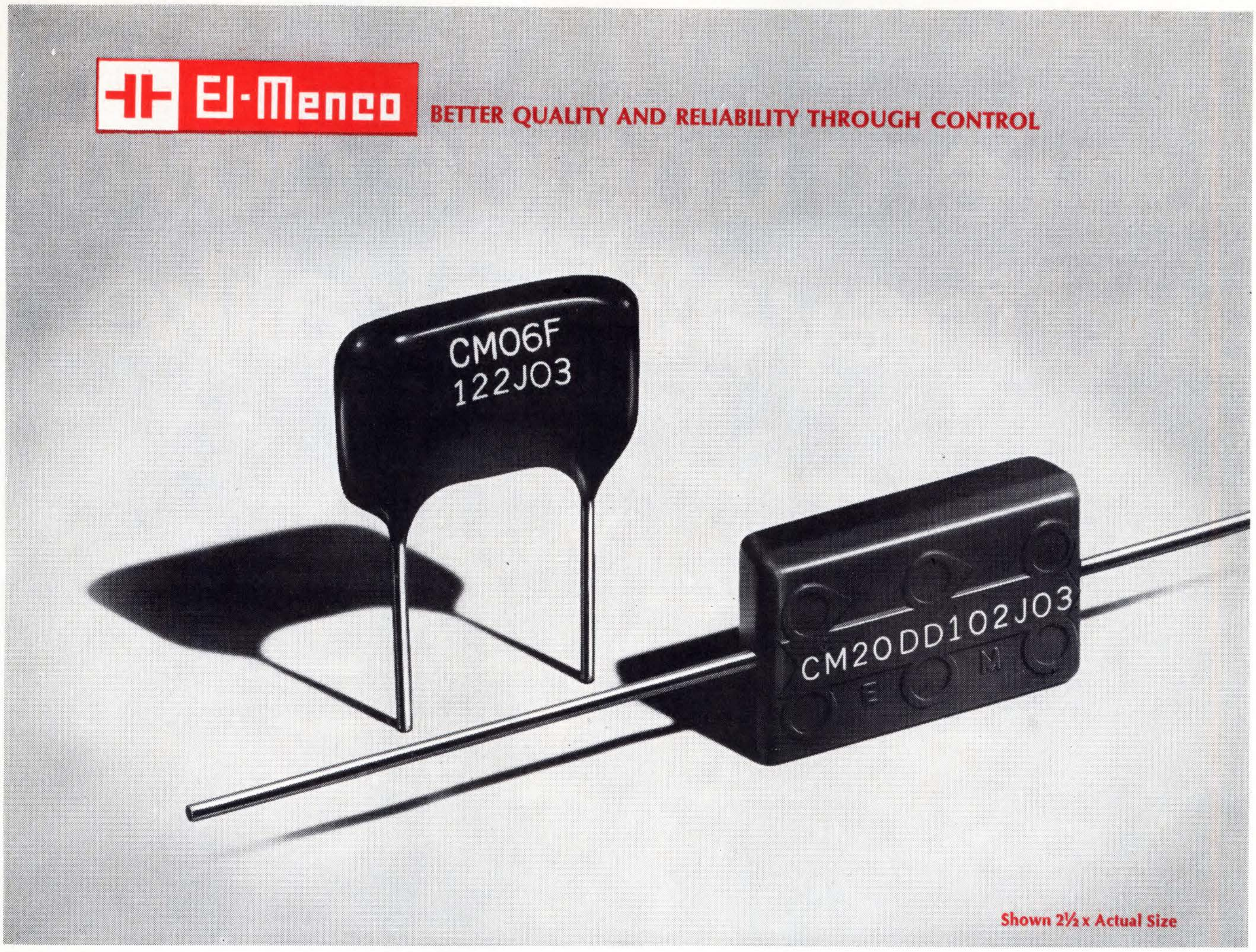


ANALOG DEVICES

CIRCLE NO. 17



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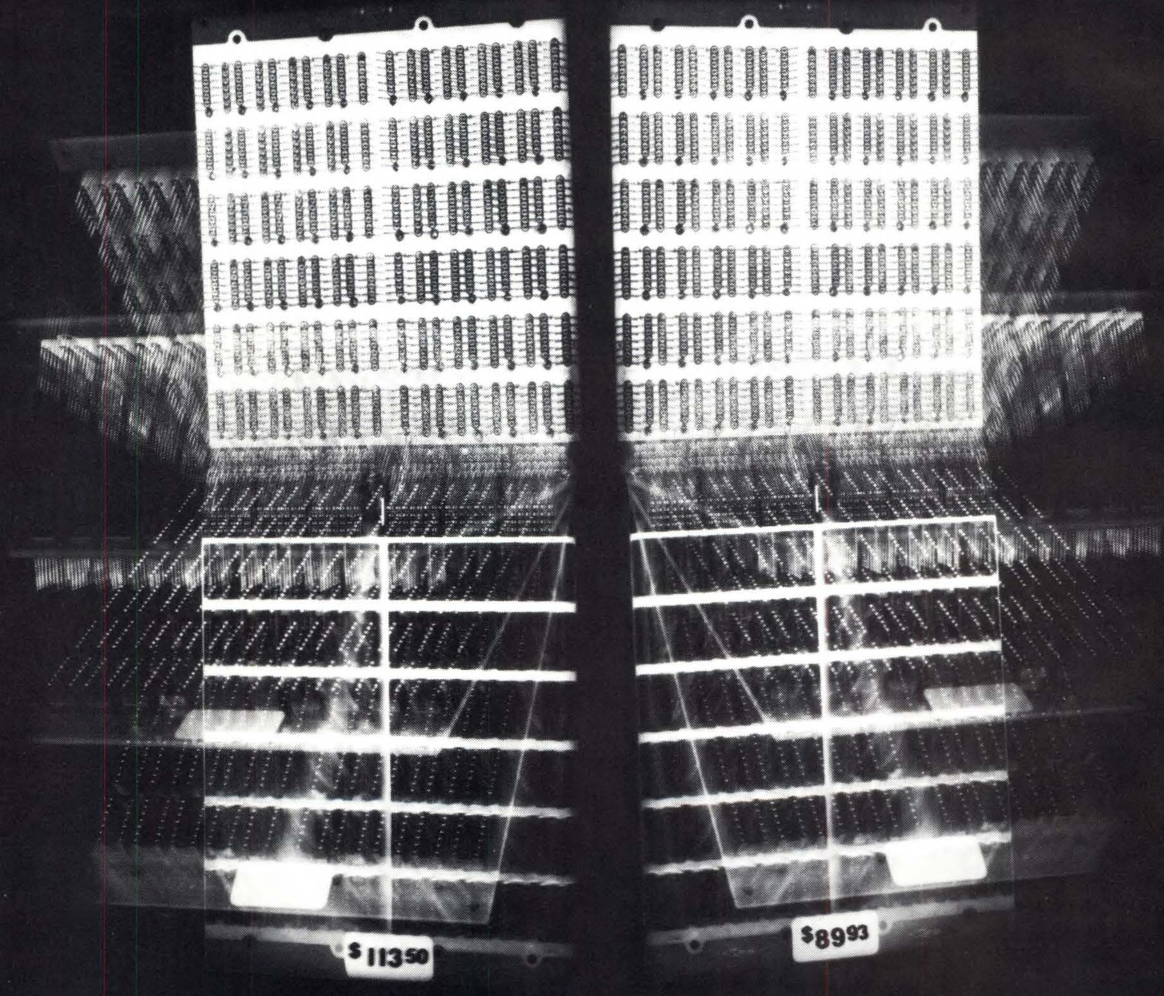

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Super-stable reference-voltage source

To Vote for This Circuit Circle 151

by Leonard Accardi
Kollsman Instrument Corp.
Elmhurst, N.Y.

With conventional reference-voltage circuits, the problem is not so much the stability of the temperature-compensated zener used, but the bothersome trimming or trial-and-error selection of the components that supply the zener current, and the often nebulous stability of the current-determining circuitry.

With the circuit described here, however, the current through the zener diode is truly independent of the power-supply voltage—which may be as low as 10V. The current is determined by the zener itself, thus one avoids the trimming and component selection needed for other circuits.

To understand how the circuit works, temporarily ignore components CR_3, CR_2, Q_1, R_4, R_5 and R_6. Let's assume also that zener CR_1 is in the breakdown region. Assume a voltage, $-V_1$, at the junction of R_1 and R_2. Then the output of A_1 is $-(V_1 + V_Z)$. But resistors R_1 and R_2 form a voltage divider, therefore,

$$-(V_1 + V_Z)\frac{R_2}{R_1 + R_2} = -V_1$$

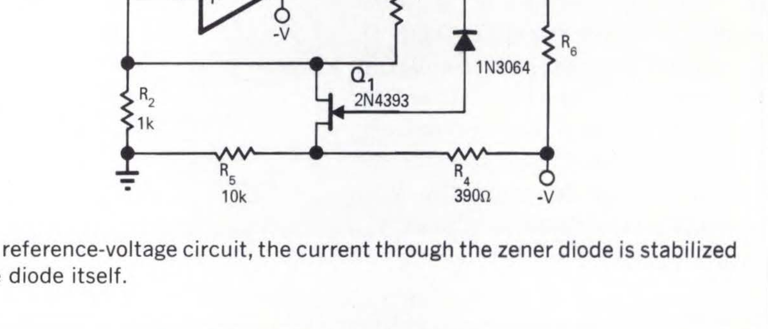
If we select R_1 equal to $10R_2$, then,

$$V_1 = \frac{V_Z}{10}$$

Therefore the zener current is given by the following equation:

$$\frac{V_1}{R_3} = \frac{V_Z}{10R_3}$$

We can then calculate the value of R_3 needed to supply the specified zener current of 7.5 mA.



In this reference-voltage circuit, the current through the zener diode is stabilized by the diode itself.

◆ CIRCLE NO. 19

Now let's examine the functions of the remaining components. Resistor R_6 is included to sink a current of around 7.5 mA because most low-cost op amps can provide only 5 mA without exceeding their output rating. The remainder of the auxiliary components insure that the circuit assumes the current stable state when power is turned on.

Temperature-compensated zeners have internal forward-biased diodes, so CR_3 is included in this circuit to clamp the output voltage of the undesired positive-output stable state to about 1V. In this state, Q_1 is ON, and a negative potential, determined by R_1, R_2, R_4, R_5, $-V$ and the ON resistance of Q_1 (100Ω), appears at the noninverting input of A_1. This causes the circuit to revert to the desired negative-output stable state, turning off Q_1 and effectively removing the auxiliary components from the circuit in normal operation.

With the specified components, output stability approaches that of the zener itself. A μA741 amplifier typically introduces less than 1 mV of output-voltage variation over a temperature range of 100°C. Using premium versions of the 741, such as the Sprague 2151D or Precision Monolithics SSS741, output variations due to the op amp can be reduced to 150 μV over the same 100°C temperature range. The op amp used in this circuit should be frequency compensated for unity-gain operation since the impedance of the zener diode is low and thus provides almost 100% ac feedback.

Output-current capability can be increased, with no sacrifice in stability, by inserting a booster transistor inside the feedback loop of A_1. Also, the circuit can be built as a positive reference supply by using a p-channel FET, reversing the diodes, and changing the current-sinking voltage to +V. ▭

Bistable switch with zero standby drain

To Vote For This Circuit Circle 152

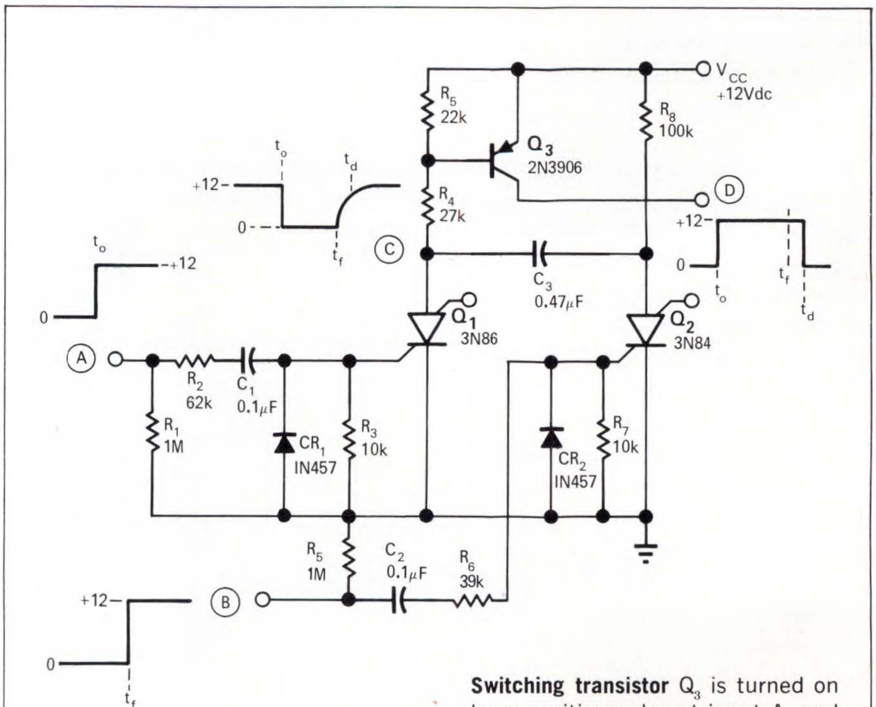
by Don B. Heckman
AMF Electrical Products
Development Div.
Alexandria, Va.

In this bistable switching circuit, the transistor switch Q_3 turns on upon receipt of an ON command at input A, and turns off upon receipt of an OFF command at input B. Current drain is zero in the OFF state. The circuit is especially useful in battery-operated equipment where supply drain must be kept as low as possible.

