Electronics®

Party-line data link: page 119

Fast Fourier speeds signal processing: page 124

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April 15, 1968
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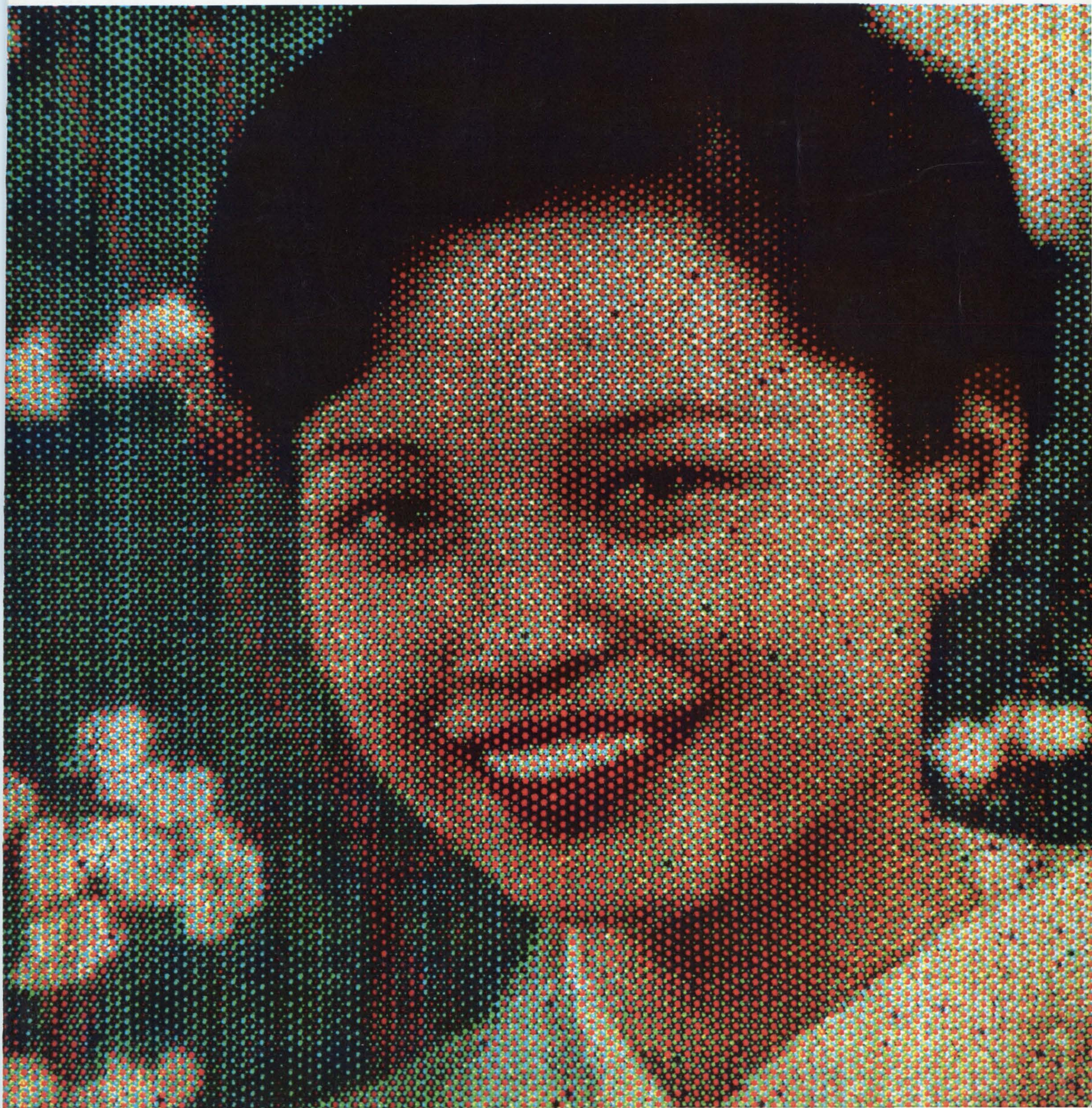
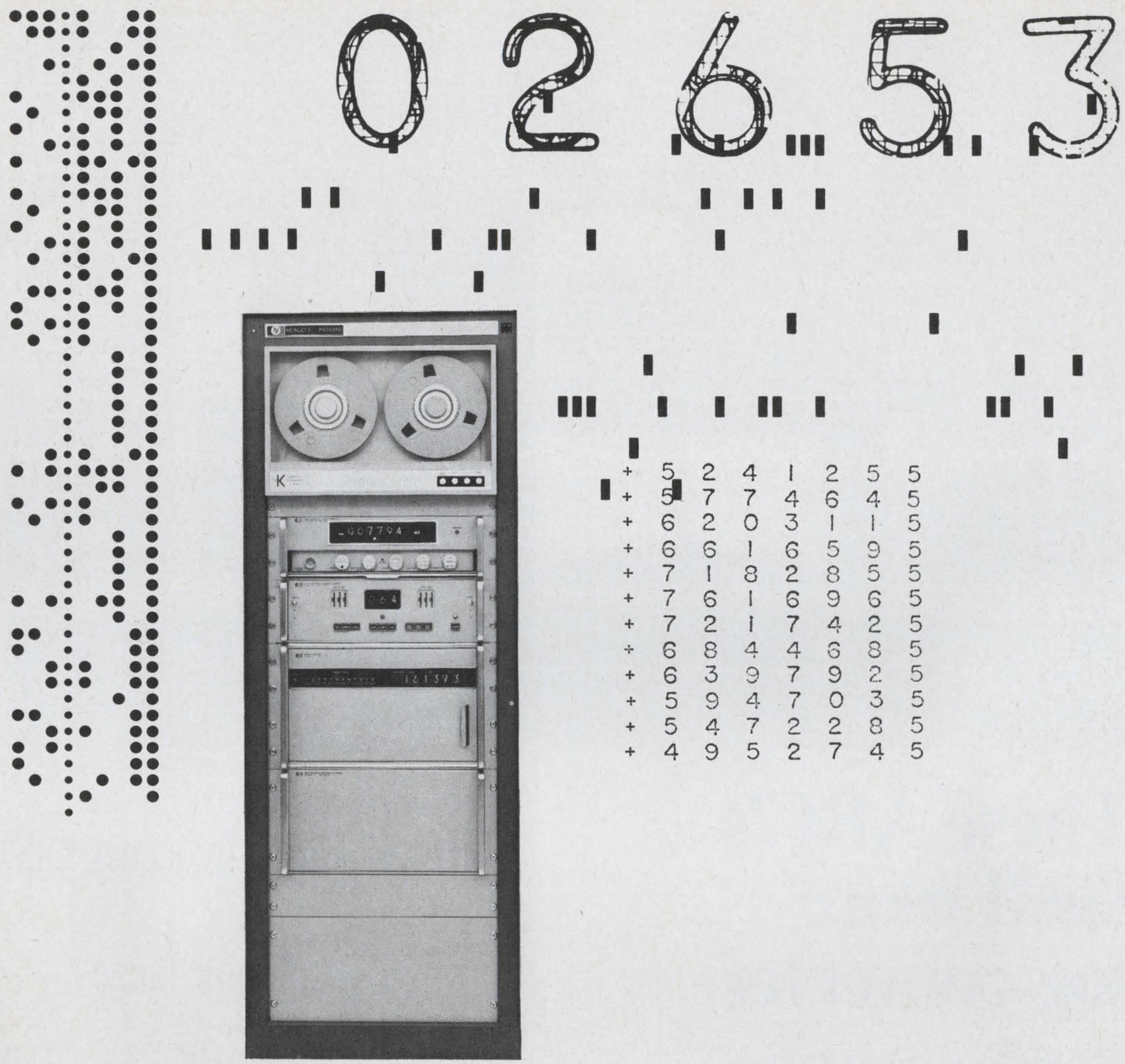
Below: Matrix scanning for color television, page 92





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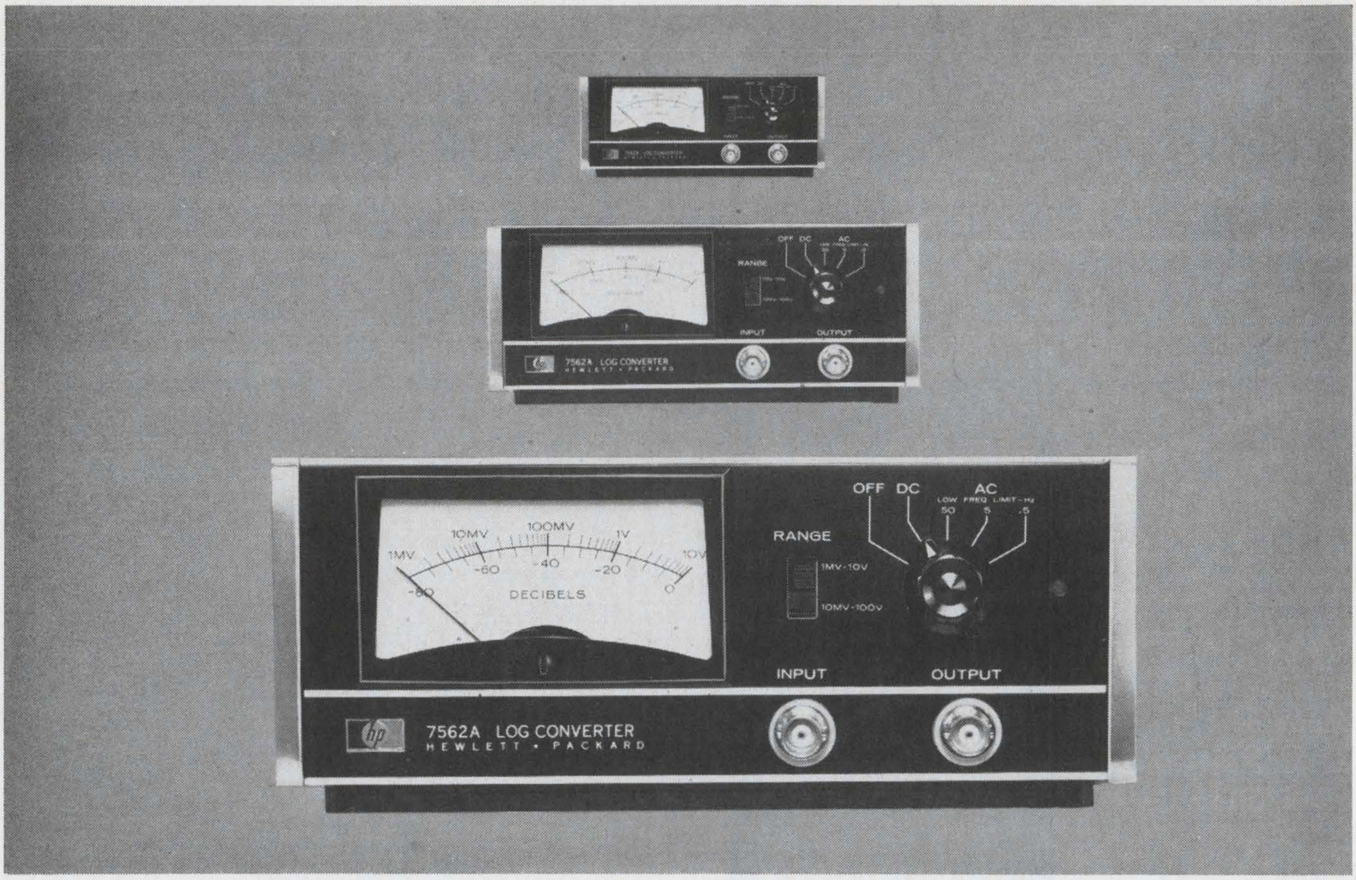

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Electronics

Volume 41, Number 8 April 15, 1968

News Features

Probing the News

Electronics Review

Electronics Abroad

New Products

Technical Articles

Departments

Electronics

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Readers Comment

In search of protection

To the Editor:

I am afraid that Petar Volkov's SCR regulator [Feb. 5, p. 88] will not always work properly; at least, it will not work with a good transformer. For instance, I am working on an amplifier intended for 120 watts rms at audio frequencies, using an output transformer and two 2N3055 transistors. I found that it needed 42 volts d-c at full load, about 5 amperes. I calculated the power transformer output as 45 volts rms; a 5,000-microfarad input capacitor would do, and the transformer output impedance, seen from the secondary, is about 0.5 ohm. With no load, the power supply's output would be about 60 volts d-c. However, this is too high—an input signal would kill one transistor and then a 115-volt collector-to-emitter voltage would kill the other transistor. Therefore, regulation was needed and Volkov's design seemed a likely candidate.

But after making some calculations I found that if the voltage was just under the desired 42 volts at the output, the SCR of Volkov's circuit would conduct before a phase angle of 40° was reached, and the input's peak voltage would charge the capacitor to 65 volts—back to the original undesired condition. Thus, a huge time constant would be necessary, and the resistor would cause much undesired heat. So I am looking for something else. Perhaps an ordinary transistor and a diode in lieu of the SCR of Volkov's design, or a two-capacitor arrangement.

Allain Le Solleuz

Brest,
France

The author replies:

As I understand it, you need a protection against voltage rise during no load periods.

A classical solution of this problem is not to use a C-input filter at all (as you and I did, I guess), but rather an L-input filter supplied with the necessary bleeder.

If weight and volume are to be kept to a minimum, then I suggest you use the SCR regulator in my

Add Sprague Series 7400A to your prints for Series 74N TTL circuits. They're pin-for-pin identical.

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SN7410N	Triple 3-Input NAND	USN-7410A
SN7420N	Dual 4-Input NAND	USN-7420A
SN7430N	Single 8-Input NAND	USN-7430A
SN7440N	Dual 4-Input NAND Buffer	USN-7440A
SN7450N	2-Wide 2-Input Expandable AND-OR-INVERT	USN-7450A
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SN7454N	4-Wide 2-Input AND-OR-INVERT	USN-7454A
SN7460N	Dual 4-Input Expander	USN-7460A
SN7470N	D-C Clocked J-K Flip Flop	USN-7470A
SN7472N	J-K Master Slave Flip Flop	USN-7472A
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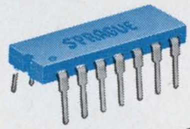

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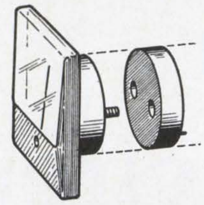

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circuit, followed by a transistor d-c stabilizer. Here the SCR regulator is used only to cut the power dissipation in the transistor d-c stabilizer (as much as 50%).

I must warn you that this SCR regulator has a ripple in the output; this is inherent in its trigger operating nature. But such a d-c voltage is good for loads like relays, signal lamps, electromagnetic valves and small d-c motors.

Petar Volkov
Zagreb,
Yugoslavia

Seen in a different light

To the Editor:

The particular point we wish to make pertains to the cover picture on your March 4th issue and your comments on page 81 as follows, "On the cover, six of these arrays are appropriately lighted to depict a running figure." A casual examination of the front cover reveals that the picture has been assembled from six photographs of the same matrix rather than from six matrixes.

This may appear to be a minor objection, but, examined more closely, it has deeper significance. There are only a few manufacturers with proven capabilities of fabricating light-emitting diode arrays and the relative capabilities of these companies are largely determined by their ability to improve emission efficiency and display area. The display device on your cover is one-sixth of the area shown; it is x-y addressed and, therefore, multiple exposures were used to create the photographs—with multiple exposures the apparent brightness can be artificially altered; not all segments are illuminated and, in fact, eight of the diodes are not illuminated in any of the pictures. Through the use of art work and scientific photography a deceptively attractive display has been assembled.

Bowmar Canada Ltd. in 1965 fabricated a 7 x 9 matrix of infrared diodes on a single 0.2″ x 0.3″ substrate and, the same year, a matrix of red-emitting gallium arsenide-phosphide diodes of equal size. Subsequently we have developed monolithic arrays of gallium phosphide diodes with individual access which permit simultaneous exposure of each data point. The status of our display laboratory in the North American marketplace hinges on our ability to build advanced display devices.

While we realize that modern advertising will always present an exaggerated impression of the state of the art, we feel that your editorial comments should be carefully weighed to prevent presentations of the form described above.

Robert D. Rinehart
Vice president, Operations
Bowmar Canada Ltd.

▪ As Robert Rinehart says, even the most casual examination of the cover shows that the same matrix was used six times. We did not expect our readers to draw the inference, from our description, that six different matrixes were used.

**Readers' letters should be addressed:
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People

The Electronic Systems division of the TRW Systems Group is changing its ways, says Paul F. Glaser, 41, the division's new assistant general manager for projects. He notes that where the division—as well as the entire systems group—has traditionally been in the space business, with its few-of-a-kind production requirements, there is a thrust now to get into more sustained production. "One of the division's changes of pace has been toward hardware production and away from the image we have of being an analysis and study house." To back up this change, the division is adding a facility in Manhattan Beach, Calif., which will have 500,000 feet of manufacturing space.

Glaser

"We're developing a capability for quick reaction—an ability to turn designs into hardware with a short turnaround time. An increasingly larger amount of our efforts are going into avionics systems, including electronic countermeasures equipment. We're doing this because we foresee such things as V/STOL aircraft and the supersonic transport requiring command, control, and communications systems as complex as those used in some of the space systems we provide."

New direction. Glaser concedes that NASA's fiscal plight has been a factor in reorienting his division. "We're now building spaceborne programers and data processors, but we've also made proposals on this kind of equipment for aircraft that could lead to reasonably high production volumes." Glaser estimates deliverable hardware now represents about 20% of the division's business; he expects that figure to double in five years.

He also predicts drastic changes in electronic equipment design over the next decade because of the influence of large-scale integration. Glaser says TRW officials had

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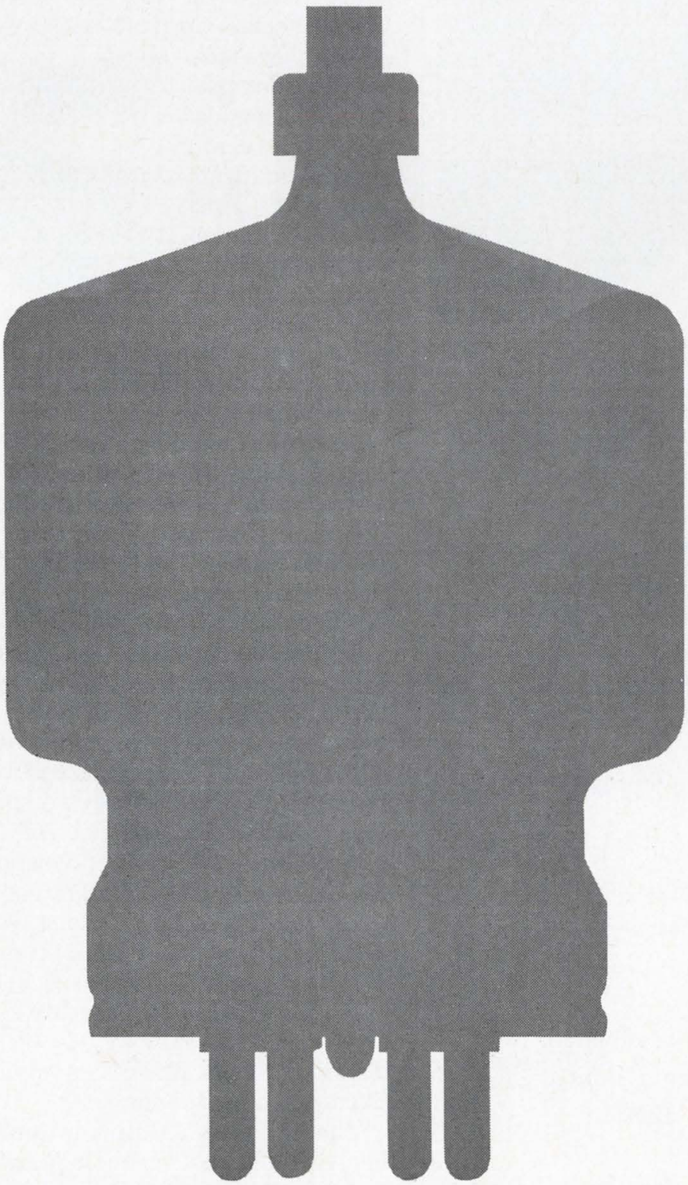

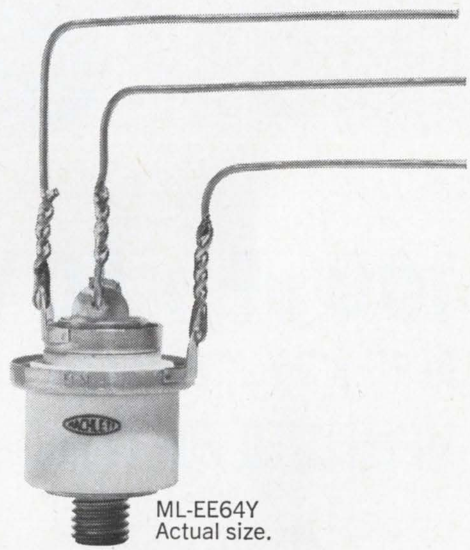

ML-EE64Y
Actual size.

RAYTHEON

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People

this in mind when they worked out plans for the new home for 4,400 Electronic Systems division employees.

"We wanted to bring engineering and manufacturing very close together," Glaser says, "because there's such a close tie between the chemist, physicist, designer, and manufacturer. It will be hard to say where physics stops and manufacturing begins."

Walter B. LaBerge, who has just stepped into the top post at the Philco-Ford Corp.'s electronics group, is convinced defense spending is about to level off—perhaps even taper off. This thrusts upon the new Philco-Ford vice president the task of channeling his divisions' resources to provide the nonmilitary area with an increasing share.


LaBerge

"Fortunately," says the 44-year-old LaBerge, "our six defense, space, and industrial electronics divisions have long experience in communications and digital handling, experience that is in growing demand in the civilian sector."

Emphasis. LaBerge, who has a Ph.D. in physics from the University of Notre Dame, is quick to point out that defense needs will still run high. "We've learned two lessons in Vietnam. First, we know that we'll have to continue putting our defense dollars into weapons for that kind of war. Second, command and control problems—tactical, strategic, and logistic—will receive greater emphasis." This, adds the Philco-Ford executive, is right down the alley of two of his divisions, WDL and Communications and Electronics.

The company is already applying the antenna technology used to track satellites for the communications subsystem of the Bay area (San Francisco-Oakland) rapid transit system, and for work related to California's water resources.

In less time than it takes to read this page, you could learn to use this new Universal Impedance Bridge.

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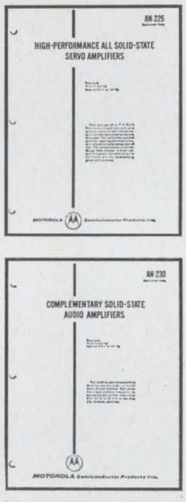

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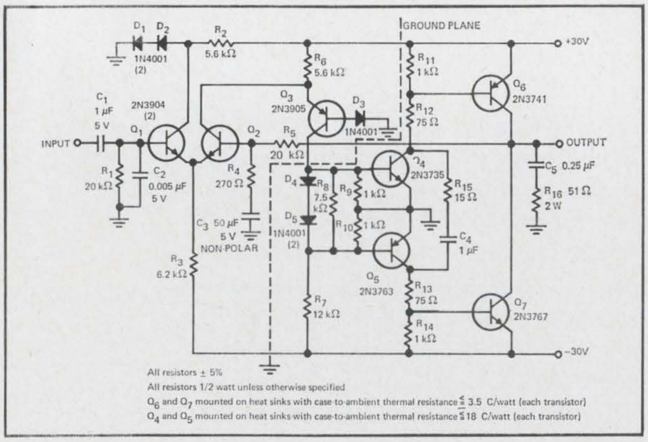

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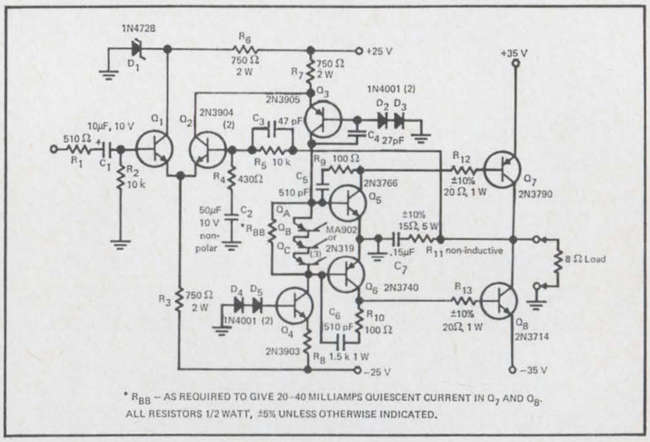

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Meetings

Southwestern Conference and Exhibition, IEEE; Sheraton Lincoln Hotel, Houston, **April 17-19.**

Symposium on Automation Techniques in Industry, Institution of Electronics and Radio Engineers; Paisley, Scotland, **April 17-19.**

State of the Art Seminar: Components and Devices in System Applications, Purdue University; Lafayette, Ind., **April 19-May 25.**

Conference on Switching Techniques, IEEE and Institution of Electrical Engineers, Institution of Electronic and Radio Engineers; London, **April 21-25.**

Conference for Protective Relay Engineers, Texas A&M, University; College Station, Texas, **April 22-24.**

Chemical and Petroleum Instrumentation Symposium, Instrument Society of America; Hotel du Pont, Wilmington, Del., **April 22-23.**

Frequency Control Symposium, U.S. Army Electronics Command; Shelburne Hotel, Atlantic City, N.J., **April 22-24.**

Region III Meeting, IEEE; Fontainebleau Motor Hotel, New Orleans, **April 22-24.**

American Power Conference, IEEE and Illinois Institute of Technology; Sherman House, Chicago, **April 23-25.**

Fiber Optics History Technology and Applications, Society of Photo Optical Instrumentation Engineers; Holiday Inn, Baltimore, Md., **April 29-30.**

Relay Conference, National Association of Relay Manufacturers and School of Electrical Engineering, Oklahoma State University; Stillwater, Okla., **April 23-24.**

Cybernetics Conference, IEEE; Munich, West Germany, **April 23-26.**

Spring Joint Computer Conference, American Federation of Information Processing Societies; Atlantic City, N.J., **April 30-May 2.**

Symposium and Equipment Show, American Vacuum Society; Grand Hotel, Anaheim, Calif., **May 1-3.**

Human Factors in Electronics Symposium, IEEE; Mariott Twin Bridges Motor Hotel, Washington, **May 6-7.**

National Conference on Aerospace Meteorology, American Institute of Aeronautics and Astronautics; New Orleans, **May 6-9.**

Technical Conference and Exhibit, American Society for Quality Control; Sheraton Hotel, Philadelphia, **May 6-8.**

Electronic Components Technical Conference, IEEE; Everglades Hotel, Marriott Twin Bridges Motor Hotel, Washington, **May 8-10.***

Short Courses

Data communications for management control, the American University, Washington, **May 20-23;** $175.

Computer-aided testing and failure diagnostics of solid state systems, University of Wisconsin, Madison, **May 23-24;** $50.

Digital control fundamentals, Milwaukee School of Engineering, Milwaukee, **June 3-7;** $150.

Call for papers

Conference on Tube Techniques, IEEE; United Engineering Center Auditorium, New York, Sept. 17-19. **May 15** is deadline for submission of abstracts to George Freedman, The Raytheon Co., Microwave Power Tube Division, Willow St., Waltham, Mass. 02154

Ultrasonics Symposium, IEEE; Statler-Hilton Hotel, New York, Step. 25-27. **July 15** is deadline for submission of abstracts to R.W. Damon, Sperry Rand Research Center, 100 North Rd., Sudbury, Mass. 01776

Allerton Conference on Circuit and System Theory, IEEE; Allerton House, Monticello, Ill., Oct. 2-4. **Aug. 1** is deadline for submission of abstracts to T.N. Trick, Department of Electrical Engineering, University of Illinois, Urbana, Ill. 61801

Circuit Theory Symposium, IEEE; Hilton Plaza Hotel, Miami Beach, Fla., Dec. 4-6. **Aug. 1** is deadline for submission of papers to B. K. Kinariwala, Department of Electrical Engineering, University of Hawaii, Honolulu, Hawaii 96822.

* **Meeting preview on page 16.**

Meeting preview

New spirit

The Electronic Components Conference, threatened with extinction a few years ago by the onrush of complex monolithic integrated circuit technology, is again back in the thick of things, with thick films. Along with the regular sessions on materials, packaging, and manufacturing, this year's conference, scheduled for Washington, May 8 to 10, will, for the first time, have two thick-film sessions.

Better performance. Among the speakers in this area will be Brian Dale, chief engineer at Sylvania's Semiconductor division, whose paper will cover the use of thick-film packaging techniques for fitting beam-lead devices to both hybrid microcircuits and inexpensive carriers. This is a process that eliminates double packaging, and makes possible air-isolated circuit components, resulting in improved high-frequency performance.

Other topics to be covered in the thick-film sessions are cermet resistors, screen-printed capacitors and high Q dielectrics.

Also scheduled is a session on integrated components and filters. In this session three Boeing engineers, V.C. Hughes, O.R. Mulkey, and M.H. Williamson, will describe how a thin-film hybrid technique was used to fabricate 17 different audio frequency RC filters with tolerances of 0.1%.

Filter design. In the same session, J.M. Giannotto, a researcher with the U.S. Army Electronics Command, will discuss the use of energy-trapping techniques in acoustical filter design. He will cover the deposition of both thin films of cadmium sulfide and resonators on quartz wafers, a process that obtains the electrical performance of conventional filters while cutting size.

Two Westinghouse engineers, M.B. Shamash and S.G. Konsowski, will describe their work in packaging in a paper on the use of nonporous thin-film dielectrics and shadow printing of high-resolution conductors.

For further information contact William S. Hepner Jr., Electronic Industries Association, 2001 Eye Street NW, Washington, D.C. 20006

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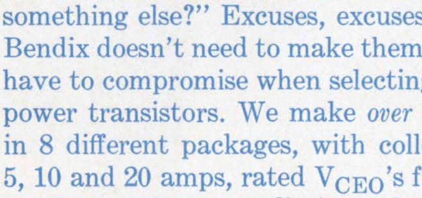
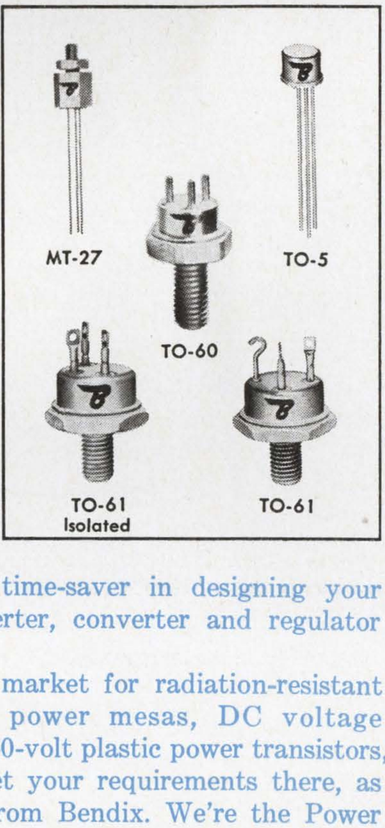
80 min. @ 3A, 10V	40 to 80V	5A	0.75V max. @ 3A, 0.3A		40	300	3.0	300	B-143002, 5, 8 B-143017, 20, 23
20 min. @ 5A, 10V		10A	1V max. @ 5A, 0.5A	25W to 50W					B-144002, 5, 8 B-145002, 5, 8 B-146002, 5, 8
15 min. @ 10A, 5V	60 to 100V	15A	1.5V max. @ 15A, 3A	100W / 60W	225	600	10	1,000	B-148002, 3, 5 B-155002, 3, 5
20 min. @ 10A, 5V		20A	1.5V max. @ 20A, 4A	100W / 60W					B-148000, 1, 4 B-155000, 1, 4

(SATURATED SWITCHING TEST CIRCUIT DIAGRAM FOR B-148000 & B-155000)



Maximum Switching Times: td $\leq$ 25 ns; tr $\leq$ 200 ns; ts $\leq$ 300 ns; tf $\leq$ 300 ns. **Test Conditions:** $V_{in} = 70V$ when generator with 50Ω internal impedance is terminated in a 50Ω load. $VBB = -5V$; $VCC = 55V$; $IC \approx 10A$; $IB_1 \approx 1A$; $IB_2 \approx 1A$; $tp = 400$ ns; $f = 720$ Hz.



Ever been handed the line: "Seems we have every type but the one you want—could we interest you in something else?" Excuses, excuses. It's nice to know Bendix doesn't need to make them. Fact is, you never have to compromise when selecting our silicon planar power transistors. We make *over 100* different types, in 8 different packages, with collector currents of 3, 5, 10 and 20 amps, rated V_{CEO}'s from 40 to 100 volts. Contact us for postradiation gain data.

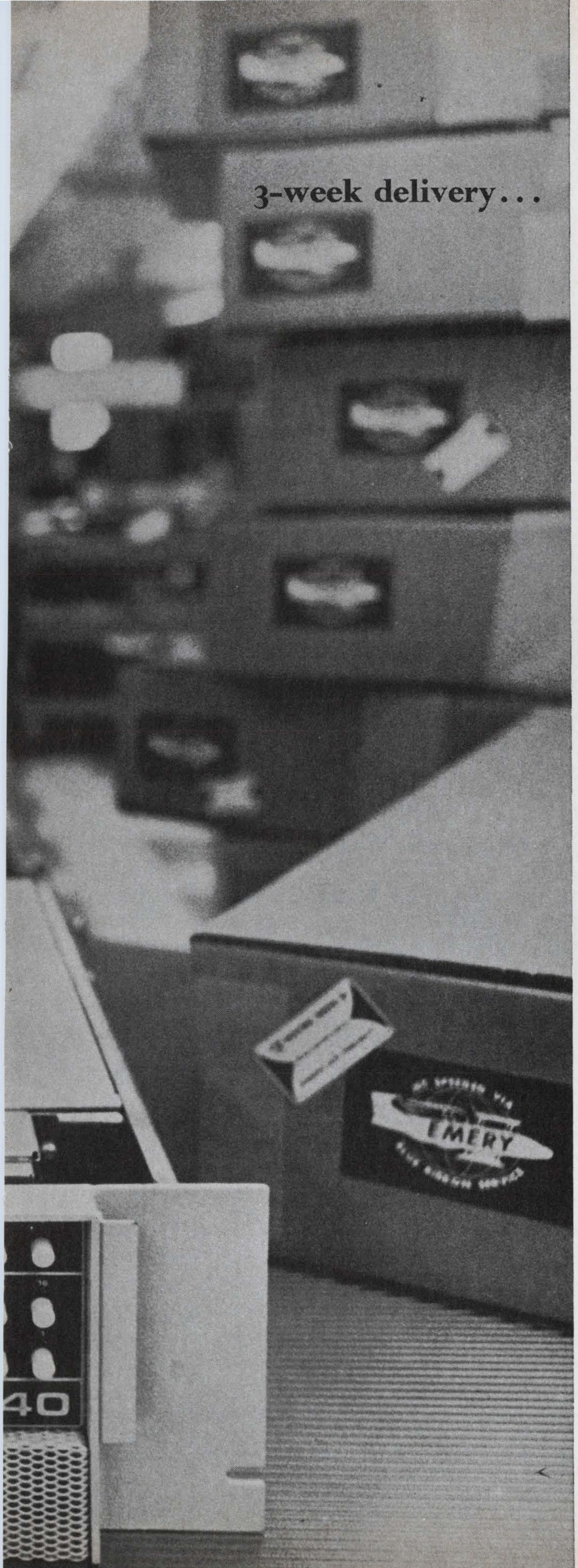
All Bendix planar power transistors are SOAR (Safe Operating ARea) specified to prevent second breakdowns. A real time-saver in designing your power amplifier, inverter, converter and regulator circuits.

If you are in the market for radiation-resistant transistors, silicon power mesas, DC voltage regulators or 35- and 60-volt plastic power transistors, odds are we can meet your requirements there, as well. Excuses? Not from Bendix. We're the Power Specialists. More information? Call our nearest sales office, or write: Semiconductor Division, The Bendix Corporation, Holmdel, New Jersey 07733.

Bendix Electronics

Chicago—(312) 637-6929; **Dallas**—(214) 357-1972; **Detroit**—(313) 548-2120; **East Northport, N.Y.**—Harry Friedman Co. (516) 692-2839; **Great Neck, N.Y.**—H. V. Sales Co. (516) HU 7-1142; **Greenwich, Conn.**—(203) 869-7797; **Holmdel, N.J.**—(201) 946-9400; **Lexington, Mass.**—(617) 861-8350; **Los Angeles**—(213) 776-4100; **Minneapolis**—(612) 926-4633; **Orlando, Fla.**—(304) 241-6559; **Rochester, N.Y.**—(716) 266-5550; **Runnemede, N.J.**—(609) 933-2550; **Seattle**—Ray Johnston Co., Inc. (206) LA 4-5170; **Export**—Cable: "Bendixint," 605 Third Avenue, New York, (212) 973-2121; **Ottawa, Ont.**—Computing Devices of Canada, P.O. Box 508 (613) 829-1800; **San Juan, Puerto Rico**—Southern International Sales Co. 723-3879.


TEST PATTERN
OPERATION MODE
MANUAL EXECUTE
TEST
NORM
MAN
READ
WRITE
ERROR
LOAD
AR
DR
RESET
HONEYWELL
ICM



3-week delivery... on the standard 1 μ-sec I/C memory system that packs 1/2 million bits in a single 5 1/4″ high unit.

That's the ICM-40. A fast, highly reliable core memory system that's ready to meet your system requirement.

And when you say so, we'll give you 3-week CFS (Certified Fast Shipment) under our accelerated shipment plan.

What's more, the ICM-40 is a standard product . . . a proven performer with over 5,000 hours of life test without failure. Plus, some 400 actual installations; same success rate. What you'd expect from the most experienced memory maker.

I/C Construction — The ICM-40 is a 1 microsecond, full-cycle, magnetic core memory designed for operation as a high-speed random-access store. It is a basic system module that takes maximum advantage of the high reliability and low power consumption of integrated circuitry.

Packaging — Compactness and a high degree of maintainability are achieved in the ICM-40 design by packaging all of the circuitry on readily accessible, removable circuit modules.

Capacity — The ICM-40 packs nearly ½ million bits in a single 5¼″ high module. The basic unit can be specified for up to 16K words, 4-26 bits per word. It's big brother, the ICM-40E with capacities of 32K words, 4-78 bits per word is available with 60-day CFS.

If you've drawn a block marked "core memory" recently, why not find out more about the ICM-40/40E. You'll be pleased by their versatility. And the standard-product pricing. And our Certified Fast Shipment commitment.

Now, don't you think it's about time you called us? Or, write Honeywell, Computer Control Division, Old Connecticut Path, Framingham, Massachusetts 01701.

Honeywell

COMPUTER CONTROL DIVISION

Circle 19 on reader service card

RECAP:

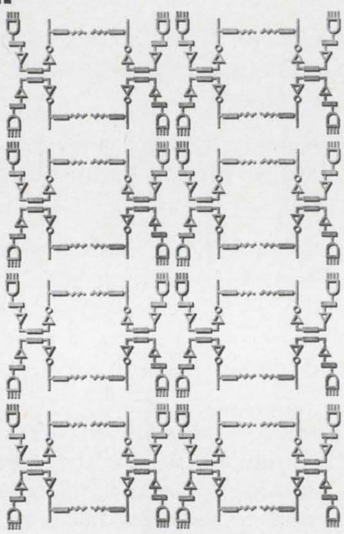
Starting October 9, 1967, Fairchild promised to introduce a new integrated circuit each week for 52 weeks. This is number **21.**

4500 BIPOLAR MICROMATRIX™ ARRAY

Fairchild's 4500 is the first device in a new, highly versatile LSI family of fundamental elements. It can be used in any digital logic system. And, it can be customized for virtually any function. Fairchild's unique LSI capability is the result of two major achievements: double-layer metal processing and computer-aided design.

The 4500 is a monolithic CCSL device consisting of eight cells. Each cell is made up of four 4-input DTL gates. The entire array is capable of custom interconnection between cells and portions of cells to produce any logic function. The primary application for the 4500 is in circuits used to interconnect basic system building blocks. However, it can also be used as a fundamental building block, itself. The new LSI array comes in an hermetic DIP as well as in flatpack.

Since the 4500 cannot be completed without your specific requirements, we've prepared a kit to help you design your own custom circuits. It's at your Fairchild distributor now. Write for detailed specs and applications information.



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CIRCLE READER SERVICE NUMBER 121

Starting October 9, 1967, Fairchild promised to introduce a new integrated circuit each week for 52 weeks. This is number **22.**

3320 MOS 64-BIT, 4-PHASE SHIFT REGISTER

The 3320 is a shift-register/accumulator. Its input logic can be used to control the loading of new information, or the recirculating of existing information, in the device. Its primary applications include digital data accumulation in telemetry systems; long-serial memories for computers; long delay lines in radar equipment and industrial serial system control.

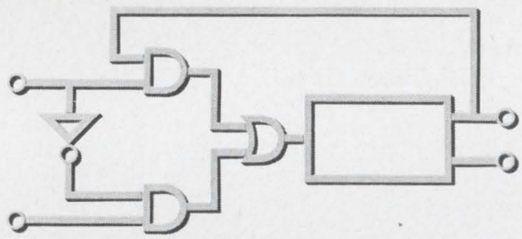
No DC power supplies are required for 3320 operation. It comes in a TO-5 can and will operate over the entire temperature range from −55°C to +85°C. Both data and data-complement output are provided. Power dissipation is approximately 200μW per bit at 2MHz.

The 3320 is a product of Planar II* P-channel enhancement mode technology. It's the sixth monolithic MOS IC we've introduced since December 11, 1967. (The others are the 3701 six-channel multiplex switch; 3102 three-input gate; 3700 four-channel multiplex switch; 3303 dual 25-bit dynamic shift register; and the 3300 25-bit static shift register.)

Volume quantities of all six devices are available. Your Fairchild distributor has them in stock. Write for complete specs and applications information.

*Planar is a patented Fairchild process.

To order the 3320, ask for:
Part No. ASF3320149
Price: $33.00 (1-24)
28.00 (25-99)
25.50 (100-999)



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CIRCLE READER SERVICE NUMBER 122

Starting October 9, 1967, Fairchild promised to introduce a new integrated circuit each week for 52 weeks. This is number **23.**

3705 8-CHANNEL MOS MULTIPLEX SWITCH

The 3705 is designed for use in analog-to-digital converters, multiplexing applications, digital transmission systems, all airborne and ground instrumentation signal routing functions, and in replacement of mechanical relays. It's CCSL compatible and has binary-coded logic inputs and all-channel blanking control.

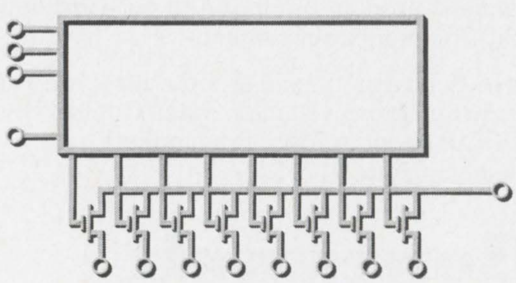
The 3705 is our seventh new MOS device. (Since December 11, 1967, we've introduced the 3701 six-channel multiplex switch; 3102 three-input gate; 3700 four-channel multiplex switch; 3303 25-bit dynamic shift register; 3300 25-bit static shift register and the 3320 64-bit, 4-phase shift register.)

The 3705 is a product of Planar II* P-channel enhancement mode technology. It features zero offset voltage, input gate protection, typical ON resistance of 150 Ohms (for input signal levels from 0 to +5 volts), nano-ampere leakage currents, and input-to-output isolation to minimize feed through. It comes in a 16-lead hermetic DIP and will operate in a range from −55°C to +85°C.

You can get volume quantities of all seven MOS devices now. Your Fairchild distributor has them in stock. Write for complete specs and applications information.

*Planar is a patented Fairchild process.

To order the 3705, ask for:
Part No. A6J3705143
Price: $50.00 ea. (1-24)
40.00 ea. (25-99)
33.50 ea. (100-999)



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CIRCLE READER SERVICE NUMBER 123

Starting October 9, 1967, Fairchild promised to introduce a new integrated circuit each week for 52 weeks. This is number **24.**

μA722 PROGRAMMABLE D/A–A/D CONVERTER CURRENT SOURCE

Fairchild's μA722 is the first MSI linear integrated circuit. It's compatible with other linears (702, 709, 710) as well as CCSL and other digital circuitry.

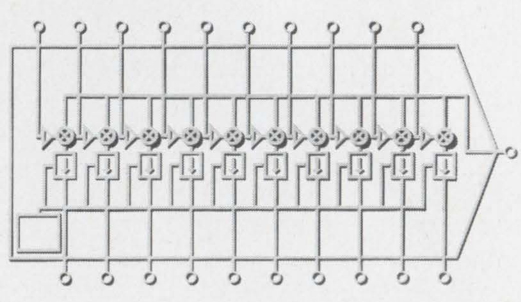
The μA722 is a high-speed, current summing, programmable, digital-to-analog converter current source. It's the result of a breakthrough in monolithic technology — the extremely tight matching of more than 70 active components. The device consists of a reference supply and 10 current sources connected to a single output summing line through 10 associated current steering switches. All on a single monolithic chip. Both the full-scale voltage range and the coding format (BCD or binary up to 10 bits) can be varied with an external resistor array. μA722 performance specs include 6-bit or 8-bit* accuracy, 10-bit resolution, 700ns settling time, 20mA maximum full-scale current, and 2.5mA minimum full-scale current.

The new device can be used as a basic building block in a number of aircraft, satellite, instrumentation and computer systems. Its most important application will be as a D/A converter in high-resolution A/D converters. (With the μA722, you can build a $1000 A/D converter for less than $200.) It can also be used as a logarithmic D/A converter, a D/A multiplier, a limited-range multiplier, and as a meter drive in digital systems where the meter is used for monitoring.

The μA722 comes in a 24-pin hermetic flatpack. It will operate over the entire temperature range from −20°C to +85°C. It's available in volume quantities. Your Fairchild distributor has it in stock now. Write for complete specs and applications information.

*Available on request

To order the μA722, ask for:
Part No. U3M7722334
Price: $75.00 ea. (1-99)
50.00 ea. (100-999)



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CIRCLE READER SERVICE NUMBER 124

Fairchild is introducing a new integrated circuit every week. The last two months look like this.

FAIRCHILD
SEMICONDUCTOR

Starting October 9, 1967, Fairchild promised to introduce a new integrated circuit each week for 52 weeks. This is number **25.**

4510 DUAL FOUR-BIT COMPARATOR

The 4510 is the first standard off-the-shelf circuit produced with double-layer metal processing—the key to all future LSI designs. It is based upon our 4500 Micromatrix™ Array (New Product #21), which can be customized for virtually any function in any digital logic system.

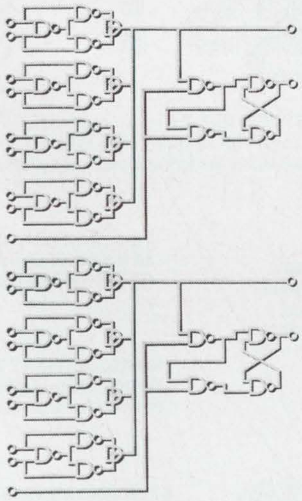
The 4510 is designed for any application where the equivalence of two numbers is required. It consists of two identical 4-bit comparators. Each comparator accepts two 4-bit characters and provides an output signal when they are identical. Inputs and outputs are CCSL-compatible. An output latch stores the comparison output when the clock input is high. Outputs may be wire ORed together to expand the comparison capability in 4-bit characters.

Applications for the 4510 include digital printers where it can be used to select the proper character in each print cycle, in digital testers to permit go/no-go functional testing and in programmable counters.

The 4510 is available in both a 24-lead hermetic DIP and in flat-pack. It will operate over military and industrial temperature ranges (−55°C to +125°C and 0°C to +70°C). We have this new device in volume quantities. It's on your Fairchild distributor's shelf now. Write for complete specs and applications information.

To order the 4510, ask for:

Part No.	Package	Temperature Range	Price (1-24)	(25-99)	(100-999)
A3M 4510 59X	Flat	0°C to +70°C	$33.00	$26.40	$22.00
A3M 4510 51X	Flat	−55°C to +125°C	47.00	37.60	31.00



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CIRCLE READER SERVICE NUMBER 125

Starting October 9, 1967, Fairchild promised to introduce a new integrated circuit each week for 52 weeks. This is number **26.**

9034 256-BIT READ-ONLY MEMORY

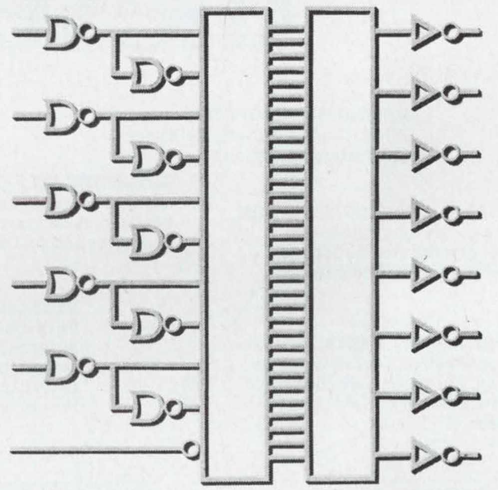
The 9034 is not only CCSL-compatible, but also has an access time of less than 50ns. It is particularly useful for control of high-speed systems, for microprogramming, for high-speed table look-up, high-speed code conversion and display driving applications.

Five input lines control selection of one of 32 8-bit words. An enable input allows the selection of one 9034 in a bank of parallel-addressed devices. The equivalent outputs of several ROMs can be OR-tied because there's an open collector output on each of the 8 bits. Each address line, and the enable line, represents one TTL load. The outputs can sink 10mA. Power dissipation is 420mW maximum.

The 9034 operates with a 5V power supply. It comes in a 16-pin hermetic DIP and operates over both military and industrial temperature ranges (−55°C to +125°C and 0°C to +70°C). The 256-bit device cannot be completed without your custom specifications. However, if you'd like to play around with one (or more), we've prepared a sample device that represents 0 through 6 of an alpha-numeric character generator for 5-by-8 dot displays. It is called the 9034AB. You can get it at your Fairchild distributor (see Part No. and price below). In the meantime, write for complete specs and applications information on the 9034.

To order the 9034AB, ask for:

Part No.	Temperature Range	Price (1-24)	(25-99)	(100-999)
A6B 9034 51B	−55°C to +125°C	$83.50	$66.50	$55.50
A6B 9034 59B	0°C to +70°C	41.75	33.25	27.75



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CIRCLE READER SERVICE NUMBER 126

Starting October 9, 1967, Fairchild promised to introduce a new integrated circuit each week for 52 weeks. This is number **27.**

3750 10-BIT MOS-LSI D/A CONVERTER

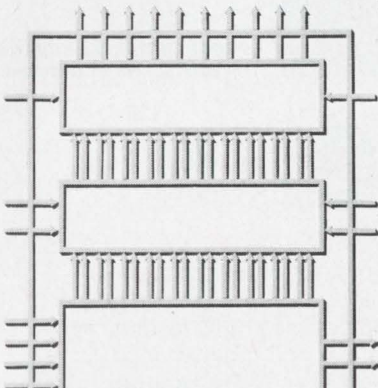
The 3750 is not only a new LSI device, but also the eighth MOS IC we've introduced since last December. (The first seven include the 3701 six-channel multiplex switch; 3102 three-input gate; 3700 four-channel multiplex switch; 3303 dual 25-bit dynamic shift register; 3300 25-bit static shift register; 3320 64-bit, 4-phase shift register, and the 3705 eight-channel multiplex switch.) All Fairchild MOS devices are products of P-channel enhancement mode technology.

The 3750 is designed for digital-to-analog conversion of data in telemetry systems, D/A plotters, servomotor control, radar tracking systems, and automatic fire control in radar and guided missile applications. The digital word can be entered serially or in parallel. (If desired, the word is available from the input shift register in serial form through an output buffer. It can be obtained in either 8- or 10-bit format.) The converter output is available through ten single-pole double-throw (SPDT) MOS switches. The holding register retains the state of the previous digital input word and drives the output switches. Transfer gates are used to isolate the holding register from the input shift register while new data is being entered. The ON resistance of the MOS switches is weighted to provide the accuracy and stability necessary for a 10-bit conversion.

Parallel word rate of the 3750 is 500KHz. ON resistance is typically 250 Ohms for the two most significant bits, and 500 Ohms for the remaining eight bits. Power dissipation is 110mW. The device comes in a 36-pin hermetic DIP and features zero and full-scale calibration logic. It will operate over the entire temperature range of −55°C to +85°C.

The 3750 is available in volume quantities. Your Fairchild distributor has it in stock now. Write for complete specs and applications information.

To order the 3750, ask for:
Part No. A6H-3750-14X
Price: $120.00 (1-24)
96.00 (25-99)
80.00 (100-999)



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CIRCLE READER SERVICE NUMBER 127

Fairchild promised to introduce a new integrated circuit each week for 52 weeks. This week we've got two. They both count as number **28.**

9624/9625 INTERFACE CIRCUITS

Now you can have the benefits of MOS technology and the advantages of CCSL circuitry in a single application. The 9624 converts CCSL logic to MOS levels. The 9625 works in reverse.

Basically, the 9624 is a dual CCSL to MOS interface gate that can be used in any system which incorporates both MOS and CCSL circuitry. It can also function as an MOS clock driver or an analog switch driver.

The 9625 is an MOS to CCSL interfacing circuit that converts MOS logic (−12 to 0V) to CCSL levels (0 to +5V). It, too, can be used in any system having both MOS and CCSL circuitry.

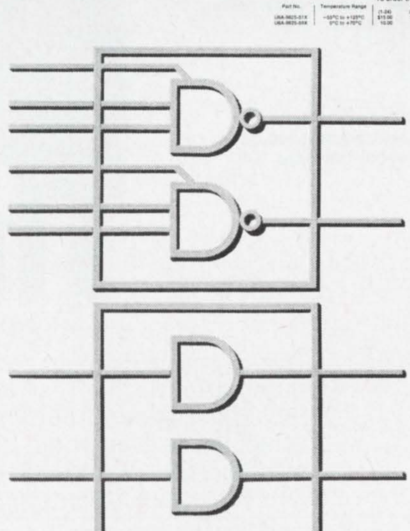
Both devices come in 14-lead hermetic DIPs and will operate over industrial and military temperature ranges (0°C to +70°C and −55°C to +125°C). Volume quantities of the 9624 and 9625 are now available. Your Fairchild distributor has them in stock. Write for complete specs and applications information.

To order the 9624, ask for:

Part No.	Temperature Range	Price (1-24)	(25-99)	(100-999)
U6A-9624-51X	−55°C to +125°C	$22.50	$18.00	$15.00
U6A-9624-59X	0°C to +70°C	15.00	12.00	10.00

To order the 9625, ask for:

Part No.	Temperature Range	Price (1-24)	(25-99)	(100-999)
U6A-9625-51X	−55°C to +125°C	$15.00	$12.00	$10.00
U6A-9625-59X	0°C to +70°C	10.00	8.00	6.67



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CIRCLE READER SERVICE NUMBER 128

Which IC Test System does all these things?

DIAGNOSTIC COMPUTER PROGRAMS automatically check out system operation.

AUTOMATIC SELF-CHECKING assures accurate data transfer between operator, teletypewriter, computer and test instrument.

DATALOG A FORCING FUNCTION, such as the input threshold level of a flip-flop needed to produce a specified output.

TYPED SUMMARY SHEETS. Whenever desired. No interruption in testing. Give total units tested per test station, test yields and bin yields.

VERY COMPLEX TEST SEQUENCES can be programmed, yet preparation of simple tests can be learned in two hours.

GROWING LIBRARY of improved software packages to insure against obsolescence.

FAST TESTING. 1.5 msec per test. If crosspoint is changed, 5 msec. 10 msec on the lowest current scales.

TEN-YEAR GUARANTEE for all instrument plug-in circuitry (it's almost all plug-in).

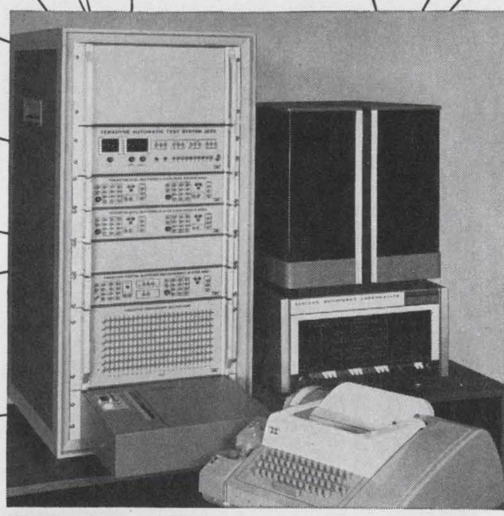
NO ADJUSTMENT OR CALIBRATION POINTS. (Eternal vigilance is the price you pay for a single adjustment.)

DIRECT ENGLISH data logging type-out, showing job name, serial number, test number, decimal point and units.

ABSOLUTE SOURCE CONTROL. Sources can be turned ON or OFF and changed in value in any sequence with variable delays from 100 μsec. to as long as you please.

DATALOG at any test station—<u>without slowing down</u> classification tests at any other station.

MULTIPLEXING. Several jobs simultaneously. Any assigned, at any time, to any test station.



OPEN AND SHORTED CONNECTIONS and **OSCILLATIONS** are automatically detected. System stops when a selected consecutive number of these occur.

COMPLETE FRONT PANEL DISPLAY at any desired step, simultaneously indicating all crosspoint connections, forced values, measured limits, binning decisions—everything about each test.

MINIMIZED REPETITIVE INSTRUCTIONS for the operator through data libraries, variable word length programming, and autopinning.

PROGRAMMABLE CURRENT LIMITS for each source at each test.

This one.

(complete for only $65,000)

This is our J259 computer-operated Automatic Circuit Test System. It includes a general-purpose digital computer, teletypewriter, test instrument (comprising modular elements: 24 x 8 crosspoint matrix, four voltage sources, measurement system, and test deck), complete software package, and courses in IC testing, system operation, and maintenance. TERADYNE, 183 Essex St., Boston, Mass. 02111 Phone (617) 426-6560.

TERADYNE

Editorial comment

A little knowledge

Shock waves from the report issued by the Logistics Management Institute earlier this year have spread beyond the Defense Department, where it was commissioned, to touch the entire industry. The institute asserted that profits for defense contractors based on percentage of total capital investment are significantly lower than those of contractors not involved with the Government. And furthermore, the report said, even those lower profits are declining. The LMI report suggested that the Government be urged to back off on controls for high-risk projects.

The Defense Department asked the Electronic Industries Association for its comments on the study; during EIA meetings in Washington last month, the report was alternately praised and pummeled.

A study that yielded contrary results was made by M.L. Weidenbaum, an economics professor at Washington University. It concludes that the large defense companies (North American Rockwell, Lockheed, General Dynamics, McDonnell Douglas, Grumman, and Thiokol Chemical) earn higher profits than nondefense firms of similar size. Weidenbaum's data shows that defense profits have grown steadily higher than nondefense profits over the past decade.

These conflicting conclusions could be attributed, in part, to the measurement techniques. Weidenbaum used net profits after taxes as a percent of stockholders' investment (return on net worth). But defenders of the LMI report suggest that it is unfair to compare all the companies involved in the LMI study with the giant aerospace firms.

Congressman Chet Holifield (D., Calif.), commenting on the LMI study, emphasizes that the figures were obtained from many individual company profit figures—some of them considerably higher than the average reported.

Providing still another viewpoint, Robert Higdon, a vice president of the Chase Manhattan Bank, notes: "Classically, profit opportunities attract competition which drives down prices. Defense contractors interviewed by LMI stated that the primary reason for defense profit being lower than commercial profits was the severity of competition." Higdon thinks this is not necessarily bad, noting that under free-enterprise concepts, marginal companies will drop out, leaving the field to the more competent.

Many companies would like a more detailed breakdown of the LMI report—into companies and categories—to help them see where they fit into the picture. Others are content with the ambiguities of the report. In this group was one company that believes the study has generated a "credible image" which might generate some Government action that would reduce the controls on high-risk projects.

Other dissenters to further analysis of the LMI report were saying, off the record, at the Washington parley that it might cast doubt on LMI's conclusions. We disagree. Additional analysis would benefit the entire industry. The Logistics Management Institute has conducted a number of studies for the Defense Department and its recommendations have been factored into the procurement regulations. We think this respected study group would be the first to agree that more light should be shed on its report.

After Vietnam

Hanoi's response to President Johnson's enunciation of a shift in U.S. policy encourages the hope that direct discussions can be arranged between representatives of North Vietnam and the United States. It may be months or years before the war is ended but now, at least, we've caught a glimmer of light at the end of the tunnel.

The current peace maneuvers bring the question of "After Vietnam, what?" into sharp focus. A year ago, a committee of the Electronic Industries Association tackled it. Its report*, issued last month, postulated a "most probable course of events."

The EIA study group believed that the U.S. would "continue its present policy of escalation, with the aim of achieving a political settlement or ultimately forcing a military settlement to the conflict." The study group sought to describe the market environment at the war's end for companies now in the defense/space business and to measure the impact on systems procurement and research and development. Its conclusions:

- After the war, defense expenditures will return to a level which would have been reached had there been no conflict. NASA spending will decline throughout the war.
- Programs will be deferred if they aren't related to Vietnam and for some this may mean their demise.
- Electronics expenditures will undergo no significant decline despite individual program losses in the short term. The latter will be offset by other programs and by an increasing electronics content in all programs, so that the long-term prospects for electronics are good.

Of the many programs that will be deferred while the war continues, research and development projects are most vulnerable. Before leaving his post as Secretary of Defense, Robert McNamara told Congress that special efforts were being made to cull out marginal R&D programs and to defer to "future years" all projects whose postponement would not have a seriously adverse effect on the future military capabilities of the U.S.

Congressman Joseph Karth (D., Minn.) put it aptly when he warned against the U.S. slipping into a "let technology wait" mood, while the war is being fought.

Programs that are deferred lose momentum and key personnel. An infusion of funds may often not be enough to revive moribund programs. Karth calls for a continuing investment in R&D in the U.S. to provide a continuing payoff, not only for a sound defense posture but to find a cure for our social ills. The point is well taken. In war or peace we cannot bypass technology.

*The Post-Vietnam Defense and Space Market Environment

Electronics Newsletter

April 15, 1968

Siliconix to offer microwave FET's

Field effect transistors are not only bucking the trend to integrated circuits but are widening their scope of operation. **The latest advance lifts commercial FET's into the ultrahigh- and microwave-frequency ranges.** Siliconix has developed a junction device with a maximum frequency of 1.5 gigahertz, plus a gain of 6,500 micromhos and a noise level of under 4 decibels.

This frequency capability, triple that of rival off-the-shelf units, is achieved by "twisting the basic geometric pattern," according to J. B. Compton, designer of the device. **He expects the method to yield 3-Ghz devices by next year and says the technique is applicable all the way up to 10 Ghz.**

Siliconix is aiming its new unit at communications applications, including radio, telemetry, and low-noise amplifying systems, but **will also sell the chip in unpackaged form to hybrid-circuit users.** The price will be under $6 each in lots of 100.

IC diode arrays get lift from air isolation

Fairchild Semiconductor is using a planar air-isolation technique to produce monolithic diode arrays that perform at the level of discrete arrays. The firm, which next month will introduce 16-diode and dual eight-diode arrays incorporating the new approach, says the isolation of the integrated-circuit elements is superior to anything achieved with dielectric, hybrid chip-and-wire, or other approaches.

The isolation—involving a fine glass that is sedimented onto the front of the wafer and an additional support wafer—is laid down after the device elements are formed. **It provides glass-encapsulation protection as well as normal oxide protection.** As a result, an epitaxial layer is left between top metallization and the p and n regions, with succeeding layers of oxide, aluminum, and glass interposed between bottom layers and the backing wafer.

Hal Clausen, senior marketing engineer for Fairchild, says the technique is applicable to all monolithic IC's, yields higher reliability, accommodates batch processing, requires fewer assembly operations, provides greater pin and layout freedom, and produces more uniform electrical characteristics. **He further declares that the method will make discrete diode arrays obsolete.**

TTL bandwagon

As transistor-transistor logic (TTL) finds its way into more integrated circuits, the race to get more of the action heats up. Motorola Inc., which announced its own TTL circuits late last year plus expansion of its second-sourced Sylvania SUHL 2 line [Electronics, Oct. 2, 1967, p. 179], **is preparing a TTL entry styled after Texas Instruments' 5400/7400 series.** The Semiconductor Products division in Phoenix is making circuits now, but it will be "a few months," says one Motorola official, before they are available.

Meanwhile, in nearby Scottsdale, little Dickson Electronics intends to "have a fling" at making TI's 7400 series, as its president, Donald Dickson, puts it. He says that if his firm gets good enough yields, shipments could begin late this year in the company's first venture into the monolithic IC arena.

Electronics Newsletter

Pentagon weighs use of satellites in limited war

The Pentagon is considering a quasi-tactical application for the long-haul strategic satellite communications system that will eventually replace the Initial Defense Communications Satellite System. **The proposal calls for the use of individual synchronous satellites in the system as regional communications centers in a limited war.** The satellites would connect several ground stations in the theater of operations.

A Defense Communications Agency spokesman, Air Force Lt. Col. Ralph Backes, described a hypothetical regional system, called Seasat, for Southeast Asia satellite, at an American Institute of Aeronautics and Astronautics conference in San Francisco last week.

Tv interests gird for spectrum battle

Watch for broadcasting interests to wage a last-ditch battle to keep land mobile radio users from "encroaching" on frequencies reserved for television. **It's now clear that the FCC will reallocate some uhf frequencies or will order channel sharing.** The tv industry got the message this month when FCC chairman Rosel H. Hyde, in his strongest statement yet on the issue, bluntly told the National Association of Broadcasters, **"It's likely that additional use will have to be made of spectrum space allocated to television."**

Broadcasters are planning to launch independent studies of land mobile. **They aim to stress to the FCC, Congress, and the public that the frequencies now assigned land mobile users are not being shared efficiently.** They also want to push the FCC to study the possible use of higher frequencies for land mobile communications.

Alaska tries to put messages in orbit

Alaska is trying hard to get satellite communications service. State legislative and communications officials will talk in Washington May 1 with representatives of the FCC, Comsat, the State Department, and the Presidential Task Force on Communications. **Alaska could either build a ground station and tie into the Pacific Intelsat system—which would allow communications to Washington State, Hawaii, and Japan and other Far Eastern points—or tie into the U. S. domestic satellite pilot system expected to be in service by 1970-71.** The domestic system is expected to be sanctioned in the next month or so.

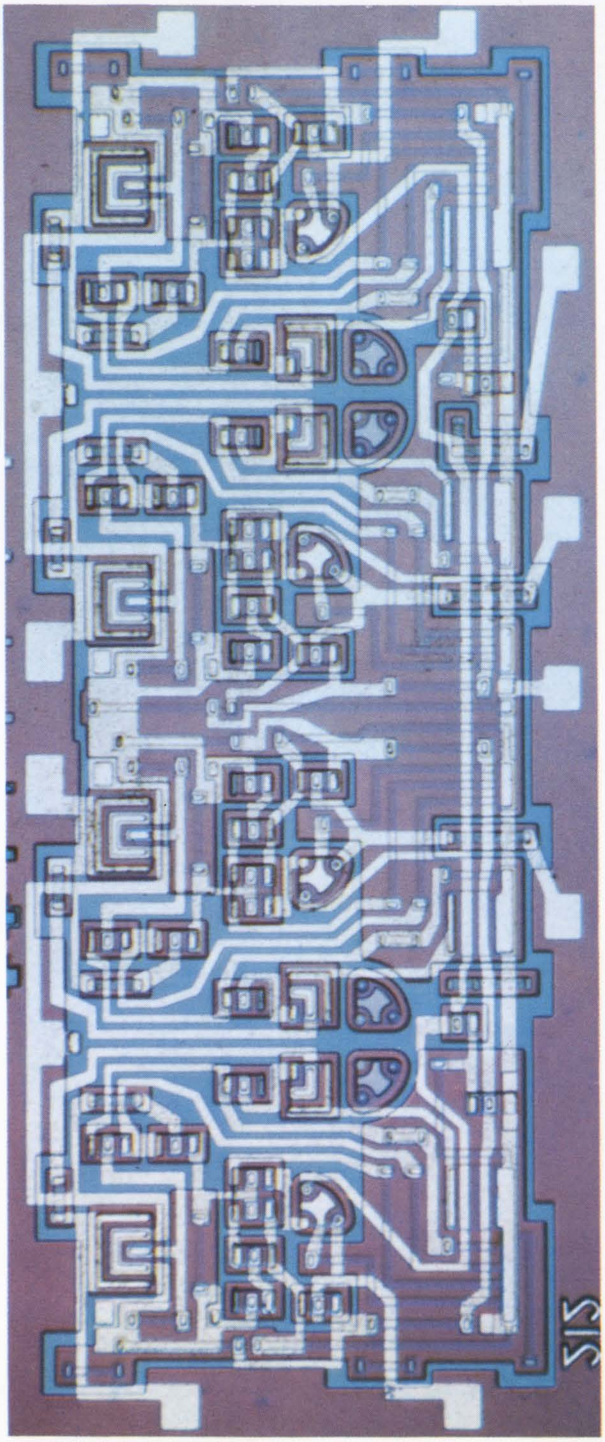
Addenda

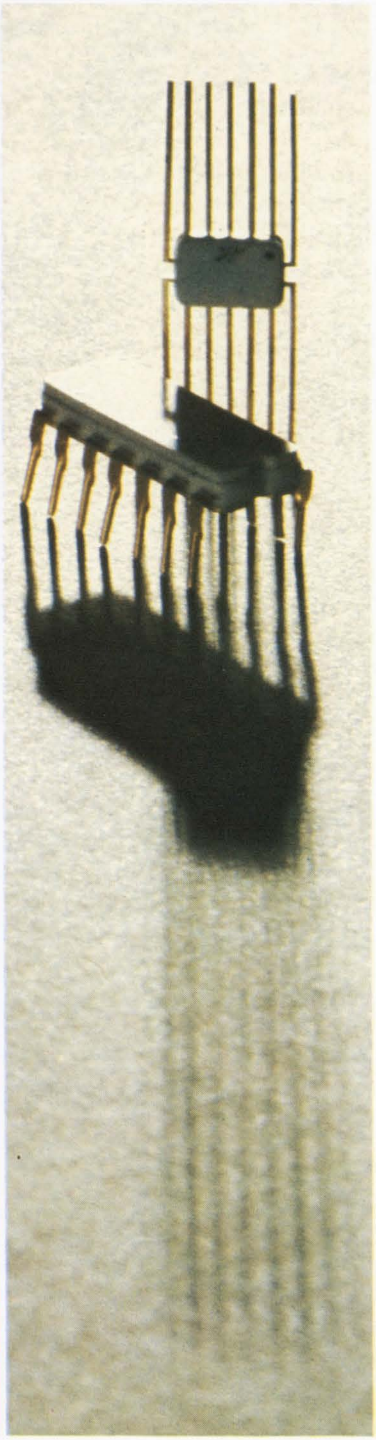
Computer manufacturers will lose many lucrative maintenance contracts on Government automatic data processing equipment if the General Accounting Office has its way. GAO, Congress's fiscal watchdog, contends that Government agencies could save money if they used their own computer maintenance personnel. Leaving out many specialized military computers, the GAO calculated that Federal agencies now spend about $50 million annually for maintenance contracts on computers owned by the Government. . . . While foreign bids are still due on the giant Intelsat 4 communications satellite, one domestic firm has already released information on its bid. Lockheed Missiles and Space has proposed a barrel-shaped satellite 9 feet wide and 16 feet high, weighing 1,075 pounds. . . . **Six unidentified firms have been asked by Lockheed-California to bid on the job of integrating the avionics hardware for its L-1011 airbus. That varies from the usual way of equipping commercial airliners,** in which the airframe manufacturer negotiates with customers directly to meet their avionics needs.

Integrated Circuit IDEAS

FROM SYLVANIA

Increase computer speed and reliability... cut size and costs at same time.





SM-60 4-bit storage register

You get all these system improvements when you design around Sylvania monolithic digital functional arrays.

Sylvania monolithic arrays come in the familiar 14-lead package—in-line or flat pack—you know so well with our SUHL™ circuits. Easy to plug into conventional circuit boards.

The big difference is packaging density—more functions per package, less pins per function and higher speed. Monolithic arrays, typical of today's most modern MSI (medium-scale integration) technology, give you in single compact units such basic computer subsystems as adders, frequency dividers, registers and memories which work at faster speeds, use less power, need fewer connections and cost less than discrete IC subsystems.

Table 1 gives you an idea of the degree to which a computer can be simplified, reduced in size and made more efficient by use of Sylvania arrays.

In addition, our arrays significantly improve total system performance and reliability. Consider some of their advantages.

(Continued on next page)

This issue in capsule

TABLE 1. MONOLITHIC DIGITAL FUNCTIONAL ARRAYS VS. CONVENTIONAL ICs

Typical Computer Subsystems	Sylvania Monolithic Digital Functional Arrays: Number of Packages	Number of Equivalent Discrete Components	Speed (nsec)	Power (Milliwatts)	Number of External Connect'ns	Conventional Integrated Circuits: Equivalent Number of IC Gates	(A) Power (Milliwatts)	(B) No. of External Connect'n
Basic Single Stage Fast Adder With Anticipated Carry	1	73	14	120	14	18	180	64
Four Bit Anticipated Carry Adder	4	292	35	480	56	72	720	252
Four Bit Ripple Carry Adder	4	264	60	400	32	36	540	132
Eight Bit Anticipated Carry Adder	12	704	45	1040	168	172	1460	602
Eight Bit Ripple Carry Adder	8	528	120	800	112	72	1080	252
Decade Frequency Divider	1	116	DC to 30 mHz	150	6	40(C)	600(C)	140(C)
Four Bit Register (Bus Transfer Output)	1	87	15	120	12	25	350	89
Four Bit Register (Cascode Pullup Output)	1	94	15	120	11	25	350	89

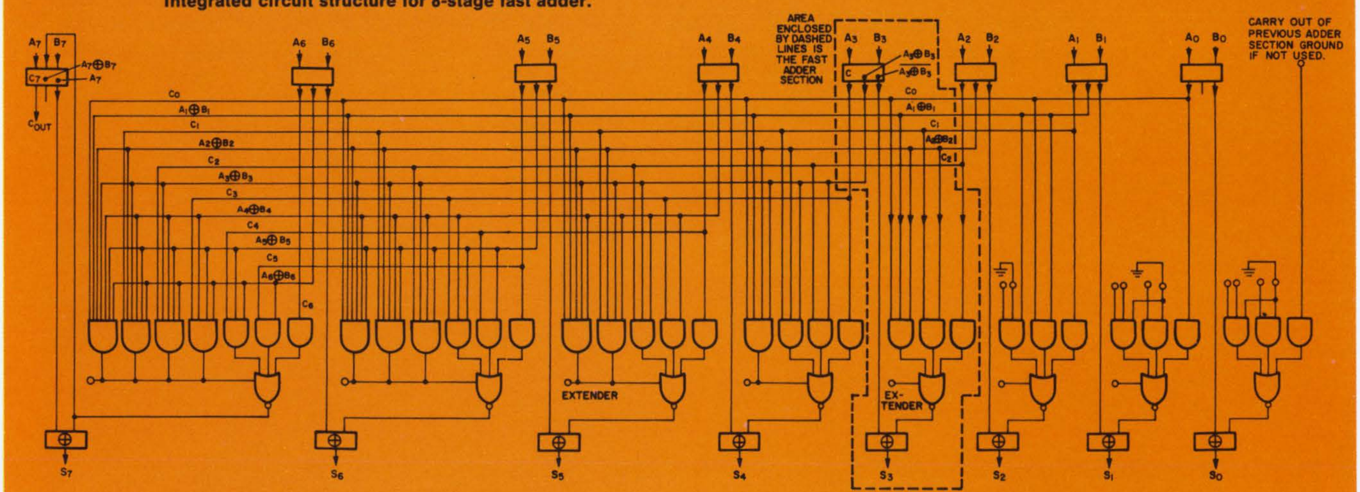
(A) Based on Average of 15 mw per NAND/NOR and Average of 5mw per AND-NOR Expansion.
(B) Based on Average of 4 Gates per 14-Lead Package.
(C) Using 4 Sylvania JKs and a Pulse Shaping Gate, the Package Count would be 5 and Interconnections 37. Average Power Drain would be 190 mw.

FUNCTIONAL ARRAYS, TYPICAL CHARACTERISTICS (+25°C, +5.0 Volts)

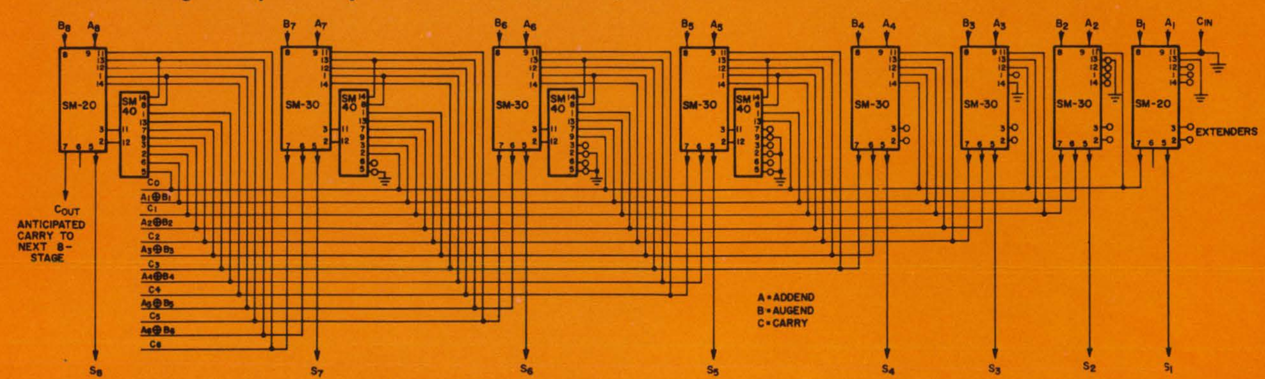
Function	Type Nos.	t_{pd} (nsec)	Avg. Power (mw)	Noise Immunity +(volts)	Noise Immunity −(volts)	**Military (−55°C to +125°C) Prime FO	Military Std. FO	**Industrial (0°C to +75°C) Prime FO	Industrial Std. FO
Full Adder	SM-10, SM-11, SM-12, SM-13	sum 22 carry 10	90	1.0	1.0	20	10	20	10
Dependent Carry Fast Adder	SM-20, SM-21, SM-22, SM-23	sum 22 carry 10	125	1.0	1.0	20	10	20	10
Independent Carry Fast Adder	SM-30, SM-31, SM-32, SM-33	sum 22 carry 10	125	1.0	1.0	20	10	20	10
Carry Decoder	SM-40, SM-41, SM-42, SM-43	2	25	1.0	1.0				
Decade Frequency Divider	SM-50, SM-52	30 MHz	120	1.0	1.0	15		15	
Four Bit Storage Register Bus Transfer Output	SM-60, SM-61, SM-62, SM-63	20	30/bit	1.0	1.0	20	10	20	10
Four Bit Storage Register Cascade Pullup Output	SM-70, SM-71, SM-72, SM-73	20	30/bit	1.0	1.0	20	10	20	10
16-Bit Scratch Pad Memory	SM-80, SM-81, SM-82, SM-83	25	250	1.0	1.0	40	20	40	10

*Minimum toggle frequency **Minimum fan-out

Integrated circuit structure for 8-stage fast adder.



8-stage anticipated carry fast adder made from SM-20, SM-30 and SM-40 monolithic digital functional arrays.



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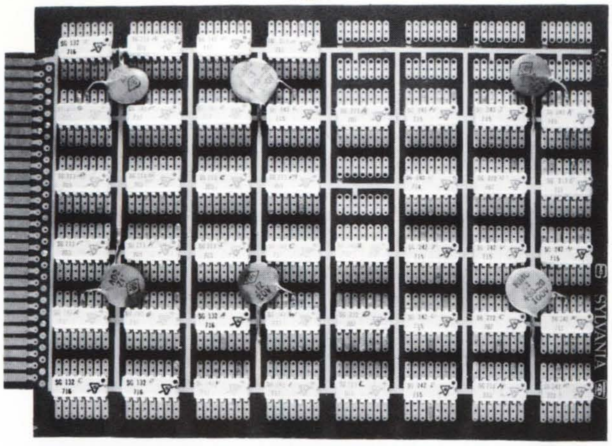

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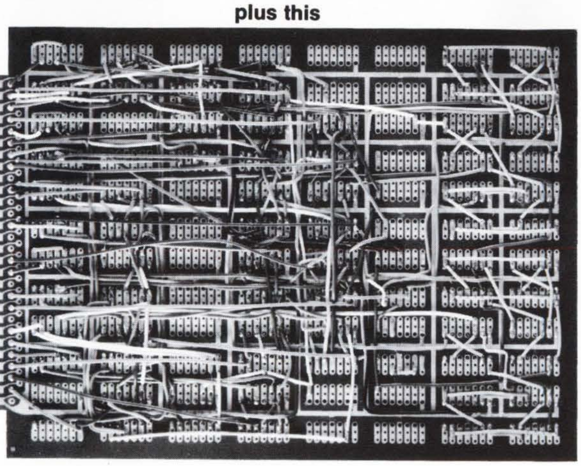


equals this

Complex Sylvania monolithic array (below, in 28-lead package) performs all the functions of the double-sided discrete-component IC circuit board, above. Available soon, it will be much more economical to produce in volume.

An array system puts more of its essential connections inside the basic 14-lead package. So there's less external wiring, and therefore a lower assembly cost, as the diagram (above) indicates.

Arrays provide more equivalent gating functions per pin: about 2 gates per pin typical in our SM-60 four-bit storage register.

Because signal paths are shorter, arrays reduce propagation-delay time and give better control of $t_{\overline{pd}}$ paths.

An array design, as opposed to a discrete-IC-board unit, has less backwiring. Shorter current paths reduce cross-talk, external noise pickup, self-induced ($L\frac{\Delta i}{\Delta t}$) noise as well as power-supply-decoupling requirements. And metallization assures better "dress" between individual components, and thus better control of inter-component-connection electrical characteristics.

Sylvania now has, or is developing, arrays for every stage of a computer:

Arithmetic	Control	Memory	Input/Output
Adders: SM-10, -20, -30, -40	BCD* counter	16-bit scratch-pad memory, SM-80	BCD* to 7-line translator
4-bit universal shift register*	Binary counter	4-bit storage register, SM-60, -70	

**Presently in engineering development stage.*

Our monolithic digital functional arrays—their numbers and functions—are shown on page 2 opposite. Tear it out and save it for reference.

CIRCLE NUMBER 300

Now SUHL™ ICs in molded plastic packages give you reliability plus economy.

More SUHL integrated circuits for the dollar, along with other advantages for you in performance and reliability. That's the big reason to consider these TTL's now in a new modern molded plastic package.

Our SUHL circuits are still available in ceramic flat packs and dual in-line plug-in packages. But now SUHL is available in molded plastic packages with glassivated wires and chips, providing an inert interface between the plastic and the active device . . . a Sylvania extra. In this package, our SUHL circuits meet the needs of design engineers more economically than ever before.

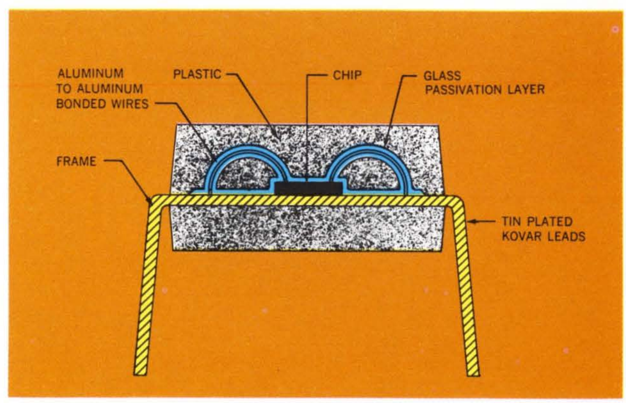
SUHL types in this newest package include the AND-NOR, NAND/NOR and J-K flip-flop families. All are temperature rated for operation over the 0-75°C range. The glass-coated chips are moisture-proof and are fully protected from contamination by foreign matter. Heat dissipation capability is equivalent to that of a ceramic flat-pack.

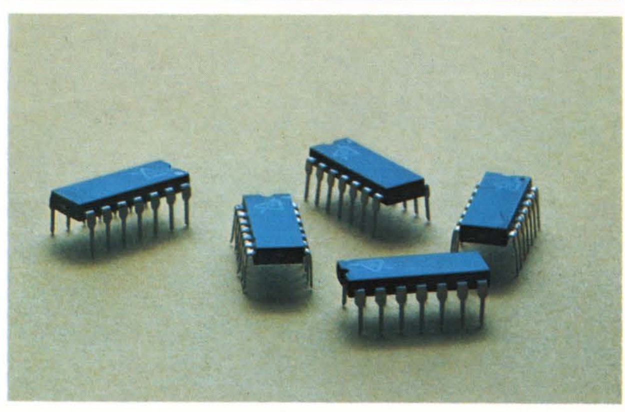
With the new molded plastic package, tinned rectangular leads are spaced 100 mils apart and are canted to facilitate automatic machine insertion in circuit boards.

Leads are attached to chips using aluminum-to-aluminum ultrasonic bonding methods. Because there is no trimetal interface (silicon can represent the extra metal), there is no possibility of self-generated bond failure due to "purple plague".

And where cost economy is important, these units offer dependable SUHL circuitry at the lowest prices ever. Sylvania passes along to the user the savings accrued through more efficient assembly processes. So you get our familiar high-quality SUHL circuits in an efficient package at the right price.

CIRCLE NUMBER 301





SUHL™ I and II IC's—the runaway favorites in TTL—now offer some 160 different types.

SUHL I TYPICAL CHARACTERISTICS (+25°C, +5.0 Volts) Function	Type Nos.	$\overline{t_{pd}}$ (nsec)	Avg. Power (mw)	Noise Immunity +(volts)	−	**Military (−55°C to +125°C) Prime FO	Std. FO	**Industrial (0°C to +75°C) Prime FO	Std. FO
NAND/NOR Gates									
Dual 4-Input NAND/NOR Gate	SG-40, SG-41, SG-42, SG-43	10	15	1.1	1.5	15	7	12	6
Single 8-Input NAND/NOR Gate	SG-60, SG-61, SG-62, SG-63	12	15	1.1	1.5	15	7	12	6
Expandable Single 8-Input NAND/NOR Gate	SG-120, SG-121, SG-122, SG-123	18	15	1.1	1.5	15	7	12	6
Dual 4-Input Line Driver	SG-130, SG-131, SG-132, SG-133	25	30	1.1	1.5	30	15	24	12
Quad 2-Input NAND/NOR Gate	SG-140, SG-141, SG-142, SG-143	10	15	1.1	1.5	15	7	12	6
Triple 2-Input Bus Driver	SG-160, SG-161, SG-162, SG-163	15	15	1.1	1.5	15	7	12	6
Triple 3-Input NAND/NOR Gate	SG-190, SG-191, SG-192, SG-193	10	15	1.1	1.5	15	7	12	6
AND-NOR Gates									
Expandable Quad 2-Input OR Gate	SG-50, SG-51, SG-52, SG-53	12	30	1.1	1.5	15	7	12	6
Expandable Dual Output, Dual 2-Input OR Gate	SG-70, SG-71, SG-72, SG-73	12	20/gate	1.1	1.5	15	7	12	6
Exclusive-OR with Complement	SG-90, SG-91, SG-92, SG-93	11	35	1.1	1.5	15	7	12	6
Expandable Triple 3-Input OR Gate	SG-100, SG-101, SG-102, SG-103	12	25	1.1	1.5	15	7	12	6
Expandable Dual 4-Input OR Gate	SG-110, SG-111, SG-112, SG-113	12	20	1.1	1.5	15	7	12	6
Non-Inverting Gates									
Dual Pulse Shaper/Delay-AND Gate	SG-80, SG-81, SG-82, SG-83	11	30/gate	1.1	1.5	15	7	12	6
Dual 4-Input AND/OR Gate	SG-280, SG-281, SG-282, SG-283	11	38/gate	1.0	1.5	10	5	8	4
AND Expanders									
Dual 4-Input AND Expander	SG-180, SG-181, SG-182, SG-183	< 1	0.9/gate	1.1	1.5				
Dual 2 + 3 Input AND/OR Expander	SG-290, SG-291, SG-292, SG-293	7	15/gate	1.0	1.5				
OR Expanders									
Quad 2-Input OR Expander	SG-150, SG-151, SG-152, SG-153	4	20	1.1	1.5				
Dual 4-Input OR Expander	SG-170, SG-171, SG-172, SG-173	3	5	1.1	1.5				
Flip-Flops									
Set-Reset Flip-Flop	SF-10, SF-11, SF-12, SF-13	20MHz*	30	1.1	1.5	15	7	12	6
Two Phase SR Clocked Flip-Flop	SF-20, SF-21, SF-22, SF-23	20MHz*	30	1.1	1.5	15	7	12	6
Single Phase SRT Flip-Flop	SF-30, SF-31, SF-32, SF-33	15MHz*	30	1.1	1.5	15	7	12	6
J-K Flip-Flop (AND Inputs)	SF-50, SF-51, SF-52, SF-53	20MHz*	50	1.1	1.5	15	7	12	6
J-K Flip-Flop (OR Inputs)	SF-60, SF-61, SF-62, SF-63	20MHz*	55	1.1	1.5	15	7	12	6
Dual 35MHz J-K Flip-Flop (Separate Clock)	SF-100, SF-101, SF-102, SF-103	35MHz*	55/FF	1.0	1.5	11	6	9	5
Dual 35MHz J-K Flip-Flop (Common Clock)	SF-110, SF-111, SF-112, SF-113	35MHz*	55/FF	1.0	1.5	11	6	9	5
SUHL II TYPICAL CHARACTERISTICS (+25°C, +5.0 Volts)									
NAND/NOR Gates									
Expandable Single 8-Input NAND/NOR Gate	SG-200, SG-201, SG-202, SG-203	8	22	1.0	1.5	11	6	9	5
Quad 2-Input NAND/NOR Gate	SG-220, SG-221, SG-222, SG-223	6	22	1.0	1.5	11	6	9	5
Dual 4-Input NAND/NOR Gate	SG-240, SG-241, SG-242, SG-243	6	22	1.0	1.5	11	6	9	5
Single 8-Input NAND/NOR Gate	SG-260, SG-261, SG-262, SG-263	8	22	1.0	1.5	11	6	9	5
AND-NOR Gates									
Expandable Dual 4-Input OR Gate	SG-210, SG-211, SG-212, SG-213	7	30	1.0	1.5	11	6	9	5
Expandable Quad 2-Input OR Gate	SG-250, SG-251, SG-252, SG-253	7.5	43	1.0	1.5	11	6	9	5
Expandable Triple 3-Input OR Gate	SG-300, SG-301, SG-302, SG-303	7	36	1.0	1.5	11	6	9	5
Expandable Dual Output Dual 2-Input OR Gate	SG-310, SG-311, SG-312, SG-313	7	30/gate	1.0	1.5	11	6	9	5
AND Expanders									
Dual 4-Input AND Expander	SG-180, SG-181, SG-182, SG-183	< 1	0.9/gate	1.1	1.5				
OR Expanders									
Quad 2-Input OR Expander	SG-230, SG-231, SG-232, SG-233	2	28	1.0					
Dual 4-Input OR Expander	SG-270, SG-271, SG-272, SG-273	2	6.7	1.0	1.5				
Flip-Flops									
Dual 50 MHz J-K Flip-Flop (Separate Clock)	SF-120, SF-121, SF-122, SF-123	50MHz*	55/FF	1.0	1.5	11	6	9	5
Dual 50MHz J-K Flip-Flop (Common Clock)	SF-130, SF-131, SF-132, SF-133	50MHz*	55/FF	1.0	1.5	11	6	9	5
50MHz J-K Flip-Flop (AND Inputs)	SF-200, SF-201, SF-202, SF-203	50MHz*	55	1.0	1.5	11	6	9	5
50MHz J-K Flip-Flop (OR Inputs)	SF-210, SF-211, SF-212, SF-213	50MHz*	55	1.0	1.5	11	6	9	5

MONOLITHIC LINEAR AMPLIFIERS TYPICAL CHARACTERISTICS (+25°C)

Function	Type Nos.	Supply Voltages	Power Dissipation (mW)	Input Impedance	Output Impedance	Output Signal Swing Vp-p	−3db Freq. MHz	Voltage Gain (db)	Temperature Range
Wide Band Video Amplifier	SA-20, SA-21	+24V	450	1.6K	1.5	13.0	100	21	−55°C to +125°C
High Gain Operational Amplifier	SA-40, SA-41 SA-42, SA-43	+12 to +6 and −6 to −3	80/40	25K	125	10.0	1.2	69	−55°C to +125°C 0°C to +75°C
Amplifier/Limiter/Discriminator	SA-500, SA-501	+10 to +5.5	125	2.5K	15K	2.8	6	75	−55°C to +125°C

Our Sylvania SUHL I and II lines offer you more different types of TTLs to do more different jobs—faster and better—than any comparable TTL line in the industry. For your convenience, the list (left) is color-coded to the IC diagrams on this page. Tear it out and save it for reference.

Applications engineers estimate that 80% of new computer designs call for TTL. And our SUHL line—*S*ylvania *U*niversal *H*igh-level *L*ogic—is the industry's acknowledged leader in TTL, the line that other manufacturers admit to copying.

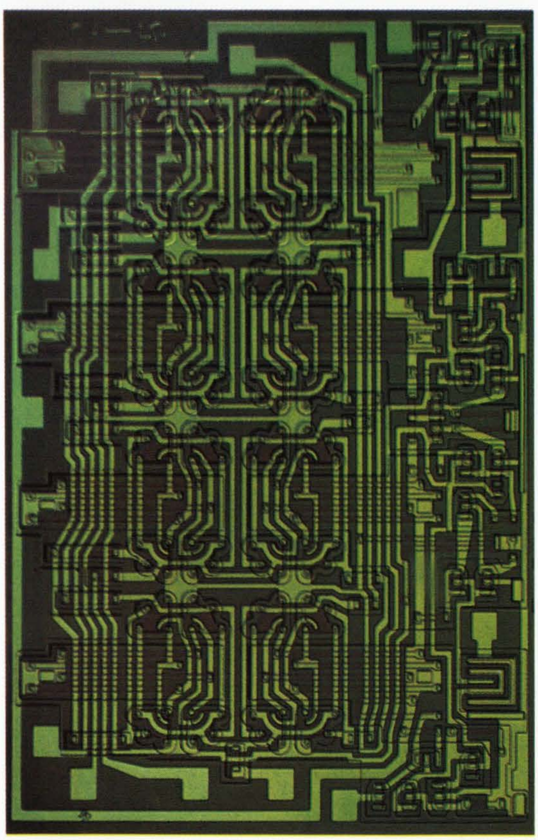
Speed is the most important advantage, of course. Our SUHL II flip-flops, for example, provide up to 50 MHz switching speed, as little as 6 nsec propagation delay time ($t_{\overline{pd}}$) while retaining extremely high noise immunity.

Shown here is a full list of SUHL I and II TTL logic elements available to you, all color-coded to the appropriate diagrams. (The chart at bottom, listing linear amplifiers, is not color coded.) Our monolithic digital functional arrays are listed on page 2 with an article on the subject.

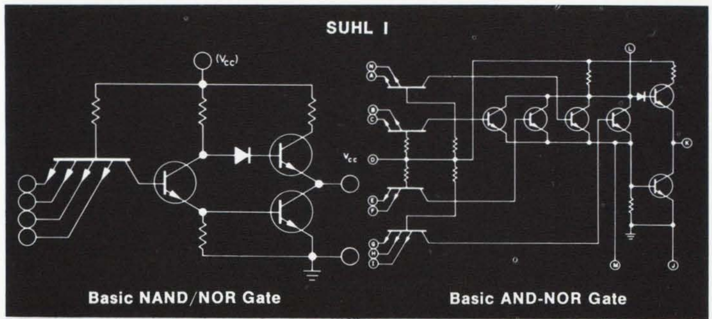
SUHL circuits are still the fastest TTL's; in addition to maintaining good switching speeds, they keep waveform integrity under varying loads and fluctuating temperatures.

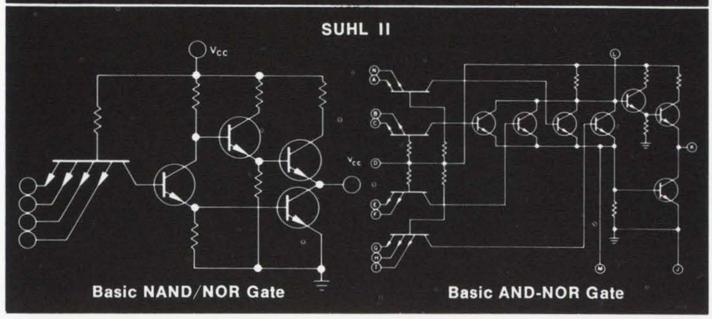
Every Sylvania TTL element is fully and automatically tested on our specially designed *M*ultiple *R*apid *A*utomatic *T*est *O*f *M*onolithic *I*ntegrated *C*ircuits (MR. ATOMIC) equipment to assure that you get the performance you pay for every time. All units, except as noted, are available in 14-lead flat-pack style or dual in-line plug-in packages.