When point A is driven positive, this triggers SCS (silicon controlled switch) Q_1, at time t_o, thus turning on transistor switch Q_3. Components R_2 and C_1 provide the necessary coupling, while R_1 is needed to discharge C_1. Diode CR_1 protects the gate-cathode junction of Q_1 when point A is driven negative. While Q_1, is on, point C is near ground and point D is near V_{cc}. Holding current for Q_1 must be provided through R_4, therefore Q_1 should be chosen for low-holding-current characteristics. With Q_3 on, C_3 is charged to almost V_{cc}, with $+V_{cc}$ at the anode of Q_2.

When point B is driven positive, the other SCS, Q_2, is gated on, at time t_f, via R_6 and C_2. Components R_5 and CR_2 have similar functions to R_1 and CR_1 as previously described. The anode of Q_2 drops to near zero potential at time t_f, thus placing $-V_{cc}$ at the anode of Q_1, and turning off Q_1. Resistor R_8 is chosen large enough to allow less than the required holding current for Q_2. After C_3 has been charged through R_4, at time t_d, Q_3 and Q_2 turn off. The complete circuit is then in an OFF state and only transistor leakage current (typically 2 to 3 μA) flows.

The circuit was designed, with the component values shown, to supply up to 7 mA of switched current from a 12V dc supply. Operation is satisfactory over the range −10 to +60°C with 12V trigger signals. ▭



Switching transistor Q_3 is turned on by a positive pulse at input A, and turned off by a positive pulse at input B.

Comparator with noninteracting adjustments

To Vote For This Circuit
Circle 153

by Gene Tobey
Burr-Brown Research Corp.
Tuscon, Ariz.

When a comparator is used in industrial applications, such as relay driving, it is often desirable to add some hysteresis to the operating characteristic. This is done to prevent "chatter" caused by noise when the input-signal level is near the trip point. Conventional circuits for adjusting hysteresis, however, cause interaction between the hysteresis adjustment and the trip-point adjustment. The circuit shown in **Fig. 1** avoids this drawback and allows the user to adjust trip point and hysteresis independently.

Amplifier A_1 provides the basic comparator action and clips the output waveform at a negative voltage determined by the feedback limiter (R_4, R_5 and CR_2). Diode CR_1 limits the positive output excursion of A_1 to approximately 0.6V.

Amplifier A_2 provides polarity inversion and precision rectification of the output of A_1. The output of A_2 is fed back to A_1 through R_8 (positive feedback), thus providing the hysteresis effect. The amount of hysteresis is determined by the ratio R_3/R_8.

$$\Delta V = V_L(R_3/R_8)$$

where V_L is the positive output level, given by the equation,

$$V_L = 15\left(\frac{R_5}{R_4}\right)\left(\frac{R_7}{R_6}\right)$$

Trip point is determined by the setting of R_1, or alternatively, it may be programmed by a voltage applied to R_2. As the trip point is varied, the amount of hysteresis (ΔV) remains constant.

Fig. 2 shows the input-output characteristic of the comparator. As shown, the hysteresis is the difference between the trip and reset levels:

$$V_S = V_R - \Delta V$$

The two output levels are zero (within a fraction of a millivolt) and the positive level V_L. With the resistor values shown, the circuit has output levels of zero and 5V. □

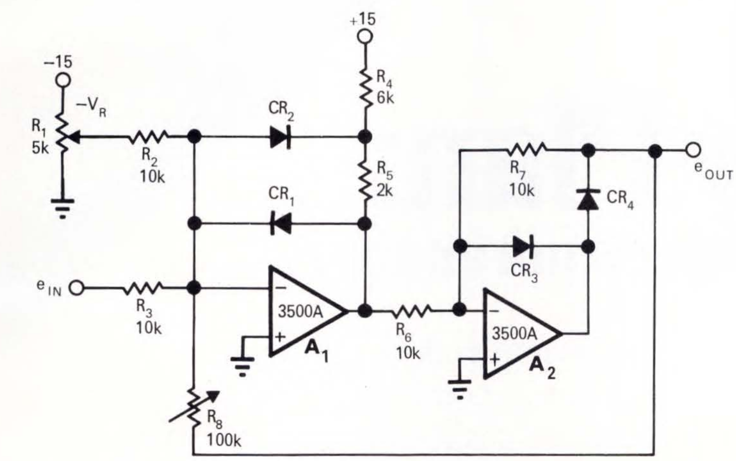
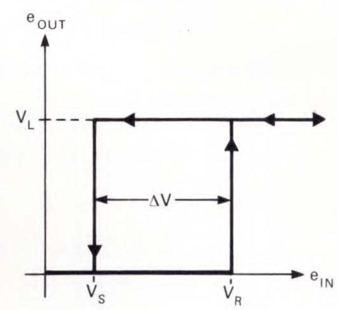


Fig. 1—**This improved** comparator has independently adjustable trip point and hysteresis. R_1 determines trip point and R_8 determines hysteresis.

Fig. 2—**Input-output** characteristic shows the effect of hysteresis (ΔV).



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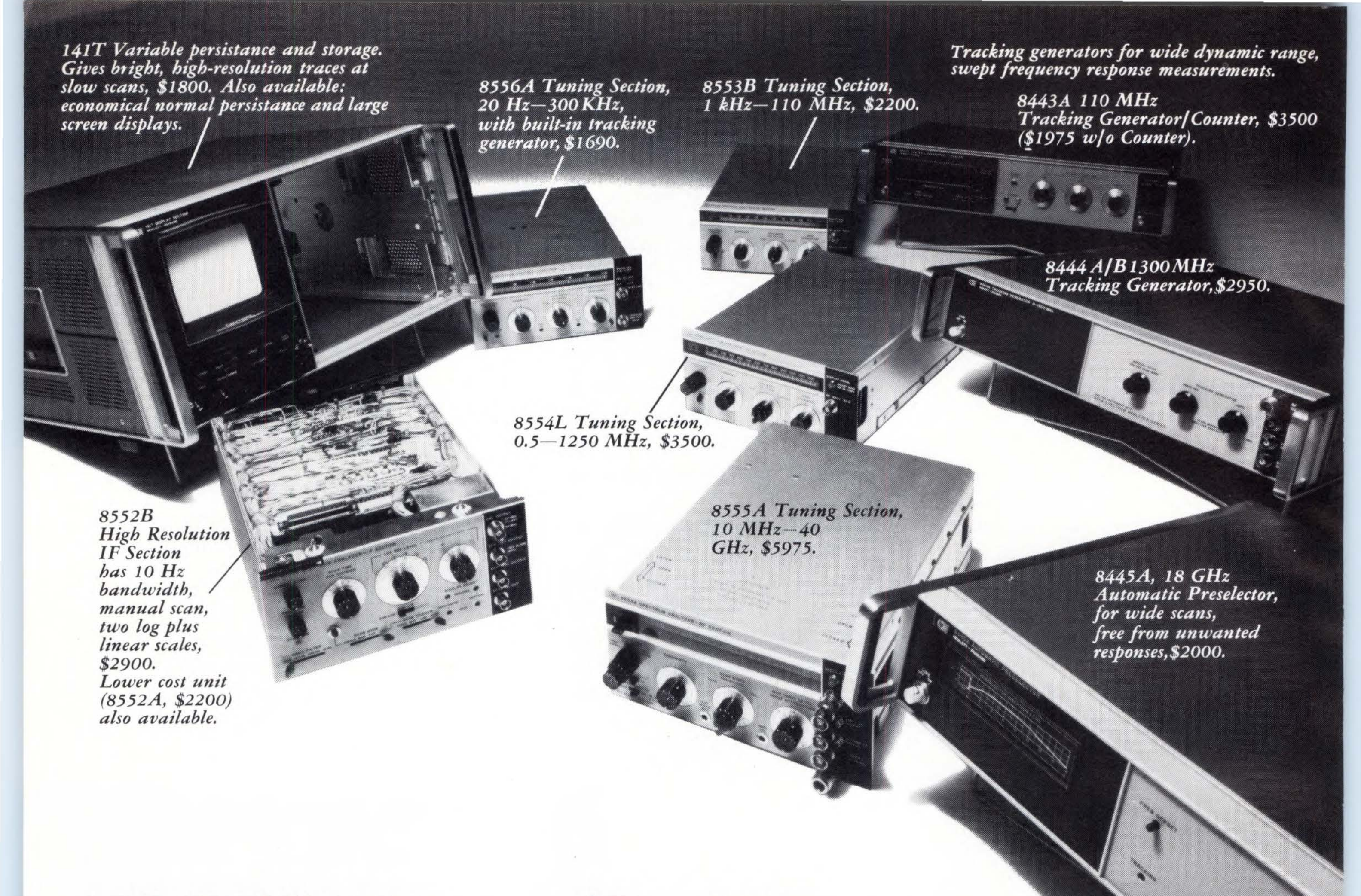

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SIGNAL ANALYZERS

CIRCLE NO. 20

ROM Look-Up Generates Sinewave In Frequency Synthesizer

PROGRESS IN INSTRUMENTATION

Laboratory sinewave generators range from $300 oscillators to $5000 synthesizers. The $300 oscillators use RC tuning to cover about five frequency decades with 2 to 5% accuracy and repeatability. The $5000 synthesizers use a fixed-frequency, crystal-controlled oscillator for 0.00001% or more accuracy and even better repeatability. The synthesizers "tune" by multiplying and dividing the crystal reference using various open and closed (phase lock) loop means.

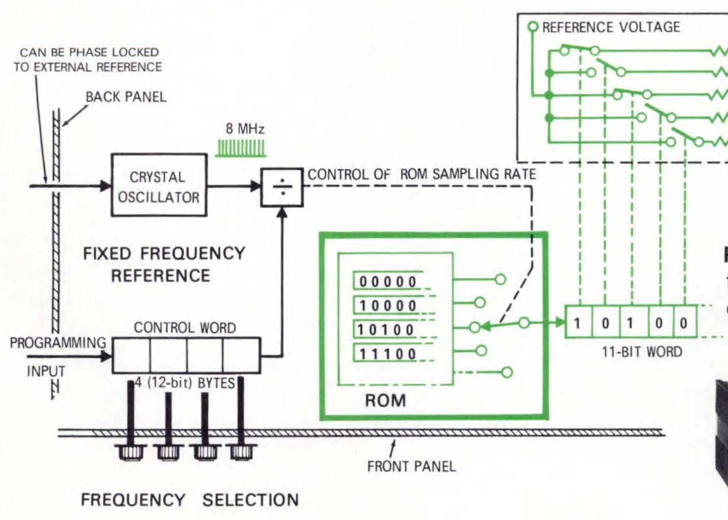
A new precision synthesizer from Rockland Systems Corp. falls halfway between the $5000 and the $300 instruments. At $2450, Model 5100 provides superior harmonic-distortion specifications (−60 vs −40 dB), but not quite as good spurious-noise specifications (−70 vs −90 dB) when compared to existing $5000 synthesizers. It has the same or better ability to switch rapidly under external digital control. Also, its fine-tuning resolution matches that of the best of the existing synthesizers—it can hit frequencies within 0.001 Hz. It is, however, limited to frequencies of 2 MHz and below because of the digital programming techniques it employs to generate frequencies.

This new instrument is more truly a "synthesizer" than previous units for it synthesizes both the sinusoidal waveshape and the frequency. The output waveform is not determined by an oscillator as in most other synthesizers.

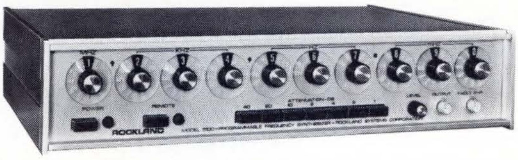
Function Generation

The waveshape in this synthesizer is repetitively looked-up, point-by-point, in a bipolar read-only memory (ROM). This provides digital precision and repeatability for the waveshape and wave amplitude, no matter what the frequency. The general approach is sketched in the diagram.

An 8-MHz clock is divided down by control adjustments to pace the ROM look-up steps. These come from either the front-panel knobs or from remote digital commands introduced at the back panel. A sequential sampling switch is shown in the sketch, but obviously a digital counter or shift register must be used (Rockland won't go into details). The ROM produces 11-bit digital numbers that represent the amplitudes of the sinewave at the sample points. In the sketch, the fourteen sample points, if sampled at 8 MHz, would sweep out an 8/14-MHz (571,428.571-Hz) sinewave.



ROM look-up "table" for the new frequency synthesizer's sinewave amplitudes serves for all frequencies, depending on how fast it is sampled.



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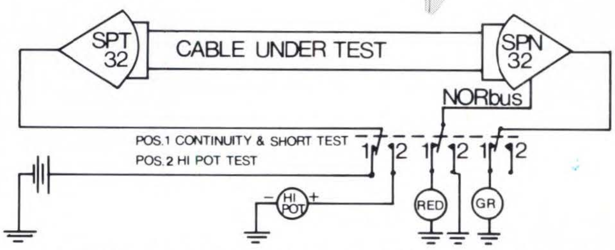

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CIRCLE NO. 21

These numerical samples are converted into a staircase sinewave by a high-speed D/A. Although this staircase sinewave appears rather rough, remember that it has been generated with 11-bit precision, which means that the levels are within 2-1/2 mV of the proper sample values for the 10V pk-pk output. This staircase waveform need only be passed through a simple low-pass filter to knock off the rough edges and a highly accurate sinewave is produced. A filter that cuts off sharply beyond the 2-MHz maximum frequency of the instrument is used to remove the 8-MHz sampling frequency. The end results are 60-dB harmonic distortion and 70-dB spurious distortion specifications over most of the instrument's range.

Programmability

As you might expect these days in any instrument that costs several thousand dollars, the 5100 can be externally programmed from TTL-level signals. But Rockland has gone one step further and provided sufficient internal buffer and signal conversion so that this instrument will accept signals in either one long 46-bit word or in minicomputer-sized 12-bit bytes, and will hold the commands so the external controller need not be tied up. The signals can be in binary or binary-coded decimal.

One advantage of the ROM look-up mode of operation is that when a new frequency is commanded, it will start at the beginning of the next ROM read cycle or at the zero crossover point. This makes for fundamentally smooth, transient-free switching even when frequency hopping at the maximum 1/2-μsec programming rates. The sinewave can be reset to the start of a cycle at any time by an external command.

This synthesizer's rapid programming and fine 0.001-Hz tuning invite elaborate control programs. Using the option for programmed attenuation ($250 extra), elaborate yet repeatable test patterns can be generated. "The most popular probably still would be linear sweeps and signal hopping, but you could conceivably write programs to generate audio and video patterns that would represent recognizable sounds and pictures," says Vice President of Engineering Leland B. Jackson. (Rockland also makes a speech synthesizer, but it works on a different principle.) Another area of application would be as a built-in element for communication, radar and industrial control systems.

Rockland Systems Corp., 131 Erie St. E., Blauvelt, NY 10913. **249**

LED Indicator Has Wide-Angle Visibility

PROGRESS IN DISPLAY DEVICES

Marco-Oak has joined the swelling ranks of companies manufacturing panel-mounting indicator assemblies that incorporate light-emitting diodes. Competing companies that have previously introduced LED indicators include Dialight, Drake, Eldema, Industrial Devices, Monsanto and Sloan. This list is lengthened considerably if one also includes companies manufacturing the basic LEDs which can be directly mounted on a panel using a simple spring clip.

Instead of rushing into the market by taking an existing incandescent-lamp indicator and merely changing the lamp socket to accept a LED, Marco-Oak's engineers carefully designed and evaluated a completely new assembly that was specifically tailored for LED applications. As a result, the Type QT/D200 LED indicator has some important features that should help it to stand out in the crowded marketplace.

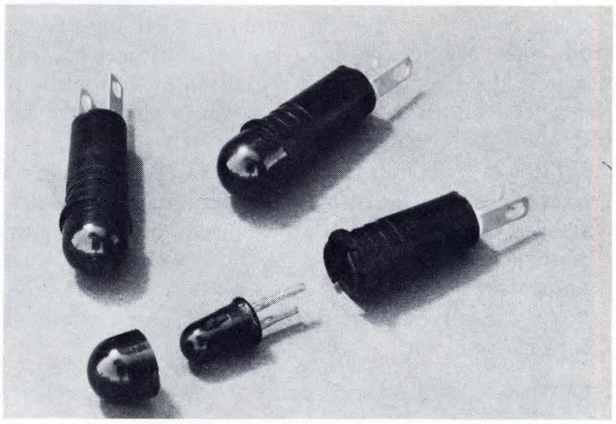
Perhaps the most significant advantage of the QT/D200 is its clear visibility, with adequate brightness under all ambient lighting conditions and over a 170° viewing angle. Admittedly, visibility can be a somewhat subjective attribute. But an EDN/EEE field editor recently had an opportunity to compare the QT/D200 with some (but not all) of the competing indicators. He found that Marco-Oak's claims of superior visibility were well-founded.

Micro-Grooved Lens

Key to the QT/D200's excellent visibility is the unusual lens which has tiny concentric grooves molded into the inside surface. These grooves scatter the light from the LED but do not attenuate it.

To improve the indicator's ON/OFF contrast ratio, a fairly dark red material is used for the lens. The actual LED also has a red envelope and the indicator's housing is black. Thus there is very little reflected light when the lamp is turned off. The inside of the plastic lens has a carefully designed taper and curvature, which in conjunction with the grooves helps to improve off-axis visibility and provide an apparently large light source.

Though several companies make LEDs that will fit the QT/D200 assembly, the company recommends use of LEDs from just one company—Hewlett-Packard. This is because the lens assembly was specifically designed for optimum performance with the HP lamp. Other LEDs with similar package dimensions tend to have subtly different pellet dimensions and positions, thus performance with substitute LEDs cannot be guaranteed.



New indicator assembly from Marco-Oak uses an HP solid-state lamp. In quantities of 100-999, it costs only $1.44 (complete with LED).

Consistent Brightness

Another reason why LEDs from HP are specified is that they are available in graded versions with various ranges of brightness. By using LEDs of a single grade, Marco-Oak is able to assure its customers that variations in brightness between individual indicators will be negligible. Also HP's solid-state lamps have been found to offer better efficiencies (in the higher grades) than some competing versions.

One possible disadvantage of the QT/D200 is that it's not available with a built-in resistor. Marco-Oak claims that this is really an advantage because it allows the user greater flexibility and allows him to operate the indicator from any suitable voltage source. They point out that if an indicator with a built-in resistor is operated from voltage sources of 12V or more, then the operating current (and hence brightness) of the LED must be reduced to avoid excessive dissipation in the resistor.

Another argument revolves around cost. Marco-Oak points out that one competing indicator with a built-in resistor costs about a dollar more than the QT/D200, and that $1 is a stiff price to pay for a small carbon-composition resistor.

The QT/D200 snaps into a 9/32-inch diam panel hole and requires no additional mounting hardware. A removable lens cap allows replacement of the plug-in LED from the front of the panel. In quantities of 100 to 999, the indicator (complete with LED) costs $1.44.

Marco-Oak Industries, Subs. of Oak Electro/Netics Corp., 207 S. Helena St., Anaheim, CA 92803. **250**

Digital Thermometer Uses Programmable ROM

PROGRESS IN INSTRUMENTATION

A precision digital temperature meter from Newport Laboratories boasts an impressive collection of advantages over competitive instruments. By employing an unusual circuit technique, the designers of the 2600 Series have managed to combine such features as wide measurement range, fine resolution, close conformity, good common-mode rejection and outstanding stability—all in an inexpensive unit no larger than many digital panel meters.

The secret to many of the 2600's performance advantages is the use of digital techniques for linearizing the response of a thermocouple temperature transducer. This approach contrasts with widely used analog techniques, which tend to be more drift prone and are usually restricted to relatively narrow temperature ranges.

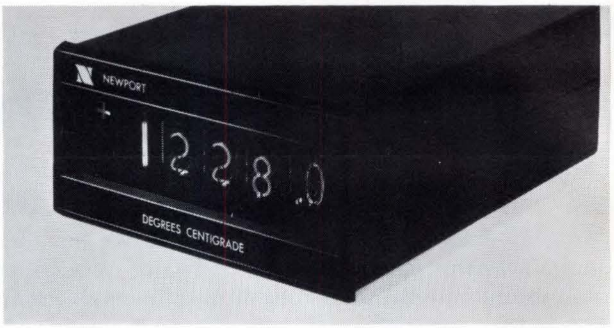
ROM Shrinks Circuitry

Of course, digital signal processing isn't a completely new technique for temperature measuring equipment. But competing digital thermometers tend to be much more expensive and much more bulky than the 2600.

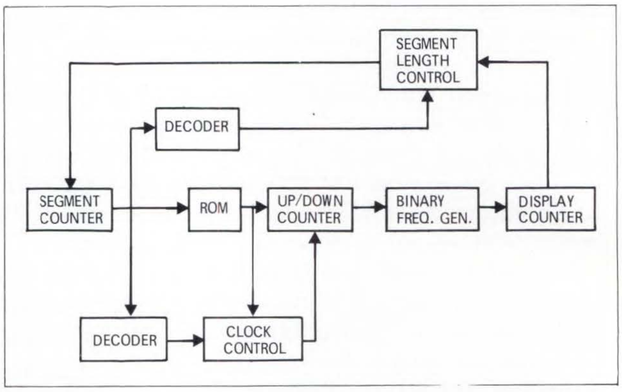
Designers of the 2600 minimized the component count for the digital circuitry by employing a read-only-memory IC. The 256-bit ROM controls a binary frequency generator which serves as the clock for the analog-to-digital converter. Because different types of thermocouples need different ROM programming to linearize their response, the unit uses field-programmable IC ROMs such as those offered by Harris Semiconductor, Intersil and other manufacturers. Newport engineers developed their own ROM-simulator equipment, which they use to determine the optimum program for a given thermocouple type. Having determined the required coding pattern, they then order custom-coded ROMs from the IC manufacturer.

Because of its novel design, the 2600 is able to approximate a thermocouple's response curve with 58 line segments. This is about three times as many segments as are generally used in digital thermometers. Thus Newport is able to accurately match the NBS linearizing tables for various thermocouples including types J, K, T, S, R and E. The 2600 can read the entire range of any given thermocouple—unlike other digital thermometers, it isn't restricted to just part of the range to achieve the desired conformity. The basic instrument can read up to 3800°F with 0.1° resolution, though in practice availability of suitable thermocouples limits the usuable range to a span of −420 to 3200°F. Readout can be either Fahrenheit or Centrigrade degrees, as required.

Though any one version of the 2600 is restricted to a specified thermocouple type and temperature range, units can be easily modified for other ranges merely by changing a few components. Custom versions are relatively inexpensive, thanks to the use of field-programmable ROMs and flexible circuitry.



Compact 2600 Series digital thermometers are available in versions for six different standard thermocouple types and with a choice of Fahrenheit or Centigrade readings. Unit-quantity price is $750.



Simplified block diagram shows how IC ROM controls binary generator in 2600 Series circuit, which approximates NBS thermocouple response with 58 line segments.

Another possible error source is minimized by providing integral reference-junction compensation to eliminate errors at the cold junction where the thermocouple wires connect to the instrument. This compensation circuit is removable to allow the instrument to operate with a remote thermocouple.

Overall system accuracy, of course, depends on a number of possible error sources, and it varies depending on the type of thermocouple used. The 2600 provides typical system accuracy of 0.5°C when used with a J-type thermocouple.

A true-differential guarded input circuit allows the thermocouple to be grounded or floated. Isolated BCD outputs allow the 2600 to operate with an external printer or recorder, thus providing hard copy to complement the integral 4-digit (plus neon "one") display. Signal-mode input noise is attenuated by more than 10,000 to 1 at 60 Hz, and the instrument provides common-mode rejection up to ±300V peak. Input circuitry is protected against overvoltages as high as 200V.

Stored outputs permit a data access time of less than 1 μsec. Data may be updated every 100 msec.

In unit quantity, basic models in the 2600 Series cost $750. The price falls to under $600 in 100-lot quantities.

Newport Laboratories, Inc., 630 E. Young St., Santa Ana, CA 92705. **251**

Thank you

for showing us that engineers still appreciate creative design. Design that isn't measured by how many jazzy junctions and metallurgical miracles you can cram onto a chip of silicon. Design that goes back to the fundamental constraints of circuits, functions and economics.

Three months ago, the engineering team which had labored so long to produce the first major instrument breakthrough in five years agreed that the job was done. So we called in the toughest bunch of critics in the business — the editors of the leading technical magazines in electronics.

We told them, and showed them, what we had done: gone back to fundamentals and developed a *completely new generation of digital multimeters.* We showed them original, patent-applied-for circuits that achieved orders-of-magnitude improved performance, at a *fraction* of the cost of the circuits then in use. Circuits that made it possible to actually cut the selling price of a premium-grade 5½ digit multimeter by 50% or more . . . while significantly reducing the component count, and thereby greatly enhancing reliability.

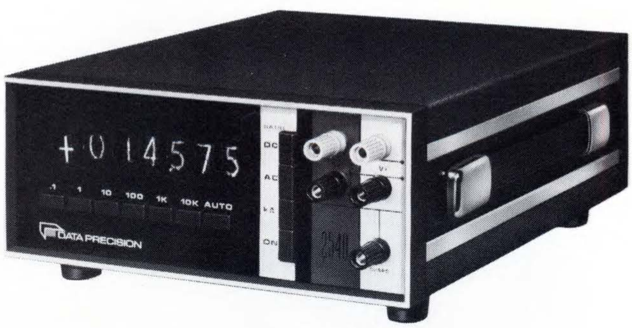
Then we showed them a vastly improved package . . . easy to use, convenient to calibrate . . . a package that saved half the size and more than half the weight that burdened earlier premium-grade DMM's. And just for good measure, we showed them a compatible family of 4½ digit designs, at equally startling savings.

They came. They saw. They probed. They challenged. (We must have explained our new TRI-PHASIC™, ISOPOLAR™, and RATIOHMIC™ circuits dozens of times.)

And then came the editorial critiques. Admittedly, we're not in the best position to be objective, but cooler, less involved colleagues tell us that they cannot remember ever having seen such a *consistently enthusiastic* editorial response to a new family of instruments.

But the story doesn't end there. The phone began to ring steadily. Letters poured in. We got firm purchase orders even before our catalog was printed. Our first production run was sold out before we had provided a single field rep with a demo unit. And the response continues to exceed all reasonable expectations.