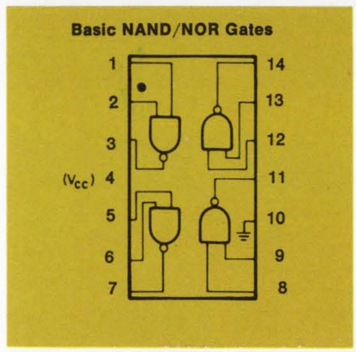
CIRCLE NUMBER 302

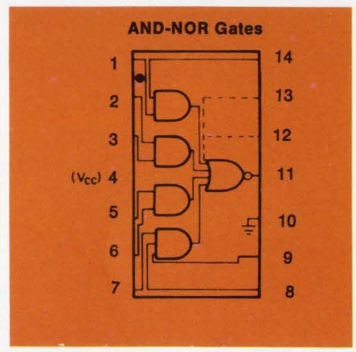


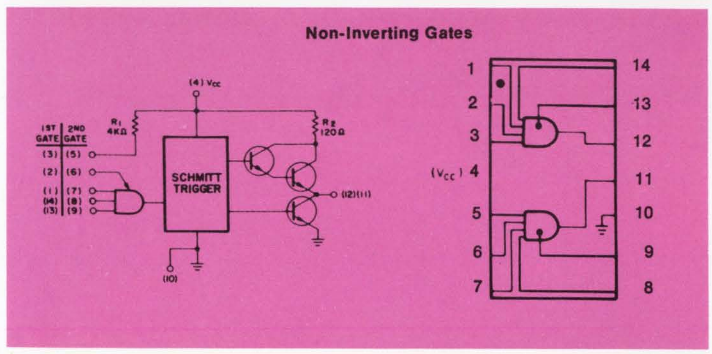
SM-80, 16-bit scratch-pad memory.

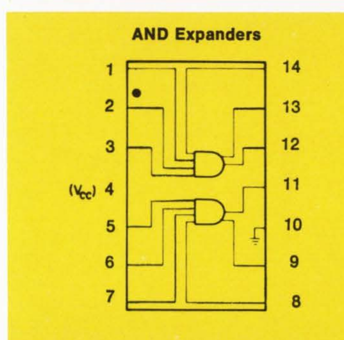


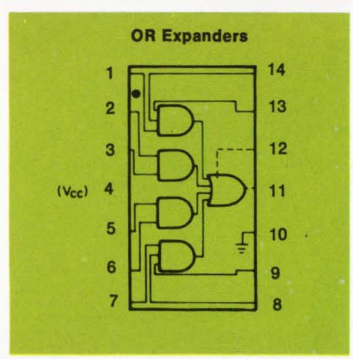


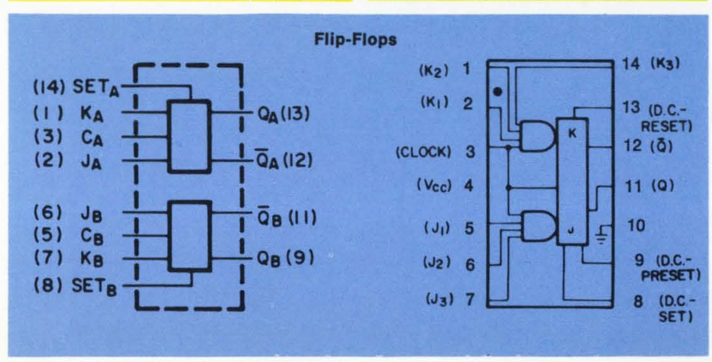












Custom microcircuits: repeatability at low cost through active trim.

Now, through active trim of hybrid microcircuits, Sylvania can meet exact requirements for repeatability of quiescent DC level balance.

Until recently, electronic circuit designers would first select circuit topology and then, to fulfill their specific requirements, would compute active and passive device values. With that approach, circuit performances could fall within a wide range of values, sometimes resulting in poor production yield.

To improve yield, previous options open to the design engineer were either to select tightly toleranced components or to specify adjustable elements to bring circuit performance within acceptable limits. These choices often lead either to relatively higher cost or to larger package size.

But now, with the conventional microcircuit, Sylvania individually trims passive components to final value through the use of a null-detecting bridge. Passive component trimming can achieve the desired circuit performance characteristics.

Final adjustment is effected after active components have been attached and after the circuit has been energized. During this final trim, the rate and amount of abrasion is controlled by monitoring the circuit characteristic of interest. This trim allows the circuit designer to work with broader tolerance of individual circuit elements. Such a technique can be cost-effective since in-process yields are substantially increased as individual component tolerances are relaxed.

As one example of an active trim application, let's take a photocell signal amplifier. It is used in a character recognition system where the quiescent DC level from a matrix of cells has to be balanced. A requirement is that the output of each amplifier must be held at a fixed DC value from unit to unit. The actual circuit is shown in Figure 1. Figure 2 is an equivalent schematic.

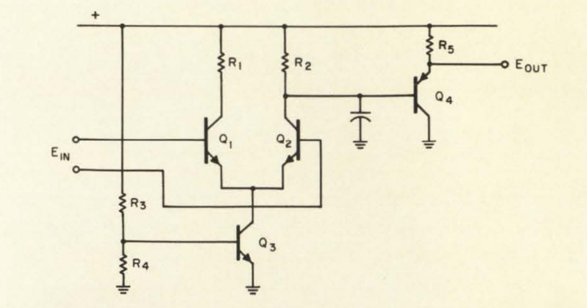


Figure 2—Equivalent circuit diagram of photocell signal amplifier.

The output voltage level is established by the output of a differential amplifier. The emitters of the differential transistor pair (Q1 and Q2) are connected to a transistor current source (Q3). The level of current is fixed by the values of resistors R3 and R4 to set a bias for Q3.

After all required adjustments have been made, this circuit is energized and R4 is adjusted to a predetermined value of output voltage. Since in the thick film technology screened resistors are fired to value below the desired nominal, R4 may be increased in value by using air-abrasive trim techniques to effect a geometry change. As the value of R4 is increased, the operating point of Q3 is changed causing the increase in collector current. As the voltage drop in R2 changes, DC level at the output of the emitter follower approaches the required level.

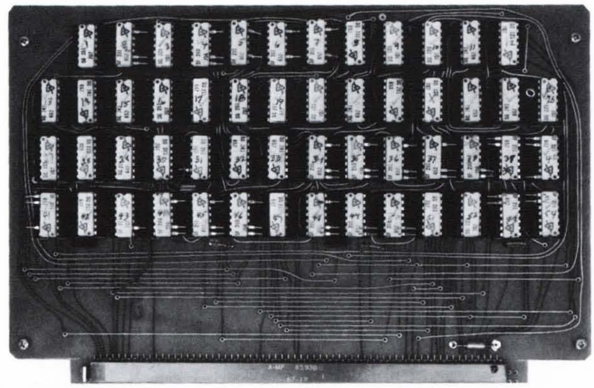
This represents just one example of how Sylvania meets the need for inexpensive hybrid microelectronic circuits tailored to your operational requirements.

CIRCLE NUMBER 303

Figure 1—Air-abrasive trim techniques are used to precisely adjust circuit operating characteristics.

Largest aircraft will rely on some of world's smallest, fastest ICs: Sylvania SUHL™II.

World's largest aircraft, U.S. Air Force C-5A Galaxy built by Lockheed-Georgia Company of Marietta, Ga., employs Sylvania SUHL II high-speed IC logic elements in its self-checking Malfunction Detection, Analysis and Recording (MADAR) subsystem, its station-keeping equipment (SKE) radar subsystem and its landing gear proximity switch control units.



One of ten printed IC mounting boards used in Galaxy's station-keeping equipment (SKE) synchronizer.

The Lockheed C-5A Galaxy will not only be the world's largest aircraft. It will also be one of the world's most self-sufficient.

Through its Malfunction Detection, Analysis and Recording (MADAR) subsystem, the aircraft continuously monitors over 600 critical test points during take-off, flight and landing. If a defect occurs, the defective subsystem's number lights up on the flight engineer's instrument panel. Then for a diagnostic check, the flight engineer calls for a live waveform and views it adjacent to comparative ideal waveforms projected on a screen from a random-access memory bank, and takes corrective measures. And as he makes manual diagnoses and corrections, MADAR continues monitoring other test points automatically.

The MADAR subsystem is designed around Sylvania SUHL II ultra-high-speed integrated circuits. Our SUHL II ICs also accomplish essential logic functions in the synchronizer unit of the aircraft's station-keeping equipment (SKE) and in the landing gear proximity switch control system. The SKE system is a low-frequency (doppler) radar which automatically maintains the correct relative flight position of every aircraft in a fleet. The landing-gear proximity switch senses the position of the landing gear and landing-gear housing doors, controls their sequence of operation and informs the crew of any malfunction.

The MADAR control and sequencer uses about 450 SUHL II ICs; the SKE synchronizer has some 378.

How important are they? Says Lockheed:

"By using integrated circuits and . . . thick-film hybrid circuits, the size and weight of these systems has been greatly reduced while reliability increased. Development of either system without integrated circuits would have been impractical; the complexity of discrete component designs, to accomplish the required logic functions, would have resulted in units too large and heavy and too unreliable to use on aircraft."

Artist's conception of C-5A in flight. Aircraft is designed to carry 100,000 pounds of payload for 6300 miles, and up to 265,000 pounds for shorter distances. It will be 82 yards long with a wingspan of 74 yards.

What more can we say?

CIRCLE NUMBER 304

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MANAGER'S CORNER

LSI...around the corner. But MSI is here now.

We've all heard tales of the girl who rejects the nice boy next door while she waits for Prince Charming . . . and winds up an old maid.

Right now in the computer business, medium-scale integration (MSI)—in the form of monolithic digital functional arrays—is in the position of the nice boy next door, while LSI is Prince Charming.

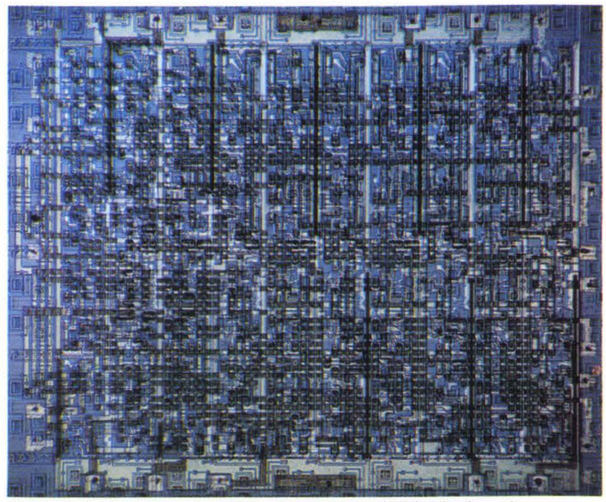
MSI devices are something *we make and you can use*—today, without redesign of your present circuit configurations. LSI is still in the future both as to volume manufacture and practical application.

There's an unfortunate tendency in this industry to "announce" something when it's on the drawing board, and to say it's "in stock" when a prototype has been produced. (By that definition, Sylvania could claim we have LSI devices "in stock", because we have produced and are testing prototypes with over 100 functions on a chip.) But we don't believe in that; when we say we have something "in stock", we mean we have a device that works and that we can deliver in quantity within a matter of days.

And we *do* have MSI devices in stock. Such devices will be the basis of practical computer designs for the next five years or so. Any computer manufacturer who passes up MSI to wait for LSI is likely to find himself in the situation of the girl waiting for Prince Charming. Left out.

Our MSI monolithic arrays, available in the familiar TO-85 14-lead flat pack or 14-lead dual-in-line plug-in package, provide in general from 20 to 50 gating functions on a single chip with a single layer of metallization. These devices are fully compatible with existing monolithic logic; they interface with present-day systems without major redesign effort on your part.

Larger-scale integration—which we're working on—refers to a functional device with more than 100 functions, created by multiple-layer interconnections using metallized fixed connective patterns. This will bring



Sylvania LSI chip: over 1200 components, 100 logic functions.

about a technique in which—on a 500-gate 2-inch wafer—by selection and rejection only functioning gates are wired. This could yield 400 or more functions in a single package . . . the beginning of the "computer-on-a-wafer" concept.

But such devices—to produce in volume and to be used practically—will require much more sophistication on the part of both manufacturer and user than the present state of the art permits. To produce them will require the ability to create an extremely high yield of usable functions on a wafer, excellent control of multiple-layer interconnection techniques and very complex testing and packaging procedures. Equipment and process requirements will be elaborate and costly.

More significantly, the engineering required by the computer designer, builder and user must be advanced to a far higher level than present technologies demand. Builders must understand the importance of these differences before committing themselves to an approach.

So . . . LSI is coming. But meanwhile, MSI in the form of functional arrays is the practical solution to *today's* computer design problems.

Harry Luhrs

H. M. Luhrs
Product Marketing Manager
Integrated Circuits

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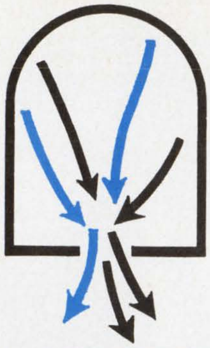

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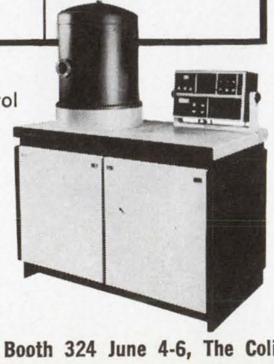

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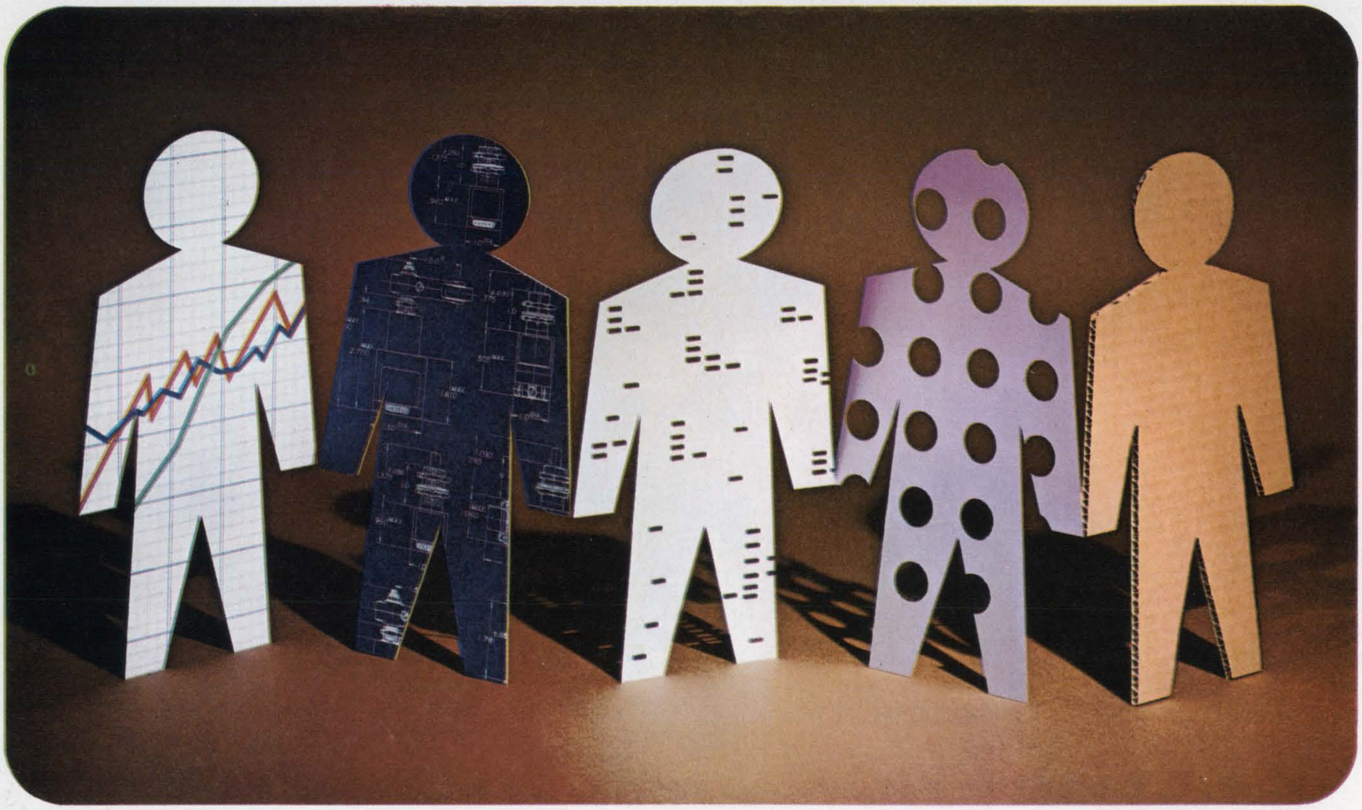

Left to right: vice president, design engineer, computer programmer, punch press operator, and shipping clerk. Not present for picture: All the other employees of MICRO SWITCH.

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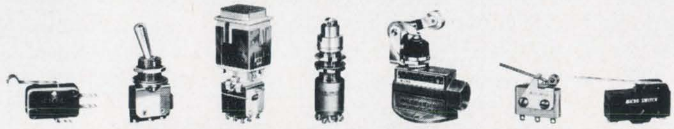

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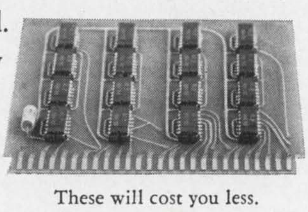

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Electronics Review

Volume 41
Number 8

Integrated electronics

Plastic IC's still 4-F

Despite manufacturers' claims about the ruggedness of plastic-packaged integrated circuits and their suitability for military applications, the Pentagon remains unconvinced. Reliability testing by Government groups, though not exhaustive, has failed to establish a basis for acceptability, according to defense officials.

But the prospect of realizing tremendous cost savings by buying plastic-encapsulated devices in place of metal-can versions has prompted the Government to call a meeting of solid state experts to tackle the question. The experts will be asked to come up with an answer, or at least a basis for evaluation.

Charged atmosphere. The conference, at which Federal officers and makers' representatives will confront one another, promises to be stickier than one might suspect. The ordinary give-and-take of such meetings will be inhibited not only by the conferees' widely differing viewpoints, but by earlier insinuations of incompleteness in the claims made for plastic IC's and by pressure from the higher echelons of Government.

On the Government side will be representatives of the armed services, NASA, the Army's Harry Diamond Laboratories, and the Jet Propulsion Laboratory, among others. Among the companies invited to the mid-May meeting in Washington are all the vendors of plastic IC's, including the big four—Texas Instruments, Motorola, Fairchild, and Signetics—plus such users as Autonetics, which, incidently, has been conducting extensive tests on the devices for the past few months. [Electronics, April 17, 1967, p. 101].

Background. Plastic-encapsulated IC's, which have been around for a few years now, have recently been aggressively promoted by many makers for use in military jobs now open only to metal-can circuits. These firms implied that the devices' moisture resistance, while not as good as that of the hermetically sealed metal-can units, was sufficient for most applications.

Since the plastic IC's usually cost only half as much as their metal-can counterparts, Government purchasing agents, beset by budget problems, have strenuously urged their acceptance by the various Federal groups responsible for reliability evaluation. But these groups have tested them under conditions the metal devices must withstand, and have found that the plastic units fail in most cases, usually because of an insufficient moisture barrier. The failures occur typically after long-term (560 hours or more of operation) testing, indicating a cumulative breakdown. The failure rate is often 100%, even after months of satisfactory performance under less than worst-case conditions.

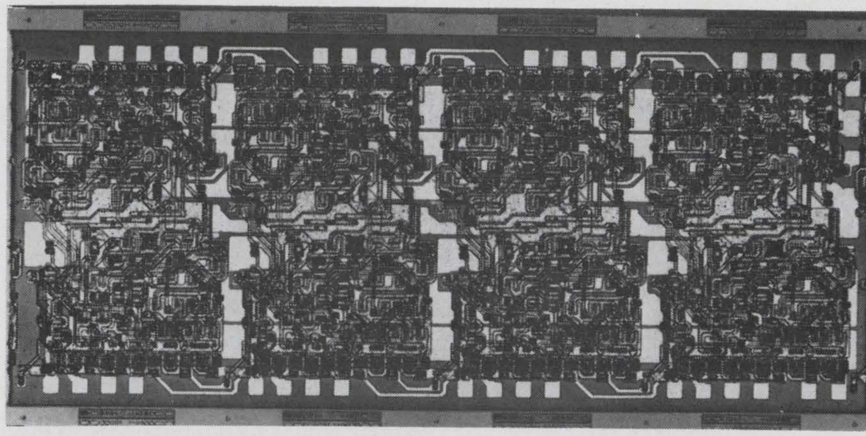
Fracture. Stress caused by shrinkage is serious enough to snap the interconnection wires on this plastic-packaged IC. Note the crack (dark oval) around the package.

No yardstick. However, since there are no specific standards for IC performance, and because each Government service and agency has its own reliability criteria, the issue can't be easily resolved. In fact, some Government spokesmen indicate an acceptance of the plastic packaged product based on the special needs of their department or agency. The Government's attitude right now seems to be that the plastic units can't be flatly rejected on the basis of the tests made so far, and that future evaluation programs should be carried out in a more coordinated manner than the earlier tests.

This general attitude won't lighten the atmosphere at the meeting. One Government official asserts that the absence of published results of long-term testing by makers is "fairly clear evidence that the plastic IC's still aren't suitable." He also criticized the short-term testing the firms do as unrealistic, and said that "if makers invested as much money into the plastic materials as they spend promoting the IC's, they'd probably come up with a suitable encasement."

Cloudy specs? The producers, on the other hand, continue to imply that plastic devices can handle most military tasks. Some have ventured that the specifications the Government issues are unrealistic and stem from the days of vacuum tubes.

One executive expressed the industry's view this way: "On the one hand, Uncle Sam tells us to use state-of-the-art devices, and the Pentagon issues a directive encouraging the use of microelectronics. On the other hand, we're instructed to use qualified parts wherever possible and we're confronted with specs that were set up for older technologies, or by no specs at all."



On the chip. Motorola will soon offer this large-scale integrated eight-bit adder as part of its regular line. The circuit contains 448 components.

First with the fastest

Engineers at the Semiconductor Products division of Motorola Inc. have been working for some three years toward the one-nanosecond speed capability they think ultrahigh speed computers will require. Now it appears the division will be the first supplier to break that barrier with a line of integrated circuits—the first three devices in its third-generation emitter-coupled-logic family. Later, the family will include at least one device incorporating large-scale integration. The first entries in the MECL 3 line [Electronics, Nov. 13, 1967, p. 26] are now in pilot production and initial orders will be filled from this operation.

For now, Motorola will introduce a dual four-input OR/NOR gate with a typical propagation delay of about one nanosecond into a 50-ohm load; a quad two-input NOR gate with the same properties and a master-slave flip-flop exhibiting a maximum delay of 1.5 nanoseconds into a 50-ohm load. With lighter loads—500 ohms at 5.2 volts—both the dual and the quad will show a typical propagation delay of just 0.8 nanoseconds. Both devices have only one layer of metallization; the flip-flop uses two layers.

On schedule. Further down the line is an eight-bit adder that has 448 components laid on a 53-by-119-mil chip using a three-layer metallization scheme. Walter Seelbach, Motorola's manager of IC research and development, estimates the adder will be ready for production in the third or fourth quarter. He said the line will also eventually include such entries as a scratch-pad memory array and a left-to-right shift register. "But for the first half of this year we'll be concentrating on the initial three parts."

Seelbach thinks Motorola is six months to a year ahead of other semiconductor manufacturers in this ultrahigh speed capability. He describes the market for MECL 3 as "trememdous."

Seelbach also believes there will be a military market. But now MECL 3 will be specified for temperatures ranging from 0° to 75° C—short of the −55° to 125° specified by the military.

High toggle frequency. "Hooked up as a binary counter, the flip-flop will be able to toggle in the 350-to-400-megahertz range," Seelbach notes. He says the previous high in toggle frequency in production circuits is the 85-Mhz figure at which Motorola's MECL 2 line is specified. He adds that the 50- and 500-ohm terminations for the dual four and quad two devices are equivalent to direct-current fanouts of 12 and 4, respectively.

Each of the three devices will go into a 170-by-250-mil hermetically sealed ceramic flatpack having 14 leads. The package design, new to Motorola, incorporates a stud that is perpendicular to the plane of the leads, which serves as both a thermal and electrical connection. "To remain flexible," explains Seelbach, "and to be able to dissipate more power down the road, we had to have better thermal characteristics in the package. Only about 7° C per watt are dissipated between the chip junction and the end of the stud. Standard flatpacks without the stud dissipate between 100° and 200° per watt inside the package. If the user mounts properly to the stud, he could get as little as 25° per watt dissipated in the package."

Michael Callahan, manager of research and development for IC devices and processes, cites some of the processing sophistication required to reach a speed of one nanosecond. "We had to develop shallow junctions—less than one-micron deep except for collector-substrate junctions. Most other current-mode logic junctions are a little deeper. Deposition also requires tight controls. Aluminum tends to go into solution with silicon and we don't want this penetration. So we use aluminum alloys that slow down this tendency and limit the metal's penetration."

Keep them small. Callahan says that individual transistors in the IC's must operate at 1 to 2 gigahertz, and must be very small to minimize the junction capacitances essential for high speed. Resistors must also be small. "The largest is 0.5 mil wide to keep parasitics down."

Regarding passivation, he explains further that oxide integrity is "excellent—less than three pinholes per wafer on the average. When we first started, pinholes were 10 times greater and we had to monitor every run. We're now down to monitoring just once a day." Motorola won't reveal yield data for any circuit, but Seelbach says, "If it weren't where it should be, he wouldn't be announcing the product."

The Phoenix division holds the basic patents on emitter-coupled logic, and Seelbach says the soon-to-be-introduced third generation is logically compatible with MECL 1 and 2 families without any interface circuitry. Prices have not yet been established.

Going naked

A number of semiconductor makers have been selling unpackaged chips—both discrete devices and integrated circuits—for quite a few years, but until recently most of them haven't been advertising the bare chips.

Several factors have contributed to this reluctance, especially on the part of the bigger vendors: the market is small (estimated at $25 million a year); small orders are typical, and vendors have felt they would be giving away some of their secrets if they made a regular business of selling unencapsulated dice.

That reluctance appears to be on the wane, principally because the market is mushrooming rapidly as hybrid-circuit suppliers step up their demand for chips they package later. The larger semiconductor manufacturers are reassessing their positions, and one—the Semiconductor Products division of Motorola Inc.—plans to introduce a line of standard unpackaged silicon transistors as its first aggressive move to get a bigger share of the business [Electronics, April 1, p. 26].

Military orders. The devices chosen—14 in all—are Motorola's most popular npn and pnp discrete transistors. One of the prime reasons for Motorola's move, says Leo Lehner, manager of product marketing at the Phoenix division, has been a big jump in demand from hybrid-circuit suppliers in the past year. He says this demand has been fueled mainly by the military's desire to integrate.

"Monolithic IC's can't meet all the requirements the military wants integrated. People have designed a lot of equipment with military-specification parts in discrete form," explains Lehner, "and now the military says integrate, so the equipment maker goes the hybrid route and has a primary position as a bidder." Some of the more popular npn silicon transistors Lehner cited in this category are the 2N2217, 2N2218, and 2N2219, all of which are covered by Motorola's unencapsulated line. The pnp counterparts are the MSC2907A and 2906 switching and amplifier transistors. Motorola substitutes the prefix MSC for the 2N prefix.

Other devices in the line are npn and pnp low-level amplifiers (MSC2484 and 3251, respectively); npn and pnp high-voltage switching and amplifier transistors (MSC3501 and 3637); npn and pnp radio-frequency amplifiers (MSC918 and 4957); npn and pnp core drivers (MSC3725 and 3467); and npn and pnp low-level switches (MSC2369 and 3546).

Joining the fun. Lehner says that Texas Instruments Inc. and the Raytheon Co. have been selling standard unpackaged chips for at least a year, and it's known that Fairchild's Semiconductor division, the National Semiconductor Corp. and the Signetics Corp. are also in the business. But none of the others appears to be pursuing the market with as much gusto as Motorola. Lehner notes that standard zener diode chips will be coming next from Motorola, to be followed by unencapsulated IC's.

Meanwhile, a new firm, Intersil Inc. of Cupertino, Calif., will begin selling as its first product a complete line of unpackaged flip-chip transistors and n-channel junction field-effect transistors.

National's marketing manager, Donald Valentine, says, "We've just been quietly selling a few dice. We never imagined anyone noticed us—much less Motorola." He says the firm sells 15 of its prime IC's and about 25 discrete transistors in chip form, and has been stocking dealers for the past six months.

Signetics has been selling unpackaged IC chips for three years, and officials there report no reluctance to do so, but neither is there any intention to introduce off-the-shelf dice.

Lehner says the military systems in which the chips are ultimately used, such as missile and guidance systems and airborne computers, involve fairly complicated technology. As a result, Motorola can get 75% to 80% of the price it asks for the same device in a metal can. "The idea of the game is not economy at all," he says. "The hybrid or multichip circuit supplier wants these chips for size reasons, technology, and to win bids."

"If he wants to make a 100-volt IC, or a fancy r-f mixer, he can't do it with a monolithic IC, so he has to go the multichip route."

Microselling. Lehner expects most of Motorola's chip sales to be in quantities of thousands, but the division isn't overlooking smaller orders. Chips in the standard transistor line will be shipped in containers for as few as 10 dice; another carrier accommodates 1,000. In both, the passivated dice fit in individual recessed compartments. A glass lid slides flush over the "bins," preventing movement of the chips in shipping and allowing the buyer to see them without opening the compartment.

Ronald Camp, Motorola product planner for silicon transistors, says buyer sophistication has done a lot to break down Motorola's earlier reluctance to sell chips. "We had to go through a learning cycle with the customer on testing, bonding, and application. Maybe he didn't know how to bond well and he'd blame us for supplying a bad chip. Now the customer is generally more knowledgeable in all these areas."

Wafers from which the chips are taken are tested only to the minimum specification for a device, but Camp points out that there will be almost no differences in the maximum ratings of the devices as chips or in packages.

Instrumentation

Lighting own way

Ever since the introduction of cold-cathode indicating tubes, instrument makers have been designing them into their products. But the Monsanto Co., whose electronic instruments group is a relative newcomer, has now decided to follow an independent line: adaptation of its own research on solid state displays. The company believes it has struck pay dirt with a light-emitting diode array. The array is used as the numerical readout in an experimental counter/timer.

Fred Katzman, who heads the instruments group, says the array represents the first time the feasibility of a solid state readout has been demonstrated as an integral part of a digital test-and-measuring instrument.

Boon. The advantages are considerable. Since each element in the array lights when it is forward biased with a current of about 10 to 100 milliamperes at about 1.5 volts, the displays are compatible with integrated circuits. Conventional displays, using cold-cathode indicators, aren't compatible because the tubes require about 100 volts. What's more, the displays can be driven directly from a dual in-line IC, while tube displays need a separate power supply and driver for each digit.

Not only are drivers, high-voltage supply, and tubes eliminated, but, says George M. MacLeod, director of the Monsanto Electronic Special Products division, "the solid state displays have longer life, greater strength, less heat generation, no parallax, and faster switching time." He claims the array eliminates the radio-frequency interference traditionally associated with gas-discharge tubes.

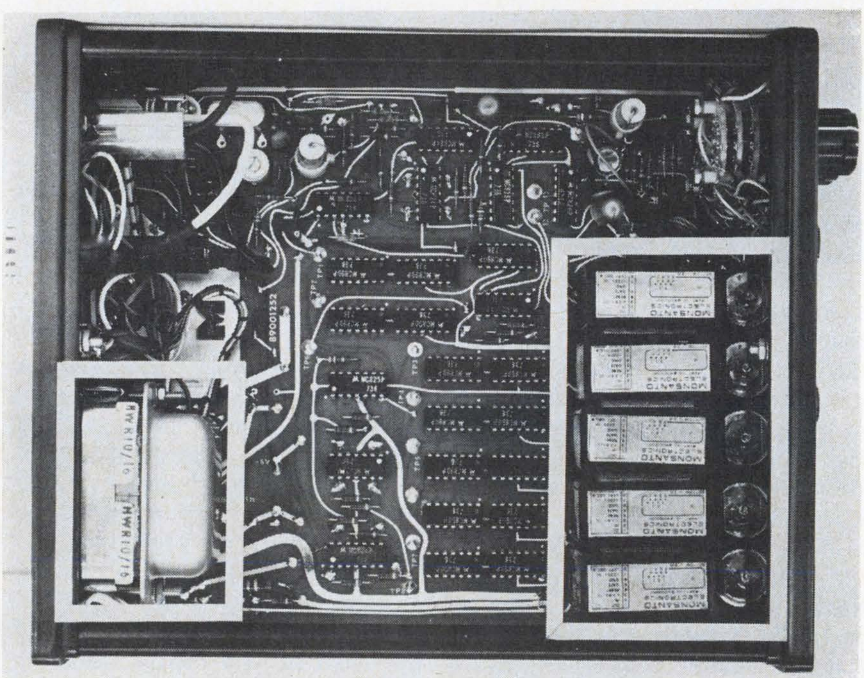
Each light-emitting diode array can combine numbers, letters, and symbols.

Says MacLeod: "No cold-cathode tube or similar readout could provide the full alphabet because there just isn't enough depth to include 26 letters."

Proof of the pudding. Monsanto modified one of its general-purpose counter/timers with the diodes. The conventional five-digit cold-cathode display was replaced with a red numeric display of gallium-arsenide phosphide diodes.

The diodes had proved reliable after several years of use singly as indicator lights on other Monsanto products. Even though the array's light output of 115 foot-lamberts is significantly less than a cold-cathode tube's 200 foot-lamberts, it is sufficient under ordinary operating conditions. Moreover, the diode array offers superior contrast.

There still is a barrier: the cost now is about $165 per digit. However, Monsanto believes that refined production techniques will make the cost competitive with conventional displays, which cost between $20 and $70 per digit.



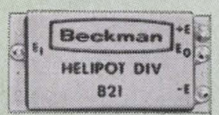
Replacement. Monsanto developed this counter/timer to prove the feasibility of a solid state display in an instrument. The light-emitting diode array eliminates power supply, drivers, and tubes of conventional cold-cathode readout displays. The electronics that have been eliminated are outlined in the photo above.

In phase

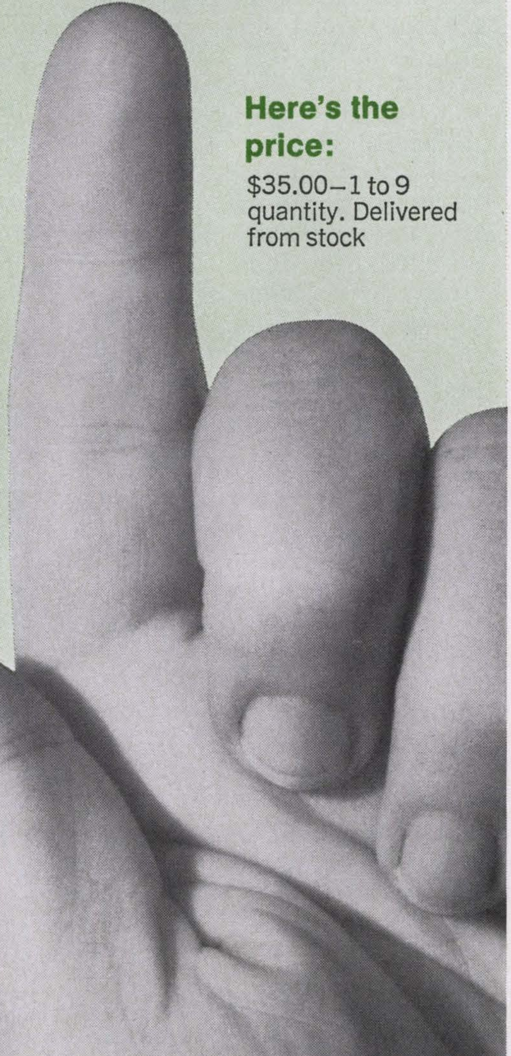
The growing sophistication of radio transmission has generated a corresponding need for quartz crystals that can give very precise frequency separation. That need, in turn, is producing a new generation of highly accurate instruments to test and measure crystal capabilities.

Conferees at the Army Electronics Command's 22nd annual Frequency Control Symposium will get a liberal helping of such devices to go with their salt water taffy when they gather in Atlantic City, N.J., next week. The Army itself has come up with one of these instruments, the Western Electric Co. another, and the Hewlett-Packard Co. has computerized

Boost IC op amp power with Helipot's miniature hybrid amplifier.



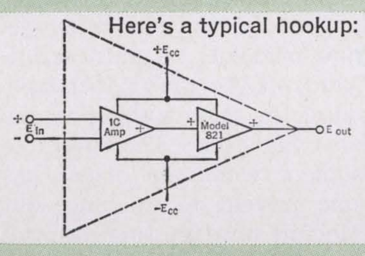
Actual Size



Here's how it performs:

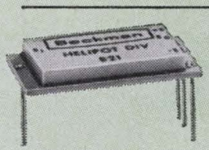
- 2.5 watt output
- 30 MHz bandwidth
- ±16V voltage swing
- less than 90° phase shift
- –55 to +125°C operation
- foldback short circuit immunity
- protects op amp and power supply from overload reflections

Here's a typical hookup:



Here's the price:

$35.00–1 to 9 quantity. Delivered from stock



The new Model 821 is a hybrid, cermet thick film power amplifier which drives load resistances as small as 100 ohms to within 4 volts of the supply voltage from d-c to 30 MHz. Its combination of unity voltage gain and wide bandwidth permits boosting the power of an IC amplifier without affecting its other performance capabilities. In addition, the Model 821's ability to block all overload reflections results in the prevention of heat generated errors in the op amp and allows immediate recovery upon overload removal.

Completely self-contained, this fully sealed power amplifier is only 0.170″ high, occupies just 0.5 sq. inches of board space, and is compatible with both flat pack and dual in-line IC packages.

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In-house. The Army's development was spurred by increasing military use of suppressed-carrier single-sideband transmission, a mode that requires precise crystals in the lower reaches of the high-frequency range. The instrument, a highly developed, well-buffered oscillator, bases its correction signal on phase-shift information rather than less accurate frequency data.

The device is extremely sensitive because it works passively: it measures a crystal tickled with only 0.1^{-15} watt and can be used with most commercially available bridges. What's more, it can measure a 100-megahertz crystal to within 0.1 hertz and is self-checking. Made under license by Parzen Research Inc. of Westbury, N.Y., the tester will be described at the symposium by O.P. Layden, A.D. Ballato, and C.L. Shibla of the Army's Electronics Command.

Familiar ring. A similar technique has been used by Western Electric's North Andover, Mass., laboratories. The method developed there by Robert P. Grenier sends a synthesizer's signal through the crystal into a calibrated phase detector. That frequency passing through the crystal with the least phase shift is the resonant frequency. By locking the synthesizer to that frequency and displaying it on an oscilloscope, the crystal's resonant point can be determined.

This technique, Grenier believes, will cut resonance uncertainty from about four parts in a million to one part in 10 million. The technique may go on the production line later this year, he adds.

Automated. The Hewlett-Packard innovation, from its labs' piezoelectric department, could bring a new look to the IEEE's specs for crystal testing, drawn up in 1957. H-P's new method, according to C.A. Adams, co-author of a paper on it with D.L. Hammond and Albert Benjaminson, uses the IEEE pi network with a vector voltmeter to make phase measurements instead of the traditional amplitude measurement. From those measurements, frequency and impedance are derived.

"When the crystal is in perfect resonance," explains Adams, "the phase goes to zero. The voltage ratio in the pi network gives you the voltage amplitude ratio. When you take a small computer and hook it up to the vector voltmeter you simply program what you want to look at in the frequency range—the impedance or resonance spectrum, for example."

With a knowledge of these parameters all equivalent circuit parameters (L_1, R_1, C_1, and C_0 as stated by the IEEE) can be computed, Adams says.

Medical electronics

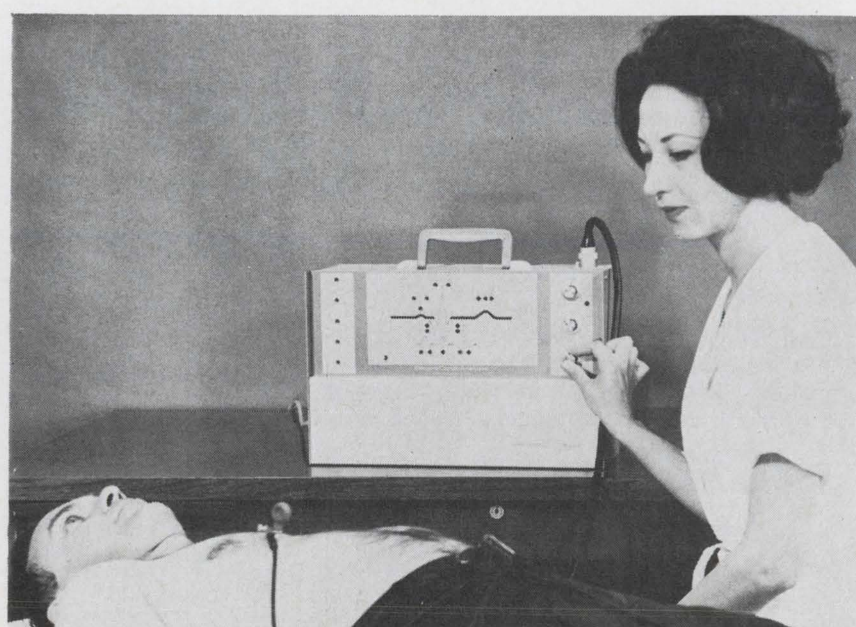
Eliminating the paper work

For every heart disorder a cardiologist uncovers with his electrocardiogram machine, he must scrutinize yards of the EKG's paper tape, searching for abnormalities in the tell-tale wiggly lines. The slow process suffices when the doctor has but one patient to examine. But with doctors now pressing for mass screenings to uncover heart troubles early, the tape-monitoring task could become Herculean. The Humetrics division of the Thiokol Chemical Corp. has now developed an EKG machine whose signals can be interpreted by a technician. It signals only when it locates something wrong. If it finds so much as a hint of an abnormality, the patient is referred to a cardiologist.

The unit—called an Electrocardioanalyzer (ECA)—is similar in function to two other machines, which monitor heart sounds rather than the EKG signal. One, the Cardioscan, is from Humetrics also and was designed for children [Electronics, Dec. 13, 1965, p. 38], and the other, for adults, was developed by Tokyo Shibaura Electric Co. (Toshiba) of Japan [Electronics, Jan. 9, 1967, p. 252].

Mass action. The new Humetrics device takes about a minute to complete the test and Humetrics officials believe more than 50 persons an hour can be monitored.

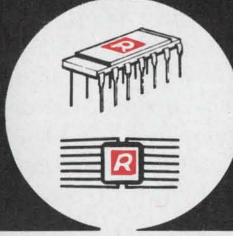
The instrument not only differentiates between normal and abnormal EKG patterns but also pinpoints the abnormal parameters. Electrocardiographic signals from the patient are picked up by electrodes attached to the arms, legs, and chest.



Quick check. Mass screening for heart defects can be performed by this EKG machine, which reports only an abnormal signal.

DON'T THINK IN TERMS OF GATES WHEN YOU DESIGN ENCODING OR DECODING CIRCUITRY.

THINK DIODE MATRICES.



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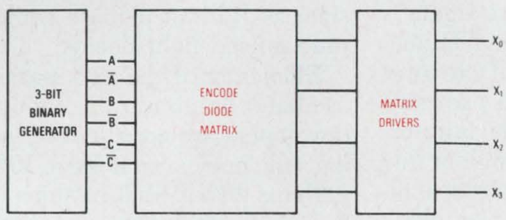
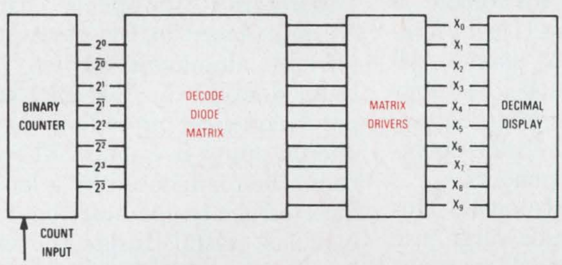
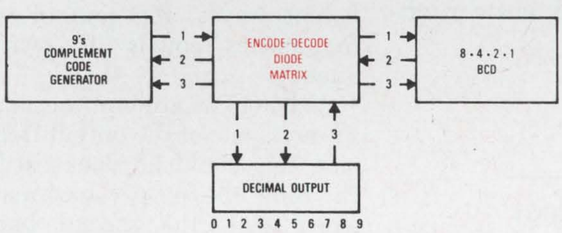


Suppose you need a three-bit binary output encoded into a four-bit binary shift code. Why use *five* AND gates and *four* OR gates? Simply combine these nine gate functions into *one* RM-30 six by eight diode matrix and save both time and money.



Why use ten logic gate packages to decode from binary to decimal for display read-out? Use only *two* RM-84 eight by five diode matrices. It makes no difference what weighted binary code you are working with, Radiation diode matrices can be easily customized to match.



When one logic code must be converted to several other codes for processing, think diode matrices! Specify only *four* RM-84 diode matrices and form a 16 by 10 matrix array. Six conversions can be performed by this single bi-directional array . . . replacing approximately 80 logic elements.

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Lee Baessler, Humetrics director of engineering, says this system presents a standard lead input to the analysis circuitry. In EKG recordings, 13 leads are used to make various physiological measurements [Electronics, July 10, 1967, p. 105]. In the ECA unit, a five-lead configuration using electrodes has been developed. These leads measure such parameters as P amplitude, P polarity, P width, PR interval, Q amplitude, Q width, R amplitude, S amplitude, and others [Electronics, July 10, 1967, p. 104] to determine if they are within acceptable limits.

To make certain the EKG signal is not giving false information, Humetrics incorporated special circuitry to prevent analysis when excessive baseline drift or 60-cycle interference exists. Abnormally high or low heart rates also prevent correct analysis and an auxiliary display alerts the operator to this condition.

In the cards. The instrument is contained in a 17-by-11½-by-7⅛-inch case weighing 28 pounds. All circuitry is contained on four printed cards incorporating Signetics micrologic and Philbrick operational amplifier components.

At $9,300 per instrument, Humertics officials foresee large use of the ECA by industrial concerns, health institutions, schools, offices, and professional and amateur athletic teams.

Advanced technology

Pick a color

Tuning a coherent light oscillator continuously through the visible light spectrum down through the infrared has finally become possible. A team at Bell Telephone Laboratories has built a continuous parametric optical oscillator that converts green light (0.53 microns) over a wavelength range covering 0.98 to 1.16 microns. The same oscillator can cover an even wider band of frequencies—30,000 gigahertz—extending from 0.4 to 4 microns (violet to far i-r).

Growing bananas. Heart of the achievement was the successful growth of a single crystal of barium sodium niobate ($Ba_2NaNb_5O_{15}$), humorously called bananas by the developers. This crystal is not damaged by laser light as other materials have been, and its ability to generate harmonics is far superior to anything so far developed.

Up to now the best continuous tuning—achieved using electro-optic techniques—has only covered a bandwidth of ±45 Ghz [Electronics, Nov. 13, 1967, p. 58]. Parametric oscillators using other crystals such as lithium niobate could only tune pulsed light beams.

Efficiency of the new parametric oscillator is about 1% though the developers are confident of increasing efficiencies to at least 10% and perhaps 20%. What remains now is to improve stabilization techniques.

Selecting mirrors. In the Bell Laboratories set-up, a bananas crystal, placed in the cavity of an yttrium aluminum garnet (YAG) laser, doubles the 1.06-micron output frequency, providing the 0.53 micron pump frequency. The green beam then is focused by a lens and directed at a temperature-controlled bananas crystal. Inside the crystal it interacts with the internal electrical fields and produces two coherent waves, the sum of whose frequencies equals its own frequency.

Although no attempt was made to suppress one of the output frequencies, this could be done easily by choosing the proper mirrors that, along with the second bananas crystal, form the parametric oscillator cavity.

For parametric oscillation to occur, the pump and two harmonic frequencies must move in synchronization through the crystal. That condition can only be met in a nonlinear optic crystal, where the index of refraction varies with crystal temperature and with the frequency (dispersion) and polarization (birefringence) of the light. In the bananas crystal there's a temperature at which dispersion and birefringence offset each other for a particular pump and pair of generated frequencies so that all three are in

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step. Then the pump gives up its energy to the harmonics, which grow into coherent waves.

The members of the development team are Joseph E. Geusic, Hyman J. Levinstein, Jerry Rubin, Shobha Singh, R.G. Smith, and Le Grand Van Uitert.

Communications

Taming the CO_2 laser

The use of lasers to beam television signals over short distances is a relatively easy stunt performed at several labs. But training the beam at a target millions of miles away is something else again. Stability problems with the laser and attenuation of the beam by the atmosphere play havoc with the signal. Researchers at the Hughes Aircraft Co. have taken a significant, albeit small, step (18 miles) in that direction.

The team at the firm's Malibu, Calif., labs have built a carbon-dioxide laser system that beams a tv signal the 18 miles between the lab and Baldwin Hills. The received signals, using optical heterodyning techniques, are good enough to meet industry standards for commercial transmission, says Frank Goodwin, head of the research team and a senior member of the technical staff. The signal-to-noise ratio has been measured at 60 decibals in the f-m mode.

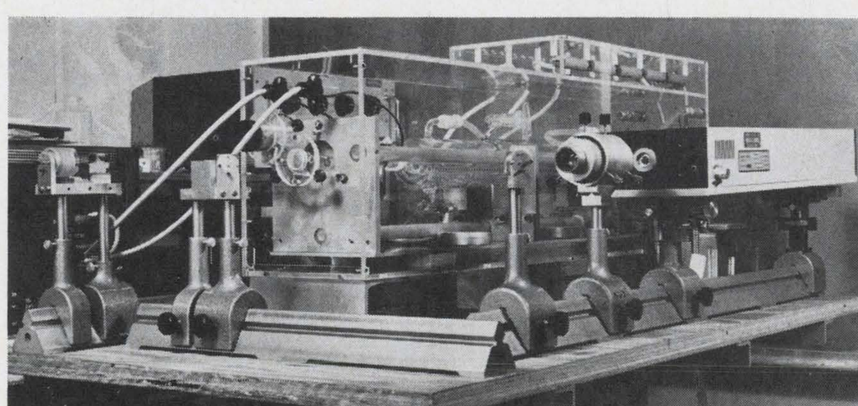
Long shot. The CO_2 laser is suitable for such long-haul transmission, says Goodwin. Carbon-dioxide designs have the highest power potential of existing lasers—outputs up to several thousand watts have already been reported. And the laser's wavelength, 10.6 microns (far infrared), is relatively immune to atmospheric attenuation. During a hazy day, attenuation of a visible beam might reach 100 db; but for the 10.6-microns laser, it's only about 15 to 20 db between the lab and Baldwin Hills, he says.

In addition, the efficiency of CO_2 lasers is much greater (10% to 15%) than that of lasers in the visible spectrum (less than 0.1% for an argon ion laser, for example). Finally, Goodwin says the far infrared is of interest because atmospheric turbulence, which disturbs the coherence of visible light, does not significantly degrade coherence at 10.6 microns.

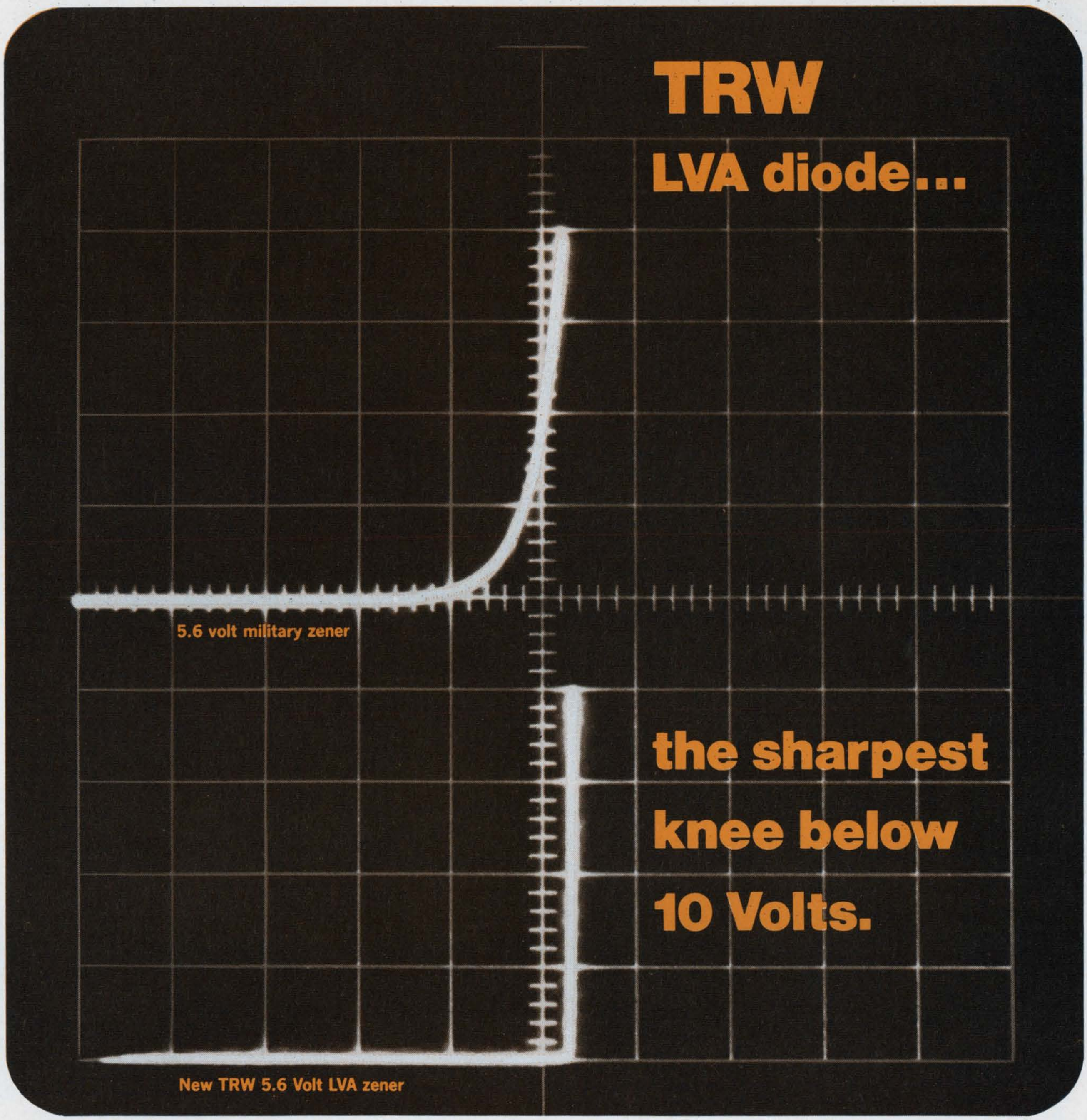
Goodwin believes existing lasers could handle the transmission of a real-time tv signal from Mars using no more than 100 watts of power.

Taking pains. The researchers went to great lengths to stabilize the output frequency, isolating the laser acoustically by suspending it in a spring system and hermetically sealing it. This eliminated vibration from the floor or turbulence from air currents.

The Hughes system consists of two identical lasers—the transmitter oscillator at Baldwin Hills and the receiver local oscillator at Malibu. The video input to the trans-



Over the air. Hughes designed this laser system for transmitting tv signals over an 18-mile link. The next step? Maybe Mars.



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mitter comes from either a vidicon camera or a commercial tv set. It is sent through a modulator driver before entering the electro-optical modulator housed inside the transmitter oscillator cavity. This modulator is a gallium arsenide crystal 5 centimeters long with its end faces polished and coated with an antireflection material.

Goodwin says frequency modulation in the laser is produced when the phase of the light is modulated.

"We achieve f-m by driving the modulator inside the laser oscillator itself," Goodwin notes.

The technique has its drawbacks, however. Putting the gallium arsenide crystal inside cuts output power from a typical 10 watts, to about 1 or 2 watts. Hughes is already working on a wideband modulator outside the cavity that might support many tv channels; the present system is limited to one. By then, the researchers plan to transmit digitally, but they will continue to use hetrodyning because of the tremendous sensitivity it provides.

The modulated signal is fed to transmitter optics, across the 18-mile span to Malibu, and into the receiver optical system. Both the transmitter and receiver optics are 3-inch-diameter off-axis parabolic reflecting telescopes.

Cold storage. Receiver optics focus the beam down onto the mercury-doped germanium detector, which is housed in a dewar and kept at 21°K with liquid nitrogen. This is where heterodyne mixing takes place. A beam provided by the laser local oscillator is superimposed on the detector and added to the incoming signal.

The i-f amplifier, with a center frequency of 30 megahertz, and an 8-Mhz bandwidth, follows the detector. From the amplifier, the signal is fed to a discriminator, to which is attached a television monitor to display the received image. Part of the discriminator output drives an automatic frequency controller. This locks the receiver local oscillator 30 Mhz away from the frequency of the transmitter laser, which is 2.8×10^{13} hertz. Goodwin says the frequency changes only about 3 parts in 2.8 million. The entire system represents an investment of about $20,000 in hardware.

Consumer electronics

Radiating worry

Concern over radiation from consumer and industrial products is spreading out in almost as many directions as the radiation itself. But color television sets, which started the whole thing, are still the source of most of the worry.

The latest reactions to these waves of apprehension include the following:

- The cloak of anonymity has been lifted from the color tv sets tested for radiation leakage earlier this year.
- Industry and Government are taking the first steps toward adoption of common standards for detecting and measuring radiation.
- The radiation protection bill passed by the House and a tougher Administration-sponsored bill will get hearings next month by the Senate Commerce and Labor Committee.
- The National Association of Government Employees is starting to question limits set for air traffic controllers who watch radar scopes.
- Studies of potential laser damage are being extended after an initial survey showed that about 10,000 workers may be exposed to dangerous laser beams.

Naming names. The National Center for Radiological Health, after a little prodding, disclosed the brand names of the 1,124 sets tested and how they scored. The initial report didn't mention any company names; the center said that to do so could be misleading, because the survey covered only sets owned by Public Health Service employees in the Washington area. Only after the press demanded the brand names under the recently enacted Freedom of Information Law did the center open up the books. The survey showed that 6% of the sets produced excessive radiation. The test results

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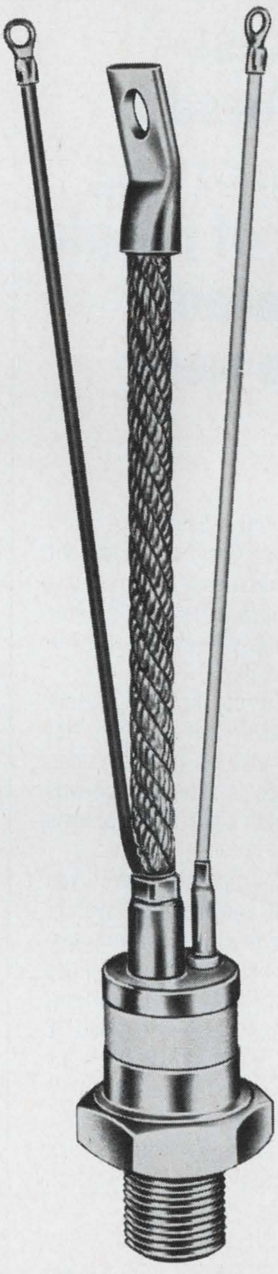

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Ih	—TYPICAL HOLDING CURRENT AT 25°C.	100 MA
Itsm	—MAXIMUM PEAK ONE CYCLE SURGE CURRENT	3000 A.
I^2t	—I^2t FOR FUSING (FOR TIMES $\geqq$ 1.5 MILLISECONDS)	37,000 A^2 SEC.
Idm	—MAXIMUM FORWARD LEAKAGE CURRENT AT 125°C. AND EBO	25 MA
t off	—MAXIMUM OFF TIME AT 125°C.	40μ SEC.
t on	—TYPICAL ON TIME	10.5μ SEC.
t r	—TYPICAL RISE TIME	3.25μ SEC.
t d	—TYPICAL DELAY TIME	7.25μ SEC.
θ J-C	—MAXIMUM THERMAL RESISTANCE, JUNCTION TO CASE (DC)	0.2°C./W
Tj	—OPERATING JUNCTION TEMPERATURE	125°C.
Tstrg	—STORAGE TEMPERATURE	—40°C. to 150°C.

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Irm	—MAXIMUM REVERSE LEAKAGE CURRENT AT 125°C. AND PRV	25 MA
dv/dt	—MINIMUM CRITICAL EXPONENTIAL RATE OF RISE OF FORWARD BLOCKING VOLTAGE	100 V./μ SEC.

TRIGGERING

Vgt	—MAXIMUM GATE VOLTAGE TO TRIGGER AT 25°C.	2.5 V.
Vgt	—TYPICAL GATE VOLTAGE TO TRIGGER AT 25°C.	1.3 V.
Vgt	—TYPICAL GATE VOLTAGE TO TRIGGER AT 125°C.	0.9 V.
Igt	—MAXIMUM GATE CURRENT TO TRIGGER AT 25°C.	200 MA
Igt	—TYPICAL GATE CURRENT TO TRIGGER AT 25°C.	100 MA
Pgm	—MAXIMUM PEAK GATE POWER	10.0 W.
Pg avg	—AVERAGE GATE POWER	2.0 W.
Igm	—MAXIMUM PEAK GATE CURRENT	2.0 A.
Vgm	—MAXIMUM PEAK GATE VOLTAGE (FORWARD)	10.0 V.
	MAXIMUM PEAK GATE VOLTAGE (REVERSE)	5.0 V.

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68R2

are shown at the right.

The test revealed some extremely high radiation leakage. Of the 66 sets leaking radiation above the accepted safe level of 0.5 milliroentgens per hours (mr/hr), 38 sets registered above 1.0 mr/hr, and three others actually hit 12.5 mr/hr—the maximum reading on the test instrument. Center engineers believe the actual readings on these sets were much higher. The three hot sets were a Setchell-Carlson, a Zenith, and a Magnavox. The Magnavox had an RCA shunt regulator tube and a Sylvania picture tube and was operating at excessively high voltage.

Twenty-three sets gave readings of between 1.0 and 2.0, five between 2.0 and 3.75, ten between 3.75 and 12.5, and three over 12.5.

The survey said the probable primary sources of X-radiation emissions were the high-voltage shunt regulator tube, the high-voltage rectifier tube, and the picture tube. However, in two sets, no specific source could be identified.

Do it yourself. James G. Terrill, the director of the center, said the Washington survey included too few sets to yield an accurate nationwide estimate. He estimated, however, that 700,000 to 1.4 million color tv sets in the U.S. leak excessive radiation.

But instead of starting a nationwide campaign to halt the leakage, the center is working with manufacturers to make certain that all new sets are tested before leaving the factory. Because of the shortage of trained technicians who are properly equipped with devices to detect and measure radiation, the center is only recommending that owners take their sets to a repair shop to make sure the high voltage is set at the proper level. This usually reduces the radiation.

The survey found that four brands—RCA, Zenith, Magnavox, and Setchell-Carlson—made up 86% of the number of sets leaking excessive radiation. There were no General Electric sets that leaked excessive amounts, obviously because GE tracked down and adjusted its faulty receivers after they set off the big scare last year.

X-ray emission from color tv

Brand name	Total sets surveyed	Sets above safety standards
RCA	360	20
Zenith	162	19
Sylvania	100	0
Motorola	75	4
GE	72	0
Sears	71	1
Magnavox	69	10
Philco	45	0
Airline	33	1
Admiral	30	0
Westinghouse	19	0
Heath	18	0
Dumont	16	0
Penncrest	15	1
Setchell Carlson	13	8
Packard Bell	7	0
Muntz	6	0
Curtis Mathis	4	0
Delmonico	2	1
Symphonic	2	1
Bradford	2	0
Clairtone	1	0
AMC	1	0
Panasonic	1	0
Total	1,124	66

Manufacturers of brand named sets

Sears	Warwick Electric, Toshiba
Airline	Hoffman Products, Hayakawa, Magnavox, Wells-Gardner, Hoffman Electronics
Penncrest	Wells-Gardner, Matsushita, Westinghouse, Clairtone
Muntz	TV Corp. of America
Bradford	Wells-Gardner, Matsushita
Clairtone	Westinghouse, Wells-Gardner, RCA
AMC	Clairtone
Panasonic	Matshushita

At the same time the center was preparing to disclose the manufacturers' names, it was sponsoring a conference in Washington on detecting and measuring X-radiation from color tv receivers. Up to now, there have been no uniform methods of detecting or measuring it. Although there are no definite plans yet, the center and the Electronic Industries Association will probably organize a committee to work out recommendations.

Question of control. Although industrial trade unions made some noises about worker protection after the GE reports, one of the first unions seriously looking into the matter is the National Association of Government Employees, which represents air traffic controllers.

Alan J. Whitney, executive vice president of the union, in testimony before Congressional committees, has implied that the Federal Aviation Administration's radiation

safeguards are inadequate. The FAA's "maximum exposure" to ionizing radiation is 100 milliroentgens a week. Based on a 40-hour week, this equals 2.5 mr/hr. The generally accepted safe level, as noted, is 0.5 mr/hr.

Hard light. In another area, a survey made by the Public Health Service's National Center for Urban and Industrial Health in Cincinnati disclosed that 60% of laser workers in the scientific instrument industry faced potential risk of eye damage or serious burns. The figure was based on a study on the use of 267 lasers in 43 plants in Massachusetts. The survey is now being extended to New Jersey and later will move to California.

The survey called laser safety requirements surprisingly lax. For example, only about 45% of the firms required eye shielding in laser areas, and about 25% of the goggles provided are inadequate. Only a few plants had laser warning signals or signs. At the same time that this report was released, the newly formed laser subdivision of the EIA voiced approval of the radiation control bill passed by the House, which covers lasers, and organized a committee to work on laser safety studies and promotion.

Military electronics

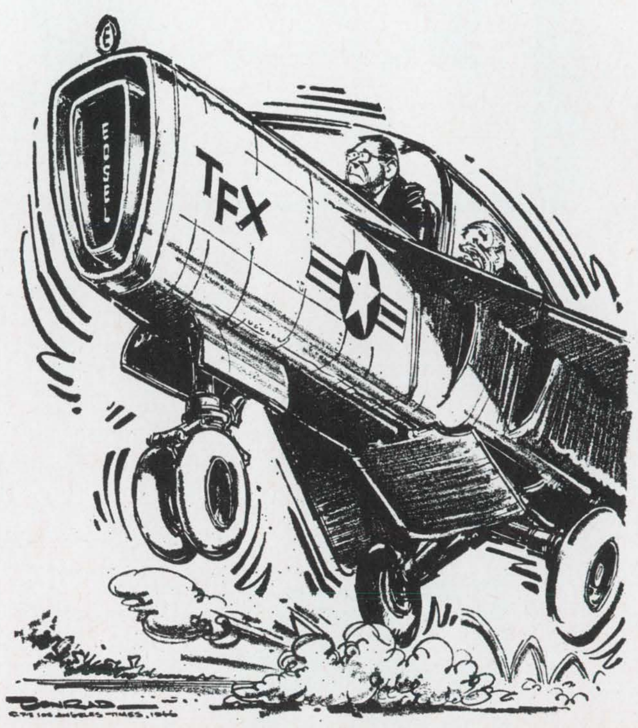
Back to the drawing board

Less than a month after Robert S. McNamara closed the door on his Pentagon office for the last time, his successor slammed the door on one of the former Defense Secretary's most cherished dreams —a military aircraft that would be almost everything to almost everyone.

McNamara had nursed the controversial craft—originally designated the TFX—through several modifications and had staked his reputation as a managerial genius on its success.

But the bubble burst late last month when one of the plane's prime missions was dropped. Defense Secretary Clark Clifford decided that the brass had been right all along: the Navy version, the F-111B, was, among other things, too heavy to be effectively flown from a carrier deck.

And just a few hours after the Defense Department's decision, the Senate Armed Services Committee axed the fiscal 1969 funds earmarked for the production of 30 F-111B's. The Congressmen in-



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Circle 61 on reader service card

sisted that the Pentagon instead come up with a new craft that would use the same Phoenix missile system and engine as the F-111B, but would be much lighter and more maneuverable and would be designed strictly for naval operations.

Substitute. Early this month, the Senate reached a compromise with the Navy and Pentagon by providing nearly $300 million for development of the alternate model during fiscal 1969; this includes funds for additional F4J fighters as an interim craft. Four aircraft companies—Ling-Temco-Vought, Grumman Aircraft, North American Rockwell, and McDonnell Douglas—are already working on designs. The timetable now calls for the project to reach its contract-definition phase by January.

The furor over the Navy version was still going on when trouble struck the Air Force version, the F-111A. Two of the first six planes sent to Thailand for combat trials were lost during sorties against North Vietnam.

Clifford, who has had to devote a lot of his time to F-111 problems during his first 30 days on the job, immediately grounded the other four planes, dispatched an investigating team to Thailand, and ordered more extensive testing of the F-111A's remaining in the States. Air Force officials, eager for a scapegoat, hinted that the plane's terrain-following radar may have contributed to at least one of the crashes. The true cause may not be known for several weeks.

Thumbs down. The F-111 program experienced an earlier setback late last year when Britain canceled a large order for the planes as part of its retreat from a worldwide military role. Only the Australians still plan to buy the craft, and only in limited numbers.

Nevertheless, McNamara's plan for a versatile aircraft isn't yet a complete washout. The difficulties with the F-111A will undoubtedly be worked out. Work on the bomber version, the FB-111, is progressing, and the plane apparently will be a success even though it's limited by a small bomb load. And the reconnaissance version, the RF-111, seems a sure success.

Industrial electronics

Change in the guard

Security at many plants is about as old-fashioned as the technology within is modern. At some installations, security still means a lonely codger checking identification cards at the front gate.

Bernard M. Van Emden, head of Litton Industries' Applied Technology division's Security Identification Laboratory, thinks electronics can do the job better, faster, and probably cheaper. He's designed a system that uses magnetically encoded ID cards that would be difficult for even the gang from television's "Mission Impossible" to forge.

In or out. The card is inserted into a card reader, which scans the encoded data. Called an Autoguard, the reader can be connected to an alarm system that would be sounded if the encoded data isn't correct. Connected to an automatic door, the reader would signal the unlocking mechanism when the data is correct.

The card, called Magna-Badge, is about the same size as a credit card and is encoded in one of two ways: for small amounts of data—up to 130 bits—a circular track is used; for large amounts of data—up to 800 bits—a multitrack, lineal configuration is used. The data can be erased and the card can be encoded as often as necessary. Photographs and other visual data can also be placed on the card.

"Duplicating any part of the system," says Van Emden, "would be a very expensive and time-consuming operation. Besides which, you must first know the code structure, and that can only be obtained from someone on the inside."

Recording data. The encoder can be a simple keyboard that is manually operated or a printer that is controlled by an on-line computer. The price of the simplest system—including encoder, card, and card reader—is about $500; cost increases with complexity.

Litton is also looking into fingerprint identification. The company is seeking to code a print digitally and then code this magnetically on the card.

Van Emden sees other possibilities for the system. For example, the Magna-Badge system could be used as a time card when coupled with an electric clock containing a readout device. Other potential applications include elevator systems in which the Autoguard could be set for certain floors, and library systems in which book-checkout procedures are controlled.

A paper will be presented on this system at the National Symposium on Law Enforcement Science and Technology in Chicago, April 18.

Manufacturing

Turned off on real time

Last fall, officials at ITT Semiconductor asked themselves whether their integrated circuit production would grow enough by the mid-70's to justify the use of a real-time computer system to control testing, inspection, and processing. The answer, after a joint study by ITT and the Burroughs Corp., is no.

When ITT started the study last November [Electronics, Nov. 13, p. 52], Irwin A. Horowitz, director of information systems, said, "If our concept proves feasible, ITT will spend about $10 million for extensive centralized computer IC test equipment in the next five years."

However, the Horowitz team found that a real-time system using two large digital computers would be too expensive. For one thing, the study showed that about 80% of the money would have to be spent for interface gear, the equipment that serves as the real-time link between the computers and the test and production stations.

Off line. Horowitz is now looking at an off-line system that uses centralized digital computers but isn't in real time. Each station will have a tape machine to accumulate test and production results. The tapes can then be scrutinized by off-line computers.

Triggered by a computer, an adapter on the tape machine reverses direction so that segments of the tape can be used to reprogram a station to test a different batch of IC's. Horowitz thinks the two- or three-hour delay in getting reports will be more than offset by the potential savings of several million dollars.

For the record

The big picture. Among the new developments unveiled at the National Association of Broadcasters' show in Chicago this month was a 3-by-4-foot color television display system suitable for use as a studio monitor. The system, developed by General Electric, operates on a proprietary principle called color selection. GE, which says the display could be expanded to 6 by 8 feet, will begin selling the system next year at $35,000.

Groovy. CBS Laboratories, under the direction of Peter C. Goldmark, has developed a seven-inch record that plays for two hours on each side. The record, which has a frequency response of up to 5,000 hertz—not good enough for high-fidelity reproduction—runs at a speed of 8⅓ rpm. CBS, also developed a thinner stylus and special playback unit for the record. The longer playing time was obtained by squeezing in 700 grooves per inch.

Washington Newsletter

April 15, 1968

U.S. maps 10-year oceanology effort

The Administration will soon issue a white paper spelling out the major details of a plan to make the 1970's a decade of international ocean exploration. **The paper will disclose that the U. S. is willing to spend from $3 billion to $5 billion on the program over the decade if other countries agree to make substantial contributions.** Informal talks with other nations, including the Soviet Union, indicate they are interested.

The domestic U. S. oceanographic program is now funded at about $500 million annually. **If approved, the new project would push U. S. spending in this field to $1 billion a year.**

L.A. studies aimed at clearing the air

The Government, stepping up its efforts to help solve urban communications problems, has chosen Los Angeles as the site for two pilot projects.

The Office of Telecommunications Management is cooperating with Los Angeles officials in a study of the city's communications administration. The second project, aimed at hitting upon the "best possible utilization" of the frequency spectrum, is a joint effort of the city, the Office of Telecommunications Management, the FCC, and the President's task force on communications policy.

IC makers start work on Sentinel

Hybrid integrated-circuit makers are feeling the first impact of production dollars in the Sentinel antiballistic missile program. **RCA, Motorola, and Texas Instruments have received $5 million each for IC production and preproduction engineering.** The Army estimates that 7 to 9 million IC's will be needed for the computers and radar.

Most of the initial production money, $85.5 million, will go for electronic systems and components. Raytheon is getting $19 million for the missile site radar, General Electric $1.7 million for the perimeter acquisition radar, and Lockheed Electronics $1.7 million for data processing equipment. The direct payment to the prime contractor, Western Electric, is $28 million. The contracts are for six months, ending September 30.

Comsat gets start on worldwide net

Comsat has taken the first step toward a permanent worldwide tracking network. **Operated full time, the network will replace the tracking and control now performed part time on communications antennas.** Acting on behalf of the Intelsat Consortium, Comsat has just contracted for a tracking station in Fuchino, Italy, that has a 44-foot antenna dish. The Fuchino station was made available when the Italian communications network put a new facility into operation at a nearby site. The newer station has a 90-foot dish.

Intelsat expects other older stations to become available as soon as newer facilities go on line.

Intelsat 3.5 bidding reopened by Comsat

Comsat has rejected the only bid it received on the Intelsat 3.5 communications satellite—from TRW Inc.—and is now asking for new proposals by April 22. It's relaxing two specifications to attract more industry interest this time around. The new ground rules call for delivery in 15 months, against 12 in the earlier specs, and bidders now have a choice of offering either the originally specified configuration of one broad earth beam and two spot (squinted) beams of 6° each, or only two spot beams.

In rejecting the TRW bid, Comsat called the offer unresponsive to the request for proposals. TRW had said its first satellite would be ready in 15 months instead of a year, and Comsat indicates that other companies would have bid if this longer delivery time had originally been allowed. Insiders feel TRW probably figured that even though it was exceeding the delivery schedule, it would, as sole bidder, win the contract by default.

Pentagon cools it on IC designs

The Defense Department is standing by its pledge to maintain a hands-off attitude toward integrated-circuit designs. **It appears that military officials are now concerning themselves only with the form, fit, and function of IC devices, not with their design.**

This is in keeping with the Pentagon's policy paper on microelectronics issued last April, a document that bars interference in the relationship between systems designer and IC supplier. **As long as a system's performance is up to specifications, the Pentagon is staying out of the way.**

One industry official comments: "We're enjoying this now, but I don't know how much longer they can carry it off. My guess is not much longer —maybe a year."

Controversial F-12 heating up another election campaign?

The F-12 supersonic fighter, which sparked a political controversy during the 1964 Presidential campaign, may do it again in '68.

From a battle within the Pentagon between civilian backers of the F-106X and Air Force supporters of the F-12, the struggle is suddenly mushrooming into a political issue. **Both sides have been busy lining up support in Congress, with the Pentagon's civilian officials openly declaring they'll fight Congressmen who'd kill the F-106X program to pave the way for the F-12.**

The Air Force, which wants the F-12 as the interceptor for the Airborne Warning and Control System (Awacs), picked up valuable ground when the Senate Armed Services Committee cut back the F-106X program. **The committee trimmed from the fiscal 1967 budget $24 million that was earmarked for modifying the F-106 with new electronics and missiles.**

Second uhf meeting stalemated, but Lee will try, try again

FCC Commissioner Robert E. Lee is a determined man. A strong advocate of uhf television, he tried again this month to get tv-receiver manufacturers to agree to detent the uhf tuners on their sets [Electronics, March 18, p. 69], but the Chicago meeting ended in a stalemate. A conference of tv makers called by Lee last month flopped because few firms attended. **But Lee isn't giving up; he plans to call a third meeting next month, this one in Washington.**

Uhf broadcasters are trying to get set makers to adopt new, solid state all-channel tuners, **but the manufacturers claim the devices would only add to the cost of the sets and would have no sales value. An additional problem is that only an estimated third of all present sets are equipped with automatic frequency controls,** devices providing the fine tuning that detent tuners generally need.

Lee's purpose in pressing for these meetings is to get set manufacturers to act voluntarily on this matter. The FCC can force them to detent uhf tuners, but only after a lenghy rule-making process.

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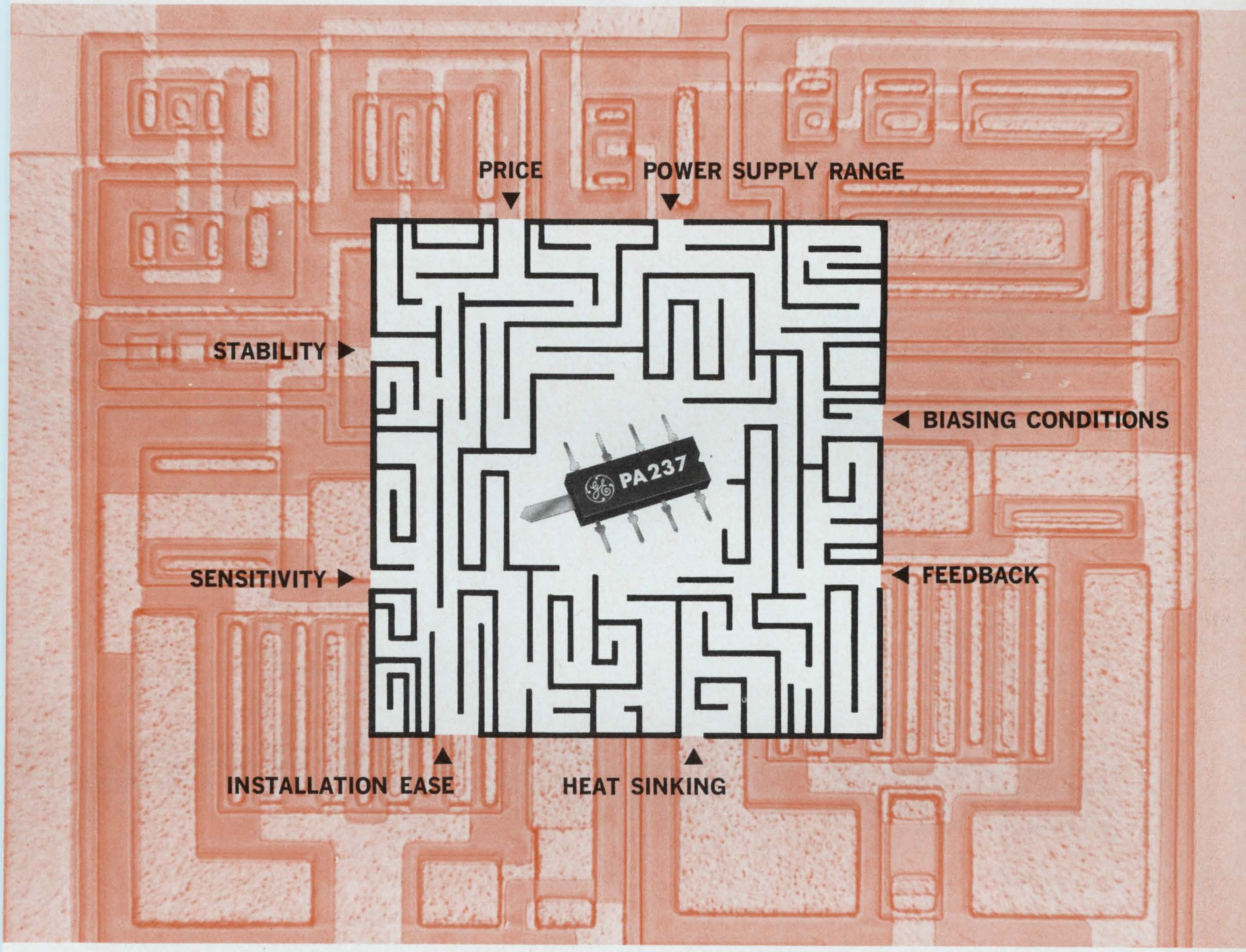

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Timing stability of 0.5% is achievable without the necessity of expensive temperature testing on individual devices to determine the compensating resistor. For more details **circle number 516.**

1200-volt, 400-amp PRESS PAK silicon rectifier costs less.

If you want a high power silicon rectifier diode with the same proved, all-diffused construction of the A90 series, General Electric offers the A390 PRESS PAK. The package innovation delivers far more continuous current than comparable stud-mounted devices, and it's smaller, too.

The new PRESS PAK package, using pressure contacts, allows double-side cooling to significantly reduce thermal resistance and, therefore, increase current ratings about 60%. Result: You get more average amps per dollar.

Light weight, hermetically-sealed PRESS PAK also features reversibility of mounting, thus eliminating the need for special reverse polarity units. And it complements many SCR's already in the PRESS PAK package. For more details, **circle number 517.**

Now you can custom tailor UJT characteristics to meet your specific needs.

With General Electric's D13T1 and D13T2 programmable unijunction transistors (PUT) you can now program unijunction characteristics such as η, R_{BB}, I_P, and I_V to your specific needs by adding two external resistors.

Generally, the D13T gives programmability without increasing circuit complexity. In fact, it often reduces circuit cost. And the PUT offers tight parameter specifications, high sensitivity, low unit cost, low leakage current, low peak point current, low forward voltage, and fast, high-energy trigger pulse too.

D13T2 is specifically characterized for long interval timers and other applications requiring low leakage and low peak point current. The D13T1 has been characterized for general use where low peak point current is not essential. **Circle number 518.**

For more information on these and other General Electric semiconductor products, call or write your GE sales engineer or distributor, or write General Electric Company, Section 220-63, 1 River Road, Schenectady, N. Y. 12305. In Canada: Canadian General Electric, 189 Dufferin St., Toronto, Ont. Export: Electronic Component Sales, IGE Export Division, 159 Madison Ave., New York, N. Y. 10016.

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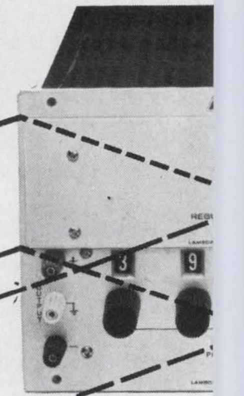

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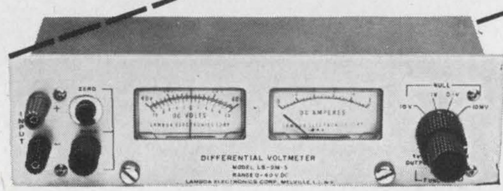

With this plug-in accessory it becomes a High Precision Power Differential Voltmeter that obsoletes any instrument now offered for this service

Basic Non-Metered Model	Voltage Range	Max. Amps at Ambient of[1]				Price[2]	Diff. VM Accessory	
		30°C	40°C	50°C	60°C		Model	Price
LS-511	0-10VDC	2.8A	2.5A	2.1A	1.7A	$375	LS-DM1	$85
LS-512	0-20VDC	1.8A	1.6A	1.3A	1.1A	375	LS-DM2	85
LS-513	0-40VDC	1.0A	0.9A	0.75A	0.6A	375	LS-DM3	85
LS-515	0-120VDC	0.33A	0.29A	0.25A	0.21A	375	LS-DM5	85
LS-516	0-250VDC	0.1A	0.09A	0.08A	0.07A	380	LS-DM6	85

1 Current rating applies over entire voltage range. Ratings based on 55-65 Hz operation.

2 This price is for Precision Power Source only. Addition of Differential Voltmeter Accessory Plug-In (next two columns) is necessary for unit to function as High Precision Power Differential Voltmeter.

- **Draw power as you measure voltage**—The first and only differential voltmeter to furnish high stability power output while being used as a voltmeter . . . no need for a separate power supply.
- **2 meters**—Monitor both voltage and current simultaneously and continuously.
- **Guaranteed for 5 years**—The only 5-year guarantee that includes labor as well as parts. Guarantee applies to operation at *full published specifications.*
- **All-silicon design** for maximum reliability
- **Convection-cooled** for convenience and reliability . . . no blowers or heat sinks.
- **5 voltage ranges:** 0-10, 0-20, 0-40, 0-120, 0-250VDC—Wide selection of ranges to suit your specific needs.
- **Illuminated Digital Readout Millimatic(TM) gang dialing**—5-digital voltage dials with automatic decade turnover provides convenient precise adjustment.
- **Only 5¼" high**—Convenient half rack size for rack or bench use.
- **0.01% + 1mV accuracy**
- **Stability** 0.001% + 100µV for 8 hours
- **Completely protected:** short-circuit proof; continuously adjustable automatic current limiting
- **Overvoltage protection** available as low cost add-on accessory
- **Rubber Feet** provided for bench use.

Power Supply specifications for Voltmeter same as for Power Supply—see next page

OVERVOLTAGE PROTECTION

For Use With	Model	Adj. Volt. Range	Price
LS-511 (0-10VDC)	LHOV-4	3-24 V	$35
LS-512 (0-20VDC)	LHOV-4	3-24 V	$35
LS-513 (0-40VDC)	LHOV-5	3-47 V	$35
LS-514 (0-120VDC)	LHOV-6	3-70 V	$35

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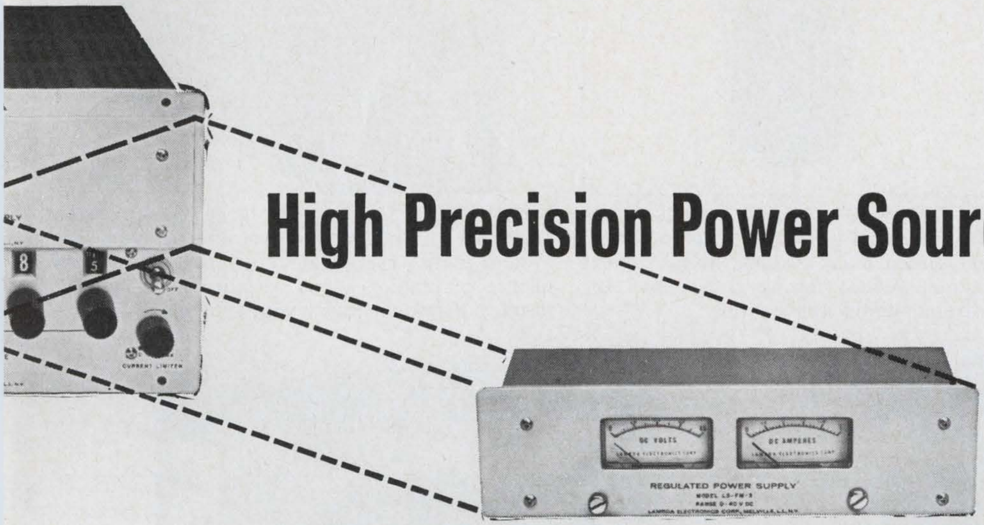

With this plug-in accessory it becomes a Metered High Precision Power Supply that offers all these features

Basic Non-Metered Model	Voltage Range	Max. Amps at Ambient of (1) 30°C	40°C	50°C	60°C	Price (2)	Metered Accessory Model	Metered Accessory Price
LS-511	0-10VDC	2.8A	2.5A	2.1A	1.7A	$375	LS-FM1	$55
LS-512	0-20VDC	1.8A	1.6A	1.3A	1.1A	375	LS-FM2	55
LS-513	0-40VDC	1.0A	0.9A	0.75A	0.6A	375	LS-FM3	55
LS-515	0-120VDC	0.33A	0.29A	0.25A	0.21A	375	LS-FM5	55
LS-516	0-250VDC	0.1A	0.09A	0.08A	0.07A	380	LS-FM6	55

1 Current rating applies over entire voltage range. Ratings based on 55-65 Hz operation.

2 This price is for non-metered Precision Power Source. Addition of Metered Accessory Plug-In (next two columns) is necessary to have Metered High Precision Power Supply.

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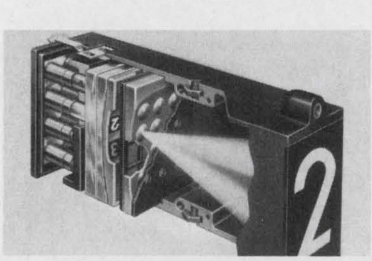
- **Multi-Current-Rated** for 30°C, 40°C, 50°C, 60°C —Covers temperatures most often encountered in laboratory work.
- **5 voltage ranges:** 0-10, 0-20, 0-40, 0-120, 0-250VDC—Wide selection of ranges to suit your specific needs.
- **Illuminated Digital Readout Millimatic(TM) gang dialing**—5-digital voltage dials with automatic decade turnover provides convenient precise adjustment.
- **Only 5¼" high**—Convenient half rack size for rack or bench use.
- **0.01% + 1mV accuracy**
- **Stability** 0.001% + 100µV for 8 hours
- **All-silicon design** for maximum reliability
- **Convection-cooled** for convenience and reliability . . . no blowers or heat sinks.
- **Remote programing** by changes in voltage or resistance for convenience in systems, test equipment and automatic equipment applications.
- **Auto Series/Auto Parallel** with Master-Slave tracking
- **Constant I/Constant V** by automatic crossover
- **Completely protected:** short-circuit proof; continuously adjustable automatic current limiting
- **Overvoltage protection** available as low cost add-on accessory
- **Rubber Feet** provided for bench use.

OVERVOLTAGE PROTECTION

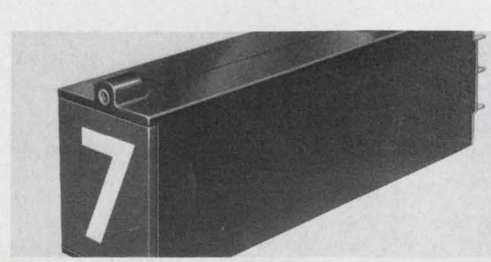
For Use With		Model	Adj. Volt. Range	Price
LS-511	(0-10VDC)	LHOV-4	3-24 V	$35
LS-512	(0-20VDC)	LHOV-4	3-24 V	$35
LS-513	(0-40VDC)	LHOV-5	3-47 V	$35
LS-514	(0-120VDC)	LHOV-6	3-70 V	$35

Quick guide to bright, legible, wide angle readouts

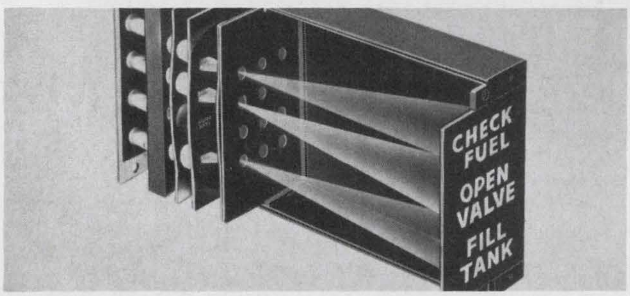


Series 360H Displays 2″ high characters easily read from over 50′. Yet unit is just 3″ H x 2″ W x 7.75″ D. New lens system provides bright, crisp display.

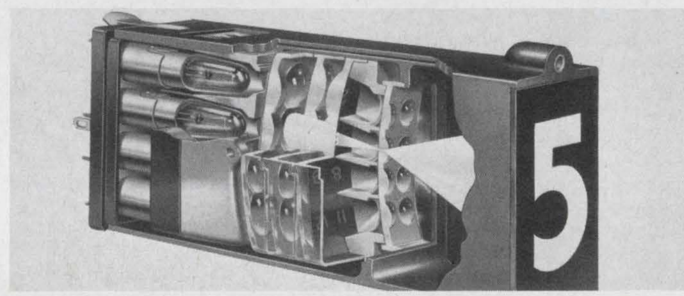
CRT Display 10-gun CRT projects single-plane digital or word displays onto fluorescent screen. Easy reading, even in direct sunlight. Wide viewing angle. Ideal for instrumentation applications.



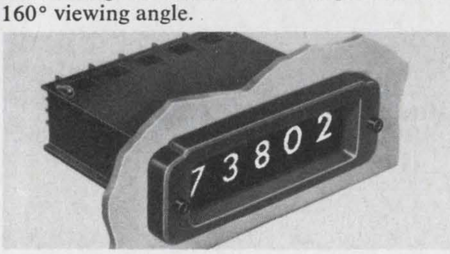
Series 160H Exceptionally large viewing area (1.56″ H x 1.12″ W for overall size. New lens system increases character brightness; reduces chance of reading error. Message lines may be displayed simultaneously with symbols.



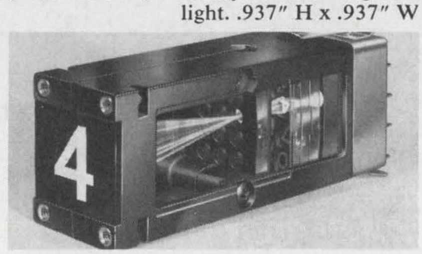
Series 80 Large screen unit particularly suited for annunciator applications . . . factory call systems, production control boards, etc. Message or character 3⅜″ high; can easily be read at 100′, 160° viewing angle.



Series 10H It's the world's most popular readout. And we've improved it. New lens system increases character brightness 4 times. Greater clarity at wider angles and longer distances, even under high ambient light. .937″ H x .937″ W viewing area. Mil-spec version also available.



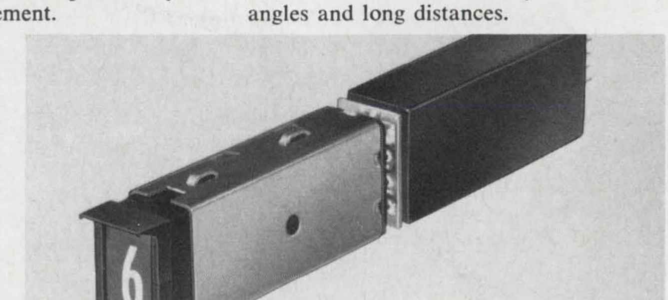
Series 345 IEE's smallest rear-projection readout. Viewing area .38″ H x .34″ W. Based lamps. Low cost. Individual readouts plug into permanently wired housing for quick message change. Easy front panel access.



Series 120H Miniature (.62″ H x .62″ W) rear-projection readout. New lens system increases character brightness 50%. Easily read from 30′ even with high ambient light. Quick disconnect lamp assembly for speedy lamp replacement.

Series 220H Miniature, plug-in, rear-projection readout meets MIL-R-39027. .62″ H x .62″ W viewing area. Special lens system increases character brightness 50%. Excellent readability from wide angles and long distances.

Series 875 Miniature, 24-position, rear-projection readout with .62″ H x .62″ W viewing area. Overall size just 1.39″ H x .90″ W x 3.095″ D. Exceptional character brightness and clarity. Quick disconnect lamp assembly for easy replacement.



IC Driver/Decoders Small, solid-state units for IEE Series 10H, 120H, 220H, 340 and 360 readouts. All models accept a variety of binary codes for decimal conversion. Take normal signal voltage. Draw less than 2 ma. (Many options, including memory.)

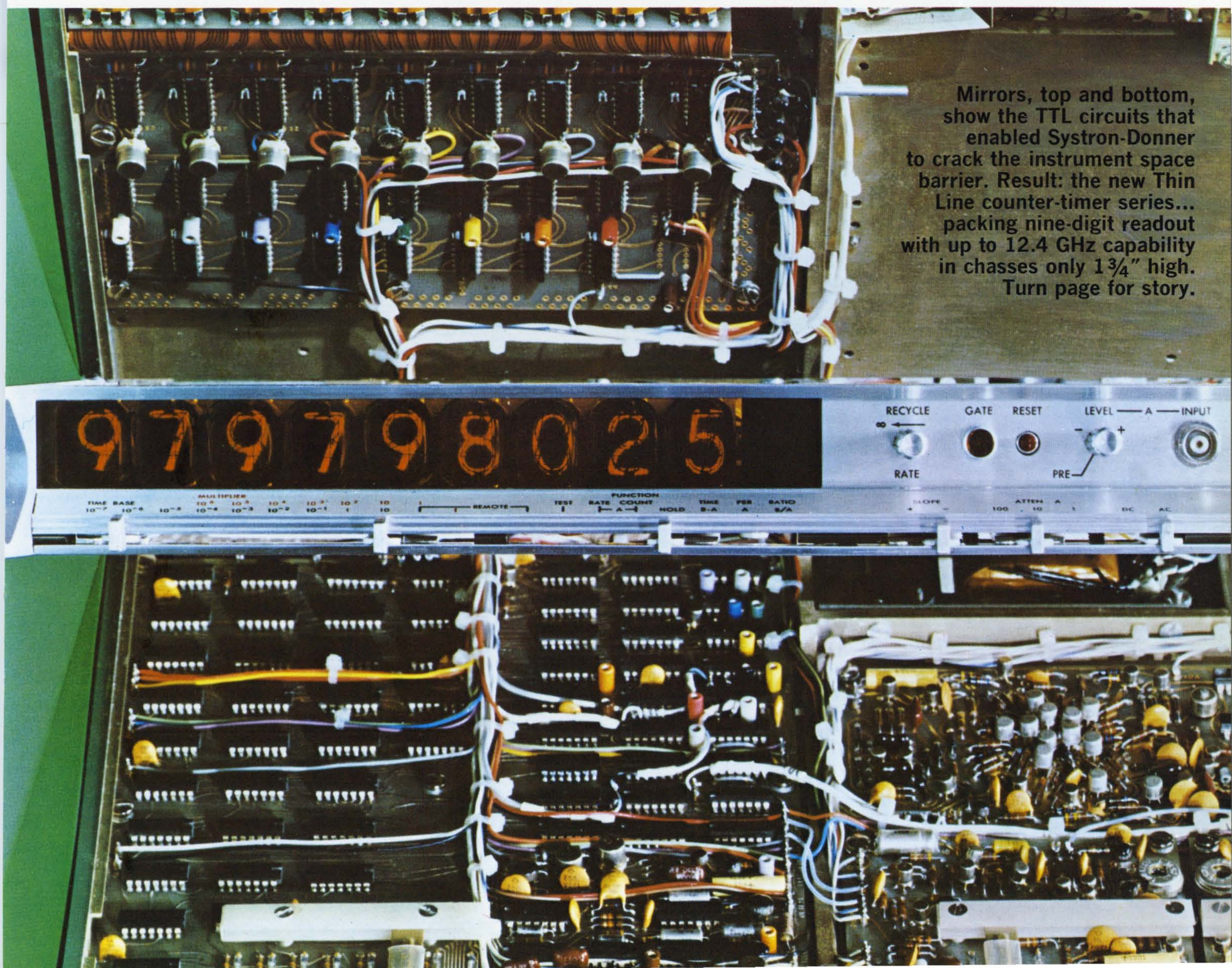
Any characters desired. Any colors or combinations. Any input, BCD or decimal. Any input signal level. Any mounting, vertical or horizontal. Many sizes. Many configurations. Many options and accessories. Many brightness choices. Long lamp life (to 100,000 hours).

IEE

Circle 76 on reader service card

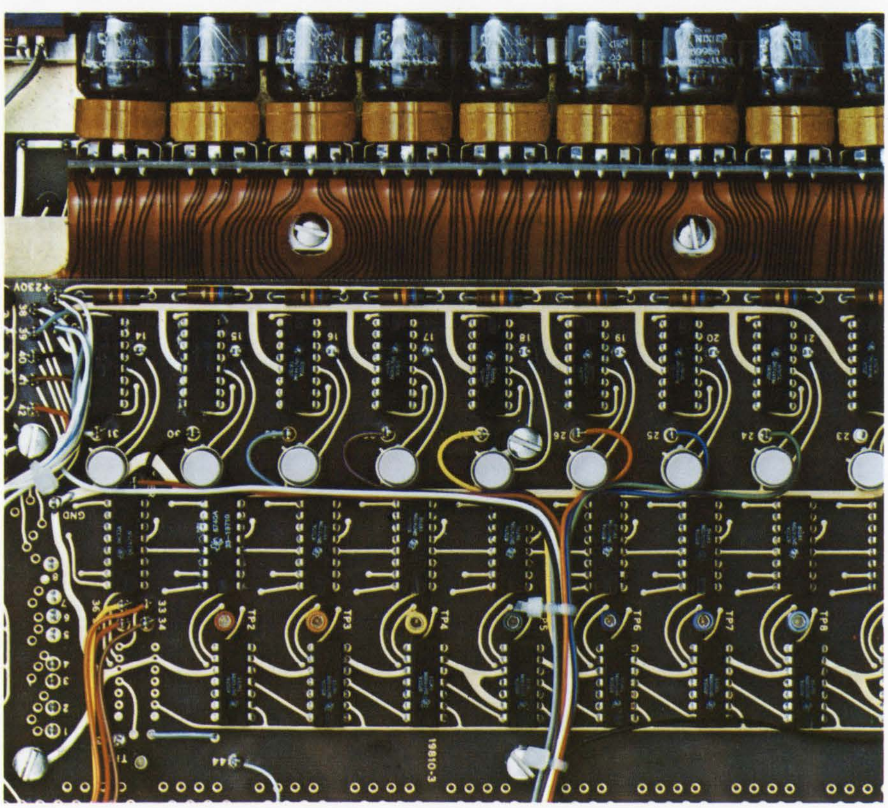
Industrial Electronic Engineers, Inc., 7720 Lemona Ave., Van Nuys, California

TTL Trends
from Texas Instruments



Mirrors, top and bottom, show the TTL circuits that enabled Systron-Donner to crack the instrument space barrier. Result: the new Thin Line counter-timer series... packing nine-digit readout with up to 12.4 GHz capability in chasses only 1¾" high. Turn page for story.

How TTL helped slim fat counters



Twenty-six TI Series 74 complex-function integrated circuits form the decade chain and decoder-driver section of this Systron-Donner Thin Line counter. Without circuits such as SN7441N BCD-to-decimal decoder-drivers, hundreds of separate transistors and simple integrated circuits would have been necessary to perform the required functions.

Mission impossible? It may have seemed so to project engineers at Systron-Donner Corp. They had the assignment of designing a radically new line of high-frequency counters—one that would give them a big jump on competition.

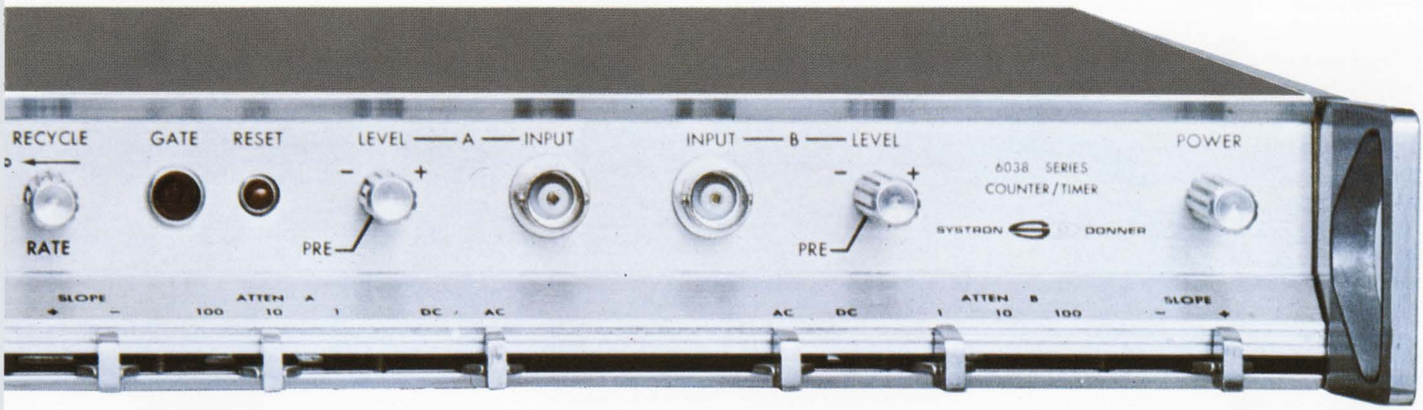
A key requirement was reduced panel height. Systron-Donner engineers wanted a *skinny* counter – one only 1¾″ high.

But, they also wanted nine-digit readout for top resolution.

Plus a 100 MHz direct counting range.

And greater freedom from repairs than ever before possible.

Integrated circuits were the obvious solution. But *which* ICs posed the tough question. Answering it triggered a two-year search that covered all major IC suppliers as well as many smaller producers. Systron-Donner's analysis included RTL and ECL logic types, in addition to TTL and DTL. Breadth of product line, depth of manufacturing facilities and competence of personnel were considered—along with price, service and performance—before the final selection was carefully made.



Texas Instruments got the nod, and its Series 74 TTL integrated circuits were selected to carry the major share of the chassis-shrinking job.

Cutting package count with complex-function ICs

Availability of complex function circuits was a prime factor in the selection of Series 74 TTL. With these advanced ICs, Systron-Donner engineers were able to make major reductions in package count – particularly in the decade-chain and related storage-readout driver section. Eight SN7490N decade counters, nine SN7475N quadruple latches and nine SN7441N BCD-to-decimal decoder-drivers replaced hundreds of simple integrated circuits and transistors. Without these TTL circuits, the new Thin Line counter design would have been virtually impossible.

Other benefits from TTL

Even where complex functions were not required, TI's Series 74 TTL line permitted significant package and space savings. For example, SN7473N dual J-K master/slave flip-flops assured high switching speeds for control binaries. A further reduction in package count resulted from use of multiple-input SN7470N J-K flip-flops.

In addition, Series 74 gates – SN7400N, SN7410N and SN7420N – provided a solid 10 MHz switching capability in those sections where such speed was desired. And the high driving capability of these gates (resulting from low output impedance) gave Systron-Donner engineers greater flexibility in wire routing and circuit board layout, without compromising switching speed.

And high noise immunity – typically 1.9 V for logical one and 1.2 V for logical zero – further simplified board layout. Series 74 ICs also permitted much faster evaluation of pilot board runs than had ever been achieved with discrete components.

Reliable, maintenance-free operation

Field experience to date indicates Systron-Donner has achieved its design goals for reliable, trouble-free service. Expectations are that the MTBF for the new Thin Line counters will far exceed that of older counters using discrete components. This improved reliability is due, in large measure, to the reduction in package count and even greater reduction in number of soldered connectors made possible by the Series 74 TTL logic family from Texas Instruments.

Planning for tomorrow

By using industry's most modern logic family, Systron-Donner has also provided for future design opportunities – at minimum cost, time and effort.

TI's growing family of TTL complex functions has provided Systron-Donner a link with the MSI and LSI semiconductor circuits of tomorrow. Why not also put this advanced IC line to work for you?

Three of the most recent additions to the TI complex function line of shift registers are featured on the next page. They typify the increasing versatility and complexity that has characterized the evolution of TI's family of TTL circuits. One of these ICs may be just the ticket for breaking that design log jam of yours.

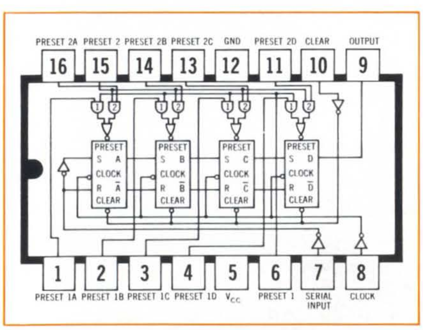
TEXAS INSTRUMENTS

INCORPORATED

3 new shift registers expand industry's broadest logic line

These complex-function TTL shift registers are far more than basic registers. Applications include shift counters, Johnson and ring counters, and shift-register generator counters.

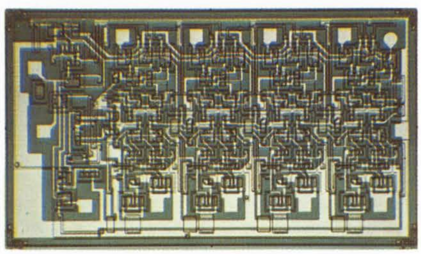
These registers incorporate additional gating as well as input and output connections, and are recommended for many storage and counting applications in addition to such shift functions as serial-to-parallel, parallel-to-serial, right-shift and left-shift operations. In all cases, substantial savings in packages, interconnections, design time and overall costs will be realized.



SN7494 4-bit shift register

This parallel entry, serial shift register includes four AND-OR-INVERT gates, four inverter drivers, and four R-S master-slave flip-flops. The result is a versatile circuit which performs right-shift operations as a serial-in, serial-out register or as a dual source parallel-to-serial converter.

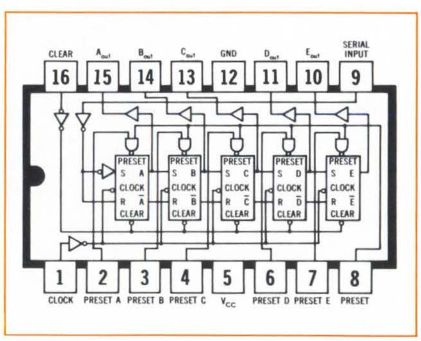
All flip-flops may be cleared simultaneously – independently of clock input. Also, the circuit has asynchronous loading capability from two strobe-controlled sources.



SN7495 4-bit shift-right, shift-left register

This parallel or serial-input shift register incorporates four AND-OR-INVERT gates, one AND-OR gate, six inverter-drivers, and four R-S master slave flip-flops.

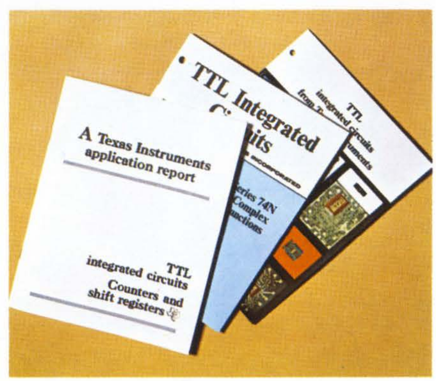
This versatile register can be used in a wide variety of applications, including serial-in, right-shift/left-shift, and parallel loading operations.



SN7496 5-bit shift register

This register consists of five R-S master/slave flip-flops, with gates and inverter drivers, connected as a shift register to perform parallel-to-serial or serial-to-parallel conversion of binary data. Since both inputs and outputs to all flip-flops are accessible, parallel-in/parallel-out and serial-in/serial-out operations may be performed.

A common clear line and strobe-controlled, individual presets permit loading of any binary information into the register. Preset is independent of the state of the clock input.



A note from you, on your company letterhead, will bring this goldmine of information . . . data sheets on these 3 new shift registers plus application information on all our 54/74 counters and shift registers... a data book on the entire 74 N complex-function family ...and finally, an in-depth 48-page brochure covering all 54/74 TTL integrated circuits. Just address your letterhead request to Texas Instruments, Incorporated, MS980, P.O. Box 5012, Dallas, Texas 75222.

TEXAS INSTRUMENTS
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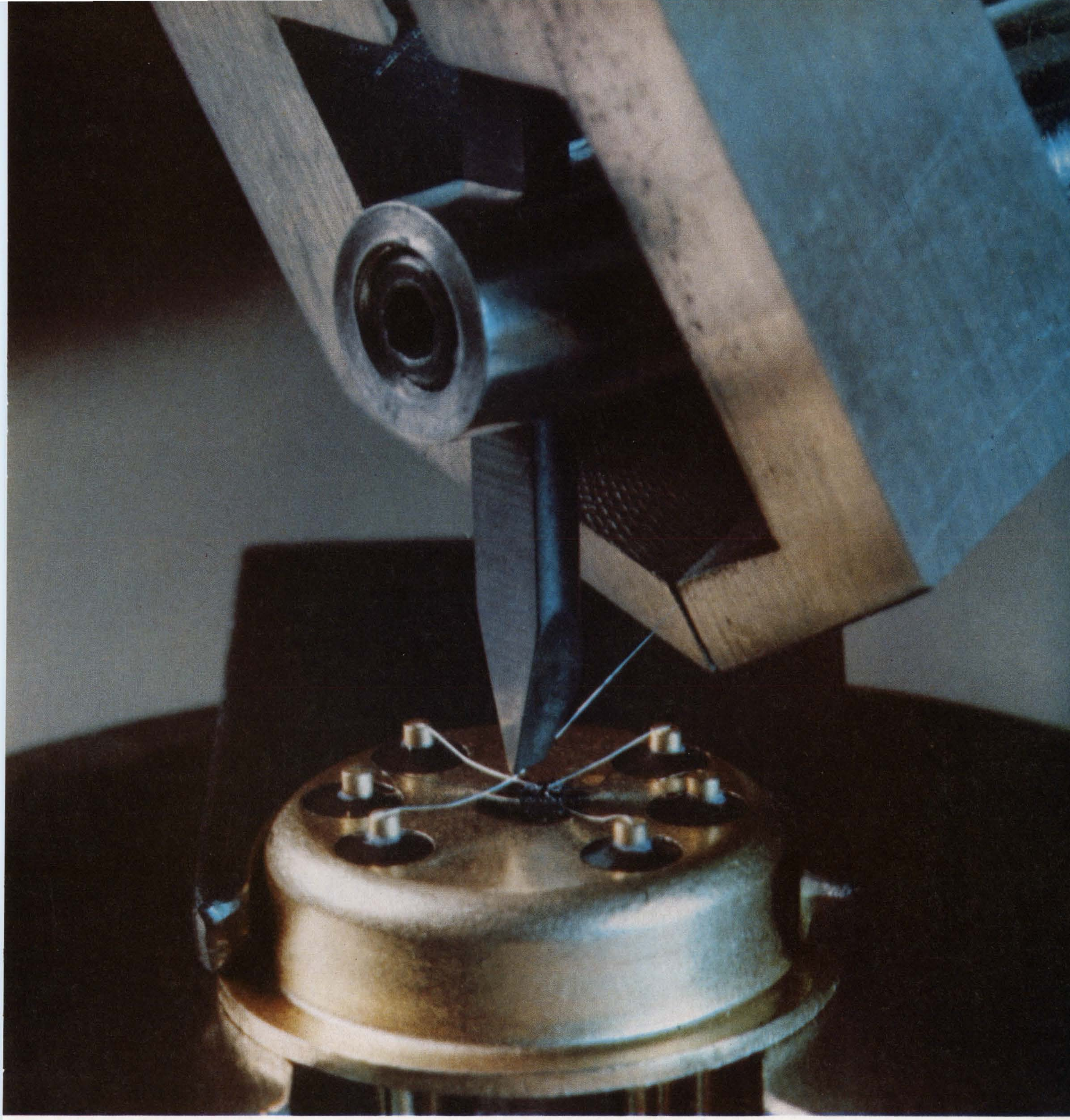

Craftsmanship in hard materials...an industry standard

HIGH PRECISION TUNGSTEN CARBIDE BONDING TOOLS, SUCH AS THE ONE SHOWN IN THIS 13× MAGNIFICATION OF AN ULTRASONIC LEAD BONDING OPERATION, WERE PIONEERED AND INTRODUCED AS PRODUCTION DEVICES BY TEMPRESS . . . IN 1963, THE TEMPRESS CAPILLARY TUBE, AN INDUSTRY STANDARD . . . IN 1967, THE ULTRASONIC BONDING TOOL, AN INDUSTRY STANDARD. The techniques and the specialized machinery developed to produce such precision products from ultra-hard materials have not been duplicated; quite probably will not be, for they are a result of the unique combination of Tempress people and the Tempress philosophy. To meet its responsibilities, Tempress maintains a continuing expansion program, limited only by strict adherence to the Tempress Standard of Excellence. (It requires as long as 11 months to train an operator for certain operations.) The same uncompromising standard is applied to Tempress Automatic Scribing Machines and to the entire growing family of Tempress miniature assembly tools and production equipment.

LEAD BONDING, DUAL FET, COURTESY OF UNION CARBIDE ELECTRONICS

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Try this $580 EAI Digital Measuring System for two weeks—FREE!

Now—you can get the EAI 6200 DVM on a two week memo billing to prove the performance claims for yourself. We bet you'll keep it, but if we lose there's no obligation. Just tell us your reasons!

What are the claims? First it's a great dc DVM, with features like automatic polarity, 100 microvolt resolution, pushbutton ranging, 1000 volt overload protection and ± 0.1% accuracy (± 1 digit); and a few more you'll find for yourself.

What makes it a DIGITAL MEASURING SYSTEM? Low cost modules that create an ac DVM and a counter. Not just any counter, but a 10 MHz crystal controlled counter and time interval meter that can totalize and measure period—all for only $210. For ac measurements, there's a 20 Hz—100 KHz converter good to 300 volts with a 1 megohm input impedance and packaged in a compact plug-in module for only $250.

For you systems-minded people, a rack-mounted version called the 6240, with a BCD output option, costs a little less—$550 as a DVM.

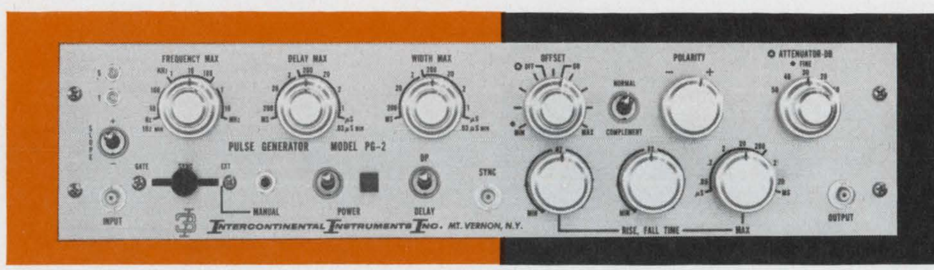
Interested? Call us—collect—at 201-229-4400 extension 6200 with a consignment purchase order and we'll ship you one for a two week trial (if you're in the US, that is... we do have to limit the offer to continental US only). Or ask for more specs...they'll be return mailed to you.

EAI® *Electronic Associates, Inc., West Long Branch, New Jersey*

 Circle 82 on reader service card

Circle 83 on reader service card→

THE OVER-ACHIEVER . . .



No other solid state pulser for under $1,000. gives you as much as our Model PG-2. Buy it for production test and you find that the development lab people prefer it for most of their development work and systems engineers keep designing it into test and operational systems. It shows up everywhere and everywhere it excels.

Maybe it's the PG-2's performance: prf to 20 MHz from 1 Hz in the double pulse mode; 16 MHz at full ±20V amplitude. Rise/fall from 10 ns to 20 ms with greater than 100:1 dynamic range between them. Widths from 35 ns to 200 ms; delay from 0 to 200 ms; DC-offset 0 to ±5V.

Or its operating flexibility: single or double pulses, normal or complement, sync pulse, plus manual one-shot. Continuously variable prf, amplitude, width, delay, rise time, fall time, DC-offset, input threshold and sensitivity. The PG-2 can be gated or triggered from DC to 10 MHz. And it is DC-coupled so that there are no low frequency or duty cycle limitations.

And probably the PG-2's outstanding reliability, operating simplicity and rugged solid state design help.

Model PG-2. Our over-achiever. $925, f.o.b. Mt. Vernon, New York. Delivery off the shelf.

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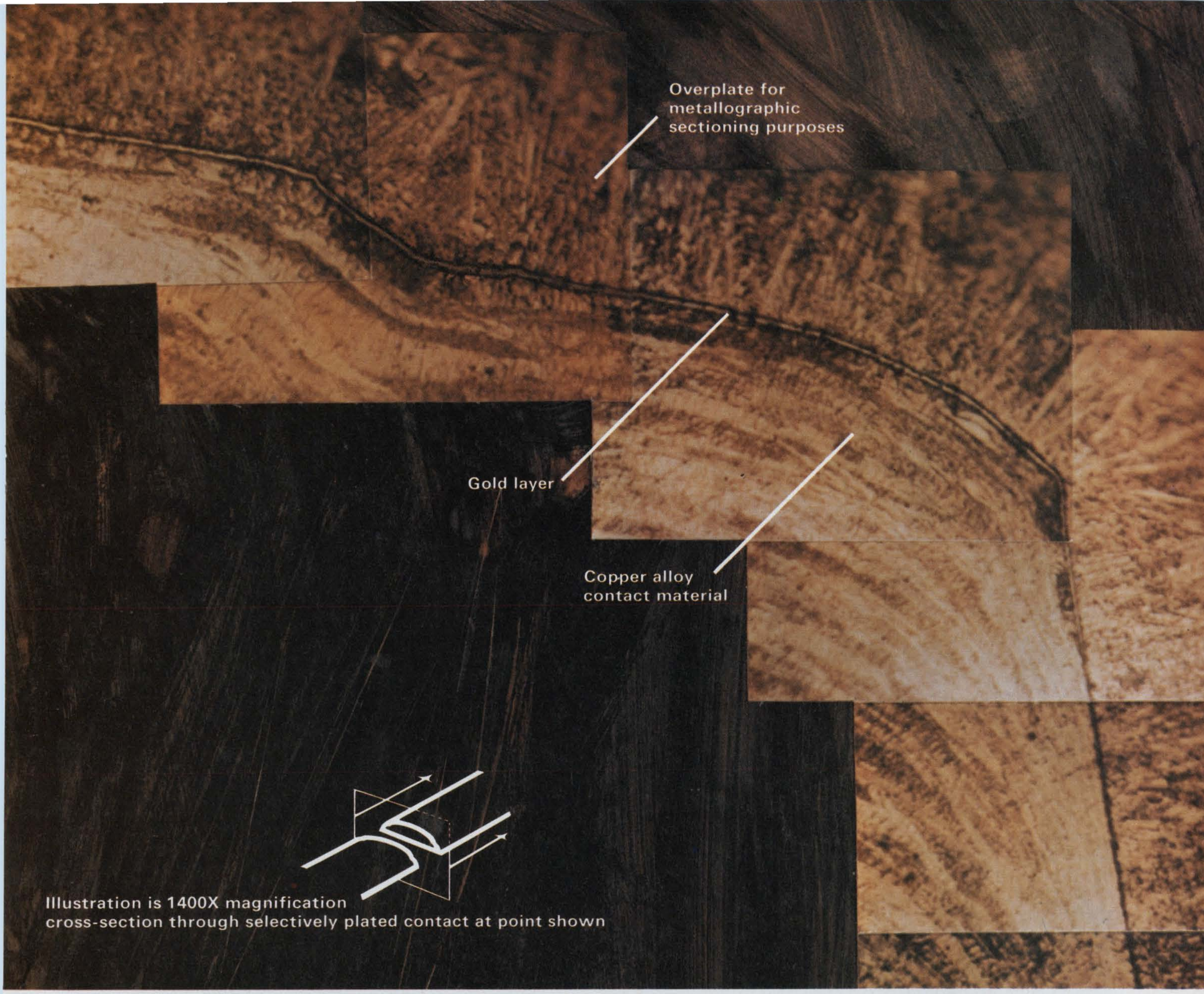
Chronetics, Inc., *500 Nuber Avenue, Mt. Vernon, New York (914) 699-4400; in Europe: 39 Rue Rothschild, Geneva, Switzerland (022) 31 81 80. Sales Offices throughout the free world; see EEM or EBG.*

PRODUCTS OF CHRONETICS



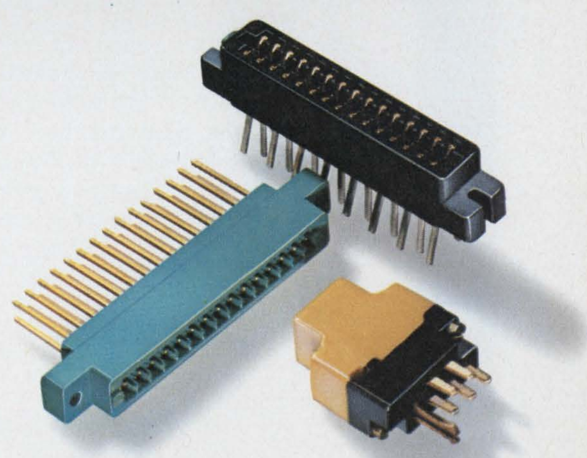
CINCH PUTS THE GOLD ONLY WHERE YOU NEED IT

IN THE AMOUNT YOU WANT—With Cinch selective plating you benefit from reduced gold content and the absolute control of gold thickness at the contact area. The result is a better connector at lower cost . . . *that also helps reduce the U.S. gold drain.*

In conventional barrel plating, the amount of gold deposited at any point is a function of the geometry of the part and cannot be accurately controlled from part to part. To compensate, excessive gold deposits must be used, but there is still no guarantee that every part will receive the minimum gold plate specified, due to the random nature of the process.

Cinch continuous process selective plating deposits the same controlled amount of gold on every contact. Only the contact area is plated, reducing gold consumption as much as 60%.

A wide range of Cinch connectors is available with selectively plated contacts. For information on how selective plating can provide you with a better product at lower cost, write to Cinch Manufacturing Company, 1501 Morse Avenue, Elk Grove Village, Illinois 60007. C-6814



CINCH

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CONSISTING OF CINCH MANUFACTURING COMPANY, CINCH-GRAPHIK, CINCH-MONADNOCK, CINCH-NULINE, UCINITE (ELECTRONICS) AND PLAXIAL CABLE DEPT.

Circle 85 on reader service card

General Electric's Helium Leak Detector will find a leak *one ten-thousandth* its size.

Our Helium Mass Spectrometer Leak Detector's sensitivity is like horsepower in a big car. Most of the time you have more than you really need; but when you *do* need it, it's there.

Specifically, our units are sensitive to at least 2×10^{-11} std. cc/sec. Put another way, GE equipment will—in less than one second—detect leakage that's at a rate of an ounce of helium in *ten years*.

But sensitivity is only part of our story. We'd like the chance to tell you about our two-years-guaranteed spectrometer tube filament; our reliable, long-life, solid-state circuitry; our models' ease of operation and servicing; our constant sensitivity; our all-welded, stainless steel high-vacuum system.

And then some. Check the reader service card, or write us direct for full particulars on manual model LC-10 or automatic model LC-20. We have a product we're proud of.

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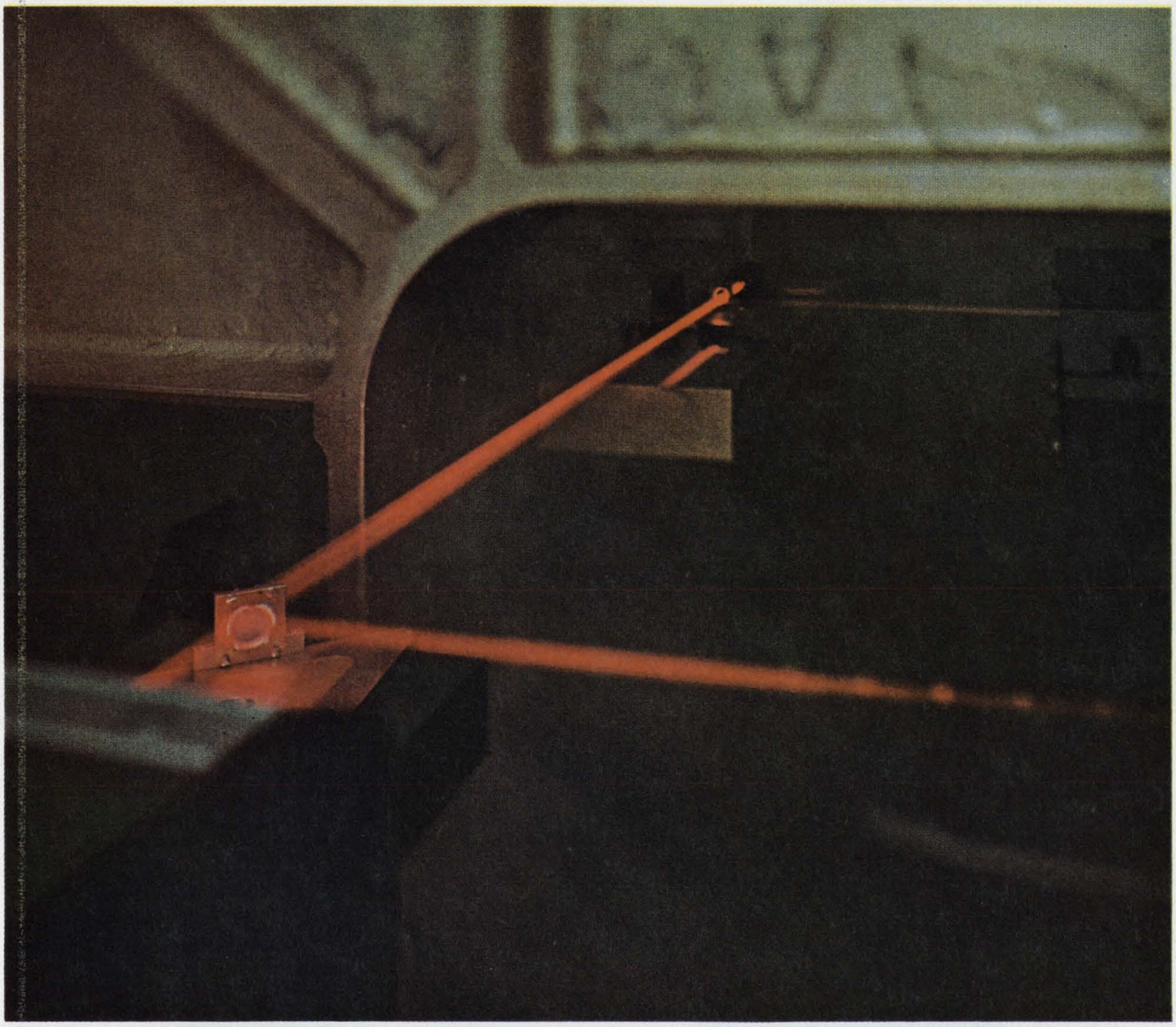
LC-2



Only ITT has laser-controlled IC mask making.

Another reason to buy from "The Predictables."

Mask variations used to mean performance variations in Series 930 DTL. Now ITT initiative has eliminated the problem. An exclusive laser-controlled, fully automated mask making machine assures absolute repeatability of masks and of circuit performance.

ITT's machine, representing an order of magnitude improvement over older processes, holds mask registration tolerances to $\pm$ 122 silicon atoms (based on the crystal lattice constant). It is tape programmed, with memory storage capacity of 10,000 separate semiconductor devices, and it can complete a matched set of up to nine masks in as little as 10 minutes.

If you think all Series 930 DTL circuits of the same type should act the same, the solution is simple: buy them from "The Predictables." ITT predictability also extends to diodes, rectifiers, and silicon planar transistors. Ask for a quote on any or all. They are on-the-shelf at your ITT distributor. ITT Semiconductors is a division of International Telephone and Telegraph Corporation, 3301 Electronics Way, West Palm Beach, Florida.

semiconductors ITT

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Now, absolute measurement of low intensity light signals

with the EG&G Spectroradiometer System

EG&G's new series of high sensitivity detector heads allow use of the Model 580/585 Spectroradiometer System for absolute measurements of low intensity, pulsed or CW, light signals. These new detector heads, which incorporate photomultiplier tubes, complement the existing line of vacuum tube detector heads by providing approximately five decades of additional system sensitivity.

The Model 585-66 Detector Head encompasses a spectral range from 200-750 mu (ultraviolet-visible) and senses irradiant powers as low as 9×10^{-13} watts/cm^2-mu and irradient energies as low as 9×10^{-13} joules/cm^2-mu at 450 mu.

The Model 585-63A Detector Head is now contained in a thermoelectrically cooled chamber (using EG&G thermoelectric modules) to minimize thermionic dark current and the resultant noise.

A separate controller unit assures constant chamber temperature. With a spectral range from 700-1200 mu (near infrared), the 585-63A detects irradiant powers as low as 5×10^{-12} watts/cm^2-mu and irradiant energies as low as 5×10^{-12} joules/cm^2-mu at 800 mu.

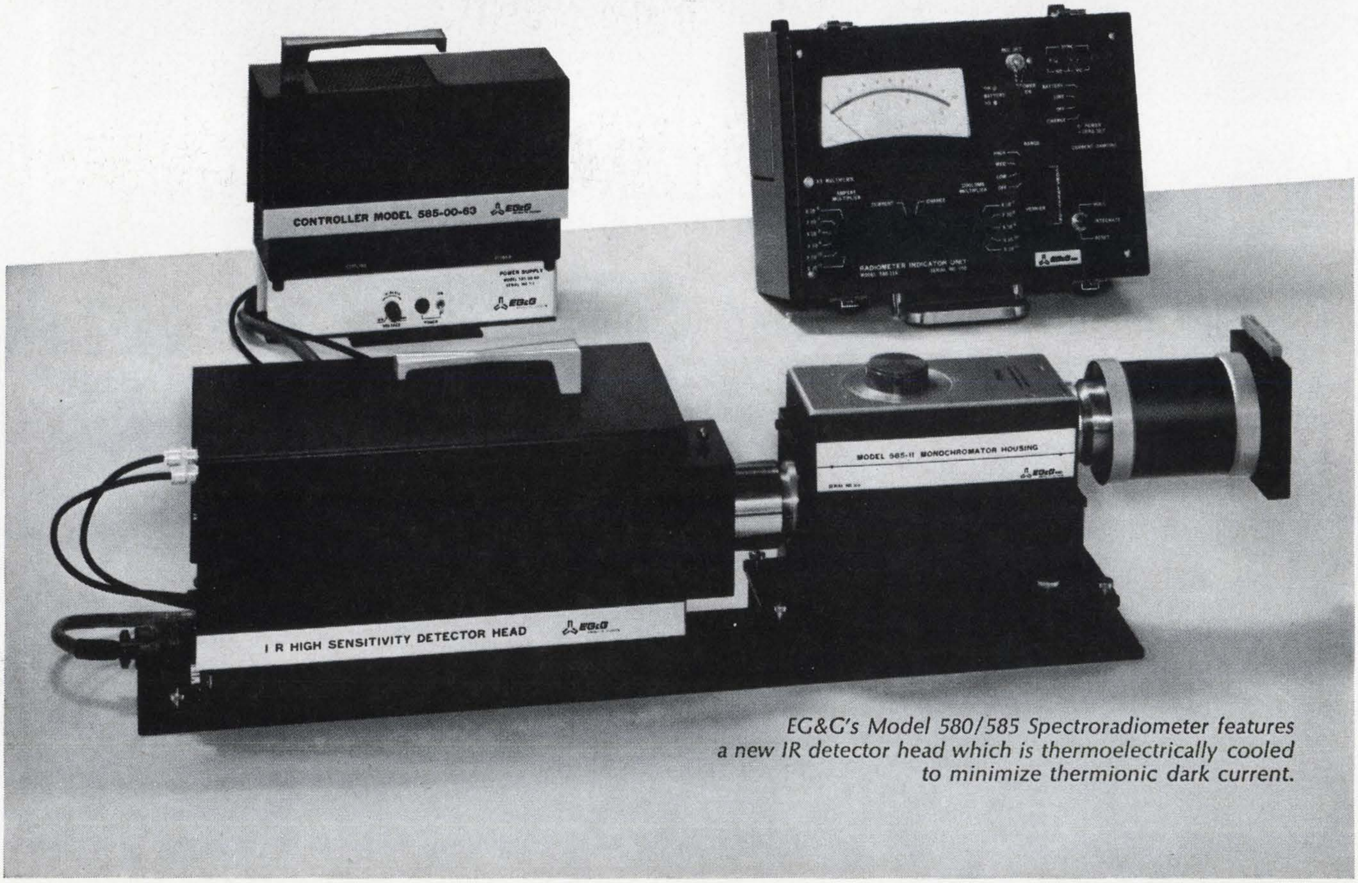
The new detector heads are provided with a regulated power supply and an internal calibration feature to ensure a stable sensitivity. Utilizing standards traceable to NBS, a complete 580/585 Spectroradiometer System is calibrated to its sensitivity versus wavelength thereby permitting absolute irradiant measurements of both continuous and pulsed (as fast as 1 ns) light sources.

Energy and average power measurements are obtained directly from the multi-decade meter of the Indicator Unit or from an external recorder.
Provision is also made for output to an oscilloscope for pulsed sources.

Applications with the new high sensitivity detector head include measurements of phosphors, chemical reaction, electroluminescence, emissivity and reflectivity of surfaces, biochemical analysis, and other low level signals.

If you'd like more information on the EG&G Spectroradiometer System, or for that matter on any of our products, such as thyratrons, krytrons, spark gaps, flash tubes, thermoelectric modules, transformers, chokes, trigger modules, photodiodes, picoammeters, flash and strobe equipment, or light instrumentation, write: EG&G, Inc., 166 Brookline Ave., Boston, Massachusetts 02215.
Tel: 617-267-9700. TWX: 617-262-9317.

EG&G
ELECTRONIC PRODUCTS DIVISION



EG&G's Model 580/585 Spectroradiometer features a new IR detector head which is thermoelectrically cooled to minimize thermionic dark current.

Compliments of a friend – a complete multimeter at less than $3000

We think you'll agree that it's pretty friendly of Cimron to put out such a flexible instrument for so little. But it's typical of the philosophy that has always guided Cimron – **customer concern.** You need the most sophisticated instruments to do your work under a variety of changing conditions. And the Model 6653 gives you a great sendoff for both systems applications and laboratory or production testing. You get 5-digit readout including overrange, with an accuracy of ±0.01% f.s. +0.01% of reading for six months or longer. You'll save on calibration costs. Sample rates up to 300 per second; automatic polarity and automatic ranging; AC, ohms, millivolts. And look! You also get auto ranging through six millivolt and DC ranges. It's especially hard to beat all those Cimron customer concern features like remote control and printout, maintainable plug-in pc boards, and accessible calibration and test points. Write Cimron®, Dept. B-106, 1152 Morena, San Diego, Calif. 92110.

LEAR SIEGLER, INC. / *CIMRON DIVISION*

Technical Articles

Experimental flat-screen color television page 92

Consumer electronics engineers look forward to flat-screen color television because it will eliminate high voltages, the danger of X rays and implosions, and misconvergence of electron beams. To learn about the problems that might crop up in building a flat-screen set of conventional size, Sony has constructed a giant experimental receiver that uses 78,000 light bulbs, 260 SCR's, and 4,000 transistors. The screen (shown in part on the cover) has a 100-inch diagonal.

Understanding common-mode errors page 108

The operational amplifier means different things to different engineers. For example, used as an inverting amplifier, it is free from common-mode error but does not give exceptionally high gain. In a noninverting configuration, its gain is high but common-mode error is present. In this article, the first of two on this subject, the author shows how amplifier design can minimize common-mode error.

Party-line data link page 119

Cabling can be an expensive item in a data-transmission system. A new method of linking transmitters to their corresponding receivers one at a time over a single two-wire cable reduces these costs. The technique also employs low-cost logic gates and flip-flops. The system can send analog or digital messages, using a binary code to address transmitter-receiver pairs.

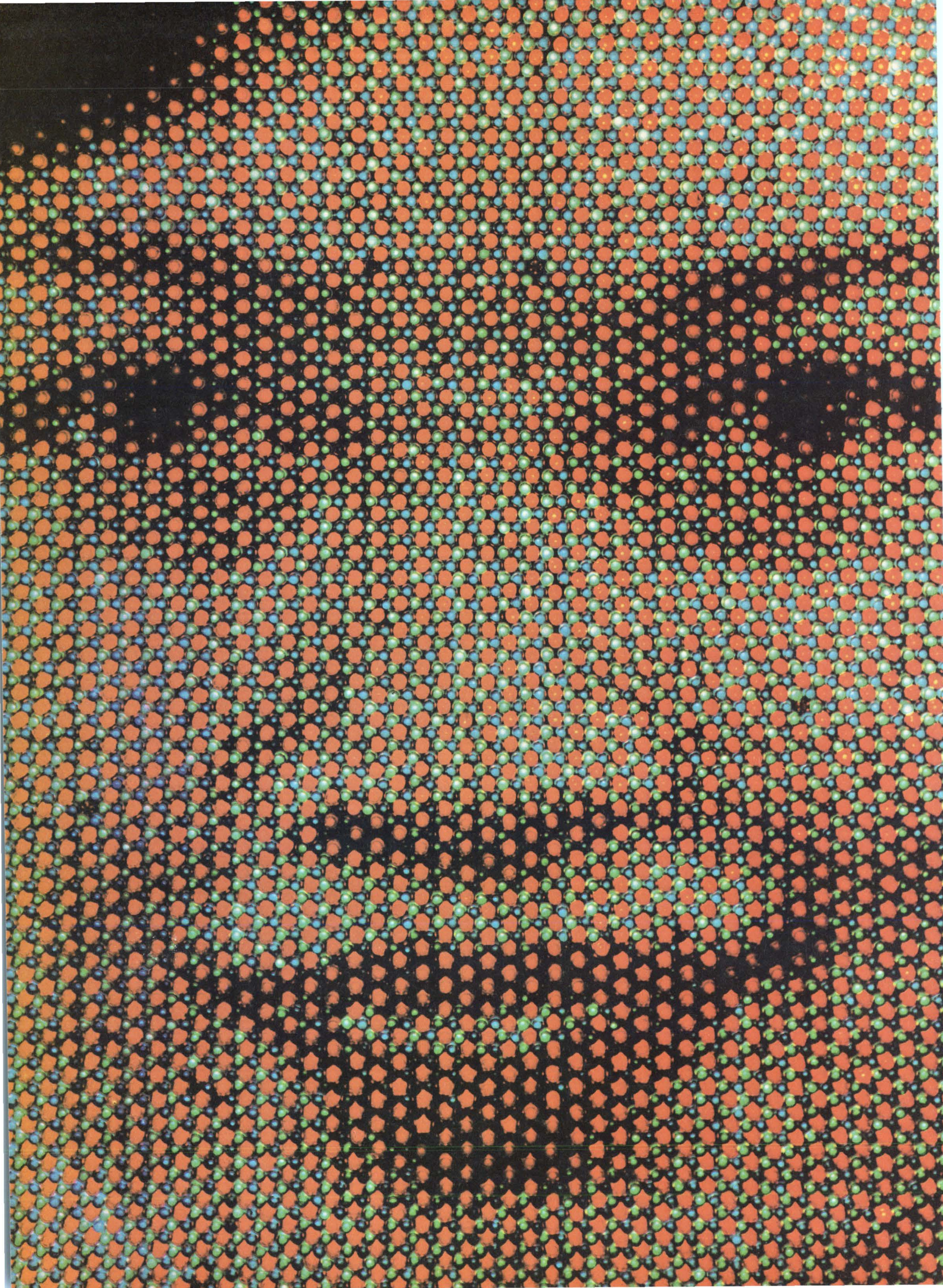
Airborne transceiver for the military page 133

A critical problem in airborne communications is electromagnetic compatibility. Now a high-frequency transceiver crams 280,000 voice channels in the bandwidth used by older sets for only 28,000. It can reject a signal 120 db above that of the tuned signal and only 50 kilohertz away from it, permitting efficient operation in crowded-frequency situations where strong interfering signals are close by. The new set also performs dynamic tests on itself.

Coming April 29

- **Automatic in-flight checkout**
- **Integrated circuits in Japan**

←Circle 90 on reader service card



Setting the stage for flat-screen tv

Experimental tubeless color set uses 78,000 light bulbs; converts standard signals with pulse-width modulation

By Satoshi Shimada
Sony Corp., Tokyo

A television receiver with 78,000 light bulbs, 260 SCR's, 4,000 transistors, and a power supply that delivers 300 amperes at 30 volts can hardly be called ready for home use. But the only way of discovering the kind of problems that would crop up in developing a small flat-screen color receiver was for Sony to build the giant 8-foot-diagonal set.

The color tv receiver has its 78,000 lamps in an x-y matrix—300 in each of 260 lines. The most important innovation in the system is the conversion of standard video signals into pulses for digitally scanning the x-y matrix with pulse-width modulated signals.

The receiving circuits use a standard color tv tuner that picks up broadcast signals and delivers the red, green, and blue color signals that normally drive the electron guns in the color tv tube. Three video amplifier channels then deliver the three signals to the horizontal video driver blocks.

These blocks convert the color signals into pwm signals for driving the lamps. The bulbs are staggered from line to line and each bulb is part of two color trios; each trio forms a triangle over two lines. Thus 600 pwm channels (200 color-trio channels) are connected to the 600 lead wires of the video panel.

The bigger they are . . .

Many engineers have completed prototypes of smaller displays, ranging from perhaps 12 × 24 elements, or 20 × 20. But the circuitry for these is far simpler than that for full-scale displays: there are no problems of high current, mistriggering, and sync or signal regeneration, and it's not difficult to delay either sync or video signals through a small number of steps in a line with a relatively short delay.

Closeup. Sony's color video panel, left, uses incandescent lamps with filter caps for the red-green-blue color trios.

In the color video panel, the vertical and horizontal conductors cross in a matrix. At each crossing is a picture element—a lamp and a diode connected in series. The diode keeps a signal current injected into a crossing from dividing and flowing into any other crossing.

Ironically, tungsten lamps will yield a good picture only with a tricolor scheme; satisfactory black-and-white reproduction with bare lamps is impossible. When tungsten lamps are dimmed, their temperature declines and their light becomes reddish. Lens-cap filters limit transmitted light to red, green or blue wavelengths and make it possible to reproduce white or gray.

Sharp, but not smooth

The 78,000 ordinary tungsten pilot lights form 26,000 red-green-blue trios. Though this is less than 1/10 the number of elements on a conventional color tube, the picture resolution isn't hurt as much as one might think. In the x-y video panel, completely independent information is injected into each light bulb. In a picture tube, the electron-beam spot is ordinarily large enough to cover three or four of the holes in the shadow mask. Furthermore, in the tube, reproduction of areas with white-peak brightness is hurt by increases in spot size, which cause the phenomenon known as blooming. However, blooming can't occur in the color video panel, because each bulb gets information independently from its neighbors. This keeps the picture surprisingly sharp.

Another advantage over the tube is that colors can't be misregistered. In the tube, beams are aimed at colors and may misland or misconverge. But in the video panel, signals are fed directly to colors and thus always stay in proper relationship.

On the other hand, the picture produced by the panel's 26,000 trios isn't as smooth as that of the picture tube, which has about 350,000 elements.

Interlaced scan can't be used, because there are only 260 horizontal lines. However, non-interlaced

Getting the whole picture

Sony's color video panel uses light bulbs arranged in a matrix with 260 horizontal lines of 300 lamps each. The lines are staggered to form red-green-blue color trios spanning two lines.

A television signal is picked up by a standard receiver and the three color signals are separated from the audio and synchronization signals.

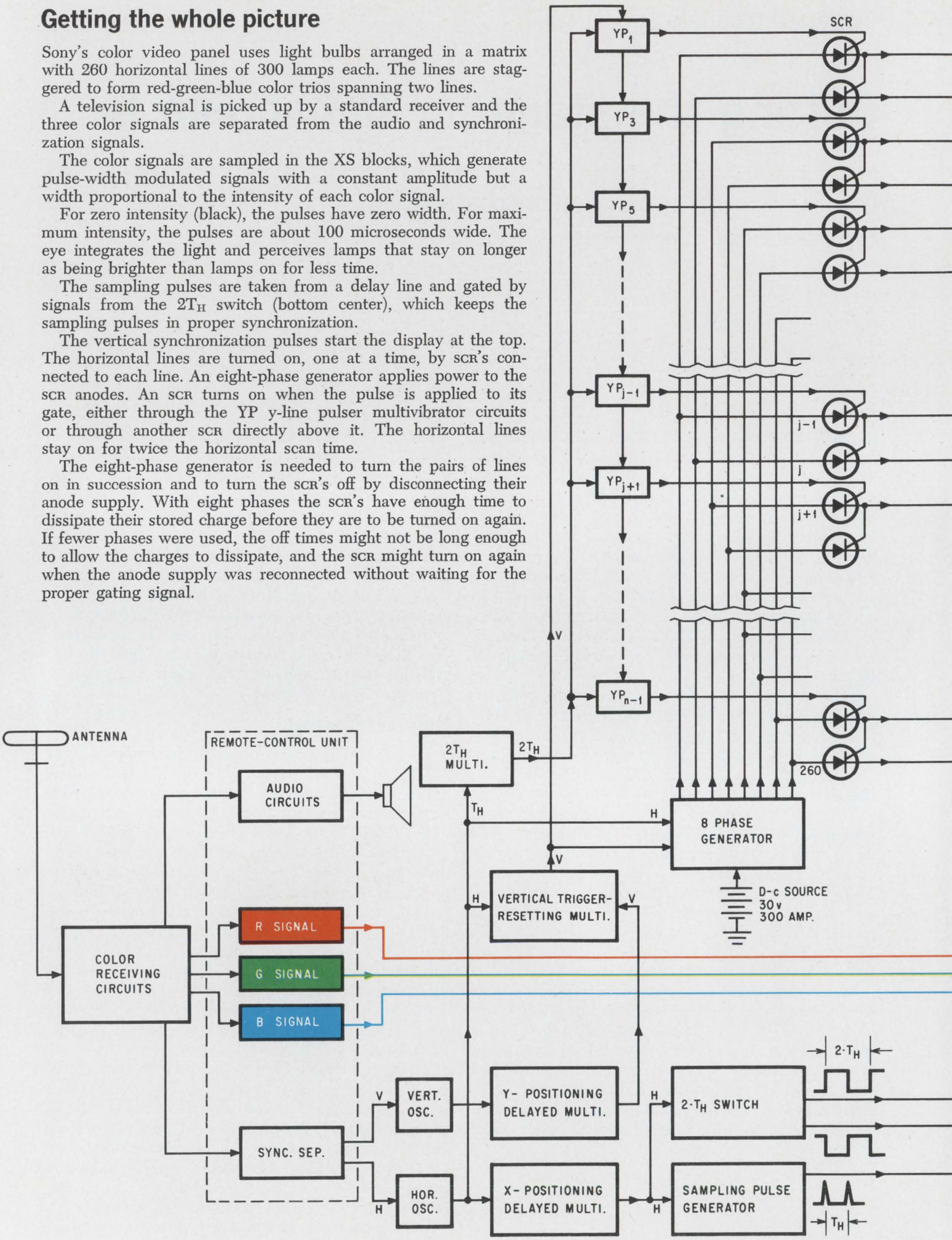
The color signals are sampled in the XS blocks, which generate pulse-width modulated signals with a constant amplitude but a width proportional to the intensity of each color signal.

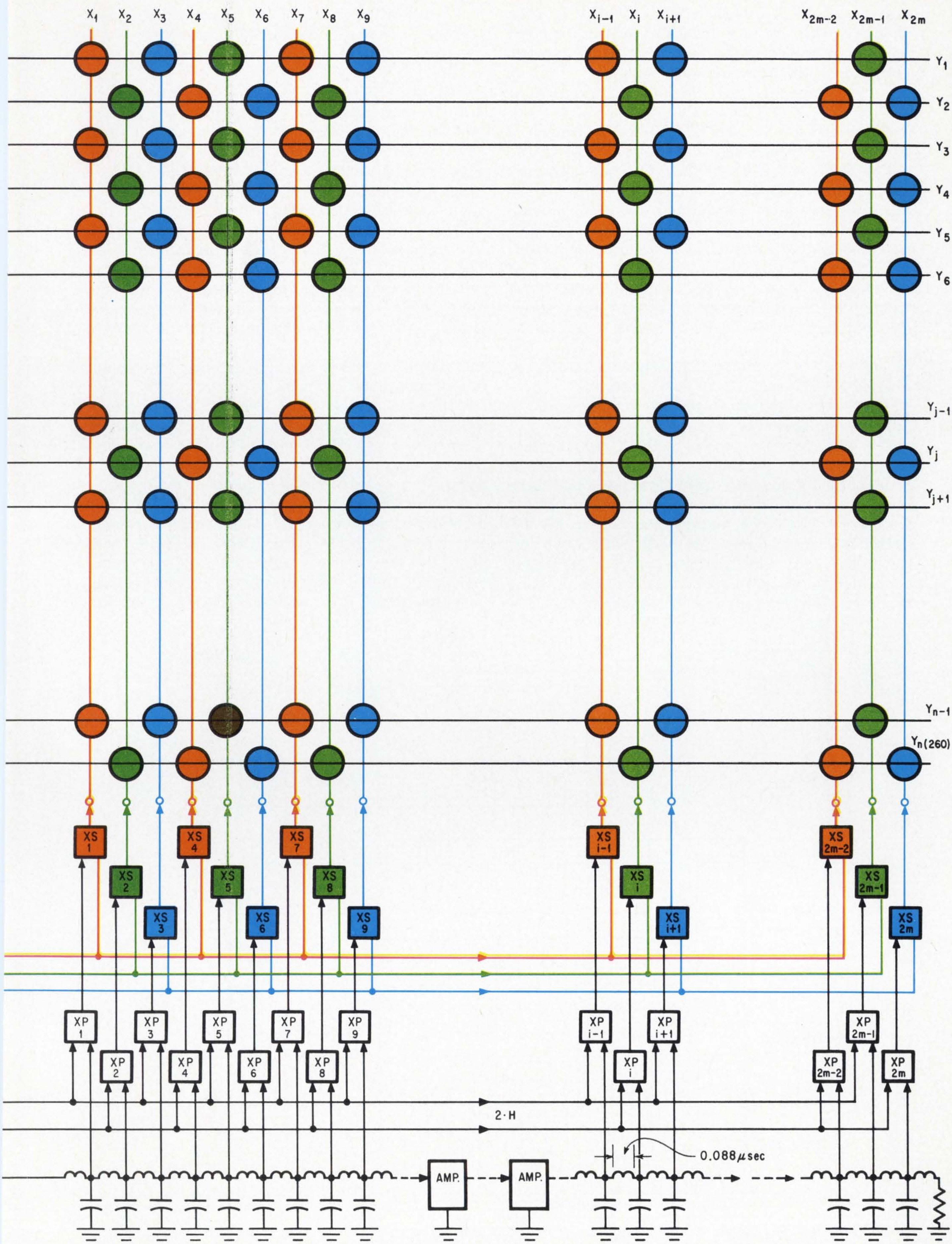
For zero intensity (black), the pulses have zero width. For maximum intensity, the pulses are about 100 microseconds wide. The eye integrates the light and perceives lamps that stay on longer as being brighter than lamps on for less time.

The sampling pulses are taken from a delay line and gated by signals from the $2T_H$ switch (bottom center), which keeps the sampling pulses in proper synchronization.

The vertical synchronization pulses start the display at the top. The horizontal lines are turned on, one at a time, by SCR's connected to each line. An eight-phase generator applies power to the SCR anodes. An SCR turns on when the pulse is applied to its gate, either through the YP y-line pulser multivibrator circuits or through another SCR directly above it. The horizontal lines stay on for twice the horizontal scan time.

The eight-phase generator is needed to turn the pairs of lines on in succession and to turn the SCR's off by disconnecting their anode supply. With eight phases the SCR's have enough time to dissipate their stored charge before they are to be turned on again. If fewer phases were used, the off times might not be long enough to allow the charges to dissipate, and the SCR might turn on again when the anode supply was reconnected without waiting for the proper gating signal.





X1 X2 X3 X4 X5 X6 X7 X8 X9
Xi-1 Xi Xi+1
X2m-2 X2m-1 X2m
Y1
Y2
Y3
Y4
Y5
Y6
Yj-1
Yj
Yj+1
Yn-1
Yn(260)
XS 1
XS 2
XS 3
XS 4
XS 5
XS 6
XS 7
XS 8
XS 9
XS i-1
XS i
XS i+1
XS 2m-2
XS 2m-1
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XP 6
XP 7
XP 8
XP 9
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XP i+1
XP 2m-2
XP 2m-1
XP 2m
2·H
0.088μsec
AMP.
AMP.

scan can provide reception that's satisfactory even though it isn't up to normal standards. Non-interlaced scan is used in the small Sony video tape recorder designed for home use.

Time to get samples

The video signal must be sampled to convert it to the multichannel signals required to drive the color video panel. With 300 lamps in each horizontal line, picture information from the original signal for any one lamp must be sampled within an interval less than 1/300 times the horizontal period of 63.5 microseconds, or about 0.2 μsec. The sampling interval is thus 0.05 to 0.1 μsec.

Sampling pulses are supplied to each pwm block through a lumped constant L-C delay line with individual sections consisting of a series inductance of 5.6 microhenries and a shunt capacitor of 1,400 picofarads. The delay time of each step is 52.5 μsec divided by 600 channels, or 0.088 μsec.

After every 24 channel delay steps, a delay of 2.1 μsec, an amplifier was inserted.

The pulses would survive without amplification for a slightly larger number of delays—although 48 would probably be too many. However, since there are repeating cycles of three colors and individual x lines are connected to alternate y lines, it's desirable to choose a number divisible by both two and three. The size of the x-output transistors makes it convenient to line up about 24 x drive-circuits on a single printed-circuit board. If pulses are regenerated between the output of one board and the input of the next, then all boards can be identical.

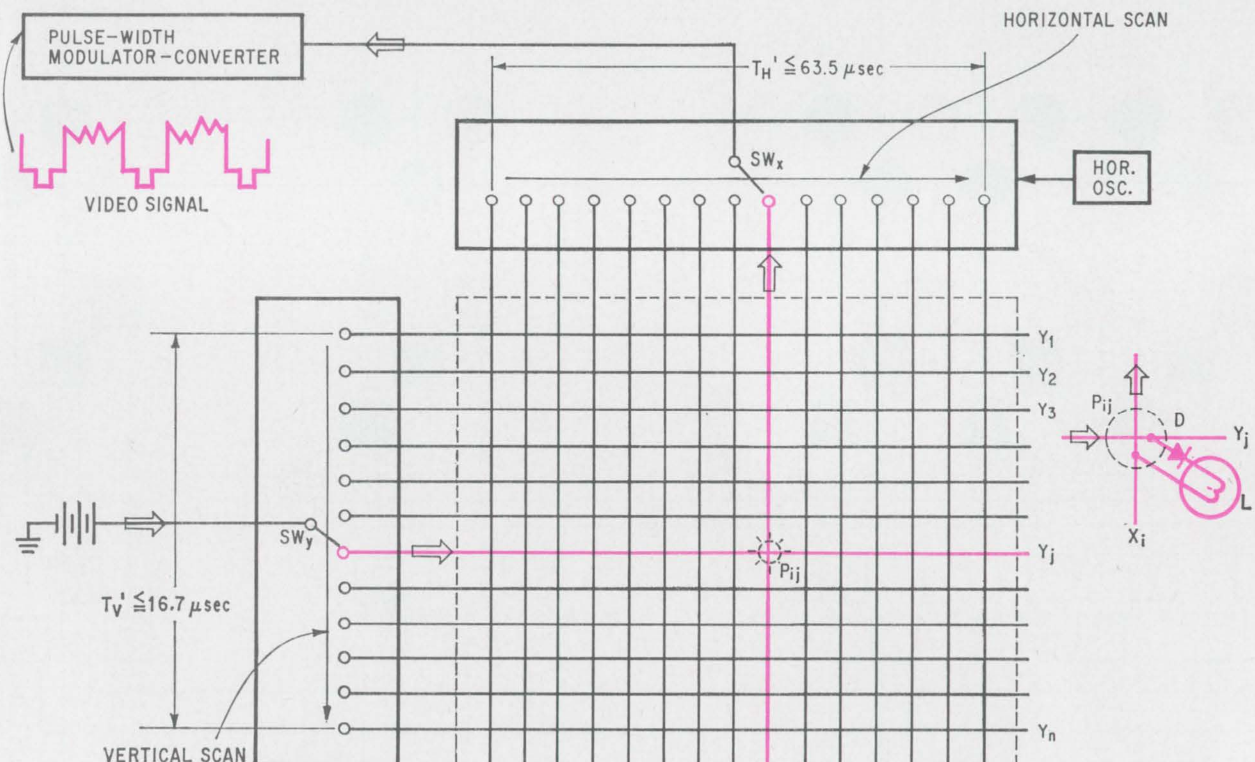
A steady gain

The pwm signal can be obtained with simple circuits. The amplifiers are saturating transistor switches that are either in saturation or off, so that gain doesn't vary between channels. Because amplifier output efficiency approaches 100% and collector dissipation is low, there is a good chance that circuits can be integrated.

With the color video panel, the pulse repetition frequency is half the horizontal frequency, or 15.75/2 equals 7.88 kilohertz. The signal varies from zero to maximum amplitude, and for black the pulses have zero width—no current flows in the lamps. Lamp voltage is constant, and the longer the bulb is on the brighter the image appears to the eye, which integrates the light to create the sensation of intensity.

With pwm, each picture element's duty cycle is 600 times better than it would be if each element were turned on and off befort the next one on the line; the same brightness can be produced with less power.

For example, if an on-off scan was used in a 260 by 300 element array, each element would operate on a $1/260 \times 300$, or 1/78,000, duty cycle. But with pwm, the duty cycle is increased 2×300 times, making it 1/130, or 600 times better. In comparison, television tubes have a duty cycle of 1/350,000,



Cross at the light. A basic lamp matrix is driven by horizontal and vertical line switches. The diode in series with the lamp prevents the current from taking sneak paths through other lamps.

Wide smile. The color video panel, shown with its power supply, right, measures about five by six feet. The message displayed at the top of the screen is generated through a separate channel.

since each picture element is turned on and off in succession.

In the practical circuit configuration for the pwm sampling and holding method, for each x channel there are six semiconductor devices—five transistors and one diode. This isn't a large number of components if circuits are to be integrated. The number of circuit blocks needed is twice the number of lamps on a line, or 600.

Because of the arrangement with 600 sample and hold units, sampling for a given x line is done only once for every second y line, so that sampling is done only at every second pulse.

The amplitude samples are converted into ramps, whose amplitude is proportional to that of the original. Ramp basewidth is also proportional to the original amplitude. By slicing the ramps near the base line, a pwm signal proportional to the original amplitude is recovered. These varying-width signals drive the lamps.

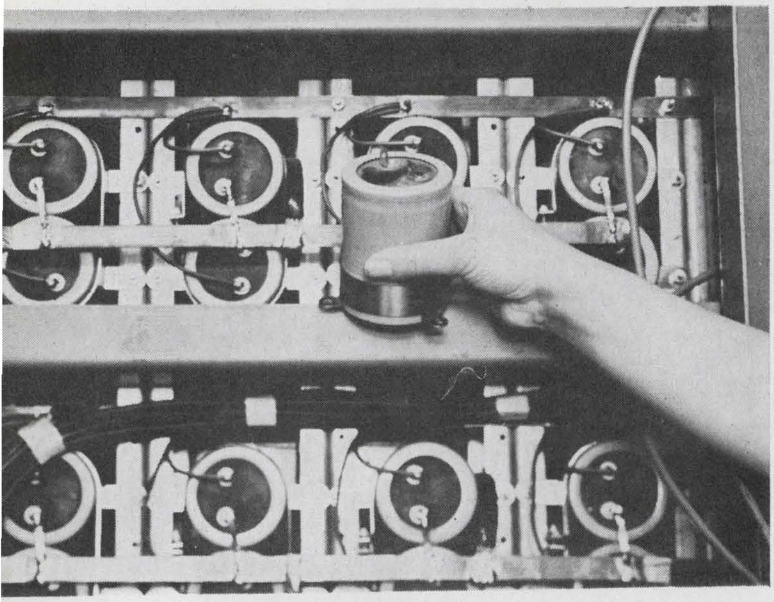
The lamp current isn't constant while the pulse is applied. Lamp voltage, as noted, is constant. The lamp current varies during the 10 μsec or so that it takes for the lamp to reach steady state, but then is approximately constant. After the lamp is turned off, brightness fades rapidly, but a faint afterglow continues for several milliseconds. Light output falls to zero, though, before the end of the frame, which lasts 16.7 msec.

These rise and decay characteristics are nonlinear, and are different for each color. If uncorrected, these differences would unbalance the color signals. Correction is applied by simple curve-shaping circuits with diodes to give segment approximation of desired characteristics in the three video amplifiers. Circuits of this type have long been used in analog computers as curve generators, and in television cameras for gamma correction.

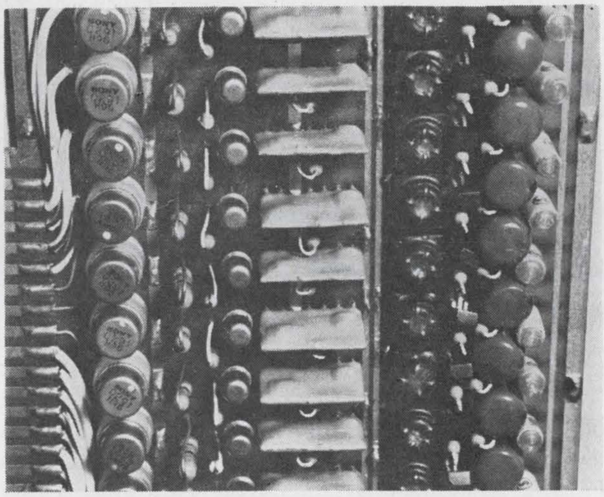
Easy work

The lamps for red have a d-c rating of 2.0 volts and 30 milliamperes. Lamps used for green have a d-c rating of 1.5 volts and 30 ma. Lamps used for blue have a d-c rating of 1.5 volts and 70 ma. However, the lamps aren't used at their rated current and voltage levels.

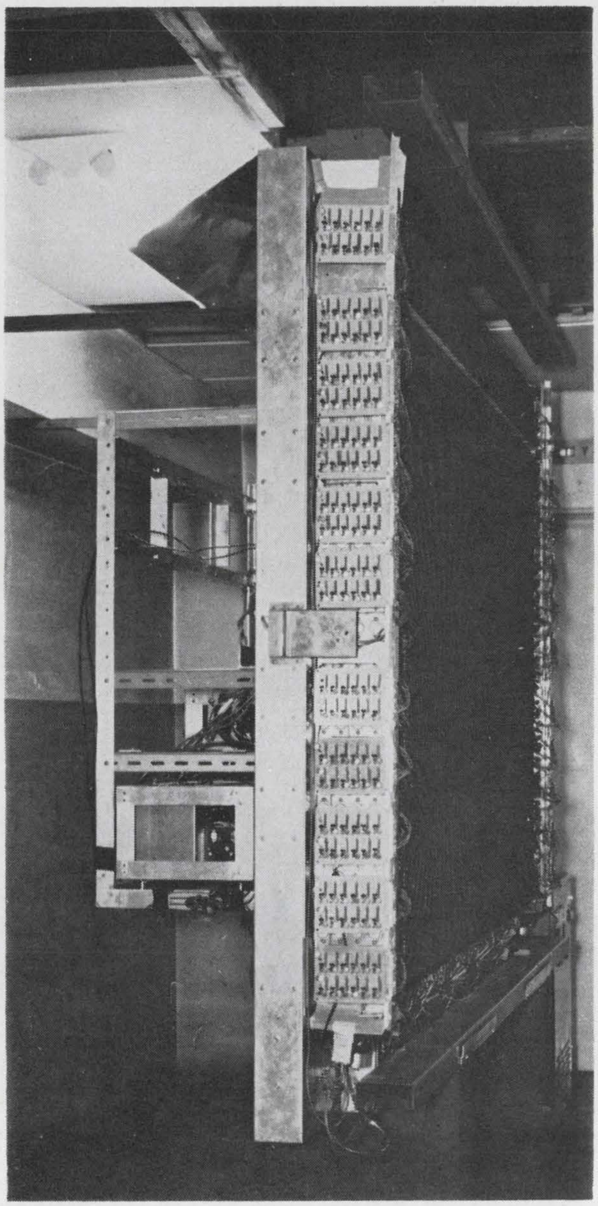
The lamps are operated only for a maximum duty cycle of 0.7%—at 30 volts for 100 μsec maximum out of each 16.7 μsec. The peak current for the red lamps is 400 ma, for the green lamps 600 ma, and



Nearly a farad. The power-supply filter uses 100 capacitors of 8,000 mircrofarads each for a total of 0.8 farad.



Pulse source. The pulse-width modulator is built around dipped hybrid integrated circuits, center.



Side view. The color video panel has drive circuits at the rear and around the edges.

peak current for the blue lamps is 1,000 ma.

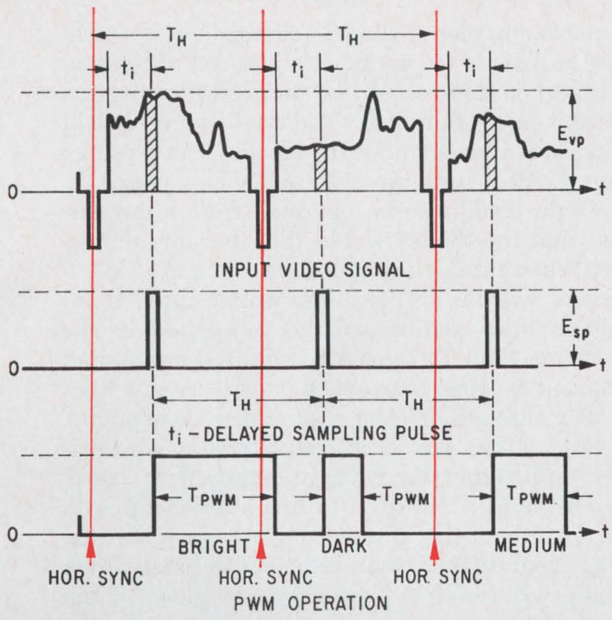
Each output transistor in the x channels is operated at a duty cycle of 0 to 75%. These transistors are operated in the pwm mode at a period of twice the horizontal-line time, or $2T_H$, with the peak currents of the lamps. For this type of operation, the dissipation of the output transistors in the various channels runs in the range of 100 to 300 milliwatts. Neither the current value nor dissipation is much of a problem; the output transistors in the x channels are operated without heat sinks.

Enter the SCRs

For y line switching there are n switches, which go on and off in succession with overlapping on-times of T_H, and with total on-time of $2T_H$. The entire process repeats at intervals with a period of T_V, which is 1/60 second.

However, unlike the x-line switches, the y-line switch must handle high values of pulse current. For each line the maximum pulse current equals the sum of the current flowing into 300 crosspoints—$(0.4 + 0.6 + 1.0)$ amp $\times$ 300 channels/3 is 200 amps peak.

Since this pulse current flows with a maximum duty ratio of 0.7% for high light white raster during a repetitive period of $T_V = 16.7$ msec, the time average value of current and the loss in the switching devices aren't excessive. But pnp or npn devices rated for handling the 200-amp peak current aren't available. One could get by with perhaps five to 10 power transistors in parallel for each line, but for a system with 260 lines this means it would be necessary to use something like 1,300 to 2,600 power transistors—and there isn't really room to fit them all in. Space and cost would be terrible, and besides



Just a sample. The sampling pulses produce pwm signals corresponding to the video signal amplitudes.

this a brute-force way of attacking the problem.

Switching 200 amps on the y line requires a device with extremely low saturation resistance—such as a silicon-controlled rectifier.

The SCR can turn on with very small trigger power. However, there isn't any good way to turn it off without turning off the d-c power supply connected to their anode circuit. Therefore, an additional power switching circuit must be connected between each SCR and the d-c power supply. The power switching circuit consists of a multiphase square-wave generator with at least two phases—in this circuit, eight phases are used.

After the anode power supply has been turned off, there may be trouble when it is turned on again; because of stored charges, current may start to flow even though no gate pulse has been applied to the SCR. It is thus necessary to increase the number of phases of the power supply, and keep the device off long enough so that the stored charges have enough time to dissipate.

The prototype video color panel has an eight-channel, eight-phase power pulse generator for current switching. Each phase has a pulse width of $2T_H$, and, repeats with a period of $8T_H$, so that the SCR's are held off for about 380 μsec. Individual phases are shifted from their neighbors by precisely T_H.

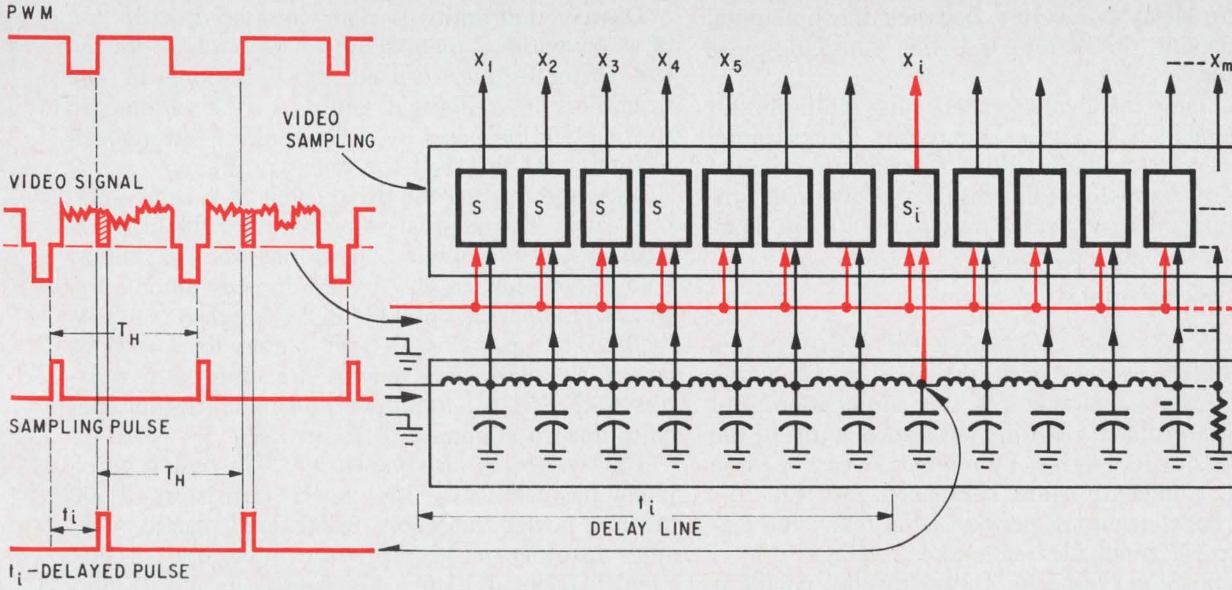
Alternate y lines are triggered by a multivibrator delay train. The line is turned on, and a d-c trigger signal is also applied from this line to the following y line. The second y SCR cannot trigger, though, because voltage has not yet been applied from the eight-phase power supply. Thus, only a total of 130 multivibrators are needed. Multivibrators are synchronized by pulses with a period of twice the horizontal scan time, $2T_H$.

At precisely the correct time for the start of a y line, voltage is applied, the SCR turns on, and the x-line transistors start injecting power into the x lines.

Adjusting the picture

When a y line switches on, the load is the current in x_1 only; the load then increases, until at a time T_H later it reaches the peak—a maximum of 200 amps. The load then declines until at a time $2T_H$ after y_j was first switched, it has fallen to about zero. The waveform is thus a symmetrical triangular pulse. During this period the next y switches on and adds to the power supply load. Currents in the two adjacent y lines overlap with a shift of T_H.

Among the x_i pwm waveforms are those with a pulse width that exceeds one T_H and those that have a pulse width of 100 μsec. These occur at the white-peak points in the picture. Taking these circumstances into consideration, the engineers de-



Delay pulse. The sampling pulses are delayed for each column of lamps and the pulse-width modulated signals thus turn on the lamps in succession across a horizontal line.

Plug-ins. Lamps are inserted in blocks for final assembly. However, since lamp ratings are different, red, green and blue lamps are not interchangeable.

signed the power supply for the entire color video panel to be able to supply a load of 30 volts at 300 amps, or about 10 kva maximum. For d-c smoothing of the power line, 100 individual capacitors of 8,000 microfarads each—totalling 0.8 farads—are arranged on the rear of the panel behind the lamps. One must also provide for correctly centering the reproduced picture. To do this, an adjustable x-positioning multivibrator delay is inserted between the horizontal synchronizing oscillator and the sampling-pulse generator.

In the same manner, a y-positioning multivibrator delay is needed for vertical centering. Furthermore, it is necessary to finely adjust the starting point of the first y channel so that the delayed vertical synchronizing pulse coincides precisely with the horizontal synchronous position.

A hope for the future

Anyone who has had experience with tungsten filament light sources might worry that the lamp's light decays too slowly for this application. But this isn't a problem with the miniature lamps of the type used for dial lights. Luminance decay of these lamps is sufficiently short compared with the 16.7 msec vertical scanning period of the television signal, because small filaments cool quickly.

Of course, one hope for future display panels is a p-n light-emitting junction. If an electroluminescent diode could now be produced more cheaply than the lamp plus a diode, perhaps by LSI techniques, and made to produce the desired red-green-blue trio, then there would be no need for tungsten filament lamps. But today's diodes aren't bright enough, and blue luminescent diodes can't yet be produced. Also, costs are high and yields poor.

The light could also be obtained from a gas discharge, and the diodes would then become unnecessary. When three glow tubes are connected in series, there will be no discharge unless three times the single tube-exciting voltage is applied to the series connection. To bypass the desired crosspoint, the current flowing between the two driving lines must flow through at least three other crosspoints.

Because of the gas tube characteristic, approximately three times the voltage required to break down one lamp is required to break down three in series. Because of this inherent selection mechanism, a voltage slightly more than sufficient to break down one lamp will result in breakdown, or glow, of the lamp at the crosspoint, and no current will flow through sneak paths. The first studies actually were with a neon lamp matrix panel—a local part of the red matrix with only 40 × 50, or 2,000, elements was operated successfully before the neons were eliminated in favor of the incandescents. But, still, a flat-package gas tube may eventually be practical, using phosphors to achieve the different colors.

The human eye is rather tolerant of chromaticity errors in the blue region. This is fortunate, because radiation in the blue region is low for tungsten filament lamps. A cyanic-blue filter cap is used on the blue lamps to pass the emitted blue light. This allows the operating current to be held low and keeps lamp life at the same high level as that of the other color lamps. Green with good color saturation can be obtained with the green filter.

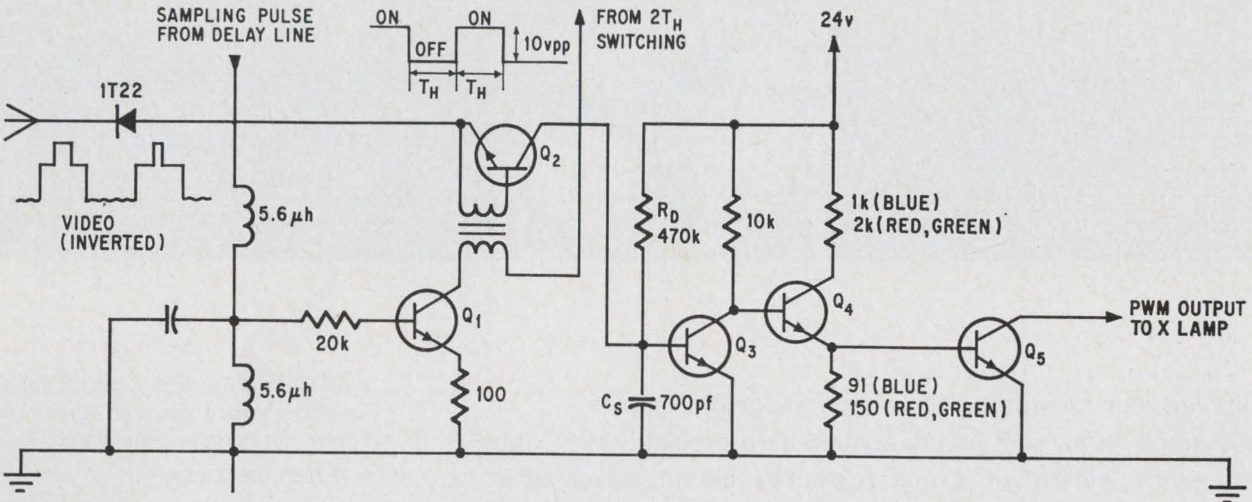
Problems, problems

The color video panel still has problems of uniformity, cost, life, and applications.

Display uniformity is poor compared with that of a conventional picture tube. The random dot-by-dot nonuniformity caused by variations in the brightness of individual lamps can be eliminated for practical purposes by tightening the lamp specifications, but this isn't the worst problem.

Variations among the drive levels of x_i or y_j channels cause "stripes" that resemble the runs in nylon stockings. With pwm operation, the variations among channels caused by differences among the transistors become small enough to neglect. But this method of operation doesn't eliminate variations caused by differences among capacitors and resistors, and there is a great need for much tighter specifications to eliminate these errors.

The system is also expensive. The color video panel has 260 SCR's, 180 power transistors, 1,500 medium-power transistors, 2,500 small plastic-package transistors—mostly in hybrid integrated circuits—and 1,000 small diodes, also mostly in hybrid integrated circuits. And it has the healthy appetite for as much as 10 kva.



Sample and pulse. The sampling and pulse-width modulation of the video signal is done with the combination of transistors Q_1 and Q_2. The three transistors to the right amplify the pulse-width modulated signals.

Money, money

The lamps and diodes and cross-grid construction into which they are plugged for display account for about 75% of the total materials cost. The semiconductors in the circuit account for about 10% of the materials cost, and other circuit components the remaining 15%. If this system were to be made into a commercial product in its present form, it would have to cost about 100 times more than a conventional color tv set. On the other hand, it would cost about the same as a color display of comparable size using projection methods, and the projection display can be viewed in a lighted room.

An early doubt regarding the 100-inch color video panel was: would the life of the bulbs be so short that the filaments would be continually burning out? Even at low temperatures, when the light from the bulbs appears reddish, it's possible to obtain enough blue light with the proper color filters. Lamps with high current ratings were therefore chosen, and the input power was increased. Since the lamps are rich in red wavelengths, red current levels are lowest. Green is a little higher and blue lamps are driven the hardest. The system has an average lamp life of 5,000 hours.

But with a total of 78,000 lamps, if lifetime is homogeneous so that at 5,000 hours half are burned out, then at 10 hours 80 lamps (about 0.1%), at 100 hours 800 lamps (1%), and at 1,000 hours 8,000 lamps (10%) will probably burn out. This might mean that every few minutes one will have to change a lamp.

On the other hand, if lamp life doesn't vary the color video panel would operate without incident for 5,000 hours.

The distribution of life among lamps isn't known. But as long as the lamps burn out in random positions the effect isn't serious. A more serious problem is that some of the lamps are far brighter than their neighbors and stand out as prominent points. But dark points where lamps have burned out are like very small freckles, and are much less noticeable than one might think—like a speck of dust on the face of a conventional picture tube.

For practical purposes one can neglect burned-out lamps until their number reaches about 1% of the total, and then replace all the defective ones at once. With the lamps now used, this must be done after about 200 to 300 hours of operation. The ability to operate this long between regular maintenance periods means that the system is suitable in this respect for practical applications.

Putting it to use

There are many closed-circuit television applications for which this display could be teamed with a color video tape recorder or color television camera. When considering applications for the color video panel, one must remember an extremely important characteristic: when a raster sweep is used on a conventional picture tube, both horizontal and vertical retrace time is needed. It isn't normally possible to use these intervals for display.

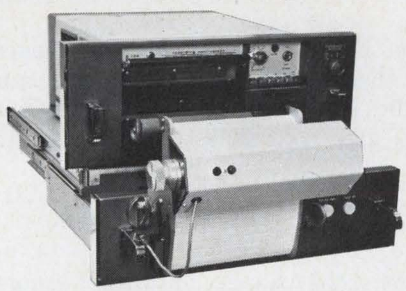
With the color video panel, non-retrace-time scanning is feasible, and it's relatively simply to display completely independent information—such as alphanumeric characters—that are derived from separate sources. In this display, the horizontal retrace interval isn't put to use, but the photo on page 97 shows a character display, picked up by a conventional tv camera, inserted above the picture display during the vertical retrace interval.

The author

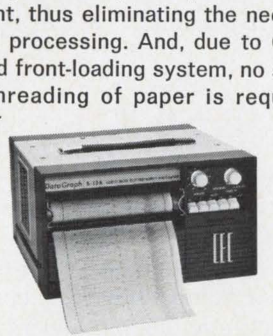
Satoshi Shimada is manager of advanced tv technology—display and cameras—in the development division at Sony. A 1953 graduate of the Tokyo Institute of Technology, Shimada joined Sony in 1959 and developed the company's first 8-inch transistorized tv receiver. He also developed Sony's 5-inch micro tv, which went on the market in 1962.

Recording / 1968

Type 5-124 Recording Oscillograph—Shown with the DataFlash Takeup Accessory which requires only 1 second to readout, the 5-124 has become a new "must" for industry. Portable, easy to operate, this instrument offers big recorder capability in a small-size, low-cost package. The 5-124 provides up to 18-channel print-out recording, and record-drive systems with options from 0.25 ipm to 128 ips.

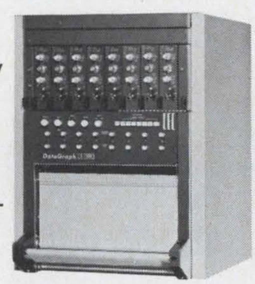


Type 5-126 Recording Oscillograph—The new *"best buy"* in oscillography. At a price hundreds of dollars less than any comparable instrument, the 5-126 offers the basic capabilities of a light beam oscillograph at a cost approaching that of a direct writing recorder. With CEC's 7-380 Galvanometer, this portable unit will record from dc to 1 KHz. Its tungsten light source assures optimum trace quality and lamp light, minimum cost and maintenance, instant operation with complete safety. Nine channels produce vivid data traces on 7-inch-wide paper. Records by direct print-out upon exposure to ambient light, thus eliminating the need for chemical processing. And, due to CEC's simplified front-loading system, no spooling or threading of paper is required.



Type 5-119 Recording Oscillograph—A truly universal oscillograph, the 5-119 has become a popular, proven performer for laboratory, mobile, airborne and marine use. Both dc and ac powered models are available. The 5-119 accepts all three types of record magazines, DATAFLASH®, DATARITE®, and conventional, making it possible to utilize every known photographic technique on either the 36- or 50-trace models.

Type DG 5510 Thermal Writing Recorder—This 8-channel recorder brings a significant advance in performance and reliability to direct-writing oscillography. The basic 5-510 recorder is a self-contained instrument with driver amplifiers and power supply capable of accepting a wide range of high-level input signals. Interchangeable plug-in attenuator/pre-amplifiers are available to further extend the input range. It employs a heated writing stylus to deliver sharp contrast rectilinear traces on CEC's DATATRACE® Thermal-Sensitive Paper.



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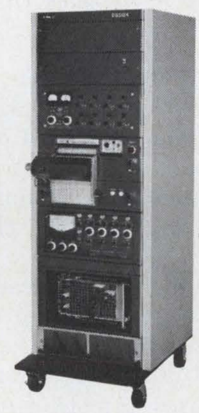

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Gate-to-source resistor stabilizes FET regulator

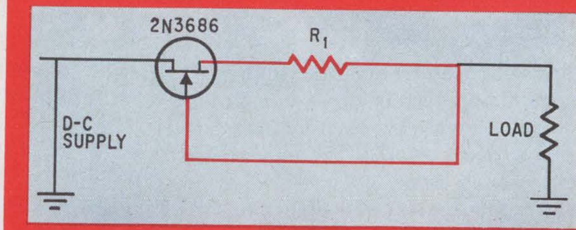
By Bill Birnbaum

Industrial Scientific Research, Orange, Calif.

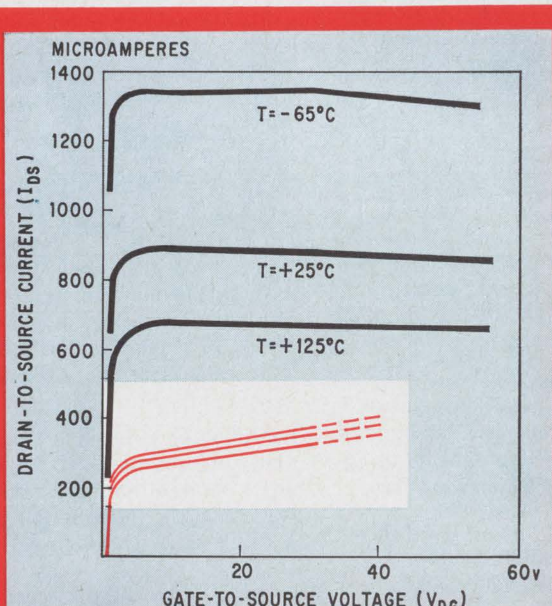
Field effect transistors, like the old vacuum-tube pentodes, are used to make d-c power supplies constant-current sources. Connected in series between the load and the supply, the FET will, when there's no gate voltage, maintain a constant current through the load despite changes in the supply voltage.

But where the FET is biased by the direct connection of gate to source, wide temperature variations can cause changes in the FET's drain-to-source resistance and drastically alter current flow.

In such cases, a resistor can be placed between the source and gate connection. With this configuration, changes in the resistor's voltage drop caused by swings in drain-to-source current develop a bias on the FET that holds the current steady. Current through the FET—the same current that flows in the load—is thus affected by both temperature and gate voltage, as expressed by the equation:



Compensation. An increase in the current through the transistor causes the voltage drop across R_1 to increase.



Stability. Drain-to-source current through the FET is nearly always constant with the resistor-compensated supply.

$$\Delta I_{DS} = \Delta I_{DST} + \Delta I_{DSG}$$

where I_{DS} is the total change in drain-to-source currents, I_{DST} is that change caused by temperature, and I_{DSG} the change attributable to gate voltage. When the drain-to-source current's relationship with the gate voltage, $I_{DSG} = g_m V_{GS}$, is inserted in the equation, the result is:

$$I_{DS} = I_{DST} + g_m V_{GS}$$

Since $V_{GS} = -I_{DS} R_1$—with the negative sign indicating that an increase in drain voltage makes the gate more negative—the equation can now be written in terms of I_{DS} and I_{DST}.

$$I_{DS} = I_{DST} - g_m I_{DS} R_1.$$

After transposing, it becomes

$$I_{DS} = \frac{I_{DST}}{1 + g_m R_1}$$

This equation indicates how R_1 and the transistor's g_m minimize the effect a temperature change has on the drain-to-source current.

The larger the resistor, the greater the regulating effect, but too large a value limits the current in the transistor to a few microamps, lowers the device's avalanche breakdown, and thereby narrows the range of d-c supplies the FET can regulate.

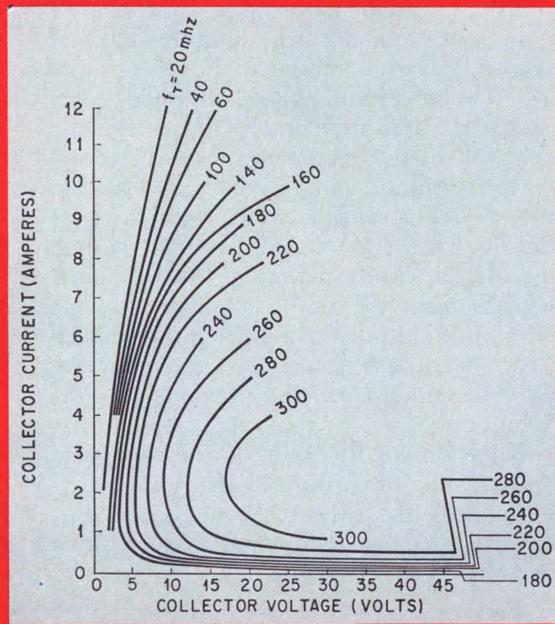
Power transistor's r-f gain measured by brief pulse

By Octavius Pitzalis Jr.

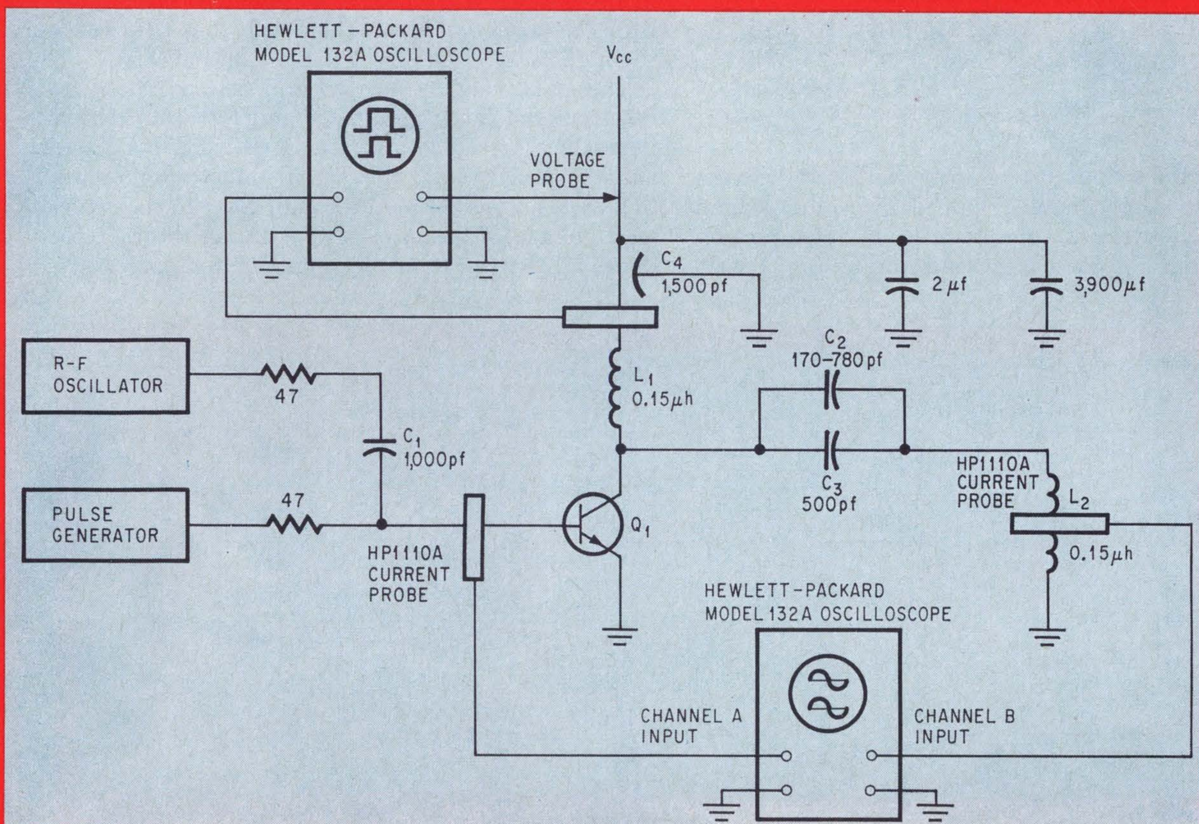
U.S. Army Electronics Command, Fort Monmouth, N.J.

The frequency at which a power transistor's gain-bandwidth product becomes unity is calculated from a current-gain measurement made at a lower frequency. If the calculated frequency, commonly called f_T, is to be meaningful, the measured current gain should be made while the transistor is operating at its recommended current and voltage levels. Unfortunately, the power dissipated at these levels raises a transistor's temperature to a point where leakage currents multiply and internal resistances increase. These changes make it impossible to measure, with any accuracy, such a delicate parameter as the transistor's current gain.

By pulsing d-c currents and voltages into the transistor for a few microseconds and measuring the current gain during this interval, high temperature and its adverse effects are prevented from



Power profile. Frequency measurements at different voltages and currents relate transistor's upper frequency limit to operating conditions.



Momentary testing. Amplification of a high-frequency signal takes place only for a few microseconds. Power dissipated for such a short time cannot heat the transistor and therefor prevents any measurement errors from occurring.

causing any detectable measurement error.

A 35-megahertz signal is coupled from the r-f oscillator through capacitor, C_1, into the base of the transistor. It is not amplified, however, until one of the 10-microsecond pulses, supplied every millisecond by the pulse generator, biases Q_1 into conduction. When the momentary amplification takes place the resultant signal is shorted to ground through the series resonant circuit consisting of C_2, C_3 and L_2. The inductance L_2 is a ¾-inch length of #16 bus wire insulated so that no shorting takes place with the probe clipped on. This short, the required output for a current-gain measurement, can be adjusted for any frequency by varying C_2. The inductance, L_1, prevents r-f currents from entering the d-c supply. Its voltage drop and any others that might occur during the pulse are overcome by the charge that exists on capacitor, C_4. Monitoring the collector voltage and current is, nevertheless, necessary and is best done with a voltage probe, a dual-beam scope and a current probe.