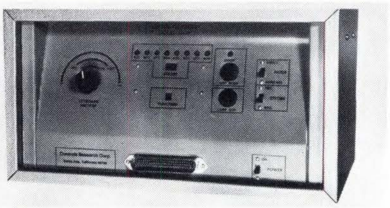
There isn't sufficient space on this page for complete specs, or competitive comparisons, just enough to show you one of our beautiful new 2000-Series Digital Multimeters. But please write or call. We'd like to show you what the excitement is all about. Data Precision Company, Audubon Road, Wakefield, Massachusetts 01880.
Phone (617) 246-1600



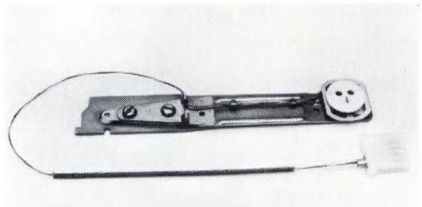
Model 2540, 5½ digits. DC volts, AC volts, Resistance, Voltage Ratio. Auto-ranging. Auto-Polarity. Isolated BCD outputs. Remote triggering. Remote ranging. Basic accuracy ±0.001% f.s. ±0.007% rdg ±1 l.s.d. for 6 months. One-piece price: $1,195.00

DATA PRECISION
...years ahead

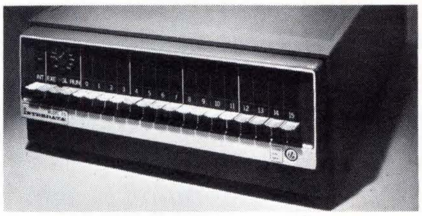
CIRCLE NO. 22



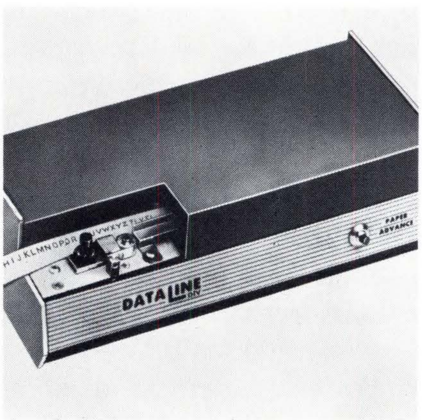
Keyboard tester, Model 1600, dynamically performs five tests on any electronic keyboard within 15 sec. The unit tests any encoded keyboard with up to 76 keys (64 coded keys and 12 function keys) against a preprogrammed ROM. Discrepancies are indicated on three front panel displays: error, strobe count (7-segment, numeric LED) and 8-bit LED indicators. Controls Research Corp., 2100 S. Fairview, Santa Ana, CA 92704. **305**



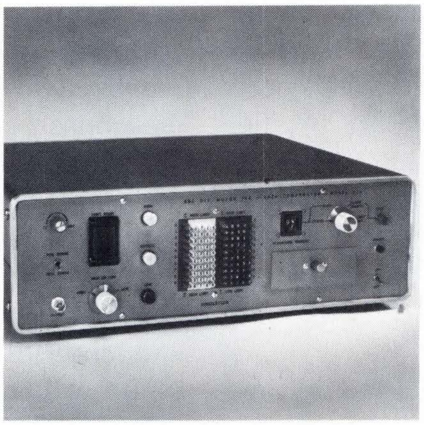
Flying-head assembly combined with a disc pack drive doubles the storage capacity of a standard 2314 type drive by recording 200 instead of the normal 100 tracks/inch. Operating at a packing density of 2200 bpi and a disc speed of 2400 rpm, the output from the head assembly at 1.25 MHz varies from 8 (outermost track) to 1.7 (innermost track) mV pk-pk. Applied Magnetics Corp., 75 Robin Hill Rd., Goleta CA 93017. **308**



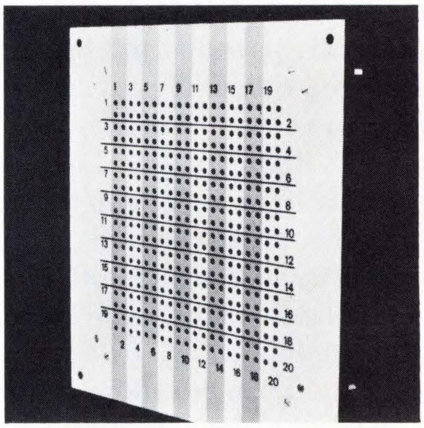
Minicomputer, first in a series of small computers, is available with field-proven software and peripherals, 8192 bytes of memory, 16 general registers (16-bit capacity) and a set of 113 instructions. The directly addressable core memory of the Model 70 is expandable to 65,536 bytes with 1-μsec cycle time and 300-nsec access time. A double buffered "Teletype" interface is built-in. Interdata, 2 Crescent Pl., Oceanport, N J 07757. **311**



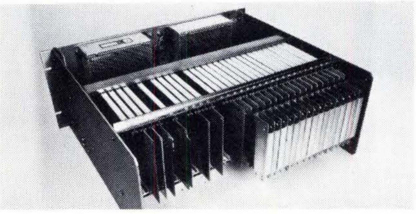
Impact strip printer prints on pressure-sensitive paper tape at rates up to 30 cps and displays 64-character ASCII subset spaced at 9 cpi. Unit dimensions are 7.625 by 4 by 2.5 inches, and weight is 4 lb. Special configurations that conform to user requirements are available. Dataline Div., Heller Roberts Instruments Corp., 700 Jamaica Ave., Brooklyn, NY 11208. **306**



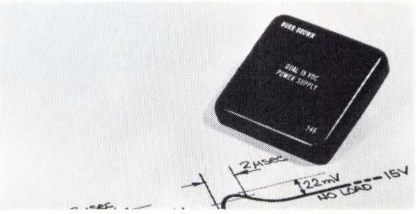
Ten-channel data comparator, Model 800S, compares 10 high and low limits and has scanning speeds up to 100 kHz. Word lengths of four decimal digits plus sign or four octal digits plus sign are programmed from front panel. These values are compared against standard BCD or octal information. SRC Div./Moxon Inc., 2222 Michelson Dr., Newport Beach, CA 92664. **309**



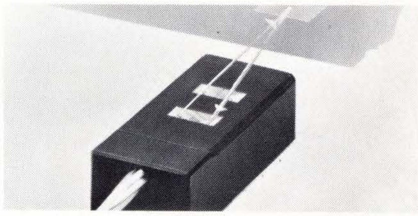
Matrix program board 676-110-107-02 features centerline spacing between holes of 4.5 mm (0.177 inch). Backplate of the board assembly consists of a "Makrolon" carrier for gold-plated beryllium/bronze contact strips. Contact rating is 6A at 50V ac or dc. No special tools are required. In quantities of 50, the price is $66 each. Interswitch, 770 Airport Blvd., Burlingame, CA 94010. **312**



Analog input system RTP7460 combines a high-speed, high-level multiplexer with a 12-bit binary A/D converter. Up to 128 input channels can be sampled at rates up to 10 kHz. Two full-scale input ranges are available (±4 and ±10V), and channel addressing can be either random access or sequential. Channel input impedance is 10 MΩ. Computer Products, 1400 N.W. 70th St., Box 23849, Ft. Lauderdale, FL 33307. **307**



DC-dc converter, Model 546, finds use with computer peripheral instrumentation. The dual output of ±15V dc, ±120 mA is derived from an input provided by a computer supply of 4.5 to 5.5V dc. Output regulation is ±0.1% for full load variations. Input to output isolation is in excess of 1000 MΩ. Quantity price for the 2- by 2- by 0.4-inch unit is $89. Burr-Brown Research Corp., International Airport Industrial Park, Tucson, AZ 85706. **310**



EOT/BOT sensor for magnetic tape drives features gallium-arsenide LEDs for the light source and photo-darlington transistors as the sensors. This hybrid thick-film package replaces the bulky assemblies using light bulbs. A special packaging feature allows the unit to be operated with sensor positioning to fit any tape drive. Price is $14 each in 100-lot quantities. HEI, Inc., Jonathan Industrial Center, Chaska, MN 55318. **313**

Magnetic tape NRZ formatter consists of a single printed circuit board and provides all computer-compatible functions for 7- and 9-track tapes. The unit can address four tape transports. Quantity price is $400 each. Digi-Data Corp., 4315 Baltimore Ave., Bladensburg, MD 20710 **314**

Bench-top test system, Model MDI-2004, finds use as a laboratory and quality assurance tool for calibration and evaluation of magnetic disc, tape and drum heads. Modular in concept, the system consists of a clock generator, pattern generator write driver and remote stage. Scientific Measurement Systems, 351 New Albany Rd., Moorestown, N J 08057. **315**

Core elements for ferrite-core memories come in 16-, 18-, 20- and 30-mil sizes and operate reliably at 0 to 75°C. A 14-mil core is currently under development, as well as a full line of wide temperature range cores for −55 to 100°C operation. Fabri-Tek, Inc., 5901 S. County Rd. 18, Minneapolis, MN 55436. **316**

X-Y plotter, an output peripheral for the Tektronix calculators, prints on 8.5- by 11- or 11- by 17-inch graph paper. Fiber-tipped pens are supplied in selected colors. Plotter accuracy of Model 915 is ±0.02 inch; repeatibility is ±0.005 inch. Tektronix, Inc., Box 500, Beaverton, OR 97005. **317**

Graphic plotter, Model 511, produces hard-copy plots at the rate of 2-1/2 strokes/sec with strokes as long as 3 inches. Unit accepts 8-level ASCII at selectable rates of 10 or 30 cps (110 or 300 baud) and accommodates both RS232C and DTL/TTL voltage levels. Gould Inc., Brush Div., 3631 Perkins Ave., Cleveland, OH 44114. **318**

MOS-RAM card SG418 is available in organizations of 4096 × 18, 4096 × 16, 8192 × 9 and 8192 × 8. Cycle time is 650 nsec and maximum access time is 500 nsec. Single unit price is $1859 or approximately 2.5 cents/bit (OEM discounts are available). Signal Galaxies, Inc., 6955 Hayvenhurst, Van Nuys, CA 91406. **319**

Off-the-shelf alterable ROMs have bit capacities ranging from 8k to over 200k/system. Customer supplies his desired data contents in either punched tape, card or tabulating listing format. Price is from $0.02 to $0.008/bit. Datapac, Inc., 3180 Redhill Ave., Costs Mesa, CA 92627. **320**

Display terminals, Models 80 and 84, are stand-alone units with 12-inch screens and switch-selectable data rates of 1200 baud asynchronous or 2400 baud synchronous. Model 80 displays 1000 characters in 25 lines, and Model 84 displays 960 characters in a 12 by 80 format. Photophysics, Inc., 1601 Stierlin Rd., Mountain View, CA 94040. **321**

Line printer, Series A0501, accepts inputs of BCD, pulse train or a combination of both. Number of characters/line is 4 to 12 and character size is 5/64 inch wide and 1/8 inch high. Dimensions of the 10-lb unit are 4.625 by 3.50 by 13.6875 inches. Hecon Corp., 31 Park Rd., New Shrewsbury, N J 07724. **322**

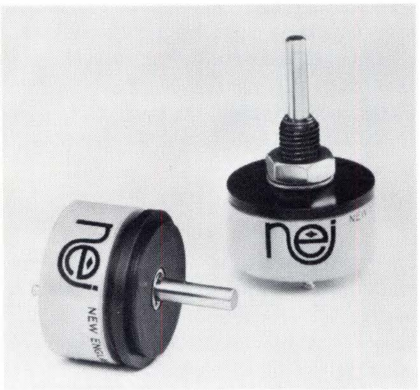
Tinnerman Thumbnail miniatures

...are made of aluminum, beryllium copper, copper, phosphor bronze, molybdenum, nickel, platinum, stainless steel, tantalum, or titanium — whatever your needs require.

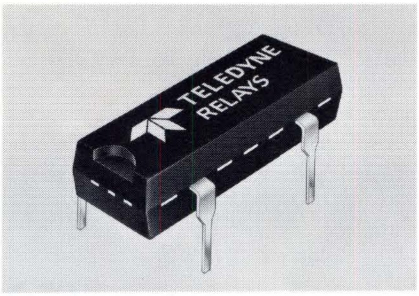
Let our Troy Plant specialists add their know-how to your specifications. Call your Tinnerman fastener expert (in most Yellow Pages and major industrial directories under "Fasteners") or write to Eaton Corporation, Engineered Fasteners Division, Dept. 12, P.O. Box 6688, Cleveland, Ohio 44101.

EATON Engineered Fasteners

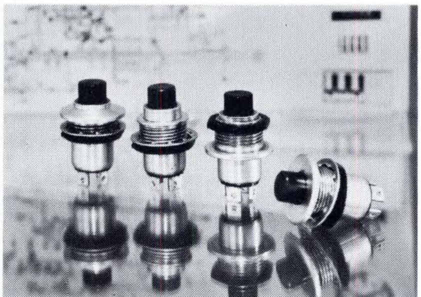
CIRCLE NO. 23



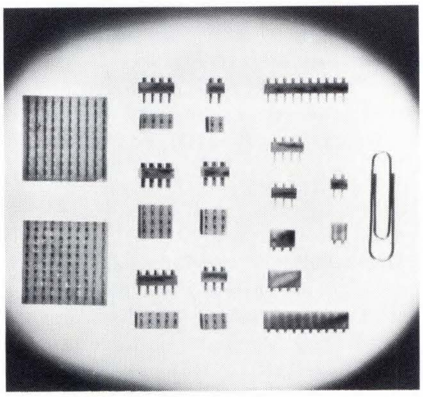
Potentiometer features long life of up to 25 million revolutions. "Econopot" Model C is available in both servo and bushing designs with a choice of 1/8- or 1/4-inch diameter shaft in a 7/8-inch case. Price in quantities of 100 is $4.99. New England Instrument Co., 14 Kendall Lane, Natick, MA 01760. **323**



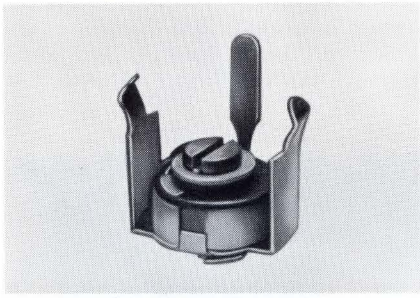
Solid-state relay in a TO-116 DIP is priced at $4.45 in 1000-piece quantity. The Model 640-1 "SerenDIP" is totally TTL compatible and switches up to 0.1A at 50V ac or dc with switching rates to 100 kHz. Teledyne Relays, 3155 W. El Segundo Blvd., Hawthorne, CA 90250. **324**



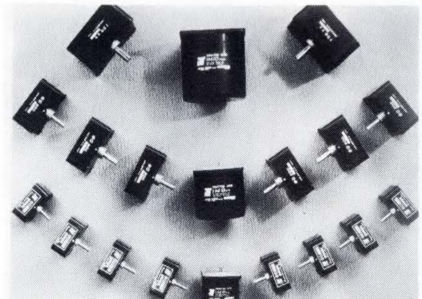
Miniature pushbutton switches offer <10 mΩ contact resistance and over 1-million-cycle mechanical life. The P3 Series is moistureproof, has low contact bounce and precise trip point. Rating is 10A resistive, 5A inductive, and price is $2.45 in 100-piece quantities. Otto Controls Div., Otto Engineering, Inc., 36 Main St., Carpentersville, IL 60110. **325**