When collector current, i_c, and base current, i_b, are measured on that portion of the frequency-gain curve when the gain is dropping 6 db/octave the following relationship is valid:

$$f_T = f\left(\frac{i_c}{i_b}\right)$$

where f_T = frequency at which the transistor's gain-bandwidth product is unity
i_c = a-c collector current
i_b = a-c base current
f = frequency at which i_c and i_b are measured

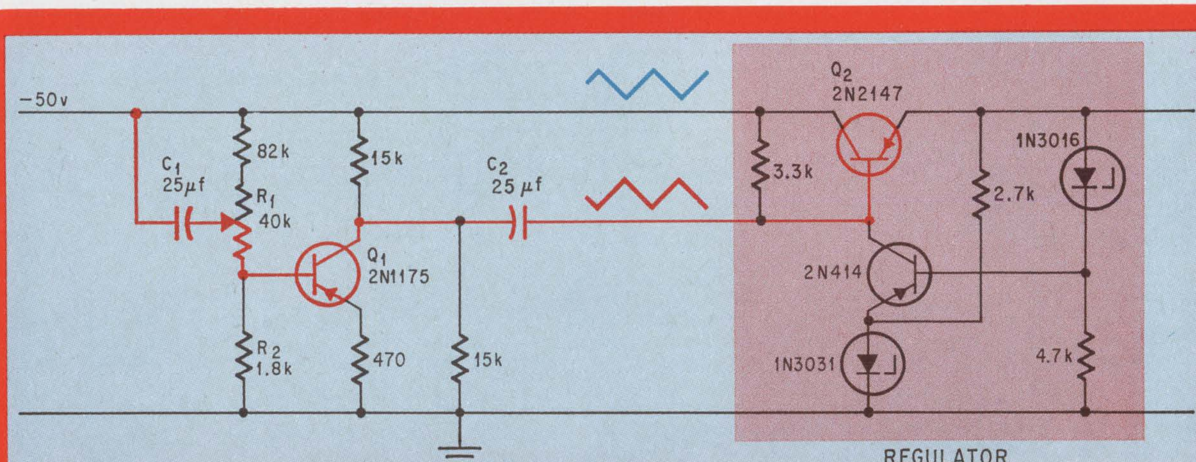
The two current measurements are made with a dual-beam oscilloscope and the frequency of the input signal is read directly on the oscillator's dial.

Amplifier flattens ripple in d-c regulator

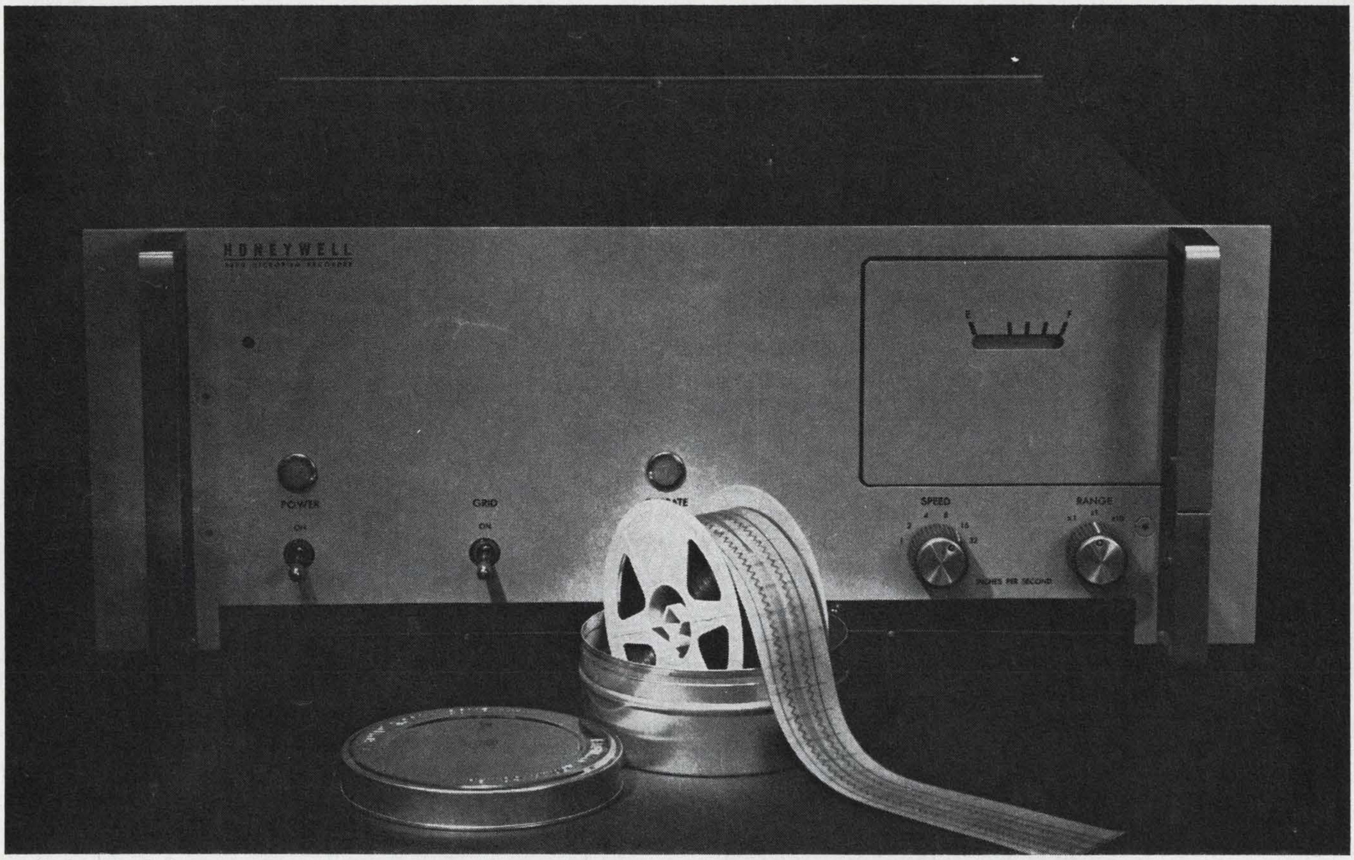
By Irvin Budych
Borg Instruments, Delavan, Wisc.

Ripple in the output of a rectifier that uses a capacitive input filter can be removed by a simple and inexpensive transistor amplifier. By taking a portion of the input ripple voltage, and amplifying it with a transistor, an inverted collector signal is obtained. Adding this signal to the ripple voltage neutralizes the input and the amplifier reduces any variations in the output to zero. It is as effective in choking ripple as a large inductor and yet does not lower the high output voltage of the capacitive filter.

The small signal needed for neutralization is taken off the line through C_1 and fed into a high impedance circuit comprised of R_1 and R_2. After amplification by Q_1, the signal—inverted now by the transistor—is coupled through C_2 onto the reference voltage at the base of Q_2. Riding there, it reduces all the ripple in the regulator to zero.



Forward neutralization. A portion of the ripple voltage is amplified and routed into the series regulator. There it nullifies the ripple voltage. With the values shown for capacitors C_1 and C_2, the circuit is able to start immediately without any warmup period.



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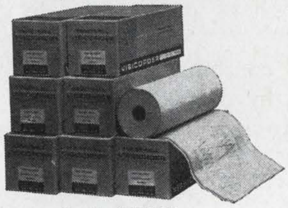

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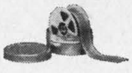

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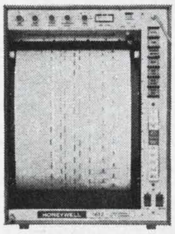

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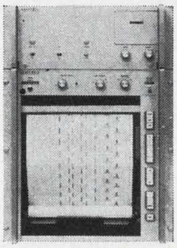

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Narrowing the margin of error

Common-mode deviations that alter the outputs of data amplifiers can be minimized by combining inverting and noninverting op amps

By Robert I. Demrow
Analog Devices Inc., Cambridge, Mass.

Engineers designing with differential operational amplifiers must continually reckon with common-mode error—a part of the difference in the voltage at the two input terminals that introduces discrepancies into the output. If they don't make allowances for the problem or act to minimize it, all calculations and measurements will be faulty.

An ideal differential amplifier with two input voltages, e_A and e_B, should respond only to the difference between them, e_n. Thus,

$$-e_n = (e_A - e_B) = \frac{e_o}{A}$$

where A is the amplifier's open-loop voltage gain, and e_o is the output voltage. If $e_A = 10$ volts and $e_B = 10.002$ volts, for example, the effective input is 2 millivolts and the ideal differential amplifier responds only to that signal.

In practice, however, the differential signals are distorted by common-mode error, resulting from a voltage common to both input terminals, a factor usually attributed to imperfections in the input circuit's symmetry. Unequal gains behind the amplifier's inverting and noninverting terminals are one cause, for instance.

A more realistic expression of a differential amplifier's response, therefore, must take into account the degree to which the common-mode voltage is rejected—a factor represented by CMRR, or common-mode rejection ratio. This practical expression takes the form

$$e_n = e_B - e_A = -\frac{e}{A} + \frac{e_{CM}}{CMRR}$$

where $e_{CM} = (e_A + e_B)/2$.

Common-mode rejection CMR is expressed in a logarithmic form:

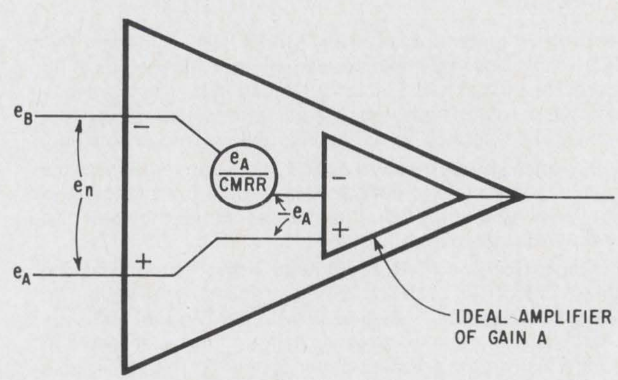
$$CMR = 20 \log_{10} |CMRR|$$

The accuracy of differential amplifiers can thus be limited by both A and CMRR. And in any amplifier, common-mode error can vary with frequency or voltage level. A circuit's over-all CMRR depends upon the inequality of the amplifier's internal gain, common-mode input resistance, and any deviations from the values calculated for the external resistors.

Joining forces

The error can be minimized by combining inverting and noninverting op-amp circuits to form a differential amplifier. The inverting type develops a negligible error because the common-mode signal here is in the microvolt-to-millivolt region. However, this circuit provides low input impedance, particularly when wide bandwidths are required, and a noninverting op amp is therefore needed for most applications. This is where common-mode error becomes important.

The differential amplifier combining inverting and noninverting circuits can be used to eliminate ground-loop potentials and can act as a bridge amplifier measuring strain, force, pressure, temperature, and other physical variables. A further description of inverting, noninverting, and differential



Common-mode error. Voltage e_n represents the difference between input voltages e_A and e_B. The common-mode error, shown as a source in series with e_B, is proportional to e_n.

circuits appear in "Amplifying remarks," p. 110.

Although the transistors used in an operational amplifier are elaborately matched and are gain-stabilized by internal feedback, there may nevertheless be a gain difference between inverting and noninverting channels of one part in 10,000, or 0.01%; this holds even for quite expensive units. Run-of-the-mill field effect transistor op amps have gain mismatches of 0.1% caused by circuit imbalance resulting from the high output conductance of FETS.

But consider an economy amplifier with a nominal open-loop gain of 10,000 and a gain error between its inverting and noninverting signal channels of one part in 10,000. The noninverting gain might then be 10,000 and the inverting gain only 9,999. If both input terminals are connected to a 10-volt common-mode source, the noninverting terminal creates an output of $10 \times 10{,}000$ volts while the inverting produces $10 \times 9{,}999$ volts. The net effect is an output of $10(10{,}000 - 9{,}999)$, or 10 volts. Thus, the common-mode output Vo_{cm} can be represented by $V_{cm}(A_2 - A_1)$, which ideally would be zero, but for this amplifier is 10 volts.

The factor $(A_2 - A_1)$ is called the common-mode gain, G_{cm}, because the 10-volt common-mode output can be regarded as having been produced by multiplying the common-mode input voltage, 10 volts, by this gain: $Vo_{cm} = V_{cm} \times G_{cm}$.

Sum of the parts

Complete circuits may also exhibit a common-mode gain. Even a circuit with an ideal op amp having identical inverting and noninverting gains can develop a common-mode error when common-mode voltage is applied in unequal proportions to its inverting and noninverting terminals.

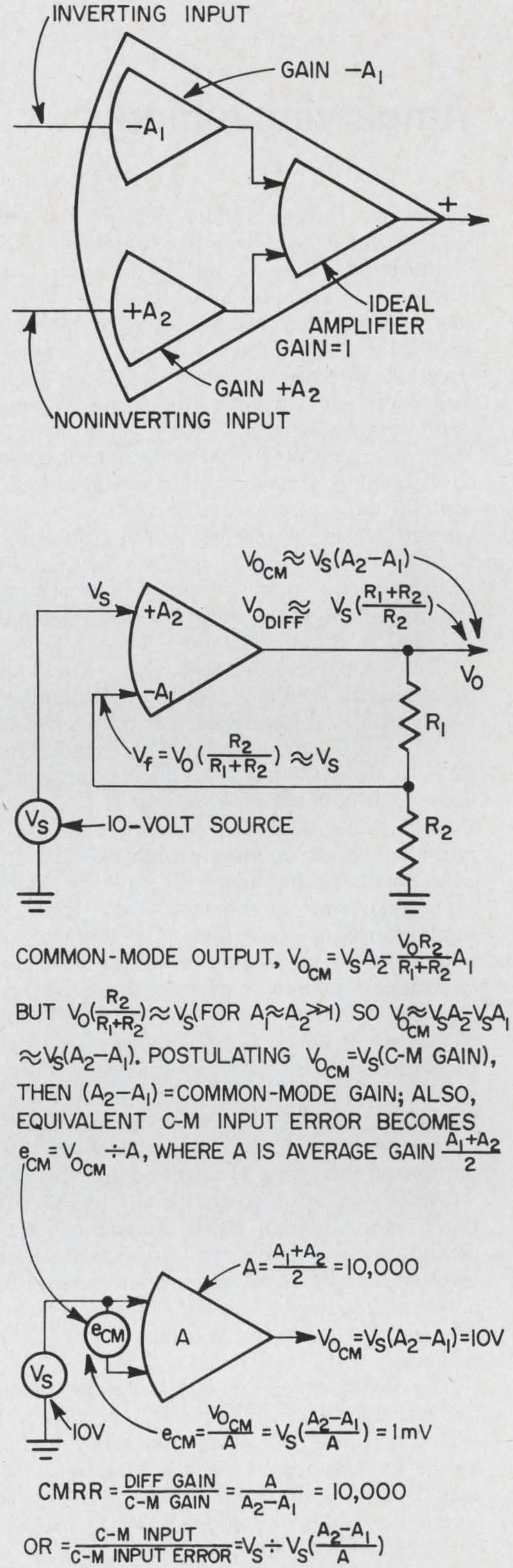
The differential configuration relies on the voltage divider effects $R_2/(R_1 + R_2)$ and $R_4/(R_3 + R_4)$ to apply equal fractions of the common-mode voltage to the inverting and noninverting terminals. If these fractions are identical, no differential component of common-mode voltage is created and the amplifier develops no common-mode output. This, of course, assumes a perfect amplifier in which $A_1 = A_2$.

But if off-the-shelf resistors with 0.1% tolerance are used for R_1, R_2, R_3, and R_4, a resistance error for the worst case may make $R_4/(R_3 + R_4)$ larger than its theoretical value, and $R_2/(R_1 + R_2)$ smaller than this same value. There will be a net fraction of common-mode voltage e_{cm} applied differentially between the amplifier's input terminals, and this will be amplified by a noninverting gain factor of $(R_1 + R_2)/R_1$ to create a common-mode output error proportional to the resistance tolerances.

The worst-case distribution of resistance errors occurs when the four feedback resistors assume new values of $R_1(1 - K)$, $R_2(1 + K)$, $NR_1(1 + K)$, and $NR_2(1 - K)$, where K is the resistor tolerance, and N is the multiplier.

Common-mode rejection ratio is defined as the ratio of closed-loop, or normal-mode, gain, $G_{cl} =$

Continued on p. 112



Defining error. Inequality of inverting and noninverting gains is the basis for common-mode error (top). A common-mode output proportional to gain inequality (center) is represented by a differential component of common-mode input, e_{cm}, applied between amplifier's input terminals (bottom). Value of hypothetical error source, e_{cm}, is common-mode voltage divided by CMRR.

Amplifying remarks

There are three amplifier designs the engineer must understand if he is to build functional circuits.

Inverting. This is the best known and probably the most versatile op amp. Its closed-loop gain, V_o/V_s, has a value very nearly equal to the negative value of the ratio of feedback to input resistor, R_f/R_i. If the op amp's internal, or open-loop, gain is high, say 10,000 volts/volt and upwards, the error voltage, V_e, at the summing junction, S, is very small—less than 1 millivolt for a gain of 10,000 volts output. In effect, therefore, point S remains within a whisker of ground potential—really at a virtual ground—so that input signal current I_{sig} is very nearly V_s/R_i. More accurately, I_{sig} is $(V_s - V_e)/R_i$, and V_e is just a few microvolts.

Because the summing junction is assumed to be at ground potential, the inverting circuit's input impedance is equal to input resistance, R_i.

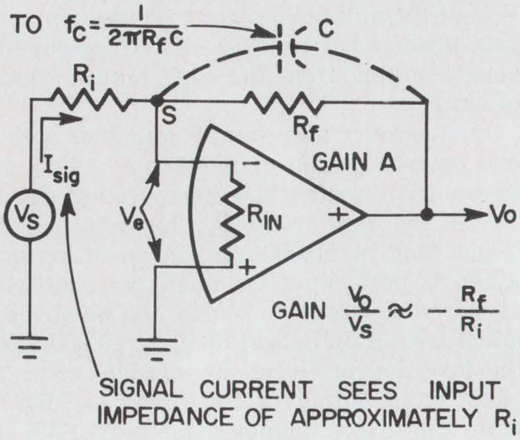
Stray capacitance—rarely less than 1 picofarad—in parallel with feedback resistance R_f, limits the circuit's bandwidth to a frequency that makes the leakage reactance $\frac{1}{2}\pi f_c C$ equal to R_f. This bandwidth, restricted to $f_c = \frac{1}{2}\pi R_f C$, not only affects frequency but influences gain and input impedance.

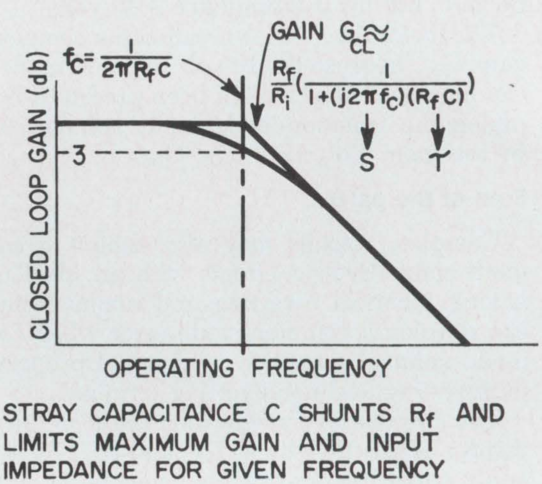
High input impedance requires a large R_i. If the amplifier has to operate at high closed-loop gain, however, feedback resistance R_f must be higher than the input resistance in the ratio, $R_f = \text{gain} \times R_i$. If the input impedance has to be 1 megohm to avoid source-loading effects, for instance, and a 60-decibel (1,000:1) closed-loop gain is required, the feedback resistance becomes $1{,}000 \times 1$ megohm $= 1{,}000$ megohms. The frequency at which the reactance of a 1-pf leakage capacitance equals 1,000 megohms is only about 160 hertz, which makes a pretty spectacular bandwidth limitation. Actually, 1,000-megohm high-stability resistors don't exist, so a circuit such as the one at the bottom of this page is required for this level of gain.

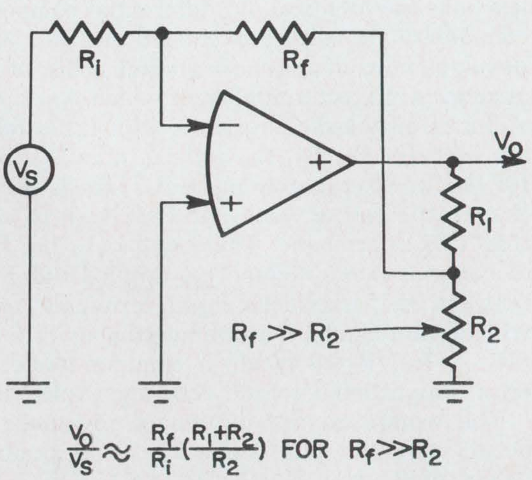
The inverting circuit is usually unsuited for applications involving high input impedance; a noninverting configuration is much more appropriate here. By using low-value resistors in its gain determining network, the noninverting design circumvents the bandwidth problem besides achieving a substantially high input impedance.

The inverting circuit holds certain advantages over the noninverting arrangement, of course. It operates with one input terminal grounded, and provides a means for obtaining long-term stability with a chopper amplifier. Also, the inverting configuration obviates any common-mode errors and operates with inputs of several thousands of volts.

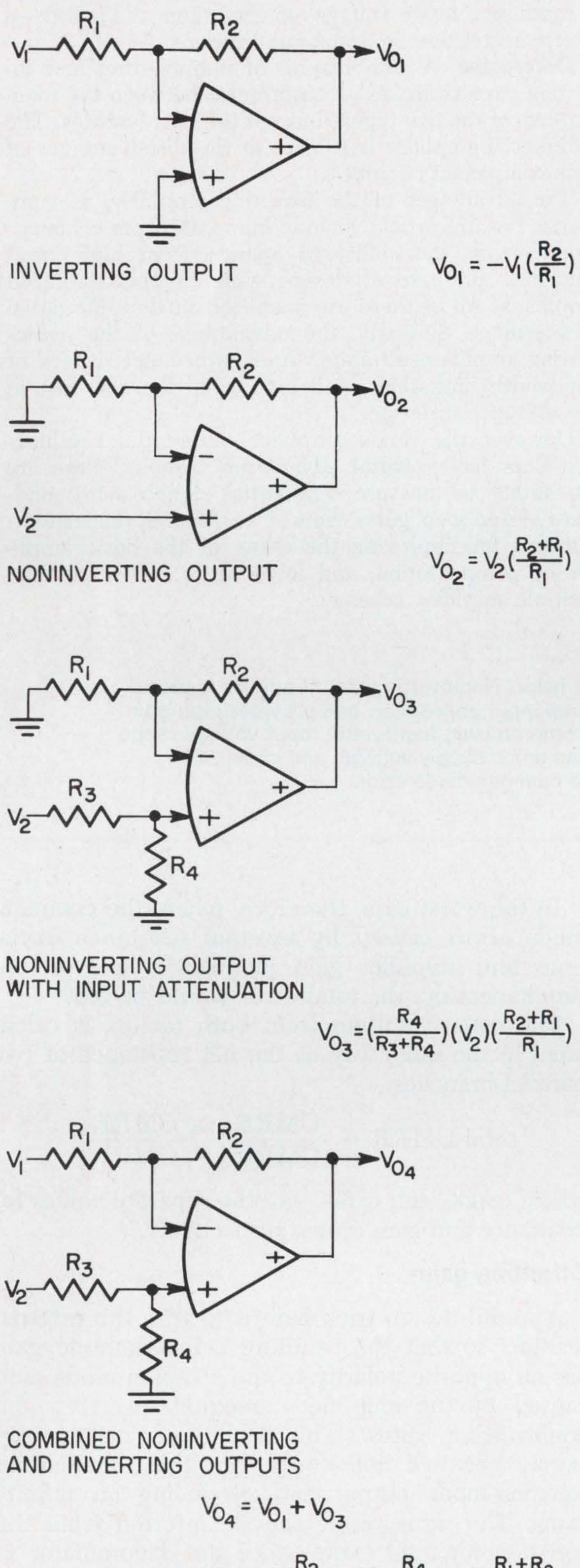
Noninverting. In the noninverting amplifier, a very high input impedance is achieved by opposing the input signal, V_s, with a feedback voltage, V_f, of almost equal magnitude. The amplifier's net differential drive signal, represented as an error voltage, V_e, is then equal to the difference between input and feedback voltages, and may be a matter of millivolts or even microvolts in high-gain amplifiers. With only millivolts across the amplifier's differential input resistance, R_{IN}, the signal current drawn from the source is proportionately low,







Bandwidth limiter. Bandwidth, gain, and input impedance of inverting circuit (top) are limited by the stray capacitance shunting the feedback resistor. Gain in the closed-loop curve (center) rolls off at 6 db/octave when operating frequency makes reactance of C smaller than R_f.



Merger. One-amplifier differential circuit combines inverting and noninverting operation. Arrangement is economical but tends to exhibit the worst features of the two circuits upon which it is based. Also, it's difficult to vary gain without introducing common-mode errors.

and this gives the effect of an artificially boosted input impedance. So far as the signal source is concerned, the amplifier draws an input current of only $(V_s - V_f)/R_{IN}$, rather than V_s/R_{IN}, and input resistance is raised from R_{IN} to approximately $AR_{IN} \times R_2/(R_1 + R_2)$, where A is the open-loop gain. More accurately, input impedance becomes R_{IN} $(1 + A\beta)$ in parallel with R_{cm}, where β is the feedback fraction $R_2/(R_1 + R_2)$ and R_{cm} is the common-mode input resistance, or the resistance from input terminal to ground.

When a typical operational amplifier with a 10^6 open-loop gain and a 1-megohm input resistance is connected in a noninverting circuit with a closed-loop gain, $(1/\beta)$, of 50, the bootstrapped input resistance R_i is 1 megohm $\times$ $(1 + 10^6/50) = 20{,}000$ megohms. The artificially increased input resistance is frequently far higher than the amplifier's common-mode input resistance, R_{cm}, or resistance from input to ground.

Consequently, it's the common-mode input resistance rather than the bootstrapped differential input resistance that sets the ultimate limit on source-loading effects. Nevertheless, an operational amplifier with a 1-megohm differential input resistance often has a common-mode input resistance of 1,000 megohms, so that this configuration does make a high-input-resistance amplifier.

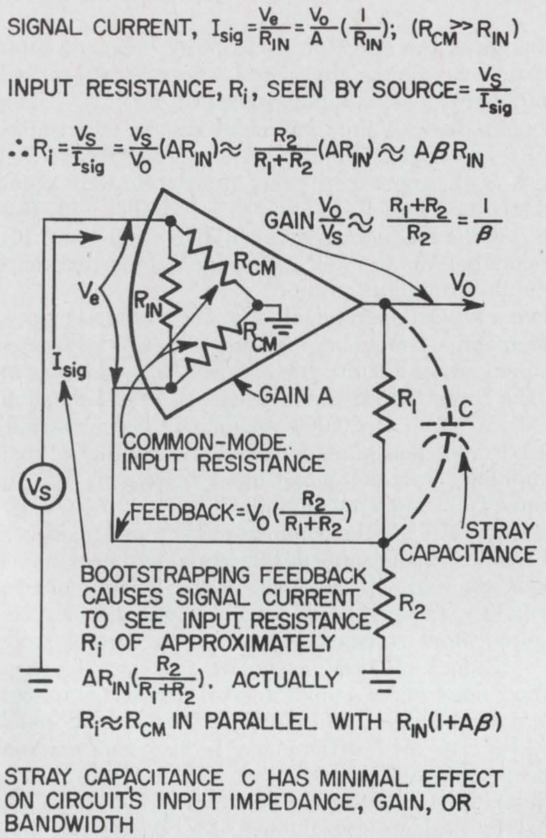
Internal amplifier bandwidth limitations are much more likely to set performance levels than external stray capacitances.

Although the gain-setting resistors, R_1 and R_2, are shunted by leakage capacitance, the bandwidth limitation for the noninverting circuit isn't as stringent as the one for the inverting. The noninverting amplifier's input resistance is independent of feedback resistance values, but does depend upon their ratio. Actual input resistance is $R_i = R_{IN}$ $(1 + A\beta)$ paralleled by the common-mode input resistance, R_{cm}. Closed-loop gain, $1/\beta = (R_1 + R_2)/R_2$, can therefore be made arbitrarily high without designing in high resistance values.

For example, a noninverting amplifier can produce a closed-loop gain of 1,000 if R_1 equals 999 ohms and R_2 equals 1 ohm. If the amplifier's open-loop gain, A, is 10^6, input resistance is raised by a factor of $(1 + 10^6/10^3)$, or 1,000; the effect of the 1-pf stray capacitance shunting the 999-ohm R_1 is negligible.

In practice, the R_1 and R_2 values are determined by the amplifier's ability to supply them with sufficient current without depriving the external circuit of its load current. A typical amplifier's output rating is ± 10 volts, 5 milliamperes, and if 4 ma is reserved for the load circuit, the minimum value for $(R_1 + R_2)$ is 10 volts/1ma = 10,000 ohms. Therefore, the values of R_1 and R_2 become 9,990 ohms and 10 ohms, respectively. Even so, the 1-pf leakage doesn't begin to roll off the closed-loop gain much below $f_o = \frac{1}{2}\pi\, 10^4 \times 10^{-12} = 15$ Mhz.

The input voltage capability of the noninverting amplifier is certainly no greater, and usually less, than the voltage of the supply lines. Thus a noninverting ampli-



Feedback helps. Noninverting circuit applies feedback to bootstrap input impedance, and provides high gain without compromising bandwidth. Input voltage range is less than unit's supply voltage, and circuit is subject to common-mode error.

fier operating from a ±15-volt d-c supply is limited to a maximum input voltage of less than ±15 volts—a severe restriction in some applications.

Differential. A combination of noninverting and inverting circuits strikes a compromise between the main features of the two types—but not the best features. The differential amplifier is subject to the disadvantages of both component circuits.

The advantages of the inverting amplifier, as summarized in this article, include immunity from common-mode errors, the ability to operate from high input voltages, and ease of design with chopper-stabilized amplifiers. All of these are sacrificed in the differential arrangement. Similarly, the advantages of the noninverting amplifier—ultrahigh input impedance, a lack of bandwidth limitations, and high gain—are also lost in the differential design.

However the single amplifier differential combination does have several advantages. Among these are the ability to measure differential signals with moderate closed-loop gains from 1 to several thousands—a means for improving the CMRR of the basic amplifier by compensation, and lower drift and noise than multiple-amplifier schemes.

R_2/R_1, to the common-mode gain, $G_{cm} = 4\ KR_2/(R_1 + R_2)$. Thus the CMRR for a single-amplifier circuit is $(1 + R_2/R_1)/4K$. However, the circuit's differential gain, R_2/R_1 appears explicitly in this CMRR expression, which may now be rewritten as $(1 + G_{c1})/4K$. The circuit's CMRR thus improves with closed-loop gain but declines with K, the resistor tolerance error.

For example

With a circuit using 0.1% resistors and operating at a closed-loop gain of 100, the CMRR becomes $(1 + 100)/4 \times 0.001$, or approximately 25,000:1.

If the same circuit were to measure a 100-mv signal superimposed on a 10-volt common-mode level, the common-mode error would be 10/25,000/100 mv, or 0.4 mv. The error would thus be 0.4% of the 100-mv signal. But this analysis reflects only the common-mode error stemming from imperfect resistors. The amplifier's internal gain inequality is another source of common-mode error, and it must be considered by the designer.

The amplifier's internal gain, $(A_2 - A_1)$, and $\text{CMRR}_A = A/(A_2 - A_1)$, apply equally to both the amplifier and the differential circuit in which it's connected. Accordingly, if the specification sheet shows the amplifier's CMRR to be 25,000, the additional common-mode error in measuring 100 millivolts superimposed on the 10-volt common-mode level is 10/25,000/100 mv, or another 0.4%.

In the worst case, therefore, where the common-mode errors caused by external resistance deviations and amplifier gain inequalities are present simultaneously, the total error would be 0.8%.

The CMRR resulting from both factors is calculated in the same way as the net resistance of two parallel branches:

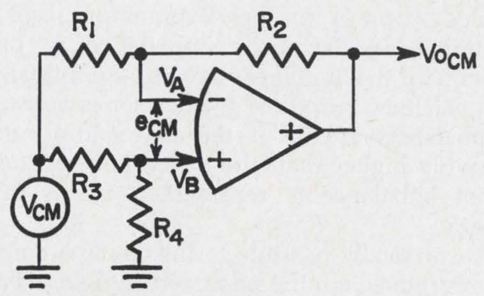
$$\text{total CMRR} = \frac{\text{CMRR}_R \times \text{CMRR}_A}{\text{CMRR}_R \pm \text{CMRR}_A}$$

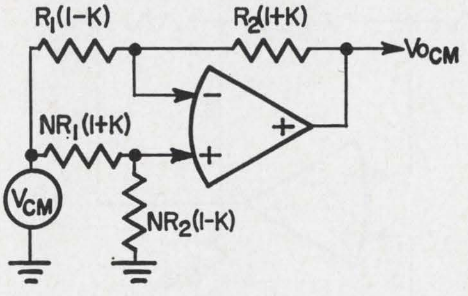
where CMRR_R and CMRR_A are the separate values for resistance and gain errors, respectively.

Offsetting gains

A useful design trick here is to trim the external resistors so that the resulting common-mode gain has an opposite polarity to the common-mode gain caused by the amplifier's unequal inverting and noninverting gains. This technique makes, say CMRR_R negative and CMRR_A positive, eliminating common-mode output and producing an infinite CMRR. The same result can be inferred from the equation for total CMRR, since the denominator in this expression, $\text{CMRR}_R \pm \text{CMRR}_A$, would be reduced to zero.

In a bipolar-transistor amplifier, as opposed to a FET-input unit, this method can boost the over-all CMRR by a factor ranging from 10 to perhaps 100. There are hazards, however. If the external resistors drift away from their tweaked-up values, for in-





COMMON-MODE GAIN IS

$$G_{CM} = V_{O_{CM}}/V_{CM} = \left(\frac{R_2}{R_1+R_2} - \frac{R_4}{R_3+R_4}\right)\left(\frac{R_1+R_2}{R_1}\right)$$

COMMON-MODE GAIN IS

$$\text{CMRR} \approx \frac{1+R_2/R_1}{4K} \approx \frac{1+G_{CL}}{4K}$$

Resistance variation. Unequal common-mode voltages, V_{cm}, are applied to inverting and noninverting terminals when external resistors deviate from assigned values (left). Worst-case common-mode error is proportional to four times the resistor tolerance fraction K; CMRR improves with closed-loop gain (right).

stance—either through temperature instability or aging—the amplifier's common-mode compensation will also drift. The compensating method depends upon the constancy of the amplifier's internal CMRR, but this parameter varies in response to several factors. For example, CMRR_A decreases in a p-channel FET when the device's applied common-mode voltage increases. It also varies with output loading; the higher the load the lower the gain. Finally, it reflects the long-term aging of internal resistors and semiconductors.

The designer must therefore familiarize himself with the amplifier's common-mode characteristics, and should make sure that his external resistors have long-term and temperature-induced drift characteristics appropriate to his accuracy needs.

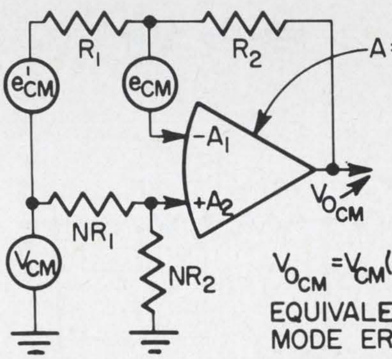
In practice, it's possible to tweak up a differential amplifier to a near-perfect circuit CMRR level by making one or another of the resistors slightly variable, or by adding a small amount of trimming resistance in series or parallel. However, it's extremely difficult to build a variable-gain differential amplifier capable of a high CMRR. It's just about impossible to replace R_2 and R_4 with a ganged pair of variable resistors and secure the same CMRR because of the difficulty of maintaining good tracking between these feedback resistors. Careful common-mode trimming would come untweaked.

Another source of common-mode error is the unbalancing effect of the amplifier's own common-mode input resistance, R_{cm}, the resistance seen between input terminal and ground. Because the common-mode resistances between ground and the inverting and noninverting terminals are, in effect, placed in parallel with feedback resistors R_2 and R_4, they modify the common-mode voltage applied to the two input terminals. These resistances are theoretically equal, but in practice are never identical.

Errors due to common-mode resistance are minimized by selecting small values for R_2 and R_4 compared with the nominal R_{cm} level, or by using an amplifier with very high common-mode input resistance, such as the FET or varactor bridge. Even recently developed high-performance differential-transistor amplifiers feature 10^9 ohms common-mode impedance. Errors due to 1,000-megohm R_{cm} values shunting 100-kilohm feedback resistances (R_2 and R_4) amount to only about a 0.01% net resistance deviation. Further, because both R_2 and R_4 are simultaneously shunted by just about equal common-mode values, the net unbalancing effect is unimportant.

Unbalanced source resistance

Besides internal gain inequality, feedback-resistor tolerances, and the shunting effect of the amplifier's common-mode input resistance, unbalanced source resistance in series with the amplifier's input terminals can cause common-mode error in a differential circuit. For instance, if the signal trans-



$$A = \frac{A_1+A_2}{2}$$

COMMON-MODE OUTPUT, $V_{O_{CM}}$ DUE TO UNEQUAL GAINS:

$$V_{O_{CM}} = V_{CM}\left(\frac{R_2}{R_2+R_1}\right)(A_2-A_1)$$

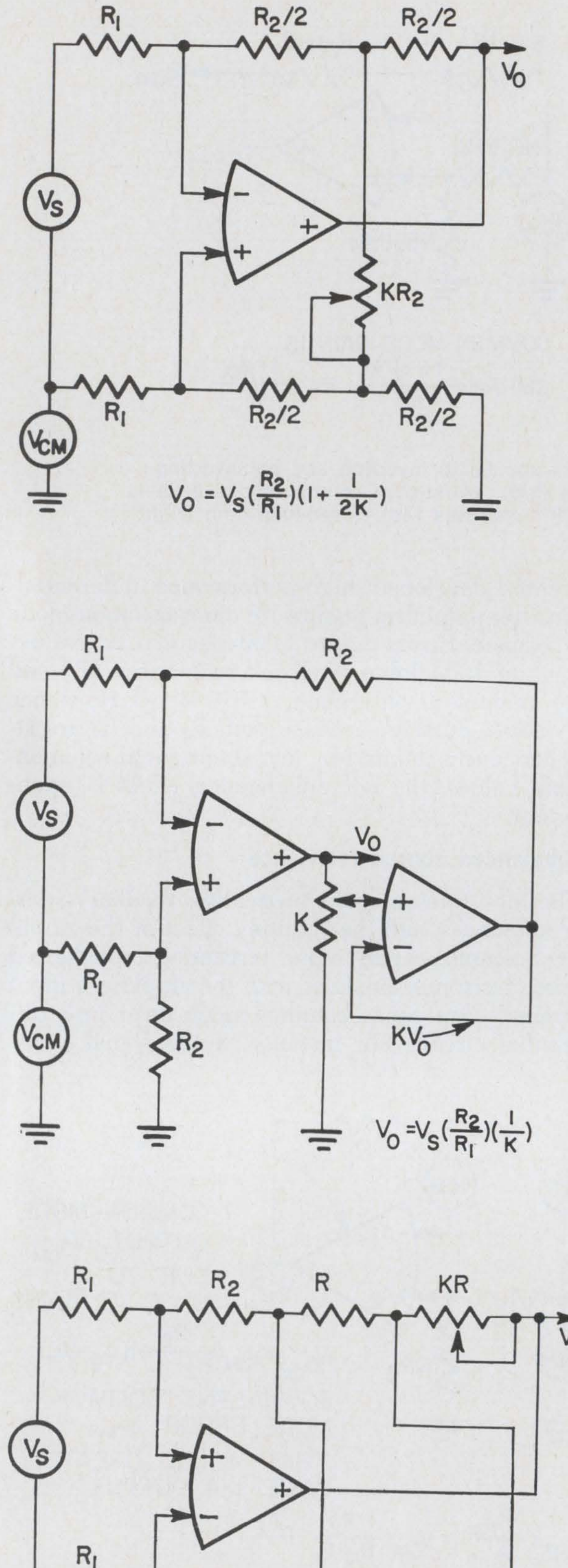
EQUIVALENT COMMON-MODE ERROR, e_{CM}, THAT WOULD CREATE SAME C-M OUTPUT IS:

$$e_{CM} = \frac{V_{O_{CM}}}{A} = V_{CM}\left(\frac{R_2}{R_2+R_1}\right)\left(\frac{A_2-A_1}{A}\right)$$

$$\text{CMRR} = \frac{\text{COMMON MODE VOLTAGE INPUT } (V_{CM})}{\text{COMMON MODE INPUT ERROR } (e'_{CM})}$$

$$\text{CMRR} = V_{CM} \div V_{CM}\left(\frac{A_2-A_1}{A}\right) = \frac{A}{A_2-A_1}$$

Matching errors. Amplifier's internal common-mode error due to gain inequality reflects a CMRR to the circuit's input that is equal to that amplifier's own CMRR: $A/(A_2-A_1)$.



ducer is operated with one of its output terminals grounded, point A in the diagram on page 115, its internal resistance or impedance is placed in series with the amplifier's inverting terminal. The two signal lines introduce further series resistance, but imbalance remains if the source resistance is appreciably higher than the signal-line resistances. The net imbalance is represented as R_u in the schematic.

It's theoretically possible to introduce a compensating resistance into the noninverting line to cancel the effect of R_u, but this can be a difficult job in practice. What happens when the amplifier is switched sequentially to read the output from an array of different transducers, each with different amounts of imbalance? Or what happens when signals are developed by an inductive-type transducer, such as a tape-recorder head, whose internal impedance varies with ground-loop and common-mode frequency? In both these instances, and in many others, common-mode errors cannot be completely compensated.

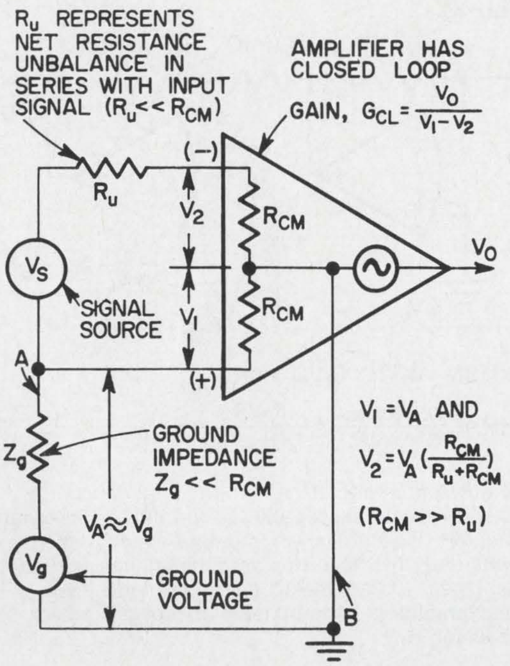
Actually, the degree of common-mode error doesn't depend upon the absolute value of resistance imbalance, but is proportional to the ratio of source resistance imbalance R_u to amplifier input resistance R_{cm}, R_u/R_{cm}. The higher the amplifier's common-mode input resistance, R_{cm}, the smaller the common-mode error. The best tack to take, therefore, in the absence of external common-mode compensation techniques, is to make the amplifier's common-mode input resistance as high as possible.

Amplifiers are typically rated—regarding common-mode characteristics—on the basis of their source resistance imbalance; this R_u value is often 1,000 ohms. To provide 10^6 CMRR with such a value requires a minimum common-mode input resistance of $R_{cm} = \text{CMRR} \times R_u = 10^9$ ohms. If the amplifier is to be used to measure 10-mv signals against a 5-volt common-mode background, the equivalent common-mode input error, e_{cm}, becomes $5/10^6$, or $5\mu v$. The percentage error, $100\% \times e_{cm}/V_s$, works out to a value of $100\% \times 5 \times 10^{-6}/10^{-2} = 0.05\%$.

Attenuating effect

The amplifier's finite differential input resistance is usually smaller than its common-mode input resistance, and this creates an attenuating effect when the device is used to measure signals from sources with appreciable internal resistances or impedances. This attenuating effect, in turn, causes a measuring

Adjusting gain. Although a single resistor is all that's needed to adjust gain of circuit at top without altering common-mode balance, six high-stability resistors are needed in the feedback circuit. Gain varies nonlinearly with K. Center circuit uses only four feedback resistors, but requires an auxiliary amplifier for unloading resistor K. Gain here also varies nonlinearly with K. Circuit at bottom provides linear gain variation with aid of auxiliary amplifier, and uses five feedback resistors.



$$\text{CMRR} = \frac{\text{DIFF GAIN}}{\text{C-M GAIN}} \approx \frac{G_{CL}}{(G_{CL})(R_u/R_{CM})}$$

Single-end source. Differential method can reject common-mode errors when working with single-ended sources, although resistance imbalance impairs the rejection process. Over-all CMRR is boosted by selecting a very high common-mode input resistance compared with the resistance imbalance.

discrepancy called source-loading error, an error equal to R_s/R_{IN} where these symbols represent source resistance and the differential input resistance of the amplifier.

With a 1,000-ohm total source resistance and a typical amplifier, the differential input resistance R_{IN} must be higher than 10^6 ohms if the loading error is to be held below 0.1%. Percentage loading error equals $100\% \times R_s/R_{IN}$.

Not only then must the amplifier's common-mode input resistance be very high to reduce common-mode errors caused by source imbalance but the differential input resistance must be very high to hold down source-loading errors.

Other error sources

Drift is a major factor in measurement accuracy. If an amplifier with a $2\ \mu v/°C$ maximum drift operates over the temperature range of 25°C to 35°C, the equivalent input error is $10 \times 2 = 20\ \mu v$, which creates—for 10-mv signals—a further $100\% \times 20 \times 10^{-6}/10^{-2} = 0.2\%$ measuring error.

Current drift, or pump-out current, must also be considered when the source impedance is appreciable. If the total source impedance is 10,000 ohms, for instance, the input error caused by a 300 picoamperes/°C current drift for a ±10°C range is $10{,}000 \times 300 \times 10^{-12} \times 10 = 30\ \mu v$, or a $100\% \times 30 \times 10^{-6}/10^{-2} = 0.3\%$ measuring error.

A source impedance of 10^4 ohms could create serious loading errors, and, if single-ended, substantial common-mode errors, too.

Differential configurations with two separate op amps can generally handle the problem of common-mode error better than any single-amplifier circuits. A differential design based on two noninverting amplifiers benefits from this type of circuit's high input impedance and relative immunity to capacitance strays. Likewise, a differential circuit based on two inverting amplifiers can remain immune to internal common-mode error with high input voltages.

Common-mode error due to external resistance deviations recreases in the noninverting circuit with closed-loop gain; in the inverting configuration, CMRR is constant. But gain equalities within the two amplifiers in the noninverting design cause error. In the design based on two noninverting amplifiers, closed-loop gain can be varied in proportion to the output amplifier's feedback resistor.

Key spec

The specification that really inhibits the use of conventional op amps in differential data-measuring circuits is common-mode rejection. Unfortunately, there are few useful operational amplifiers with a CMRR beyond 500,000:1; those op amps emphasizing CMRR tend to suffer from high cost or some other parameter deficiencies.

However, for more practical applications where the signal source is a low-impedance thermocouple or strain-gage bridge, no currently available operational-amplifier model fits the CMRR requirements set forth and at the same time features high stability, open-loop gain, input impedance, and fast response at moderate cost.

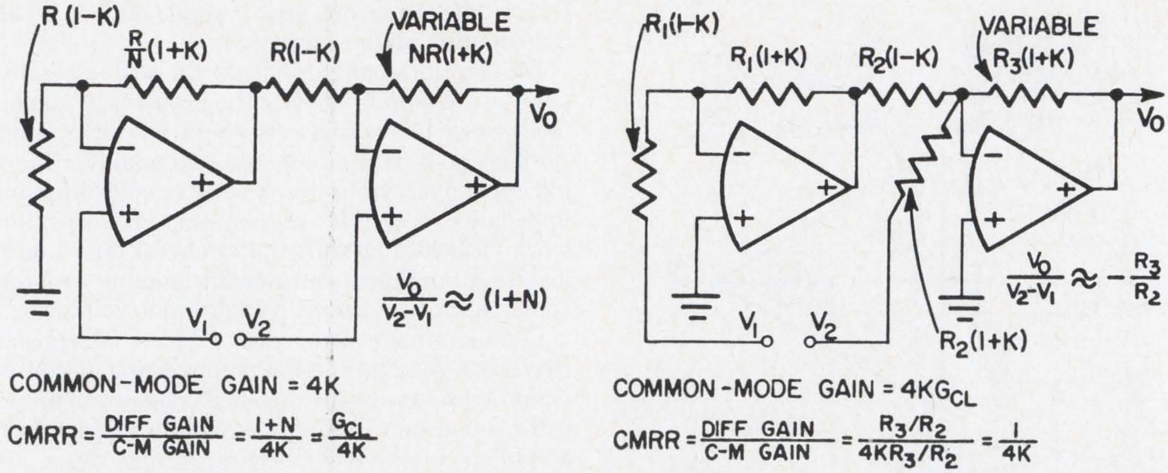
There's therefore a need for a data amplifier designed from the ground up. This device would achieve adequate performance at reasonable cost and the op amps used as building blocks cannot meet cost and performance specs if such features are required as 10^6 CMRR, 2,000 maximum gain, 10^9 and 10^7 common-mode and differential-input impedance, and $2\ \mu v/°C$ drift.

A differential amplifier that's immune to common-mode errors caused by resistance deviations appears at the bottom of page 116. However, this design is still subject to gain inequality between the two amplifiers.

The error analysis reveals that the circuit has unity common-mode gain when the two amplifiers are considered separately. And because both amplifiers have this same unity common-mode gain, the common-mode output measured between the output terminals is theoretically zero. This means that the common-mode differential gain is also zero, and the circuit's common-mode rejection ratio is theoretically infinite.

Galvanometers, relays, coils, and other isolated loads can be driven directly from the push-pull output with near-perfect immunity to resistor-induced common-mode errors. But an added stage of differential amplification is needed for single-ended loads.

For an error-cancelling circuit followed by a



Pairing amplifiers. Coupling two noninverting amplifiers gives differential circuit high input impedance and a CMRR that improves with closed-loop gain. However, the circuit is susceptible to amplifier's internal common-mode errors, has limited input voltage range, and requires isolated power supplies when based on chopper-stabilized amplifiers (left). Alternative circuit (right) uses two inverting amplifiers, has constant CMRR for external resistance deviations, handles high input voltages, is immune to common-mode error of individual amplifiers, and can be based on chopper-stabilized amplifiers without needing special power supplies. However, input resistance is limited to the value used for R_1.

differential-to-single-ended-interface amplifier the over-all gain of the two cascaded stages is given by

$$\text{Gain (A)} \times \text{Gain (B)}$$

and the total CMRR is Gain (A) 1 + Gain (B)/4K.

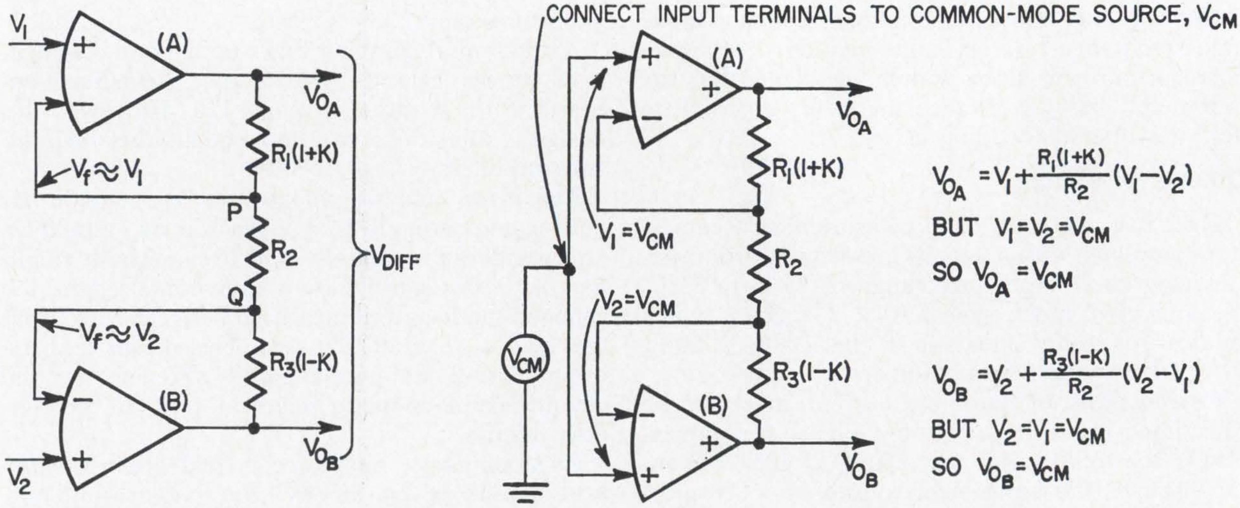
The circuit's common-mode performance can be maximized by assigning most of the gain to the first stage; in fact, fractional gain for the second stage appears to improve CMRR considerably.

This advantage can't be pushed too far without running into another source of difficulty. Designing the first stage for high gain will either restrict the level of common-mode voltage or cramp the circuit's dynamic signal swing.

Because the individual amplifiers used in the first stage operate with unity common-mode gain, their output signals vary around the common-mode level, V_{cm}, of the input. If, for example, V_{cm} is 9.5 volts, and the amplifiers are built for a ±10-volt output rating, the maximum output signal swing can't be greater than 10 − 9.5 or 0.5 volts.

A circuit with 100:1 first-stage gain couldn't handle input signals larger than 0.5/100, or 5 mv, without driving the output into the stops. Large input signals could only be handled either by using lower values of first-stage gain or by reducing the common-mode level upon which these signals are superimposed.

The future trend for improved CMRR in amplifier circuits will come from improved technology in



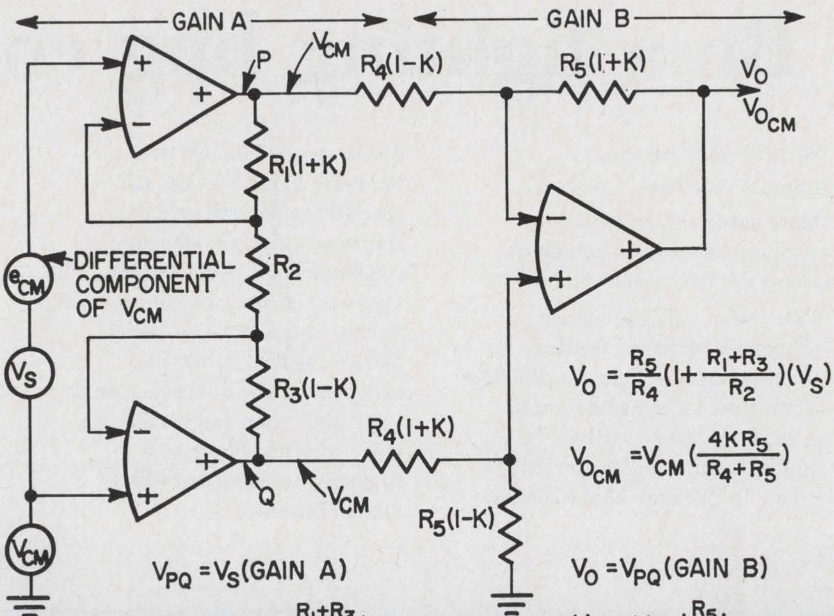
Differential immunity. Differential circuit is immune to common-mode errors caused by resistance deviations, but remains susceptible to the amplifier's internal common-mode errors. It can drive galvanometers, relays, magnetic coils, and other isolated loads without requiring conversion to single-ended output.

resistor and transistor manufacture, and innovation in circuit design.

In the area of thin- and thick-film resistors long-term stabilities of better than 5 ppm per year and very close ratio temperature tracking, less than 1 ppm/°C, will improve circuit CMRR.

Monolithic manufacturing techniques with both bipolar and field effect pairs should improve the voltage feedback ratio balance on bipolar transistors and result in both higher ratios of small forward transconductance to output conductance of an FET and closer matching with a resultant higher CMRR capability for the amplifier.

Another article in a subsequent issue will describe the problems of ground loops, and the use of operational amplifiers to solve them.



$$V_O = \frac{R_5}{R_4}\left(1+\frac{R_1+R_3}{R_2}\right)(V_S)$$

$$V_{O_{CM}} = V_{CM}\left(\frac{4KR_5}{R_4+R_5}\right)$$

$$V_{PQ} = V_S(\text{GAIN A}) \qquad V_O = V_{PQ}(\text{GAIN B})$$

$$V_{PQ} \approx V_S\left(1+\frac{R_1+R_3}{R_2}\right) \qquad V_O \approx V_{PQ}\left(\frac{R_5}{R_4}\right)$$

SECOND STAGE CONVERTS V_{CM} AT P AND Q INTO COMMON-MODE OUTPUT $V_{O_{CM}} = V_{CM}\left(\frac{4KR_5}{R_4+R_5}\right)$

DIFFERENTIAL COMPONENT OF V_{CM} AT INPUT, e_{CM}, IS C-M OUTPUT DIVIDED BY OVER-ALL DIFFERENTIAL GAIN; $e_{CM} = V_{O_{CM}} \div \left[(\text{GAIN A})(\text{GAIN B})\right]$

$$e_{CM} = V_{CM}\left(\frac{4KR_5}{R_4+R_5}\right) \Big/ \underbrace{\left(1+\frac{R_1+R_3}{R_2}\right)}_{\text{GAIN A}}\underbrace{\left(\frac{R_5}{R_4}\right)}_{\text{GAIN B}} = V_{CM}\left(\frac{4KR_5}{R_4+R_5}\right)\left(\frac{R_4}{R_5}\right)\left(\frac{1}{\text{GAIN A}}\right)$$

$$\text{OVER-ALL CMRR} = \frac{V_{CM}}{e_{CM}}$$

$$\text{CMRR} = V_{CM} \div \left(\frac{V_{CM}\left(\frac{4KR_4}{R_4+R_5}\right)}{\text{GAIN A}}\right)$$

$$\text{CMRR} = \frac{\text{GAIN A}}{4K}\left(1+\frac{R_5}{R_4}\right)$$

$$\text{CMRR} = \frac{\text{GAIN A}}{4K}(1+\text{GAIN B})$$

(GAIN A)(GAIN B)=100		CMRR
GAIN A	GAIN B	$\frac{\text{GAIN A}}{4K}(1+\text{GAIN B})$
0.1	1000.0	100.1/4K
1.0	100.0	101/4K
10.0	10.0	110/4K
100.0	1.0	200/4K
1000.0	0.1	1100/4K

Converting an output. Right-hand differential stage develops single-ended output from push-pull input. Arrangement provides high input impedance and permits the use of low-value, high-tolerance resistors for wide bandwidth and maximum CMRR. Chart lists advantages of having first stage contribute most of the gain. But the superimposition of output signals at P and Q onto the common-mode voltage, V_{cm}, cramps dynamic range or signal gain or both. If the common-mode voltage approaches maximum amplifier output voltage, the circuit develops only small signal excursions at P and Q; large excursions would drive the first-stage amplifiers into saturation.

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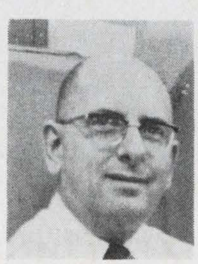
The author



Robert I. Demrow, a staff engineer at Analog Devices, has the job of finding new applications for operational amplifiers, evaluating the devices' performance, and checking out problems. He received his MSEE from Northeastern University in 1958, and has worked for GE, the Foxboro Co., and Honeywell.

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Saving money on data transmission as signals take turns on party line

Proposed system uses a single two-wire cable to connect all stations of a control or monitoring installation, and gives each transmitter and receiver its own listed number in binary code

By James W. Cofer Jr.

Georgia Institute of Technology, Atlanta

Even before the copper strike, when wire cost less, the long runs of data-transmission cabling in a control system made up a big part of the system's cost. To make matters worse, installation costs far more than the cable itself. For example, the over-all cost ranges from 50 cents to $1.50 a running foot for three-conductor, 14-gauge, armored cable—depending on terrain and other conditions—even though the cable itself costs only about 5 cents a foot. Thus, a major goal in digital monitoring and control systems has been a simple data-transmission method that's stingy with wire.

This goal seems feasible with a new system that can be made from readily available, low-cost, digital components such as flip-flops and logic gates. The method, which looks especially good for smaller installations, does away with the need for individual lines to each station. Only one two-wire cable—one wire for data bits and the other for timing pulses—is necessary.

Called a circulating pair, the two wires (three if an earth ground isn't satisfactory) are run close to each transmitter and receiver. Short runs of other wire pairs connect these stations to the circulating pair.

The author

James W. Cofer Jr. received a bachelor's degree in electrical engineering from the Georgia Institute of Technology in 1967. He is an assistant research engineer in the electronics division of Tech's experiment station and continues his studies part-time.

Any transmitter and any receiver can be hooked to the line anywhere along its length, giving extreme flexibility for system installation. Alternatively, all transmitters may be relatively close at one end of the circulating pair and all receivers clustered at the other, or transmitters may be connected along the line and the receivers grouped at one end. Or receivers may be divided into groups, each group installed on a console for surveillance by plant operators. Each station has its own binary address and handles only those messages intended for it, no matter where it is.

Call information

The system can be used for both analog and digital transmission, but only an arrangement with all-digital inputs will be described. A key part of any configuration is the scanner that generates address codes to connect transmitters and receivers.

The address scanner clears previously sent codes from the system, addresses corresponding pairs of transmitters and receivers in sequence, then idles long enough for the messages to be sent and received. The scanner does this until all pairs have communicated, then repeats the cycle.

To clear the data line, the scanner sends a series of binary ones—1111. The address code, though, is a series of binary 1's and 0's, each series corresponding to an address built into the transmitter-receiver pairs. For a system with 15 such pairs and one clear word, the 16 code combinations can be obtained with four binary bits. That is, $2^4 = 16$. In the message itself, every fourth bit must be a 0 to prevent the appearance of the all-1's sequence that would clear the system.

The scanner produces a string of binary pulses whose length is the sum of the clear, address, and message words. The system in this example, with 15 pairs, one clear word, and a six-bit message, requires a 16-pulse sequence as represented by

1111 AAAA XXX0 XXX0

where the 1's are the clear word, the A's the address word, which can assume all binary combinations (0000 to 1110) except 1111, and the X's the message, which can assume all binary values, with, as noted, 0's always in every fourth position.

Ringing up

The pulses come from a ring counter driven by a fixed-frequency digital clock, as shown in the schematic for the address scanner [see p. 121]. The ring counter is an eight-stage shift register whose outputs are fed back into the opposite inputs. Each stage of the shift register is a standard J-K flip-flop with capacitively coupled inputs for set and reset.

Each time a pulse from the digital clock enters the ring counter, one of the eight flip-flops changes to its other state, emitting a pulse and thereby advancing the ring counter. Thus, the ring counter has 16 states, and for every pulse from the digital clock, a different one of the ring counter's 16 outputs will emit a pulse in the time sequence 1,2,3,4 . . . 15,16,1,2. . . . These pulses drive not only the next ring-counter stage but also other electronics in the system.

Pulse-positions 1 through 8 place the clear word and the address code—that is, 1111AAAA—on the data line. A single flip-flop clear-word generator, connected through an OR gate to the data line, is cut on by pulse 1 from the ring counter and shut off by pulse 5. It allows four 1's to be produced in all transmitters and receivers to clear out previous address codes.

The address generator—a four-bit counter—advances one bit every time it receives an input pulse from one output of the ring counter. (The selection of output 3 to do this is arbitrary.) With this input the address generator develops a unique code combination for each successive group of 16 pulses from the digital clock. Thus, in sequence, it develops 15 unique codes—0000 to 1110. The 1111 combination—clear-word code—is kept from developing by a d-c signal that resets the counter to 0000. When the four 1's are present they instantly operate through the AND gate to provide the reset signal.

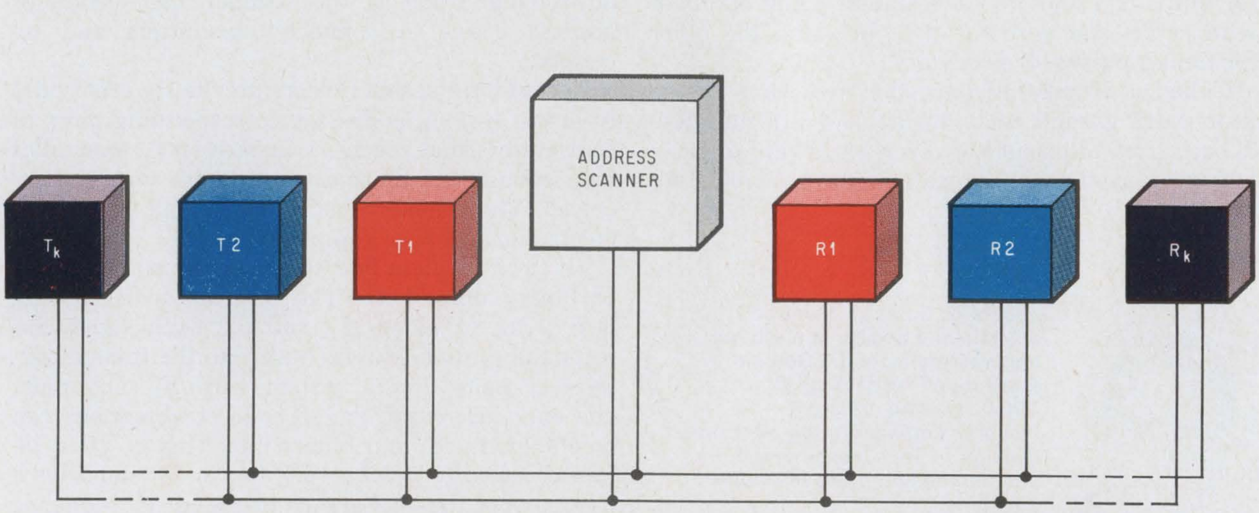
Ring-counter output 5, the one that has shut off the clear-word generator, causes the code stored in the address generator to be read out in parallel into the shift register. Pulse 5 also moves one of the bits just entered in the shift register onto the data line, and pulses 6, 7, and 8—via a three-input monostable multivibrator—send the other three address code bits onto the line in sequence. Finally, pulse 9 removes any binary-1 voltage placed on the data line by the scanner. Having addressed a transmitter-receiver pair, the scanner now remains off the line for the next eight pulses, which are the message.

Getting ready

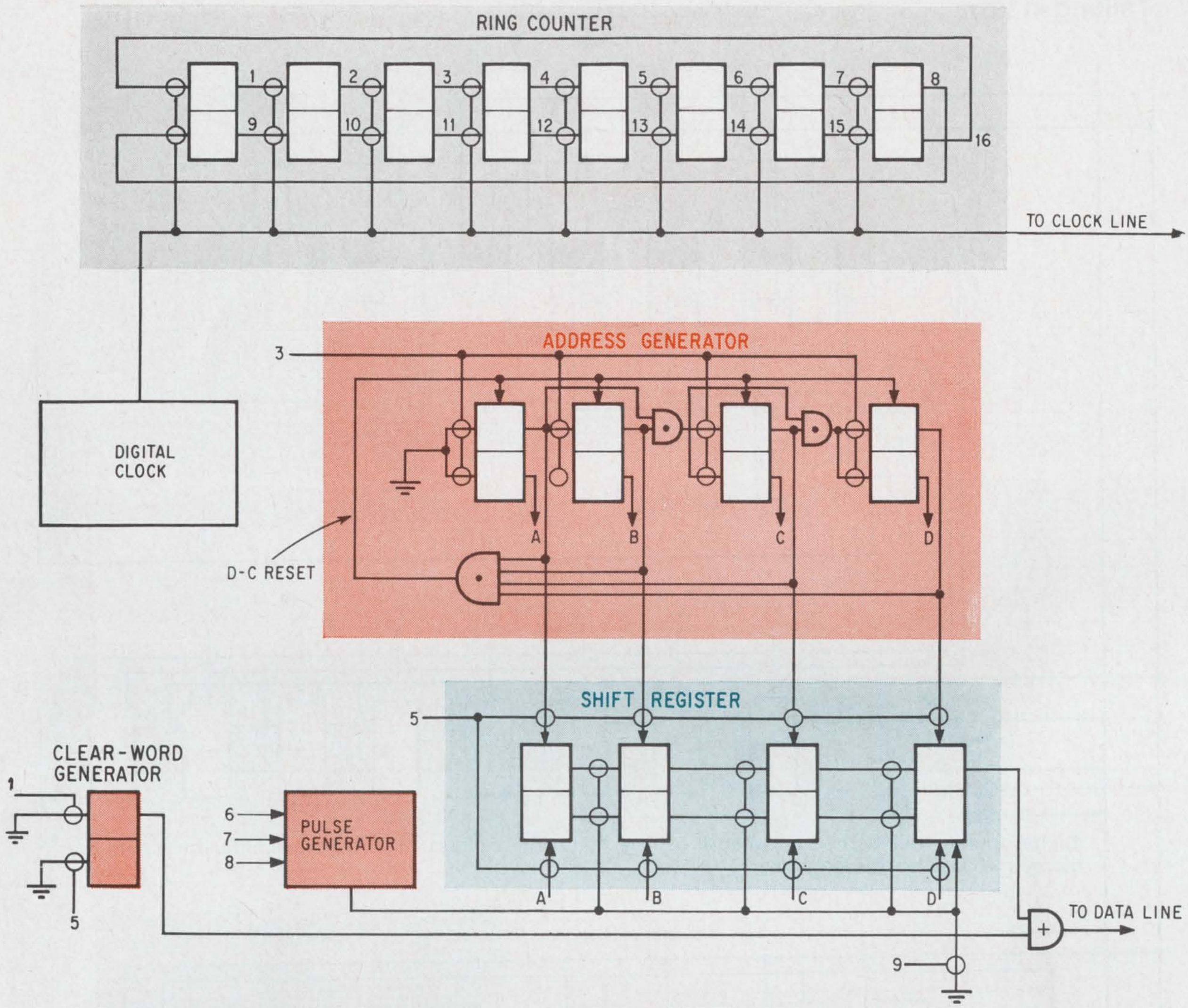
The transmitter for handling a six-bit message word is also made of flip-flops, capacitively coupled inputs for set and reset, and logic gates [see p. 122]. The address detector—four flip-flops—on the transmitter senses the clear word and then the address code.

The address for the transmitter is coded by the way the four dashed-line inputs of the lower AND gate are connected to the four flip-flops. For example, to build in an address of 1100, the two inputs of the AND gate are connected to the true (binary 1) outputs of the first two flip-flops, and the other two inputs of the gate are wired to the complementary (binary 0) outputs of the third and fourth flip-flops. This code is built in when the transmitter is wired, and can be changed only by rearranging the connections.

The transmitter must first clear its address detector of previous codes so it can receive its own



Circulating pair. Two wires connect all transmitters and receivers but only one transmitter and receiver talk at a time.



Address scanner. The scanner generates a clear-word code, then an address code to connect corresponding pairs of transmitters and receivers.

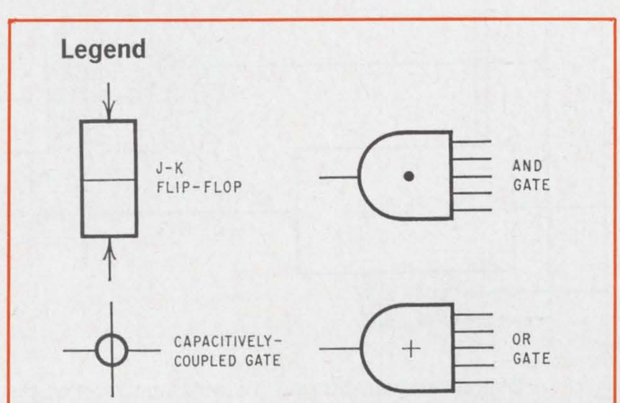
code. This is done by the address detector and the upper AND gate to the left of the detector. This AND gate is permanently connected to the four true outputs of the flip-flops. When the first bit of the clear word arrives at the address detector, it sets the flip-flop on the far right to 1. This 1 shifts left and sets the adjacent flip-flop to 1 when the next 1 in the clear word arrives at the right flip-flop. The sequence continues until all four flip-flops contain a 1. That is, the address register has now sensed the arrival of the clear word. The AND gate then emits a d-c signal to reset the address detector.

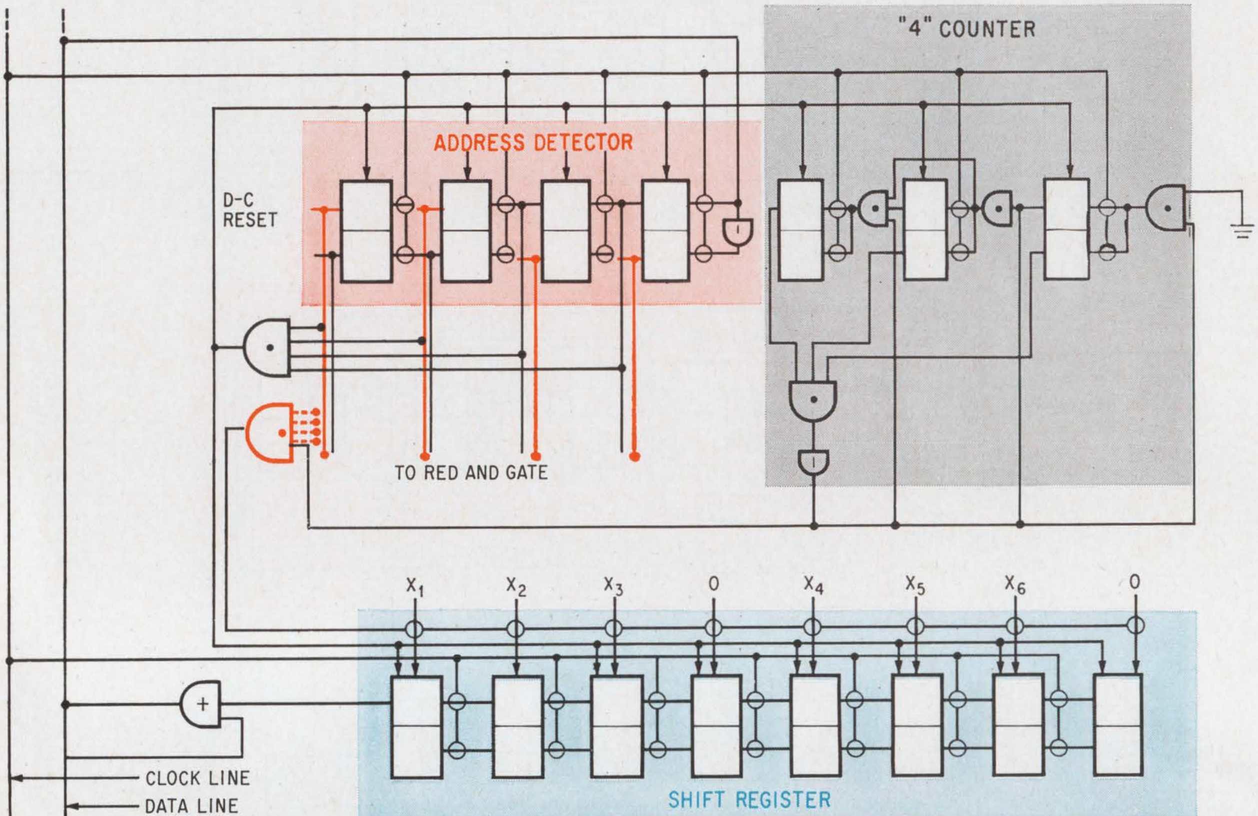
Moving the bits

The detector is now ready for its second job—responding to its address. If the code sent down the data line is 1100, then, in this example, the lower AND gate produces a pulse that loads eight bits—the six of the message and the two extra 0's—into the lower shift register.

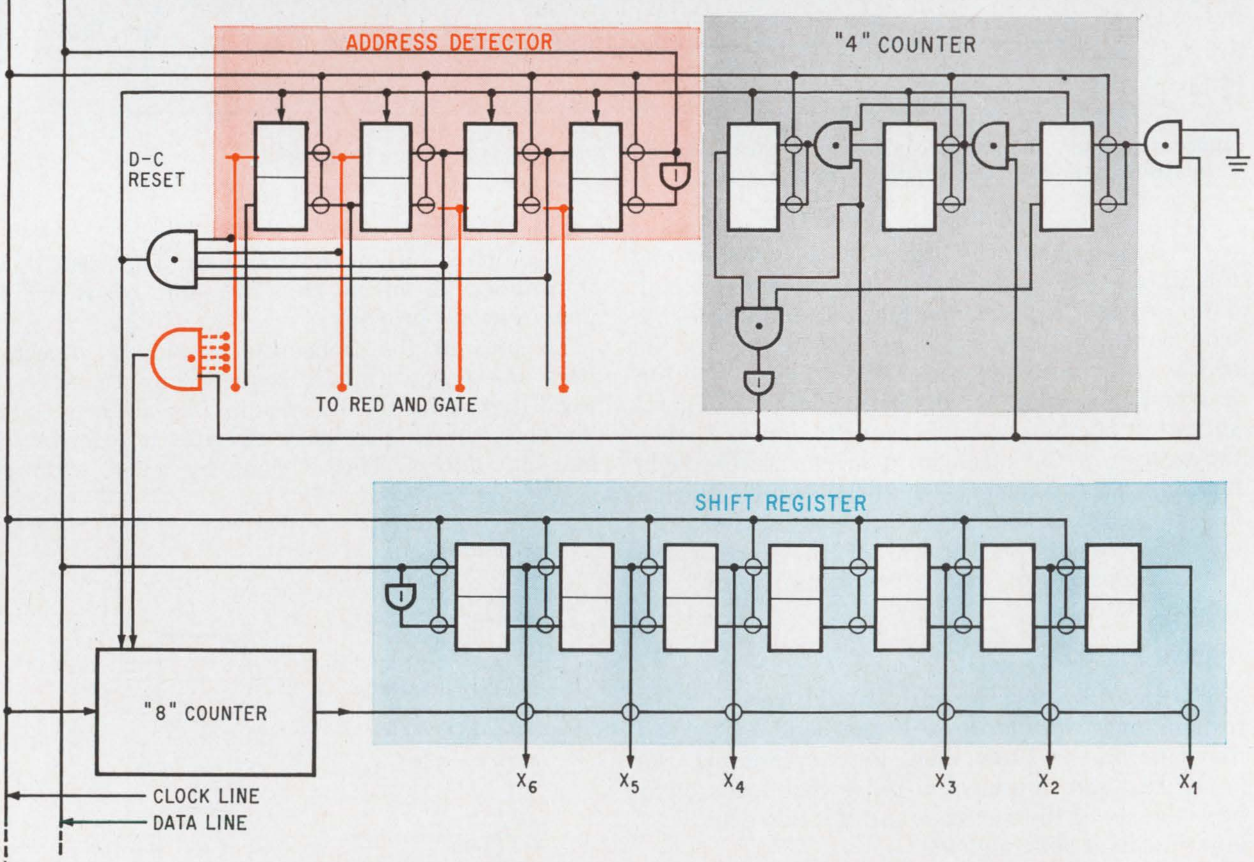
The next eight clock pulses move these eight bits onto the data line to be detected by the correspondingly addressed receiver. The last 0 is transmitted to ensure that the shift register flip-flops respond properly.

To prevent the transmitter's address detector from answering a binary sequence in the message word that could be the same as the address code, the detector must be shut off after it receives its four-bit address. This is done by a "4" counter,





Digital transmitter. Turned on when it senses its unique address code, the transmitter then puts the binary message on the data line.



Digital receiver. Storing the message serially, the receiver's shift register reads out in parallel when it senses the last pulse.

the three-flip-flop counter at the upper right. When the "4" counter contains the code 100, the binary equivalent of 4, it places a 0 on one input of the lower AND gate and cuts off the address detector. Simultaneously, this 0 is fed back to the AND gates associated with each stage of the "4" counter. The counter then shuts off, and can be restored to 000 only by the same d-c reset signal that detects the presence of the 1111 sequence, or clear word.

Sensing the message

The receiver, opposite page, is similar to the transmitter. In fact, the two circuits' clear-word and address detectors and three-bit "4" counters are identical.

The receiver senses and stores the message-word pulses from the data line. The eight-bit message sequence is detected serially by the seven-stage shift register, the first pulse coming in at the left and shifting to the right with each succeeding pulse. Only seven of the eight transmitted bits have to be stored in the receiver because, as noted, the last 0 in the sequence isn't part of the message.

After the seven-bit message has been sensed by the register, the "8" counter, at the lower left, emits a pulse that causes all stored bits to be read out in parallel. The "8" counter operates like the "4" counter, except that it has four flip-flops so it can produce the output pulse when the counter contains 1000, the binary equivalent of eight. All bits on the line pass through the receiver register, but parallel readout takes place only when the proper address is present.

Finding sequence length

The number of pulse positions, p, required for one sequence can be found from the formula

$$p = 2n + \left(\frac{nm}{n-1}\right)$$

where n—the length of the clear or address codes—is the number of binary bits needed to distinguish the number of circuits, k, as determined from $2^n = k + 1$, and m is the message word length before the extra 0's are inserted to prevent the appearance of the clear-word code. The factor $(n - 1)$ tells how many bits in m can be used in sequence before a 0 is inserted.

If the parenthetical expression in the formula doesn't result in an integer, then m is extended with enough 0's to make the term equal the next highest integer divisible by n. The number of flip-flops in the ring counter is half the number of pulse positions in the total sequence.

For the arrangement described previously, the number of pulse positions is

$$2 \times 4 + \left(\frac{4 \times 6}{4-1}\right) = 8 + \left(\frac{24}{3}\right) = 8 + 8 = 16$$

and the ring counter thus has eight flip-flops.

For a system that also has 15 circuits $(n = 4)$, but uses a message length, m, of eight bits, then

$$\left(\frac{nm}{n-1}\right) = \frac{4 \times 8}{3} = \frac{32}{3} = 10\frac{2}{3}$$

This won't work. The next highest integer divisible by 4, of course, is 12. Thus the sequence requires $8 + 12 = 20$ pulse positions and looks like

1111AAAAXXX0XXX0XX00

The next-to-last 0 has been added to fill out the message word. For this system, the ring counter needs $20/2 = 10$ flip-flops.

To complete a cycle of sending a message to all stations requires pk pulses, where p is determined as above and k is the number of transmitter-receiver pairs. For the arrangement in the main example, $pk = 15 \times 16 = 240$ pulses. The value pk helps establish the pulse frequency of the digital clock. If, for example, the installation requires that any change in any input appear at its corresponding receiver within five seconds, then the clock rate is

$$CR = pk/T = 240/5 = 48 \text{ pulses per second.}$$

For such a system, a 60 pps clock rate would probably be used because it is easily synchronized with power-line frequency.

A choice idea

This idea for multiplexing data from many input stations over a single two-wire line (and a ground) can be used in many ways. The binary message word needn't be for a numerical value; it could represent the states (on-off) of a group of switches that indicates the operational status of a piece of equipment. The station pairs, instead of being interrogated continuously, could get a burst of pulses only once every few minutes.

Used with a larger digital data acquisition system or with a computer control installation, the data link's receiver-readout register could be part of the computer or connected to it. These receivers would store inputs at their own rate, and the computer could interrogate them at a different rate, depending on its own needs and priorities. For example, the computer wouldn't have to wait while pulses are accumulated from a turbine flow meter.

However, the system won't be feasible for encoded digital transmission from the measurement site of such analog-process variables as temperature, pressure, and level until someone develops an analog-to-digital converter and storage register small and cheap enough to be installed at each transmitter. Several makers of controls are investigating this area, and are looking to large-scale integrated circuits as an answer. How soon these devices appear on the market depends on the economics of LSI on the one hand and user demand for digital sensors on the other.

FFT—shortcut to Fourier analysis

Mathematics, not electronics, enables engineers to develop faster ways of extracting information from complex waveforms

By Richard Klahn and Richard R. Shively
Bell Telephone Laboratories, Whippany, N.J.

Major advances made by engineers in producing faster data-processing systems usually stem from the development of electronic devices. But this is not the case with signal- and data-analysis applications involving Fourier transformation techniques. Here, the advances have been triggered not by electronics, but by mathematics.

Fourier transformation is a useful tool in extracting the information contained in many kinds of waveforms—such as seismic waves, electro-encephalograms, and data signals telemetered from deep space. Many approaches have been taken to find the energy content of these frequencies. One familiar and inexpensive method calls for a bank of filters. But this is an analog approach, which is inherently limited in resolution and flexibility. Although digital techniques are better, they are difficult to apply. The straightforward digital form of the Fourier transform, for example, has proved costly in computer time. However, this has changed.

Cooley, Tukey and the FFT

About three years ago, the International Business Machines Corp.'s James W. Cooley and Bell Telephone Laboratories' John W. Tukey developed a technique for rapidly computing the spectral components of a waveform containing many frequencies. Their mathematical innovation, which has come to be known as the fast Fourier transform (FFT) reduced the computational effort required to obtain discrete Fourier transform coefficients of digital data, and made practical the use of digital-computing systems in a number of design problems, data analysis applications, and signal processing functions. To the engineer concerned with the filtering of data, or determining the spectral distribution of power in an electrical signal, the Cooley-Tukey technique is as important as any piece of hardware.

This led to the development of FFT programs for general-purpose computer systems as more and more engineers wanted to use the Fourier transforms. But even with FFT, general-purpose computers are impractical for some applications that involve large amounts of data and require results in a reasonable amount time. For example, real-time signal processing of information demands a very fast execution rate. And this holds true for simulation studies involving random data and requiring thousands of transformations. For such applications, special-purpose processors organized to execute the algorithm would be far better than general-purpose computers running FFT programs.

From a computer designer's standpoint, FFT permits some interesting specialized designs in processors that, as a result, have much shorter execution times than are obtainable on general-purpose computers built with the same kind of components. For example, because the computation involves an arithmetic sequence that is always the same, an arithmetic section's speed can be closely matched to that of a memory, allowing an overlap of arithmetic operations and memory transfers. Moreover, both units could handle the real and imaginary portions of complex values in parallel, thereby saving processing and transfer time.

Factor of hundreds

Without the FFT algorithm, the number of arithmetic operations required to compute the discrete Fourier transform from N samples is proportional to N^2. With the FFT algorithm, however, the number of operations becomes proportional to $N \log_2 N$. Therefore the factor of improvement is

$$N^2/(N \log_2 N) = N/\log_2 N,$$

which is approximately 100 for $N = 1{,}024$ and more than 600 for $N = 8{,}192$—the capacity of the processor's memory.

The algorithm attains its speed because it shares intermediate results to the greatest possible extent. Without the FFT, each Fourier coefficient is computed itself, using all the input samples.

The Fourier series can be expressed in both continuous and discrete form. In continuous form, the Fourier series can be written as an infinite series of either real or complex terms. The sum of the infinite series is exactly equal to the original function; a finite sum is an approximation. In real form, the Fourier series is expressed as a summation of an infinite series from zero to plus infinity. A periodic waveform is described in terms of a fundamental frequency and various harmonics, or multiples of the fundamental, and can include a d-c term. Phase differences between the harmonics are accounted for by the presence of both sine and cosine terms in the series. The period of the fundamental equals the period of the waveform.

A complex form is obtained from the real form by expressing the sine and cosine terms as the sum and difference of complex exponentials:

$$\sin kx = \frac{1}{2j}\left[\exp(jkx) - \exp(-jkx)\right]$$

$$\cos kx = \frac{1}{2}\left[\exp(jkx) + \exp(-jkx)\right]$$

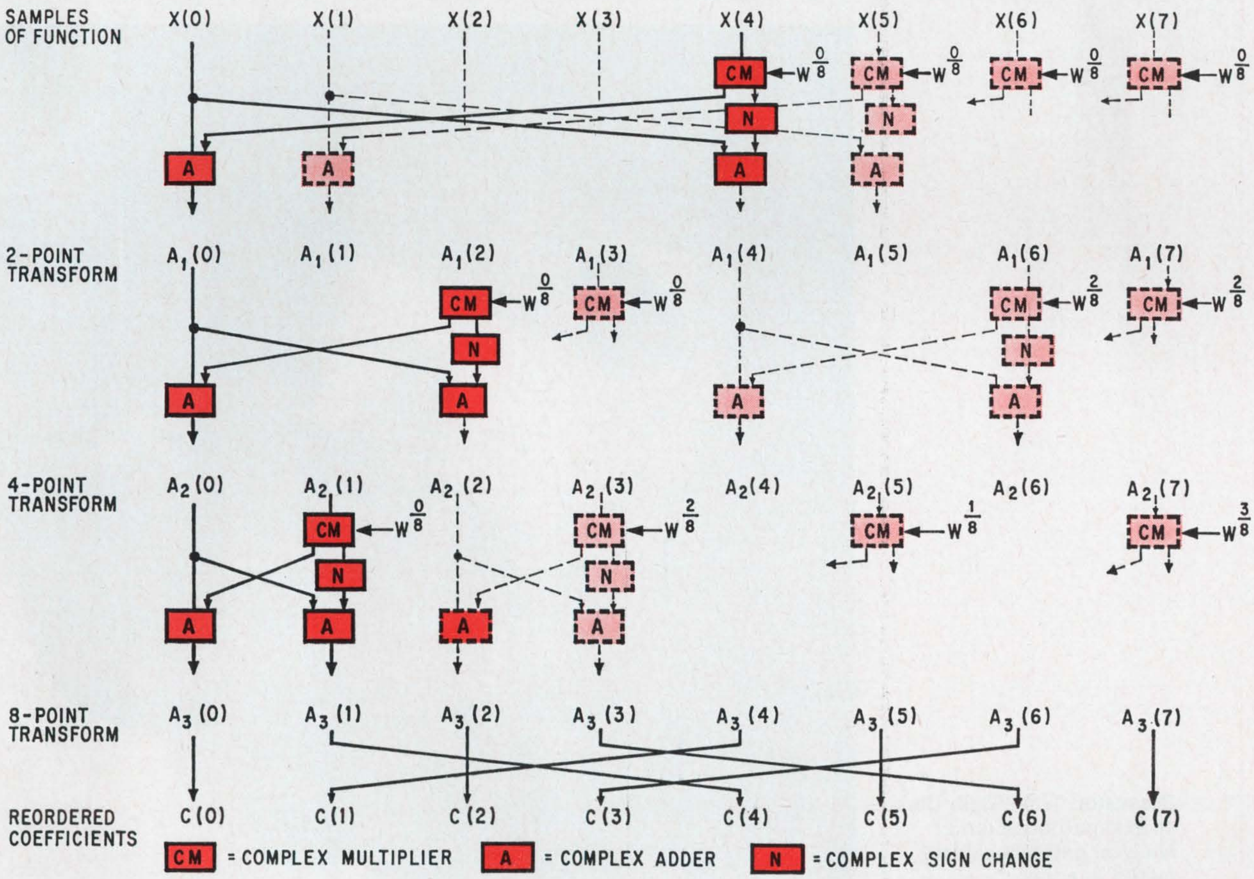
After substituting the exponentials, algebraic manipulations result in a doubly infinite summation—from minus infinity to plus infinity. Each term in the summation is the product of two numbers—an amplitude derived from the coefficients, and an exponential that expresses the phase.

Sampled signal

The digital or discrete form of the Fourier series is analogous to the complex continuous form, except that it deals with uniformly spaced samples extending over a specified interval of the waveform. The closer together the samples are taken, the more accurately the resulting series represents the original waveform. Because the method is digital, it cannot operate directly on the continuous waveform. Moreover, practical equipment precludes the extension of this method to positive or negative infinity. The sum of the finite series, considered as coefficients of successive harmonic frequencies, is an approximation to the original waveform:

$$f(t) \approx \sum_{n=0}^{N} A(n) \exp(j\omega_n t)$$

The nth Fourier coefficient, $D(n)$, with a set of N samples taken at uniform intervals throughout a segment of a waveform, is obtained by multiplying each sample by a number $\exp(-j2\pi ns)/N$, adding the products, and dividing the sum by N. The number s is the index of a particular sample during the computation of one summation for a particular co-



Transform procedure. The fast Fourier transform first combines pairs of samples into two-point transforms, then turns these into four-point transforms, and so on, until a single transform is obtained based on all the original samples.

Digging out buried signals

A small, two-year-old company in Palo Alto, Calif. —Time/Data Corp.—was the first to market a special-purpose computer designed specifically for Fourier analyses. Just a few short months ago, Time/Data delivered its first three machines to the Environmental Sciences Service Administration, the Air Force, and the University of California's Brain Research Institute.

Called the Time/Data 100, the computer's job is to find biochemical, radar, sonar, seismic, or other signals that are buried in noise—and to find them in real time. The computer does this by calculating the Fourier coefficients of the complex waveform in which the signals are buried. Other jobs the machine can perform are auto- and cross-correlation, auto- and cross-spectrum analysis convolution, and averaging functions.

Lost and found. In 1942, mathematicians G.C. Danielson and Cornelius Lanczos published an algorithm—a method of calculation—for a rapid Fourier transform. But for some unknown reason the process was somehow "lost." Only when Cooley and Tukey revealed their own fast Fourier transform in 1965 was the older algorithm rediscovered.

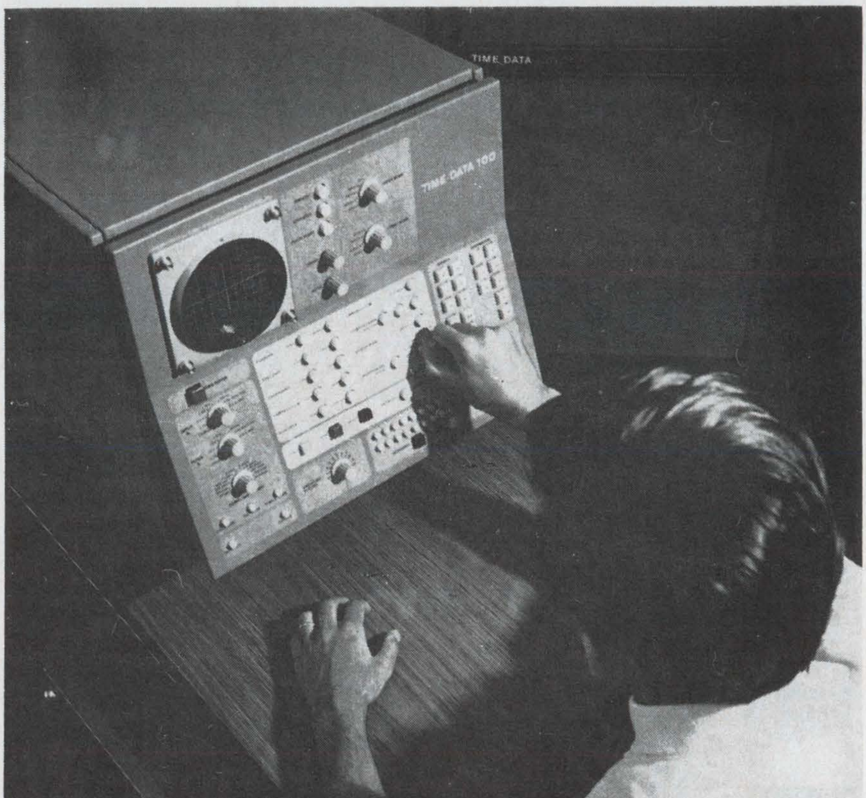
The Cooley-Tukey algorithm set off a flurry of renewed interest in computer-assisted Fourier analysis. The Bell Telephone Laboratories' signal processor, designed by authors Klahn and Shively, also incorporates the algorithm [Electronics, Sept. 4, 1967, p. 40], and is being used for research. Bell Labs doesn't intend to market the machine.

Sylvania Electric Products Inc., developed a similar machine for digitizing speech signals, and the International Business Machines Corp. is also working on one [Electronics, Oct. 30, 1967, p. 26].

Ten-year project. Time/Data's machine is the brainchild of mathematician Edwin Sloane, who got the idea while working on the distant-early-warning-line (Dewline) project at the Massachusetts Institute of Technology's Lincoln Laboratory. Sloane spent 10 years developing the algorithm, which he calls the rapid Fourier transform—so-called to distinguish it from Cooley's and Tukey's fast Fourier transform. Sloane's algorithm is based on the Danielson-Lanczos method. The rapid Fourier transform compares the input waveform with a series of sinusoidal "templates" of various frequencies previously wired into the machine.

Says Sloane: "The integral of the product of two sine waves in phase is larger than any other integral involving sine waves out of phase or of different frequencies."

The transform takes advantage of redundancies in the sine and cosine functions. Sloane and Martin Fletcher, Time/Data's vice president in charge of engineering, chose to take advantage of these redundancies to gain speed, by "pipeline" processing. This arithmetic technique uses several small fast



Excavator. Time/Data Corp.'s special-purpose Fourier analyzer extracts signals buried in noise.

adders or multipliers in series, each one working on the result of the preceding unit. Thus, as the last unit in the string starts work on its part of a problem, the first unit is several steps ahead of it.

Time/Data claims its method is simpler than the Cooley-Tukey approach, which is based on a set of nested multiplications.

Data by the block. The Time/Data machine can accept analog data at frequencies up to 20 kilohertz, which it promptly converts to eight-bit digital words, or it can accept direct digital input at up to 200,000 words per second. The data is stored in a core memory containing 4,096 18-bit words.

Time/Data's machine accepts data for one second, provided neither channel takes in more than 1,000 samples. When data comes in faster than that, only the first 1,000 samples are accepted before the input is shut off; at the 200,000 bit/sec rate, for example, the input is active for only 5 milliseconds and idle for 995 msec. But, in general, during any one-second interval, the machine accepts one block of data, processes the previous block, and clears the block before that, in analog or digital form. The Bell Labs' machine, on the other hand, can accept up to 8,192 samples in as short an interval as 8.2 msec; it could easily process 1,000 samples in 30 msec. There is a drawback, however: the shorter the sampling interval, the poorer the resolution of the output.

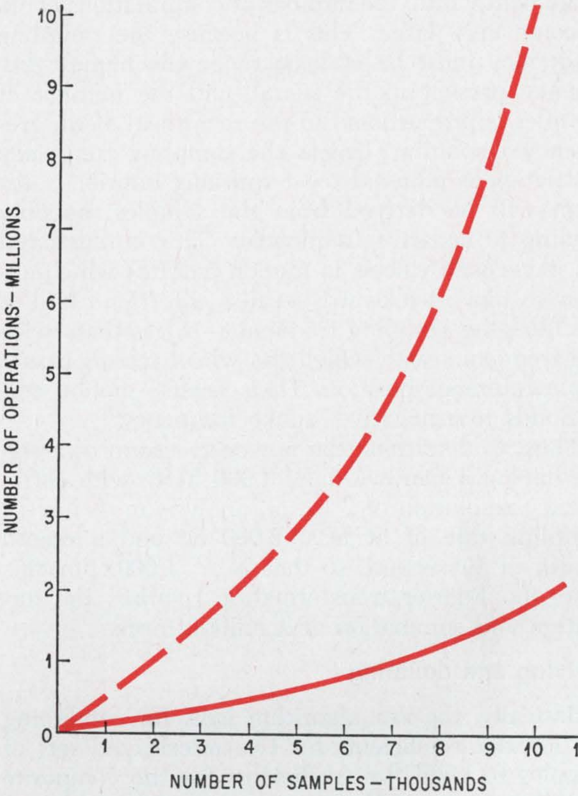
Sloane emphasizes that speed is not the only important consideration. The Bell Labs' machine must be used in conjunction with a computer that actually collects the samples, perhaps multiplexed from several sources. The computer requires a program to collect the data and transfer it to the processor, to fetch the Fourier coefficients after they have been computed, and to transfer them to the outside world. The Time/Data machine is a total system that needs no computer, although it can be linked to one if desired.

"We have a powerful analysis tool for signal processing," says Sloane, "which can be used directly for a wide variety of applications—biomedical instrumentation, for example, or structural analysis, antisubmarine warfare, acoustics, radio physics, meteorology, and even astronomy."

A few extras. Outlook for the IBM development is that it will follow the general approach of the Bell Labs design, with perhaps a few added features for speed. For example, the Bell Labs multiplier design, with a substantial addition of hardware, could multiply two complex numbers almost instantaneously. IBM's Federal Systems division is working on a design in connection with a military application; a commercial version may come later.

Sylvania's machine, like Bell Labs, is for research, but the company may decide to market it later. It was originally designed as a simulator to study radar signal processing and communication problems, and is now being used to simulate modems (modulators-demodulators) in military systems. In some respects it resembles the Bell Labs machine, in the techniques it used to achieve high speed. But like Time/Data's new computer, Sylvania's machine can stand alone.

—Wallace B. Riley
Computers Editor



Startling improvement. Solid line shows number of operations required when computing with FFT, as compared with conventional form (dashed line).

efficient; s therefore takes on all values in the range 0 to N − 1 for each value of n, which also eventually covers the same range.

The coefficient of the first term is simply the average value of all the samples—their sum divided by N. Rather than omit the exponential multiplier, it is set to +1 by making n = 0. This is why n and s range from 0 to N − 1 instead of from 1 to N. Equally important, this setting simplifies hardware implementation.

The process can be described as:

$$A(n) = \frac{1}{N} \sum_{s=0}^{N-1} f(s) \exp(-j2\pi ns)/N$$

Considering the workload

The computational effort depends on both the number of samples of the original function and the frequency spectrum that must be represented. Without the fast Fourier transform, these Fourier coefficients would have to be calculated for each frequency separately. Each coefficient would require the summation of N real and N imaginary quantities, each of which is the product of a sample value and a trigonometric weight. In the case of a real function, only N/2 coefficients have to be calculated —those more than half the sampling frequency are complex conjugates of those below. Thus, a total of $2N \cdot N/2 = N^2$ products would be required to compute the coefficients.

If a fine spectral resolution is required over a large bandwidth, the number of computations could become very large. This is because the sampling frequency must be at least twice the highest frequency present in the signal, and the number of samples is proportional to the reciprocal of the frequency resolution. Unless the sampling frequency restriction is adhered to, a spurious Fourier transform will be derived from the samples, possibly leading to negative frequencies. This is illustrated by stagecoach wheels in motion pictures which appear to move backward because the frame rate of the film—the sampling frequency—is less than twice the frequency with which the wheel spokes pass a given reference position. Their reverse motion corresponds to a negative "spoke frequency."

Thus, to determine the power spectrum of a signal having a bandwidth of 1,000 hertz with a frequency resolution of 2 hz, an analysis must have a sampling rate of at least 2,000 hz and a record length of ½ second, so that $N = 1{,}000$. For this case, the Fourier transformation requires the formation and summation of a million terms.

Halving and doubling

Basically, the FFT algorithm calls for combining the Fourier coefficients for two interleaved sets of samples to yield the coefficients for the composite set. Thus, the coefficients for the even-numbered samples and those for the odd-numbered samples can produce a single set of coefficients for all the samples.

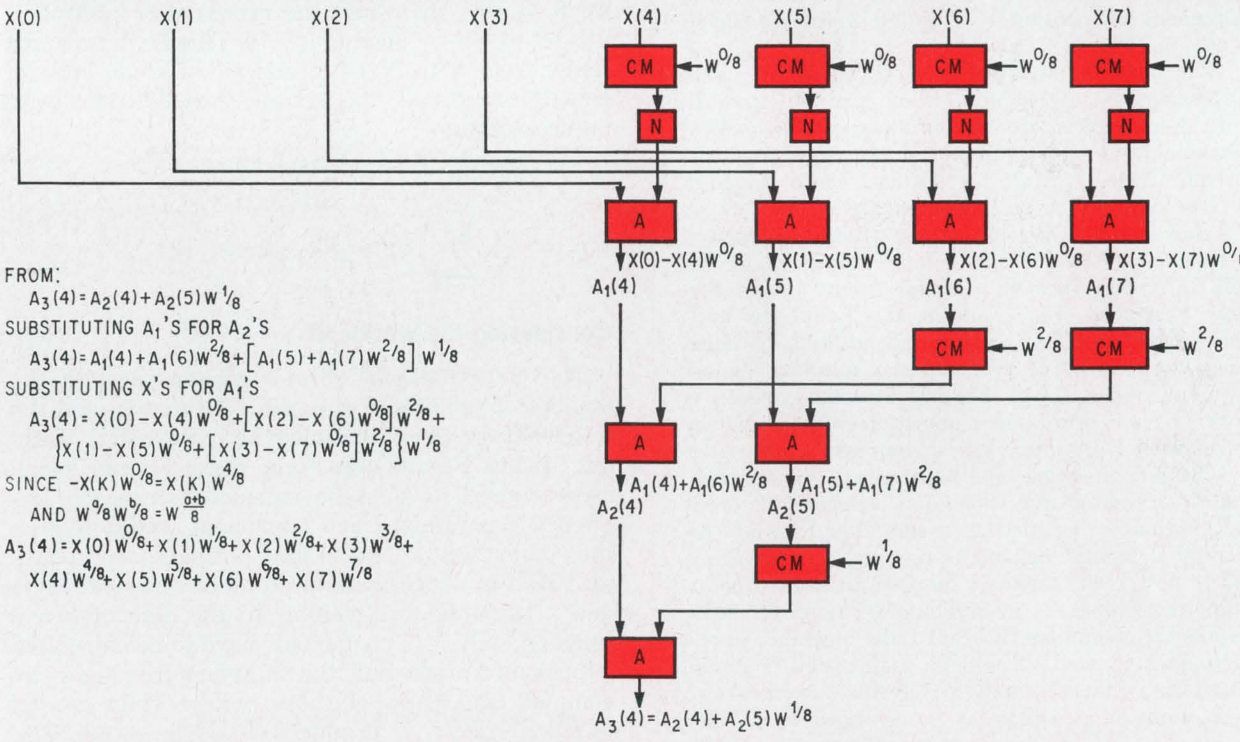
In the same way, coefficients derived from samples 0, 4, 8, 12, . . . can be combined with coefficients from samples 2, 6, 10, 14 . . . to produce the even-numbered coefficients. Odd-numbered coefficients result from combining the coefficients of samples 1, 5, 9, 13, . . . and 3, 7, 11, 15, . . .

Thus, each set of coefficients is the equivalent of two subsets—derived from half the number of samples. The ultimate subdivision of a single set of coefficients is N subsets, each containing only one coefficient that describes the waveform, but very poorly. These coefficients are none other than the original samples.

Reversing this process, then, the samples can be combined into pairs, then quadruples, then octets, and so on, until a single set of coefficients based on the entire set of samples is obtained. The procedure is iterative. The FFT's speed comes from executing fewer operations, using this iterative procedure, on the same data that the conventional Fourier transform uses.

The process used to compute the nth Fourier coefficient for a set of N samples is thus applied twice to alternate samples—once each to the odd-numbered and the even-numbered samples. But this time the multiplication is by $\exp(-j4\pi ns)/N$, instead of $\exp(-j2\pi ns)/N$, and the result for each half-set of samples is doubled. Then, multiplying the half-result for the odd-numbered samples by $\exp(-j2\pi n)/N$, adding the even-numbered half-result, and dividing by 2 gives the same result as was originally obtained for the full set of samples, for half the final set of Fourier coefficients. The other half of the final set is obtained by subtracting the odd half-result from the even half-result after the multiplication.

These half-result operations are equivalent to a



Working backward. Every sample is involved in the computation of any given output, yet without extensively duplicating the work. Equations at left outline the procedure and the substitutions that take place.

single interleaved set, and can be expressed by

$$\text{even:}\quad A_o(n) = \frac{2}{N}\sum_{s=0}^{N/2-1} f(2s)W^{2ns/N}$$

$$\text{odd:}\quad A_1(n) = \frac{2}{N}\sum_{s=0}^{N/2-1} f(2s+1)W^{2ns/N}$$

These are for a fixed value of n; the sample number s varies from 0 to $N - 1$, and W stands for $\exp(-j2\pi)$. The magnitude of this expression is always equal to $+1$, but W is always raised to a fractional power, so that the multiplier is a complex root of $+1$.

The two groups of Fourier coefficients are

$$A(n) = \tfrac{1}{2}[A_o(n) + A_1(n)W^{n/N}]$$

$$A\left(n + \frac{N}{2}\right) = \tfrac{1}{2}[A_o(n) - A_1(n)W^{n/N}]$$

where n varies from 0 to $(N/2) - 1$. This process is repeated over and over for finer and finer interleaved sets until two sets are finally interleaved into a single series.

This procedure is also applied to the half-sets of samples, by computing quarter-results on alternating quarter-sets. If N is a power of 2, this dissection process should occur $\log_2 N$ times, which would bring it down to the point where coefficients can be computed from individual samples of the original record.

Therefore, starting with N samples, each of which is a "series" with only one term, the equations are applied over and over again. Each iteration halves the number of series and doubles the number of terms. This form of the algorithm is sometimes called decimation-in-time form. Other forms have been proposed--for example, one called decimation-in-frequency.

An important consequence of this approach is that the results of each iteration can be stored in the same memory space from which the input to the iteration was taken—destroying the previous results. Another consequence: the final Fourier coefficients are not in consecutive order. The rearrangement of the coefficients, which follows a simple pattern, is nevertheless extremely difficult to program on a general-purpose computer. Indeed, half the execution time in a typical FFT program is spent on rearranging the final results, which involves much manipulation and testing of index values.

Computing with FFT

A rather short record of only eight samples illustrates the principles of FFT. Because W represents the complex exponential, it is found that $W^{0/8} = +1$ and $W^{4/8} = -1$, and that $W^{(8M+a)/8} = W^{a/8}$ for any integer value of M.

The FFT computational procedure, one form of which is diagramed on page 125, first uses pairs of the original samples to obtain simple two-point transforms based on two of the original samples. For example, samples X(0) and X(4) are combined to get $A_1(0)$ and $A_1(4)$:

$$A_1(0) = X(0) + X(4)W^{0/8} = X(0) + X(4)$$
$$A_1(4) = X(0) - X(4)W^{0/8} = X(0) - X(4)$$

The quantities $A_1(0)$ and $A_1(4)$ represent estimates of the d-c term and first harmonic. The same mathematical procedure makes other estimates of the d-c and first harmonic from each pair of original samples, obtaining the four two-point transforms $A_1(0)$ through $A_1(7)$.

Pairs of two-point transforms are then combined to obtain four-point transforms $A_2(0)$ through $A_2(7)$. Again, the arithmetic operations are similar, except that the spacing between pairs is halved, and different powers of W are used in the complex multiplications. The final step for an eight-point record determines the A_3 terms that are the desired complex Fourier coefficients within a scale factor of 1/8.

Although the diagram shows only the real component computations, the imaginary components are computed concurrently with the same procedure.

All of the eight-point Fourier coefficients may be obtained from this rather simple process, and the components can be verified by working back through the process, as shown in the diagram on the opposite page. This computational procedure can be extended to transform data records of any length, provided the number of samples is a power of 2. For all cases, the calculations require $\log_2 N$ iterations. The first iteration uses W raised to the zero power, or simply $+1$, and later iterations use fractional powers of the coefficient. Each basic operation of the computation involves one complex multiplication, one sign change, and two complex additions. In general, for a record length of N samples, each iteration requires N/2 basic operations. Thus, the entire process requires a total of $N/2 \log_2 N$ basic operations, compared with N^2 real multiplications when FFT isn't used. The graph on page 127 illustrates the dramatic effect FFT has on computational efficiency when N is large.

The authors

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Richard R. Shively, also on the technical staff, has been working on radar-signal processing and the Nike X computer since 1963. He has a doctorate from the University of Illinois, and was at IBM before joining Bell Laboratories.

Making it in pictures

Electric field intensity can be mapped on presensitized Polaroid film; method is quicker, simpler, and more accurate than mechanical scanning

By Keigo Iizuka
Harvard University, Cambridge, Mass.

The only way at present for engineers to map an electric field is to mechanically scan it, point by point, with a small probe. The technique has its drawbacks. It's time-consuming, recording isn't continuous, and the original field can be disturbed by the probe's lead wires and supports. Microwave holography would be a solution, but there's no convenient microwave analog to the photographic plate.

However, standard Polaroid film can do the job. This method, based on the temperature dependence of the developing process in uniformly exposed film, has proved to be inexpensive, accurate, and remarkably uncomplicated. A field's intensity can be mapped simply by holding the film in the field for less than a minute.

The Polaroid film is first presensitized by a brief exposure to uniform light. The developing process is started, and the film, still in its packet and shielded from light, is then placed in the microwave field.

The Polacolor Type 58 film employed here is normally used for taking 4-by-5-inch color pictures and consists of negative and positive layers and a developing reagent. The negative, the positive, and a pod of developer are pulled through the rollers of a Model 500 Polaroid 4x5 Land film holder. This breaks the pod and releases the viscous processing reagent in a thin layer between the negative and positive.

The film starts to develop as soon as it comes into contact with the reagent. Immediately after the reagent is spread, the film is placed in the microwave field, where an image is formed on it.

The electric-field component in the plane of the film produces a heating effect in the exposed silver-halide grains by inducing a current in them. The temperature rises by an amount proportional to the square of the field intensity, and because of this, the thermal field produced in the film exactly represents the intensity distribution of the electromagnetic field. The localized heating in the grains leads to localized increases in the rate of diffusion of the developing reagent to the grain sites, thus speeding the chemical development in the heated portions of the film.

The developer is removed from the film before the normal developing time has elapsed. The film at that point holds a visible pattern corresponding to the field's intensity distribution.

The film's sensitivity to microwaves can be controlled in three ways. In the first, the pre-exposure temperature is brought down to a level ensuring the maximum deposition of the silver-halide grains. Experimental results put this optimum temperature in the vicinity of 25° to 35°F.

To achieve this level, it's best to chill the film to the temperature of dry ice before inserting it into the microwave field, since the film is warmed by the ambient temperature during the exposure process. Care should be taken not to cool the reagent pod, however, because it solidifies at around 32°F.

Second, the color of the light to which the film is pre-exposed influences its sensitivity to microwaves. The film's emulsion-coated negative contains dyes of different colors in nine separate layers. The time required for the developer of one of these dyes to reach the surface of the negative depends on the distance between the dye and the surface.

If the negative is pre-exposed to light of a wavelength that allows only that dye lying closest to the surface to emerge, development time will be relatively short; light of a different wavelength, of

The author

Keigo Iizuka, now a research fellow and lecturer at Harvard's Gordon McKay Laboratory, holds an MSEE from Kyoto University. He also received a master's degree in applied physics from Harvard in 1958, and a Ph.D. from the same institution in 1961.

course, will cause a longer development time.

Thus pre-exposure of the color film to cyan (blue) light results in a longer development time than does pre-exposure through a yellow filter. In effect, the thickness of the diffusion layer can be controlled this way.

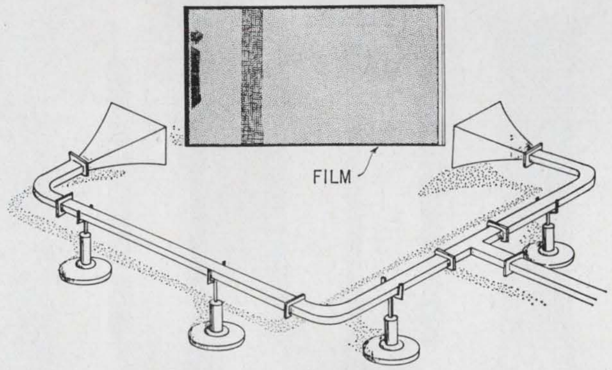
In practice, pre-exposure to yellow light would be used for stronger microwave fields, cyan-colored light for weaker.

A simple box camera can be used to pre-expose the film. The camera is aimed at a sheet of white paper illuminated at 45° by two carbon arc lights (5,600° K); the incident illumination is measured by Kodak Neutral Test Card. The intensity of light reflected from the card is about 50 foot-candles. To obtain the cyan color, the film is first exposed through a blue filter (47) for 1/10 second with a lens opening of F/9/5, and then through a green filter (61) for 1/5 second with the same lens opening as for the first step.

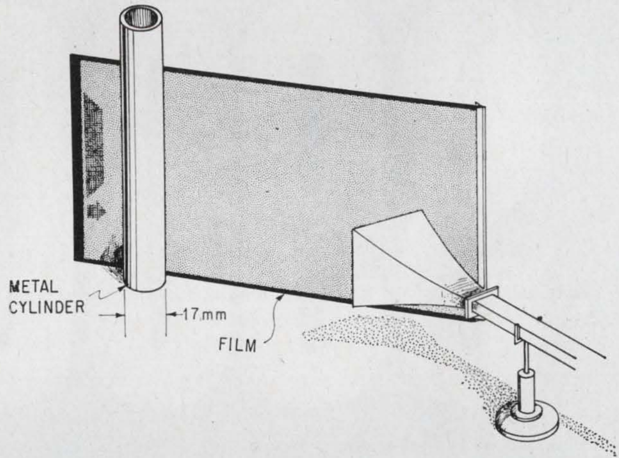
The third method of enhancing film sensitivity is to place a metal reflector behind the film. This disturbs the original field, but the reflector permits maximum power dissipation of the microwaves in the film by adjustment of the distance between it and the film.

Black-and-white Polaroid film Types 52, 57, 55 P/N, and 107 are also suitable, but their sensitivity isn't as high as the color type's. When only a small area of measurement is needed, the eight-exposure color pack (3¼ by 4¼ inches) is useful.

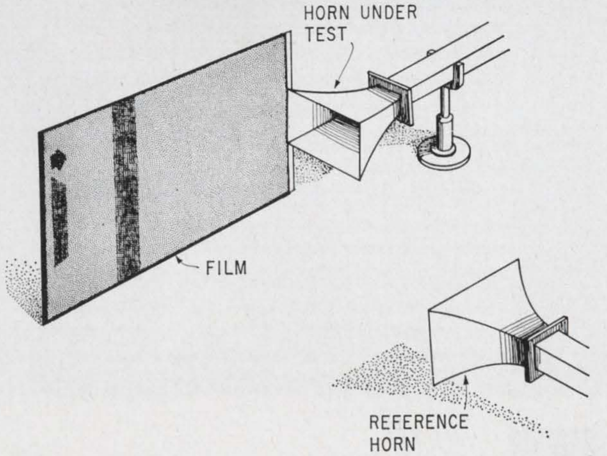
The method isn't limited to mapping electromagnetic fields. It should be applicable to the recording of any physical phenomenon capable of generating a thermal image. For example, the temperature distribution within the flame of a candle was successfully mapped by holding the film vertically in the flame. A distribution within the emulsion is generated, and this causes the film to form an "image" whose intensity is directly proportional to the flame's internal temperature distribution.



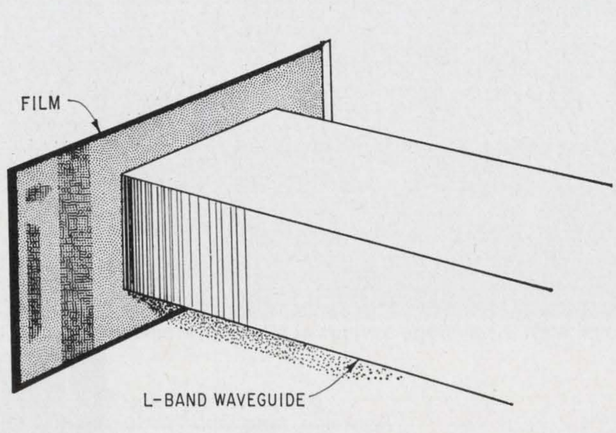
Between the horns. The Young's fringe pattern launched from two horns at an angle of 90° to each other can be mapped on a film packet at 45° to each horn with respect to the incident waves.



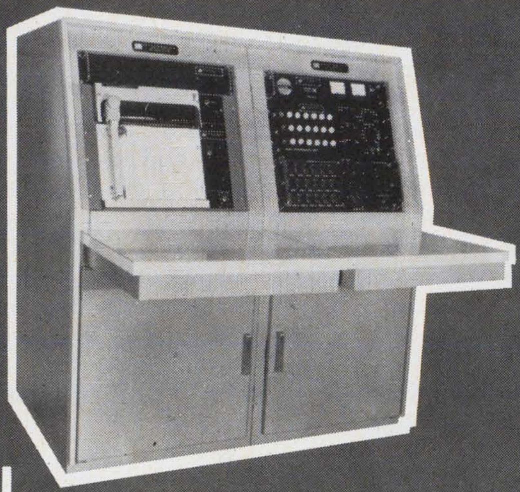
Scattered field. Film is used here to record field from a metal cylinder 17 millimeters in diameter. The E field is polarized in the direction of the cylinder's axis.



On the flank. Film is held against an edge of an X-band horn, parallel to the center axis, to map the horn's radiation pattern. The reference field is superimposed so that the distribution of the wave front can be observed.



Covering the mouth. The field intensity distribution at the mouth of an open-ended L-band waveguide is recorded by placing a cooled film packet at that point.



Airborne military transceiver finds room in crowded spectrum

Through artful design that keeps intermodulation distortion extremely low, the ARC-104 transmits and receives high-frequency single sideband signals in 280,000 channels spaced only 100 hertz apart

By I.P. Magasiny
RCA Defense Communications Systems Division, Camden, N.J.

A newly developed high-frequency transceiver goes a long way toward solving the critical problem of electromagnetic compatibility in airborne communications. It can send and receive 280,000 voice channels in the bandwidth older transceivers used for only 28,000.

Known as the AN/ARC-104, and developed by RCA for the Naval Air Systems Command, the set can reject a signal as high as 120 decibels above that of the tuned signal and only 50 kilohertz away. These characteristics allow it to operate almost trouble-free in crowded communication areas where high-powered interfering signals are close by. Now in the production prototype stage, the transceiver is still being improved.

The ARC-104 can operate in a single sideband, frequency-shift-keying or amplitude-modulation-equivalent mode, transmitting 400 watts at peak-envelope or continuous-wave power.

Such improvements are made possible by:

- Eliminating all variable tuning circuits
- Synthesizing all frequencies from stable, phase-locked crystals
- Mixing with linear parametric amplifiers
- Using the same mixer injection frequencies for both transmitter and receiver
- Gating out noise before it generates spurious signals.

The ARC-104's other features are also impressive. It tunes automatically to any of 280,000 channels in a maximum of one second, has a mean time between failure of 7,500 hours, can be tested dynamically with built-in circuits, and can be taken apart and put back together in less than half an hour. Previous transceivers took as long as two minutes to tune, had mean times between failures ranging from 10 to 100 hours, and had no internal test circuits.

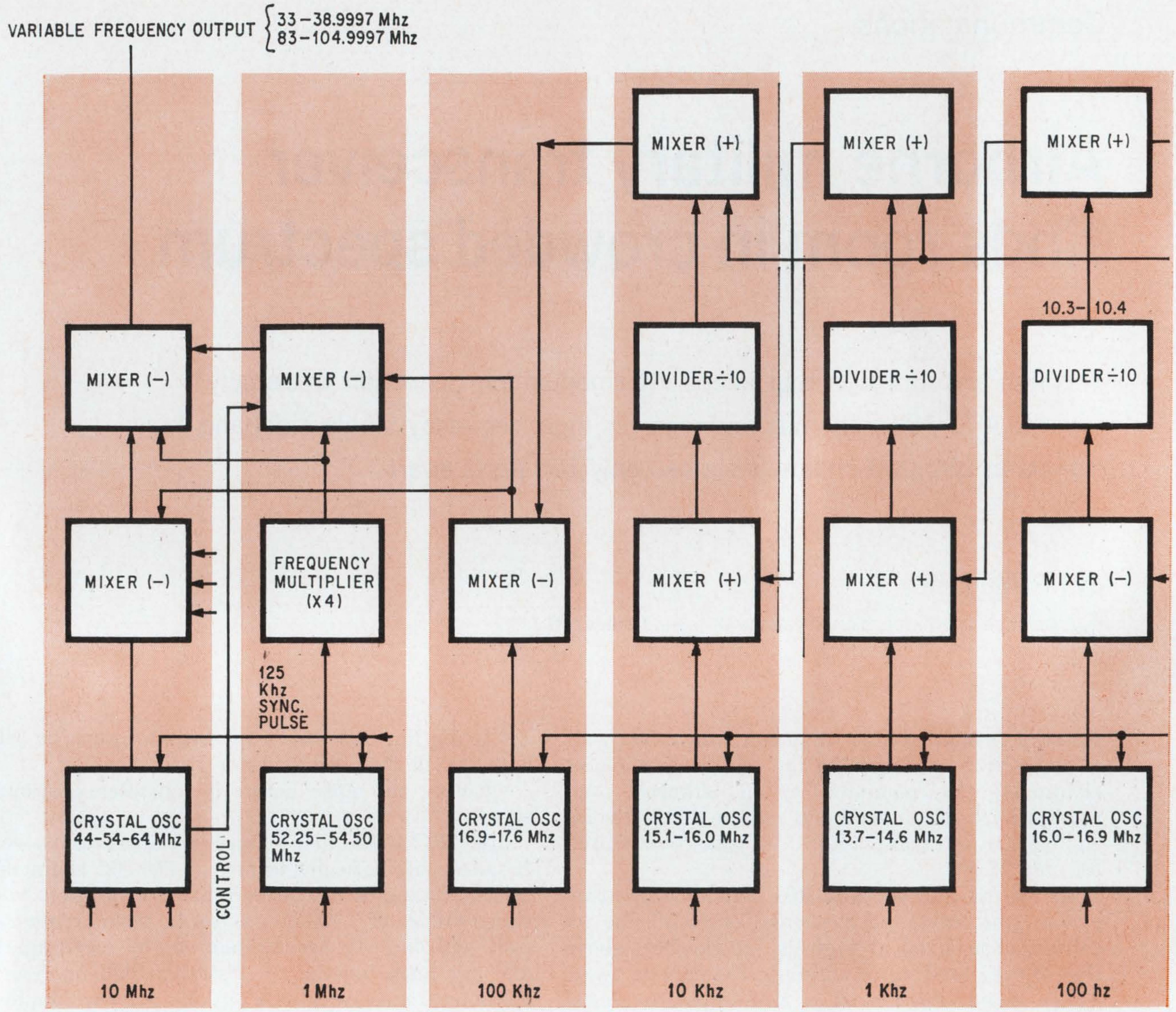
A standard of excellence

One of the keys to the low intermodulation distortion and low spurious output in the ARC-104 is the extreme stability and accuracy of the synthesizer, which generates frequencies accurate to 1 part in 10^9 per day and 1 part in 10^8 per month. This is achieved by using crystal oscillators and by phase-locking each to a single ultrastable crystal frequency standard. The synthesizer generates all frequencies either directly from the standard or from the oscillators.

Two types of circuits offered the high stability needed for the standard—either the Pierce or Meacham bridge oscillators. The former was picked because it did not require as close a control on the quartz crystal or as tight tolerances on circuit components. Because phase shifts within the oscillating circuit affect the oscillator's stability, components had to be carefully selected. To maintain stability in all weather and at all latitudes, the crystal is placed within a system of double ovens. The inner

The author

Irving Magasiny, manager of RCA's high frequency programs, has worked on the design of h-f single sideband equipment since 1965. He holds a master's degree from the University of Pennsylvania and has worked with Teledynamics Inc., Philadelphia, and with the Schaevitz Engineering Co., Pennsauken, N.J.



oven keeps the crystal at a temperature that varies by no more than a few milli-degrees. The outer oven keeps the temperature surrounding the inner one constant. Amplifier feedback of 20 to 25 db was necessary for the stable gain needed to control the oven temperatures. That feedback also insured immunity to noise within the amplifying loop and protection against component variations. Temperature-compensated voltage-reference diodes are used throughout the amplifier, and d-c control is employed to avoid interference with synthesized frequencies.

A long time in port

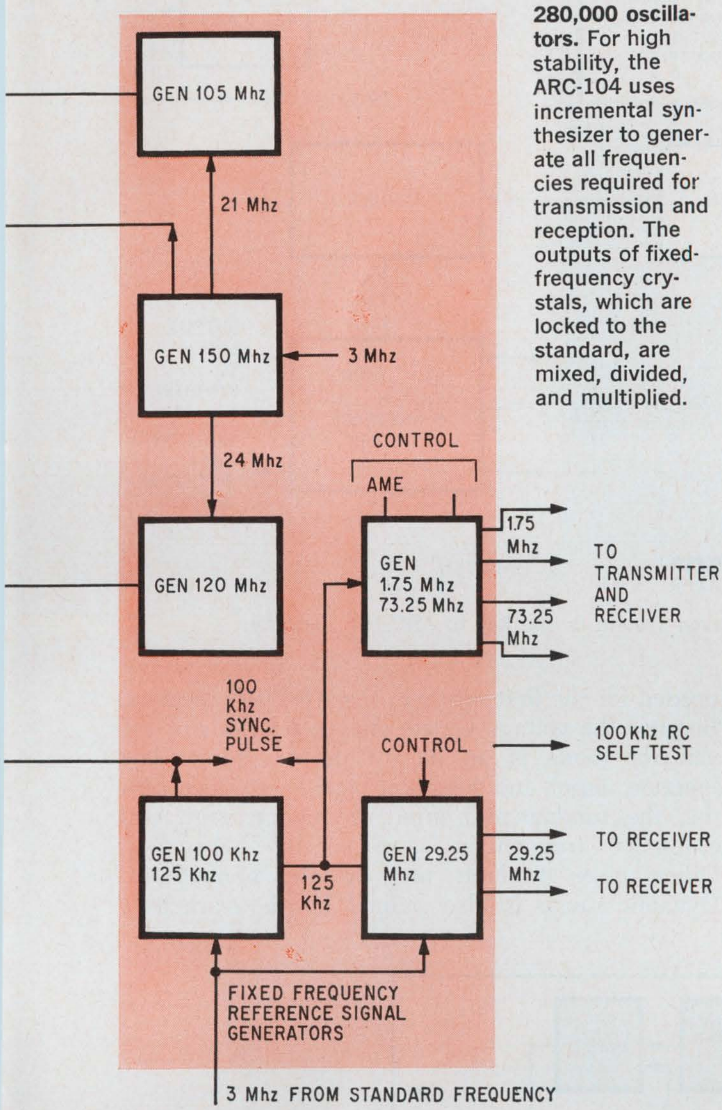
Work on the ARC-104 goes back all the way to mid-1962 when RCA received a Navy research contract. In the following years, transceiver requirements and design approaches changed several times to take full advantage of the rapidly evolving technology. For instance, transistors were scrapped in favor of IC's and synthesizer requirements were upped from 1 khz to 100-hz frequency spacing.

Finally, RCA built several experimental models and tested them under the direction of the Naval Air Development Center. Now RCA has started qualification tests of the production prototype.

The making of channels

Early versions of the ARC-104 synthesizer were digital, using bipolar or field effect transistors. Digital synthesizers lend themselves to circuit integration but at the frequencies required they weren't sufficiently reliable or stable resulting in jitter, microphonics, and spurious signals.

The synthesizer finally developed includes six decade oscillators; five of which have 10 crystals, and one has three. Decade oscillators correspond to the 100-hz, 1-khz, 10-khz, 100-khz, 1-Mhz and 10-Mhz digits of the 33 to 104.999-Mhz signal sent to the receiver and transmitter. A control signal from the tuning panel selects the appropriate frequency from each oscillator, which then locks on to the standard. Outputs are incrementally mixed, repetitively divided or multiplied, then mixed.



280,000 oscillators. For high stability, the ARC-104 uses incremental synthesizer to generate all frequencies required for transmission and reception. The outputs of fixed-frequency crystals, which are locked to the standard, are mixed, divided, and multiplied.

Both the receiver and transmitter in the ARC-104 use fixed frequencies of 1.75 and 29.25, and 73.25 Mhz for frequency translation, modulation, and demodulation. Crystal filters reduce spurious signals 120 db below these frequencies. The synthesizer itself uses internal local oscillator signals at 105 and 120, and 75 Mhz.

To generate decade frequencies, the synthesizer mixes the output of the 100-hz decade oscillator with the 120-Mhz signals then divides it by 10. The resulting 10.3 to 10.4-Mhz signal mixes with 105 Mhz, providing the local oscillator-injection signal for the 1-khz decade oscillator. Each successive divide-by-10 operation reduces the controlled frequency increments by 10. Crystal frequencies in the synthesizer are actually separated by 100 khz but frequency division by 1,000 (three divide-by-10's) achieves the desired 100-hz frequency spacing required in the transceiver.

The output signal of the 100-khz decade oscillator mixes with 1-Mhz increments derived in a similar manner from the 1-Mhz digit crystal oscillator, producing a low-band synthesizer output of 33 to 38.9 Mhz corresponding to antenna frequencies from 2.0 to 7.9 Mhz. Similarly, the 100-khz decade output mixes with the 10 Mhz-digit oscillator to ultimately produce outputs corresponding to antenna frequencies from 8 to 29.9 Mhz.

To prevent spurious couplings in the mixers, oscillator frequencies were carefully selected in relation to each other and to the fixed frequencies generated by the synthesizer. Each decade oscillator operates in a slightly different frequency range from the others.

Despite precautions, the synthesizer's variable frequency output is too high in spurious content and noise. Therefore, a phase locked oscillator in the receiver section boosts signal-to-noise ratio and reduces all spurious frequencies more than 120 db below the generated signals.

Turned on

Each crystal decade oscillator consists of the frequency selector, varactor controlled oscillator, sampling phase detector, and pulse shaper. Each section is designed to insure the highest accuracy and stability of synthesizer operation.

When a frequency is selected in the ARC-104, a control signal is sent on the appropriate lead to one of 10 p-i-n diodes in each decade oscillator. This switches on the diode, placing the desired crystal, bias network, and frequency-centering inductor in the circuit. Diode on-impedance is less than 10 ohms while its off-impedance is 10,000 ohms, thus insuring that all crystals except the one operating are completely out of the circuit.

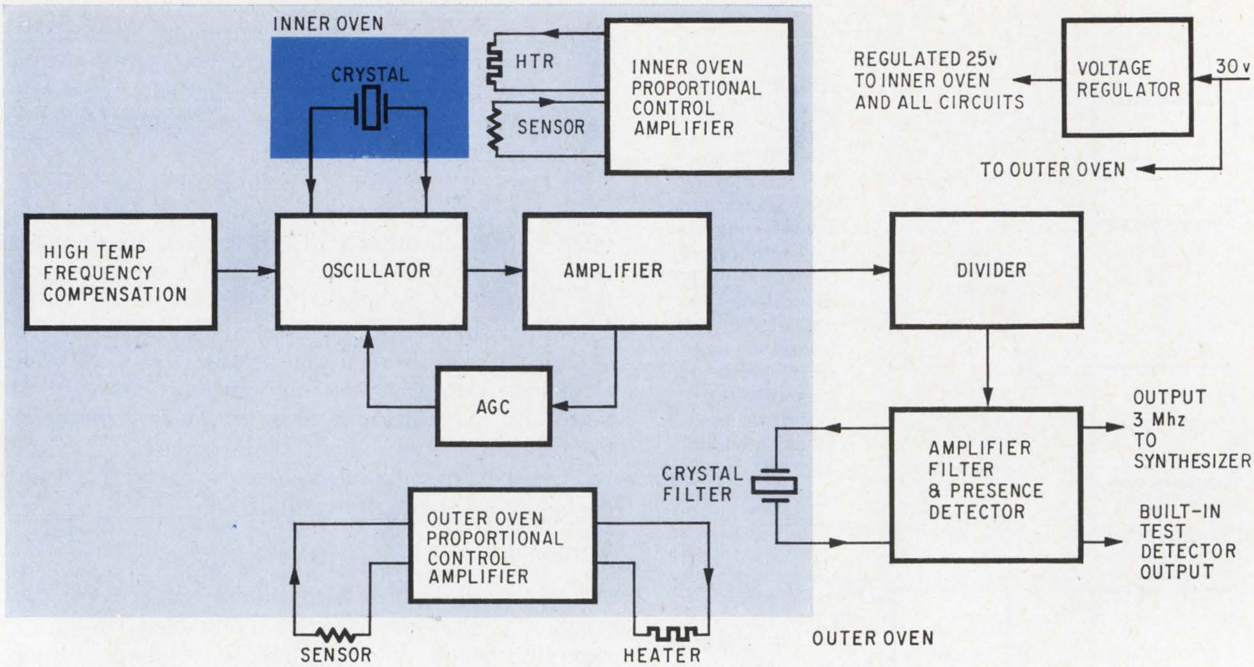
The oscillator section includes two amplifier stages with feedback. It functions only when a low impedance is inserted in the emitter of the first stage. The inserted impedance consists of a varactor diode in series with the p-i-n diode, the crystal, and the center-frequency inductor. Thus, the emitter impedance is low only at the series-resonant point of the selected crystal. The varactor acts as the control in the loop, locking the crystal to its correct frequency.

At the same time that the control signal is sent to a crystal, a synchronizing pulse derived from the frequency standard and the pulse generator is transmitted to a blocking-oscillator, which shortens the pulse and sharpens its edges.

Finally, the shaped pulse closes a switch in the sampling phase-detector section of the oscillator, thereby connecting the oscillator output of the selected crystal frequency to a capacitor. The voltage is stored on the capacitor until the next pulse, and is also delivered to the varactor, which controls the crystal oscillator frequency. Varactor frequency control simplifies filter design, increases the ratio of capture to lock-range, and reduces the frequency modulation caused by ripple.

Receiver dynamics

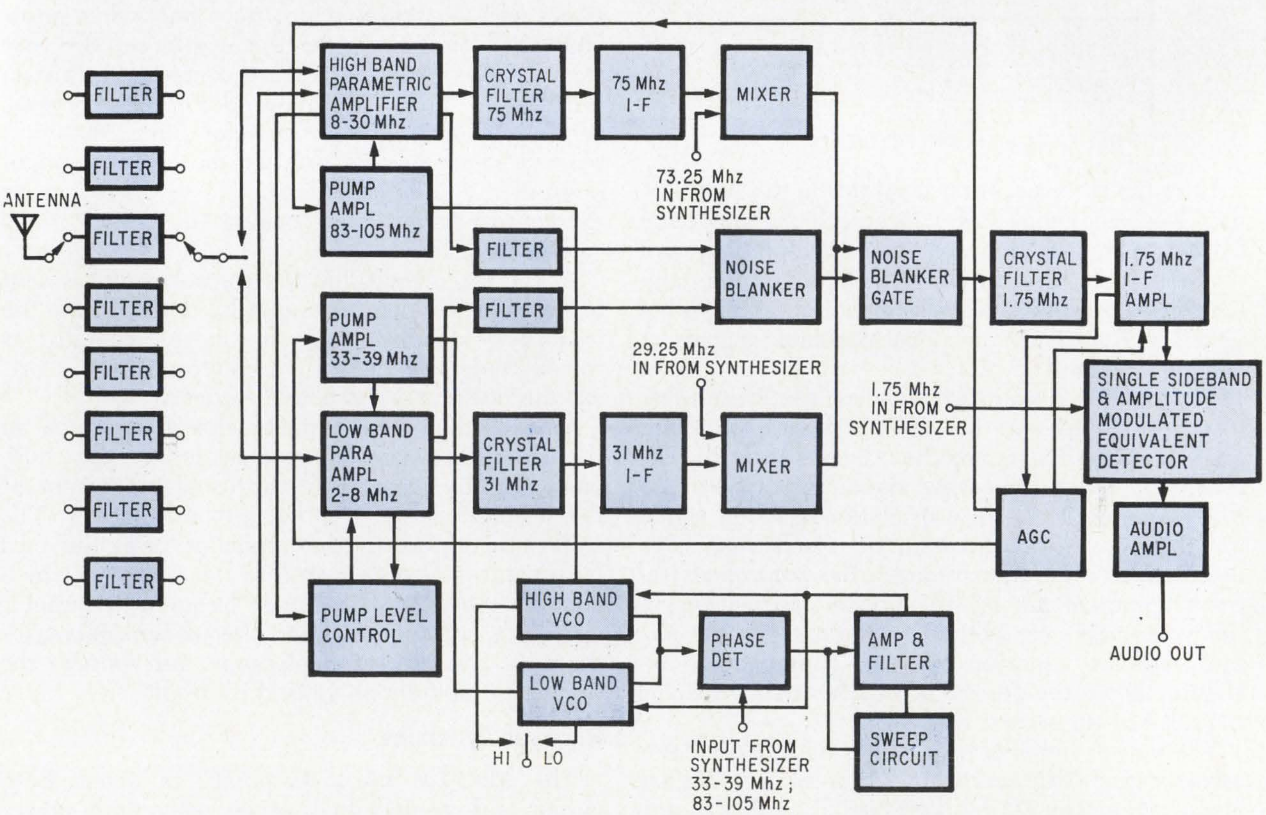
The ARC-104 owes its ability to detect both strong and weak signals—even when high-power interfering signals are close by—to the high linearity



Stable generation. Frequency standard controlled by dual oven system is one key to ARC-104 linearity.

of its front end. A double-superheterodyne detection technique makes use of parametric amplifiers to convert r-f signals to higher intermediate frequencies. I-f signals are then passed through highly selective crystal filters to bring spurious signals down at least 120 db below tuned signals.

A varactor parametric up-converter is the only device now made with the linearity and noise figure needed for the first mixer in the ARC-104 receiver. Because the voltage versus charge relations of the varactor diode is an almost perfect square-law function, input and injection signals produce only d-c, the fundamental input frequency, sum and difference frequencies, and second harmonics. Other mixer products are virtually nonexistent. Dynamic range is also helped by the varactor's



Receiver combination. Parametric up-converters and noise-blanking techniques keep spurious signals down.

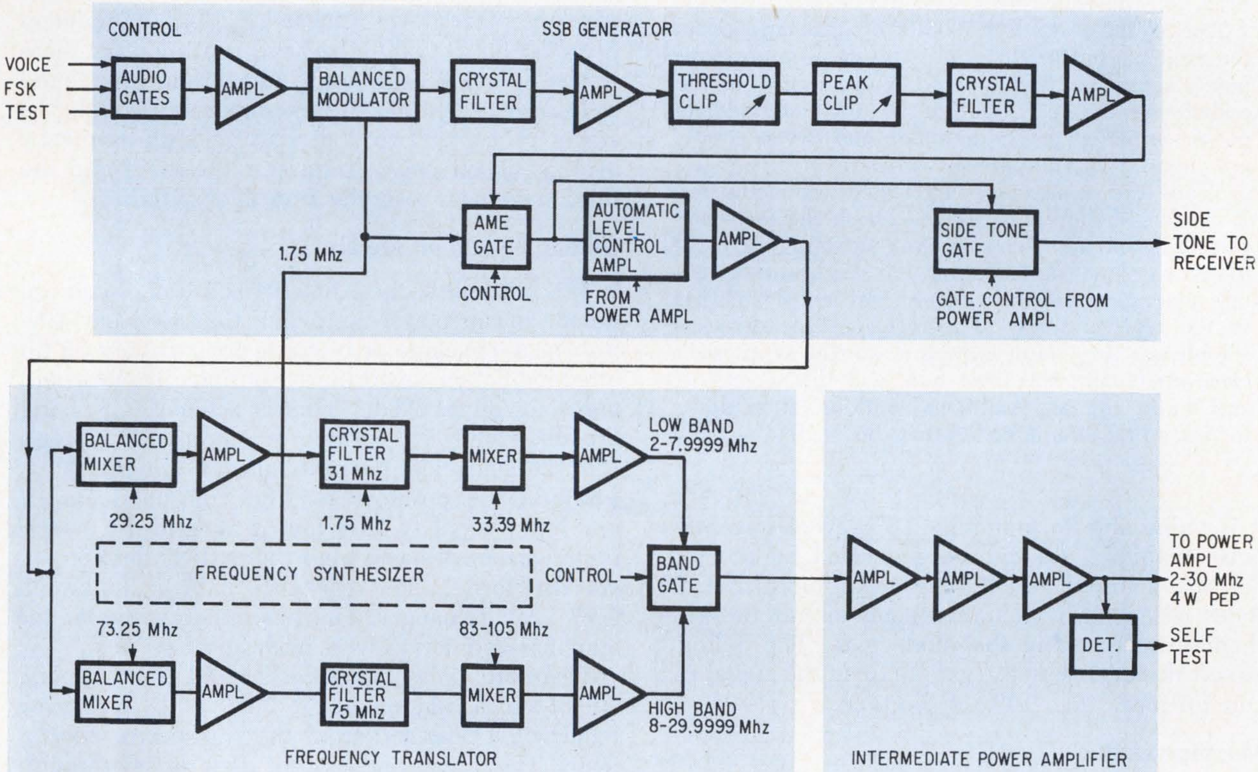
ability to handle strong signals without breakdown and low signals without adding appreciable noise or attenuation.

A low noise amplifier pumps the varactors in the parametric device with a maximum 2-watt injection signal. Pump control is derived from an automatic level control circuit and automatic gain control detector (agc). The automatic level-control circuit reduces the pump signal power if it exceeds the maximum required level while the agc detector reduces the power if the intermediate frequency signal level increases. The i-f rejection filters eliminate pump noise amplified at 31-Mhz or 75-Mhz.

Input signals to the receiver section of the ARC-104 are selected with the help of eight bandpass filters, which eliminate the need for electrically sistor oscillators (one for the low band, the other for the high band), a phase detector, a direct-coupled amplifier, a compensating network, a low-frequency sweep generator, and a sweep-inhibit and gate circuit. The sweep circuit tunes the oscillator so that it sweeps past and locks on to the synthesizer signal. The sweep-inhibit-and-gate circuit isolates the oscillator from interference.

In the first i-f section of the receiver, low band signals (2 to 7.9 Mhz) are converted to 31 Mhz, high band signals (8 to 29.9 Mhz) to 75 Mhz. Signals in either band are then converted to a second i-f frequency of 1.75 Mhz, and passed through a noise-blanker gate and crystal filter.

The noise-blanking circuit, together with the parametric mixer, contributes in large part to the



The way out. Transmitter exciter is broadband, untuned, low-noise, and low spurious signal circuit.

or mechanically tuned tracking circuits and also simplify remote control. The filters are designed so that the ratio of maximum- to minimum-passband frequencies is limited to 1½:1, thereby keeping the second harmonic at least 120 db below that of the input signal. The injection signals are far enough away from the passband frequencies so that they're sufficiently attenuated. After the appropriate band has been selected, signals can be tuned in precise 100-hz increments merely by changing the first injection signal.

Before mixing with the received signals, the variable frequency injection signals are processed in a buffer circuit, which improves their signal to noise ratio to greater than 40 db. This "clean up" circuit is composed of two voltage-controlled tran- ARC-104's ability to operate in areas of high man-made and natural noise. The spectrally pure injection signals also minimize spurious output from the transmitter. The noise blanker recognizes impulse noise and gates it out of the circuit for about 800 microseconds. This prevents transients from ringing the 1.75-Mhz crystal filter.

The pulse-detection circuit bypasses the first i-f filter and has much greater bandwidth. It recognizes impulse noise varying in intensity from 100 microvolts to 1 volt. An IC, logarithmic amplifier with 70-db gain at 1 Mhz enables weak pulses to be detected. Once the pulse is detected, it triggers a flip-flop that generates an 800-μ pulse, tuning off the diode gate preceding the 1.75-Mhz filter.

Because the logarithmic amplifier is broadband,

Report in 4 Seconds

Because the ARC-104 is designed to operate in aircraft, it's also designed to diagnose its own troubles, simplifying maintenance. Aided by detectors and indicators in each functional module, a test module consisting of 75 integrated circuit flatpacks allows an operator to quiz the set on its performance and get a report in four seconds. The module sets a magnetic latch indicator on the control panel if there's trouble and pinpoints the fault by also setting an indicator on the defective module.

Dynamic tests at any channel frequency in 100-kilohertz increments and in any operating mode are made on all parts of the transceiver. Fault indicators stay set even with power removed, requiring no current. They can be reset only by taking out the defective module. However, they don't have to be reset for the transceiver to continue operating.

During the tests, a 1,500-hertz signal applied to the exciter input produces a 400-watt peak envelope power signal that is dissipated in an internal 50-ohm carbon-resistor load. Output of the intermediate power amplifier, power amplifier, and power supply are checked by comparison with reference voltages.

While the exciter is being tested, its modulated 1.75-Mhz i-f output is used to check the receiver's second i-f and audio circuits. And an amplitude modulated r-f signal derived from the synthesizer's 100-khz generation and the 1,500-hz test signal connects to the receiver input. The receiver functional assembly has three fault indicators: for the synthesizer clean-up circuit, the front end, and the second i-f and audio circuits. Additional fault isolation down to individual circuit boards can be made.

it is vulnerable to jamming. To prevent unwanted noise blanking, the pulses generated by the flip-flop are counted and if they occur more than 75 times a second, a Schmitt-trigger circuit prevents them from reaching the diode gate. The Schmitt circuit doesn't allow the gate to open the signal circuit for more than 10% of the time.

Message center

Like the receiver, the ARC-104's transmitter exciter is a broadband, untuned, low-noise and low-spurious signal circuit. It accepts data or voice signals either from microphones or from military intercommunications sets such as the AN/AIC-14 or AN/AIC-25, producing either a single sideband, amplitude modulated equivalent, or frequency-shift-keyed signal of 2-watts-peak envelope power. Making up the exciter are a single sideband generator, frequency translator, and intermediate-power amplifier.

In the single sideband generator, voice, fsk, or test signals are gated through a circuit with ± 10 db of adjustable gain. Then the signals are amplified and modulated onto a 1.75-Mhz carrier with the carrier sideband removed. If amplitude-modulated equivalent transmission is used, the carrier is reinserted.

Part of the i-f signal goes to an antomatic level control amplifier and then to the frequency translator; part is gated off by a diode and is sent to the receiver i-f as a side tone that tells the operator whether the transmitter is operating properly.

In the translator, the modulated 1.75-Mhz carrier mixes with either a 29.25-Mhz injection signal (for transmission in the 2- to 7.9-Mhz band) or a 73.25-Mhz signal (for transmission in the 8- to 29.9-Mhz band). The low band i-f, 31 Mhz, and the high band i-f, 75 Mhz signals, are then filtered, mixed with the selected injection frequency that assigns them to a channel, amplified, and sent through a band-selector gate to the intermediate-power amplifier. Using the same injection frequencies in both receiver and exciter minimizes coupling and spurious signal generation.

In the exciter's final section, the intermediate-power amplifier boosts all signals to a 2-watt-peak envelope power level. Linear broadband amplification over the 2- to 30-Mhz band is attained in three stages by using negative feedback and broadband transformers that match impedance and couple the stages. The first two stages use a high-frequency overlay silicon power transistor (2N3375) and the third stage uses a similar transistor (2N2876).

Getting on and off the air

The last link in the ARC-104 is a broadband untuned, linear power amplifier that delivers 400-watt-peak envelope or c-w power with only 35 db intermodulation distortion. Spurious signals and noise are down 90 db. This is achieved by using broadband-output coupling transformers, a single 750-watt linear output tube, and an antenna filter. The tube was designed for high transconductance, low input capacity, and low peak grid-drive level requirements. It has a high thermal conduction anode that forms a low-resistance path to the amplifier's heat exchanger. The base plate supports the amplifier and serves as a heat sink.

There are eight broadband output transformers, one of which is automatically selected by a rotating bandswitch operated from the transceiver control panel. The transformer output then passes through a low-pass filter before transmission to remove spurious as well as second and higher harmonics. Power output is limited by the exciter's automatic-level-control amplifier, which is controlled by the transmitter output detector and adjustable threshold circuit.

Mounted with a blower, the ARC-104 set meets military Class 1 A requirements—it can operate up to 35,000 feet altitude over a temperature range of $-55°C$ to $+55°C$. Mounted without blower and cooled from an external system, the set meets Class II specifications—it can operate up to 70,000 feet altitude over a range of $-55°C$ to $+71°C$.

RCA has taken steps to obtain an output of 1-kilowatt-peak envelope power and c-w using a single tube. Another version of the transceiver permits twin and independent sideband operation with fsk or phase-shift keying multitone data as well as voice.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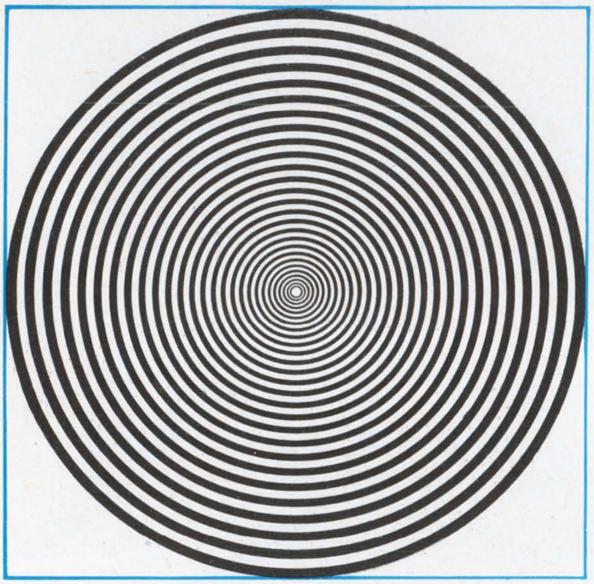

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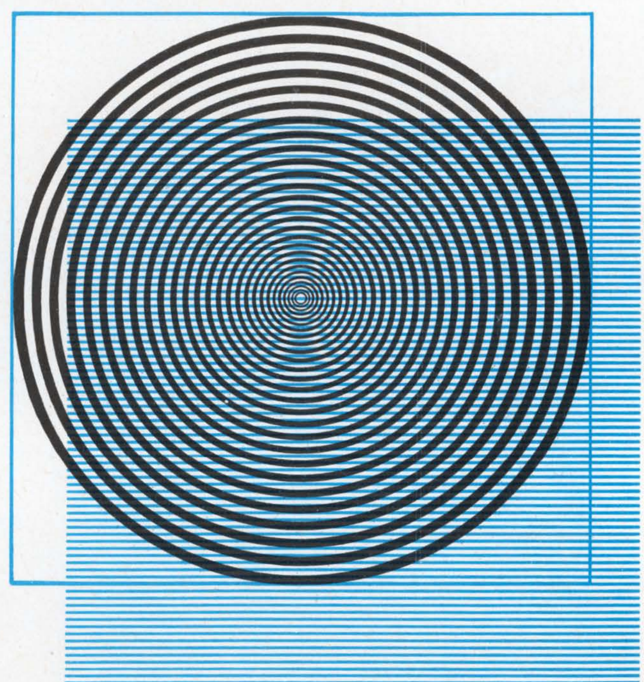

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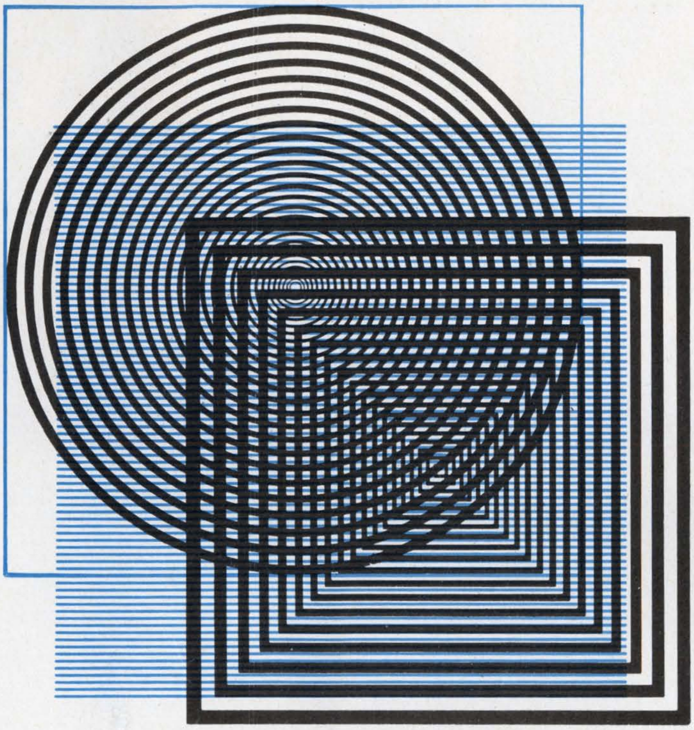

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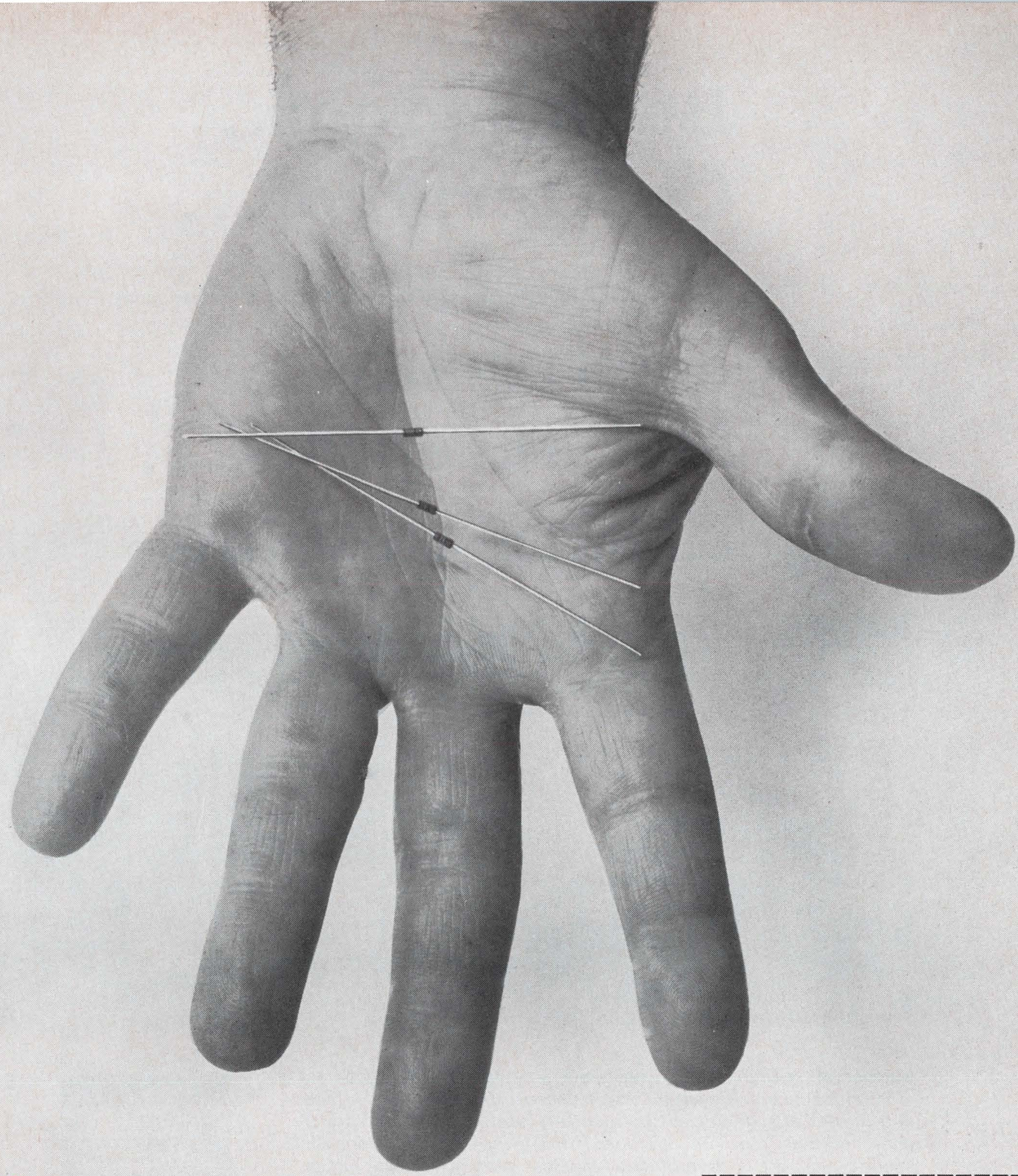

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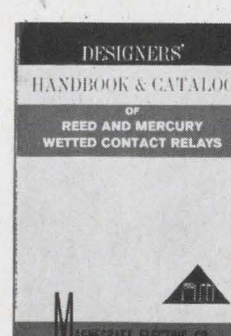

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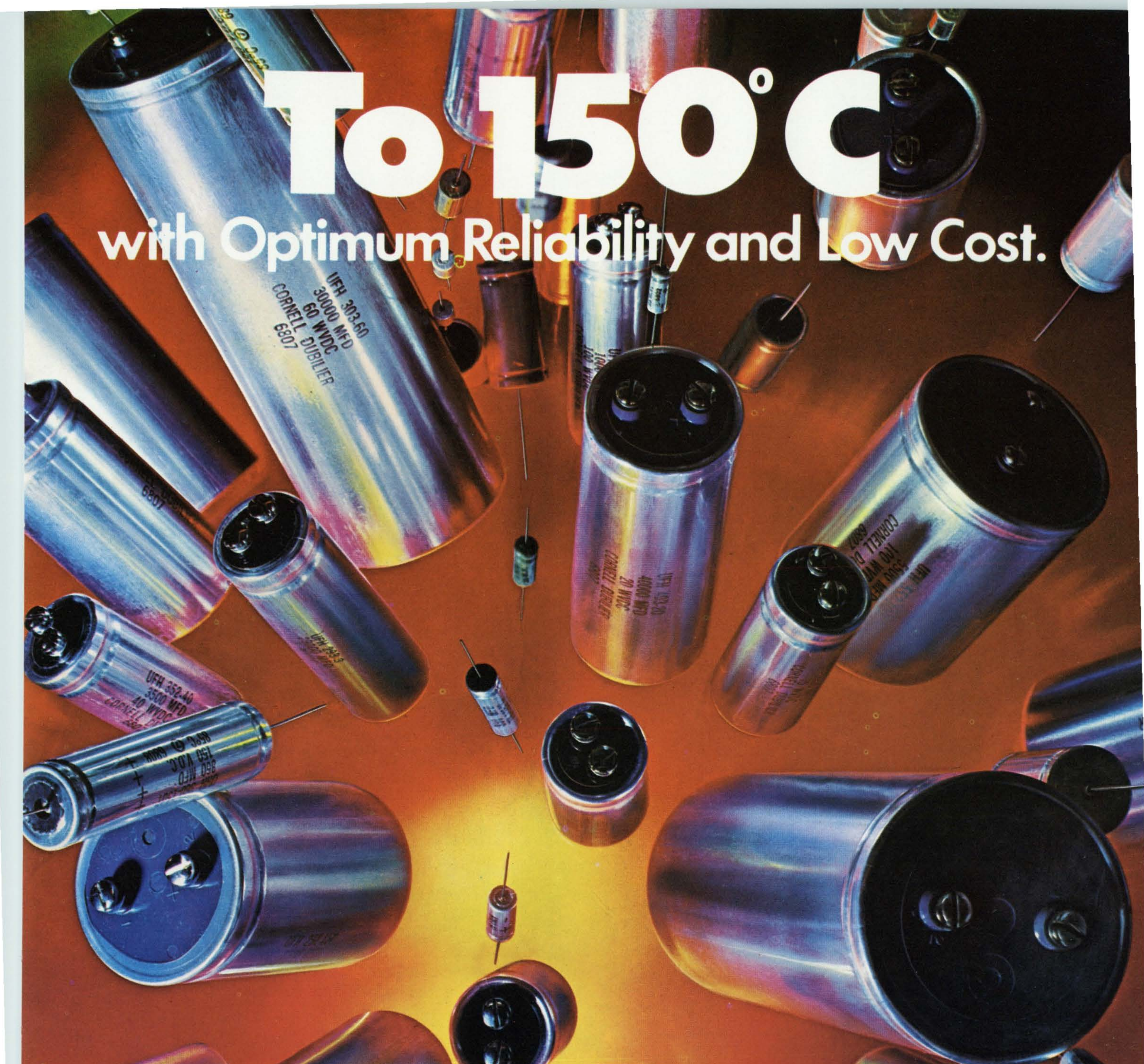

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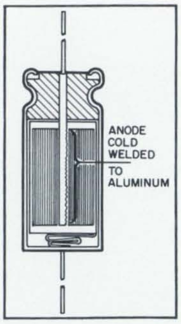

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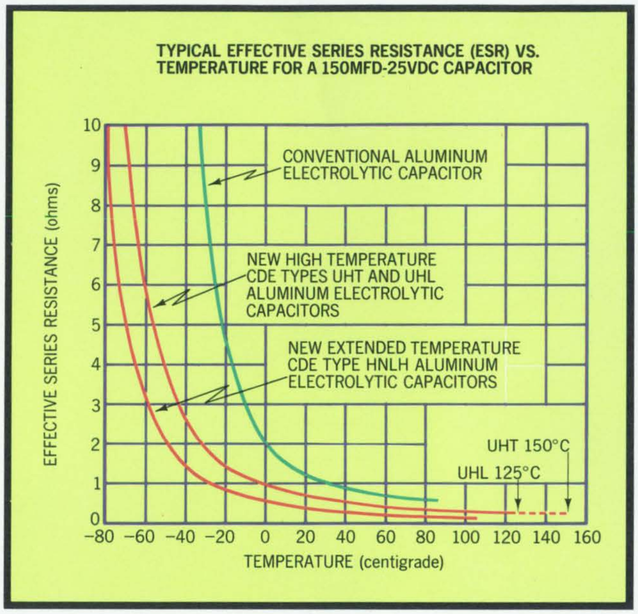

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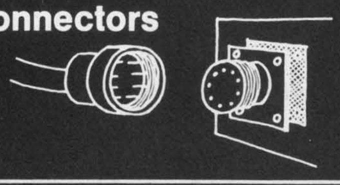

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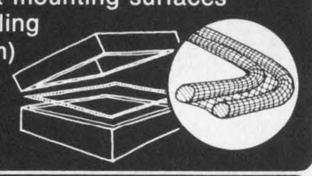

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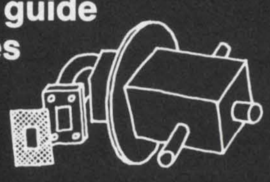

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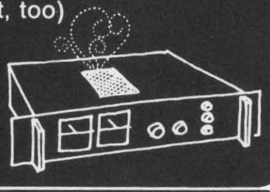

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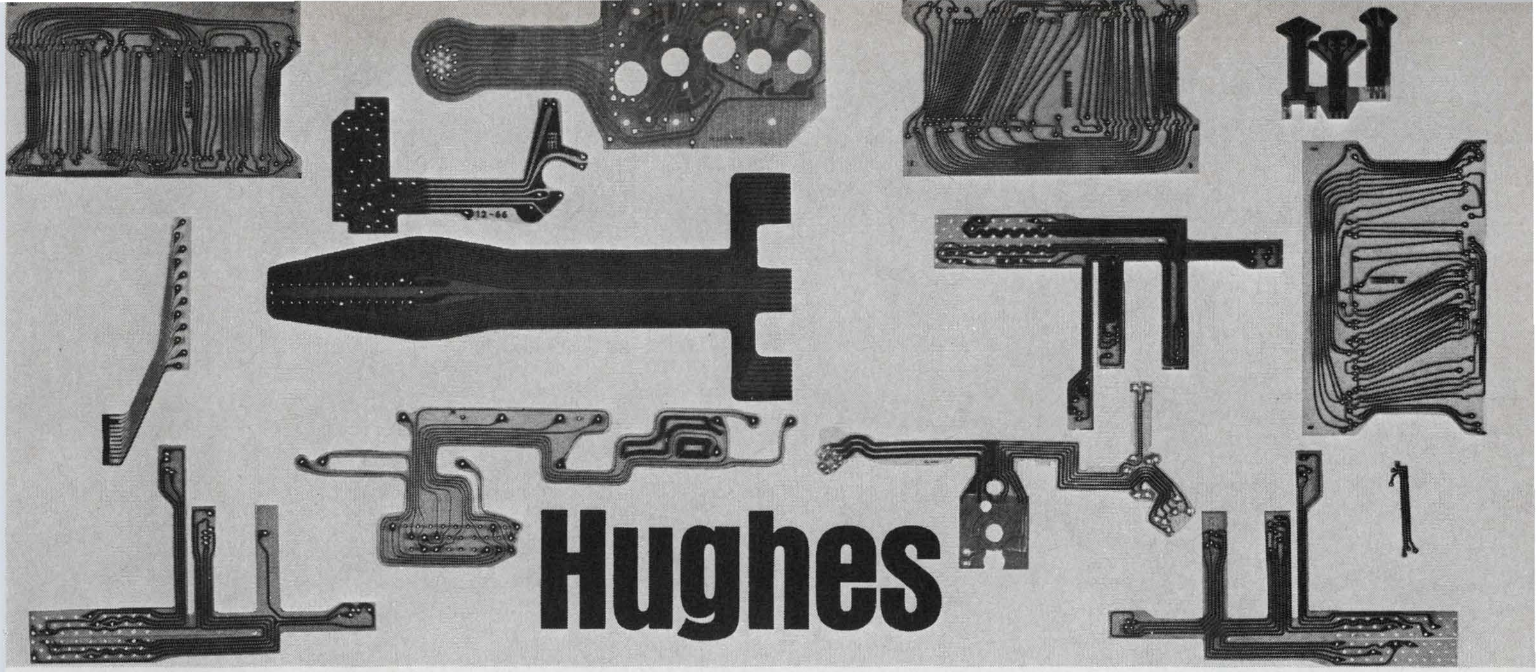

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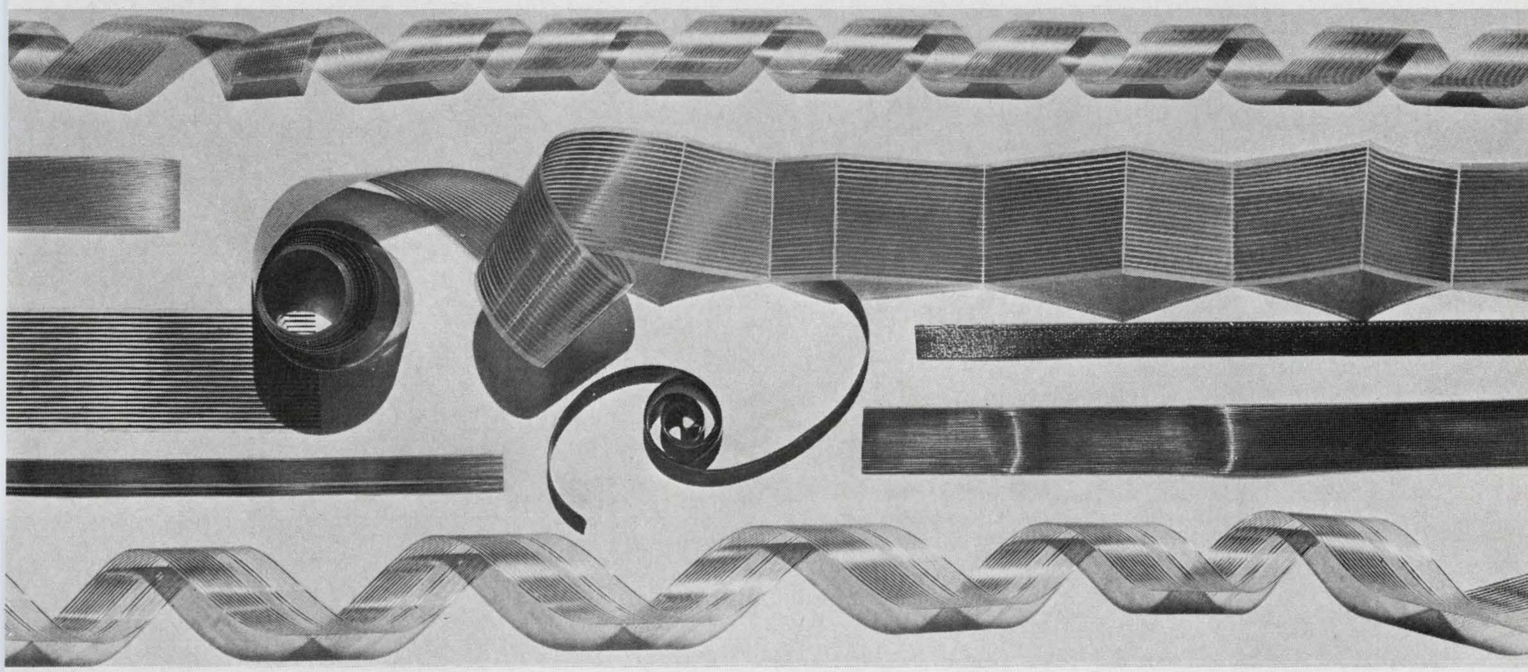

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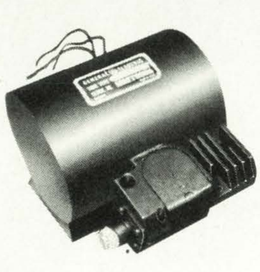

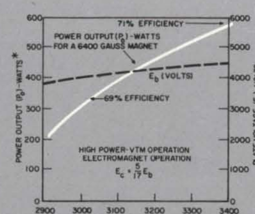

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GE 69F900 wet slugs meet high-density application needs with highest volumetric efficiency of any capacitor. We halved the military (CL64) wet slug size, and essentially kept its electrical and performance traits.

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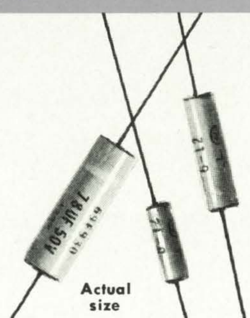

Actual size

stored to —65C. Operating range is —55C to +85C. It's tough too—withstands vibration to 2000Hz; 15G acceleration!

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RATING	CASE SIZE	VOLUME
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solid (CS12)	.341X.750	100%
wet slug (CL64)	.281X.681	58%
69F900	.145X.600	15%
15V, 80 μf		
solid (CS12)	.341X.750	100%
wet slug (CL64)	.281X.681	58%
69F900	.145X.600	15%
6V, 180 μf		
solid (CS12)	.279X.650	100%
wet slug (CL64)	.281X.641	100%
69F900	.145X.600	25%

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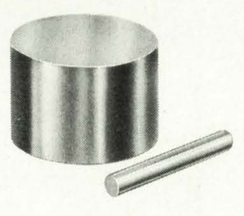
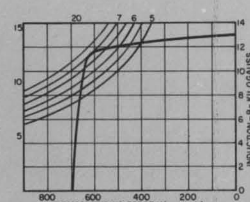
Alnico 5-7 magnetic material—a great improvement over Alnico 5

GE Alnico 5-7 improves or equals performance of conventional Alnico-5 —with reduced magnet length, smaller cross-section.

Alnico 5-7 has great advantage where space and weight must be minimal, and high demagnetization resistance is required.





Demagnetization vs energy output, Alnico 5-7

Typical applications for Alnico 5-7 are high-density meter movements; electron tube devices; compact loud speakers; motors and generators.

Let our engineers work with you to design a Cast Alnico 5-7 magnet for your application. Circle **Number 233** for technical and ordering information.

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Construction is the key to Volt-Pac's optimum performance. Here's why.

A spring-loaded, grain-oriented carbon brush means even contact, reduced wear. Self-lubricating nylon bearing lessens voltage selector friction.

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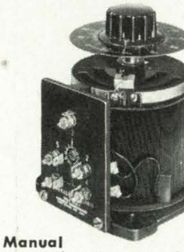

Manual uncased unit, exposed terminals

sulation of coil windings gives extra reliability. Aluminum radiator and base evenly dissipate heat, extend life. Gold-plated track reduces possible heat build-up at brush contact, minimizes burn-out risks.

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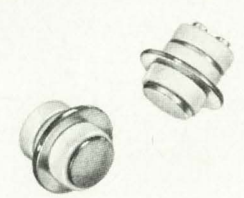
Bonded heater version of popular 7077/7486 tube now available

The new GE16411 may solve your most perplexing oscillator problem.

This small planar triode provides low levels of oscillator side-band noise. A bonded heater addition makes the GE16411 useful under high shock, vibration conditions.

GE16411 recently made possible significant im-



Actual size

provement in short-term, long-term stability characteristics in a spectrum-analyzer design.

It also provides direct retrofit fast warm-up capability for the 7077/7486 family—about 3 seconds to 90% of steady-state plate current.

The new triode is another example of how GE product improvements can aid you in designing reliable, top performing equipment. Circle **Number 235** for more information.

how big is a micron?

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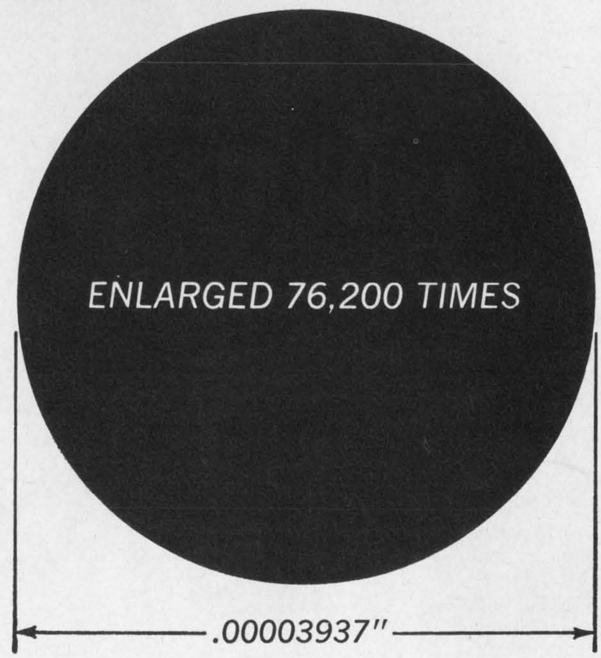

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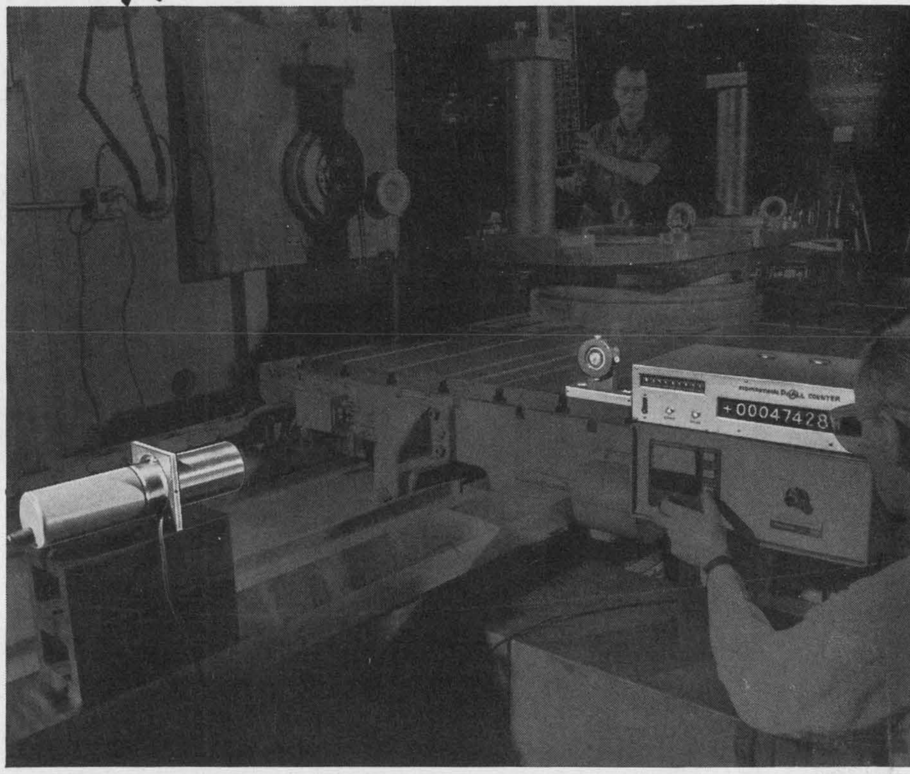
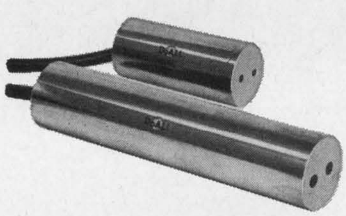
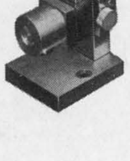
PRODUCTION LASER INTERFEROMETRY



...a new approach to linear measurement provides high-precision production floor inspection with speed and economy





New compact optics puts interferometer in 3½-in. diameter tube, revolutionizes absolute long-length measurement on production work. Model 121, in a 16 in. long tube, is double-path interferometer with self-contained laser and power supply, designed for N/C machine tool calibration. Model 127, in 8-in. long tube, is single-path interferometer, operates with external single-mode helium-neon laser, designed for measuring machines or permanent installation on machine tools, for two-axis monitoring with single laser.

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Tektronix 50-MHz dual-beam oscilloscope

The Tektronix Type 556 Dual-Beam Oscilloscope features 50-MHz bandwidth, calibrated sweep delay, 6 x 10 cm scan per beam and dual plug-in flexibility. Using two plug-ins at a time, the Type 556 offers many display combinations, including: dual-beam single-shot; multiple-trace; sampling and real-time; frequency and time; delaying and delayed sweep.

The two independent horizontal deflection systems provide full bandwidth triggering and calibrated sweep speeds from 5 s/cm to 100 ns/cm, extending to 10 ns/cm with the X10 magnifier. The calibrated sweep delay range is from 100 ns to 50 seconds.

The Type 556 with the Type 1A4 Four-Channel Plug-in and the Type 1A2 Dual-Channel Plug-in provides up to six channels, each with 7-ns risetime and DC-to-50 MHz bandwidth. (Up to eight traces with two Type 1A4 Plug-ins.) You can also select from differential plug-ins with bandwidths to 50 MHz, TDR and sampling plug-ins with 90-ps risetime, and spectrum analyzer plug-ins that cover the spectrum from 50 Hz to 10.5 GHz.

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Type 556 Dual-Beam Oscilloscope	$3250
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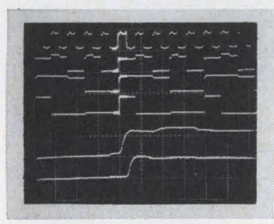
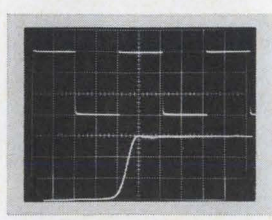


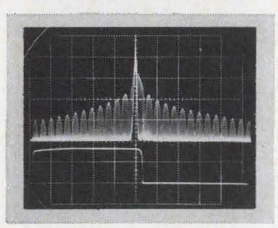
Multi-Trace

The six waveforms are time related digital pulses. The upper four displays are A Sweep (2 μs/cm) with the Type 1A4 Four-Channel Plug-in. The lower two displays are B Sweep Delayed (100 ns/cm) with the Type 1A2 Dual-Trace Plug-in.



Sampling and Real-Time

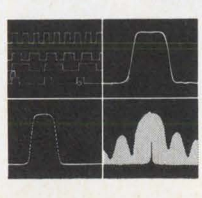
The upper beam shows a square wave at 2 μs/cm as applied to a Type 1A2 Dual-Trace Plug-in. The lower beam shows the risetime of the same pulse with the Type 1S1 Sampling Plug-in at 1 ns/cm.



Frequency and Time

The upper beam shows the spectral output of a 200 MHz gated oscillator applied to the Type 1L20 Spectrum Analyzer; calibrated dispersion is 1 MHz/cm. The lower beam shows a real-time display of the 2.5 μs gating pulse.

Multi-trace, differential, sampling and spectrum analysis



... in all Tektronix 530-540-550-series plug-in oscilloscopes

Probing the News

Systems engineering

Electronic traffic control: can it make the grade?

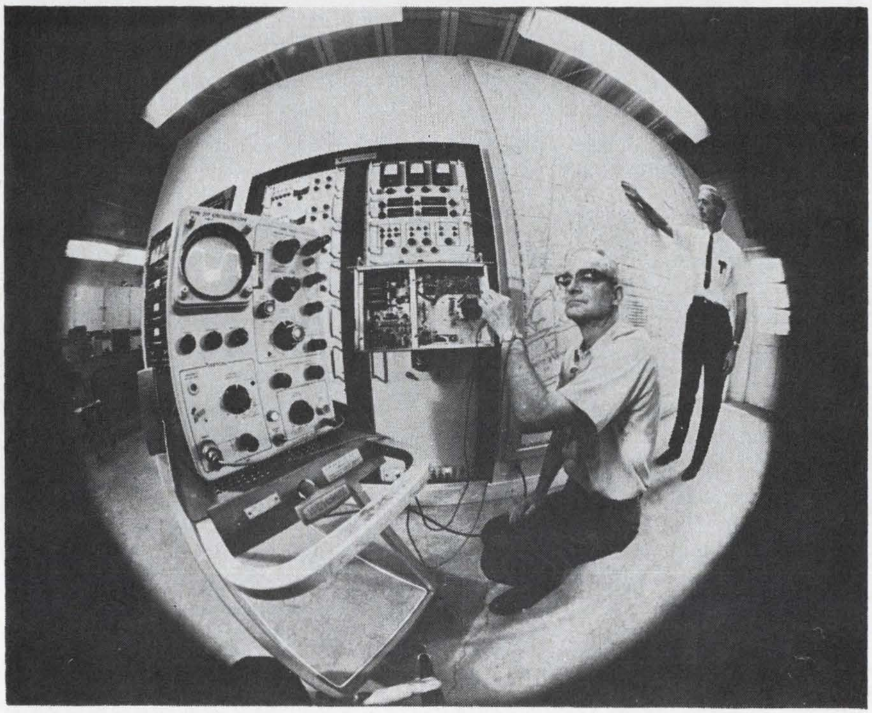
Most engineers are optimistic, but unreliable hardware and high costs are creating many problems for the cities

By Howard Wolff
New York bureau manager

Inside every traffic engineer there's a systems designer screaming to get out. His frustration comes from looking at the infuriating tableaux that have become commonplace in American cities:

- A line of autos waits at a corner for the light to change even though nothing is moving through the intersection from the other direction.
- A string of signals along a broad, one-way avenue is set to keep things moving at 25 mph during the 5 o'clock crush when actual speed is 5 mph.
- Cars are backed up diffidently on a freeway entrance ramp as traffic on the freeway itself swooshes by at 60 mph.

Everyone agrees that there must be a better way. Virtually everyone agrees that electronic traffic control is the answer. But almost no two authorities agree on just what mix of available hardware—sensors, detectors, controllers, computers—can do the job best.

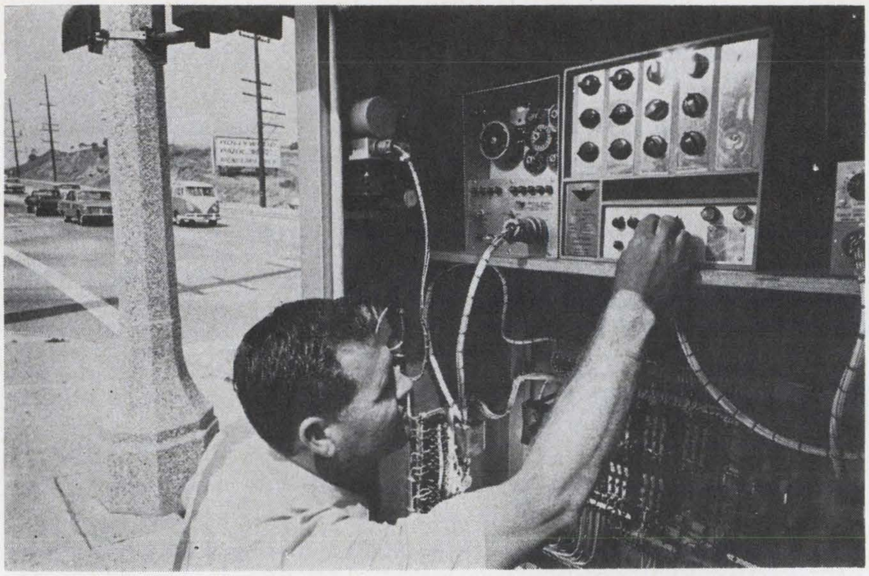


Eye of the storm. Bill Gemell of the Long Beach, Calif., traffic department checks one of city's four eight-year-old computers.

Better mousetraps. The people who design the equipment and those who buy it tend to operate on different wavelengths. The electronics engineers, in the words of one disgusted civil servant, "are obsessed with state of the art, with super-sensitive devices that can't be repaired by anyone who didn't go to MIT, and with the notion that money is no object." Adds another: "They seem to consider traffic control a nice little market for stuff that was designed to find out if there's life on Mars."

In fairness to the EE's, though, it's a rare traffic man who knows what's available and what he wants. One of those rare ones is Henry A. Barnes, New York's outspoken traffic commissioner. Not only does he know what's available and how it's being used around the world, but he also likes to talk about it.

"What the electronics industry needs," says Barnes, "is a system permitting cities to use their present street-corner controllers. Such a system should be modular, in increments of 100 intersections, to get the cost down to where smaller cities could afford the investment." And Barnes, still feisty after his un-



Man in the street. Long Beach's Don Riedel, traffic signal foreman, works on Eagle signal controller on Pacific Coast Highway.

happy, and much-headlined, three-year experience with the Sperry Rand Corp.'s Gyroscope division, is about to put his money where his mouth is: New York City plans to try out an International Business Machines Corp. system that incorporates controllers already installed on the city's corners.

I. Bumpy road

The Barnes-Sperry contretemps could well serve as the first chapter of a textbook on how not to do business with a municipal government. The $5.4 million contract, awarded in 1965 and canceled last January, was to be Sperry's entree into the traffic field; in fact, the company is believed to have underbid experienced competitors by more than $1 million because New York intended eventually to spend $100 million on traffic control. The key to the situation appears to be changes made by Sperry in the original specifications, changes Barnes feared would leave the city open to lawsuits from the unsuccessful bidders. Not only that, but delivery of hardware was running more than two years late. "They just couldn't get the stuff to work," says Barnes. He also insists some equipment that was delivered was shoddily made. He says that on one controller shown to him by Sperry, he was able to loosen 23 screws with his thumbnail.

A considerable amount of hardware was called for. There were 1,052 detectors (which determine the presence of a vehicle); 1,397 sensors (which determine vehicle speed and direction); 2,693 controllers; 10 zone computers; and one central computer. It all would have been used to control 2,693 intersections, or less than 400 of the city's 6,000 miles of street. The sensors were to have been doppler-radar affairs mounted 17 feet above the pavement and operating in the S-band at 2,455 megahertz. But none was ever delivered; Barnes says Sperry couldn't get them to measure speed properly. All of the 58 controllers delivered failed. "The company then said it couldn't service them," adds Barnes. The computers were to have been digital Univac 413's; these machines are modifications of the 418.

Stuck in traffic. Sperry Gyroscope spokesmen refuse to talk. Barnes is more than willing. He says that Sperry considered the order peanuts when stacked beside giant Federal contracts, and tended to take engineers off the New York job for reassignment to those more lucrative projects. Furthermore, Barnes maintains, the company's lack of experience in the traffic field stuck out like a red light and "top management" failed to exercise proper supervision. Even an 11th hour management shuffle failed to save the contract.

In the words of one man close to the situation, "What Barnes says is pretty much the way it was. It would be kind to say a nice word about Sperry's role, but it's difficult to think of one."

II. Keeping the motor running

Meanwhile, IBM, one of the unsuccessful bidders for the New York contract, kept working quietly on a traffic control system of its own. What has emerged is a picture of simplicity and economy: an off-the-shelf model 1800 computer that interfaces with existing street-corner controllers.

Go west. IBM got its feet wet in San Jose, Calif., [Electronics, Nov. 14, 1966, p. 221]. The system was installed in 1965 using a model 1710 computer contributed by the company, but the city has since purchased a faster 1800 for $200,000. Induction-loop sensors are imbedded in the pavement, setting up magnetic fields that are interrupted every time something metallic enters. Some of the loops are made by the Link group of the General Precision Systems Corp., some by RCA, and still others are homemade.

The computer, which can implement 128 timing patterns at each intersection, makes a total of six measurements.

Mecca. San Jose has become something of a star in the west for U.S. traffic men. They flock there to examine the traffic-control system in action and generally agree it's potentially one of the best around. Yet, many leave shaking their heads. The reason, in the words of one visitor: "Why don't they use the darned thing to control traffic? They kept showing me reams of statistics—numbers, numbers, numbers collected by the computer. They're so interested in proving that they saved the local drivers 1,500 seconds yesterday that they're ignoring the real reason the whole shebang exists."

The 1800 is so loaded down with engineering and statistical tasks that it's available for actual traffic control only a few hours a day. There appears to be disagreement within the traffic department on whether to control traffic or do research on traffic control.

In or over. The use in San Jose of buried loop detectors has contributed to an intrafraternity disagreement along the lines of buried vs. pole-mounted detectors. Backers of buried-loop devices say they're less likely to provide false measurements, are immune to weather, and are less expensive. The pole sitters insist that such devices—ultrasonic or radar—are easier to install and maintain, don't interfere with buried cables and lines, and are capable of wider coverage. New York's Barnes points out that most of his streets have no foundations and therefore shift constantly, and that it's ridiculous to tie up traffic while burying the loop inductors or digging them up later for repairs.

Still, the majority appears to favor the loop. The Philco-Ford Corp.'s WDL division in Palo Alto, Calif., is believed ready this summer to start selling a solid state loop, using metal oxide silicon integrated circuits. It's now being tested in Palo Alto and Oakland, Calif. However, Howard W. Carmack, assistant superintendent of Oakland's electrical department, feels that IC's are unnecessarily sophisticated for traffic controllers. Relays, he says, operate fast enough and aren't apt to go off half-cocked because of environmental noise.

The source. One can even get an argument that it's the computer, not the sensors and detectors, that counts in electronic traffic control. The man behind that argument, Oser I. Bermant of IBM, was also one of the men behind the San Jose installation.

His thesis is that problems arise when analog computers are used. Such machines, he maintains, can't tell when a sensor has gone wrong. Digital computers, on the other hand, can be programed to check each detector or sensor continuously; when a failure is noted the computer can correct it or signal for repairs. "Digital computers have changed the game," says Bermant. "They can offer flexibility, analysis, and economy."

While Bermant's view could be called part of his job, the rate at which IBM is convincing cities that the digital route is the way to go lends extra weight. Wichita Falls, Texas, has 57 intersections under 1800 control; Portland, Ore., will link 85 intersections with an 1800 later this year; and Austin, Texas, will hook up 48 intersections, to be expanded to 200, with an 1800 in the fall. And, adds Bermant, IBM is going after "quite a few" additional contracts.

The other fork. Despite IBM's success, many cities are skeptical about the efficacy of computers in

What the auto makers say

Car makers have not only thought about electronic vehicle controls, they have pioneered in them, in line with the industry philosophy that in order to remain competitive, it is necessary to have as much advance knowledge of market conditions as possible. In the case of science and technology, this means wading right in at the research stage.

General Motors. GM's Research Laboratories have had programs on development of "automatic highways" since 1956. Included in GM's 1965 experimental Firebird III prototype car was an electronic steering system. Called Autoguide, the system included two pickup coils suspended beneath the forward end. They picked up signals from a cable imbedded in the road. The signals were ciphered by a small inboard computer and the car's steering system was automatically actuated to keep it on course.

GM also has constructed and tested in miniature an automobile control system. Utilizing sunken highway cable, the system allows for automatic vehicle spacing, steering, and collision prevention—by slowing and, if necessary, stopping a car when it gets too close to one in front of it.

GM had an extensive program with RCA in 1959, which culminated in the construction of an experimental automatic highway system at the RCA labs in Princeton, N.J.

Last July, General Motors Research Laboratories received a $493,000

Follow me. Experimental Route Guidance System provides head-up display mounted on dashboard to give directions.

Federal contract to develop hardware for and evaluate a highway route guidance system. The contract called for:

- Experiments and instrumentation needed for an objective evaluation of route guidance.
- Practical hardware to investigate the feasibility and cost of a national routing system.

In line with the contract, GM has submitted plans for the hardware, supposed to be ready this June. The guidance system will work this way:

At the start of a trip, the driver dials his destination code into route guidance equipment inside the car. The vehicle automatically transmits the code to roadside equipment at key points enroute. After processing the code, the roadside equipment signals the driver by visual display or electronic voice inside the car, and gives him proper routing instructions.

Ford. A recently established Department of Transportation Research and Planning at the company will study all phases of vehicular activity as it relates to the over-all environment.

Foster Weldon, who heads the department, says Ford's programs are built around video readout computer simulation techniques using mathematical models of the various factors that make up urban areas—physical, social, political, and economic.

A complete specification of the components—decision options—of a transportation system is fed into a series of computerized models that calculate transportation supply and demand relationships, interpret pricing, and predict effects of the system on growth and form of the region. Among the transportation systems under study is automatic vehicle control.—**Vince Courtenay**

. . . but the City of Angels gave up, went back to the old timeclocks . . .

general and digital equipment in particular. One is Seattle. Robert Warr, senior traffic engineer for signal systems there, says: "The electronics industry has offered a lot of fancy systems no one knows how to run. Computers have their place, but sometimes using a computer to control traffic is like using a shotgun to kill a fly."

All the same, Seattle is spending about $100,000 a year on control equipment, the biggest project being conversion of 150 intersections in the central business district. That five-year program will be completed this year, with Automatic Signal, a division of Laboratory for Electronics Inc., the big supplier. Interestingly enough, Seattle's "shotgun" will be an analog machine.