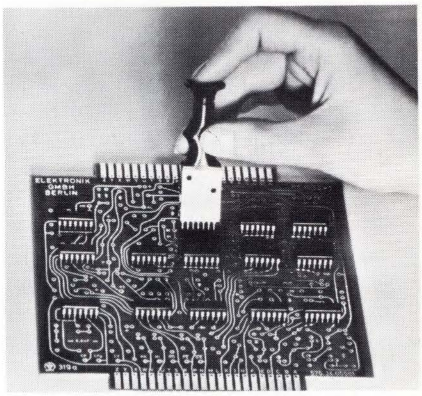
Miniature connectors of various configurations can be custom fabricated by the user from basic plug and receptacle blocks that are approximately 1 inch square and contain up to 100 contacts. Connector bodies are high-temperature phenolic, and pins and sockets are gold-plated brass. Microtech, Inc., 777 Henderson Blvd., Folcroft, PA 19032. **326**



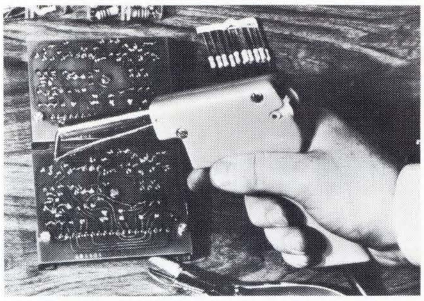
Bottom-tuning trimmer capacitors allow through-the-board adjustment. The Series 9320 units range from 1.7 to 50 pF with a rating of 250V dc. Price is $1.35 to $0.25 each. Johanson Manufacturing Corp., 400 Rockaway Valley Rd., Boonton, N J 07005. **327**



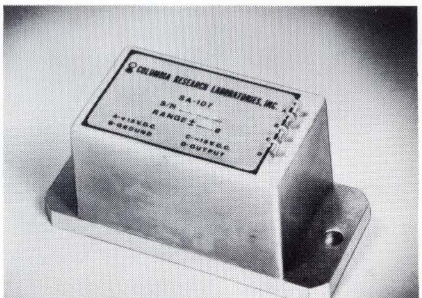
Induction brake motors of the M Series feature interchangeable gearheads on frame diameters of 2-1/2, 3 and 4 inches to provide output speeds from 1 to 3600 rpm and torque ratings from 2 to 1500 oz-in. Internal brake mechanism permits precise positioning and rapid direction reversal. Japanese Products Corp., 51 Cliff St., New Rochelle, NY 10801. **328**



DIP insertion tool speeds assembly. "Dip-A-Dip" fits all 14- and 16-lead ICs and has an adjustable screw for variable pin length. It allows unskilled assembly personnel to insert a DIP in less than 5 sec. Unit price is $8.50. Micro Electronic Systems, Inc., 30 Lawson Lane, Ridgefield, CT 06877. **329**



"One-Hander" features a self-contained, self-feeding solder source and a special alloy tip requiring no tinning. Several models designed for continuous use are available to meet various application requirements. Bilectro, Inc., 258 El Camino Real, San Bruno, CA 94066. **330**



Accelerometer measures inertial changes as low as 0.000005 G. Accuracy is better than 0.2% of full scale with a resolution of <0.001%. Hysteresis is <0.05% and repeatability is <0.1%. Price in single quantity is $250. Columbia Research Laboratories, Inc., MacDade Blvd. & Bullens Lane, Woodlyn, PA 19094. **331**

Programmable Type-JAEP 4-pole double-throw switch can handle 1A at 100V. It is available as four ON-OFF positions or 1-4 progressive in a package size approximately 1.2 by 1.02 by 0.32 inch. ITT Jennings, Div. of International Telephone & Telegraph Corp., 970 McLaughlin Ave., San Jose, CA 95108. **332**

Incandescent digital readout requires only 0.01A/segment at 4V for 1700 fL brightness. Display size of the microminiature Series 5 is 0.37 by 0.2 inch with a 5° slant. Price is $2.70 in quantities of 1000. Readouts, Inc., Box 149, Del Mar, CA 92014. **333**

Polyimide-insulated magnet wire is silver-plated OFHC conductor insulated with three mils of "Kapton". This wire, available from 34 to 8 AWG, can be used for long periods at temperatures to 240°C and short periods to 400°C. Berk-Tek, Inc., Box 60, 535 N. 5th St., Reading, PA 19601. **334**

Gearmotor is available in nine standard speeds from 1 to 200 rpm with torques up to 50 in-lb. The VW-11 provides high starting torque and excellent braking ability. Solenoid or disc brakes are available. Von Weise Gear Co., 9353 Watson Industrial Park, St. Louis, MO 63126. **335**

Platinum resistance elements are available in 14 standard diameters and lengths and in ceramic-covered and waterproof styles. Three standard diameters in both two-wire and three-wire units are available in the metalclad style. Standard 100Ω elements are provided with either copper or platinum leads. Hy-Cal Engineering, 12105 Los Nietos Rd., Santa Fe Springs, CA 90670. **336**

Microminiature four-position temperature recorder, Model 442, is 1/8 by 3/8 inch and indicates four different temperatures/recorder in ranges from 110 to 450°F. Direct and permanent readout is provided with an accuracy of ±1%. William Wahl Corp., Temp-Plate Div., 12908 Panama St., Los Angeles, CA 90066. **337**

Test socket for "Micro-T" and "Mini-T" miniature axial-lead transistor packages accommodate up to three devices. Hinge top permits fast load/unload operation for burn-in or other test applications. Part No. 0001938 is priced at $1.90 in quantities of 100. Robinson-Nugent, Inc., 800 E. Eighth St., New Albany, IN 47150. **338**

Silicon rubber grounds RF emissions and provides an excellent seal. MOX-CS strip-seals are available in "e," "p," and "d" cross sections and flat forms in practically any length. Moxness Products, Inc., 1914 Indiana St., Racine, WI 53405. **339**

"Quencharc" capacitor/resistor series protects electrical contacts and suppresses high voltage noise. The unit consists of a metallized film capacitor in series with a carbon resistor. Standard capacitance values range from 0.1 to 1 μF. Paktron, Div. Illinois Tool Works Inc., 1321 Leslie Ave., Alexandria, VA 22301. **340**

Polysulfone film dielectric capacitors are available in a new line from 0.001 to 10 μF in 100, 200, 400 and 600V dc ratings. Styles include round and oval wrap and fill, rectangular epoxy with axial or radial leads and hermetically-sealed metal cases. Electro Cube, Inc., 1710 S. Del Mar Ave., San Gabriel, CA 91776. **341**

High-temperature nickel-cadmium battery is rated for continuous operation at 65°C. At temperatures between 25 and 50°C, expected life of the "Goldtop" battery is several times that of conventional units at the same temperatures. A quick-charge version can be recharged in 3-1/2 to 4 hours using conventional chargers. General Electric Co., Battery Products Section, Gainesville, FL 32601. **342**

Epoxy die bonder, for die attachment in the manufacture of hybrid circuit or epoxy strip packs, deposits silver- or gold-filled one-part epoxy with a dot size of 10 to 100+ mils. The Model E-750 utilizes a vacuum system for handling the die. Mech-El Industries, Inc., 73 Pine St., Woburn, MA 01801. **343**

Standard cell is double-salt saturated and has a temperature coefficient of 4 PPM/°C. The "Trancell" is available in conventional "H" configuration or in a small cylindrical shape, Model T3S Type 10, which can be inverted without damage to the cell. Stan-Cell Labs., Inc., Box 143, Dept. 23, Hazlet, N J 07730. **344**

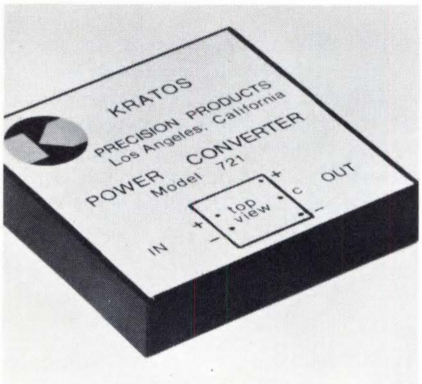
Portable shielded line isolators eliminate high frequency line transients, 60-Hz leakage current and will break ac power ground loops. Units are available with 0.1 to 2 kVA ratings. CEA, Div., of Berkleonics, 1221 S. Shamrock Ave., Monrovia, CA 91016. **345**

Transformer and coil encapsulation compounds require no mixing or de-airing, and are offered in a wide range of viscosities and hardness grades. Cures may be made as rapidly as 30 min. at 300°F or 60 min. at 250°F. Operating temperatures range from 105 to 180°C. Amicon Corp., 25 Hartwell Ave., Lexington, MA 02173. **346**

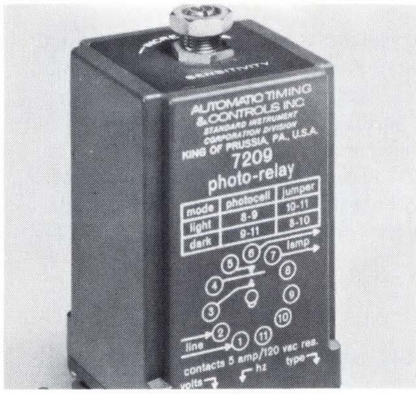
Holographic system includes all the equipment, except the laser, needed to make professional quality 100- by 125-mm holograms. Objects up to 30 cm in any dimension can be accommodated. Price of Model 60-635 is $250. Metrologic Instruments, Inc., 143 Harding Ave., Bellmawr, N J 08030. **347**

Pressure-sensitive tape features a "Kapton" polyimide-film backing and a thermosetting acrylic adhesive. Normal operating temperature range is −40 to 350°F. Various widths from 1/4 to 2 inches are available in standard 18- or 36-yard rolls with thicknesses of 1 or 2 mils. Dodge Industries, Inc., Subs. of Oak Electro/Netics Corp., Hoosick Falls, NY 12090. **348**

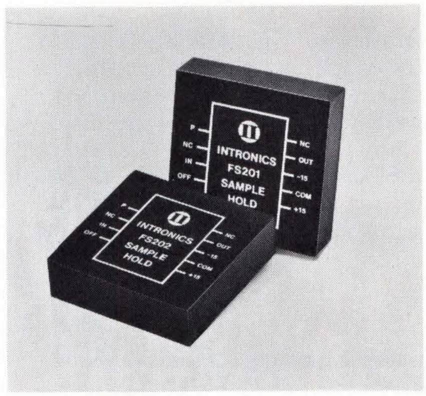
AC rms transducers with overload protection from very high currents are designed to convert watts, vars, current, voltage and frequency to a highly accurate current or voltage output. They are virtually unaffected by frequency variations over a wide span. Multi-Amp Instrument Corp., 61 Myrtle St., Cranford, N J 07016. **349**



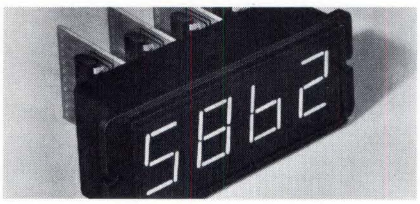
Power converter, Model 721, converts 5V dc to ±15V dc for op amp, D/A and A/D converter applications. Package is 2 by 2 by 0.4 inch and cast of solid epoxy. These precision units feature transformer isolation from input to output, as well as input filtering and magnetic shielding. Precision Products, Div. of Kratos, 11161 W. Pico Blvd., Los Angeles, CA 90064. **350**



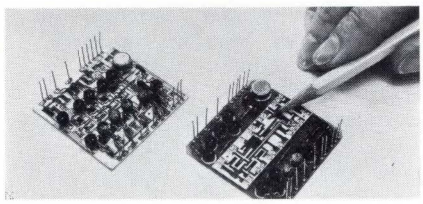
Photoelectric amplifier, Series 7209, requires only a photoresistive photocell receiver, a light source and 120V ac to function as a complete control system. The unit may be wired for either dark or light operation. Sensitivity is adjusted by screwdriver adjustment. Unit price is $50. Standard Instrument Corp. Div., Automatic Timing & Controls, Inc., King of Prussia, PA 19406. **353**



Sample-hold modules, FS201 and FS202, find use in moderate speed, high performance applications. A full-scale 10V signal is obtainable in <30 μsec to accuracies of 0.03% and 0.01% for the two models. Output decay rates (hold mode) are <50 mV/sec (FS201) and 10 mV/sec (FS-202). Prices (1-9) are $55 (FS201) and $80 (FS202). Intronics, Inc., 57 Chapel St., Newton, MA 02158. **356**

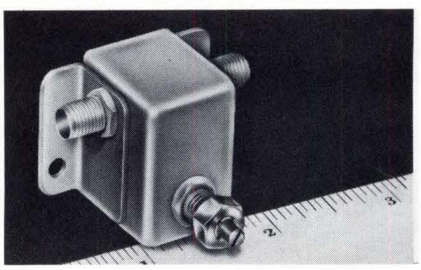


Readout assembly, Series 739, displays from 1 to 10 characters that are 0.625 inch high. The display, made up of gallium phosphide diodes, is arranged in a 7-segment format. Each character is mounted on a PC board with a decoder/driver. Price ranges from $52.25 (100-lot) to $38.85 (1000-lot) for a 4-digit assembly including decoder/driver, bezel and nonglare filter. Dialight Corp., 60 Stewart Ave., Brooklyn, NY 11237. **351**

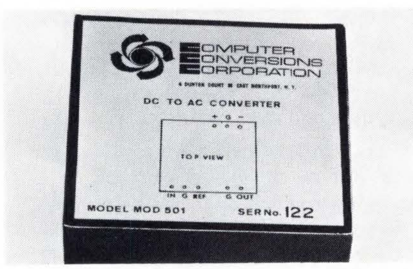


D/A converter DAC-10Z is a pin-for-pin replacement for Model DAC-10H and sells for $29. This redesigned converter provides 10-bit resolution, ±1/2 LSB linearity and ±10V, ±5 mA output. Settling time for ±1/2 LSB accuracy is 5 μsec. Other features include built-in reference source, DTL and TTL compatibility and a 2- by 2- by 0.4-inch modular package. Analog Devices, Inc., Route 1 Industrial Park, Box 280, Norwood, MA 02062. **354**