Dallas Cooper, division superintendent of the Long Beach, Calif., Public Service department, has still another formula for success. "We've gotten pretty good results," he says, "because we've stayed with a proven system." That system includes four eight-year-old variable-frequency Eagle computers stuffed with vacuum tubes and loop detectors. There are four grids—the biggest involving 90 downtown signals—representing an investment of almost $500,000.

Land of Lincoln. Illinois is funding, designing, and installing systems on main expressways surrounding Chicago with 90% of the money coming from Washington.

The original test was on Chicago's Eisenhower Expressway in April, 1961, and it was considered operational in November 1967 when Illinois installed control equipment on Chicago's Dan Ryan Expressway.

The system in Chicago is controlled by a General Electric GE/PAC model 4040 process computer, a machine that was originally sold as a data logger.

Chicago's system uses loop sensors to count the traffic, converting the count into traffic density, and uses traffic densities to control signal lights that regulate traffic flowing down entrance ramps into the expressway.

Comprehensive. Perhaps the most completely computerized traffic control is in Baltimore. The system, installed by Henry Barnes when he was traffic commissioner there, is now 10 years old and involves around 850 intersections—some outside the city. Seven Automatic Signal tube-driven analog computers do the controlling, and a variety of detectors—radar, loop, pressure, and sonic—are on the job. Norbert Nitsch, assistant commissioner in charge of signal engineering, says the system works "exceptionally well." Evidence of this is the fact that the U. S. Bureau of Public Roads says the system moves traffic so well that an expressway isn't needed by the city.

III. Red light

In one large city, all signals for electronic traffic control aren't go. Los Angeles is unconvinced.

Los Angeles' attitude is particularly surprising in view of its almost total dependence on the automobile. But a 28-signal system on Sunset Blvd. was switched back to timeclocks after two years, and the same thing was done after two-year trials on three principal east-west arteries—Wilshire Blvd., Olympic Blvd., and Sixth St. Says William Hutchinson, assistant city traffic engineer: "Recordings of traffic patterns at peak hours on those streets indicated they were predictable to the extent that we could rely on timeclocks."

Los Angeles used a TRW computer and peripheral sensing equipment. "The difficulty with the computer," says Hutchinson, "was that it would change the operational mode (signal patterns for the main artery as well as all cross streets) on the basis of what we would consider insufficient evidence. For example, during peak conditions the timing could be changed as often as every four or five minutes merely because a disproportionate amount of vehicles passed a particular point at a particular time."

IV. The searchers

Past, as historians like to point out, is prologue; no one knows this better than engineers—traffic and electronic. So even as they argue gently about sensors, computers, and timeclocks, they are driving hard at test tracks and laboratories to make the future safer for mind and body of the Average American Motorist in his 400-horsepower Gaseater with the padded dashboard.

Detroit is the home of the National Proving Ground for Freeway Surveillance Control and Electronic Traffic Aids, which has tested various electronic traffic apparatus and systems since 1962.

The testing ground, a section of the John Lodge Freeway, is supported by the state of Michigan, Wayne County, city of Detroit, U.S. Bureau of Public Roads, and 13 other states.

Not here. In the 3.2-mile test stretch, traffic is directed by indicators above lanes that tell whether or not the lane should be used with either a red X or a green arrow. In conjunction with the lane signals, there is an electric signal board that indicates vehicular speed requirements for optimum traffic flow and safety.

Input data is gathered by closed circuit television cameras and ultrasonic sensors mounted on 14 freeway overpass bridges. The cameras provide ramp-to-ramp surveillance, and feed into a console bank of receivers at Proving Ground headquarters. All cameras are General Electric TE9 systems that span 30° left and right, have full tilt arc, and telephoto lens. Cost, including installation, came to $10,000 per camera.

The sensors, made by the General Signal Co., bounce a pulse from the freeway. The return pulse is picked up and transmitted to a Control Data Corp. 8090 computer, which can assess vehicle count and speed with an accuracy of ±20%.

Proving Ground engineers seek better detectors that will provide finer vehicle speed and count data. They suggest that doppler radar or light scan systems could be developed.

Reporting for this article was provided by Walter Barney and Peter Vogel in San Francisco, Bill Bell in Los Angeles, Ray Bloomberg in Seattle, Robin Carlson in Boston, Vince Courtenay in Detroit, Bruce Cross in Chicago, Barbara Koval in Pittsburgh, Bob Skole in Washington, and Mike Payne in London.

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Simulators go to the head of the class

Airlines find electronic teachers cheaper, safer, and better than flight training, and will need more as new planes arrive

By Paul A. Dickson
Washington regional editor

During recent weeks, air carriers have been making what amount to mass purchases of the airbuses to be built by the Lockheed Aircraft Corp. and the McDonnell Douglas Corp. Eastern, Trans World Airlines, Delta, Northeast, and Great Britain's Airholding Ltd. have all signed up for L1011's or DC-10's.

But Lockheed and McDonnell Douglas aren't alone in their good fortune; producers of electronic simulators and visual aids also stand to benefit. For airlines are increasingly anxious to bring their flight-crew training down to earth.

For one thing, the skies are getting more crowded. For another, even more complex aircraft like the supersonic transport and the Boeing 747 are on the horizon. As a result, airlines are becoming more concerned about how to train their crews safely. Many now consider electronic simulators with realistic visual displays the most practical solution.

I. Safer, cheaper, and better

At a recent meeting of airline training officers in Washington, simulators versus in-flight training was a hot topic. Officials from a dozen or so carriers agreed that safety was the main argument for simulators, but the machines have lots of other advantages:

- Economy. The estimated cost of an hour's training in a 747 is more than $2,000. An hour in a simulator costs only a small fraction of this and doesn't result in loss of passenger revenues.
- Results. "We can let a man do and learn things on the ground that he could never try in the air," says one official. And Frank Petee, the training manager at Allegheny Airlines, says, "In the case of a carrier like ours it isn't necessarily cheaper to use a simulator, but we rule out this factor because we feel they do a better job."
- Convenience. Flight crews can be ushered in and out of simulators around the clock without the red tape of flight clearances and other airport procedures.

Airlines are willing to pick up the first-class fares electronic firms are asking for sophisticated training devices. Over-all, U. S. airlines now have 56 simulators representing an investment of $65 million to $70 million. Most of these machines have been installed in the past five years. Before 1970, the carriers are expected to double their total investment by buying another 35 simulators. The new units will cost an average of $2.5 million. General-aviation customers and overseas carriers will push the total market close to $100 million.

Value added. Furthermore, the advanced simulators will channel more money into other electronic training aids. For example, Pan American World Airways is thinking about using relatively simple procedural trainers controlled by a computer. The system would be used to prepare crews for a Boeing 747 simulator.

Although there are no projections for after 1970, there is every reason to believe that the market will continue to expand. A spokesman for the Air Transport Association sees two factors bolstering the upward trend: "The airlines are now becoming more and more dependent on simulators, and sales are tied to aircraft purchases, which are rising."

One manufacturer points out that in 1960 airlines might have had only one simulator apiece but are now averaging one for every 15 to 20 aircraft. The number of simulators could rise to one for every 10 to 15 aircraft when the 747 goes

Stand-ins

While airlines are getting ready to buy computer-controlled simulators, a complementary airborne scheme is also attracting attention.

The so-called stand-in simulator is a smaller aircraft rigged up to act like a larger one. Cornell Aeronautical Laboratories Inc., working under an Air Force contract, is modifying a Convair C-131 to give it the flight characteristics of much larger planes like the giant C-5A or the supersonic transport.

In the Cornell program, dubbed TIFS for total in-flight simulator, an extra cockpit is installed in the front of the Convair for the trainees. The existing cockpit is manned by two "safety pilots" who will take control in an emergency. An airborne computer, programed with the characteristics of the larger aircraft, figures out how the smaller craft should act. Servos then drive flaps and other control surfaces to give the effect of the larger plane.

Cornell recently agreed to give commercial rights to the TIFS system to Aero Spacelines, a subsidiary of Unexcelled Inc. A spokesman for the company predicts sales of about 20 TIFS-type aircraft by 1972.

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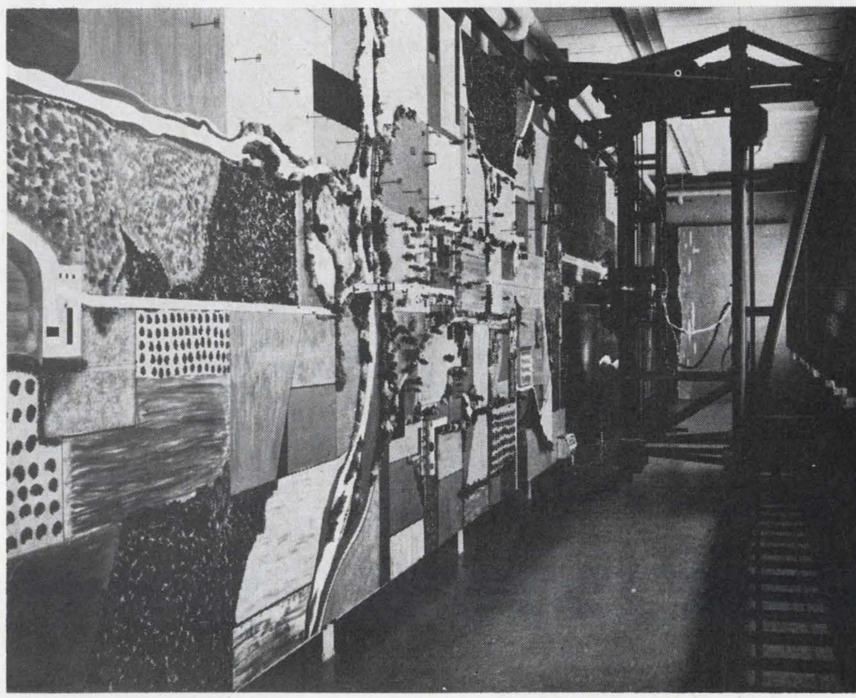


Truth in landing. The scale model of an airport runway looks like the real thing when viewed by TWA flight crews duplicating landings and takeoffs in simulator. Carriers are pushing for even better displays.

into full service. United Air Lines' experience at its flight training center in Denver typifies the carriers' new dependence on simulators. United, which now has 17 simulators, will receive another this month and has five on order: a Boeing 747 unit from the Link Group of the General Precision Equipment Corp. (with an option for another), two 747 simulators, a DC-8 machine, and a Boeing 727 unit from the Conductron Corp. Within a month United will select a visual system for the 747 machines from one of six competing firms. Herb Monroe, director of United's simulator division, says, "The visual system may be used with two or three existing simulators like the 727 or DC-8 units."

Monroe notes that the Denver center has already made room for a Concorde SST simulator and that by the end of the year contract requirements will have been defined.

Overtime. The center is using its simulators from 6:00 a.m. to midnight; the wee hours are reserved for maintenance. A United pilot now gets about 80% of his training in simulators.

The story is much the same at Pan Am. The line now has eight simulators at three training sites and will soon add a 747 simulator from Conductron to its facility at Kennedy International Airport in New York. Pan Am is now shopping for a visual system to supplement the 747 unit, and is considering adding visual aids to its older simulators. William Angleman, senior flight instructor, says the company is using its facility seven days a week, with only a few hours out for maintenance. Similar conditions prevail at other airlines.

II. Sight unseen

Although the market for simulators is maturing, the airlines are also getting more demanding. They're seeking more realism in the simulator cockpit and in the sound systems. However, the consensus is that the most pressing need is for better visual systems.

The airlines want improved visual training aids and have banded together to present their demands. Under the aegis of the ATA, eight lines have set up a committee and compiled a list of requirements for today's simulators and those to be developed for the SST and other advanced aircraft. Among the needs cited in a report issued earlier this year were visual representation of yaw and pitch and depiction of landing variables, such as engine reversing and braking. The committee would also like depiction of such operations as taxiing, docking, and circling.

The group requires a minimum field of view of 60° and has established specifications for resolution of the display.

Critics. The chairman of the ATA's training committee, John A. Walker, a Pan Am pilot, says: "Our ultimate goal is to do all flight training in simulators." However, there are only six visual systems for the 56 simulators now owned by the airlines.

Walter A. Moran, director of flight training at American Airlines, says existing visual simulators are "quite limited in terms of replacing the real world."

Deficiencies of the visual simulators are, then, the real stumbling block in making the simulator a total trainer for the airlines. And the problems are compounded by the lines' refusal to underwrite research and development in this area. Says one airline official, "An airline R&D program is called a purchase order."

Side order. About half a dozen firms are making visual systems, usually sold independently of the simulator. Systems cost from $250,000 to more than $800,000; the most expensive comes from the Dalto Electronics Corp. The company's equipment is currently the only visual system being ordered by an airline; TWA has contracted for a model 4000 wide-angle visual flight simulator.

Dalto has supplied visual simulation gear for such customers as Lockheed, NASA, the General Dynamics Corp., the Air Force, and the Navy. Robert Friedman, vice president and general manager, predicts a market for 40 visual systems among five major airlines alone during the next two years. These would be for existing and new simulators. Friedman says he expects Eastern, American, and Pan Am to announce purchases of Dalto equipment soon.

With interest now centering on visual simulation, several types of systems are competing:

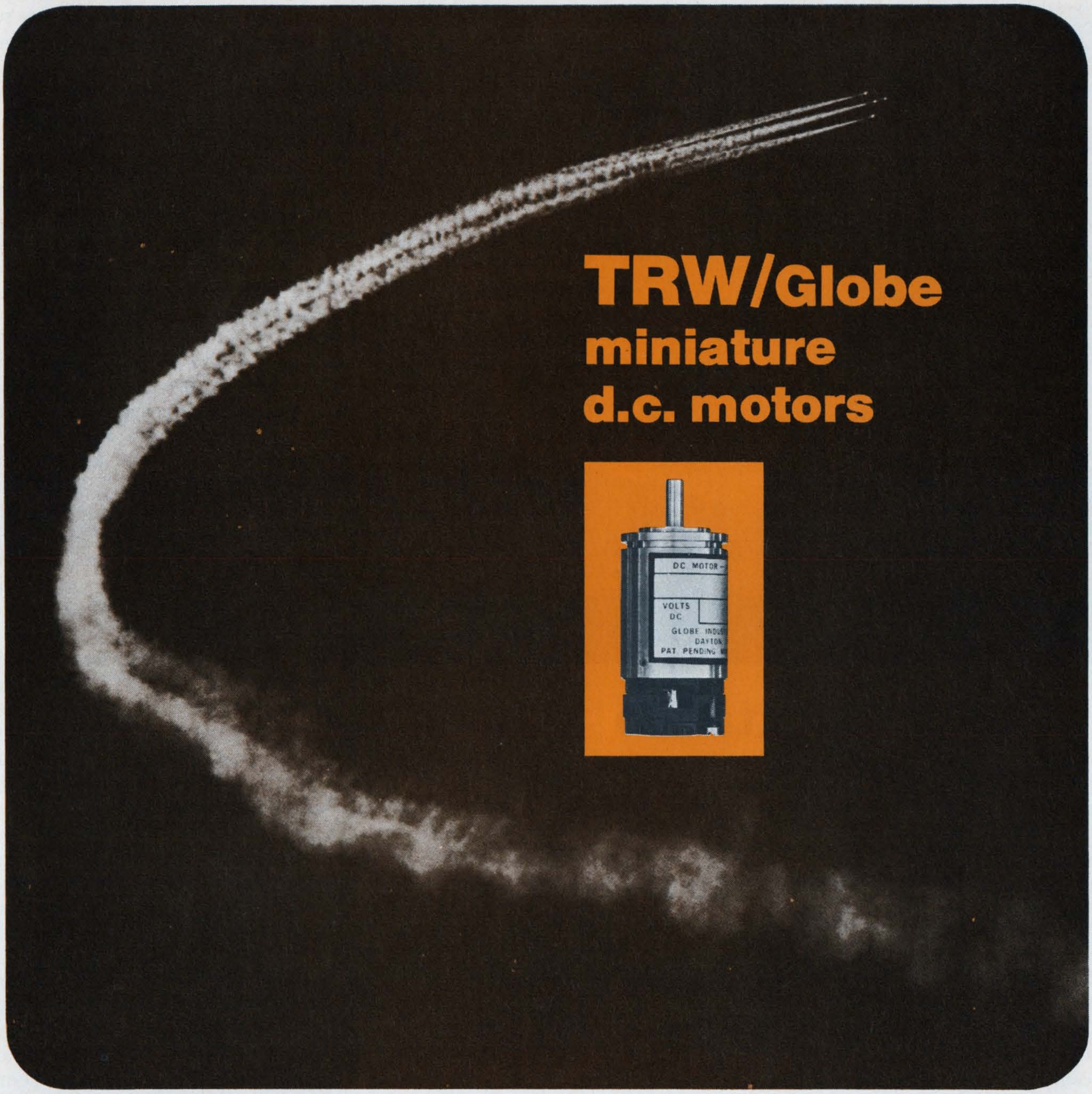
- Dalto's DEC 4000. A high-resolution, closed-circuit, color television system whose camera follows the pilot's maneuvers as its scans a terrain model of a typical airport and its surroundings. The camera has a single wide-angle lens that picks up the image from the terrain model. The image is relayed into four identical window channels via a beam splitter in the camera. Each channel contains an image corresponding to the perspective that would be seen from a cockpit. Four high-resolution orthicon cameras scan the images to provide a four-window display in the simulator cockpit. The system presents such variables as takeoff, approach, landing, taxiing, circling, and terminal parking.
- Link's variable anamorphic motion picture (VAMP) system. It uses 70-millimeter Todd-AO color motion picture film for training pilots in takeoffs and landings under limited visibility. The film is made in the course of flying an ideal pattern. Desired visibility conditions are added during processing. The system uses an anamorphic lens—one with greater magnification in one axis than in another—driven by a servo attached to the student's controls. If the student veers to the right of the proper landing path, the view of the runway appears as it would if he had made the error in flight. The Air Force will buy the first VAMP for use with an F4F simulator. Link offers the system as an option with its simulators for $265,000.
- Conductron has a wide-angle optical system with map models of the ground or airport terrain made of photographic transparencies. The transparencies are spliced together in continuous belts approximately 12 feet wide by 52 feet long. Altitude changes are depicted by use of a zoom lens.

Tilt. New generation of simulators like this one from Link have double the number of axes of motion freedom.

III. Dynamic Duo

There are more than a score of firms in the simulator business. But the commercial airline aircraft sector is still dominated by Link, which supplied 36 of the 56 machines now in service. The runner-up, the Curtiss-Wright Corp., has provided nine analog systems. Of the dozen simulators now on order by the airlines, about half will come from Link and the rest from Conductron.

Both companies are now using general-purpose rather than special-purpose computers in their simulators because their assignments are getting so complex. In the 727 units, 120 discrete and 40



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variable failures had to be programed; the 747 simulators will have about 1,000 programed malfunctions.

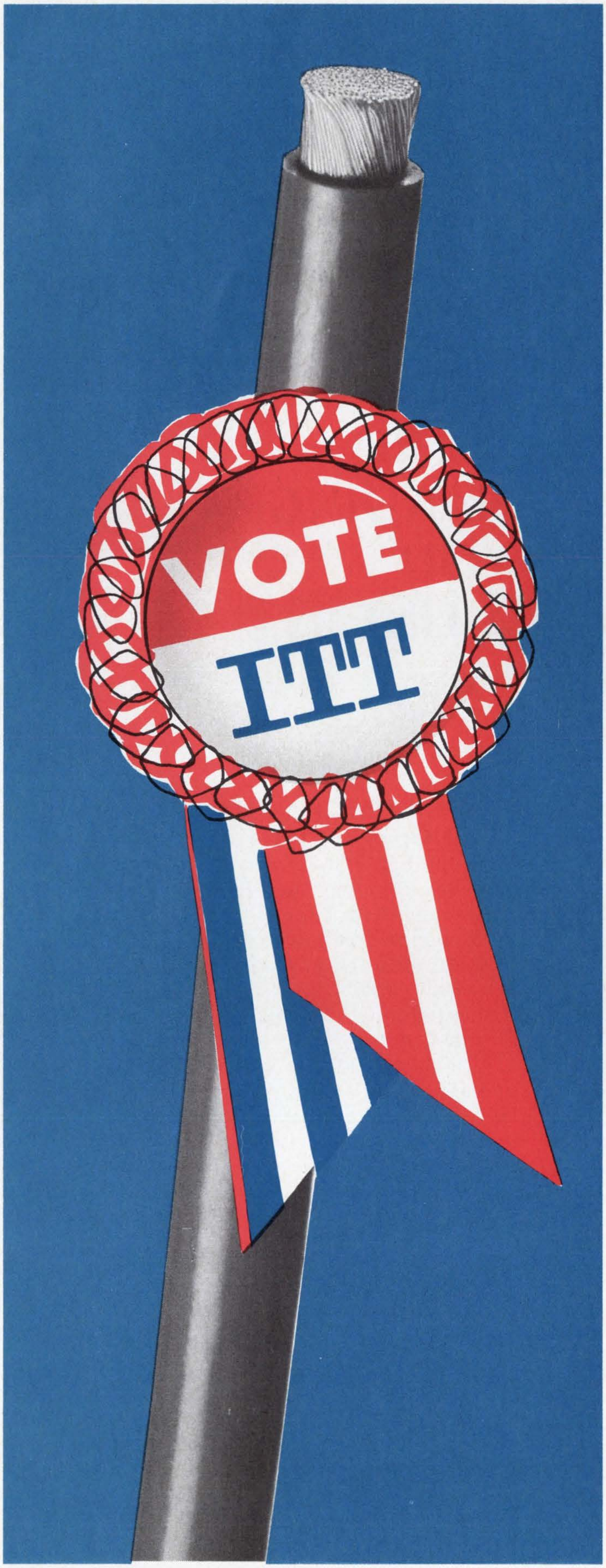
Link is using Scientific Data Systems Inc.'s Sigma 5 computer in the 747 simulators and Conductron is using Honeywell Inc.'s DDP-324 machine for its 747 orders. Thomas R. Bristow, assistant director of advanced trainers and simulators of Conductron's Missouri division, points out that the switch to a general-purpose computer allows a company to specify the best machines available and use manufacturer-supplied software. Software includes assembly programs and debugging routines as well as Fortran programs for updating the simulation program.

Link and Conductron are providing six axes in their 747 simulators double those of their 707 and DC-8 units. The gain will permit aircraft motion to be simulated with greater realism.

The greater complexity of the 747 and the SST will arise from more control surfaces, for example, as well as more radio and navigation aids. All this requires not only greater computer capacity but also more interfacing circuitry and subsystems.

Customer's men. Both Link and Conductron would like to mass-produce simulators. But they find that it's impossible because of the equipment differences from airline to airline. Each carrier will wind up with a custom-designed unit. The same is true for visual attachments. Dalto's Friedman notes, "Everybody is asking for something entirely different, but that's the nature of this business and it will probably never change."

Monitor. The Federal Aviation Administration, which must qualify simulators to replace in-flight training, is all for the greater use of such systems. "We believe in them and encourage their maximum use," says Ralph Noltemeier, chief of the agency's flight technical program in the flight standards division. "Theoretically, it's possible to achieve a one-to-one transfer between the real world and the world of the simulator." But he points out that this depends on the development of motion cues in the simulator and on the visual attachments.



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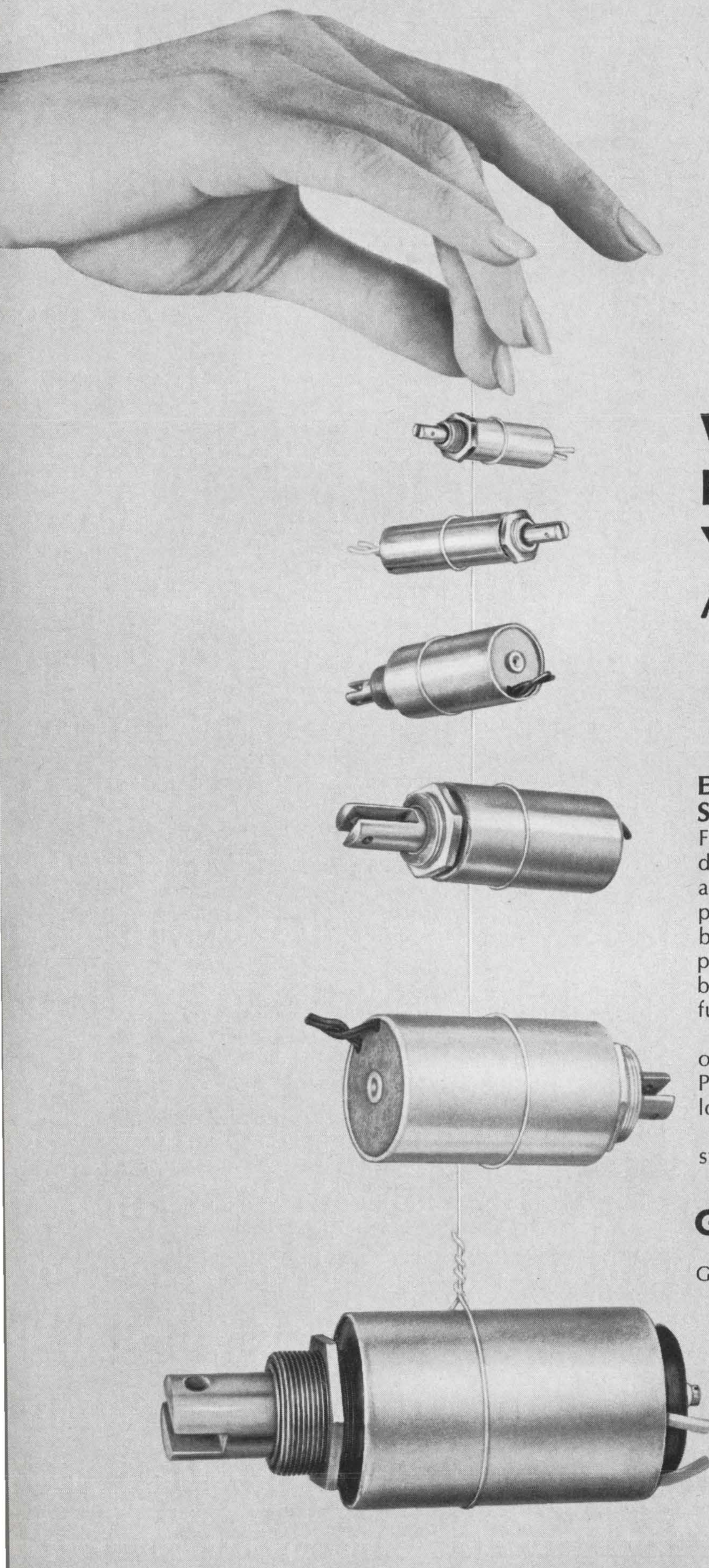

Navy drafts standard hardware

Service is using uniform electronic modules for fire-control system of Poseidon missile to relieve maintenance and logistics problems

Military commanders in the field—beset by the logistics and maintenance problems involved in using electronic equipment of varying age, condition, and complexity—pray often for standardization. However, designers are apostles of change, anxious to usher in improvements as quickly as they clear the laboratory.

In an effort to reconcile the divergent and parochial interests of both groups as efficiently as possible, the Navy's Special Projects Office is going at flank speed on a standard hardware program (SHP).

Number one. The Poseidon missile will be the first major project affected [Electronics, May 1, 1967, p. 35]. Initially, the program which is designed to standardize modular building blocks without sacrificing flexibility in circuit design will zero in on the missile's Mark 88 fire-control system.

The General Electric Co.'s Ordnance department at Pittsfield, Mass., is building the Mark 88 for the 31 submarines that will carry the Poseidon. The fire-control system on each craft will have about 16,000 electronics modules, some 5,000 of which will be made to SHP specifications. If all goes well, many other Navy projects will eventually adopt standard hardware.

I. Means to an end

What the Navy hopes to have when the Mark 88 goes operational in the early 1970's is a design so versatile that technological innovations can be incorporated at any point in the system's life. To achieve this, the physical and functional characteristics of the modules are standardized. However, the circuitry can evolve right along with technological developments. "I don't care whether vendors stuff a vacuum tube or a large-scale array inside, so long as the package does what it's supposed to," says a staff engineer at the Special Projects Office. "All we want to specify is what the module must do and how it fits into the system."

In addition to keeping weapons systems up to date technically, the principal advantage of the standard hardware program is ease of maintenance. In most cases defective modules will simply be replaced by plug-in units that are physically identical.

Complications. Feathering the Navy's nest is proving to be a complex task for vendors. Notwithstanding the Special Project Office's boast about dealers' choice on circuitry, the rigid reliability requirements effectively dictate that advanced solid state technology be applied. So far, most of the modules have been hybrid arrangements with both integrated circuits and discrete devices.

In developing the standard hardware program, the Navy has selected 136 electronic functions it considers widely applicable. Another 16 are under study and may well wind up in the Mark 88. An estimated two-thirds of the selected functions could be applied in other systems.

An electronic function is Navy jargon for a module's job assignment within the system. The possible variations are virtually limitless. Among other items in the Mark 88, there are: an isolation module with 19 direct-through connections; a 15-

The long and the short of it. Poseidon missile at right is slated to replace the Polaris in 31 of the Navy's submarines. System will have Mark 88 fire-control gear incorporating 5,000 standard hardware modules.

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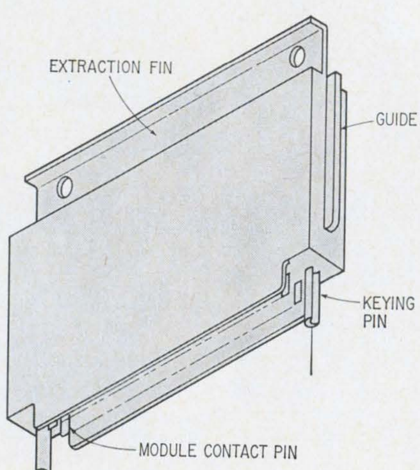
volt capacitor module; and a transformer module.

II. Second sources

Because of the volume lots involved, an ancillary advantage of standard hardware is that the Navy gets bids on modules from more vendors than usual. At the moment, 19 firms that are a cross-section of the electronic industry are qualified to build modules for the Mark 88. Thus, the isolation module that was developed by the Control Data Corp., Minneapolis, Minn., is also supplied by GE. Similarly, a diode unit developed by GE is also turned out by Globe-Union Inc., Milwaukee, Wisc., and Texas Instruments Incorporated, Dallas, Texas.

To become qualified to participate in the program, a company must first bid for a particular contract. Under such agreements, the firm is given a free hand on internal design. Reliability, performance, and packaging specifications are the only constraints.

Suppliers do a lot of reliability testing, including burn-in, on their own. After production, a number of units are picked at random for shipment to the Naval Ammunition Depot in Crane, Ind. Here, they are subjected to exhaustive environmental checks. Suppliers whose output passes these tests automatically become qualified bidders. However, should a spot check reveal deficiencies at any time, ven-



Starting point. The basic module in the Navy's standard hardware program measures 2.62 by 1.95 by .29 inches.

dors are knocked off the list. Getting back on involves repeating the original routine.

Double standard. In an effort to cut paperwork, the Navy decided to set only two environmental standards for modules. Class 1 covers temperatures from 0° to 60° C; in Class 2, the range is from —40° to 100° C. Modules are judged on their capacity to stand up under varying conditions of temperature, humidity, shock and vibration. For example, modules in both classes must be able to withstand a high degree of relative humidity at 44° C for 96 hours. Likewise, units must be able to take one-half sine pulse of shock for 11 milliseconds at 50 G's.

The Navy expects that competition will reduce the price of modules. So far, however, this has not been so. One standard logic module, for example, is now going for $50 a shot. Officials hope an "acceptable" level will be reached this year when bids for the production contract are received. While they're not talking about what they consider acceptable—for fear of influencing prospective bidders—a $5 price tag would appear to be in the ball park.

Commenting on the standard hardware program, an industry spokesman says: "Most companies will go for the concept but not without some reservations and nervousness. The idea is still new to them, and while it sounds good, there's a lot of skepticism." This source notes that electronic outfits realize that maintenance and logistics as well as responsiveness to changes in the state of the art are increasingly crucial concerns of the military services. He speculates that with the Pentagon enforcing functional modularity, it will eventually prove advantageous to apply such techniques in commercial hardware.

But not everyone views the standard hardware program as a millenium. "It sounds rather like the Navy's trying to make the industry into a job shop," says a source at a subcontractor on the Poseidon program.

Eventually, the Navy should be able to reach its low-cost goals because—in theory at least—vendors turning out standard hardware should be able to keep their lines open for longer runs. This factor

. . . the Navy wants to increase the number of throwaway modules . . .

should reduce outlays for tooling, training, and related items. However, much will depend on just how many big programs are brought under the standard umbrella as well as on how much interchange proves practicable.

New home. Engineers at the Special Projects Office are optimistic about expanding the number of applications for standard hardware. And they are specifying that modules be used in several of the Poseidon's automatic fault-finding equipment and test sets to reduce the logistics base still further.

Officials in charge of two other big Navy programs plan to incorporate standard hardware modules. These programs are the Walleye air-to-ground missile system and the AN/BSQ-13 Sonar. Other designers, particularly those working on avionics and astronautics projects, are considered likely converts.

III. Missionary work

Navy engineers are confident other systems designers will be enlisted, citing these attractive advantages of standard hardware:

- Because of Navy assistance and

Third-generation fire control

The Mark 88 fire-control system has many complex assignments. It keeps the 16 Poseidon missiles carried by the submarine ready for launch, and stands by to feed in up-to-the-minute target data. Complicating the system's mission is the fact that each missile has a number—probably eight—of independently targetable nuclear warheads with total firepower equivalent to 20 million tons of TNT for lift off to areas as far as 5,000 miles away. In addition, the system must be failsafe and so encoded that it can be actuated only on the direct orders of the President. Finally, the Mark 88 must operate reliably in the hostile environment of the oceans' depths.

The Poseidon's Mark 88 fire-control system is being built by the General Electric Co.'s Ordnance department under a subcontract from the Lockheed Missile and Space Co., the prime contractor.

Number three. The Mark 88 is a third-generation fleet ballistic missile fire-control system. General Electric also built the Mark 80 for the early Polaris subs. The design of this equipment was an analog/digital arrangement and the gear was used in only 10 subs. The Mark 84, also made by GE, came next. It is basically a digital system.

The Mark 88, now in advanced design phase, will first be installed on the USS James Madison in 1969. Then 30 more of the subs now carrying the Polaris will be equipped with the Poseidon and will have Mark 88's installed during regular shipyard visits.

The entire Poseidon program is costing the Navy more than $2 billion. In addition to the improved missile and the Mark 88, the system will carry new navigation gear.

In addition to its primary duties, the Mark 88 will compute missile motion at the time of launching, translate all data inputs to the missile, align the guidance system in azimuth, and set the missile's guidance timing.

Versatile. The multiple-targeting capability is the main operating distinction between the Mark 84 and the Mark 88. This capacity requires higher speed and accuracy in the digital geoballistic computer for targeting and target flexibility. This is provided by the rapid insertion of new target data and assignments into the guidance computer.

A fully automatic control system will prepare the missile for launching. The firing console will contain logic circuits that will initiate each launch step in sequence after the "Go Code" is fed in.

The entire firing sequence can be activated by pushing a button. During the firing sequence the control system will automatically check each missile's readiness. If a missile is faulty, it will be bypassed and the sequence continued. The operator can intervene manually at any point in the automatic sequence.

Four New Babcock Relays

BR42	BR30	BR24	BR26
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• Single-Coil	• Single-Coil	• Single Coil	• Single-Coil
• Universal Contacts	• All-Welded	• Universal Contacts	• Universal Contacts
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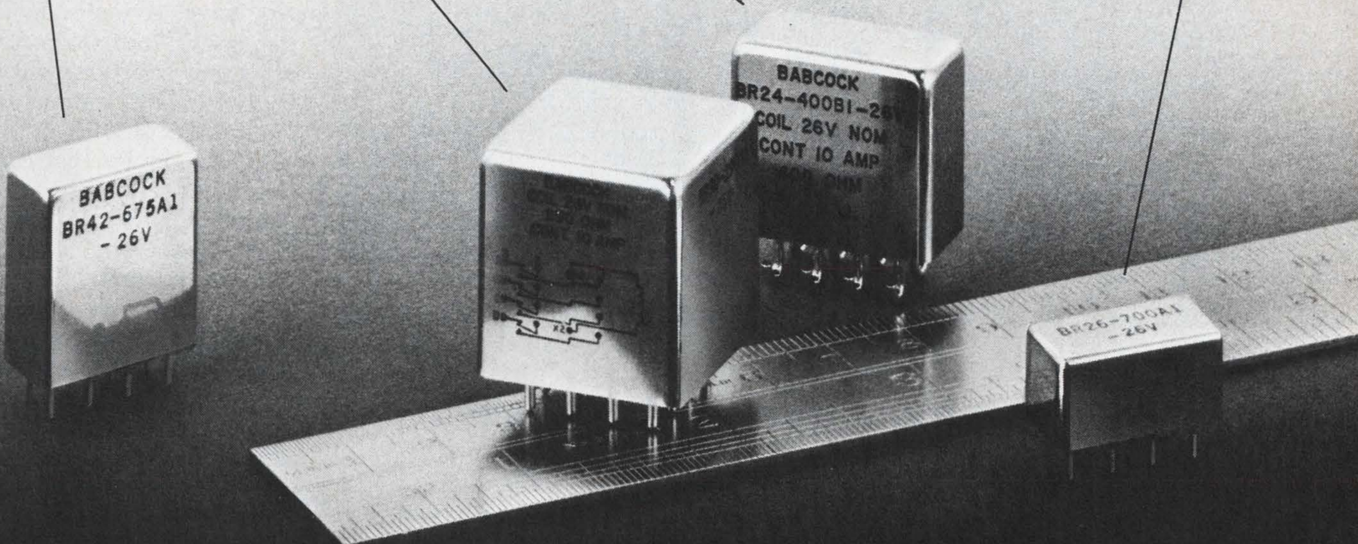

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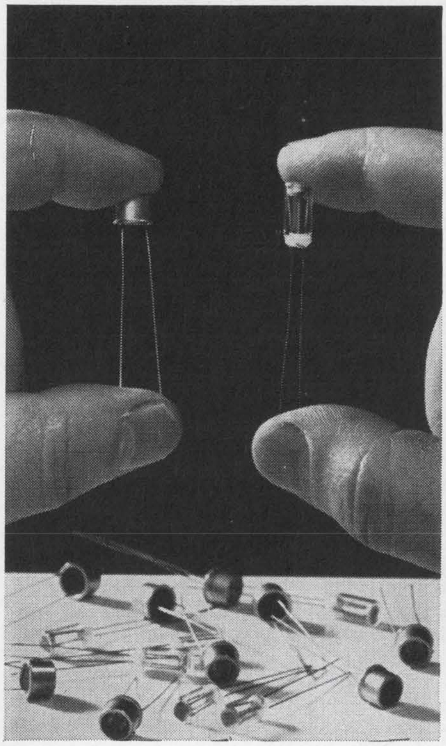
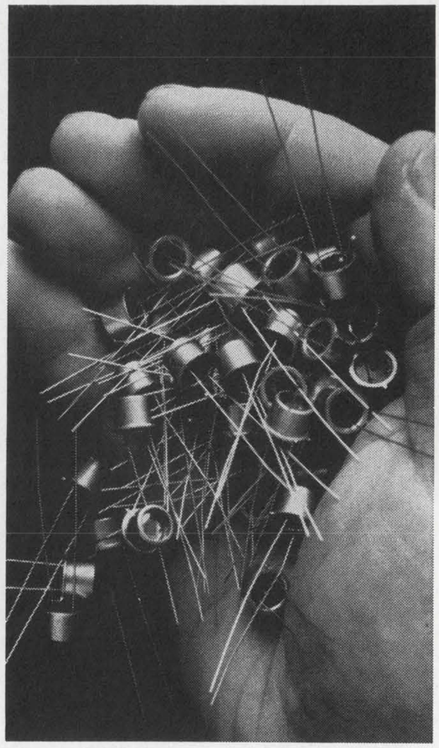
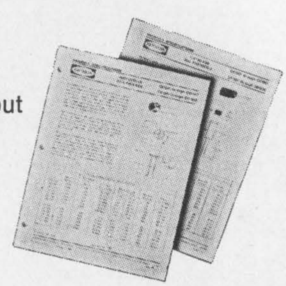





the single-minded nature of the modules, development costs are relatively low.

▪ Design and test documentation are uniform; mechanical and electrical interfaces are standard.

▪ Potentially, there are broad applications for most modules.

Throwaways. Navy engineers are preoccupied with upping the number of modules that can be jettisoned rather than repaired when they fail. To this end, the Special Projects Office worked closely with the Naval Avionics Facility in Indianapolis, Ind., to determine which electronic functions lent themselves to broad applications—and hence standardization.

Only modules that can be specified by function are taken into the standard hardware program. Units thus chosen are generally considered nonrepairable. In cases where a custom module is required, it is thrown into a design-disclosed category. When this happens, the supplier must furnish detailed information on all components so the module can be repaired should the need arise. The Navy has also established a special category for modules equivalent to the standard throwaways but lacking applications outside the system for which they are designed. Depending on cost data that remain to be developed, such units may or may not be thrown away when they fail.

An important element in standard hardware's versatility is the design of the module. After a great deal of study, the Navy decided on a basic size: 2.62 inches wide, 1.95 inches high, and .29 inches thick. Height is not a variable, but width and thickness can be increased in increments of 3.0 and .3 inches, respectively.

Components like transformers for power-supply modules sometimes lead to deviations from the basic configuration. In such cases, design waivers are granted for thickness.

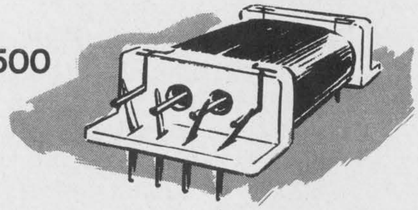
Lockout. A variety of key pins are used to prevent a module's being plugged into the wrong spot. For example, a delta arrangement would effectively preclude a unit's being jammed into a female receptacle with half delta guides.

A basic module width has 40 male contacts arranged in two rows. Contacts are spaced one-tenth of an inch apart in the grid pattern.

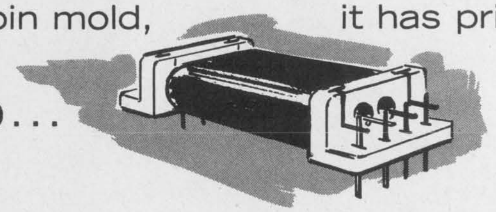
Cold weld, encapsulation system built for Western Electric, seals 1000 crystals in every 8-hour shift; pump-down, 37 sec. to 10^{-7} Torr; full cycle <75 sec.

At last... VERSATILITY in a reed relay

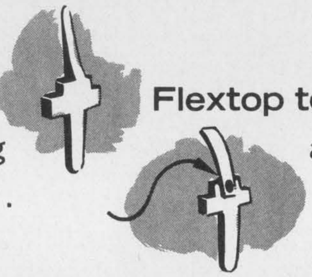
The Series 3500 has printed circuit board mounting terminals... on 1 inch x .100 inch centers.



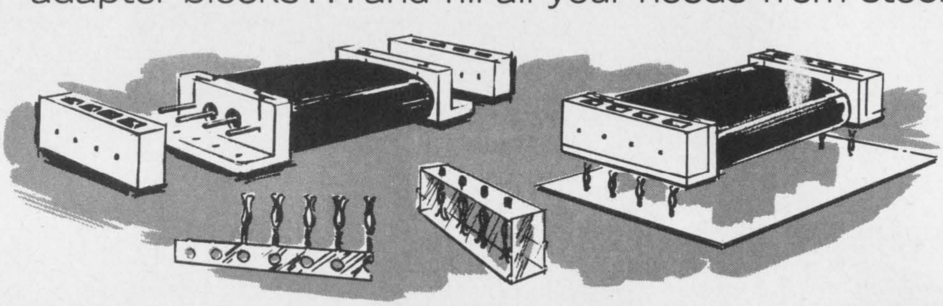
... or, when we slide a plate into our bobbin mold, it has printed circuit board mounting pins on 1 inch x .150 inch centers and is called **Series 3600**...



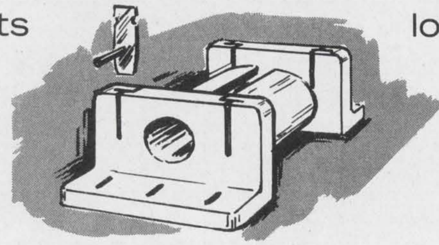
Both versions use our new **Flextop terminal** to give stress-free reed assembly without requiring an intermediate nickel "ribbon" strip and its extra welds...



But, when you need a relay that plugs in and out without fuss, or just want an independent source for Berg Pin mounted relays, we add adapter blocks... and fill all your needs from stock!



Either way you get a big bore bobbin that holds even the largest "miniature" reeds without sacrificing its low .350 inch profile, and unique fully recessed coil terminals that eliminate exposed magnet wire and intermediate coil leads.



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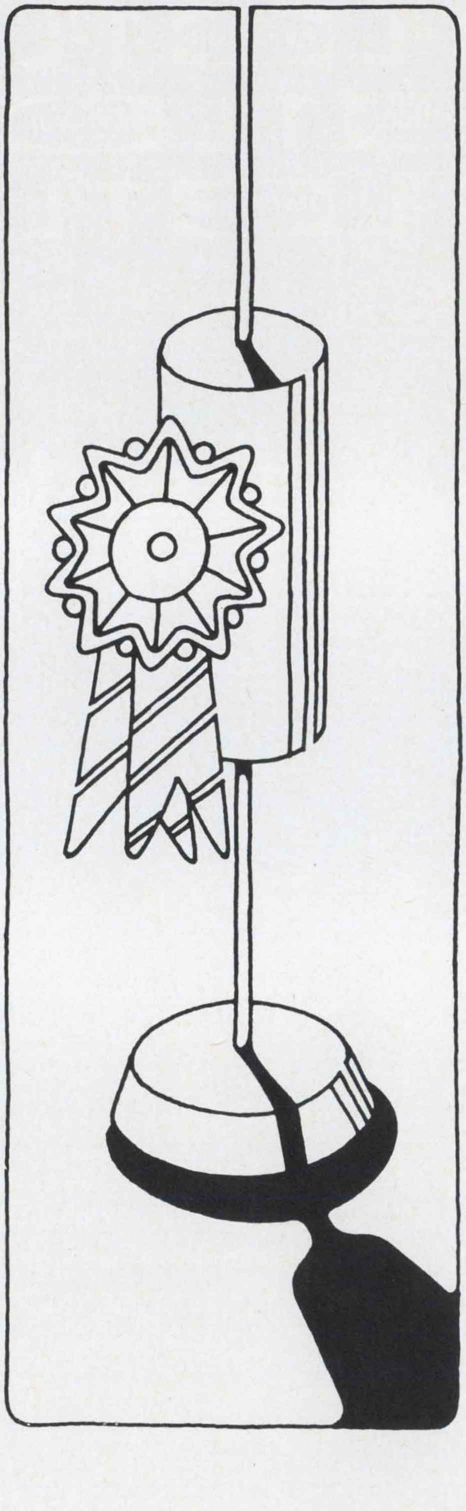

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2×10^{-11} stnd dev/yr
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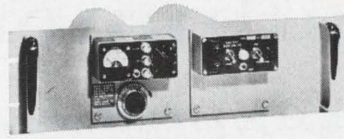

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5 to 0.1 MHz
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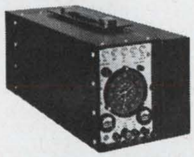

PORTABLE RUBIDIUM ATOMIC CLOCKS
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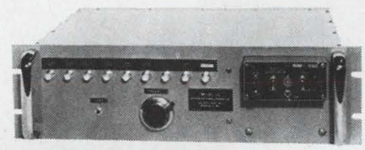

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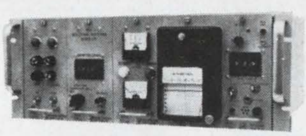

VLF TRACKING RECEIVER/COMPARATORS
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LINEAR PHASE/TIME COMPARATOR
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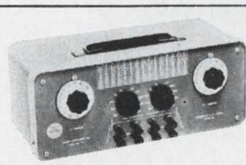

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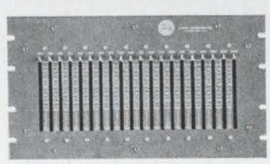

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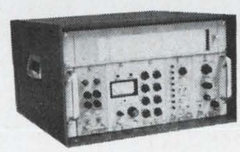

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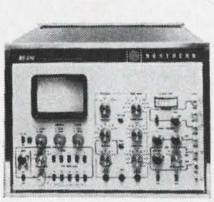

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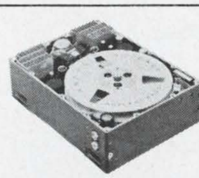

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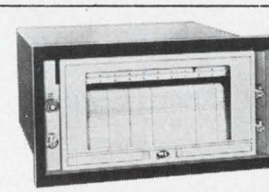

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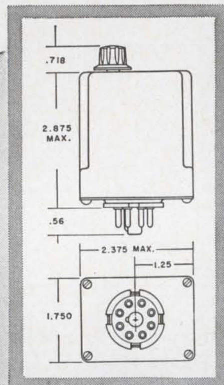

Sound an alarm, start or stop a motor, activate or cut off a system automatically with P&B's new series of voltage sensors. A sensitive solid state circuit "reads" changes in voltage. Over or under voltage deviations greater than predetermined levels cause an internal relay to operate . . . in 25 ms or less. Drop-out or pick-up is positive, and loads of 3 amperes at 120V AC resistive can be switched.

Three types are available: one with adjustable pick-up and drop-out; one with fixed pick-up and adjustable drop-out; one with fixed settings for both pick-up and drop-out. All models are available for either AC or DC operation. All have octal plugs.

Single lot prices for standard models, available from leading electronic parts distributors, range from $22.70 to $32.50. Today, call your P&B representative for complete information.

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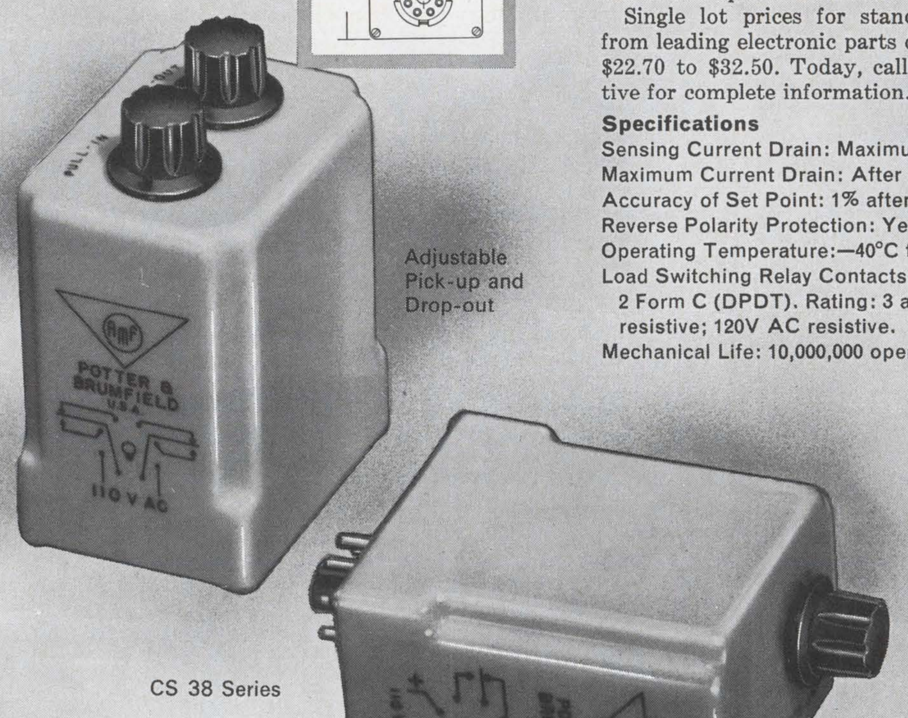

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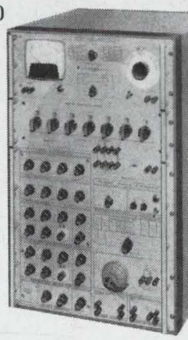

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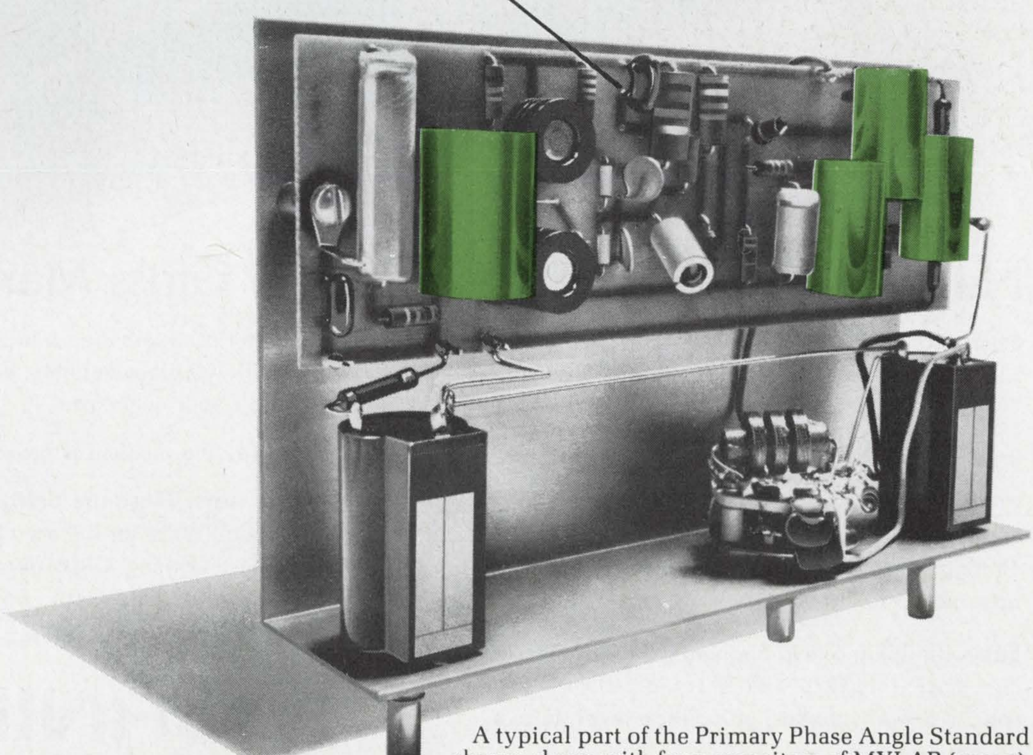

A typical part of the Primary Phase Angle Standard shown above with four capacitors of MYLAR (green).

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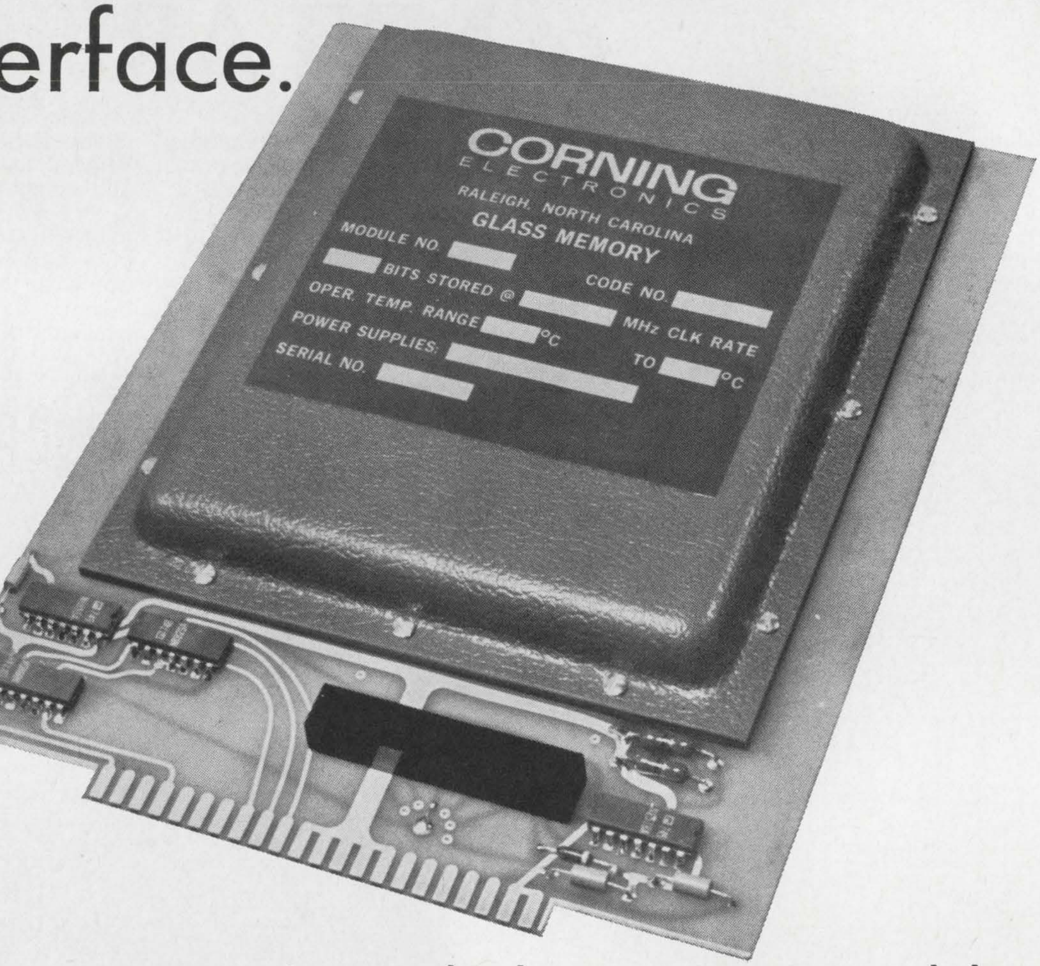

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Fast

Available Frequencies	Available Delay Time 64 μsec.	128 μsec.	256 μsec.
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Circle 189 on reader service card

VOL. I
ISSUE XVI

DCL Bulletin

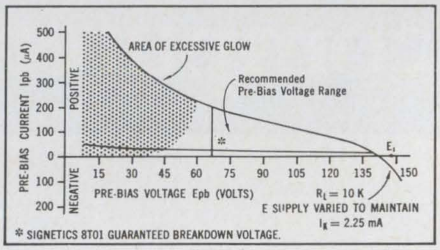
WHETHER or not you use Designer's Choice Logic, you have to admit that Signetics' idea of guaranteeing cross-family compatibility in integrated circuits can save you time and money in design.

PUBLISHED BY SIGNETICS: THE RESPONSE/ABILITY COMPANY

NEW IC NIXIE DRIVER GETS UNGLOWING REPORT

Guaranteed 67V Breakdown

Signetics Corporation today announced the first monolithic IC Nixie Driver that permits Nixie* tube operation without excessive background glow and does not require any discrete external components for interfacing. "We've whipped the problem of getting a state-of-the-art 2.5-ohm centimeter process into production, so we can guarantee a 67V breakdown," a company spokesman said.



Pre-bias Voltage vs. Current Characteristics of a typical NIXIE Tube.

Officials also said that the new device, designated 8T01 Nixie Decoder/Driver, is the only one of its kind that will interface directly with all commonly used DTL and TTL circuits and drive Nixies directly. The new member of Signetics DCL family is offered in a 16-pin silicone DIP.

When told of this new device from Signetics, a competitive manufacturer stated, "Dammit."

**Nixie is a registered trade mark of the Burroughs Corp.*

Big shift to new Shift Register

Unique Device Announced

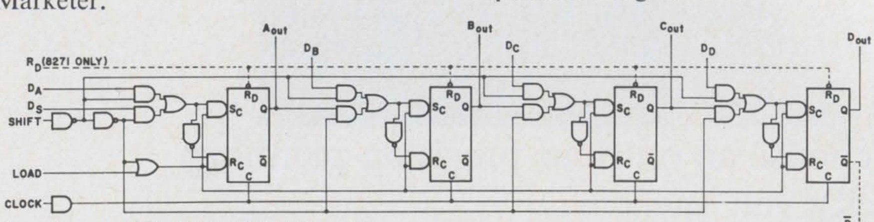
"Your new shift register is the answer to my prayers."

That quote, from a Dallas designer, is typical of the response to Signetics' introduction of a new 4-Bit Shift Register in the DCL line, according to Bill Slaymaker, a Signetics Product Marketer.

"This device has a unique organization and functional capability," Slaymaker commented.

The new 8270/8271 4-Bit Shift Register is fully synchronous and offers parallel or serial input and output. The device operates at clock rates up to 20 MHz and has a mass reset line (in the 8271, a 16-pin configuration) that is independent of the clock. A unique feature is separate load and shift controls that make it unnecessary to gate the clock to inhibit the shift, thus eliminating clock skew problems. Power consumption is 40mW per binary.

The 8270/8271 is supplied in 14 lead flat pak, and 14 or 16 lead silicone DIP in both full MIL and industrial temperature ranges.



Signetics new 8270/8271 4-bit shift register. Comes in 14 lead flat pack or DIP and 16 lead DIP.

Signetics announces new publication

Signetics launched a new publication today, the DCL Bulletin. As you can see in the masthead the first issue is the 16th issue, the first fifteen issues having never been published. DCL has been famous and well-loved since 1966, so it would be just plain silly to call the first issue the first issue.

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New Products

Computers

Punched cards on the ropes?

Fast, compact machines can transcribe data directly onto tape; optical character and magnetic readers are also in contention

By Wallace B. Riley
Computer editor

The admonition, "Do not bend, fold, staple or mutilate this card," may eventually take its place alongside such expressions as "Twenty-three skiddoo," and "All the Way With LBJ." And "eventually" may be just around the corner. Several recent developments indicate that the days of the punched card as a computer input medium may be numbered. Two machines, now on the market, can transcribe data directly from a keyboard to magnetic tape; an experimental magnetic-card system was recently announced, and cathode-ray tube units and optical character readers are arousing more and more interest in the computer industry.

Long run. The punched card as a medium for moving data in and out of automatic equipment is 81 years old. The present standard format—80 columns and 12 rows of positions for rectangular holes in a 0.007-inch-thick card 7⅜ by 3¼ inches—has remained unchanged since 1928.

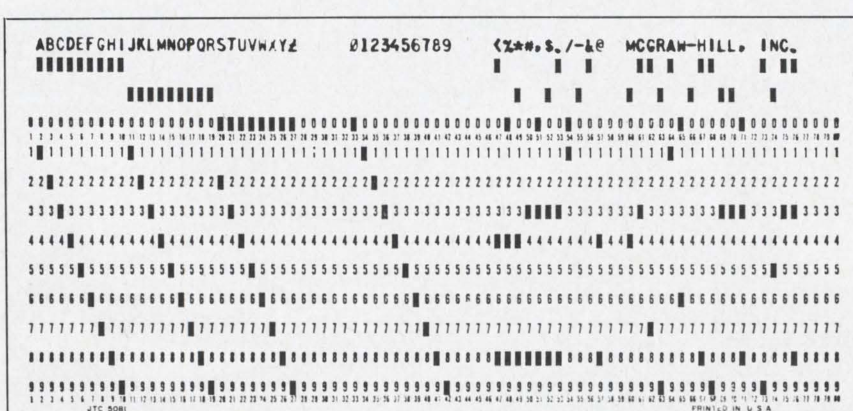
With this kind of longevity, the punched card isn't likely to disappear completely for many years. In fact, the number of punched cards used each year has been increasing an average 11% since 1962, almost entirely because of the explosive growth of the computer industry. For one thing, 80% to 90% of the field relies on punched cards for input. For another, the cards cost only about a tenth of a cent. But the growth is expected to taper off to perhaps as little as 2% a year within five years because new kinds of machines are appearing, and interest is growing in other media such as disk packs—removable magnetic disks that share the bulk-storage advantages of magnetic tape but have the random-access characteristics of large disk files. Such developments are reducing the number of cards consumed per user. But for the moment, this attrition is more than offset by the increase in the number of users.

I. Bill of particulars

Interest in alternatives to the punched card is heightened by its numerous disadvantages, some of which are critical now that faster and faster computers are being produced. Among the drawbacks:

One shot. A card can be punched only once. If a keypunch operator makes a mistake, he has to start over on a new one.

Cozy. One card contains a maximum of 80 characters of data, except when unusual special codes



Code. In a conventional 80-column, 12-row punched card, a single punch in one of the nine numeric rows or zero zone represents one of 10 decimal digits. Numeric plus zone punches represent alphabet letters. Other combinations stand for a variety of special symbols.

In and out. The removable magnetic tape cartridge in Communitype's data communication system has capacity of 180,000 characters or 30,000 words.

Quick trick. With Honeywell's Keytape, data can be transcribed directly onto computer-ready magnetic tape through a keyboard.

are used. When record lengths require more than 80 characters, additional cards are necessary. However, only 60 to 70 characters can be used per card; the rest of the space is needed for codes that identify cards containing parts of a single record.

Inefficient. The 12-row Hollerith code used on most punched cards is highly redundant; only 64 characters are defined, out of a possible 4,096—an efficiency of about 1½%.

Slowpoke. Most card readers used as input devices with computers have a maximum speed of 400 to 800 cards per minute; a few can get up to 2,000 cpm. Even with every card packed full of data, the maximum possible input is only 2,667 characters per second—at least 40 times fewer than today's standard magnetic tapes. As a result, large-scale systems usually include one or more small peripheral computers that transcribe card data onto tape in a separate process. This lets the central processor work directly with magnetic tape.

Closet case. Any significant amount of data kept on punched cards for future use takes up a lot of storage space and is heavy.

Slow shuffle. Dropping a deck of cards may require a complete resorting—this means lost time, extra handling, and the possibility of damage or contamination of the cards.

Fallout. Cards tend to generate dust and lint in the machines that handle them. Specifications can minimize but not eliminate such difficulties.

Down time. A damaged or worn-out card can jam the machine processing it; the process must be stopped and a new card punched and inserted in its proper place before the job can be resumed.

Redeeming virtues. Of course, the punched card does have its good points. It can carry any kind of information, and the punches can be read visually if one knows the code. It can be read into the machine with only a simple computer program. What's more, the punched card has some actual advantages over other media. It can be separated from the file, mailed, or otherwise handled individually, and restored to the file at any time. And in many applications cards can be economically processed only

Punched cards then and now

During the 1880's the records of the Census Bureau were still being compiled by hand. But the growth of the U.S. made it apparent that existing techniques wouldn't provide the results of the 1890 census until well after 1900. As a result, a bureau statistician named Herman Hollerith set out to develop a mechanized tabulating system. His machines, first tested in 1887, were controlled by cards with three rows of 32 punch positions along the top edge, and three more rows along the bottom—a total of 192 possible positions for holes.

Stepping stone. The processing of the 1890 census with Hollerith's machines was so successful that he founded the Tabulating Machines Co. to develop and market the machines commercially. About 20 years later Hollerith's firm merged with the Computing Scale Co., a maker of butcher scales, and the Time Recorder Co., which produced time clocks for factories. The corporation was named the Computing, Tabulating, and Recording Co.

The merger wasn't particularly successful, and in 1912 a new president was brought in. He was 40-year-old Thomas J. Watson Sr., who had just left his job as sales manager at the National Cash Register Co. after a falling out with the chairman of the board. Watson succeeded in improving the company's fortunes and it prospered; in 1923 it changed its name to the International Business Machines Corp.

Solo. Then and for many years thereafter, IBM was the only company making card-controlled electric accounting machine. In addition, its name continues to be synonymous with punched cards. The company made the switch to electronic computers in the early 1950's over the objections of the elder Watson, who kept effective control of the concern until shortly before his death in 1956. Nevertheless, the company continued to turn out electric accounting machines, which still account for a substantial part of sales, although they have been largely eclipsed by computers.

once and then discarded.

II. No bargain either

The key punch, a machine used to transfer data manually from source documents to punched cards, also has drawbacks. It's a mechanical device subject to breakdowns and is very noisy and tiring to operate. The machine can't check the punched data; a separate verifier machine, usually requiring an additional operator, is necessary to ensure accuracy. Physically, the verifier is almost identical to the key punch, but has mechanical "feelers" instead of punches.

Only the International Business Machines Corp. makes key punches. A 1956 consent decree with the Justice Department requires IBM to make its design specifications available to anyone who wants, to build equipment to interface with IBM computers, but no one had taken advantage of this opportunity. However, several companies make other kinds of equipment that's compatible with IBM gear.

Lilliputians. The company insists that it has competition in this area. But only a half dozen or so firms make equipment for punching holes in cards, and such products—with one exception—are all portable, hand-operated devices that wouldn't be suitable for volume production. For example, Taller and Cooper Inc., Brooklyn, makes a portable printing punch that works like a toy typewriter. A dial turns to the character to be punched, and a bar simultaneously drives the corresponding punch knives through the card and prints the character at the top of the card just like IBM's key punch does. The Taller and Cooper machine even has a tabulator that permits skipping over several columns at once.

The printing punch is marketed by Taller and Cooper and by the Wright Line division of the Barry-Wright Corp.; an agreement with the National Cash Register Co. is being negotiated. Taller and Cooper is also developing the only machine that has anything like the capability of an IBM key punch; it looks and works like a typewriter. The machine, an electrified version of the portable printing punch, is being developed under a contract with the U.S. Navy, which needs a compact and versatile unit to use in submarines and destroyers. It will be commercially available for about $2,500 in about six months.

. . . not even Univac builds key punches . . .

IBM's electrically driven key punch is a sophisticated device; it feeds cards automatically and is capable of skipping and duplicating under control of a program drum that can be set up for any data format. The company's design and service have proved so good that no one has seen any percentage in taking on the giant in this area. And with the advent of machines that bypass punched cards and the prospect of a declining market, it's unlikely that anyone will want to develop anything in the future.

Dead issue. Not even the Univac division of the Sperry Rand Corp. builds key punches. Some years back, however, it did turn out machines that punched round holes in 90-column cards used in electric accounting machines and computers like the 1004 and 1050. But now that Univac's 9000 series of processors uses 80-column, IBM-format punched cards, the company has left the key punch field altogether.

III. New directions

Three years ago, a small company in upstate New York, the Mohawk Data Sciences Corp., making the first real effort to overcome the disadvantages of punched cards, brought out its data recorder, a machine with a keyboard almost identical to that of the key punch.

The operator keys in data as he would with a key punch, but the data is stored in a core memory until the record is completed. The data is then written at 200 bits per inch on a strip of seven-track magnetic tape that can be processed directly on a computer. The record can be verified on the same machine immediately after writing or later; errors can be corrected immediately without starting the record over. One reel of rolled-up tape, 2,400 feet long, taking up about a tenth of a cubic foot of storage space, can hold as much data as about 36,000 cards requiring more than 40 times the storage space. (This holds true if the data is recorded on the tape in essentially the same format as on the cards.) More sophisticated techniques can greatly increase the amount of data stored on the tape. And the tape

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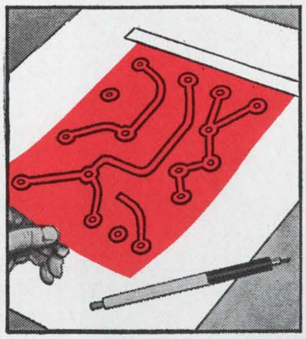
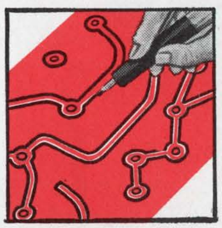
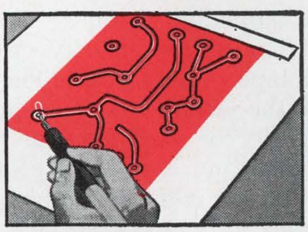


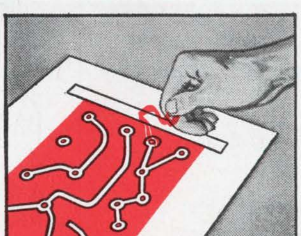
Cut a piece of the desired film large enough to cover area to be masked. Tape it down firmly at the top *with dull-side up.*



With sharp blade, outline the areas to be masked. *Do not cut through the backing sheet.* The Ulano Swivel Knife does the job quickly, easily.



Using the tip of the blade, lift up a corner of the film thus separating it from the backing sheet.



Now carefully peel off the film as outlined leaving a completed mask, positive or negative, that corresponds exactly to the desired pattern.

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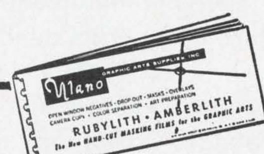

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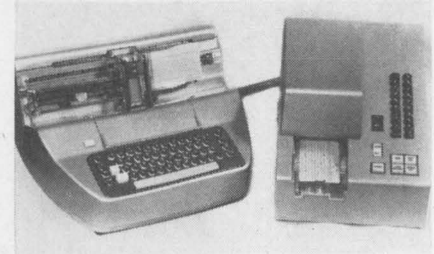


Sea duty. Navy will post this electric keypunch setup being built by Taller and Cooper to sub and destroyer fleet.

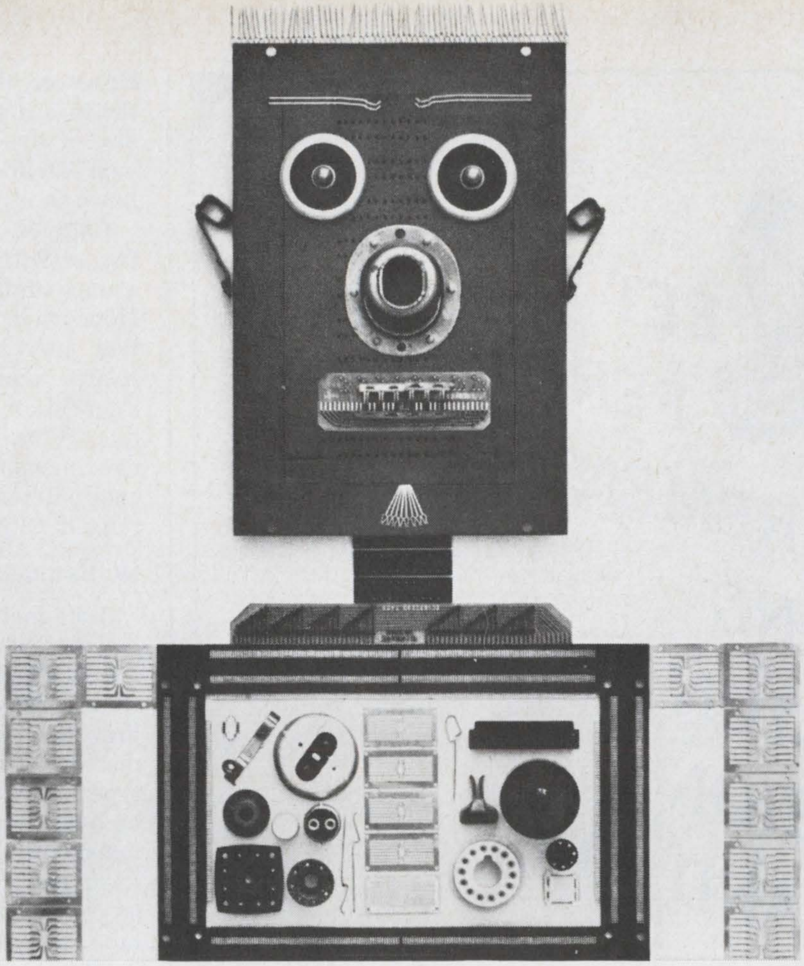
can be reused after the data is discarded.

Newcomers. The original model 1101 data recorder, first produced in 1965, has since been joined by a line of machines that provide: pooling of data from several keyboards onto one tape; data communications capability; and input from paper tape, punched cards, or a typewriter keyboard. Other models put longer records at higher density on nine tracks for compatibility with the newest computers. The machines are sold directly by the Mohawk Co. and, under a private-label arrangement, by National Cash Register.

The Mohawk machines, although pioneers, weren't the first of their kind. During the early 1950's Univac (then part of Remington Rand Inc.) marketed the Unityper, which recorded individual characters from a typewriter at low density on a metallic tape. Mechanical difficulties with the incremental drive and the difficulty of verifying the recorded data and correcting errors led Univac to withdraw the machine from the market.

Bigger buffers. Mohawk has recently been joined by Honeywell Inc., which introduced its Keytape machine this January. Keytape is the functional equivalent of the data recorder, but Honeywell claims a faster speed and the capacity to record at higher densities on seven-track tape. Honeywell's machine is essentially a standard tape drive like those used on computers, winding tape from reel to reel. The company says this is superior to Mohawk's technique in which the tape is unreeled as it is written, dumped loosely into a bin, and wound at the end of the job.

Both Mohawk and Honeywell depend on the 80-character record length, just as punched cards do.



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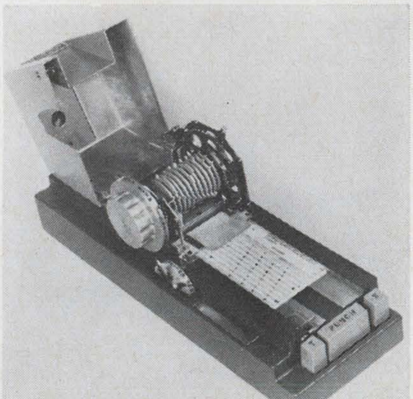
However, the machines can extend the record simply by increasing the size of the buffer memory. Honeywell intends to compete with Mohawk in replacing keypunches.

Another one. Sangamo Electric Co., of Springfield, Ill., is preparing a unit similar to the Mohawk and Honeywell machines for introduction later this spring along with related equipment for data communication applications. Sangamo recently acquired a California outfit—a move that attests to its heightened interest in data recording and related activities.

IV. Communications link

A magnetic recording device similar in several respects to the data recorder and the Keytape was introduced last fall by a New York firm, the Communitype Corp. The machine transcribes data from a typewriter keyboard onto magnetic tape in a small cartridge and simultaneously makes a hard copy on the typewriter. If the typist makes an error, the typewriter and the tape can be back-spaced to correct it. The recorded data can be speedily transmitted over a telephone line, re-recorded on computer-compatible tape in a separate converting machine, or automatically recopied on the typewriter. An optional addressable memory unit, actually another piece of tape in a small desk-top housing, stores frequently used information; the data can be transcribed onto the cartridge tape without being repeatedly entered from the keyboard.

The Communitype device is similar to the others in that it makes card punching unnecessary. But it is primarily a data communica-



No toy. Taller and Cooper produces a portable unit that prints characters and makes punches just like IBM gear.

... some machines read only single lines ...

tion device. Since its tape isn't computer-compatible, there must be an extra operation—over a telephone line or locally—to put the data into a form directly acceptable to a computer.

Cousin. A related device, primarily for communications but also applicable to computer inputs, is Digital Devices Inc.'s new buffer (see page 218), which uses a magnetostrictive delay line instead of a piece of magnetic tape as a temporary storage.

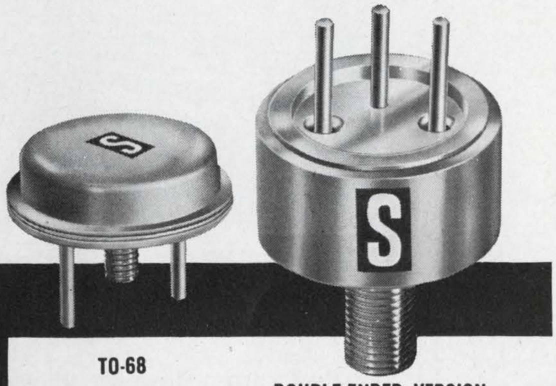
Univac recently developed a new kind of unit record that has many of the advantages of punched cards and few of the disadvantages [Electronics, March 18, p. 48]. It's a plastic card, able to store up to 100 times as much data, that's recorded magnetically like a standard punched card. The data can be erased and the card reused indefinitely. And the cards can be individually handled.

V. Look-see

Other potential threats to punched cards are optical character readers and magnetic-ink character readers. The latter form of recording is already used by most commercial banks for checks.

Optical character readers are made by several companies, including the Optical Scanning Corp., National Cash Register, Farrington Electronics Inc., IBM, the Control Data Corp., Recognition Equipment Inc., and the Philco-Ford Corp. Some machines read only single lines, while others can assimilate whole pages. Some read only stylized type fonts, other almost anything. "Most of the machines are quite expensive from a systems point of view," says Myron Angier, director of Honeywell's Special Products division, home of the Keytape machine. "They will eventually take over the unit record function that punched cards now handle, but we don't expect much competition from them for quite some time." Honeywell doesn't now make an optical character reader.

On display. Crt displays with associated light pens or keyboards offer another possible alternative to



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MHT1809	MHT1909	60V	45V	15 min @ 50A	1.25V	.45V
MHT1810	MHT1910	40V	30V	15 min @ 50A	1.25V	.45V
2N 2730	2N 2733	80V	60V	15 min @ 65A	1.25V	.45V
2N 2731	2N 2734	60V	45V	15 min @ 65A	1.25V	.45V
2N 2732	2N 2735	40V	30V	15 min @ 65A	1.25V	.45V
SDT1860	SDT1960	80V	60V	20 min @ 65A	1.25V	.30V
SDT1861	SDT1961	60V	45V	20 min @ 65A	1.25V	.30V
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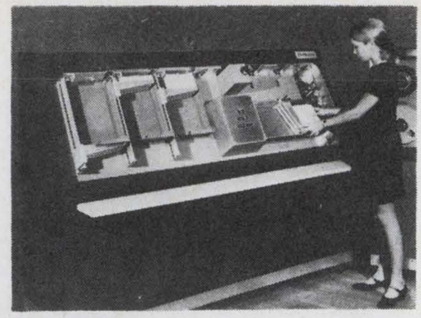
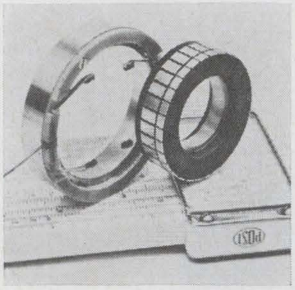


Op art. Optical Scanning's character reader can read single-line forms at a speed of 600 per minute.

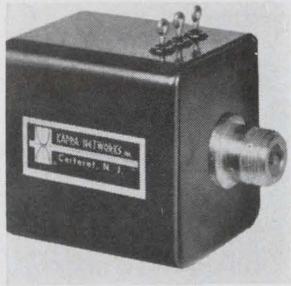
punched cards. However, they too cost much more than conventional equipment, and hard copy isn't automatically available from a display. The principal advantage of crt's is their ability to provide online real-time access to a computer —a capacity fundamentally beyond punched-card systems.

Further development work on OCR's and crt's will make them more and more attractive as possible replacements for punched-card equipment. Meanwhile, another, less obvious alternative is a "keydisk" setup. Perhaps a machine could be built to enter data directly through a keyboard onto a portable disk pack. However, no one could use enough of this system's potential to justify its high cost. For one thing, a single disk pack holds about as much data as a reel of tape but is much more expensive. Its most effective application would probably be storing data from several keyboards running in parallel. Its random-access capability would separate the data from the various keyboards.

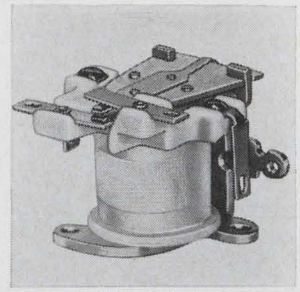
A way to take advantage of this pooling capability isn't evident now. Both Honeywell and Mohawk offer pooling devices as accessories to their machines, but the pooling operation is separate from the keyboard operation. First, the individual tapes are made, then several of them are pooled onto a single reel. Also, despite the recent rapid growth of the disk-pack industry, disk packs themselves are still a very small part of the total industry picture. They will remain so for some time, partly because of the vast prior installation of magnetic tapes as a bulk storage medium. Also, disk packs sell for $490, as against $25 to $35 a reel for magnetic tape.



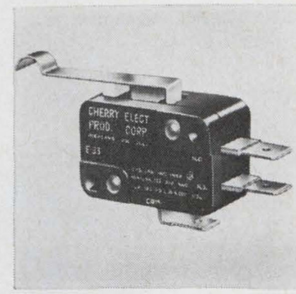
D-c torque motor 1700-040 develops 15 oz in. of peak torque with 65 w input. Frameless configuration allows the motor armature to be mounted directly to the driven load shaft. The motor is axially thin (0.40 in.) and o-d is 1.69 in. Rotor inertia is 0.007 oz/in./sec^2 and no load speed is 4500 rpm. Magnetic Technology Inc., 21001 Kittridge St., Canoga Park, Calif. 91303. [341]



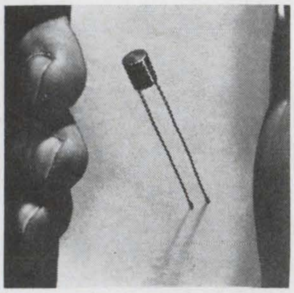
High power baluns and impedance matching transformers are for applications in matching unbalanced transmitter outputs to balanced antennas or transmission lines. Models are available in 100, 500, and 1,000-w ratings for the 2-to 30-Mhz range. Model PB500 is rated at 500 w average power at maximum frequency. Kappa Networks Inc., 165 Roosevelt Ave., Carteret, N.J. 07008. [342]



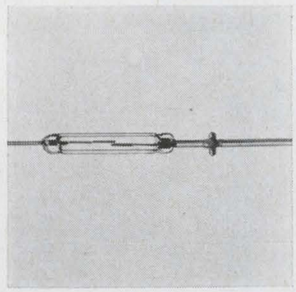
Sensitive relays designated RBM MS 40 are spdt units that measure $1\frac{1}{8}$ x $1\frac{1}{8}$ x $\frac{15}{16}$ in. They feature long life and low cost. Contact ratings are 2 amps non-inductive at 28 v d-c and coil power range is 0.050 to 1.0 w. The armature is common to the frame with 4-40 mounting and solder terminals. Controls Division, Essex Wire Corp., 131 Godfrey St., Logansport, Ind. [343]



Miniature switch E33-90H features contoured form on integral hinged lever actuator for cam or slide actuation from either direction. It is rated 10 amps, $\frac{1}{2}$ h-p 125/250 v a-c, but can also be furnished in 5 amp and 15 amp versions. Net cost (2,000 pieces) is $0.437 each. Cherry Electrical Products Corp., 1650 Old Deerfield Rd., Highland Park, Ill. 60035. [344]

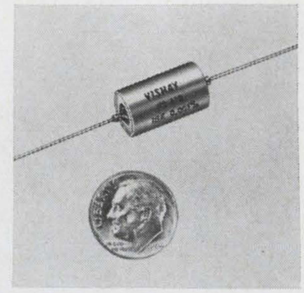


Miniature bobbin wirewound resistor WWP-225 is rated at $\frac{1}{8}$ w in a temperature range from $-55°$ to $+125°$C, derating to zero at 145°C. It stands 0.312 in. high by 0.250 in. diameter. It is available in tolerances from 0.05% to 1% within a resistance range of 0.1 ohm to 515 kilohms. Temperature coefficient is ± 20 ppm/°C. Dale Electronics Inc., Box 609, Columbus, Neb. [345]



Miniature reed switch MR338 is a nitrogen gas-filled, center-gap, spst unit suited to permanent magnet or electromagnet operation. Rhodium contacts are rated 10 w d-c resistive, 12 v-a a-c resistive, and 0.003 amp. Minimum voltage breakdown is 1,500 v d-c. Price is $1.24 in quantities of 100 pieces. Gordos Corp., 250 Glenwood Ave., Bloomfield, N.J. 07003. [346]

High deflection sensitivity and high brightness are features of the WX30764 electrostatically focused crt. The $5\frac{1}{2}$ x $4\frac{1}{2}$-in. tube, with a center line width of 0.015 in. (15 mil), is for oscillographic and data display applications. It has an aluminized, rectangular screen, weighs $3\frac{1}{4}$ lbs, and mounts in any position. Westinghouse Electronic Tube Division, Elmira, N.Y. 14902. [347]



Resistor series HA is usable from d-c to 100 Mhz and above, with absolute tolerances to 0.001%, shelf stability of ± 5 ppm/yr. Temperature coefficients are 0 ± 1 ppm/°C (absolute), 0.5 ppm/°C (tracking) and 0.25 ppm/°C (matching). Price, in 100 lots, is $5.70 each for the 0.01% HA412 units. Vishay Resistor Products, 63 Lincoln Highway, Malvern, Pa. 19355. [348]

New components

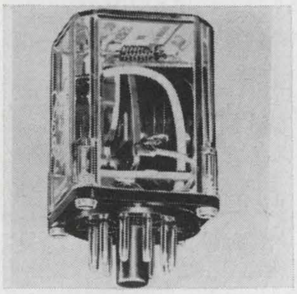
Cable assemblies get the thin look

First connector specifically designed for flat cable with 50-mil centers, features environmental shielding

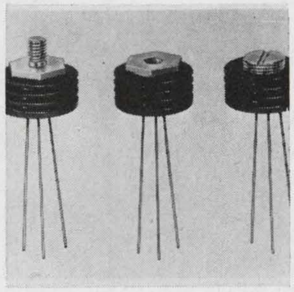
Only about 4% of the wiring going into new aircraft and missile airframes is flat conductor cable. But according to industry estimates, this figure could soar to about 85% in 10 years if the right hardware is developed. Now Microdot Inc. believes it has come up with some of that hardware.

According to Wendell Jacob, connector and cable products manager at Microdot, "Up till now, the only connectors available were warmed-over versions of some other kind of connector such as printed-circuit types, and they're for 100- or 75-mil cable. In our Mark 220 connector we've developed the first unit for 50-mil centers."

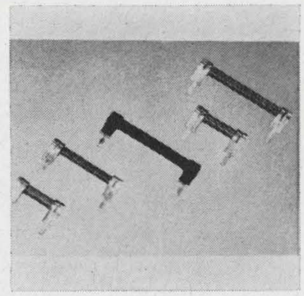
Microdot first got interested in designing such a device after the firm was approached by a major aerospace manufacturer with its requirements for flat conductor-cable terminations. Then the McDonnell Douglas Corp. verified the need for the unit after performing a cost-weight study on aerospace cables and connectors for NASA. Finally, after Microdot had its in-house development program under way, it learned that the Army's Picatinny Arsenal was preparing a new military specification, now circulating



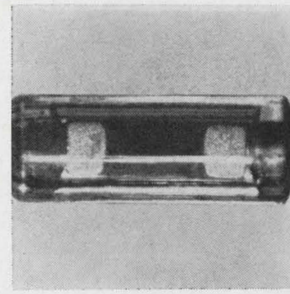
General purpose industrial relay style L is available with contact arrangements from spdt to 4 pdt and ratings from 5 to 10 amps. Contact resistance is rated at 0.05 ohm max. Ambient temperature range is −55° to +85°C. Dielectric strength is 1,250 rms. Predicted mechanical life is 1 million operations. Price Electric Corp., E. Church & 2nd Sts., Frederick, Md. 21701. [349]



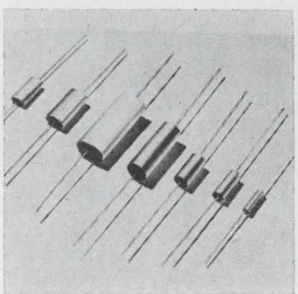
Radiator heat sinks feature a patented insert that fits on the heat sink case and makes a firm pressure contact to the rim, top and over 60% of the side surface. This assures a thermal conduction coefficient of 2 w/°C from transistor case to heat sink. The HA-05R fits TO-5 cases; the HA18R, TO-18 cases. Horex Electronics Inc., 1729 21st St., Santa Monica, Calif. 90404. [350]



Power resistors series FP and XFP are for p-c board applications. They can be inserted in 0.050 or 0.070 diameter holes, and are 0.020 thick x 0.035 or 0.054 wide. Center-to-center distance of prongs on the terminals is variable from 0.5 to 2.5 in. Resistance range is from 0.2 ohm per in. to 1,000 ohms per in. Lectrohm Inc., 5560 Northwest Highway, Chicago, 60630. [351]

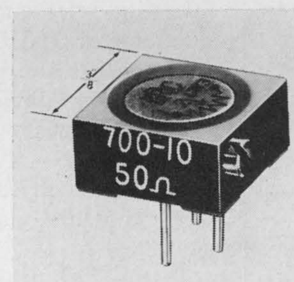


Glass-encased Neptune ceramic capacitors offer 10 to 10,000 pf in a case size of 0.250 x 0.095 in. The ceramic slug is both brazed to the lead-cap and encapsulated in an inert-gas atmosphere, thus preventing contamination. Units are available with a temperature coefficient of 30 ppm/°C. San Fernando Electric Mfg. Co., 1509 1st St., San Fernando, Calif. 91341. [352]

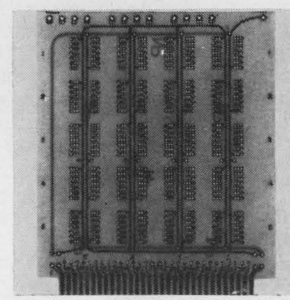


Ultraminiature tubular and flat Thinfilm metalized polycarbonate dielectric capacitors series 396-397 are available in 0.01 to 10μf. They operate within the range of −55° to +125° C without voltage derating. Dissipation factor at +25° is less than 0.5% at 1,000 hz. Leads are axially oriented. Gudeman Division, Gulton Industries Inc., 340 W. Huron St., Chicago 60610. [353]

Ten-turn precision wirewound Pixiepot has plastic shafts up to 1.8 in. long, minimum torque to 2.0 oz-in. Model 3253 has a resistance tolerance of ±5% over a standard range of 100 ohms to 100 kilohms. Linearity is ±0.25% and resolution for a 1-kilohm pot is typically 0.022. Duncan Electronics Div. of Systron-Donner Corp., 2865 Fairview Rd., Costa Mesa, Calif. 92626. [354]



Wirewound trimmer style RT-24 type 700 meets environmental requirements of MIL-R-27208. It features positive clutch action that insures against damage to contact wiper and drive mechanism. It is available over a resistance range of 10 to 50,000 ohms, ±5% tolerance, and is rated 3/4 w at 85°C. IRC Inc., 401 N. Broad St., Philadelphia, Pa. 19108. [355]



Plated-through-hole p-c boards facilitate mock-up circuitry. Four configurations available accept 14-pin dual in-line IC's, TO-5 packages, and discrete components. Extra holes are provided in the land areas for jumper wires to effect circuit hook-up. Circuit changes may thus be made easily and quickly. Midwest Circuits Inc., 1111 E. Excelsior Blvd., Hopkins, Minn. 55343. [356]

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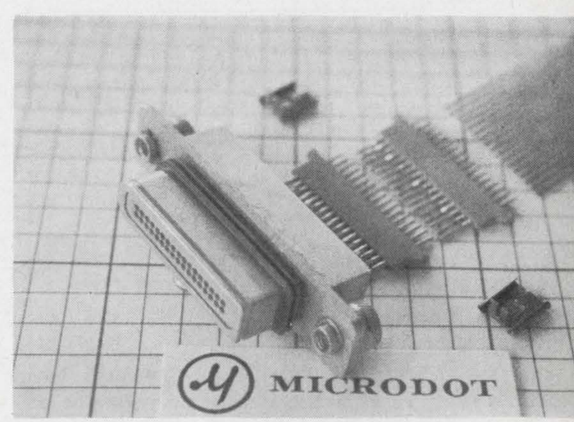
for industry comments, covering flat conductor cable connectors.

At the show. User requirements for flat cable connectors were outlined at a meeting of the Institute of Printed Circuits in New York last month. One user at the meeting says that while Microdot and the International Telephone & Telegraph Corp.'s Cannon Electric Division had connectors to show, neither meets all the requirements the users want.

However, he did say Microdot was the first company with enough courage to come up with a new connector for flat cable, and it came pretty close to the requirements the users gave.

According to Jacob, the users aren't sure exactly what they want. He also attended the meeting and says the users are not in agreement, especially in the area of electromagnetic capability, so Microdot will try to incorporate environmental sealing inside the shell if it does not interfere with reliability. The users asked for this, along with a different kind of coupling mechanism—jack screw or snap lock coupler.

Jacob says Picatinny personnel indicated the Microdot design philosophy was sound, assured Microdot officials there would be a con-



Housing. Connector shells are impact-extruded aluminum and are gold-plated—a requirement of the aerospace industry.

tinuing market and substantiated that Microdot was the first firm they knew to be designing a connector strictly for flat cable. With this reassurance, Microdot proceeded with the Mark 220, without waiting for sponsorship to underwrite the development, which, says Microdot's John Redwine, is usually the way new connector developments are launched.

Same as before. The Mark 220 will incorporate the twist pin employed in all Microdot connectors rather than screw-machine-produced pins. Microdot is under license to the New Twist Corp. for this concept, in which the pin is made of 10 strands of 48-gauge to 50-gauge wire, and has an outside diameter of 0.0315 inch; the socket that accepts the pin has an inside diameter of 0.028 inch, so that the wider pin twists and elongates as it enters the socket, giving more positive electrical contact than screw-machine-made pins, Redwine says.

In the 220, pins and sockets are joined to their respective flat cable conductors in an insulator module made of diallyl phthalate. Redwine says the material was chosen because of its good temperature characteristics and good compressive strength. Microdot inserts the pins and sockets in their respective molded insulator modules, and the customer will join each half of the connector to the flat cable.

The mating call. Jacob points out that when the Mark 220 design was initiated, the company wanted to fashion it so that the entire flat cable could be mated to the insulator module—containing pins or sockets—in an automatic process independent of the type of connector shell that would ultimately house the mated pair. In this manner, he believes, the insulator module-to-cable termination can be done in a 30-second welding of pin or socket module to the wires in the cable. With round cables, as much as 10 to 15 minutes can be consumed in soldering individual wires to the connector. This production speedup will be as persuasive as potential weight savings in contributing to

The first $1500 digital multimeter that sells for $895.

The new trio/lab Digital Multimeter Model 501 is the first battery-portable, automatic ranging and polarity, full-capability DMM ever offered — at any price.

State-of-the-art IC techniques, high sampling speeds, rugged construction, rechargeable ni-cad batteries . . . perfect for both field and bench use. This unique instrument is simplicity itself — just push a function button and read.

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Ranges: Voltage — DC/AC: 1 mv to 1 KV in 4 ranges
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Accuracy: DC Volts, DC ma, Ohms, ±0.1% of reading + 1 digit
AC Volts, AC ma, ±0.5% of reading + 1 digit

Over-ranging: 100% with no loss of accuracy

Input Z: 10 Megohms

Mechanical: 4⅜" x 10½" x 10¾" deep; 12 lbs.

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ORIGINAL CONCEPTS IN INSTRUMENTATION

the predicted boom in flat conductor cable, Jacob adds.

Other uses. Microdot is considering a commercial/industrial version of the connector for such hardware applications as computers, but officials say they've just begun to study the most suitable material for the housing.

The connector is made in sizes from one inch to three inches wide, in increments of one-half inch, and accommodates from one to three stacked cables.

Specifications for the industrial version have not been fully worked out, Jacob says, because Microdot wants to encourage the industry to spell out its needs. Prototype devices for feasibility or research and engineering evaluation can be delivered in 8 to 10 weeks. Prices have not been firmly fixed, but Redwine estimates the devices will cost about $1 per mated contact (one pin in one socket) plus housing costs—or about $60 for a mated pair of 34-conductor units.

Microdot Inc., 220 Pasadena Ave., South Pasadena, Calif. 91030 **[357]**

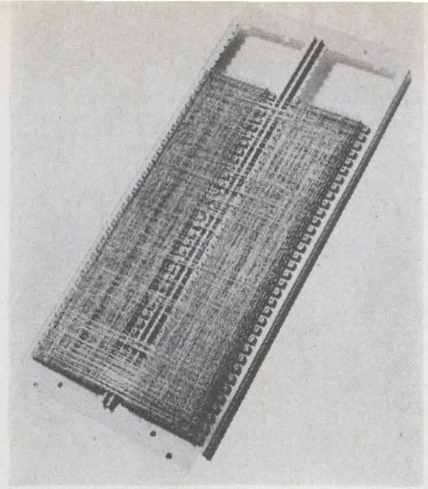
New components

Taking complexity out of pin positions

Automatic wire wrapping boosted by simpler, less costly connection method

Despite the superiority of automatic wire wrapping over hand wiring, not everyone has climbed on the bandwagon. Although higher initial cost has kept some would-be users away, complex pin positioning has caused others to back off. Tolerances are so tight that the slightest error can lead to costly production delays.

Now, however, Litton Industries' Winchester Electronics division has developed what it calls AccurFrame packaging—a far simpler and less costly system of putting pins on a plate than conventional methods.



James Muller, Winchester's sales manager, says the AccurFrame method costs from 1 to 3 cents less per contact than other techniques.

Consisting of the company's HW series edge-board connectors, custom-designed positioning and wiring frame tools, and HW series contact-replacement kits, AccurFrame is merely an extension of the connector-molding technology. Conventional methods use multiple punching of close center holes in the plate-type assemblies.

Making the fit. With AccurFrame, two alignment holes, one round and one square, are molded into the base of the HW connector blocks. These fit over accurately-positioned guide pins, also one round and one square, on a master alignment tool. Each pin is independently measured from reference points and is within 0.001 inch true position. With the connectors in position, a frame is placed over the assembly and attached by machine screws to the connectors.

If the terminal posts become damaged during assembly or production, they can be replaced with the simple hand tools provided in the contact-replacement kit.

The HW connectors are precision molded of diallyl phthalate. The contacts are retained in the connector block by a 90° twist—resulting in a diagonal placement. Conventional methods of locking in the contacts—staking and dimpling—tend to weaken the contacts and lead to a high degree of breakage.

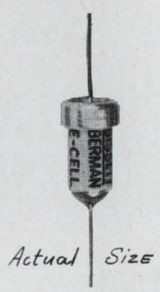
The price of AccurFrame is about 5.5 cents per contact, depending on the size and the number of frames produced.

Winchester Electronics, Main St. and Hillside Ave., Oakville, Conn. 06779
[358]

How to Use E-CELL™ Timing and Integrating Components

Something really different!

The Bissett-Berman Components Division engineering staff answers four basic questions often asked about E-CELL* devices



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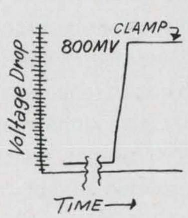
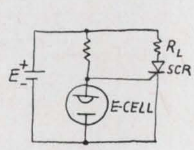
1. What is an E-CELL device?

An E-CELL device is a new kind of circuit element that looks like a discrete electronic component but does the work of a complex assembly. Its main functional part is a center electrode, which is surrounded by an electrolyte; the metallic container also serves as the second electrode. In terms of its physical operation, an E-CELL unit is a reversible micro-coulometer, i.e., it converts the current-time integral of an electrical function into an equivalent mass integral (or the converse operation) up to a maximum of several thousand microampere-hours. Exactly one atom is transferred for each electron impressed on the E-CELL unit. Power drain is normally in the microwatt region. The mass integral can be read out at a known current, the time to read it out being proportional to the original integral. When a mass is given as part of the initial condition, this same process generates a precise *time* interval.



2. What does an E-CELL device do?

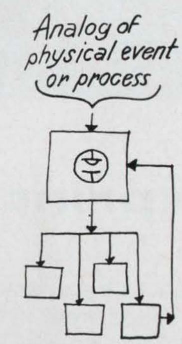
For *timing* applications a constant current is applied to a *pre-charged* E-CELL unit. The selected time delay is determined by a combination of the E-CELL type and the specific constant current being used. The range of timing is from seconds to months. The output voltage swing that occurs when the mass has been completely transferred is normally used as a bias transition with semiconductor devices.



For *integration* applications, an *uncharged* E-CELL unit accepts d-c, periodic, or random inputs in any waveshape and stores these as the mass equivalent of a current-time integral. Readout is handled in essentially the same manner that the timing function is handled for a pre-charged E-CELL unit, i.e. the measured time required to reach the point of the abrupt voltage swing, multiplied by the readout current, will be the accumulated charge integral. This could represent the total "count" of a series of events analogous to the input pulses.

3. When should I consider using an E-CELL device?

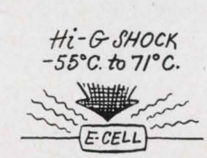
The scope of applications is as broad as timing and counting functions themselves. New uses are continually being devised. Here are two prime applications areas:



Control: You can use E-CELL devices in circuits for timing, gating, starting, stopping, delaying, relaying, monitoring, actuating, sequencing, measuring —wherever the control condition can be represented by an electronic signal.

Information Handling: You can use E-CELL devices in circuits for data capture, totaling and subtotaling time periods or discrete events, elapsed time logging, running time monitoring, out-of-limits logging, maintenance status reporting, real-time analog computing —wherever the input data can be represented by an electronic signal. Readout can be formatted as either analog or digital data.

4. What are some present production uses of E-CELL devices?

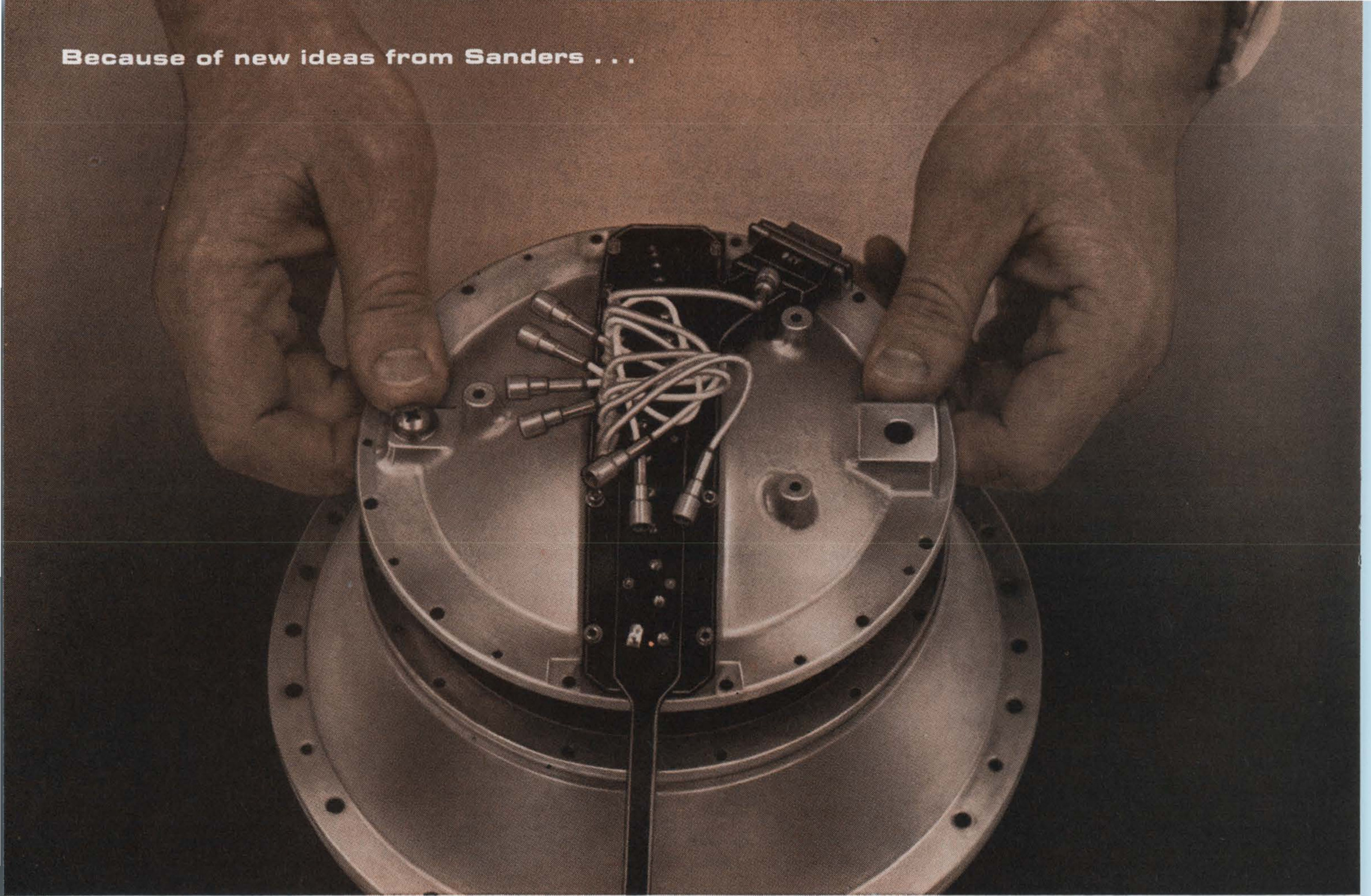


Fuzing and arming;
battery charging;
cardiac output integration;
sonobuoy scuttling;
high-power tube protection;
engine maintenance scheduling;
warrantee monitoring;
time delay relays;
transistor aging racks;
program timer;
r-f level monitoring.

**Patents applied for.*

BISSETT BERMAN

For technical information and application notes, contact: Components Division, The Bissett-Berman Corporation, 3860 Centinela Avenue, Los Angeles, California 90066. Telephone: Area Code 213, 390-3585.



Flexprint® circuitry matches coax capacitance

There had to be a way to control and stabilize capacitance within a limited area.

By matching coaxial capacitance through careful selection of dielectric materials, constant capacitance can be predetermined and controlled through the entire FLEXPRINT Circuit.

The result is a lightweight, stable circuit that conforms to the spherical surface of the package, matches standard coaxial cable and connectors and is 100% reliable.

If you have a complex circuit problem with unique characteristics and no solution in sight, FLEXPRINT Circuitry may be the answer. Call or write Sanders Associates, Inc., FLEXPRINT Division, Grenier Field, Manchester, New Hampshire 03103. Phone: (603) 669-4615.

This sophisticated multi-layer circuit, used in the Northrop Nortronics Floated Ball inertial platform for the C-5A Galaxy, is designed for extremely close tolerances. It utilizes fine-line etching and consists of two shields and one circuit layer. The circuit requires only 1/3 the space of conventional cable and permits a 20% weight savings. This totally encapsulated circuit provides constant capacitance values over a wide temperature range.

Creating
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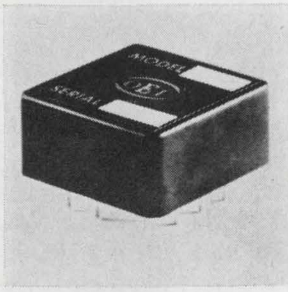
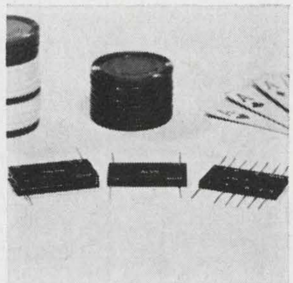
Circle 214 on reader service card

*T.M., SANDERS ASSOCIATES, INC.

New Subassemblies Review

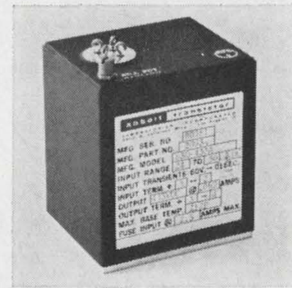


Bipolar logarithmic amplifier model 2369 occupies 0.5 cu in. Maximum error is ±1% typical. Features include current or voltage signal input, and 100 db dynamic range. Applications include nonlinear bipolar function generation, and compression of transducer output. Price is $71 each for 1-2, $65 each for 3-9. Optical Electronics Inc., Box 11140, Tucson, Ariz. 85706. **[381]**

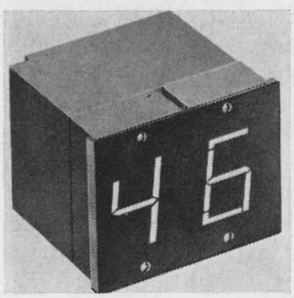


Lumped constant Chip Series delay lines serve low profile, high density packaging. Standard sizes range from 0.515 to 2.815 in length; width on all packages, 0.610. Thinness of the package is 0.110. Eleven basic models offer nsec delays from 2.5 to 50 in the 125-Mhz cut-off range. Valor Electronics Inc., 13214 Crenshaw Blvd., Gardena, Calif. 90249. **[382]**

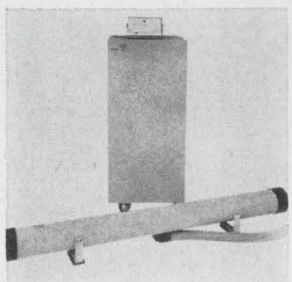
Series 20 DiGiCator is a 7-segment, incandescent, lighted numeric readout. The multiple character display is contained in an integral package 1/4 in. thick. Each character measures 1 in. high by 9/16 in. and is readable to 50 ft in bright daylight ambients. Price is $7.95 per character in 1,000 lots. Discon Corp., 4250 N.W. 10th Ave., Fort Lauderdale, Fla. 33309. **[383]**



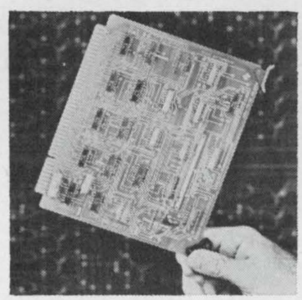
Power module B3D converts 28 v d-c to any output voltage from 5 to 2,080 v d-c at 30 w. True hermetic sealing and encapsulation enables units to meet MIL-E-5272C at 100°C. Units feature isolation of inputs and outputs, and output voltage adjustment range of 12% from nominal. Price is $304 up. Abbott Transistor Laboratories Inc., 5200 W. Jefferson Blvd., Los Angeles. **[384]**



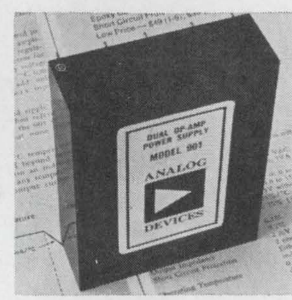
Dual digital display series NQT employs multiplexing techniques. The complete decoder-driver and display module is 1.97 in. high, 2.20 in. wide, 2 in. deep, and sells for less than $19 per decade in production quantities. The unit will accept 4-line BCD inputs at IC levels and requires only 105-125 v a-c power input. Mesa Co. Inc., 220 Mill St., Bristol, Pa. 19007. **[385]**



Carbon dioxide gas laser model CO2100, for cutting and slitting nonmetals, has a power output adjustable up to 100 w at a 10.6-micron wavelength. Specifications include a beam diameter of 1.5 cm, a beam divergence of less than 2 milliradians, and a focus spot size down to 0.004 in. in diameter. Price is $11,900. Westinghouse Electric Corp., Box 8606, Pittsburgh, Pa. 15211. **[386]**



A compact modular converter can accept 6 BCD digits on 24 lines and convert them to 20-bit natural binary output. It facilitates decimal to binary conversion in such areas as programing switches, computer input typewriters, and BCD outputs from digital voltmeters to a computer. Price is $390; delivery, 60 days. Texas Instruments Inc., P.O. Box 66027, Houston 77006. **[387]**

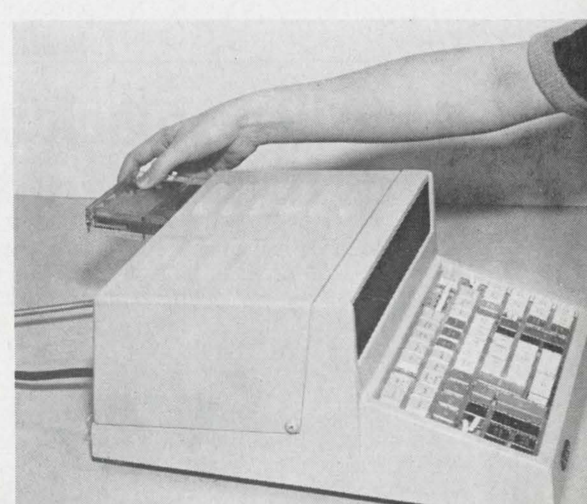


D-c power supply model 901, designed for energizing operational amplifiers, delivers 40 ma at ±15 v. Up to 4 op amps, each with 10 ma max. supply current, can be operated simultaneously. The unit is encapsulated into a 2½ x 3½ x 7/8 in. p-c mounting module. Price is $39 each in 10-piece lots; delivery, from stock. Analog Devices Inc., 221 Fifth St., Cambridge, Mass. 02142. **[388]**

New subassemblies

Wang offers grown-up calculator

380 System has 640-step programing capability on punched cards or cassette-loaded tape



When Olivetti unveiled its Programma 101 desktop calculator in 1965, it also unwrapped a fresh market for electronics. This new breed of machine incorporated the features of existing calculators—addition, subtraction, multiplication, and division—and added two key characteristics of the digital computer: operation on a stored program (in this case magnetic cards with a 120-step program), and the ability to base an instruction to itself on the results of a previous instruction or a set of instructions. What's more, the 101 did all this

. . . new keyboard works with older units . . .

for only $3,200.

Growing up. Since then, such calculators have become more and more common in offices. They've also become faster, smarter, and less expensive. Now Wang Laboratories Inc. of Tewksbury, Mass., has introduced another advance in the field: a 640-step programing capability, optional printout, and a program on casette-loaded magnetic tape. Punched cards also can be used with the system—which is dubbed the 380—and it is compatible with other Wang units.

The system consists of a keyboard costing $1,500, an electronics package called the 362E for $2,295, and an electric typewriter for the printout priced at $1,500. The total: $5,295.

This calculator, says the company, fills a price gap in its product line, which includes machines costing from $1,300 to $10,000. The device can handle long programs and provide speeds up to 10 times faster than existing Wang models because of the tape capability. The tape itself, two-track and available in lengths of 80 to 640 steps, runs at 18 steps per second; the machine can use cassettes available from Wang or those already on the market.

Split. While the new keyboard can be used with other Wang electronics packages, the 362E offers more storage. It provides 12 storage registers, each including a plus or minus sign, decimal point position, and 12 digits. When only data is stored, each register may be split in half to provide up to 24 six-digit registers. The 12 registers also can serve as accumulators with floating addition and subtraction, positive and negative numbers, and results to 12 digits. And there are two additional accumulators standard for use with all Wang units.

The printout, on a 379-5 output typewriter, operates at 13 characters per second. Connected through the control unit to the keyboard, the printout can be controlled by the program or by the calculator's keyboard input.

Display. There's one other data output option—an oscilloscope—

aimed primarily at the science-oriented user. It, too, can interface with other Wang calculators in line with the company's policy of introducing new models on a building-block concept to avoid letting its older equipment slip into obsolescence.

Up to four basic 380 keyboards can be used with each electronic package, and keyboards may be spotted up to 500 feet from the package.

Wang Laboratories Inc., Tewksbury, Mass. [389]

New subassemblies

Buffer talks fast but keeps still

Memory can put 4,800 bps on line, cutting costs; has no moving parts

Fast talkers don't usually save anyone money, but Digital Devices Inc. has developed one that does. It's a buffer without moving parts, the 608E-2, that stores 8,192 bits, as 5- or 8-bit words, and, on command, dumps them on a line at up to 4,800 bits per second. This speed can cut costs of leasing a line, which are often based on how long it's used.

Information fed to the buffer enters a shift register, then goes in serial form to the memory, a magnetostrictive delay line. When the dump signal is received, the information is transferred into an output register and out to the line. The buffer is also used at the receiving end to accept data fast and feed it to slow devices, such as printers. The output can be serial or parallel. A device to adjust the data-output rate is optional.

Paul Bauer, a sales engineer at Digital, says he expects his first customers to be designers of teletypewriter installations. He says the delay-line buffer may eventually replace paper-tape buffers in large telecommunication centers.

Time for silence. The buffer can

Now, you'll be pinning down your control system designs faster, easier, and with far greater economy

Over 200 micromodules from Philco-Ford's WDL Division stand ready to accept your system challenge. In compatible 5 to 40 MHz logic, standard DTL and T^2L circuits, they contain some of the most sophisticated designs in today's state-of-the-art, including multiplexers, operational amplifiers, D-to-A and A-to-D circuits, and an extensive array of computer interfaces.

The micromodules employ monolithic IC's, using thin-film and discrete components only where necessary. A hard nylon cover keeps out dust, protects circuits against damage. Clearance holes at the top of the micromodule provide fast front-panel access to all input/output terminals. No need to troubleshoot from the back! A color-coded label identifies module type at a glance.

The micromodule's modest dimensions, coupled with the complexity of the logic it contains, permits highly effective packaging density. A 180-module system can be mounted in a drawer only 3½" high by 19" wide. Modular systems fit readily into rack mounts, bench mounts, or portable instruments. In service for over three years at NASA's Manned Space Flight Center in Houston, WDL micromodules have compiled an excellent record of performance reliability. Write Product Sales Manager, WDL Division, Philco-Ford Corp., Mail Station C-41, 3939 Fabian Way, Palo Alto, California 94303. Or telephone (415) 326-4350, extension 6017.

ADD (Automated Design and Documentation) This Philco-Ford computer-programming service generates system documentation at a cost significantly below that of hand-prepared equivalents. The computer program error checks design input data, optimizes the arrangement and sequence of wiring instructions, calculates wire lengths, provides wire lists sorted by length and by name, and maintenance lists. The program is available to all users of Philco-Ford micromodules.

PHILCO Ford

PHILCO-FORD CORPORATION
WDL Division • 3939 Fabian Way
Palo Alto, California • 94303

Circle 219 on reader service card

. . . buffer holds data at remote sites . . .

also be used to feed a computer. The longer a central processor is tied up, the higher the user's expense. By storing data or commands from a card or tape reader until they're complete, and then dumping them into the processor, the 608E-2 reduces processing time.

Other applications are being considered. For example, the buffers could be used for prolonged data storage at remote sampling sites where such conditions as weather, traffic, or pollution are measured. This would eliminate continuous communication with sites; the stored data would be transmitted periodically to a processing center on command.

Memory under stress. The magnetostrictive delay line holds an electrical signal 10 microseconds for every inch of wire.

Hang-up. Buffer is constructed for rack-panel mounting.

Certain alloys are deformed by a magnetic field. In a magnetostrictive line, the input signal passes through a coil and induces a magnetic field at one end of a nickel-alloy wire. The field induces a stress wave that travels in the wire at about the speed of sound. At the other end of the wire another coil produces a magnetic field that induces the output signal. In memory applications, this output is continually fed back to the delay-line input. Since the output is the second derivative of the input, integrators are used in the feedback loop.

Bauer says that where an engineer can live with millisecond access times and thousands-of-bits storage levels, magnetostrictive delay lines are the most efficient and economical memory.

The 608E-2 costs less than $1,000 and is delivered in 12 weeks. It's compatible with most standard logic circuitry.

Digital Devices Inc., 200 Michael Dr., Syosset, N.Y. 11791 **[390]**

Don't let the good looks of Honeywell's MS Taut-Band Meter fool you.

What you see is a combination of functional advantages.

Modern curve.

The concave cover gives the meter a very contemporary look, alright.

But besides: By curving the cover, we minimized glare and shadows. That makes the meter easy to read.

Clean face.

We uncluttered the face by leaving out all the extraneous data. We made the scale longer. We printed the numbers above the scale.

Very stylish.

But also very easy to read.

More window.

We made the sides of the cover out of crystal-clear Plexiglas, just like the front of the cover. That makes the whole meter sparkle.

It also brightens the dial by letting more light in.

The specs.

As for the insides of the meter, the Honeywell taut-band mechanism is completely frictionless, so it responds to even the slightest inputs. Hysteresis-free, so its repeatability is near perfect.

Honeywell Series MS Taut-Band Meters come in 20 standard colors. In 33 standard ranges. And 3 sizes (1½″, 2½″ and 3½″).

The price.

This is the taut-band meter that costs even less than a pivot-and-jewel meter.

So if you like it, there's nothing to keep you from having it.

(We'd like to send you a catalog. Write Honeywell Precision Meter Division, Manchester, New Hampshire 03105.)

The Classy Meter from Honeywell

It takes all kinds of meters to make the Honeywell line.

Our new "4th-generation" 12.5 MHz universal counter/timer. Wonderful versatility in a wonderfully small package — at an even more wonderfully small price.

With the new Model 100A you can measure average frequency, frequency ratio, single period or time interval, or count total events. It has a crystal-controlled clock, Monsanto integrated circuit construction, and built-in compatibility with a rapidly growing assemblage of accessory modules.

With its $575* price tag (accessory modules are pegged at comparably modest rates) you can have big-league counter/timer performance at costs never before possible. Small wonder we are selling (and delivering) Model 100A's just as fast as we can build them.

Call your local Monsanto field engineering representative for full technical details, or contact us directly at: Monsanto Electronics Technical Ctr., 620 Passaic Avenue, West Caldwell, New Jersey 07006. Phone (201) 228-3800; TWX 710-734-4334.

*U.S. Price, FOB West Caldwell, New Jersey.

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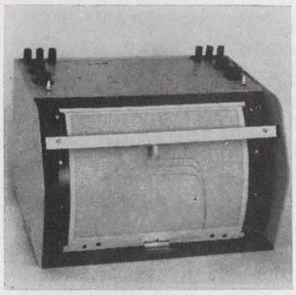
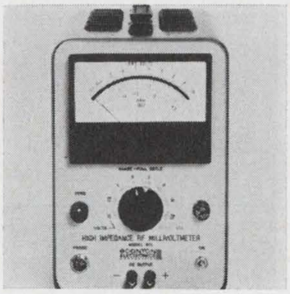
ELECTRONICS

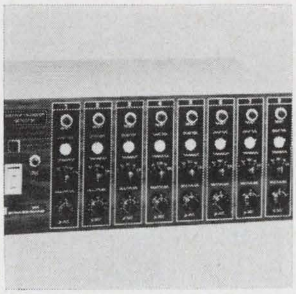
New Instruments Review



X-Y recorder model 30 records on 8½ x 11 in. graph paper, with an accuracy of better than 1%. Pen slewing speed is 10 ips. Span is continuously variable from 100 mv/in. to 1 v/in. Input resistance is 100 kilohms, and the X and Y channels are electrically independent. Overall dimensions are 14 x 10 x 10 in. Yeiser Laboratories, 881 W. 18th St., Costa Mesa, Calif. 92627. **[361]**

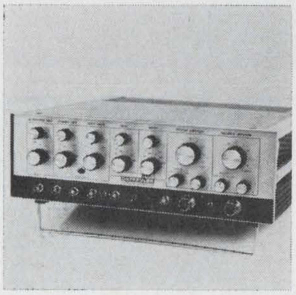


R-f millivoltmeter model 91K has an input impedance greater than 4 megohms shunted by 2.5 pf at frequencies up to 25 Mhz falling to about 1 megohm shunted by 2.5 pf at 100 Mhz. Frequency coverage is 0.5 to 600 Mhz with 8 ranges of sensitivity from 10 mv full scale to 30 v full scale in a 1-3-10 sequence. Price is $680. Boonton Electronics Corp., Parsippany, N.J. 07054. **[362]**

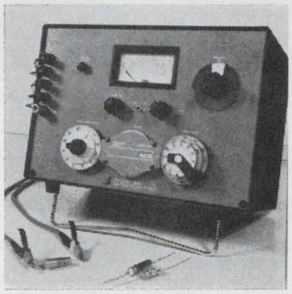


Chatter and transfer detector model BR-650 monitors and indicates undesirable opening or closing of active circuit paths during dynamic environmental tests such as shock, acceleration and vibration. The unit provides 8 channels with 4 inputs per channel in either chatter or transfer mode. Bunker-Ramo Corp., Defense Systems Division, 8433 Fullbrook Ave., Canoga Park, Calif. 91304. **[363]**

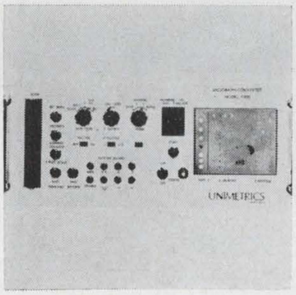
Sweep and marker generator 1484A is a low cost, solid state unit. Frequencies may be selected up to 1 Ghz, and pulse markers, c-w and harmonic birdie markers, r-f turn-off markers and post-injection markers can be specified. A 4-position switch selects band positions, and remote control of bands and tuning can be provided. Kay Electric Co., Pine Brook, N.J. 07058. **[364]**



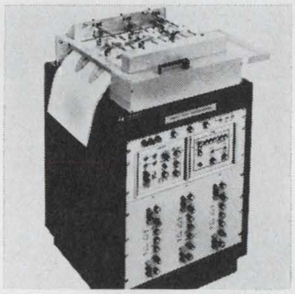
Pulse generator 113 has built-in burst capability. Two repetition rate oscillators are used. A h-f oscillator gives rep rates from 500 khz to 250 Mhz. A l-f oscillator (0.5 hz to 500 khz) is used to gate the h-f oscillator for 10 nsec to 10 μsec bursts or as a trigger for low rep rates. Price is $3,375. Datapulse Inc., 10150 W. Jefferson Blvd., Culver City, Calif. 90230. **[365]**



Capacitance bridge 273 operates on 9 ranges, from 0 through 120 pf to 0 through 12,000 μf. Accuracy is ±0.1% on middle ranges, ±0.3% on the highest. Effects of lead resistance are eliminated by a 4-terminal kelvin connection, and a high value internal standard reduces effects of shunt capacitance. Electro Scientific Industries Inc., Science Park Dr., Portland, Ore. 97228. **[366]**



Digigraph converter model 1000 transforms perforated-tape data into analog voltages for plotting on X-Y or incremental advance recorders. Featuring logarithmic conversion of linear data, it has facilities for overlays of data from separate tapes and from different portions of the same tape for comparison and detailed analysis. Unimetrics Corp., 2712 S.W. Freeway, Houston 77006. **[367]**



X-Y recorder 6756 has a 6-pen X-Y or T-Y recording capability. The X or paper axis can be driven with an analog input or on a time base by push button selection. Speed ranges are 0.5, 0.1, 0.2, 15, 1 and 2 in./sec, in./min., and in./hr. Each pen axis has 36 voltage ranges from 0.2 mv/in. to 100 v/in. Houston Instrument Div., Bausch & Lomb Inc., Bellaire, Texas 77401. **[368]**

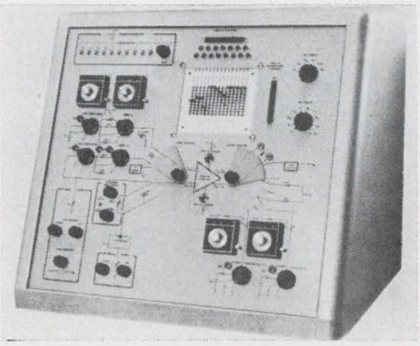
New instruments

Linear IC tester checks 22 values

Measurement system serves the needs of both the design engineer and the circuit inspector

Trying to impose order on the chaos of parameter definitions and test procedures for linear integrated circuits bought from different makers, two engineers wound up designing their own low-cost linear IC tester.

Robert Bisey and Frederick Gans, of the Grumman Aircraft Engineering Corp.'s Microelectronics Laboratory, began by defining 30 parameters and outlining how to measure each. Most of their definitions and tests are being included in MIL STD 883 [Electronics, Dec. 11, 1967, p. 26].



Circuit shown. Panel of 401 is schematic of test circuit.

Available IC test equipment, they found, was either too limited or too expensive for Grumman's use. Most instruments were built with a spe-

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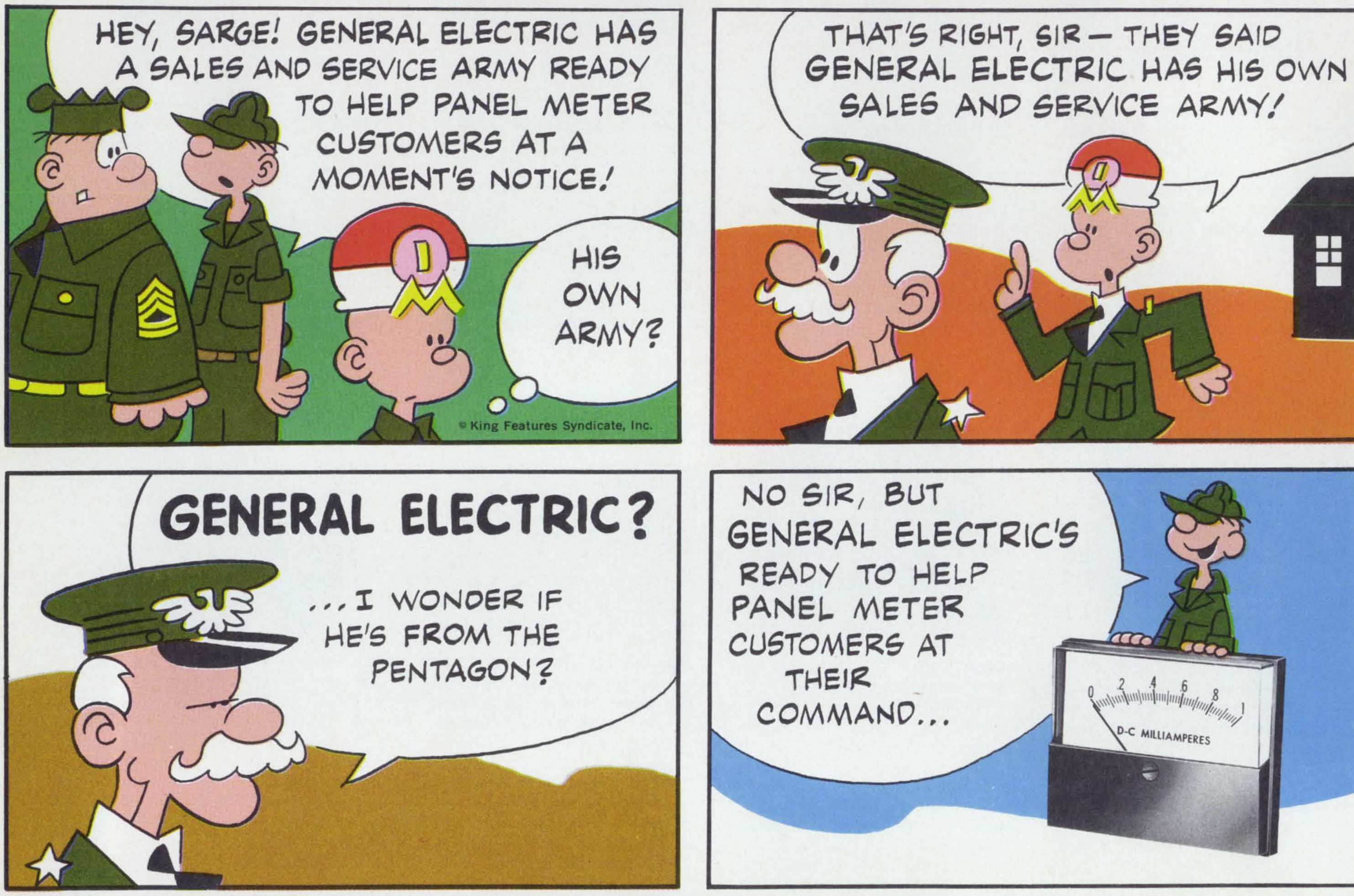

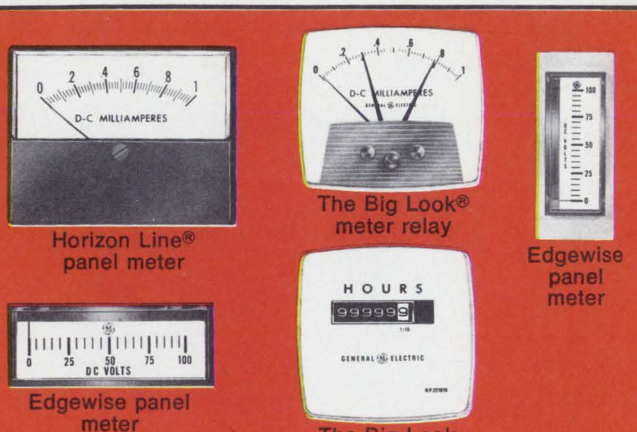

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Edgewise panel meter

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GENERAL ELECTRIC

. . . schematic layout of 401 panel allows designer to see changes in test circuit as he makes them . . .

cific maker's set of tests in mind, and there wasn't anything that could measure more than 15 parameters. So Bisey and Gans designed a unit that could measure 22 parameters, according to their own standards.

Now, under a licensing agreement, Integrated Circuit Measurement Corp. will build and sell the Grumman tester, the Model 401.

Out of steps. The 401 handles any IC package because the circuit being tested is plugged into a socket mounted on a printed-circuit board. The board, in turn, is plugged into the tester. The operator electrically connects the IC leads to the test circuits with sliding switches on the 401's front panel. Tests can be run on the main types of linear IC's—single-ended input and output amplifiers, differential input and output amplifiers, and differential input and single-ended output amplifiers.

Bisey and Gans were thinking of the system designer when they laid out the front panel of the 401. Symbols, labels, switches and knobs are placed so the designer can see, schematically, the test circuit in use. And when he throws a switch, he knows immediately what part of the test circuit he's changing.

Rather than outlining test procedures step-by-step, the 401 instruction manual shows block diagrams of the 22 test circuits. This feature, combined with the panel layout, means easy and quick setups.

Yes or no. Besides being a design tool, the 401 is useful for making go-no go tests on large batches of IC's. P-c cards are made up for a variety of tests, and given to an inspector. For a given test, he plugs a card into the programed-amplifier socket on the 401's front panel and the card by-passes the sliding switches and makes the necessary connections for the test. The inspector then just plugs an IC into the test socket, pushes a button, looks at a meter, and accepts or rejects the IC .

The designers of the 401 kept the price under $2,500 by omitting input sources and readout devices on the grounds that the auxillary equipment needed to operate the tester would be available in most laboratories.

Most tests have been designed so results can be read as output voltages. The accuracy of the readings depends only on the accuracy of the auxiliary equipment.

Extra equipment can be bought with the 401, including: an oscilloscope with differential input, a d-c vacuum tube voltmeter, an a-c voltmeter, a dual voltage power supply, an audio oscillator for measurement of dynamic parameters, and a radio frequency generator for the measurement of bandwidth.

Integrated Circuit Measurement Corp., 55 Northern Blvd. Greendale, N.Y. 11548 **[369]**

New instruments

Recorder can go to the action

Portable unit has four channels, operates on a-c or d-c, costs $2,900

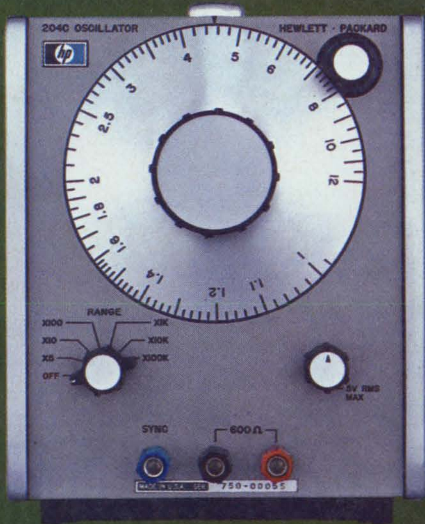
A scientific investigator working outside the laboratory has usually had to pay a high price for a recorder with more accuracy or channels than he needed because nothing else was available.

Engineers at the Sony Corp. had this researcher in mind when they designed the PFM-15 data recorder. It costs $2,900, weighs 37 pounds, and can be powered by a 12-volt battery. It records, by frequency modulation, four channels of data on ¼-inch magnetic tape. Associated with one channel is an audio amplifier and speaker, so the researcher can record his own play-by-play.

Variable power. Line voltage from 50 to 400 hertz at levels of 100, 110, 117, 125, 220, or 240 v will also power the PFM-15. Switching to a-c operation requires changing one module and setting a ac circuit design starts with an oscillator...

START WITH THE BEST

Hewlett-Packard invented the first stable Wien-bridge oscillator. Now



they have added several design improvements to two new solid state oscillators — 0.5% (0.05 dB) flatness—FET's in the bridge for improved stability — <0.1% (-60 dB) distortion—balanced output—sync in/out without degradation in specs. Now, choose from 17 hp oscillators —the widest choice in the industry!

The new hp 204C Oscillator has a frequency range of 5 Hz to 1.2 MHz, 5 Vrms output. The 204C can be operated with line power, mercury battery or a rechargeable battery pack. Price hp 204C, $250-285.

The new hp 209A Oscillator generates simultaneous sine and square wave outputs over a frequency wave of 4 Hz to 2MHz. Amplitudes are independently adjustable. Output voltage is 10 Vrms for sine wave; 20 V peak-to-peak for square wave. Price: hp 209A, $320.

Start with the best! Get complete information on the two new—or all 17 hp Oscillators—from your near-

est hp field engineer. Or, write to Hewlett-Packard, Palo Alto, California 94304. Europe: 54 Route des Acacias, Geneva.

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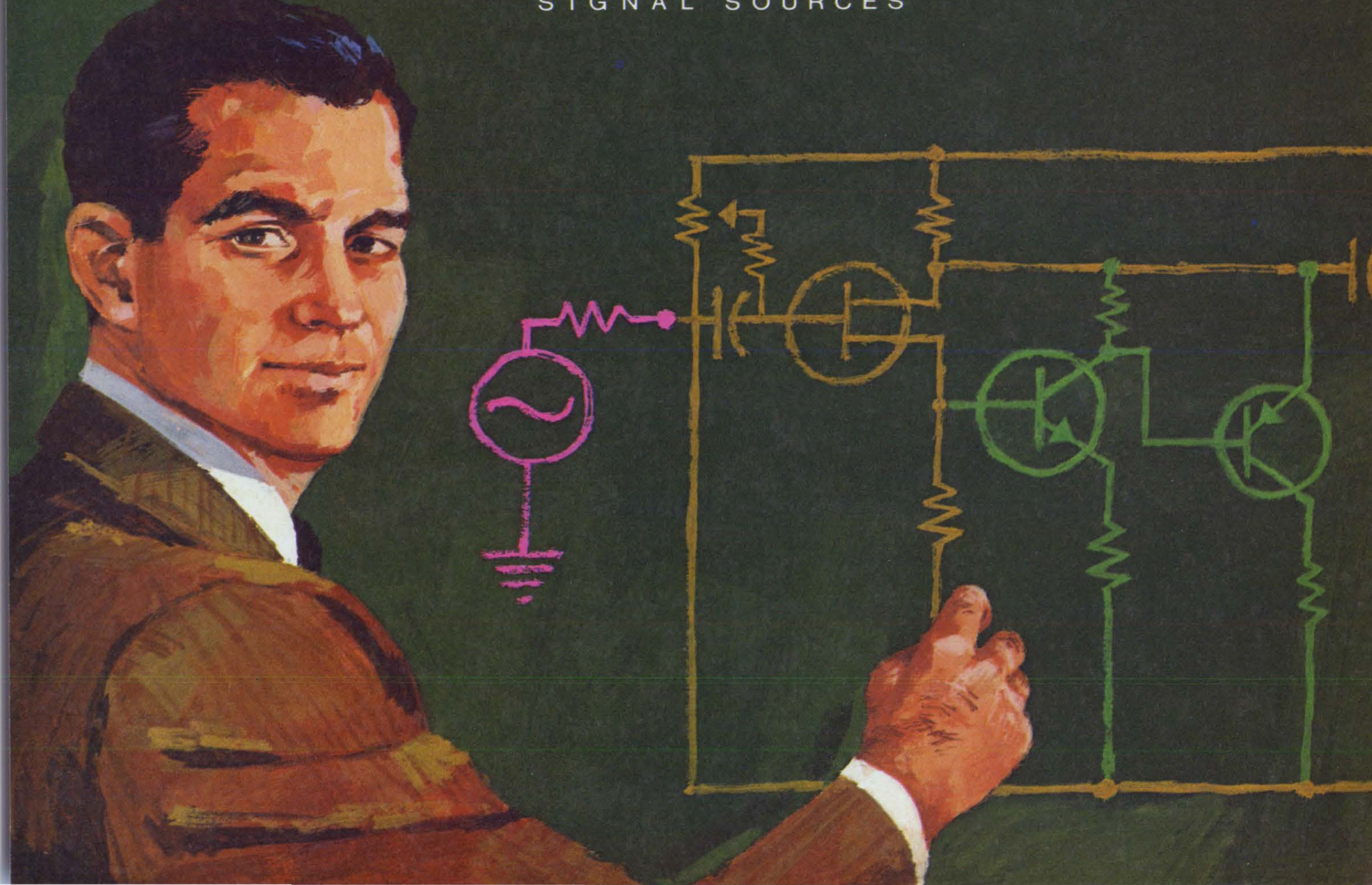
SIGNAL SOURCES



Heart beats. PFM-15 feeds the data, obtained with recorder in intensive-care ward, to averaging computer.

panel switch to the proper voltage.

The unit records linearly within ±1 decibel from d-c to 2.5 kilohertz. The operator can extend the range to 5 khz by making connections on one of the instrument's circuit cards. At this wider range, linearity is within +1 db and −2 db. The signal-to-noise ratio is 45 db, and crosstalk is −37 db. Total harmonic distortion is under 2.5% of full output, and the recorder has an input/output level meter and a level adjustment for each channel.

A servo system, used as the tape transport mechanism, maintains a constant tape speed of 7.5 inches per second.

Baby talk. Gerald Wade, a biomedical engineer with Hoffman-LaRoche Inc. (a large pharmaceutical house), has already put the PFM-15 to use. Hoffman is working with RCA to develop an automatic monitor and alarm system for the intensive care of premature infants. The system will measure such parameters as blood pressure and temperature continuously, and when any abnormal signal is received from the infant, an alarm will sound. The key to the system is knowing what are the normal and abnormal physiological signals from a premature infant, and what are artifacts.

To find out, Wade is using a PFM-15 in the intensive care unit of Columbia Presbyterian's Babies Hospital in New York. He records a variety of physiological signals and takes the tapes back to his lab at Hoffman, where he has another PFM-15, for analysis.

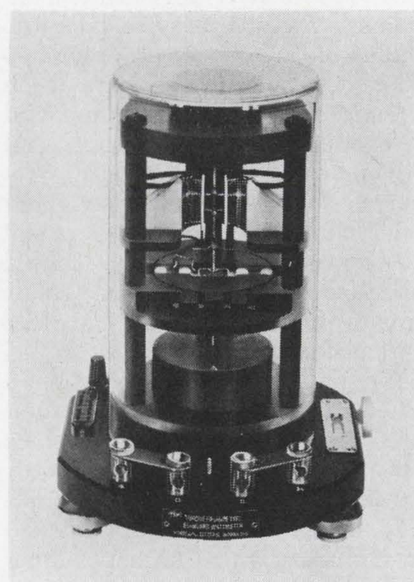
Sony/Instrumentation Data Prod., 2 Maud Graham Circle, Burlington, Mass. [370]

Wattmeter has 0.02% accuracy

Japanese calibrator uses feedback and three moving coils to increase linearity

It won't make electricity bills any easier to pay, but a new wattmeter from Japan may ensure that they're based on more accurate readings. Developed by Yokogawa Electric Works Ltd. as a calibration standard for wattmeters and watthour meters, the APR-2 has an accuracy of 0.02% and a repeatability of 10 parts per million. Hallmark Standards Inc., which will sell and service the unit in the U.S., claims the APR-2 is at least five times as accurate as present calibrators.

Like most wattmeters, the new device is a dynamometer; a moving coil on a shaft is arranged inside a fixed coil. To measure power dissipated by a load, the fixed coil is put in series with the load, and the moving coil is placed in parallel with it, so that the deflection of the moving coil is proportional to the product of current in and voltage across the load. The problem here is that as one coil rotates,



Converter. Isolation of the three moving coils allows use of feedback loop to reduce change in mutual inductance.

mutual inductance changes, and coil impedances change. As deflection increases, therefore, linearity decreases.

Spin stopper. In the APR-2, a feedback loop reduces deflection. There's a second moving coil inside another fixed coil on the instrument's shaft. When a 10-kilohertz signal is applied to this fixed coil, the resulting rotation of the shaft induces a current in the second moving coil. This current is amplified and then mixed with the 10-khz signal to produce a d-c signal, porportional to load power, that flows into an output resistor.

The mixed signal is also fed into a third moving coil situated between the poles of a permanent magnet. This signal tends to move the shaft in opposition to the rotation caused by signals from the load, and keeps the maximum deflection of the shaft under 0.05 degrees.

Isolation. Russell Brownell, engineering vice president at Hallmark, explains that the unit's accuracy stems from the fact that "power sensing, torque sensing, and deflection sensing are electrically isolated while being mechanically connected." Brownell says the feedback approach has been attempted before, but that the APR-2 is the first instrument to use three moving coils. Other feedback systems, he adds, use one or two coils and are plagued by interaction.

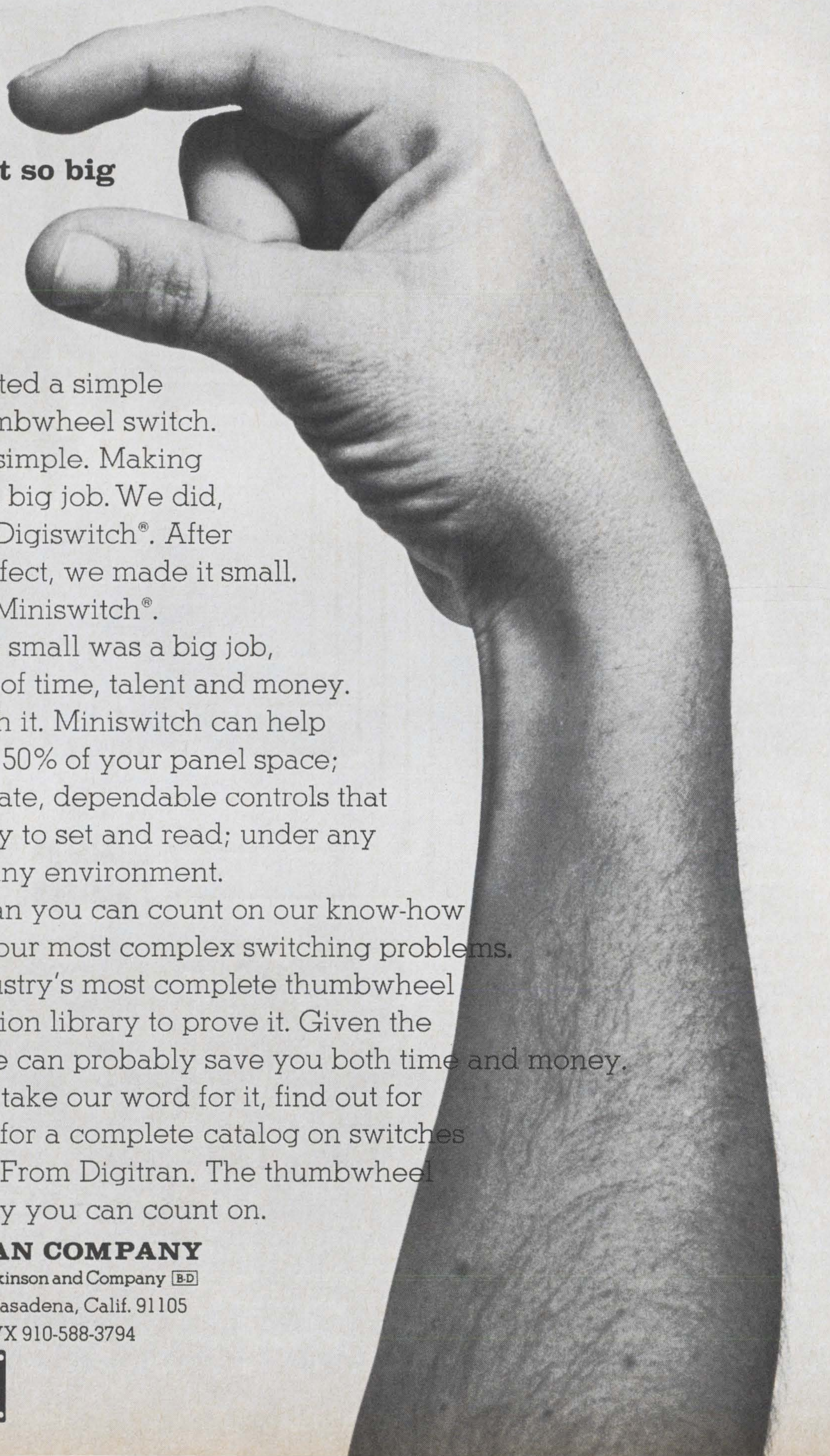
Accuracy is guaranteed up to 2 khz, and Hallmark says the unit gives good results up to 10 khz. It can handle 110 volts and 5 amps, and settling time between readings is less than 5 seconds.

Loss check. Although the APR-2 was designed for use in calibration labs, other applications are possible. Fuji Steel doesn't need 0.02% accuracy when it measures core loss, but it's doing the job with APR-2's anyway. Fuji uses the instrument's 0-to-1-volt d-c output to digitalize power readings.

The APR-2 comes in three parts—a converter that contains the dynamometer section, an amplifier, and a standard-resistance box. Cost is $6,650, and delivery time is six months. Hallmark hopes to eventually build the units in the U.S.

Hallmark Standards Inc., 145 Library Lane, Mamaroneck, N.Y. 10543 **[371]**

Digitran made it big



about so big

Digitran perfected a simple idea... the thumbwheel switch. Making it was simple. Making it perfect was a big job. We did, and called it a Digiswitch®. After we made it perfect, we made it small. We call that a Miniswitch®.

Making it small was a big job, too. It took lots of time, talent and money. But it was worth it. Miniswitch can help you save up to 50% of your panel space; give you accurate, dependable controls that are simple, easy to set and read; under any conditions, in any environment.

At Digitran you can count on our know-how to help solve your most complex switching problems. We've the industry's most complete thumbwheel switch application library to prove it. Given the opportunity, we can probably save you both time and money.

But don't take our word for it, find out for yourself. Send for a complete catalog on switches (big and little). From Digitran. The thumbwheel switch company you can count on.

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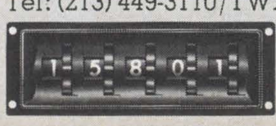
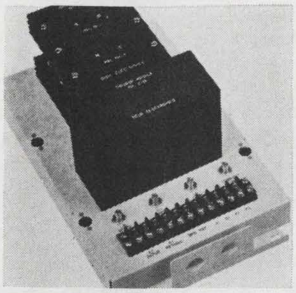
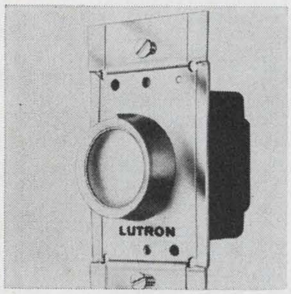
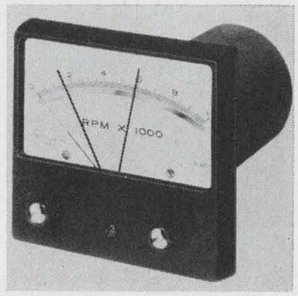




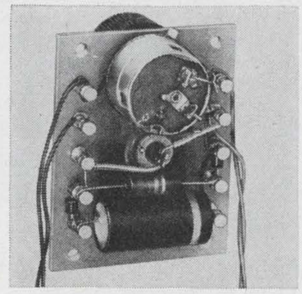
Plug-in SCR motor speed control 2100 is for d-c shunt wound motors. It consists of 2 plug-in modules that are readily removed without disconnecting wiring. Replacement is achieved in 30 sec by unskilled personnel. The unit covers d-c motors from 1/4 to 1 h-p at 115 v a-c; and 1/2 to 2 h-p, 220 v a-c input. Seco Electronics Corp., 1001 2nd St. South, Hopkins, Minn. 55343. **[421]**



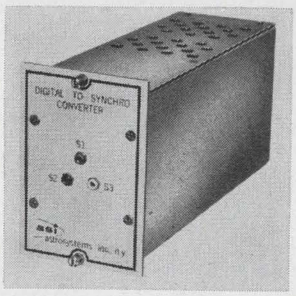
Solid state Fandial continuously varies fan and blower speeds from maximum to any desired lower speed within inherent shaded-pole or permanent split-capacitor capability. Standard thyristor modules FS-5 (5 amps, 120 v a-c, list price $11.95) and FS-10 (10 amps, 120 v a-c, list price $24.95) are available. Lutron Electronics Co., Emmaus, Pa. 18049. **[422]**



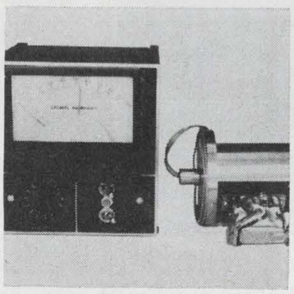
Electronic tachometers for both indication and alarm are offered in a wide choice of ranges calibrated directly in rpm, cps, mph, fpm, or special ranges. The line features accuracy of ±1% and linearity of ±1% over 9 ranges from 0 to 50 to 0 to 20,000 hz. Three sizes of meters are offered: 3 1/4, 4 1/2 and 5 1/2 in. API Instruments Co., Chesterland, Ohio 44026. **[423]**



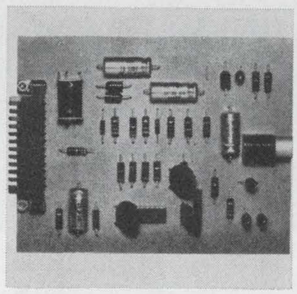
A-c motor speed control model MS-6A features feed-back for constant speed under varying load conditions, and a speed adjustment that enables a variation of speeds during operation. Input voltage is 117 v rms ±10%, 50-60 hz. Output wave shape is 60 hz sine wave. Maximum load current is 6 amps. Price (1-25) is $28 each. Oven Industries, Box 229, Mechanicsburg, Pa. **[424]**



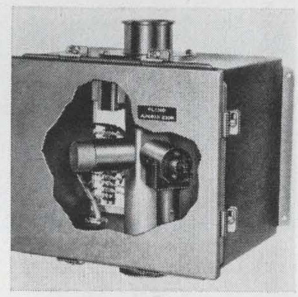
Solid state digital-to-synchro converter model DS800 is designed for simulation and industrial control. It accepts a 10-bit parallel binary input and provides a completely isolated synchro output at 11.8 v, 40 hz line-to-line, with accuracy of better than 30 minutes of arc, no load to full load, without adjustments. Astrosystems Inc., 6 Nevada Dr., New Hyde Park, N.Y. 11040. **[425]**



Noncontact instrument RMI-1500 is a solid state unit for measuring and controlling temperature on rotating machines, with a single sensor. Over its 0 to 1,500°F range, readability is a constant 1/2°F. Controller action is failsafe. Accuracy is 1% of full scale absolute. Units operate from 115 v, 60 hz. S. Himmelstein & Co., 2500 Estes Ave., Elk Grove Village, Ill. 60007. **[426]**



Alarm card series 625 is for single or multi-point temperature alarm applications. It can also be used as an on-off controller for 1 amp at 120 v a-c (spst). The unit uses a reed relay type of output for maximum reliability. It will accept a thermocouple input, resistance bulb or other d-c input signals. Price is $45. Electronic Control Systems Inc., Fairmont, W. Va. 26554. **[427]**

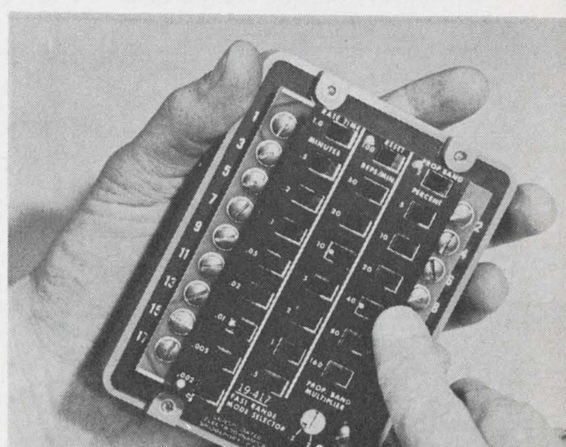


Fluid analyzer model 260, for industrial and processing uses, comes in ranges of 0 to 1 ppm and 0 to 300 ppm. It consists of an in-line sensor and indicator, and the two units may be located up to 500 ft apart. Standard model process fluid temperatures are up to 140°F, with optional temperature capability up to 450°F. Gam Rad Inc., 16825 Wyoming Ave., Detroit, Mich. **[428]**

New industrial electronics

Blind controller eyes special situations

Dropping extras, compensator based on operational amplifiers applies to large and small custom projects



When a process controller contains more than a customer wants to pay for, the supplier can forget about the sale or he can design a stripped-down version that competes with his own and other conventional lines.

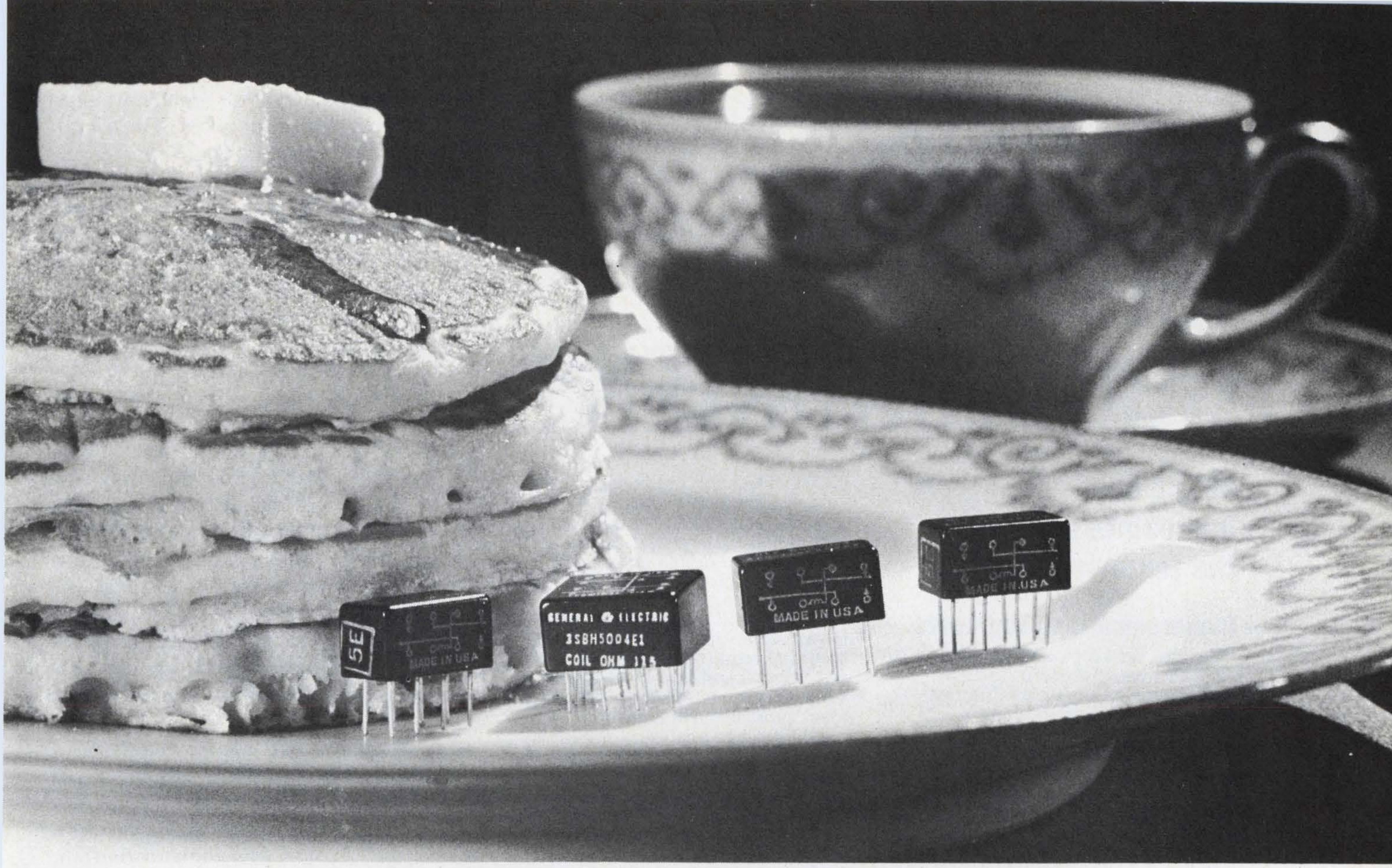
Encouraged by customers' suggestions, C. Kenneth Hines, general manager of the Control Products division of the Consolidated Electrodynamics Corp., a Bell & Howell company, took the second route. The result is a blind, three-mode, electronic analog controller with a basic price of $265—more than one-third less than that of conventional indicator controllers. The term blind means a controller that—unlike conventional counterparts—has no built-in indicators or recorders that add several hundred dollars to the cost and often can be superfluous.

Keeping each control loop at its preset value is accomplished with analog controllers that introduce just the right amount of dynamic compensation to counteract disturbances. Because different loops exhibit different dynamics—flow loops can be fast responding whereas temperature loops can be much slower —commercial controllers have adjustments that permit the selection of the amount of dynamic response to match the characteristics. This matching is called tuning.

Blind controllers have been around for years, particularly pneumatic versions. But there's more interest in them now because experienced users are finding control applications that involve both the dynamic compensation supplied by the controller and the computation supplied by other analog modules. If needed, the computed variable is displayed.

Field-proven. The blind controller, called Model 19-417, was developed about two years ago but has been used mainly as a module in larger systems. Some were sold as individual items, mainly to the Lubrizol Corp., whose engineers used the controllers in their engine test stands. Mostly unattended, these stands operate on a 24-hour basis to evaluate the company's chemical additives for lubricants and fuel. Because these additives must be tested under many conditions, the controllers receive programed setpoints to keep engine speed, cooling-water temperature, and oil temperature at the selected values.

The blind controller has been used in a much larger application, too. A flow of cooling water on the runout table of a new hotstrip mill, built by the Youngstown Sheet & Tube Co. in East Chicago, Ind., is being manipulated by these instruments. To assure adequate cooling



Flat as a pancake...
and selling like hotcakes

And why not?

General Electric's new high performance 150-grid sealed relays are smallest where it counts most—only 0.320" high. What's more they come in 4 versions: 4 Form C, 2 Form C, 4 Form C AND-logic type, and a 50 milliwatt sensitivity 1 Form C (or 1A+1B).

Result: for the first time you can get really small size, a variety of forms to choose from, and exceptional performance all in one relay type.

These General Electric 150-grid space relays meet or exceed the environmental and mechanical specs of much larger Mil Spec micro-miniature relays. And compared to relays of comparable size, GE 150-grid space relays have 3 times the magnetic force and over twice the contact force of the nearest competitor.

Outstanding features include:

- High vibration capability
- Excellent minimum current switching ability
- Excellent thermal resistance
- High overload capability—can withstand 5 amps each contact and make and carry 10 amps for short periods
- No flux contamination because of all-welded construction and design.

For more information on the small relay that's going over big, contact your General Electric Electronic Components Sales Engineer. He can tell you more about them and help with your individual application. Or write for bulletin GEA-8042B, Section 792-41, General Electric Company, Schenectady, New York 12305.

Specialty Control Department, Waynesboro, Virginia

GENERAL ELECTRIC

Circle 291 on reader service card

without wasting water, the controllers are joined with electronic analog computing modules. These provide both feed-forward and feedback regulation. As a result, the amount of water needed to cool the steel strip is adjusted precisely in each of 45 sections along the table according to the temperature, thickness, and speed at which the strip is moving.

Easy attachment. Control dynamics is accomplished with two operational amplifiers with adjustable resistance-capacitance networks. In this regard, the controller is not substantially electronically or functionally different from other controllers. But its small size, and availability via screw terminals to all salient portions of the circuit, simplify custom packaging and connection to additional circuits for computation and connection to a meter for display.

Unlike most analog controllers which have perhaps eight or 10 selectable values in each mode, the Model 19-417 has up to 516 discrete values. To get this high resolution, slide switches change the amount of resistance in the dynamics networks, the tuning-constant value being the sum of the values assigned to the individual switches. The proportional mode has seven slide switches, the reset mode eight, and the rate mode nine. For example, with its eight switches the (fast range) controller's reset mode can be tuned in 256 steps—its lowest value being 0.5 repeats per minute with one switch actuated, its highest 188 repeats per minute with all switches actuated.

Specifications

Output	1-5 ma d-c (or 0-10 v) into 2,800 ohms
Input	0 to 10 v at 200 kohms
Fast model ranges	
Proportional band	1 to 318%
Reset mode	0.5 to 188 repeats per minute
Rate mode	0.002 to 1.88 minutes
Slow mode ranges	
Proportional band	1 to 318%
Reset mode	0.05 to 18.8 repeats per minute
Rate mode	0.02 to 18.8 minutes
List price	$265
Options	
Internal relay for automatic/manual transfer	Add $30
4 to 20 ma d-c output	Add $10

Consolidated Electrodynamics Corp., a sub. of Bell & Howell Co., 706 Bostwich Ave., Bridgeport, Conn. 06605 **[429]**

Servo potentiometer charts many courses

Process-control recorder is built for easy service and a long life-span

Servo potentiometers are as important to process control as the controller is. And because they usually run around the clock, they must be trouble-free. Honeywell Inc. designed its newest recorder, the ElectroniK 111, so that it requires only routine servicing.

ElectroniK 111's automatic control units can be removed for servicing without interrupting the process. To make the recorder trouble-free, Honeywell used all-silicon circuitry, including the chopper and amplifier. Moreover, the input filter has a floating shield to minimize the effects of radiated noise, and a precision slidewire made of corrosion-resistant platinum alloy. The slidewire has a four-finger contact so that at least one finger maintains contact at all times.

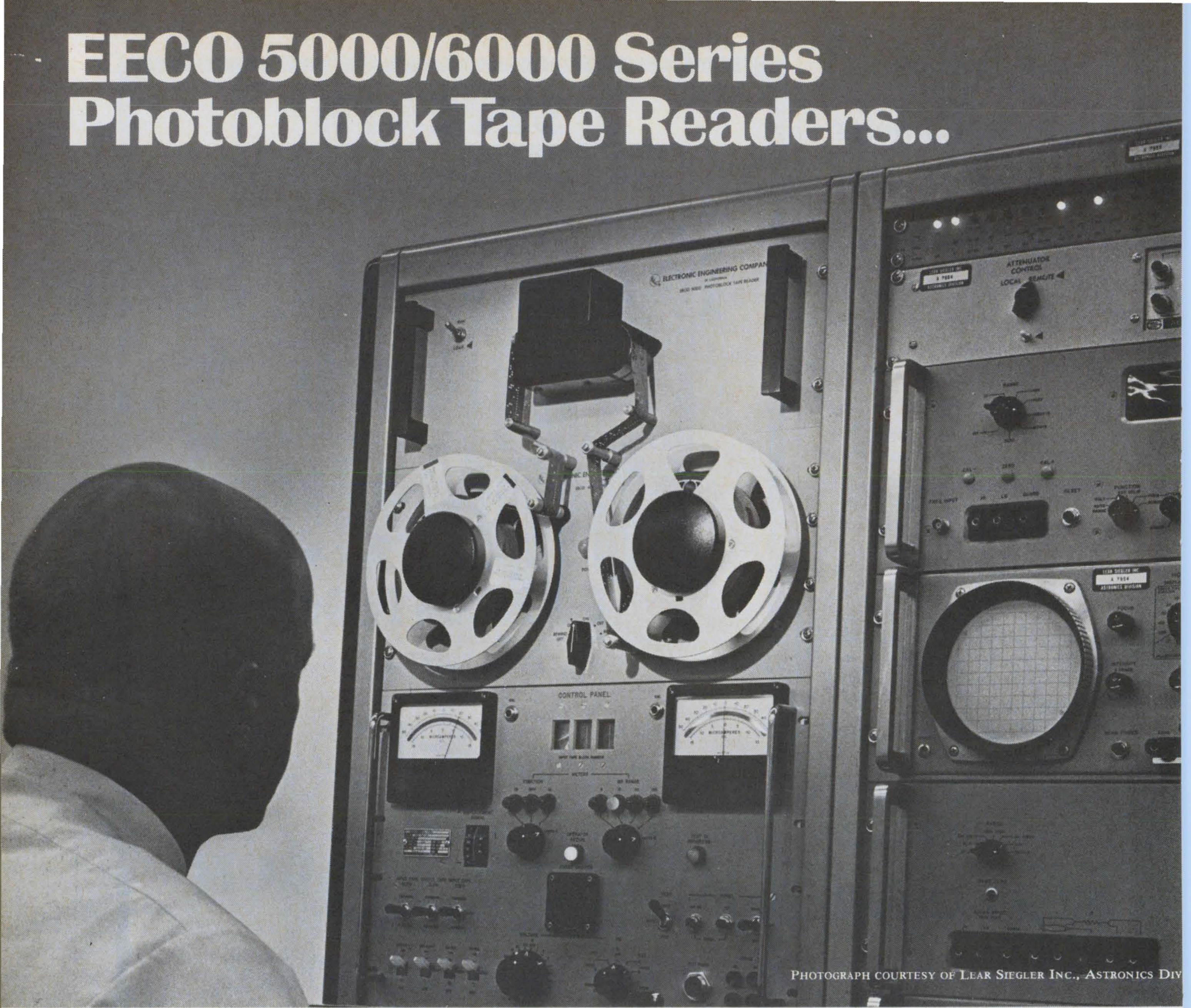
Other features include an interchangeable chassis, and a lift-out chart transport.

User's choice. The recorder is available with three kinds of outputs; current, position, and time proportioning. It uses a 6-inch-wide chart that's available in drive speeds of 1, 2, 6, 10, 12, 20, 30, and 60 inches per hour. Circular charts come in 1, 4, 8, and 24 hours per revolution varieties.

The device comes as a circular or a strip-chart recorder; the characteristics are the same for both. Accuracy is ±0.3% of span; reproducibility, ±0.15% of span; dead band, 0.1% of span; response time, 5 seconds (15 seconds is optional); source resistance rating, 2,000 ohms max.; input impedance, infinite at balance, 200 kilohms min. off balance. The recorder operates in ambient temperatures up to 140°F, and costs from $625 to $1,000 depending upon control units. Delivery is 10 to 12 weeks.

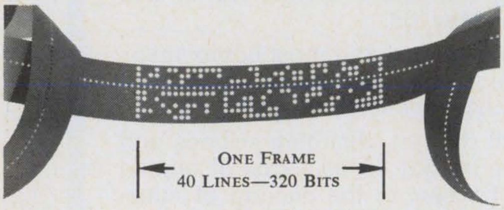
Honeywell Inc., Industrial Div., MS 436, Fort Washington, Pa. 19034 **[430]**

EECO 5000/6000 Series Photoblock Tape Readers...



PHOTOGRAPH COURTESY OF LEAR SIEGLER INC., ASTRONICS DIV

speed production testing



Segment of tape showing one 40 line block of data used to program instrument ranges and comparator limits.

EECO 5000/6000 Series Photoblock Tape Readers can be used to program a variety of electronic test instruments. Frequently, they are the most versatile economical method of automating the production testing of electronic products.

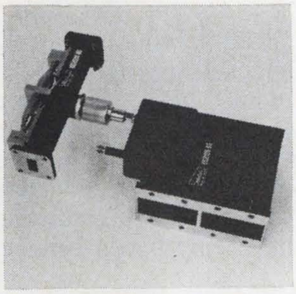
Tape with 5 to 40 8-bit lines of test sequence data (40 to 320 bits) is photo-electrically read to program a particular test. The 5000 Series reads at rates to 12 blocks per second (100 lines/sec) ... the 6000 Series to 20 blocks per second (200 lines / sec). Twenty output options facilitate interface with present test instrumentation.

All EECO Photoblock Readers use solid state controls and step motor drives. EECO's *exclusive latching output option,* which keeps output lines "latched-in" between block advance commands, allows testing to continue while the tape is moving.

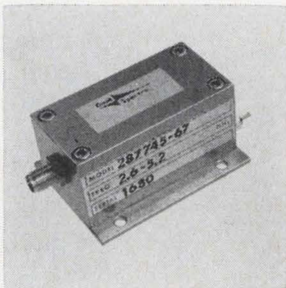
Compare EECO 5000/6000 Series Photoblock Readers for versatility, economy and reliability with such other programming methods as single line readers with buffer memories. Ask for data sheet and prices.

INSTRUMENTS DIVISION

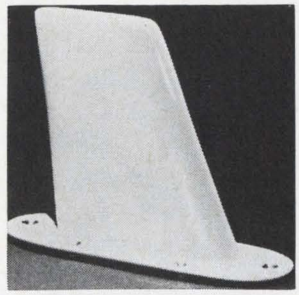
ELECTRONIC ENGINEERING COMPANY OF CALIFORNIA
1601 EAST CHESTNUT AVENUE · SANTA ANA, CALIFORNIA 92701 · (714) 547-5501



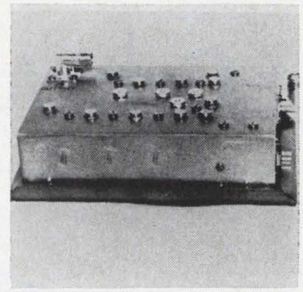
Tunable, low-noise parametric amplifier model APC-5 is compatible with C-band radar systems. It operates in the 5.4-to 5.9-Ghz range. It has a 20-Mhz instantaneous 3-db bandwidth. Noise figure is 3 db max. with 18 db of gain. Calibrated gain and frequency controls permit tuning with excellent repeatability. Melabs Inc., 3300 Hillview Ave., Palo Alto, Calif. 94304. **[401]**



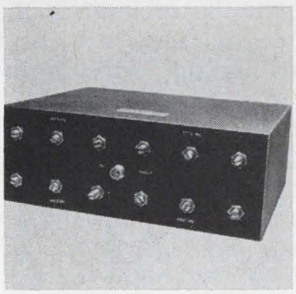
High-Power, solid state voltage-tuned oscillators can be used as VTM and BWO replacements in military countermeasures systems as well as in commercial sweep oscillators. Units measure 1 x 1 x 2 in. The 28774-66 produces 200 mw across the 2 to 4 Ghz octave; the 287745-67, 20 mw over the 2.6-5.2 Ghz octave. Omni Spectra Inc., 24600 Hallwood Ct., Farmington,Mich. 48024. **[402]**



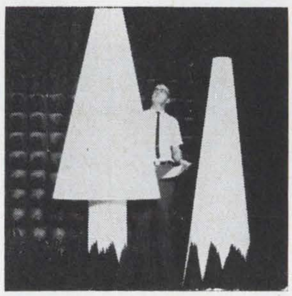
Vertically polarized L-band antenna L10-16 operates over the range of 975 to 1,225 Mhz. Impedance is 50 ohms; vswr, 1.5:1 or less. Radiation pattern is essentially omnidirectional. The unit is made of fiberglass and epoxy materials, and measures 3⅞ in. high. Communications Components Corp., 1524 W. 15th St., Long Beach, Calif. 90813. **[403]**



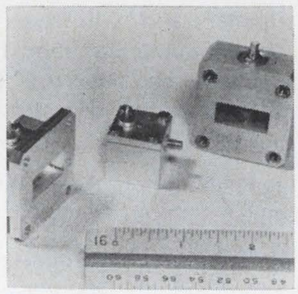
Two standard octave transistor preamplifiers, one covering 250 to 500 Mhz and the other 500 to 1,000 Mhz, are for military communication uses. Noise figures are 7.5 and 10.5 db, respectively. Both have input and output impedance of 50 ohms and gain of 13 to 17 db. Each features vswr of 2.3 to 1 max. Micro State Electronics, 152 Floral Ave., New Providence, N.J. 07974. **[404]**



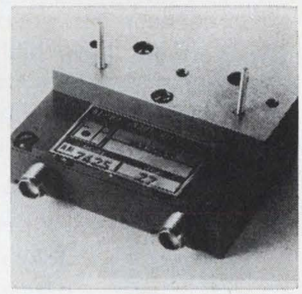
Multiplex passive filter 18205 has a simple r-f input and affords 4 r-f output channels at 366, 377, 410 and 456.7 Mhz. Each output has a 3-db bandwidth at 1.0 Mhz. Channel insertion loss is less than 1.5 db (pass band). Rejection outside pass band is greater than 70 db at 18 Mhz. Microwave Cavity Laboratories Inc., 10 N. Beach Ave., LaGrange, Ill. 60525. **[405]**



The Eccoless target support columns fill the need for rugged low-reflectivity rotatable supports to hold targets or models during reflectivity measurements in a microwave anechoic chamber. A variety of sizes and shapes are available. Typically the dielectric constant is 1.03, and the loss tangent 0.0002. Price, on special quotation. Emerson & Cuming Inc., Canton, Mass. 02021. **[406]**



Semiconductor microwave oscillators using the IMPATT (impact avalanche transit time) principle and quietly delivering a nominal 60 mw c-w are for use at the fixed frequency of 10.525 Ghz in the public service radio location band. Typical applications include local oscillators and in low-power railroad monitoring. Varian Bomac Division, 8 Salem Road, Beverly, Mass. **[407]**



Compact, lightweight coaxial balanced mixer model AM-7425 features ease of diode replacement (by removal of 2 crystal caps), resulting in virtual elimination of system down-time. Frequency range is 1 to 2 Ghz; noise figure, 7.5 db typical; vswr, 1.5 max. Unit measures 2 x 2.10 x 0.75 in., weighs 3 oz. Alpha Industries Inc., 381 Elliot St., Newton Upper Falls, Mass. 02164. **[408]**

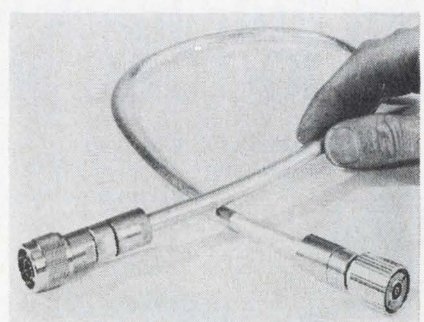
New microwave

Cable assembly takes a turn

Flexible waveguide exhibits characteristics as favorable as those of rigid units

The performance of microwave instrumentation has been limited by the connector so that it was almost impossible to use the device's full capability. The development of precision, 7-millimeter coaxial connectors helped in part. But these connectors performed only to specification when used with rigid airlines. Consequently, many microwave instruments were unusually bulky.

Two developments from the Amphenol Corp. should eliminate this problem. The company has perfected the techniques for manufac-



Dual mates. Semi-rigid aluminum jacket coaxial cable accommodates either precision 7-mm (at right) or type-N connectors.

. . . designed electrically, not mechanically . . .

turing semi-rigid, aluminum-jacketed coaxial cable that retains its diameter while being bent and twisted. Amphenol's RF division has also developed a technique for mating precision 7-mm connectors with the cable. This technique can also be used with N-type connectors.

Besides giving flexibility to the microwave-instrument manufacturer, Amphenol's semi-rigid coaxial assemblies allow precision connectors to be used in aircraft. Coaxial cable removes the frequency restrictions on aircraft microwave systems that previously had to incorporate band-limited waveguides. In addition, the waveguides had to be preformed; the semi-rigid coaxial line can be bent and shaped as the cable is installed.

These semi-rigid cable assemblies are designed electrically and not mechanically as in the traditional approach. As a result, assemblies can be held to an impedance of 50 ±0.5 ohms—roughly one-fifth the tolerance of the previous state-of-the-art for semi-rigid cable assemblies. Moreover, the maximum vswr (voltage standing wave ratio) is 1.15 at 12.4 gigahertz. The cable assemblies are available in four standard lengths—one, two, three, and four feet. However, other lengths are available on special order.

Previously, users of semi-rigid cable assemblies had to live with relatively large changes in impedance as the cable's diameter changed with bending. Also, the vswr changed if the center conductor shifted. For example, a change of 250 microinches in the diameter of the cable could add as much as 0.2% to the cable assembly's vswr.

Amphenol's aluminum-jacket cable is built with a foamy material between the jacket and the polyethylene insulating core material. The foamy material allows accurate sizing of the cable to achieve the 50-ohm impedance without stressing the inner conductor.

Amphenol Corp., RF division, 33 E. Franklin St., Danbury, Conn. 06810 **[409]**

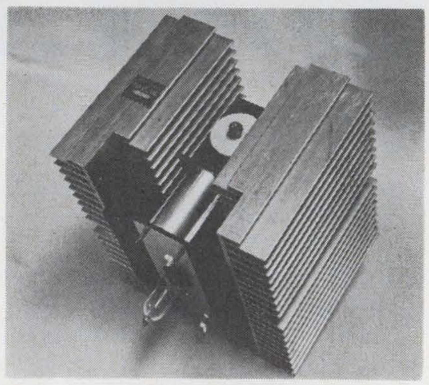
New microwave

Japanese cook up cool oven with fins

Aluminum alloy dissipates heat of magnetron that delivers 600-watt output

The trick in using a microwave oven is to be able to bake a cake without baking the magnetron along with it.

Engineers at Japan's Matsushita Electric Industrial Co. have developed a magnetron for cooking applications that is convection cooled with aluminum-alloy fins. In most magnetron applications, heat is dissipated by forced-air or water cooling. By going to the convection technique, Matsushita has eliminated the need for fans, air ducts, air filters, and water pumps and



jackets. Moreover, since the technique is passive, power consumption and noise levels are low.

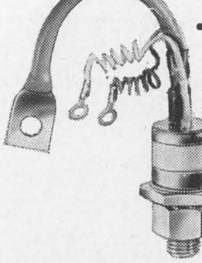
Serving up power. The company's magnetron delivers 600 watts of output power and, according to Matsushita, is the largest ever to be cooled with convection techniques.

The tube is a self-contained unit that need only be connected to a power supply. The oscillator tube, magnet, radiator, and filter circuits are in a single package. In operation, the anode and the aluminum-finned radiator are grounded, and 3 volts are supplied to the filament. Operating frequency is 2.45 gigahertz.

Matsushita Electric Industrial Co., Osaka, Japan [410]

60A, 1400V Controlled Avalanche Thyristors..

If you are visiting London for the Instruments, Electronics and Automation Exhibition (Olympia, May 13-18) call at the Mullard stand to see these thyristors, and a wide range of semiconductors, valves, tubes and components for industry.



...part of a range covering 1·0 to 62·5A, 100V to 1·4kV in 4 different series

Standard types, high temperature types, avalanche types and inverter grades—all readily available from Mullard at competitive prices.

Here are the details—

Avalanche Types	Average Current Ratings	Up to 60A
Rated: 85°C Stud	Min. Avalanche Voltage	Up to 1400V
High Temperature Types		
Rated: 110°C Stud	Average Current Ratings	Up to 11.5A
	Max. Crest Reverse Working Voltage	Up to 400V
Inverter Types	Turn off time	
Rated: 85°C Stud	(up to 10A)	10 μs
	(up to 62.5A)	15 μs
	Max. Crest Reverse Working Voltage	Up to 500V
Standard Types	Average Current Ratings	Up to 62.5A
Rated: 85°C Stud	Max. Crest Reverse Working Voltage	Up to 1000V

Every designer should have a copy of the Mullard Quick Reference Guide containing information on thyristors, rectifiers, stacks and modules.

Also ask to be put on the mailing list of the Mullard Bulletin—a regular publication which gives details of new components and applications . . . the result of extensive research and development programs in the Mullard laboratories in England. Mullard employ 1,000 qualified scientists and engineers and have six major plants, with over 3 million square feet of floor space.

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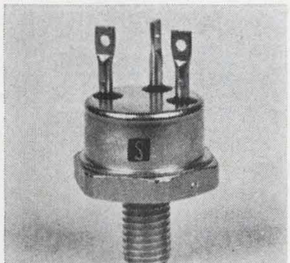
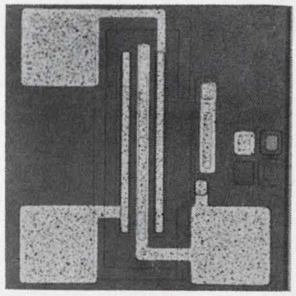
U.S.A. enquiries to Mullard Inc., 100 Finn Court, Farmingdale, Long Island, New York. 11735 U.S.A.
Telephone: (516) 694-8989 Telex: 961455

Mullard LIMITED

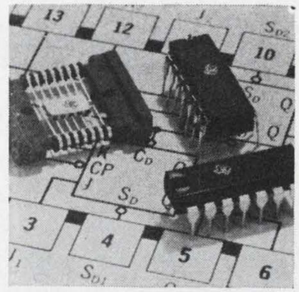
Medium power DTL IC's in the CD2300 family come in 15 circuit types in 14-lead ceramic dual-in-line packages. They are directly interchangeable with the 980 and 830 series DTL IC's. Unit price in lots of 1,000 ranges from $2.25 for a dual 4-input expander to $3 for a clocked R-S flip-flop. RCA/Electronic Components, 415 S. Fifth St., Harrison, N.J. 07029. **[436]**



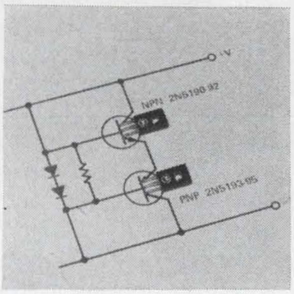
Complementary pairs of 20 amp and 10 amp npn and pnp silicon power transistors come in the isolated TO-61 case. Devices offer breakdown voltages up to 120 v, power dissipation of 50 w at 100°C and gain-bandwidth products of 30 Mhz minimum. Applications include high current amplifiers and bridge circuits. Solitron Devices Inc., 1177 Blue Heron Blvd., Riviera Beach, Fla. **[437]**



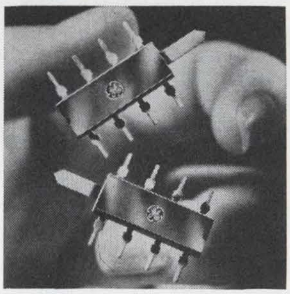
P-channel enhancement mode MTOS transistor MEM 556 is a high voltage device. It is suited for multiplexing, series and shunt chopping, and commutating. Features include 80-v max. operation and an off-to-on ratio of 2 x 10^8. The unit shows less than 60% threshold shift with 25-v substrate biasing. General Instrument Corp., 600 W. John St., Hicksville, N.Y. 11802. **[438]**



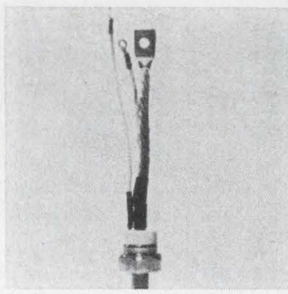
Four dual flip-flops (types SN15 9093,-94,-97,-99), 2 hex inverters (SN15 936,-37), and 3 fast-rise-time gates (SN15 949,-63,-61) have been added to the series 930/830 DTL IC line. All are available in flatpacks and ceramic and plastic dual in-line packages, and with military or industrial temperature ratings. Texas Instruments Inc., Box 5621, Dallas 75222. **[439]**



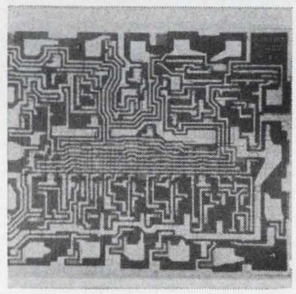
Silicon transistors 2N5190-95 are 4-amp npn/pnp units that eliminate the need for expensive matching transformers, and can handle up to 35 w of power. Thermopad construction—with a chip-to-heat sink thermal path of 0.030-in.—means low thermal resistance and minimum derating in chassis-mounting uses. Motorola Semiconductor Products Inc., Box 955, Phoenix, Ariz. 85001. **[440]**



Monolithic IC audio amplifier PA234 delivers 1 watt of continuous power to either a 16- or 22-ohm speaker. It requires only 4 external components and is designed to operate from the power supply range of 9 to 25 v. Applications include usage in headphones, phonographs, tape players and tv receivers. General Electric Co., Electronics Park, Syracuse, N.Y. 13201. **[441]**



Thyristor SCR 260 is rated at 175 amps half-wave average. Among the major parameters is the forward blocking voltage through 1,500 v steady state, and a 300 v/μsec minimum dv/dt to rated voltage. Surge current rating is 5,000 amps. Price (25-99) is $167 each for the 600-v unit, and $509 for the 1,500-v unit. Westinghouse Electric Corp., Youngwood, Pa. 15697. **[442]**

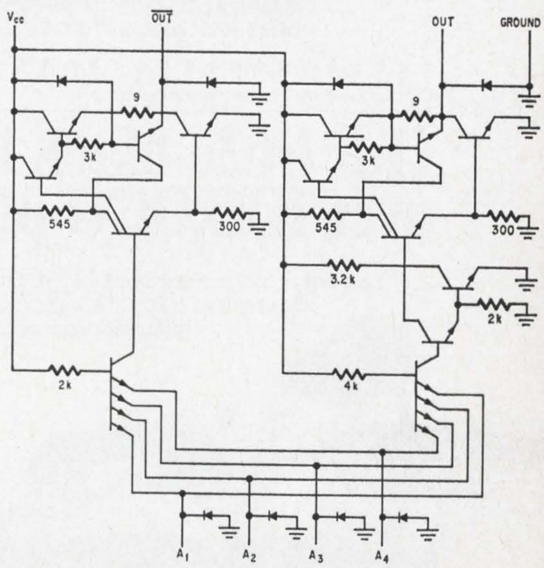


Decoder 9307 is a 28-gate circuit that features 4 inputs in 8421 BCD code and provides active high outputs for a 7-segment numerical display. The chip is sealed in an all-ceramic, 16-pin dual in-line package, with the 16 leads optimally arranged for p-c layouts. Maximum package size is 0.200 x 0.375 x 0.785 in. Fairchild Semiconductor, 313 Fairchild Dr., Mtn. View, Calif. 94041. **[443]**

New semiconductors

A logical approach to linear IC's

Line receiver and driver operate on single power supply; logic compatibility eliminates need for interface circuitry



Steering clear of the me-too approach to integrated circuits, the National Semiconductor Corp. is fast building a reputation as a first-of-a-kind IC maker. Its newest linear circuits to be sold off the shelf—a dual line driver (shown at right) and a dual line receiver—require a single power supply and are compatible with transistor-transistor logic, diode-transistor logic, and resistor-transistor logic.

Similar standard circuits now on the market require two power supplies and external circuitry for interfacing with TTL, DTL, and RTL.

. . . line driver provides differential output . . .

Developed by National's director of advanced circuit development, Robert J. Widlar, and design engineer James Kubinec, the IC's are the DM7820 dual line receiver and the DM 7830 dual line driver. Both need only a 5-volt supply. They have built-in overvoltage, short-circuit, and overshoot protection. Compared with other IC's National Semiconductor's are less susceptible to environmental noise.

Difference counts. Line receivers attenuate a low-level logic signal, riding on a twisted wire pair, to prevent it from being smothered by common-mode voltage. Having a common-emitter input stage after the attenuator network, the receiver then processes the differential signal. The DM7820 differs in that it has a common-base amplifying stage instead of the common emitter, enabling the circuit to operate at a single, lower bias. Moreover, this leads to greater attenuation of the input.

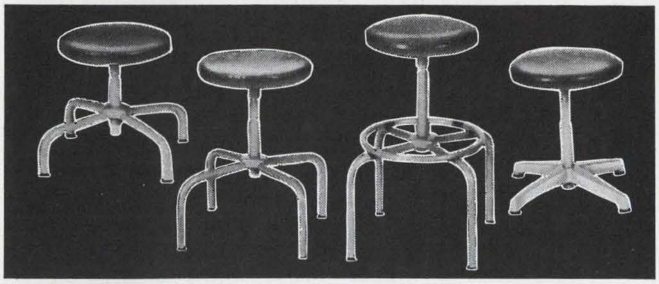
National Semiconductor's line receiver has wired-OR options at the output, termination resistors, and response time control, and accommodates independent channel strobing. Also, the circuit's output section contains a current-source arrangement that doesn't require pnp elements.

The dual line driver feeds twisted pair or coaxial transmission lines, and provides differential outputs for maximum signal-to-noise ratio. The DM7830 has a propagation delay of 60 nanoseconds for a 100 ohm-5,000 picofarad load, and has clamp diodes at both the input and output stages to prevent overshoots in the signal.

The military version of DM7820, designed to operate between —55° and +125°C, is priced at $24 in lots of 100; the industrial version, with a temperature range of 0° to 70°C, costs $10 in similar quantities. The military version of the DM7830 is priced at $16, and the industrial version at $8. Both circuits are constructed with a zero-volt threshold level.

National Semiconductor Corp., 2975 San Ysidro Way, Santa Clara, Calif. 95051 **[444]**

NEW from Cramer



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Cramer Adjust-A-Lok is immediately adjustable to any workers height. Just release the safety stop, and lift or lower. It can be done just that quick. Since fatigue is a critical factor in efficiency of seated workers, it's just good economics to provide tools that minimize fatigue. With Adjust-A-Lok every worker can find his own most comfortable and efficient level. 6 seat styles and 5 base types provide 30 available models. For more information: write V. P. Sales, Cramer Industries, Inc., 625 Adams, Kansas City, Kansas 66105.