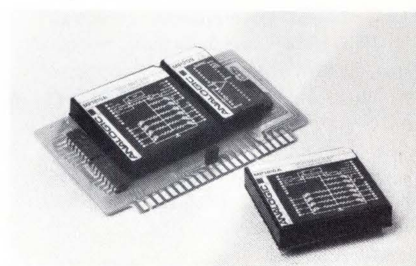
High-level mixers, Models M9AC, M9BC and M9C, operate from 0.05 to 500 MHz. The 1-dB conversion compression point is 10 dBm for the M9AC and M9C and 8 dBm for the M9BC. Packaged in hermetic metal containers, the mixers meet specifications from −54 to 100°C after MIL-STD-202D stressing. Small quantity prices are $55 (M9AC), $75 (M9C) and $90 (M9BC). Relcom, 2329 Charleston Rd., Mountain View, CA 94040. **357**



Variable attenuator, Model ARM-1, offers optimum performance from dc to 50 MHz. Because of inherent broadband characteristics, it can operate up to 400 MHz. The 1.44- by 1.1- by 0.94-inch unit weighs 1.4 oz. Other minimum specifications include 0 to 20 dB attenuation range, 1 dB insertion loss, and 1.2:1 VSWR. Small quantity price is $80 each. Merrimac Research & Development, Inc., 41 Fairfield Pl., West Caldwell, N J 07006. **352**



DC-to-dc converter MOD 501, a proportional phase reversing type, accepts ±10V dc and provides 0 to 6V rms output. Full-scale linearity is ±0.1%. These 3- by 3- by 0.625-inch units have an output impedance of only 5Ω max, and are insensitive to ±10% reference line changes. Power requirement is ±15V at 20 mA max. Price for OEM quantities is $89 each. Computer Conversions Corp., 6 Dunton Ct., East Northport, NY 11731. **355**



D/A converters, MP1810A and AN1810M, are DTL/TTL compatible and are available in all standard unipolar and bipolar 10-bit configurations. Typical settling time (1/2-bit accuracy) is 4 μsec. Typical TCs of range and offset are 10 PPM/°C and 50 μV/°C, respectively. The dc reference is internal, and the operating temperature range is 0 to 70°C. Prices range from $69 to $94. Analogic Corp., Audubon Rd., Wakefield, MA 01880. **358**

Amplifier/limiter Model T7804, a broadband, circulator coupled tunnel diode amplifier, compresses 30 dB input range into 11 dB output. Small signal gain is 42 dB ±2.5 dB minimum and the noise figure is 7 dB maximum. Frequency range is 7 to 11 GHz. Aertech Industries, 825 Stewart Dr., Sunnyvale, CA 94086. **359**

Switches and switch-driver assemblies operate in the 2 to 2000 MHz range. Standard models include SPST, SPDT and DPDT transfer configurations. Typical values for standard units are <1 dB insertion loss and >60 dB isolation. Prices start at $95 each. Hyletronics Corp., Newtown Rd., Littleton, MA 01460. **360**

Three-phase ac parametric converters, designated "Phasac", provide Wye or Delta outputs of 120V ac (4-wire), 208 or 230V ac (3-wire) at 0.3 and 1 kVA. Output is regulated to within ±5%. Only passive and magnetic components are used. Wanlass Div. of AMBAC, 525 Virginia Dr., Fort Washington, PA 19034. **361**

Miniature UHF receiver, Model TRR01, is designed specifically for "tone ranging" applications. Options available in similar models include 130 to 550 MHz frequency range and 6 to 750 kHz IF bandwidth. Bayshore Systems Corp., 5406 A Port Royal Rd., Springfield, VA 22151. **362**

Differential FET-input op amp FST-160 A/B is capable of settling to 0.01% of full scale (±10V) within 0.6 μsec. Slewing rate is 100V/μsec. Unit prices are $49 to $55. Dynamic Measurements Corp., 6 Lowell Ave., Winchester, MA 01890. **363**

FET operational amplifier, Model 1027, settles to within 0.01% of final value in 0.8 μsec. Slew rate is 75V/μsec. Output is ±10V at 20 mA. Price is $33.50 each in 1 to 9 quantity. Teledyne Philbrick, Allied Dr. at Rte. 128, Dedham, MA 02026. **364**

Synchro signal converter, called "Torqsyn", translates either 60-Hz inputs to 400-Hz outputs or 400 Hz to 60 Hz. System is immune to high transient voltages and currents. Vernitron Control Components, Div. of Vernitron Corp., 2440 W. Carson St., Torrance, CA 90501. **365**

Series of 2- and 4-port multicouplers operates in the 1.5 to 125 MHz frequency range, occupies 0.08 in³ and either mounts in a 14-pin DIP socket or can be soldered on a PC board. Small quantity price is <$25. Elcom Systems Inc., 151-24 W. Industry Court, Deer Park, NY 11729. **366**

Solid-state time-delay relays have repeat accuracies of ±5%. Two timing ranges are available: 0.3 to 30 and 3 to 300 sec. Voltages offered are 115V ac and 24V dc. Relays plug into standard octal socket. Deflecto Mfg. Div., Amperite Co., Inc., 600 Palisade Ave., Union City, N J 07087. **367**

Video buffer amplifier VB950 is a variable gain, complementary emitter follower voltage amplifier for CRT display systems. Bandwidth is dc to >50 MHz (output terminated in 50Ω). Input impedance is 1 kΩ with <5Ω output impedance. Celco Pacific Div., 1150 E. 8th St., Upland, CA 91786. **368**

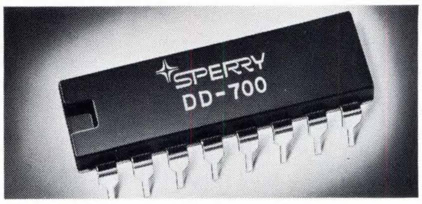
Temperature-compensated crystal oscillators, designated TCXO, come in two frequency groups—4.5 to 15 MHz and 20 to 60 MHz. Output is a distorted sine wave with the first harmonic approximately 15 dB down. Price in 1000 lots is $45 each. Amperex Electronic Corp., Hicksville, NY 11802. **369**

Solid-state voltage comparator, "Voltsensor" Model 550, has a set point resolution and repeatability of 1 mV, hysteresis <50 mV, operating time <25 μsec and trip point stability <8 mV/°C. Price ranges from $38 (single unit) to $26.60 (100 units). California Electronic Mfg. Co., Inc., Box 555, Alamo, CA 94507. **370**

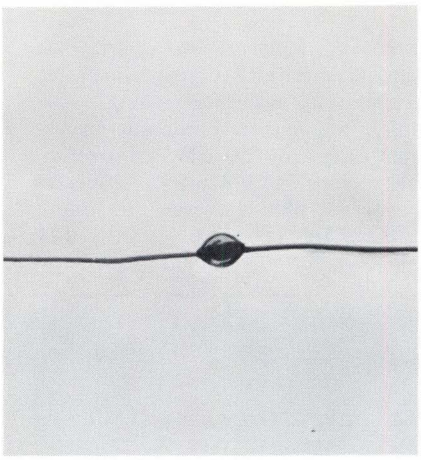
Digital panel meter, Series 200A, with automatic polarity sensing sells for $139. Providing 0.1% resolution reading ±1999 counts of any four dc voltages or five dc current ranges, the units have a programmable reading rate of 4 to 60/sec. Newport Laboratories, 630 E. Young St., Santa Ana, CA 92705. **371**

1020 TURNPIKE STREET, CANTON, MASSACHUSETTS 02021 / TELEPHONE (617) 828-6395 TWX 710-348-0135

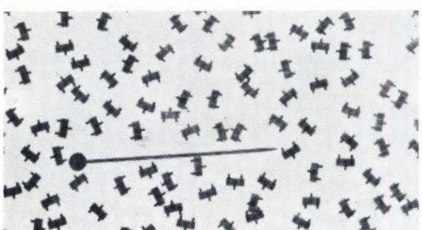
CIRCLE NO. 24



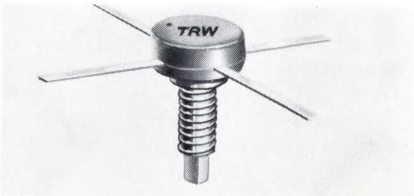
Monolithic decoder/driver, Model DD-700, accepts 8-4-2-1 BCD input (DTL/TTL compatible) and decodes the information to generate an output for driving a 7-segment display. The hexidecimal output can be used to generate numerical readout from 0 to 9 and letters A through F. The unit comes in a standard 16-pin dual in-line package. Sperry Information Displays Div., Box 3579, Scottsdale, AZ 85257. **372**



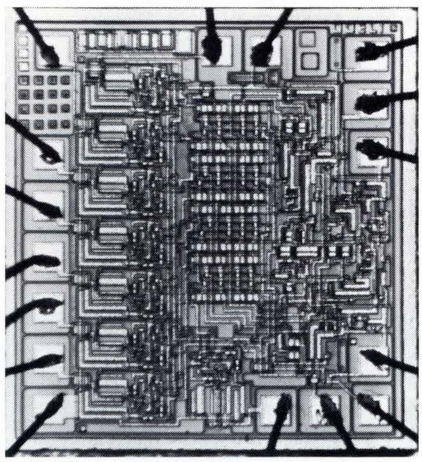
High-voltage diodes have a maximum reverse current of 2 nA at peak-inverse voltage ratings from 1 to 4 kV and a continuous forward current of 20 mA. These 0.06- by 0.06- by 0.13-inch diodes have a maximum capacitance of 1 pF at 0V. Scientific Components, Inc., 350 Hurst St., Linden, N J 07036. **373**



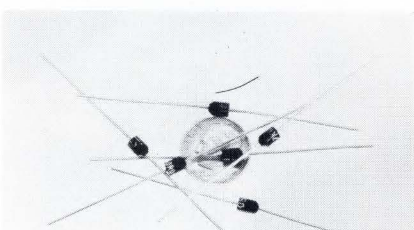
Miniature transistors, ET60 (npn) and ET61 (pnp), are intended for thin- and thick-film applications for AF input stages and switching requirements. Characteristics include 5V base emitter voltage, 8 pF output capacitance and 150 mW power dissipation rating. Price (1000 pieces) is $0.42 each. European Electronic Products Corp., 10150 W. Jefferson Blvd., Culver City, CA 90230. **374**



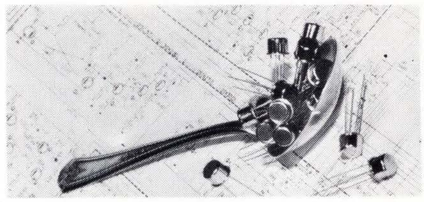
12.5V linear power transistor PT5741 provides 30W PEP or CW across the 1.5 to 30 MHz band for single-sideband applications. The device has 13 dB power gain, 30 dB or better intermodulation distortion and will withstand all phase infinite VSWR at 16V in a broadband circuit at full power output. Price is $21.75 each for 100-up quantities. TRW Semiconductor Div., Communication Products Plant, 14520 Aviation Blvd., Lawndale, CA 90620. **375**



Eight-channel CMOS multiplexers, HI-1818 and HI-1828, come in two configurations—eight switches with one common output (HI-1818) and two sets of four switches, each having its own common output (HI-1828). Prices (100 to 999) are $29.95 (commercial) and $39.95 each (military). Harris Semiconductor, Melbourne, FL 32901. **376**

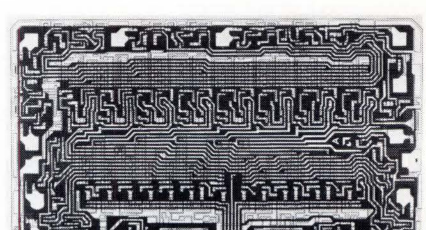


One-amp epoxy rectifier Series HSR-0 has a forward voltage drop of <0.5V with maximum reverse recovery of 9 nsec and maximum forward recovery of 1 nsec. This series is composed of five separate types: 1RO, 2RO, 5RO, 7RO and 10RO with peak-reverse voltages of 10, 25, 50, 75 and 100, respectively. Solid State Devices, Inc., 12741 Los Nietos Red., Santa Fe Springs, CA 90670. **377**



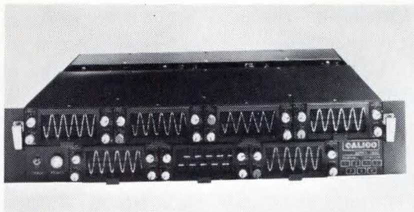
Current sensor employs a low resistance load current-carrying element to trigger a transition metal-oxide polyconductor thin-film output device. The output element changes from 100 kΩ typical to 500Ω on the application of overload currents >150% of rated current. Devices are available in current ratings of 0.25, 0.5, 1 and 1.8A. Superior Electronics Inc., 2255 Dandurand St., Montreal 331, Quebec, Canada. **378**

RF transistor XB50-28 is a 400-MHz, 28V device having 50W power output, 12 dB gain and an input Q of <2. The unit is a single chip, hermetically sealed in a new "Microstrip" package (patent pending). Price is $90 in 1 to 99 quantities. Communications Transistor Corp., 301 Industrial Way, San Carlos, CA 94070. **379**

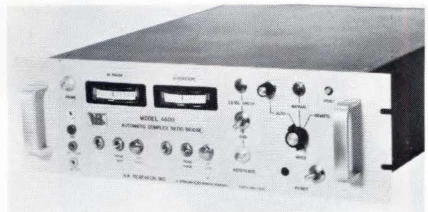


Eight-bit multiple port register Am9338 is a three-address memory capable of simultaneous read/write operation. Organized as 8 words by 1 bit, this memory has maximum power dissipation of 99 mA and guaranteed write and read times of 16 and 65 nsec, respectively. Prices for 100-up quantities range from $5.40 to $11.80. Advanced Micro Devices, Inc., 901 Thompson Pl., Sunnyvale, CA 94086. **380**