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Circle 307 on reader service card

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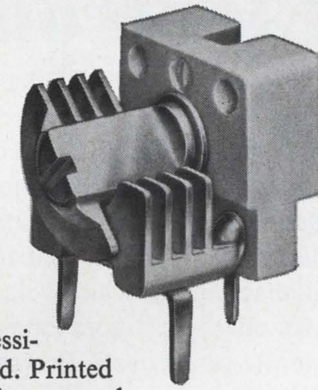

1. Save space with new, horizontal-mounting, printed circuit, type "U", machined-plate capacitors. Available in various sizes, with capacity values ranging from 1.2 pf to 24.5 pf, these tiny trimmers provide tuning accessibility from edge of board. Printed circuit boards can be close-spaced, resulting in compact equipment designs. TC—plus 45 ± 15 PPM/°C. "Q"—greater than 1500 at 1 MHz. All metal parts silver plated. Famous Johnson quality throughout.

2. Cut costs with new, Johnson RIB-LOC™ Tip Jacks that save production line time with *press-in* design. No mounting hardware to assemble or handle. Simple insertion tool presses Tip Jack into pre-drilled chassis hole for a secure mount that resists loosening and turning. Jack accepts 0.080″ tip plug in a recessed, closed-entry type contact. Insulating body is molded of low-loss polyamide. Brass solder terminal is silver-plated and Iridited. Low cost.

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Circle 308 on reader service card

Circle 245 on reader service card

Diode from Japan crowds the Halls

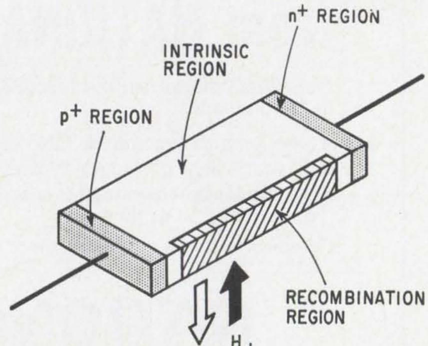
Device's magnetic sensitivity is 100 times greater; flux determines the resistance

Challenging Hall-effect elements is a diode whose sensitivity to magnetism is 100 times greater—so sensitive that it is affected by the earth's field. The diode is the SMD, from Japan's Sony Corp.

The SMD is a two-terminal device that is less than half a centimeter long. It acts like a junction diode when put in a circuit that isn't exposed to magnetic flux. But when a magnetic field is present, the diode's forward resistance changes—the direction of the flux determines whether resistance increases or decreases. Reverse-bias characteristics, however, aren't influenced by a magnetic field.

Bending the path. Sony engineers make the SMD by doping the ends of a 3 x 0.6 x 0.4-millimeter block of germanium. One end is a p+ region and the other n+. The distance between these regions is much larger than their thickness. Next, a thin layer of an impurity, like nickel or copper, is deposited on the front of the block, forming a region where electrons and holes recombine rapidly. The mean lifetime of these electrons and holes determines the SMD's forward resistance.

Magnetic flux passing through



Controlling lifetime. Magnetic field determines diode resistance by bending carrier paths.

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you would see a complete Integrated Circuit Amplifier!

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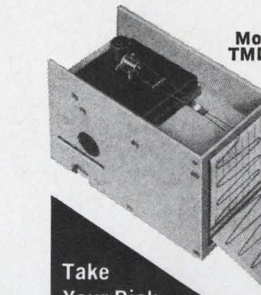
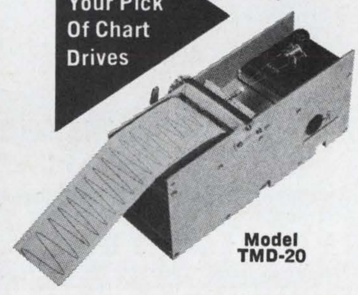
Model TMD-25



Take Your Pick Of Chart Drives



Model TMD-20

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Circle 311 on reader service card

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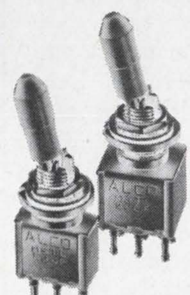

Alco has managed to reduce the size of the handle on this unusual miniature switch series and still have a perfect grip. Currently available in single and double pole in maintained and momentary locking configurations. Designed for accident-proof applications. 6 amps @ 125 VAC.

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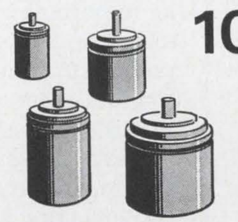

1001 uses for STEPPER MOTORS

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The uses for stepper motors are as unlimited as your imagination. New applications are constantly being discovered. What new use will you next make of stepper motors? Let us know about your ideas; we'll be happy to work with you.

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. . . four-diode bridge has bilateral response . . .

the diode, perpendicular to the broad surfaces of the block, deflect the carriers. When the carriers are pushed toward the recombination region, the lifetime of the electrons and holes decreases and resistance increases. When the flux direction is reversed, the carriers are steered away from the recombination region and resistance drops.

The competition. The diode's sensitivity is 1 millivolt per milliamp per gauss, compared to 0.001 to 0.01 mv for most Hall elements. Matsushita Electric Industrial Co. recently introduced a thin-film Hall element with a 0.02 mv sensitivity.

Despite having poorer detection ability than the SMD, Hall elements still have a future, according to George Kiriazides, sales manager for American Aerospace Controls, a maker of Hall elements. He predicts the SMD will open new areas but won't cut into those markets now dominated by Hall elements. His reasons: Hall elements are thinner, making them more versatile as probes, and they are bilateral, an important consideration in many measuring applications. He also points out that Hall elements have found a place in analog multipliers that the SMD isn't likely to fill.

Sony, however, is readying the SMD to compete with Hall elements by packaging a four-element bridge that is bilateral.

Heat problems. The SMD's one drawback is its sensitivity to temperature. For a 6-volt input and 1,000-oersted field strength, the current in the diode will rise parabolically from 0.5 ma to 5 ma for a 0°C to 80°C rise.

The maximum power dissipation of the SMD is 50 milliwatts, so, for some applications pulse operation will be necessary to limit heating.

Possible uses for the SMD are in magnetic detectors, brushless d-c motors, proximity switches, and noncontact switches. Sony will put the diode in a d-c motor that was designed for a tape recorder the company will introduce in the fall. The diode will be marketed by Sony for $3 in quantity.

Sony Corp., 7-35 Kitashinagawa-ku, Tokyo, Japan **[445]**

Omni-

The TERMI-BLOK★ terminal junction system takes care of all your bussing. Feed-to and feed-thru. Replaces MS terminal strips and screw-type blocks. It's denser, lighter, more versatile, and more reliable. It succeeds where others fail. It's crimpable, insertible and extractible–with MS tooling. Automated tooling's available for volume production. For more information write, AMP Inc., Harrisburg, Pa.

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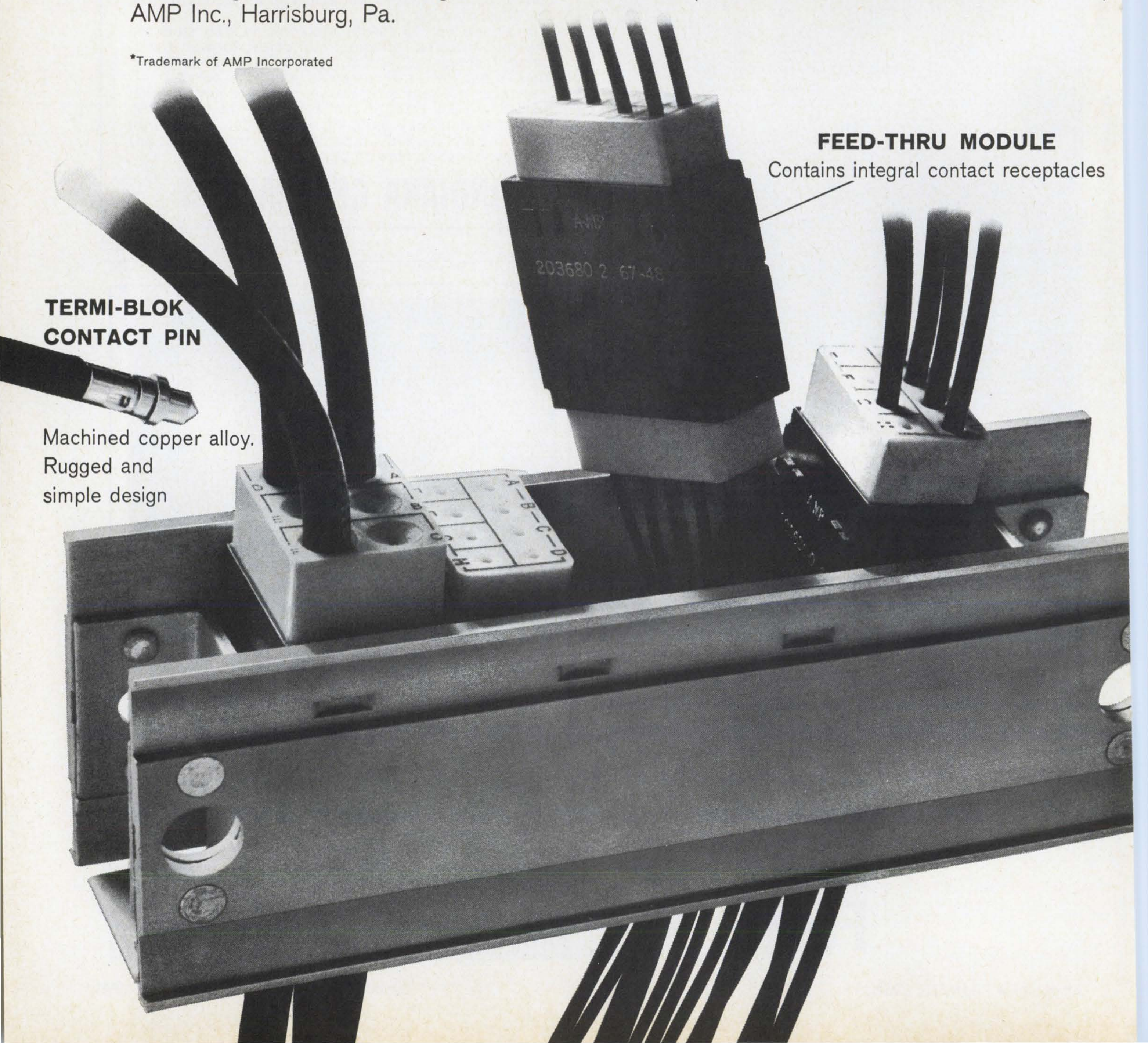
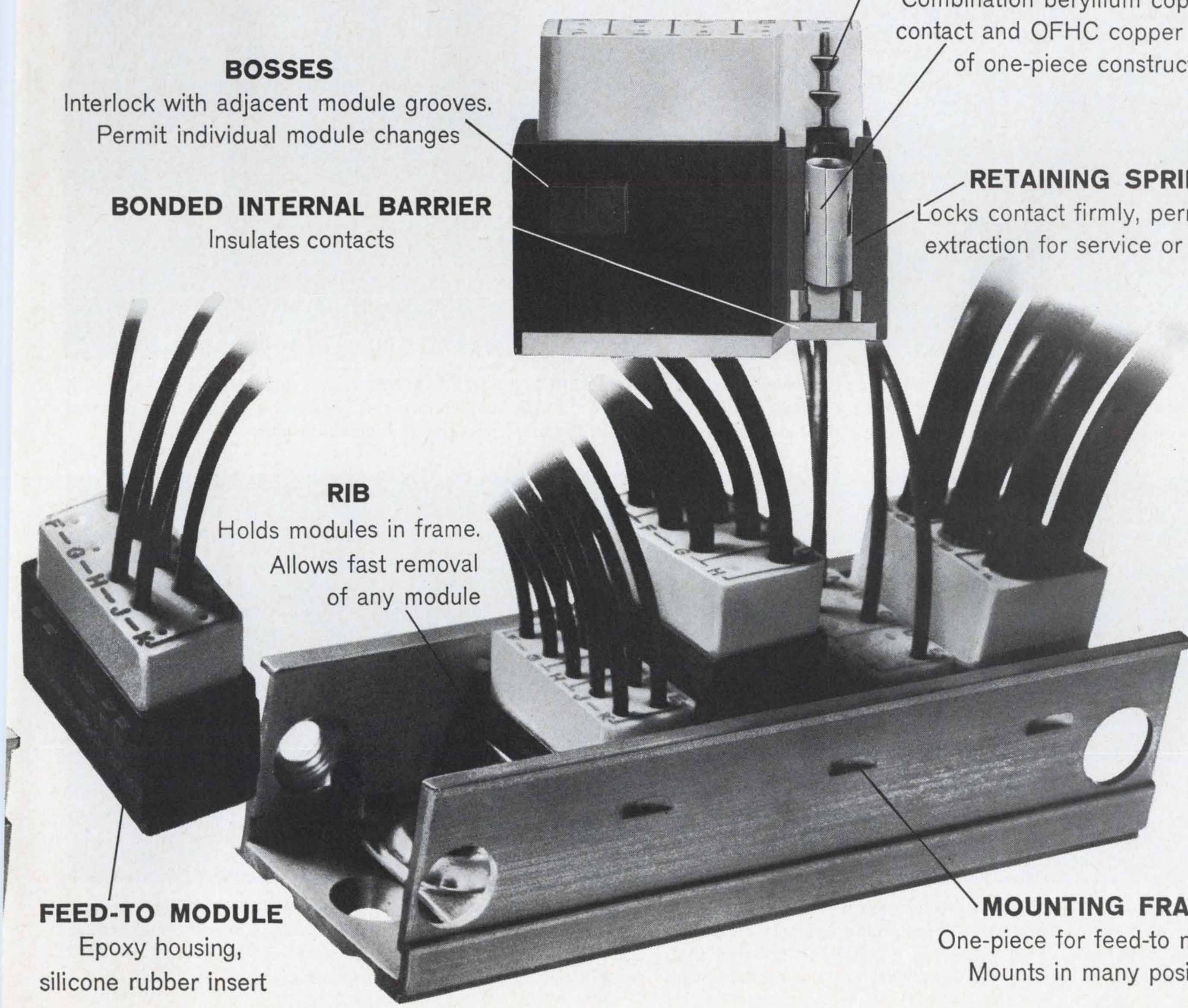
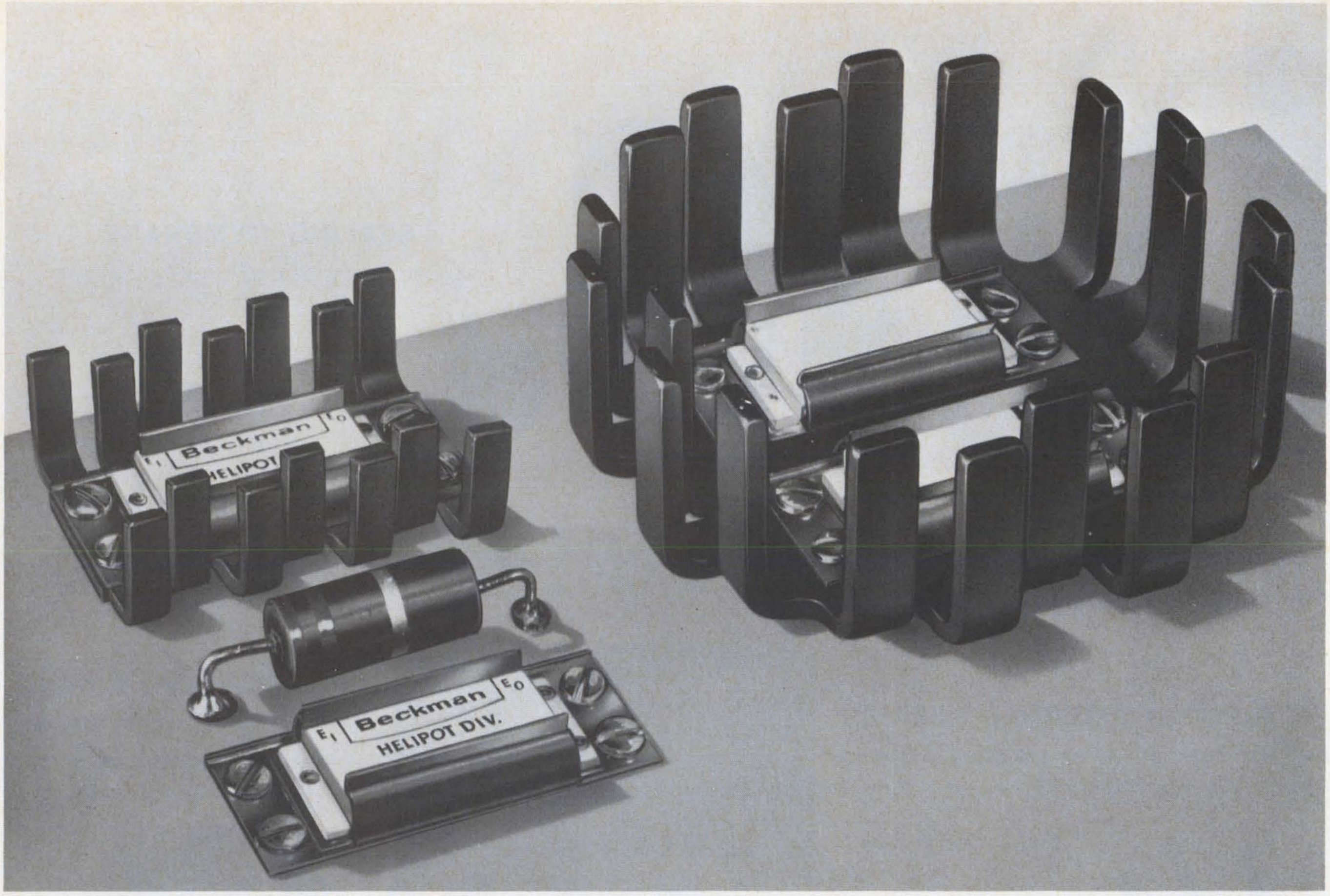


bus.

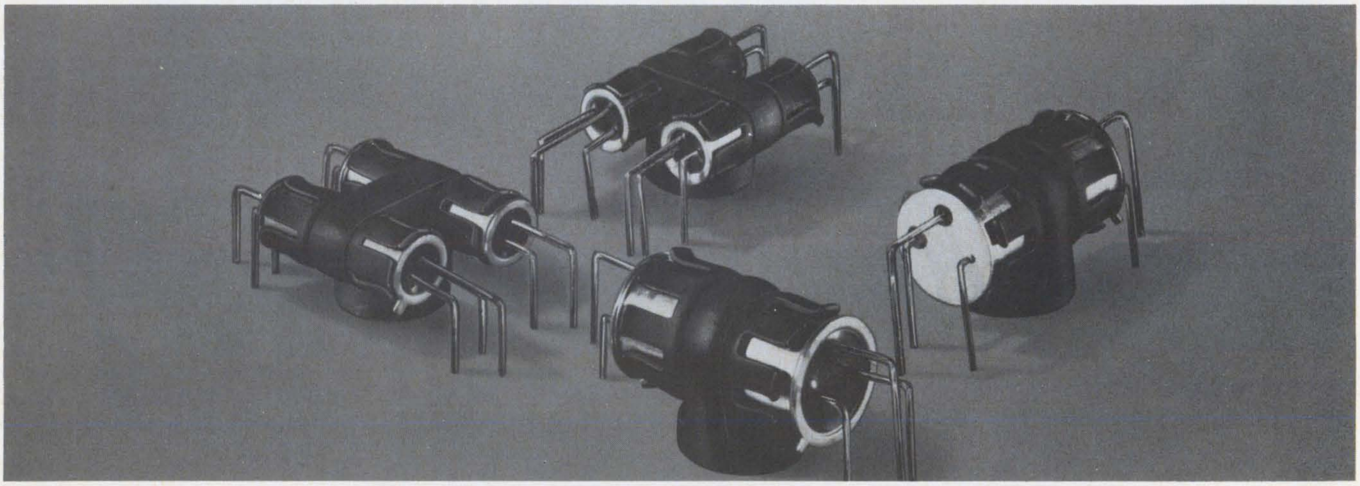


AMP

Circle 251 on reader service card



Cool off microcircuit devices with a choice of four new dissipator/retainers. Example: with natural convection, a typical microcircuit device dissipates 1.8 watts with case temperature rise of 103°C. Add IERC's model LBOC2-61B and you dissipate 5 watts with the same case temperature rise. Retainer-clip may also be used alone to mount package to conduction plane.

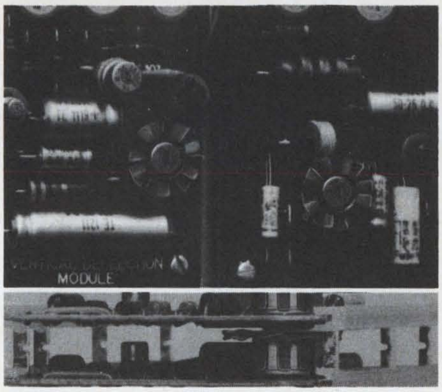


These special dual and quad Therma-Link dissipators permit thermal mating of matched transistors. Therma-Link retainers do exactly as their name says: They provide a thermal link between transistors and the chassis or heat sinks. They are also available with .060″ beryllium oxide washers which have the excellent thermal conductivity of aluminum, are electrically insulative and reduce normal mounting capacitance by ½ to ⅓. The washer is brazed to a brass slug or hex stud for mounting.

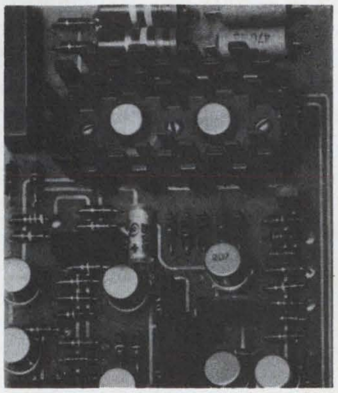
Need a non-hygroscopic finish with excellent dielectric properties, 50 K megohms insulation resistance and high heat emissivity? Use Insulube 448. It also protects against salt spray and fungus and other adverse environments.

Tips on cooling off hot semiconductors and microcircuits

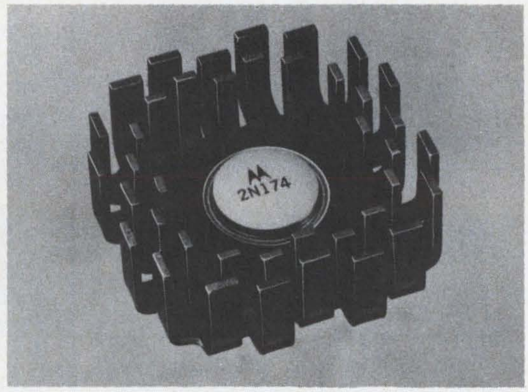
Read on. Find out how circuit designers use IERC heat dissipators to protect and improve circuit performance of semiconductors and microcircuits.



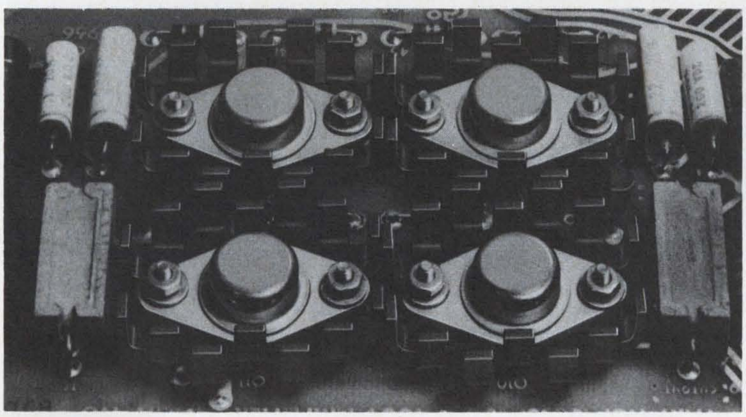
Fan Top Dissipators for TO-5 and TO-18 cases add almost nothing to board height. Don't need much room *on* the board either. Available for both metal and plastic cases. Spring fingers make installation simple. And Fan Tops cost just pennies.



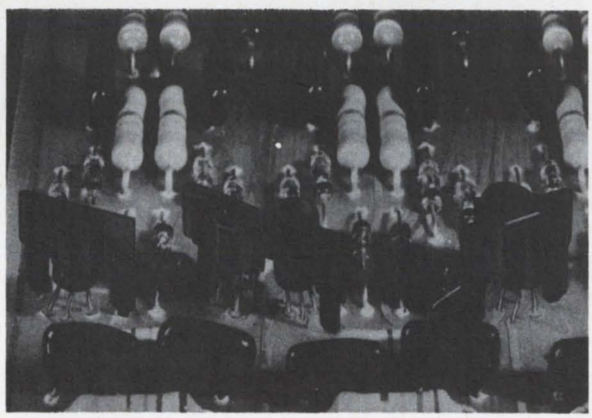
Help low-to-medium power transistors keep their cool with IERC's stagger-fingered LP's. Available in single or dual mounting for thermal mating of matched transistors. They fit both TO-5 and TO-18 cases.



Cool power transistors and diodes with lightweight HP Series devices. High heat transfer rate. HP3 displaces only 9 cu.in. and weighs just 1.5 oz. Yet it dissipates as much heat as many finned extrusions requiring 13.5 cu.in. Two sizes for nesting or back-to-back use.



Keep TO-66 transistors cool with any of four IERC dissipators. The application shown is a 100-volt amplifier with four LB66B2B's dissipating 8 watts per transistor. Exclusive staggered-finger design. Choice of finish: black anodize or Insulube® 448 for positive insulation to 500 watts.



New "Universal" Spade Series for plastic transistors fits all D-case sizes. Spring clip allows for variation in case diameters. Excellent dissipation lets you boost operating power 33%. Both single and dual models as shown.

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New Books

A welcome jump

Quantum Electronics
Amnon Yariv
John Wiley & Sons
478 pp. $14.95

As published material on quantum electronics piles up at an alarming rate so, unfortunately, does the jargon. The "in" language makes it difficult and sometimes impossible for the beginner or nonspecialist to comprehend this important field. First-year graduate students—for whom this book is written—and working engineers seeking to break into the field will welcome this volume, which defines all the terminology and uses it consistently to draw together a wealth of fundamental data from a wide variety of sources.

By reviewing pertinent areas of quantum mechanics and magnetic resonance early in the text, the author lays the theoretical foundation for the advanced discussions that follow. A senior-undergraduate or first-year graduate course in the subject would help the reader to understand this complex subject, but are not absolutely essential.

The book covers optical resonators and laser oscillation; first the general theory and then the specifics or working systems. Included are solid state, gas, and semiconductor laser types. The author also ties together the many diverse aspects of electro-optics and nonlinear optics, topics that are often given isolated treatment in most literature on the subject. He introduces the electro-optic effect by discussing light propagation in crystals, with and without externally applied electric fields. Then he treats the applications in modulation and light deflection.

A section on nonlinear optics examines optical phenomena that involve energy flow between fields of different frequencies. It includes second harmonic generation, optical parametric oscillation, stimulated Brillouin scattering, and stimulated Raman scattering.

Yariv's volume, now in use at the California Institute of Technology, shows signs of careful organization; the problems at the end of each chapter add to its value for students. For others, already active in quantum electronics, the book provides an excellent summary of the technology's fundamentals.

R. T. Denton
Bell Telephone Laboratories
Murray Hill, N.J.

Turning the heat off

Temperature Control
Myer Kutz
John Wiley & Sons Inc.
212 pp., $10.95

Second to no other problem faced by designers and users of electronic devices, circuits, and systems, is thermal behavior—the effect temperature variations have on the equipment.

Kutz approaches the subject of controlling the thermal environment from the point of view of the electrical rather than the mechanical engineer. The book is oriented towards applications in computers, guidance and control systems, aerospace equipment, power networks, and modules, not turbines or engines.

Kutz's purpose is to relate the basic empirical and mathematical principles of heat transfer to specific engineering tasks. He covers the mechanisms of heat transfer, the ways of computing the transfer rate in common physical situations, and the thermal properties of basic materials and surfaces. He discusses materials and surfaces, methods of fixing heat-transfer rates, heat exchangers, and thermal-control systems. He also shows how to sense and excite temperature, explains the control of satellite temperatures, and describes the elements of electronic temperature-control systems.

Equipment covered includes electrical resistance elements, power semiconductors, thermostats, thermoelectric devices, and spacecraft systems. The mathematics expressing the relationships is differential and system-derived. This is something EE's should feel comfortable with, and is a long way from the oversimplified, half-explained algebraic treatments electronics engineers usually find in thermodynamics texts.

In fact, the reader needn't even have a background in thermodynamics to understand the work and apply its principles; Kutz provides all the grounding necessary for the subject in three chapters on fundamentals.

J.B. Steuer
Reimers Electro-Steam Inc.

Unaccustomed as I am . . .

Presenting Technical Ideas
W.A. Mambert
John Wiley & Sons
216 pp., $6.95

You don't have to be a technical man to be dull, but it helps. Anyone who has found his eyes closing while a speaker—all to often an engineer or scientist—drones on, will appreciate Mambert's effort to improve the communication of technical ideas to an audience.

Increasingly, engineers are required to explain complex ideas to their colleagues, to management, to government groups or to non-technically oriented audiences at a variety of seminars and meetings. In his preface, Mambert, who is on the communications staff of the International Business Machines Corp., states the obvious—you can't get ahead in business until you become adept at presenting technical ideas.

About three-quarters of the book is given to practical tips on analyzing the audience, defining the objectives, gathering information, writing the manuscript, preparing notes, using mechanical aids, rehearsing, and handling the unexpected during the delivery of a talk (Someone snoring, perhaps?).

But the reader who takes to heart Mambert's 35 imperatives—which will make him a better communicator of technical ideas, says the author—will discover that he's being asked to restructure his personality. For example, among the fiats issued by Mambert are these: Develop empathy. Become an opportunist. Know thyself. Learn to walk alone. Learn how to break rules. Learn how far you can go. Operate with complete integrity. Be flexible. Be ruthless, sometimes. Love. Develop your sense of humor.

Urging the reader to develop a sense of humor is like telling him to develop sex appeal. Either he


our adaptable
conformist.

has it or he doesn't. Nonetheless, were a reader able to change his behavior, using the author's 35 precepts as his guide, he'd develop a calculating self-discipline that could carry him to sanctity or the White House. Or both.

Rare bit from Wales

Principles of Automatic Control
Martin Healey
D. Van Nostrand Co., Inc.
334 pp., $9.00

Neophytes in the field of automatic control should read this book because of its careful organization of the standard technology. And experienced engineers should read it because the clarity and brevity of the presentation permits new insights to well-known subjects.

Healey, who teaches at the University College of South Wales and Monmouthshire, claims no technical originality nor contribution to the field. All he has done is write one of the best texts on the subject.

Included are the usual basic subjects on closed-loop control, but Healey goes beyond the fundamentals—with sections on statistics, nonlinear systems, sampled-data systems, state variable and matrices, computing and simulation.

Essential to an understanding of the advanced—and even the most basic—concepts of control, is a good grasp of mathematics. If the math involved in specific instances is complex, Healey provides the necessary material in a clear and succinct fashion.

The book contains an excellent exposition on statistics in closed-loop control. In just one page of text, the reader learns about stationary time series, ergodicity, and stochastic signals. Here is a precis of that page:

A stationary time series is a continuous function which has the same long-term properties at any time. A random noise signal from an electronic device is stationary time series; a single transient is not.

Statistical properties of a function can be found by considering a large number of similar signals on any one instant in time, termed an ensemble value, or by considering one signal at a number of intervals of time, termed a time value. If these two properties are equal, the function is said to be ergodic. To be ergodic, the function must also be stationary.

A signal which has stationary properties but is not completely random—it has some definite probability as to its content—is called a stochastic signal. Limiting cases of stochastic signals are a predictable one like a sine wave, and a completely random one like white noise.

Bit-by-bit

Introduction to Computer Programming and Coding
Francis K. Walnut
Prentice-Hall Inc.
429 pp., $17.30

Walnut's book on the basics of computer programing is aimed squarely at those unfamiliar with data processing techniques.

The first few chapters provide background on the principles and history of data processing, briefly describe binary and intermediate number systems, and summarize input-output methods.

When he moves on to coding, the author first defines machine language instructions, then introduces the reader to symbolic language. Brief mention is made of higher-order languages. Practical coding is discussed in relation to variable-word-length and fixed-word-length binary computers. The first machine is typical of small-scale commercial computers, the second of large-scale scientific units.

Among the subjects covered are input-output coding, loops, subroutines, serial-search procedures, and sorting. Walnut makes liberal use of flow charts to illustrate the various techniques. Problems—and answers—are presented after each chapter to review material covered.

The book will surely be of value to those engineers seeking a working knowledge of programing, but it may also serve as a refresher course for those practicing the art.

Stephen Strell
Computer consultant

←Circle 256 on reader service card

Technical Abstracts

Oceans of data

Electronics: the technological key
James C. Elms
NASA Electronics Research Center
Cambridge, Mass.

Exploring and exploiting earth resources places high demands on electronics technology, specifically for a variety of new sensors and for more efficient data management.

What electronics specialists will have to contend with can be seen from a typical earth-resource study of the future. The assignment is to sense, condense, transmit, and analyze information about conditions of the ocean.

This could be accomplished with a satellite that would interrogate thousands of beacons fixed on the ocean's surface and that would carry some sensors of its own. Each beacon would gather and transmit data on underwater characteristics to the satellite, which would retransmit all the data to a land-based collecting point. Typical measurements taken on board the satellite would be temperature, color, and surface roughness of a wide expanse of ocean.

Technology exists for transmitting information to a central point, but the required data rate might create a bandwidth problem. Selecting the pertinent data and compressing it could help. The main effort will be to analyze and interpret the data for the benefit of, typically, fishing, shipping, weather prediction, and recreation interests. Development of appropriate computer software seems the most likely route to rapid and accurate specialized interpretations.

Remote sensing of the ocean's surface presents an even greater technological challenge. To make accurate temperature measurements from the satellite would require precise radiometers operating in one or more infrared regions. Color sensing, however, is even more complicated. It will need scanning and amplitude recording in three, if not more, optical or near-optical regions to determine a color value. A measure of ocean roughness might best be made by active radar techniques at one or more microwave frequencies with one or more polarizations.

Developing these sensors and finding ways to handle the resulting mass of data will take many years, and early hopes may wane before exploratory systems become operational.

Presented at the IEEE International Convention, New York City, March 18-21.

Which way to go?

Trends in the applications of microcircuits in industrial use
R.F. Eade
A.E.I. Automation Ltd.,
Leicester, England

Designers of industrial instruments and controls now have available a variety of microcircuits, based on different semiconductor technologies, that result in low-cost, off-the-shelf modules. Prices of standard integrated circuits have fallen rapidly over the past few years. In 1964 the cost of an IC version of a typical logic package was about 2½ times that of its discrete-component equivalent; in 1968, the cost of the IC version is about half.

Still, IC's have not made any great impact in the industrial field, except perhaps in computers. But the IC is now expected to have major effects on the business and customs of many electronic systems manufacturers.

First, the percentage of electronics in the prime cost of a system will increase when IC's are bought on the outside. Second, economics will force a systems maker to use the standard modules also available to his competitors. Third, when the systems maker believes that a custom IC is justified, he will commission a manufacturer to design and make the device—and will thereafter have to depend on that supplier.

Such considerations have led some systems companies to build up complete in-house facilities for microcircuit production. But this can be more expensive than most companies can afford unless they intend to become IC suppliers. An intermediate step is to arrange in-house facilities for the assembly and test of special devices to meet internal requirements, but to buy such components as diffused chips from specialist manufacturers.

Presented at the Symposium on Applications of Microelectronics, the Institution of Electrical Engineers and the Institution of Electronic and Radio Engineers, University of Birmingham, England, March 27.

All in good time

Satellite multiaccess operation with pcm

K.W. Pearson
Standard Telecommunications Laboratories Ltd.
Harlow, England

A communications satellite that hopes to compete with other transmission methods must be able to talk with several earth stations at essentially the same time. Such a multiaccess operation can separate signals either by frequency or time. Frequency division is more common now, but analysis shows that time-division multiple access using pulse-code modulation could be the better method if faster digital circuits can be developed.

With time division, only one signal is present at any moment and intermodulation among stations can't occur. Input levels from the earth stations to the satellite's transponder don't have to be equal, and the number of stations and number of channels in each can be readily varied.

Disadvantages of a pcm system would be that time division would require more radio-frequency power than frequency division, and that most earth stations, which now use frequency or amplitude modulation, would have to be converted to pcm.

In a time-division multiple-access system using pcm, the transmitted information, which would normally occupy an entire time slot, is compressed at the transmitter and expanded in the receiver. To do this, the digital pcm data is stored at the transmitter at its normal bit rate and extracted for transmission at a higher bit rate. The opposite is done at the receiver, to yield an essentially continuous message.

However, before time-division multiple access using pcm can rival frequency-division multiple access, a high logic speed must be attainable. A satellite with 1,200 channels will need a rate of 70 million to 100 million bits a second.

Technical Abstracts

Logic circuitry for such speeds is already in use experimentally, so one can expect a system accommodating up to 25 earth stations to be built soon.

Presented at the Colloquium on Pulse-Code Modulation, The Institution of Electrical Engineers, Electronics division, London, March 4.

Position wanted

The laser gyro
Frederick Aronowitz
Systems and Research Center
Honeywell Inc.
Minneapolis, Minn.

Most inertial navigation systems rely heavily on the integrating rate gyroscope to keep track of a vehicle's position in space. A new gyroscope, using the laser and general relativity for its operation, measures rotation in inertial space without the spinning mass found in conventional gyros. Since there is no mass, the laser gyro is unaffected by error-inducing acceleration forces. It also senses higher rates of rotation with greater accuracy, and does so at low cost, low power, and with no special cooling. It has a digital output.

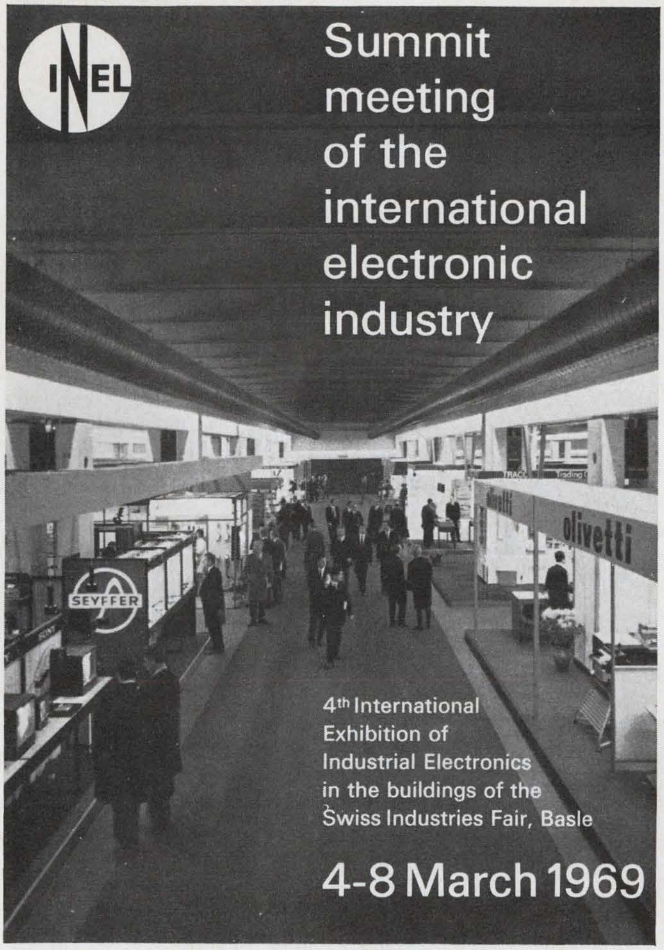
The cavity configuration consists of several mirrors arranged so that energy from the laser point source is built up in the cavity in the form of two waves traveling in opposite directions. These waves can oscillate at different frequencies and amplitudes.

Since the point source is moving relative to inertial space, the light going around the ring-shaped cavity in the direction of rotation must travel a greater distance than the light going in the opposite direction.

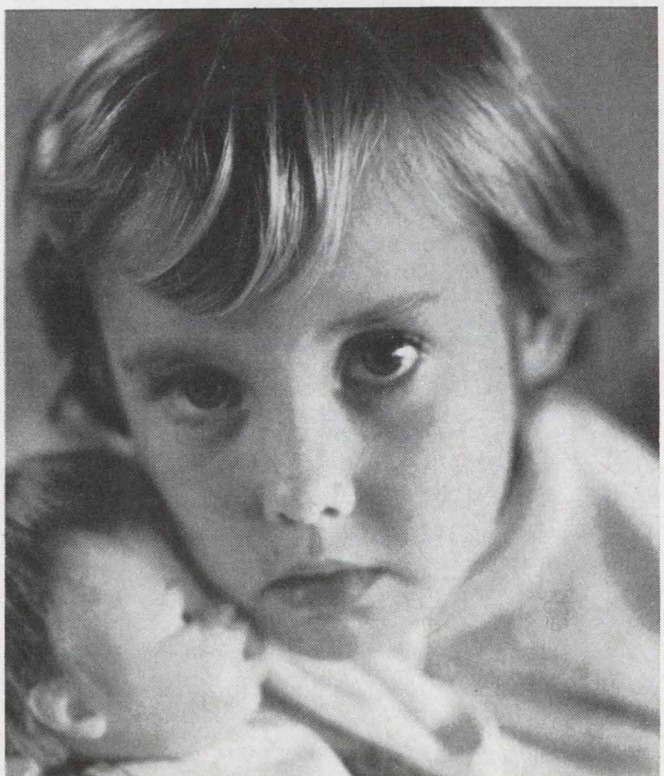
The magnitude of this difference depends, among other things, on the cavity's rate of rotation and on the velocity of light. This change in optical path can also be considered to be a frequency difference.

Readout in the laser gyro is obtained by combining the waves to form a fringe pattern. The fringes move at the frequency difference rate and, hence, by summing fringe counts the gyro produces a digital output related to position.

Presented a the IEEE International Convention, New York City, March 18-21.



Circle 334 on reader service card



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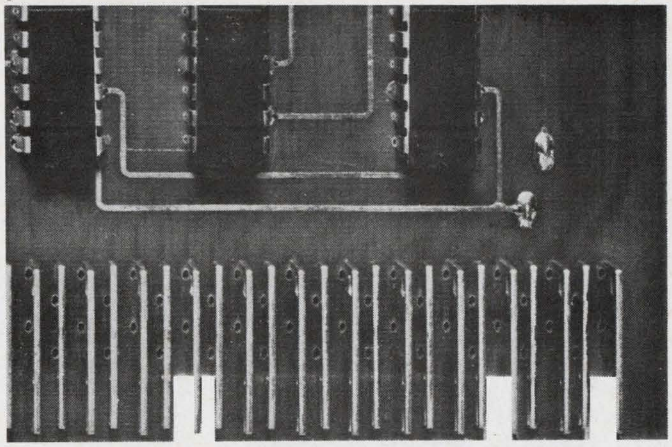

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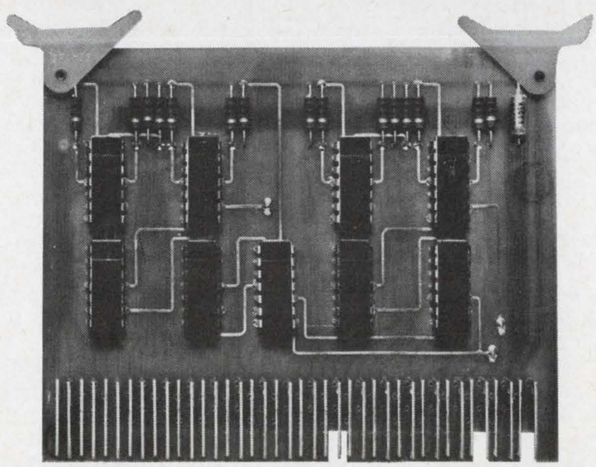

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1590 Monrovia Ave., Newport Beach, Calif.
TEL. (714) 646-9371 TWX (910) 596-1358

Circle 261 on reader service card

New Literature

A-c regulators. Electronic Research Associates, Inc., 67 Sand Park Rd., Cedar Grove, N.J. 07009. Catalog 153 describes a line of solid state, fast-acting a-c regulators.
Circle **446** on reader service card

Fixed coaxial attenuators. Weinschel Engineering, Gaithersburg, Md. 20760, offers a data sheet describing series 1 and 2 precision fixed coaxial attenuators available in 10 values from 3 to 80 db. **[447]**

Bimetal thermostat. Elmwood Sensors Inc., 1655 Elmwood Ave., Cranston, R.I. 02907. Snap-acting, precision bimetal thermostat No. 3450, measuring 0.390 x 0.625 in., is described in bulletin 900. **[448]**

Flexible printed circuitry. Sanders Associates Inc., Granier Field, Manchester, N. H. 03103. Electrical characteristics, design information and a variety of applications of Flexprint circuitry are described in a 14-page handbook. **[449]**

Module tester. Radio Engineering Laboratories, 29-01 Borden Ave., Long Island City, N.Y. 11101, has available literature on a module test fixture designed to be used in conjunction with its 2600 series radio relay equipment. **[450]**

Tunable oscillator. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif. 91343, offers a bulletin describing the model S-300 silicon transistor tunable oscillator. **[451]**

Laser system. Space Ordnance Systems Inc., 122 Penn St., El Segundo, Calif. 90245, has available a four-page brochure on its Macro-Pak portable neodymium laser system. **[452]**

Audio connectors. ITT Cannon Electric division of International Telephone and Telegraph Corp., 3208 Humboldt St., Los Angeles 90031, has published catalog AUD-4 covering a series of audio connectors. **[453]**

Transducers. Consolidated Controls Corp., Bethel, Conn. 06801. A single-sheet bulletin contains complete specifications and fully dimensioned drawings for pressure-to-pulse-rate output transducer type 41PF8. **[454]**

Head demagnetizer. Ampex Corp., 401 Broadway, Redwood City, Calif. 94063. Description, instructions and specifications of the model HD-16 hand-held head demagnetizer for instrumentation tape recorders are included in data sheet D083. **[455]**

Pulse height analyzer. Hamner Electronics Co., 1945 E. 97th St., Cleveland, Ohio 44106. Technical bulletin NC-15 describes a time-stable pulse height analyzer for high-counting-rate applications. **[456]**

Push-button switches. Nexus Inc., Stamford, Conn. 06902. A six-page folder offers specifications on momentary and push-pull switches for military and commercial applications. **[457]**

Boron nitrides. The Carborundum Co., Niagara Falls, N.Y. 14300. A 12-page brochure includes detailed application information and tabular and graphical property data for Combat boron nitride solids, powders and coatings. **[458]**

Microwave packaging. Sage Laboratories Inc., 3 Huron Drive, Natick, Mass. 01760, has available a 40-page system designer's guide to microwave packaging. **[459]**

Flat ribbon cable. Spectra-Strip Corp., Box 415, Garden Grove, Calif. 92640, has issued a 12-page capabilities brochure and short-form product catalog on flat-ribbon cable and related products. **[460]**

Heat sink nomograph. Astrodyne Inc., 207 Cambridge St., Burlington, Mass. 01803, has published a nomograph that permits determination of total heat-sink area required for cooling semiconductor devices. **[461]**

Mass core memory. Ampex Corp., 401 Broadway, Redwood City, Calif. 94063. Specifications, functional block diagram and general description of the 20-million-bit model RM mass core memory are contained in brochure CO38. **[462]**

Sealed capacitors. Film Capacitors Inc., 100 Eighth St., Passaic, N.J. 07055, has issued an engineering bulletin covering type E4 polycarbonate hermetically sealed capacitors. **[463]**

Circular connectors. Elco Corp., Willow Grove, Pa. 19090. A 12-page catalog describes and illustrates in detail a complete line of circular connectors manufactured to conform to MIL-C-26500. **[464]**

Magnetic core memory. Ampex Corp., 401 Broadway, Redwood City, Calif. 94063. Description, user information and specifications of the model RG magnetic core memory are included in brochure CO34. **[465]**

A/D converter. Aero Geo Astro, a division of Aiken Industries Inc., 4810 Calvert Road, College Park, Md. 20740, offers a single-sheet bulletin on the model 801 analog-to-digital converter for economical conversion of analog data to 8 bits of binary data at a 1-Mhz word rate. **[466]**

New Literature

Low pass filter. Kappa Networks Inc., 165 Roosevelt Ave., Carteret, N.J. 07008. Bulletin 68-1 describes the model 552 series low pass filter designed for p-c board applications. **[467]**

Display terminal. Transistor Electronics Corp., Box 6191, Minneapolis 55424. Brochure 639 describes the Data-Screen display terminal, an input/output crt display system. **[468]**

Quartz crystals. Bulova Watch Co., 61-20 Woodside Ave., Woodside, N.Y. 11377, has published a 16-page illustrated catalog detailing its complete line of quartz crystal resonators from 1 khz to 150 Mhz. **[469]**

Converter. Airborne Accessories Corp., 1414 Chestnut Ave., Hillside, N.J. 07205. Bulletin PS-20 describes model 1000 millivolt to milliamp converter, a universal temperature transmitter with an accuracy of $\pm 0.2\%$. **[470]**

Coaxial slotted line. Alford Manufacturing Co., 120 Cross St., Winchester, Mass. 01890. Bulletin 703 describes a 3.5-mm coaxial slotted line for the 2- to 36-Ghz frequency range. **[471]**

Indicator lights. Dialight Corp., 60 Stewart Ave., Brooklyn, N.Y. 11237. Catalog L-203 presents a complete line of ultraminiature indicator lights for rear mounting in 3/8 in. clearance hole. **[472]**

High temperature adhesive. Aremco Products Inc., P.O. Box 145, Briarcliff Manor, N.Y. 10510. Product bulletin 516 deals with Ultra-Temp 516, a ceramic adhesive for use at temperatures up to 4,400°F. **[473]**

Filters. American Electronic Laboratories Inc., P.O. Box 552PC, Lansdale, Pa. 19446, has available a 16-page brochure delineating its line of standard and custom filters in the frequency range from 2 Mhz to 18 Ghz. **[474]**

I-f recorder test set. Radio Engineering Laboratories, 29-01 Borden Ave., Long Island City, N.Y. 11101, has released a bulletin covering an adjustable-bandwidth, i-f recorder test set. **[475]**

Fractional h-p motors. McLean Engineering Laboratories, Princeton, Junction, N.J. 08550. A six-page short form catalog on fractional h-p motors presents the company's line of MIL-Spec and commercial permanent split-capacitor motors. **[476]**

Xenon flashtubes. EG&G Inc., 160 Brookline Ave., Boston, Mass. 02215, has issued a catalog containing information and specifications for its expanding line of internally triggered xenon flashtubes. **[477]**

New Literature

Strip chart recorders. Simpson Electric Co., 5200 W. Kinzie St., Chicago, Ill. 60644, has published a four-page folder giving complete details on the model 2750 precision low-speed strip chart recorders. **[478]**

H-f antenna systems. Delta Electronics Inc., 4206 Wheeler Ave., Alexandria, Va. 22304. An eight-page short-form catalog describes high power antenna switching matrices with manual and remote control for coaxial and balanced transmission lines. **[479]**

Inband signaling units. Quindar Electronics Inc., 60 Fadem Road, Springfield, N.J. 07081, has available bulletin 114 on its QT-QR-18 inband signaling units with plug-in adaptors for 600 or 10,000 ohms input/output impedance. **[480]**

Integrating microvoltmeter. Doric Scientific Corp., 7969 Engineer Road, San Diego, Calif. 92111. Bulletin D100-E illustrates and describes an automatic integrating microvoltmeter with transducer conditioning for physical and scientific measurement. **[481]**

Logic assemblies. Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, Mass. 02138, announces a 96-page catalog providing detailed technical data on its complete line of integrated-circuit logic assemblies and accessories. **[482]**

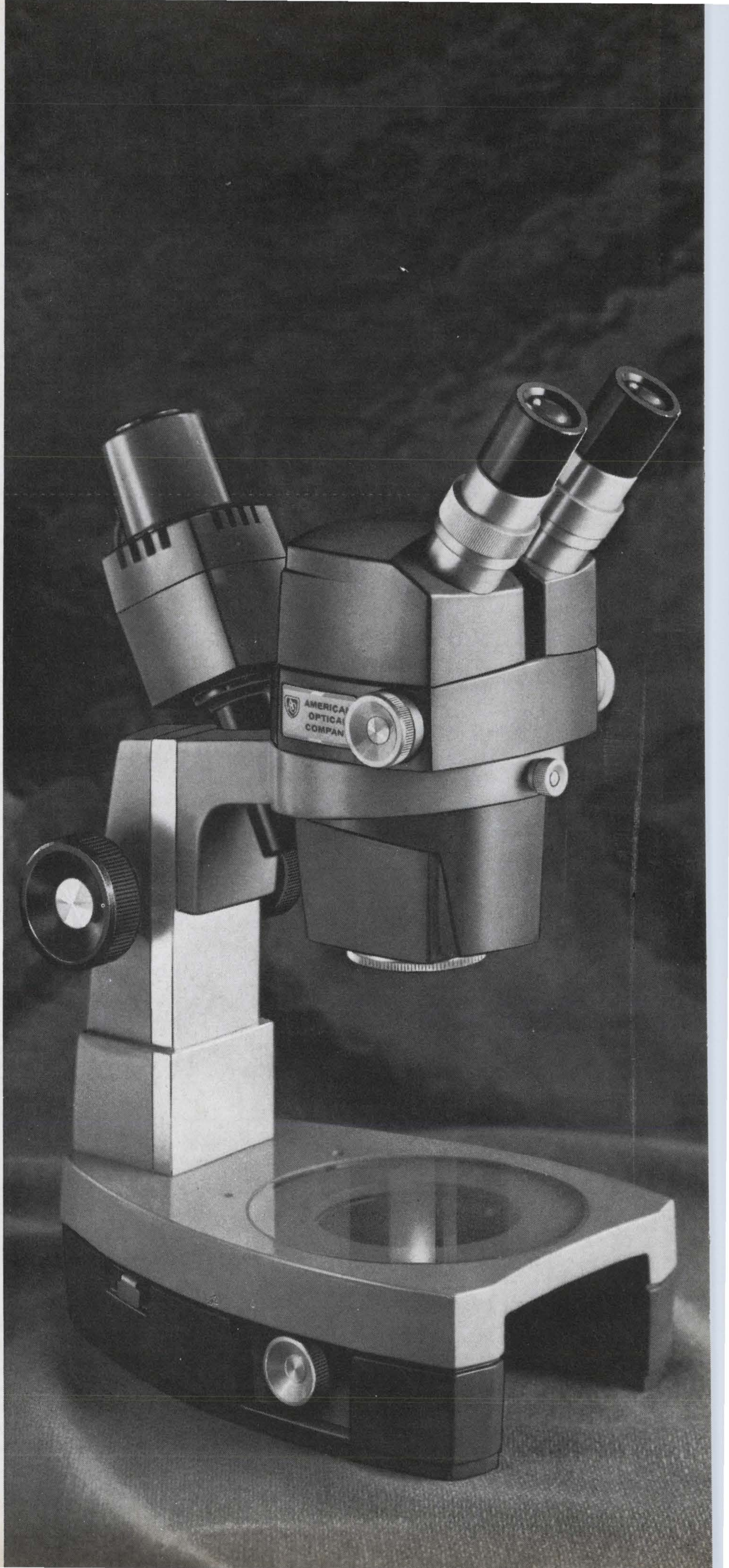
Varactors. Micro State Electronics, 152 Floral Ave., Murray Hill, N.J. 07974. Bulletin D-103 covers a line of gallium-arsenide Micropill varactors for parametric amplifiers, harmonic generators, and switches. **[483]**

Coaxial diode limiters. Microwave Associates Inc., Burlington, Mass. 01803. Bulletin 7039 contains technical information on a series of broadband, fast-recovery, coaxial diode limiters. **[484]**

Power supply. Quindar Electronics Inc., 60 Fadem Rd., Springfield, N.J. 07081. Bulletin 138 covers the QP-17 solid state power supply designed to provide 1700 ma at 12 v d-c for supervisory control, telemetering, and audio tone equipment. **[485]**

Alternator/stator winder. Possis Machine Corp., 825 Rhode Island Ave. South, Minneapolis 55426. Two-page bulletin 6712 describes the model PAW-15A automatic alternator/stator winder. **[486]**

Motor speed controls. Sterling Electric Motors Inc., 5901 Telegraph Rd., Los Angeles 90022. A six-page technical bulletin describes new rotating and solid state variable frequency speed controls for one or more a-c slave motors. **[487]**



Newsletter from Abroad

April 15, 1968

France zeroes in on instruments . . .

The French government has launched the third in its series of moves to strengthen the domestic electronics industry through financial aid and mergers. **The latest scheme, Plan Mesure, is designed to help instrument makers.**

But industry leaders suspect the government won't back Plan Mesure with muscle. Their estimate is based on the mixed results of the other two drives. There has been considerable support for the computer industry under Plan Calcul, **but the components effort, announced a year ago as Plan Composants, hasn't produced more than a few million dollars in aid.**

There's little doubt that instrumentation is a sector where the French need help. The vast complex of state-run research organizations buys half of its measuring instruments abroad, almost entirely from the United States. The percentage of foreign-bought instruments is even higher in the private sector.

Plan Mesure will have a tough row to hoe. **There are more than 50 manufacturers, many of them small, family-owned firms, jealous of their identity.** In components, as a comparison, there are five major companies, two of which have merged their component activities.

. . . as Collins Radio decides to back out

French electronics executives are breathing easier now that the Collins Radio Co. has shelved for at least five years plans to build an instrument plant in France. **Collins says it withdraw because of heavy new investments in the United States and the balance of payments deficit.**

Many French industry leaders had viewed Collins' interest, abetted by the Finance Ministry, as a repeat of the great semiconductor assault when U.S. companies flooded the country.

Sanyo calculators shift to the MOS

Development of electronic calculators is getting to be a habit with the Japanese. The newest arrivals are the Sanyo Electric Co.'s 12-, 14-, and 16-digit models. The firm says it's the first in Japan to use bipolar diode-transistor logic for control and gate functions and metal-oxide-semiconductor shift registers for register and memory functions. Sanyo uses transistors and diodes to interface these two types of circuits and to interface the readout. Other Japanese calculators use cores, delay lines, or bipolar multivibrators where Sanyo uses the MOS shift registers.

The company will start domestic sales later this year but is already shipping export orders. The 12-digit model costs $555, the 14-digit $695, and the 16-digit $830.

Symphonie officials fear U.S. parts ban

French and German managers of the Symphonie communications-satellite project are asking European companies to develop launcher components that would normally be supplied by U.S. firms. Symphonie will compete with the Comsat-controlled system sponsored by the International Telecommunications Satellite Consortium (Intelsat), and **European space officials fear the U.S. will do everything possible to stall it—including slapping an embargo on American-made electronic components.**

The parts in question would be used in the booster's apogee and perigee motors. And West Germany's Boelkow combine, contractor for Symphonie's third-stage guidance and control engines, has been trying lately to interest German companies in developing replacements.

Franco-German fears of a parts squeeze have so far been fed only by isolated incidents. **A French company says it had to design its own traveling-wave tubes, for example, because the U. S. wouldn't grant export licenses to would-be American suppliers.** And while U. S. firms are helping to develop noncommercial European scientific satellites, none has been permitted to offer even advisory aid to the teams vying for Symphonie contracts.

French seeking to end GE deal

General Electric Co., under President de Gaulle's pressure to get out of the French semiconductor business, is selling its 49% interest in the Societe Europeenne des Semiconducteurs, which it established in 1962 with the Compagnie Francaise Thomson Houston-Hotchkiss Brandt.

At the same time, GE is renegotiating a 50-year-old agreement with Thomson Houston in which the French company pays royalties for GE know-how covering a broad area. Lately, however, Thomson Houston has been increasingly dissatisfied. Although both parties feel that the agreement should be updated, they're miles apart on fees.

Some ranking Thomson Houston officials, however, want to get out of the accord altogether, and GE lawyers are now reviewing the phone-book-size agreement to establish Thomson Houston's withdrawal rights. **Chances are the French company would have to pay GE a whopping termination fee.**

Raytheon closing Italian tube plant

The 900 workers at the Raytheon-Elsi cathode-ray tube plant near Palermo, Sicily, are being laid off as the plant closes. **The company blames sagging black-and-white set sales in 1967, with no improvement in sight, and the plant's distance from major set makers, most of which are in the north.** The mass layoff has triggered some demonstrations and sympathy strikes.

Swiss, Germans soup up rocket

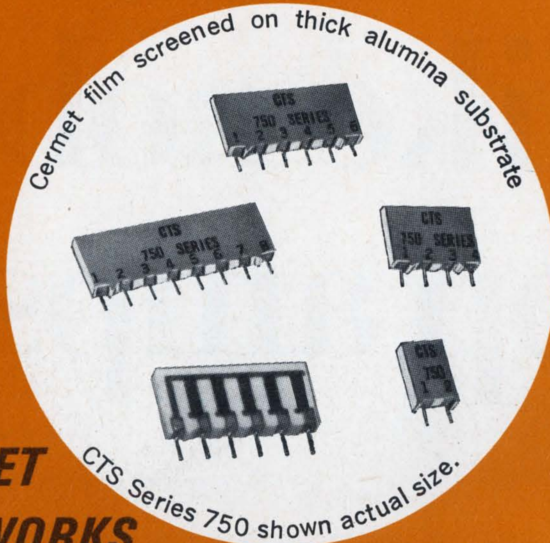
Switzerland's Contraves AG and West Germany's Dornier System GmhH are developing a more powerful version of their Zenit research rocket. **The new high-altitude rocket will have an operational ceiling of 180 miles and will be capable of carrying a payload of 110 pounds.** The highest Zenit can now soar to is 123 miles, with a 55-pound payload—but at lower altitudes it can carry up to 280 pounds.

The two firms are eyeing the growing European market for space hardware—the European Space Research Organization alone will need about 200 instrument-carrying rockets over the next five years, West Germany itself about 70.

Addenda

The giant Russian exhibit at Rome's electronics show is casting political shadows. With general elections coming up, many Italian politicians view the Soviet effort as an attempt to help the nation's declining but still powerful Communist party. . . . The British Decca Navigator Co. has granted ITT the South American manufacturing and marketing rights to its sea and air navigation systems—subjects of a patent dispute between the firms [Electronics, July 10, 1967, p. 189].

NEW LOWER PRICES



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TC	±300 ppm/°C
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Moisture Resistance: .1 rated wattage at 70°C, 90-98% humidity, 1000 hrs.	±0.50% Δ R max. ±0.20% Δ R av.
Insulation Resistance: measured wet after moisture resistance test, 200 VDC	500 meg. Ω
Thermal Shock: 5 cycles, −63°C to +125°C, no load	±0.10% Δ R max. ±0.03% Δ R av.
Short Time Overload: 2.5 times rated voltage, 5 sec.	±0.25% Δ R max. ±0.05% Δ R av.
Low Temperature Exposure: −63°C, 4 hrs.	±0.10% Δ R max. ±0.04% Δ R av.
Terminal Strength: 5 lb. tensile & compression, 30 sec.	±0.10% Δ R max. ±0.03% Δ R av.
Effect of Soldering: 63/37 solder, 246°C, 2 sec.	±0.10% Δ R max. ±0.05% Δ R av.

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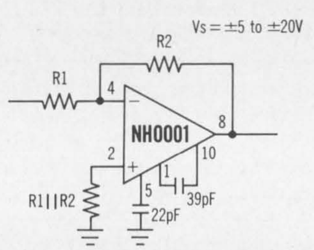
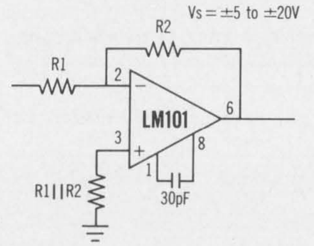
1. VERY LOW POWER



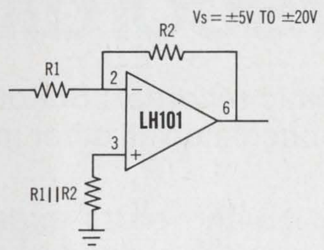
The typical dissipation of the NH0001 is but 1.8mW at Vs = ±15V and 0.6mW at Vs = ±6V. Something of a record, no? And further, the mighty NH0001 will deliver over ±10V into a 2K load from Vs = ±15V supplies. It's priced at $48.00 in 100 to 999 quantities.

2. GENERAL PURPOSE



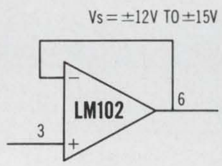
Old faithful LM101 is both general purpose and no-sweat in operation. It's short-circuit proof and has a large differential input voltage allowance. Moreover, frequency compensation is simple, and there is no latch-up problem. The price is $40.00 in 100 to 999 quantities. (There is also a commercial version, the LM201, priced at $8.80.)

3. FULLY COMPENSATED, GENERAL PURPOSE



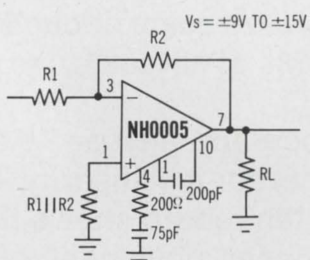
The LH101 is kin to the LM101. The essential difference is that all the required frequency compensation is *inside* the package. Current drain is low, even with the output saturated. There is no latch-up when common mode range is exceeded and there's continuous short circuit protection. Price for 100 to 999 is $48.00. The commercial version LH201 is $11.40.

4. HIGH SLEW RATE VOLTAGE FOLLOWER



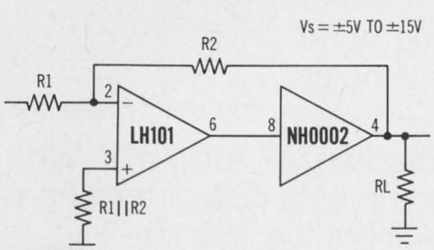
The LM102 voltage follower is the first monolithic amplifier that has combined low input current with high speed. Slew rate is 10V/μs. The maximum input current is an incredible 10nA. Input currents better than 10nA at 125°C are guaranteed. The price: $30.00 each in 100 to 999 quantities. The −25°C to +85°C LM202 is priced at $12.00, LM302 commercial at $5.40.

5. HIGH OUTPUT CURRENT



When we say high output current, we *mean* high. The output current on this, the NH0005, is ±50mA into a 100Ω load. The price in 100 to 999 quantities is $45.00. And there's a commercial version, the NH0005C, priced at $22.50.

6. VERY HIGH OUTPUT CURRENT, WITH BUFFER

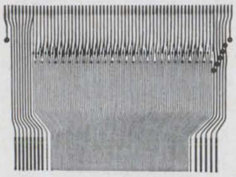


The NH0002 is something else. It has an output current of ±300mA into a load of 50Ω. The NH0002 buffer is useful in the loop in all your high current op amp applications. The price is $20.00 in 100 to 999 quantities.

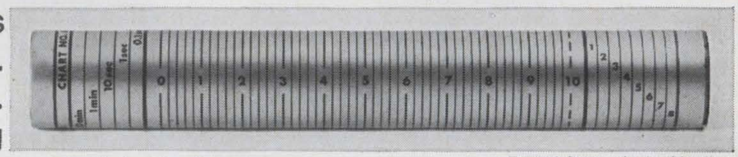
This new idea ended an era in data recording.

August, 1967, Varian introduced to the world the electrostatic recorder: Statos™, first significant advance in its field in over 10 years. At a stroke, it obsoleted all other methods of graphic data recording.

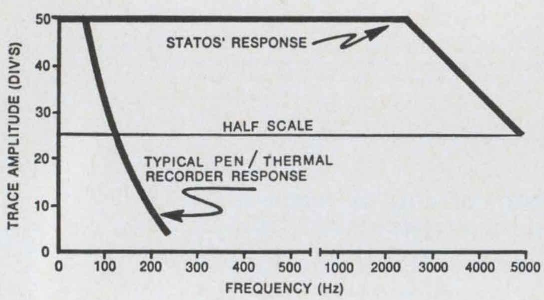
Statos writing heads have up to 100 data styli per 40 mm.



A simple thing. Statos has no moving parts except the paper drive. The signal is impressed on paper by a fixed recording head driven by transistorized preamps and IC digital logic. There is no arcing, burning or post-fixing of paper, nothing to introduce inertia into the writing system. Think what this does to operation. And reliability. With no pens to adjust, ink to spill, solutions to mix, Statos sets up in one minute. You have no galvanometers to calibrate or replace, and off-scale signals have no adverse effect on Statos whatsoever. And it uses blank paper. Prints its own chart as it records data. You change chart formats by switching rollers, and never have to stock more than one kind of paper.



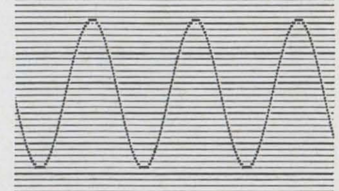
Typical Statos chart grid roller.



Frequency response and rise time. Compare response curves for pen/thermal recorders with Statos' full-scale amplitude past 1500 Hz. LBOs go higher, of course, but at the expense of accuracy —a parameter that remains constant in Statos. And while direct-writing recorders claim about 4 ms rise time between 10% and 90% of full scale, we go from 0% to 100% in 0.2 ms.

Accuracy, anyone? About the closest you get to an accuracy spec for a direct-writing recorder is "linearity." Here's what we say. At any frequency from DC to 1500 Hz, our written record shows the input signal's value within 1% of full scale, including effects of paper movement, plus non-linearity, plus hysteresis, plus overshoot...you name it!

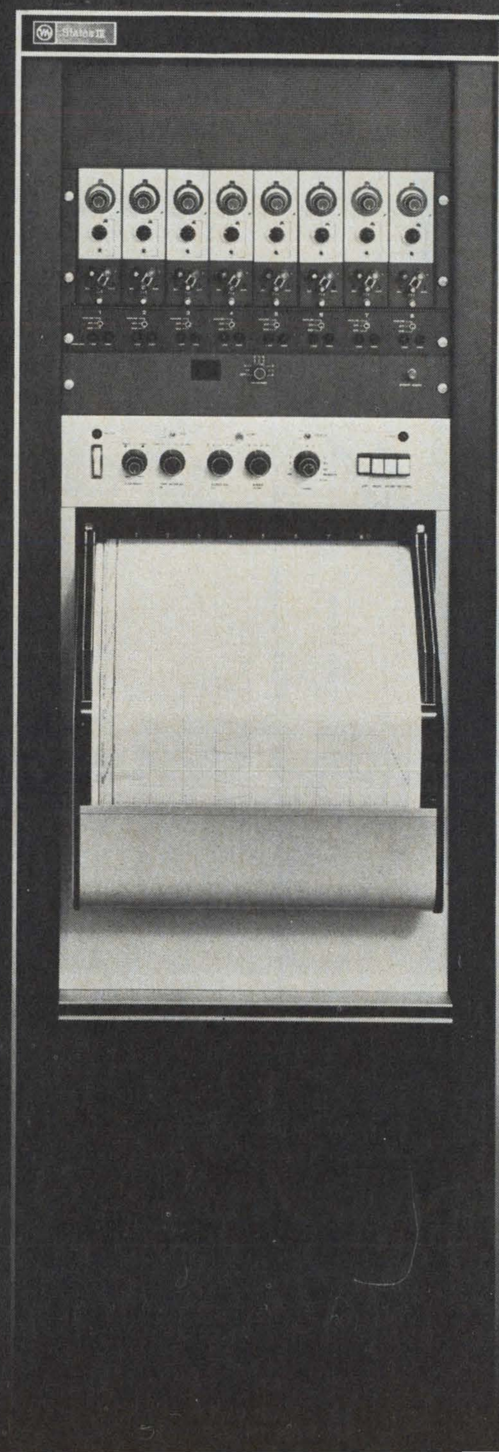
Resolution. Statos has a digitized readout, but don't let that fool you. With over 50 styli to the inch, our writing head's pattern is fine enough to show any signal within our frequency limits. And our 50 cm/sec chart speed (250% that of direct-writing recorders) gives you the time-base resolution you need at higher frequencies (for instance, 25 cycles per inch of chart at 500 Hz).



Actual size sine wave recorded on Statos.

One last word: versatile. With IC digital logic an integral part of its nature, Statos interfaces with computers as real-time output device (no D/A converter or buffer needed) or input monitor for either digital or analog data (since it accepts analog and/or BCD inputs). Its variable recording speed DC motor lets you slave paper speed to external test equipment. And more, much more. That's why we said all those other recorders are obsolete. They are. Statos did it. Send for data from Sales Manager, Varian Recorder Division, 611 Hansen Way, Palo Alto, California 94303. International offices in Zug, Switzerland and Sydney, Australia.

varian
recorder division



ANDREW

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higher power

8″ diameter flexible HELIAX® coaxial cable

8″ Air dielectric HELIAX coax extends the advantages of flexible cable to very low attenuation or very high power applications that formerly required rigid transmission line.

Corrugated inner and outer copper conductors accommodate thermal expansion without the need for sliding contacts. End connectors mate with 6⅛″ EIA flanges and lock inner and outer conductors together to eliminate differential expansion.

The continuous, connector free cable assures freedom from the VSWR "spikes" associated with the periodic inner connectors of rigid line in a long feeder. Cable assemblies can easily be electrically tested on the reel to assure your exact system performance. For complete details write Andrew Corporation, 10500 West 153rd Street, Orland Park, Illinois 60462.

HJ 10-50 HELIAX COAXIAL CABLE

	At 30 MHz	At 600 MHz
Attenuation	.027 dB/100 ft	.15 dB/100 ft
Average Power	300 kW	58 kW
Other Power Ratings	For SSB, 200 kW PEP with antenna VSWR of 3:1 2 Megawatts Peak	TV transmitter power ratings, 223 kW at Channel 4 and 70 kW at Channel 35

2-68

Electronics Abroad

Volume 41
Number 8

Great Britain

Track record

Hard hit by the rise of the automobile, British Rail is constantly on the lookout for ways to run its trains more efficiently.

One long-off day, the government-owned railway hopes to have trains without engineers clicking along its tracks. But that will be at the end of the automation line. Meanwhile British Rail researchers have settled already on a technique—induction coils and binary coding—that they feel will work for a whole range of controls, from simple setups to complex systems.

British Rail expects to start trying out prototypes of its basic hardware before the end of the year on a 6½-mile test track. The line's researchers are at work also on a small computer to pair with their building-block units. How fast the mating will come depends in large measure on how well the coils perform in their first trials.

Looped. Basic to the system are groups of coils—up to 32 of them—connected in series to form a track loop. The coils will be mounted on the track's ties. On the train, there's a 50-kilohertz oscillator to excite the loop as the train passes over it. There's also a receiver to sense the magnetic fields set up by the coils.

The field direction can be either of two ways, depending on how the coil is connected into the loop. Thus the loop connections establish a 32-bit binary word to feed instructions from the track to the moving train. Binary "0's" and "1's" are sorted out by comparing the phase of the voltage pulses induced in the receiver as it passes over each coil on the track to the phase of the exciting oscillator output. The string of binary bits is then fed to decoding logic to extract the message for display.

Getting there. After it's proved out the fundamental system, British Rail most likely will use it first to signal unchanging information like general speed limits for track sections, spotting coil groups about every half-mile. The 32-bit word will probably include an 8-bit address, a 16-bit message, and an 8-bit ending that indicates the distance to the next coil group. This last is necessary because the system will be set up to fail safe. It will automatically put on the brakes if the train passes over a signal group without the engineer acknowledging the message.

The next probable step is adding switchable coil arrays that could feed changing information like free and occupied blocks from the track to the cab.

After that, fast trains will get their small computers. Fed with constants like the train's weight, its length, its running schedule, and its brake power—plus the general speed limits picked up from the coil groups on the track—the computer would continuously display the maximum permissible speed for the train in question. The computer further would compare actual speed with the acceptable one and apply brakes automatically if necessary.

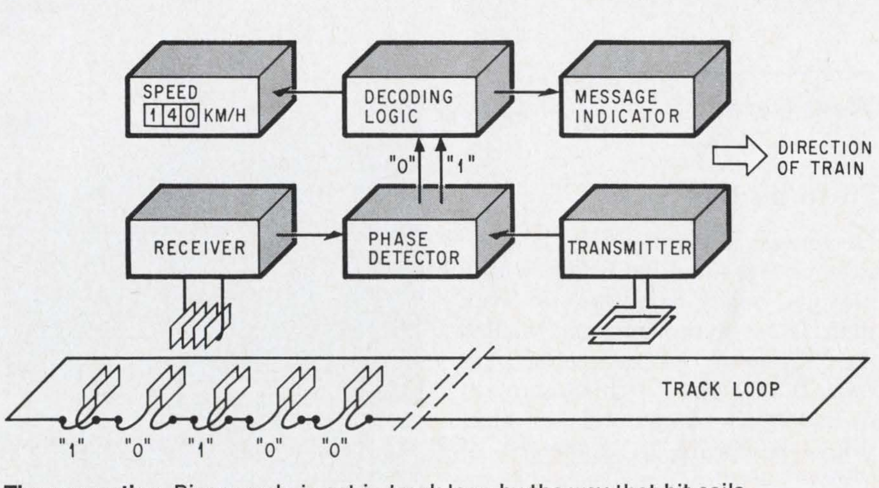
Light brigade

Her Majesty's cost-effectiveness experts figure there's an outlay of $180 every time the Royal Army fires a round of tank ammunition. With the current drive to hold down government spending, that means tank crews get very little live gunnery practice.

Even when live rounds are available, all that tank gunners can shoot at are targets on firing ranges, quite a different thing from enemy tanks whose crewmen have ideas of their own about what should—and shouldn't be—blasted into smithereens.

To get around these limitations on battle training, Britain's Ministry of Defense may turn to the laser. Later this month, the ministry very likely will order preproduction versions of a mock gunnery system it calls the "direct-fire weapons effects simulator"—essentially an infrared laser projector that "fires" at detectors on "enemy" tanks.

Smoke signals. Solartron Electronic Group Ltd., a subsidiary of Schlumberger Ltd., developed the system in collaboration with the ministry. Details are a military secret, but Solartron has disclosed that the laser "gun"—the company



The connection. Binary code is set in track loop by the way that bit coils are wired into it. The system that British Rail has in mind will handle instructions with up to 32 bits.

says its infrared output is so low that it's harmless—mounts directly on the tank barrel. Detectors on the target tank actuate smoke bombs when there's a direct hit. Alternatively, the system can be set up so that the gunner sees a pair of flashing lights in his gunsight rather than a puff of smoke. For this effect, point-of-impact information is transmitted over a telemetry link from the target tank to the tank firing the laser.

Several other refinements give gunners an illusion of reality. For one thing, the straight-line laser path is offset to account for the trajectory of the type of ammunition being simulated. Further, the number of "rounds" available can be set into the transmitter so that a trigger-happy gunner runs out of shells as he would in battle.

The target apparatus, too, adds reality. It can be adjusted to reflect armor thickness so that a light "shell" smacking a heavy tank won't register a kill. The target detectors can be arranged to show whether shots are landing ahead of or behind the tank.

Sortie. It's a safe bet that other armies around the world are working on laser gunnery simulators. But none, apparently, has its system as far along as Solartron has. A ranking U.S. general, the company claims, rated the laser setup the most impressive gunnery simulator he'd ever seen. With that encouragement, Solartron will demonstrate the system to Pentagon officials this fall.

West Germany

Fit to be tied

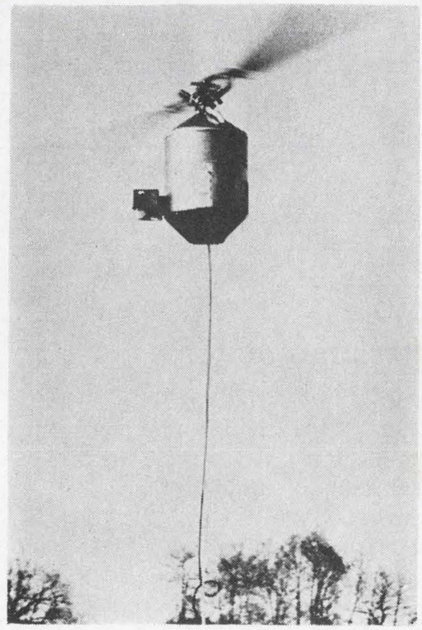
Designers at Dornier GmbH seem to have crossed a helicopter with a barrage ballon to come up with their latest flying machine. Called the "Kibitzer," it's a tethered platform that uses rotor blades to lift as much as 120 pounds of electronic hardware to a height of nearly 1,000 feet and keep it there indefinitely.

Dornier engineers say the $25,000 buoy-shaped platform, officially designated the DO-32K, can "fly" a variety of missions. Put a radar aboard, they explain, and the platform acts as a spotter of low-flying aircraft. Add a television camera and it becomes an observation station. Install a repeater and it turns into a communications-network link.

High wire. The tether, Dornier notes, could make an admirable long-wire antenna for low-frequency broadcasts. And the company's engineers are currently testing a direction-finding system whose antenna elements are mounted on the rotor blades.

Although the platform was developed under contract to the West German defense ministry, Dornier hopes to sell it eventually to broadcasters, weather watchers, and highway traffic controllers. The Kibitzer will make its debut later this month at the Hanover Air Show, and the German armed forces will get their first machines for tests and evaluation in the fall.

Hold it. The platform, powered by a pneumatically driven two-blade rotor, can climb up to its near 1,000-foot maximum altitude in five minutes. Once on station, it's held stablized to within 1° by a system based on six gyros—two for each axis. The German subsidiary of the Perkin-Elmer Corp. supplied the stabilization equipment.



Tether's end. Capsule can climb to 1,000 feet to serve as lofty lookout.

To get unlimited air time for the platform, it's tied to its mobile ground carrier by a fuel hose as well as a tether. Fuel tanks on the platform can thus be continually replenished. If the air compressor system that drives the rotors konks out, the blades will free-wheel and the autogyro will prevent a crash landing.

Ready to rise. West German kibitzing capsule for electronic gear rides its carrier to launching point.

Canada

Satellite in sight

Canada's chances of getting a domestic satellite communications network on the air by the early 1970's now seem better than ever.

As the government released its long-awaited White Paper on satellite communications early in April, Minister of Industry Charles Drury indicated there'd be no further heel-dragging in Ottawa on the effort to set up a $100-million system. The initial reaction in Washington, whose accord is needed for the rockets to launch the satellites, implied there'd be little, if any, opposition.

Unless there's an unforeseen hitch, Drury will put enabling legislation for the scheme before the Canadian Parliament next fall. By then, the ruling Liberal Party should have settled back into the governmental groove after choosing a new leader to take over from retiring Prime Minister Lester Pearson.

High finance. What the government wants is a corporation that would make it partners with private enterprise. Finding them won't be hard. The country's common telecommunications carriers proposed much the same setup last year when they argued that Canada stake out a space claim soon [Electronics, June 26, 1967, p. 211]. Even earlier, a group backed by the Power Corp. of Canada had put in its bid to finance and operate a satellite network.

Still to be established is the division between government and private holdings in the upcoming corporation. R.M. MacIntosh, a Toronto banker, has been tapped to block out the financial and management structures. But whatever the share allotted for private interests, the government will retain control over operation.

Dozen? Essentially, the system called for in the White Paper is much like that proposed by the common carriers—two satellites parked in a stationary orbit over the equator at approximately the longitude of Winnipeg. But where the earlier proposal called for 12 channels for each satellite, the government may decide to slash the number to four, although it has not ruled out the larger spacecraft. With four channels, Drury claims, the system could be operating by 1971. The larger system would take a year longer, the government figures. Each channel could carry one television signal or 1,200 telephone circuits.

Two consortiums, one headed by Northern Electric Ltd. and the other by RCA Victor Ltd. of Canada, have been asked to work out detailed proposals for the satellite system and submit them within six months. Each proposal will be submitted in two parts, one spelling out what the consortium sees as the hardware for the system, the other outlining the group's project-management schemes.

Meanwhile, Canadian space officials presumably will start negotiating with the U.S. for launch vehicles. Washington has been cool to Canada's plan for a domestic satellite system [Electronics, Sept. 4, 1967, p. 131]. Now that Canadian intentions to go ahead with the project are clear, though, the U.S. apparently will become more neighborly. Ottawa insists its domestic intentions don't run counter to the aims of the International Telecommunications Satellite Consortium and if it can convince Washington on that point there should be no problem.

Soviet Union

Integration drive

Western traders who keep a sharp eye on Russian industrial trends are now convinced that the Soviets are fast nearing mass production of integrated circuits.

Although Soviet planners haven't tipped their hand as to when and where, an Italian semiconductor specialist on the Moscow scene maintains that a big pilot production facility for silicon devices is under construction and scheduled to start up next year. Another West European engineer insists, "In two years they'll be in full-scale production of integrated circuits."

Signs. There's plenty of evidence to back up these predictions. The Russians have begun offering semiconductor materials for export. Along with silicon, the Soviets want to sell gallium arsenide, indium antimonide and other hard-to-fabricate materials. An engineer who had a chance to test some Russian crystals calls them "comparable to those of Monsanto and other companies' products."

Experienced Westerners see an important clue in the Russians' recent interest in buying a family of computers—the Saab D22 seems to be the one they're eyeing hardest —with IC's. In the past, these traders say, the Soviets have bought single computers for specific uses. If they're negotiating for a whole line, the reasoning goes, it's because they expect to produce their own versions soon.

Countersigns. Although there's fairly general agreement that the Soviets are getting closer to volume IC output, some Moscow watchers say there are at least two major problems that still have to be solved.

One is slicing and polishing equipment for semiconductor wafers. According to a prospective buyer of Russian crystals, the export agency that peddles them invariably refuses to slice the doped silicon to buyers' specifications.

The other problem is yields. Although the Russians have been producing transistors since 1960 they apparently are still getting low yields. One Soviet engineer insists the lab he works for has paid the equivalent of $40 for semiconductor devices that cost less than $1 in Western countries.

Japan

New way to skin a cat

For many a sidewalk superintendent, the cat skinner rates as the most talented performer on a construction job. Perched atop his bulldozer, feet and hands darting over a maze of pedals and levers, a skilled cat skinner is a highly-paid maestro of earthmoving.

Cat skinning, though, may soon be just another construction job. The Komatsu Manufacturing Co. has developed a bulldozer remote control that lets an untrained operator perform like a veteran. The remote operator, in fact, has the advantage of being able to see the front side of the blade. And he can handle jobs with his unmanned bulldozer that would be perilous to a cat skinner.

No man's land. Komatsu's earthmoving automation is getting its first use at a steel mill where hot slag has to be moved around. And like the West German radio-controlled scoop loader delivered earlier this year to the Karlsruhe nuclear research facility [Electronics, Feb. 5, p. 211], the Japanese machine can handle radioactive debris.

Since Komatsu hopes one day to see its radio control become fairly common, it has opted for a low-power transmitter—about 10 milliwatts—that needs no license. The transmitter operates in the 150-megahertz band and has frequency modulation. On the bulldozer, the transmitted commands are picked up by a double superhet receiver.

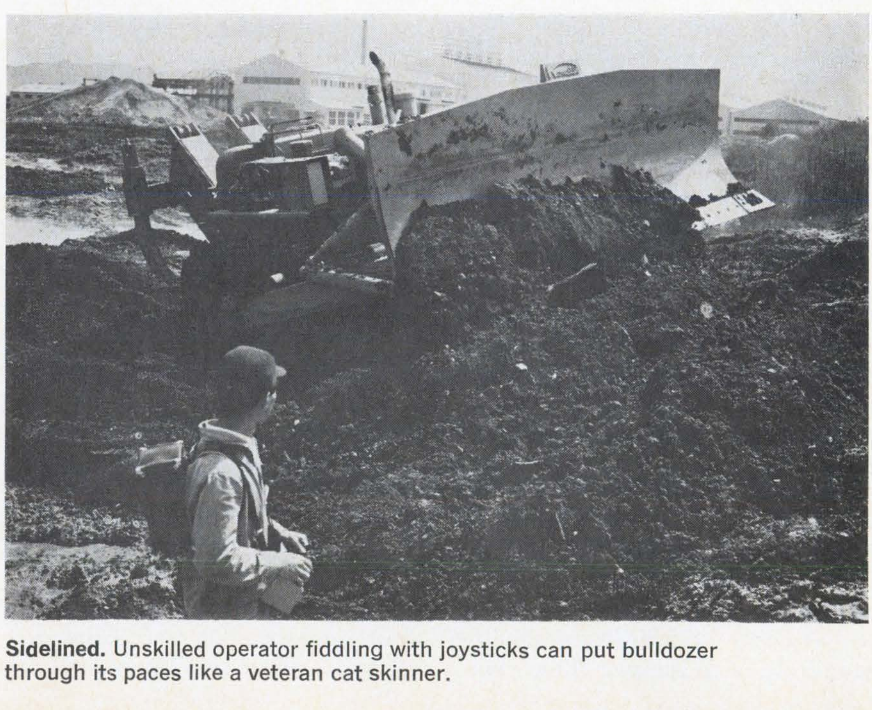
Handy. The control box, carried on a strap by the operator, doesn't duplicate the pedals and levers found in conventional bulldozers. Instead, there are two joysticks, one for directing the machine and one for working the blade. Switches control the less frequent functions, such as making throttle settings and turning the engine off and on.

Drive and blade commands are transmitted in a two-out-of-six frequency code, meaning there can be 15 different combinations. Logic circuits in the transmitter unit break up the joystick movements into individual commands.

Each joystick in effect controls one transmission channel since the drive and blade signals are transmitted one after the other on a time-shared basis every 50 milliseconds.

Separation. At the receiver, the pairs of modulation tones are separated by six filters and fed to a matrix to recover the command corresponding to the pair. The signals from the matrix control transistor power switches that drive pneumatic valves. They, in turn, control the hydraulic-control valves of the bulldozer.

Komatsu says it can now build the control system for about $8,400, although the first model cost more than twice that much.



Sidelined. Unskilled operator fiddling with joysticks can put bulldozer through its paces like a veteran cat skinner.

It adds up

For Japanese desk-calculator makers, it's not a matter of whether to shift to integrated circuits but when. And for the Canon Camera Co., the time is now. The company will start selling IC calculators in Japan on May 1. The machines will most likely make their bow in the U.S. sometime this fall.

Canon's move makes it the third major Japanese calculator producer—after the Hayakawa Electric Co. and the Sony Corp.—to get a line of IC models into production. But where Hayakawa counts on Japanese semiconductor suppliers for its kingpin circuits and Sony makes its own, Canon has turned to Texas Instruments.

The Canon calculators, designated the models 163 and 161S, are built around seven types of TI diode-transistor-logic packages. Canon claims the packages are built to its specifications, but one competitor insists they're the same packages TI supplies for the Singer Co.'s Friden printing calculator.

On the line. Whether specials or simply specially tested off-the-shelf packages, the IC's Canon is getting from TI add up to a whopping order. Canon says it plans to produce some 1,500 IC machines a month, and each one will employ 170 DTL packages; this works out to 250,000 packages a month.

Along with the IC's, which are used for arithmetic, program, and control operations, the new calculators have discrete transistors to drive the readout displays. And there's a magnetic delay line that functions as five registers—three for arithmetic and two for memories. Both the displays—cold-cathode tubes—and the delay line are new items in Canon desk calculator equipment.

Comparable. The performance of the model 163 is said to match that of Hayakawa's CS-32A, also a 16-digit IC calculator. Average add and subtract time for the Canon machine is 0.01 second; average multiply and divide time is 0.2 second. In Japan, Canon will sell the model 161 for $958, some $14 less than the price Hayakawa lists for its CS-32A. Hayakawa has the edge, though, in size. Its calculator fits into a standard desk drawer; Canon's is a little too tall for drawer storage.

Canon's 161S, an economy version of the 163, omits many calculation features, such as automatic square root, and contains only one memory. It will sell in Japan for $764.

Italy

Unkind cut

Italians have taken to long-distance direct dialing with gusto. It's fast becoming a national habit to ring up a distant relative from the nearest phone—as long as it's someone else's.

Enough subscribers have complained about unauthorized out-of-town calls that phone companies are taking a hard look at devices that make it require more than a furtive look to place a long-distance call. Small locks that put a subscriber's phone off limits for any kind of unauthorized call are on the market, but the country's phone manufacturerers have their eyes on a more sophisticated attachment—one that cuts off the phone only when an unauthorized out-of-town call is attempted.

SGS-Fairchild, a major European semiconductor producer [Electronics, Nov. 27, 1967, p. 135], developed the attachment. It's built around a dozen integrated-circuit packages that essentially decode the dial pulses for the first digit of the called number. If the pulses are for a "1," a "9," or a "0"—all direct-dialed long-distance calls start with one of these—the decoding circuit actuates a relay that cuts the phone off the line forthwith—before the complete number can be dialed. Input to the attachment is from a transformer whose primary is wired across the phone's line.

The relay that normally disconnects the phone can be arranged so that the call goes through but an external monitor is alerted. There are also versions where a key can override the cutout relay.

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April 15, 1968

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New All-Solid-State hp 1200 Scope System Sets New Standards of Performance for Your dc-500 kHz Measurements

Now you can upgrade your low frequency measurements with the new hp 1200 scope system for better performance, greater sensitivity and improved accuracy in the dc to 500 kHz range.

The hp 1200 scope system has an all-new design from the inside out to provide all-solid-state reliability and stability. Drift has essentially been eliminated to allow accurate measurements—even in the 100 μV dc area. Controls on the front panel have been grouped to give faster measurements, quicker set-up, direct dial readout even when using the magnifier.

Choose from four models to get single or dual trace 100 μV/cm sensitivity, or single or dual trace 5 mV/cm sensitivity. The 100 μV scopes have 17 calibrated ranges in 1-2-5 sequence with vernier for continual adjustment between ranges. (The 5 mV scopes have 12 calibrated ranges.) All four models have large 8 x 10 cm internal graticule CRT's, single-ended or differential input on all ranges, complete triggering versatility, external horizontal input, dc-coupled Z-axis, beam-finder—many of the features you normally associate only with high frequency scopes.

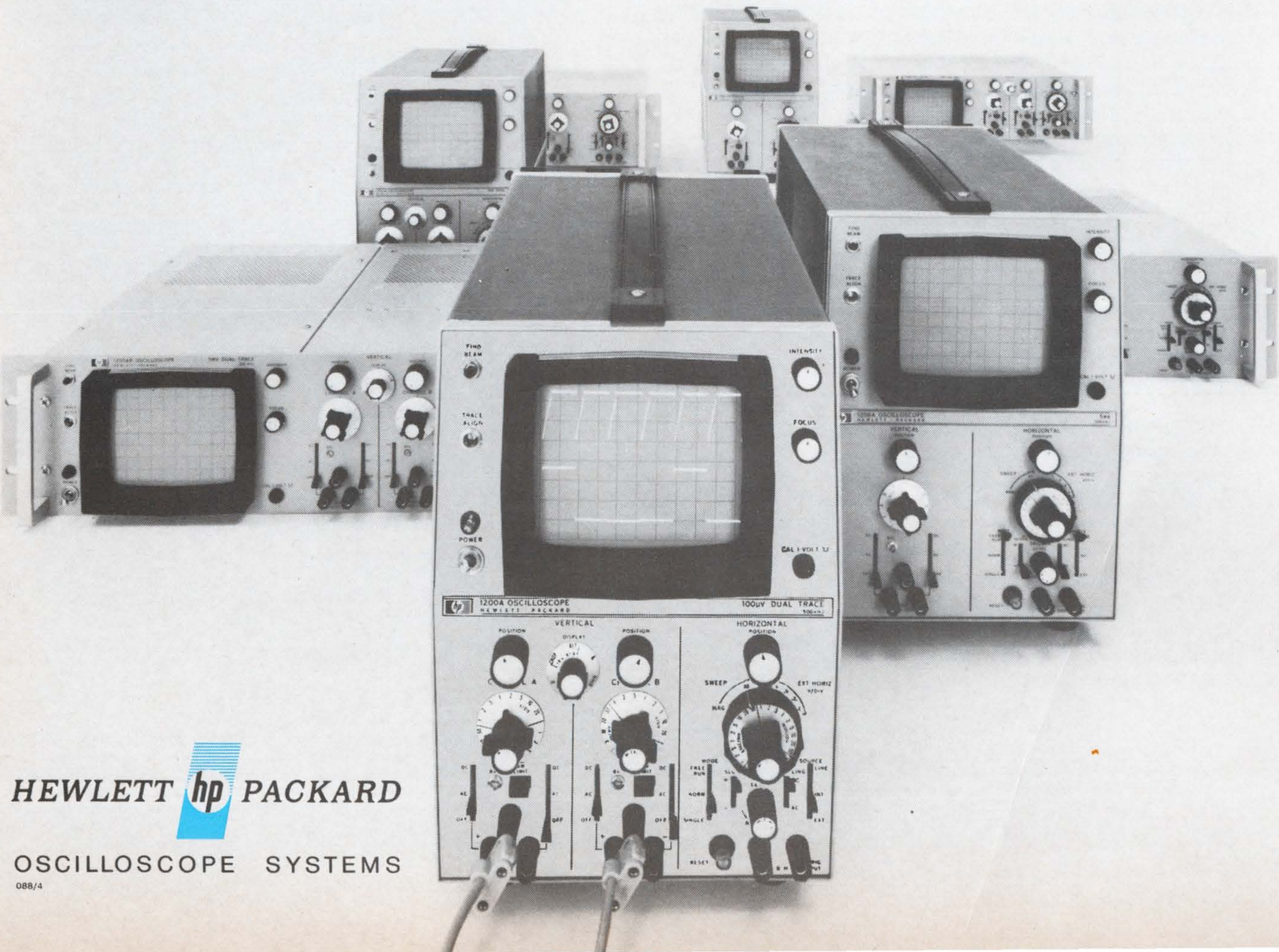
All four models are available as lightweight (< 25 pounds) cabinet or 5¼″ high rack mounts. Power consumption of 33 watts eliminates need for cooling fans.

For details on how you can increase your measurement confidence and your measurement accuracy in the low frequency range, contact your nearest hp field engineer. Ask him about the new hp 1200 scope system. Or, write to Hewlett-Packard, Palo Alto, California 94304. In Europe: 54 Route des Acacias, Geneva.

Circle 901 on reader service card

	1200A/AR*	1202A/AR*	1205A/AR*	1206A/AR*
Number of Channels	2	1	2	1
Maximum Vertical Sensitivity	100 μV/cm	100 μV/cm	5 mV/cm	5 mV/cm
Common Mode Rejection (Differential)	100 dB	100 dB	50 dB	50 dB
X-Y Capability	Identical Amplifiers (17 ranges)	17 vertical vs. 4 horizontal ranges	Identical Amplifiers (12 ranges)	12 vertical vs. 4 horizontal ranges
Price	$990	$790	$875	$715

* AR indicates 5¼″ rack mount model



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OSCILLOSCOPE SYSTEMS

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