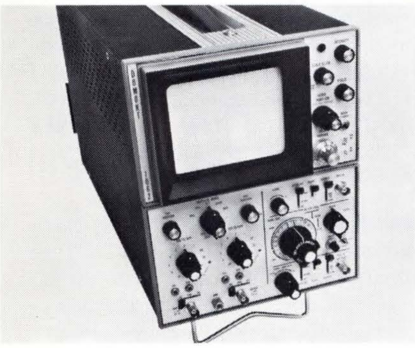
Digital voltmeter with 4-1/2-digit LED display, Model 266, has 0.02%-of-reading accuracy, resolution of 100 μV and voltage measurement to 1000V dc. Features include guarded input, isolated BCD and system functions and both self-check zero and calibration controls on front panel. Price is $525. United Systems Corp., 918 Woodley Rd., Dayton, OH 45403. **381**



Seven-channel monitor scope in 3-1/2-inch package, Model 7000, features no vertical drift between 0 and 55°C, bandwidth from dc to 10 MHz, sensitivity from 50 mV/inch to 10V/inch and automatic triggering on a 5-mV signal. CRT face is 1 by 3 inches. Price is $2795. California Instruments Co., 5150 Convoy St., San Diego, CA 92111. **384**



Automatic complex ratio bridge, Model 4400, is designed for use with several systems. Features include all solid-state switching, BCD printer output, tracking mode, operation in manual, automatic or remote mode and accuracy to ±0.02%. Both in-phase and quadrature are measured simultaneously. NH Research, Inc., 1510 S. Lyon St., Santa Ana, CA 92705. **387**

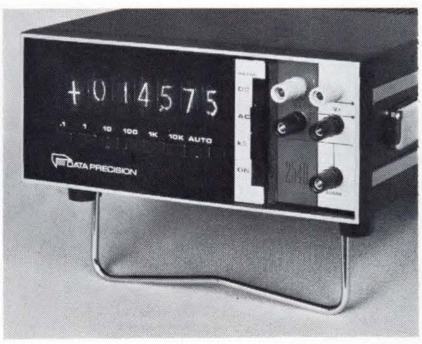


Sixty MHz scope family has 8- by 10-cm screen and features calibrated delayed sweep, variable hold-off, plug-in transistors and a minimum of variable components. Model 1062 with delayed sweep is priced at $2045 in either cabinet or rack version. Model 1063 without delayed sweep sells for $1845 in either version. Dumont Oscilloscope Laboratories, Inc., 40 Fairfield Pl., W. Caldwell, N J 07006. **382**

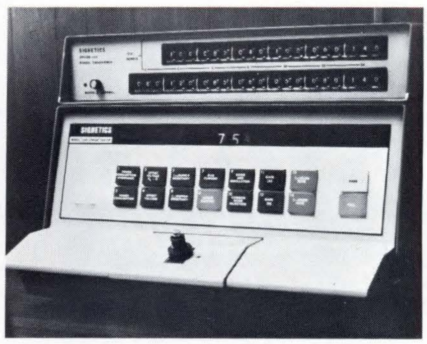
Frequency synthesizers with frequency range of 0.01 Hz to 13 MHz have harmonic content from 40 to 60 dB down, depending on frequency setting. Model 3320A with uncalibrated output sells for $1900, while Model 3320B (calibrated output) sells for $2400. Both synthesizers are programmable, and digital remote control is an option. Hewlett-Packard Co., 1601 California Ave., Palo Alto, CA 94304. **385**

DMM with LED readout and function indicator accepts all plug-in card options for the earlier Model 350. Model 351 features dual-slope integration and autorange, and provides four dc ranges with 80% overrange capability and settable reading speed from 1 to 10/sec. Base price is $749 including autorange. Data Technology Corp., 1050 E. Meadow Circle, Palo Alto, CA 94303. **388**

Flatness measuring instrument with accuracies to 1/20 wave (0.000001 inch) is self contained and needs no external light source or reference flat. The "flatscope" weighs 13 oz, operates from 115V ac and is priced at $195. Optical Industries, Inc., 1218 E. Pomona St., Santa Ana, CA 92707. **383**

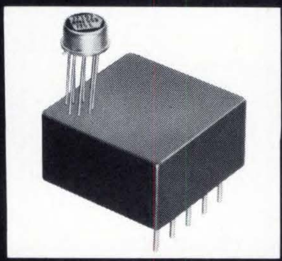


DMMs of the 2500 Series are 5-1/2-digit instruments that provide autoranging, isolated remote control and isolated digital outputs. Prices range from $995 for Model 2520 with dc volts and dc ratio to $1195 for Model 2540 with ac and dc volts, ohms and dc ratio. Data Precision Co., Audubon Rd., Wakefield, MA 01880. **386**



Manual programmer (Option 450), when used with Signetics Model 1420 linear IC tester, permits users to make rapid changes in parameter test limits without modifying existing (or building new) program boards. Price for the option is $980. Signetics Measurement/Data, 341 Moffett Blvd., Mountain View, CA 94040. **389**

HOW MANY OP AMPS



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Equipment

DVM/multimeter features input noise kickback of less than 1 mV into 1 MΩ source. The 5-1/2-digit Model 7005A provides four dc voltage ranges and incorporates a built-in active filter. Price starts at $1295 including filter, reaching $2200 with all standard options. Systron-Donner Corp., 888 Galindo St., Concord, CA 94520. **390**

Real-time audio spectrum analyzer covers from 40 Hz to 16 kHz with 27 parallel bandpass filters. Model 8050A, priced at $3018, has built-in scope and power supply. Altec, Inc., 1515 S. Manchester Ave., Anaheim, CA 92803. **391**

Thermistor temperature controller permits direct dialing from −10 to 80°C and controls as close as 0.05°C. Model 74 uses interchangeable thermistor probes. Indicator lights signal whether temperature is above or below the set point. Price is $170 each. Yellow Springs Instrument Co., Yellow Springs, OH 45387 **392**

Computer-controlled component insertion system handles intermixed 14- and 16-lead DIPs at rates up to 4000/hr. The Model DIP-A/K 1 can be supplied as a stand-alone unit or as part of a larger system. USM Corp., 140 Federal St., Boston, MA 02107. **393**

Diagnostic system for data networks automatically performs fast, accurate, end-to-end testing and is easily used by nontechnical personnel. The "Detect" unit may be either desk or wall mounted and is permanently connected into the circuit. Data Products Corp., 6219 DeSoto Ave., Woodland Hills, CA 91364. **394**

Keyboard tester dynamically performs five tests on any electronic board in 15 sec. Featuring a custom read-only memory, the Model 1600 employs 8-bit lines that permit testing of any electronic keyboard (with up to 76 keys) against the preprogrammed ROM. Either positive or negative strobe signals are handled, and logic levels may be positive or negative DTL/TTL. Price is $1480 each. Controls Research Corp., 2100 S. Fairview, Santa Ana, CA 92704. **395**

Sound/noise level alarm, priced at $120, is equipped with the A weighted scale and flashes a red warning light when a preset level (between 85 and 100 dB) is exceeded. Ophthalmic Div., Bausch & Lomb, 465 Paul Rd., Rochester, NY 14624. **396**

Vibration analyzer/dynamic balancer, Model 5115, measures the amplitude and frequency of machine vibration and displays the waveform on its built-in scope. Response to displacement, velocity or acceleration is selectable. Options include an oscilloscope camera and a stroboscope. Metrix Instrument Co., Box 36501, Houston, TX 77036. **397**

Touch-tone decoder, Model 200, features an LED readout. Encoded tone signals may be inputed as fast as 40 msec/digit. Price each is $960. Voice-Print Laboratories Corp., Subs. of Motek Corp., Box 835, Somerville, N J 08876. **398**

Digital comparator features dual limits of either polarity, continuous or controlled comparisons, built-in control relays, limit lights and complete comparison logic code selections. Model CD-200 is priced at $425 each. Dixson Instruments, Box 1449, Grand Junction, CO 81501. **399**

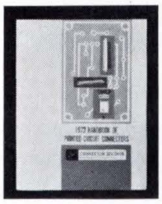
Sound-level meter, Type 1565-B, meets requirements of ANSI S1.4-1971 Type 2 specification. It operates up to 50 hrs on self-contained batteries and permits measurements with A, B or C weightings. Price is $365 each. General Radio, 300 Baker Ave., Concord, MA 01742. **201**

Digital capacity meter/converter features 4-1/2-digit readout with 0.05% resolution. Capacitance ranges are from 2 to 2000 pF, and the Series 2450 makes three-terminal single capacitor or differential measurements. Price is $1875 each. Spearhead, Inc., 1401A Cedar Post Lane, Houston, TX 77055. **202**

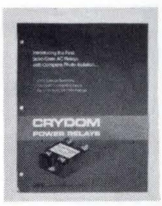
Computer-automated test system features the PDP-11 computer along with Model 3610 system interface unit. Adding Model 7110 multimeter and 6153 universal counter provides for automatic measurements of frequencies to 3 GHz, time to 10 nsec and ac/dc volts and resistance to 5-1/2 digits. Including a Series 154 pulse generator provides programmable pulses to 50 MHz. Typical system cost is $50,000. Systron-Donner Corp., 888 Galindo St., Concord, CA 94520. **203**

Automatic micrometer sorter reads directly to 0.0001 inch and handles 240 parts/min. Setup is simple, and no lubrication is required for the life of the instrument. Price is $1895. Ellipsco, Inc., 7990 Dagget St., San Diego, CA 92111. **204**

Photosensors providing high spectral response in the blue (400-nm) region are described in Catalog No. 114. Curves illustrate typical output, time responses, temperature characteristics and short-circuit current characteristics. Sensor Technology, Inc., 7118 Gerald Ave., Van Nuys, CA 91406. **205**



"Handbook of Printed Circuit Connectors," 1972 edition, displays seven basic connector series for use with printed circuit boards. Dimensions and contact hole patterns are detailed. Positronic Industries, Inc., Connector Div., 1906 S. Stewart, Springfield, MO 65804. **206**

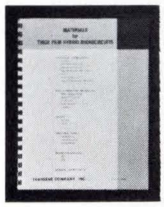


Solid-state dc relays with complete photo isolation are described in a brochure featuring six different models. Units operate from a minimum 1.5 mA, 3V dc signal and switch 2, 10 and 25A at 120 and 240V. Crydom Div., International Rectifier Corp., 1521 Grand Ave., El Segundo, CA 90245. **207**

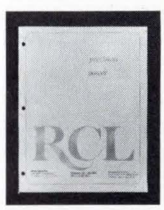
Product selection guide contains instrument photographs, short descriptions, abbreviated specifications and complete prices on digital multimeters, oscilloscopes, digital measuring systems, tube and transistor testers, data collection terminals and card and industrial readers. Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, OH 44108. **208**

Scanning electron microscope is described in Bulletin 3000. Contents include a brief history and review of analytical microscopy, basic operating principles of the Ultrascan SM-3, various detection schemes and hardware description. Ultrascan Co., 18530 S. Miles Pkwy., Cleveland, OH 44128. **209**

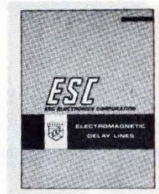
Voice response units designed for use with any computer are featured in this four-page booklet describing the "Digitalk" 256 and 3100. Both units utilize magnetic drum memories but differ in the amount of word storage. Metrolab, Inc., 10457 Roselle St., San Diego, CA 92121. **210**



"Materials for Thick Film Hybrid Microcircuits" contains 22 pages of information on conductor cermet pastes, temperature metallizing, low temperature bonding, dielectric pastes, protective coatings and resistor cermet. A selector guide is included as an application aid. Transene Co., Inc., Rte. 1, Rowley, MA 01969. **211**



"Precision and Power Wire-Wound Resistor Engineering Handbook" provides data on 19 separate resistor series, DIP networks and ladder and summing networks. Also included are specifications on dual-function fuse resistors, engineering curves and resistance vs temperature characteristics. RCL Electronics, Inc., 700 S. 21st St., Irvington, N J 07111. **212**



Electromagnetic delay lines are covered in this 20-page catalog, which includes such types as distributed constant, continuously variable, low-profile and standard PC mounting, nanosecond, extended delay/rise time and others. ESC Electronics Corp., 534 Bergen Blvd., Palisades Park, N J 07650. **213**

Oscillators are the subject of this 20-page catalog which describes VCOs and crystal, high stability, low current drain, computer clock and power oscillators. Frequency and power conversion charts are included. Accutronics, 628 North St., Geneva, IL 60134. **214**

Solid-state miniature modules are described in this 32-page short form catalog. Converters, oscillators, pulse generators, amplifiers, choppers, transformers and others are presented with specifications and application information. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, CA 91343. **215**

"Modular Test Equipment" is the title of a 20-page booklet describing angle shaft positioners, angle indicators, synchro-resolver standards, level sensor alignment components, portable readout displays and dial assemblies. Typical application diagrams are included. Singer Co., Kearfott Div., 1150 McBride Ave., Little Falls, N J 07424. **216**

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Literature

Capacitive read only memory (CROM) is the subject of a technical bulletin which contains a section on theory of operation, system features and performance characteristics with a typical timing sequence. Various system configurations illustrate the flexibility of the system for use in different applications. Integrated Memories, Inc., 260 Fordham Rd., Wilmington, MA 01887. **217**

"Keyboard News" is a quarterly publication with news of design, production, application and keyboard theory to keep management and engineering staffs abreast of keyboard progress. Micro Switch, Div. of Honeywell Inc., 11 W. Spring St., Freeport, IL 61032. **218**

"Real Time—Time Compression Spectrum Analysis" is the title of a 12-page technical bulletin discussing spectrum analysis techniques, parameter selection and interplay, use of a digital integrator, and the "Saicor" spectrum analyzers and various signal processing systems. Signal Analysis Industries Corp., 595 Old Willets Path, Hauppauge, NY 11787. **219**

Programming switch for PC boards that provides the function of rotary and slide switches in a low profile package is described in a two-page data sheet. Siemens Corp., 186 Wood Ave. S., Iselin, N J 08830. **220**

Cordsets, wiring assemblies, wiring harnesses and wire leads are covered in a 24-page catalog that includes selection tables and a guide that identifies the UL and CSA approved power cords for more than 130 manufactured products. J. E. Messenger Co., 117 Republic Ave., Joliet, IL 60434. **221**

Instruments for cassette drives and cassettes are described in a brochure that features a torque tester, head and guide gauge and a tension monitor. Information Terminals Corp., 1160 Terra Bella Ave., Mountain View, CA 94040. **222**

Gear motors are the subject of a four-page brochure that provides dimensions, mounting patterns, speed and torque specifications and material features of a wide range of subfractional-horsepower gear motors. Mec-O-Matic Co., 8515 S.W. 129th Terrace, Miami, FL 33156. **223**

IC product guide provides quick-reference application charts and data, device features, definitive data, schematic, block and logic diagrams, dimensional outlines, package and socket information and a complete listing of available technical literature for linear and digital ICs. Form No. CDL-820D contains 48 pages. RCA Commercial Engineering, Harrison, N J 07029. **224**

Tuning-fork and crystal oscillators are the subjects of Bulletin 71C, an eight-page catalog. A guide to oscillator specification and a brief description of precision frequency power inverters are included. Fork Standards, Inc., 211 Main St., West Chicago, IL 60185. **225**

Cathodochromic storage display is described in a data sheet that provides complete specifications, photographs and ordering information on the Model D-20. The unit can display and store alphanumeric, graphic and pictorial information from computers, data banks, facsimile systems and other sources. Optel Corp., Box 2215, Princeton, N J 08540. **226**

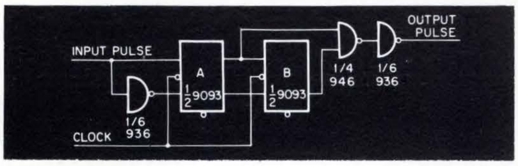
Microminiature solid-state electronic choppers are listed providing comparative data for 23 different models of germanium and silicon units. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, CA 91343. **227**

"Solid State Sources" is the title of a six-page brochure that provides comprehensive specifications on phase-locked, cavity-stabilized, crystal-controlled and free-running oscillators as well as complete receiver front end assemblies. Engelmann Microwave Co., Skyline Dr., Montville, N J 07045. **228**

"Maintenance in a Case" kit for electrical, temperature and rpm measurements is described in a two-page data sheet detailing the Model 990 analyzer and its accessories. Triplett Corp., Bluffton, OH 45817. **229**

Optoelectronic encoder assemblies are discussed in New Product Application No. 21 which outlines systems applications for the OPB 120, 242 and 243 assemblies. Electrical and mechanical specifications are provided. Optron, Inc., 1201 Tappan Circle, Carrollton, TX 75006. **230**

New "One-Shot" or Old "Edge Detector"



Reader Charles Conkling of Logos Designs has written to us commenting on this circuit ("Synchronized One-Shot," by Frank Nesbitt of McDonnell Douglas Electronics) which appeared in the May 15 issue. He says that the circuit is not new and points out that it should more correctly be called an "edge detector" rather than a "one-shot". Here is part of his letter:

"When I see my favorite edge detector or clock sync called a 'one-shot,' I get a little upset. The circuit has a number of outstanding features that come from its ability to synchronize an external pulse to an internal clock. The author is correct in stating that the input pulse should be five times the width of the internal clock pulse, but the output pulse is one full internal clock period (not two clock pulses as stated in the article). The circuit detects the leading edge, trailing edge or both. The expressions for these functions are:

$A \cdot \overline{B}$ = leading
$\overline{A} \cdot B$ = trailing
$A \oplus B$ = both

These expressions depend upon the logic sense of the input pulse. Also, if TTL is being used, the NOR allows a decode with a single gate."

We asked Frank Nesbitt to respond to these comments. He agreed that there was an error in the article: the output pulse has a duration of only one clock pulse. He also agreed that the circuit will trigger on either edge of a pulse and said that he has used the circuit both ways. Regarding the title of the article, he says that the actual name chosen is rather insignificant. The important thing is that whatever it's called, the circuit is a powerful tool.

In response to the article "Let's Gang Up on Pollution" by Charles House (Jan. 1, 1971), EDN/EEE received the following ecological soliloquy.

Pollution

"Do nothing in excess", the wise Greeks said,
"Collectively or individually";
In every case, the piper must be paid
– But man ignores his ancient history.
Each culture has within itself the seeds
Of self-destruction, ruin, and decline
When heedlessly, to satisfy its needs,
It flouts the pleas of Nature and of Time.

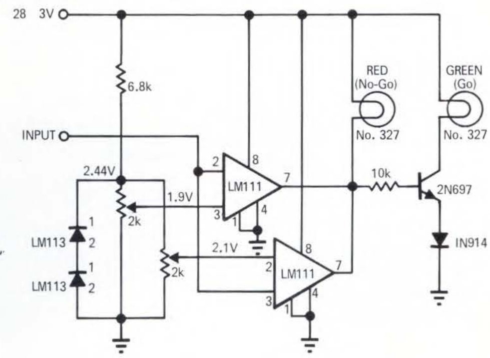
And so it's come to pass upon this earth:
Mankind has wrought excess of poverty,
Noise, poisons, hatreds, crimes, sex, Human Birth
– Excess of everything but Charity.

Thus planets through their own pollution die,
And float as littered coffins in the sky.

-Harry de Metropolis
(20th Century)

"That's a good design you gave us – now, give us an idea as to where we can get the money to build it."

Comparators Compared



Improved Window Comparator Schematic

Several letters have been received commenting that Mr. Nirschl went to unnecessary trouble and expense in the design of his "Window Comparator" which appeared in the June 15th issue.

Mr. Durward Priebe of National Semiconductor Corp. submitted the circuit shown below with the comments: ". . . This circuit uses 12 components, runs off one unregulated 28V supply, requires only 120 nA from the voltage level being monitored and yields twice the measured stability of the previous circuit. Threshold level stability was found to be within 0.3% over the −55 to 55°C temperature range using a 28V supply varied ±3V."

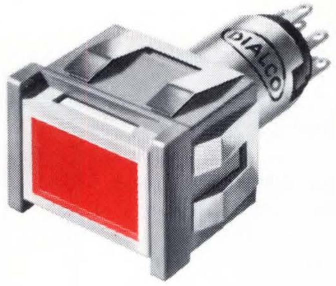
Mr. Robert Dadd of California Electronic Manufacturing Company pointed out that his company markets over 40 different models of comparators under the name "Voltsensor."

Mr. Nirschl's reply: ". . . No question, Mr. Priebe's circuit is indeed a lot simpler than what I had described. It was not until recently that I became aware of the LM111 IC comparator by National Semiconductor, which evidently is ideally suited for the (window) comparator function. It apparently can operate from a single supply, is capable of switching relatively high loads and features low input current and offset voltage. As far as the relative complexity and component count of my circuit are concerned, I can only state that at the time (1970) this was my approach to the problem, and considering that this circuit could replace a commercial potted (nonrepairable, discrete circuit) module costing approximately 12 times the component cost of the IC circuit I used (about $30), for the same function, I thought it was an economical approach at that.

Let me also explain the following: One of the more costly parts avoided in Mr. Priebe's circuit is the relay, and I certainly appreciate Mr. Priebe's thought that there was no reason for having a relay in order to switch the load current of the #327 bulb (approx. 20 mA). I chose to retain a relay in the circuit for better isolation and independence of the indicator circuit. This permits, for example, the use of low voltage ac (400 Hz) powered incandescent bulbs which are popular in avionics equipment (apparently due to higher reliability). Regarding the two voltage regulators (15V), I should mention that they were not specifically introduced for the comparator circuit, but already available within the system of which the comparator was a part."

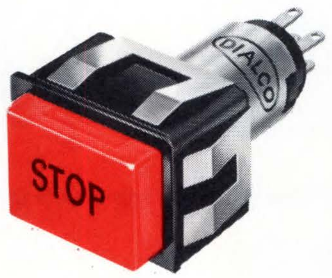
You say you want a

low-profile snap-in-mounting push button switch or matching indicator that is interchangeable with most 4-lamp displays . . . available in a full range of cap colors . . . with a choice of bezels with or without barriers in black, gray, dark gray or white.



and a

legend presentation that's positive (like this one) or negative (like the one below) or just plain (like the one above) . . . one that's white when "off" and red, green, yellow (amber), blue or light yellow when "on" . . . or colored both "on" and "off."



and a

highly reliable switch proven in thousands of installations . . . available in momentary or alternate action . . . N.O., N.C. or two circuit (one N.O., one N.C.) . . . that accommodates a T-1¾ bulb with midget flanged base, incandescent, in a range of voltages from 6-28V.

etc.
etc.
etc.

Now, for the first time Dialight gives you custom panel designing with a standard line of push-button switches and matching indicators

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Dialight Corporation, 60 Stewart Ave., Brooklyn, N.Y. 11237 DT-125

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Application Notes

"Plain English Guide to Specifications—Electronic Temperature Controllers," Bulletin 52-4057, gives a brief background in control theory. A seven-page table defines control terminology and provides a basis for evaluating specifications. Honeywell Inc., Apparatus Controls Div., 2727 S. Fourth Ave., Minneapolis, MN 55408. **231**

Multi-axis Fresnel lens is described in Technical Paper No. 409. It discusses use of the lens in smoothing the spatial output of LED arrays and other non-uniform light sources. Instrument Development Services, Box 8186, Irondequoit Plaza Station, Rochester, NY 14617. **232**

"Reduce Hum, Crosstalk & Stray Pickup—DC-1000 MHz" is an application note that discusses problems involved when the elements of an electronic system are interconnected with transmission lines. Solutions are offered involving the use of power-line isolation transformers, signal isolation transformers, signal isolation chokes and photon coupled isolators. Deerfield Laboratory, Box 1300, Los Altos, CA 94022. **233**

MOS/LSI IC Catalog CC-402 contains 314 pages with specifications, schematics, cross-reference guide, package details and applications data. Data sheet information is provided for shift registers, ROMs, programmable logic arrays, RAMs and special purpose circuits. Texas Instruments Incorporated, Box 5012, MS/308, Dallas TX 75222. **234**

"Programming and Minicomputer Costs" is a six-page article reprint that discusses the minicomputer software situation and sets down guidelines for programming that will yield minimum cost solutions. Interdata, 2 Crescent Pl., Oceanport, N J 07757. **235**

IMPATT diodes used in microwave power generation and amplification are discussed in a 32-page application note, AN 935. Principles of operation and construction of IMPATT diodes are discussed along with a description of diode design in oscillator and amplifier circuits. Several practical circuit designs are described, and an extensive bibliography is included. Hewlett-Packard Co., 1601 California Ave., Palo Alto, CA 94304. **236**

"Effects of Electromagnetic Coupling Between DC Motor and Tachometer on Servo Stability" provides a black-box model, an analysis of the problem and a conclusion that describes a technique for measuring this coupling. It is available by letterhead request to Torque Systems, Inc., Box 167, 225 Crescent St., Waltham, MA 02154.

"The Western Electric Engineer" has a special July/October issue that contains 18 articles on subjects ranging from plastics extrusion to manufacturing aluminum-conductor cable. Western Electric Technical Information Dept., 195 Broadway, New York, NY 10007. **238**

High-power frequency converter with variable frequency three-phase output is described in application note, AN-4673. This note shows schematic diagrams and discusses the operation of a converter that delivers 120/208V rms at frequencies from 380 to 1250 Hz. Waveshapes for each circuit and transformer construction details are shown, as well as output waveforms and performance curves. RCA Commercial Engineering, Harrison, N J 07029. **239**

Reprints Available

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L64	Look, No Contacts	33
L65	Versatile Inexpensive Pulse Generator	37

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CIRCLE NO. 27

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RCA Solid State

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TA6018W	Decade Counter/ Divider with 7 Segment Display Outputs (Display Enable Input)	CD4026AD CD4026AE CD4026AK	16 pin DIC 16 pin DIP 16 pin F.P.	12.50 5.95 13.15
TA5872W	Dual J/K F-F with Set/Reset	CD4027AD CD4027AE CD4027AK	16 pin DIC 16 pin DIP 16 pin F.P.	5.50 2.65 6.15
TA5873W	BCD to Decimal Decoder	CD4028AD CD4028AE CD4028AK	16 pin DIC 16 pin DIP 16 pin F.P.	8.25 4.10 8.90
TA5925W	Presettable, up/down Counter, Binary or BCD Decade	CD4029AD CD4029AE CD4029AK	16 pin DIC 16 pin DIP 16 pin F.P.	\$11.95 5.75 12.60
TA5940W	Quad Exclusive OR Gate	CD4030AD CD4030AE CD4030AK	14 pin DIC 14 pin DIP 14 pin F.P.	3.95 1.55 4.60
TA5963W	Triple Serial Adder (Positive Logic Version)	CD4032AD CD4032AE CD4032AK	16 pin DIC 16 pin DIP 16 pin F.P.	7.20 4.25 7.85
TA5677W	Decade Counter/ Divider with 7 Segment Display Outputs (Ripple Blanking)	CD4033AD CD4033AE CD4033AK	16 pin DIC 16 pin DIP 16 pin F.P.	12.50 5.95 13.15
TA5951	Triple Serial Adder (Negative Logic Version)	CD4038AD CD4038AE CD4038AK	16 pin DIC 16 pin DIP 16 pin F.P.	7.20 4.25 7.85

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