Electronics®

I-f amplifier with linear IC's: page 66

Hardening semiconductors against radiation: page 73

Computer speeds cable link: page 85

October 30, 1967
$1.00
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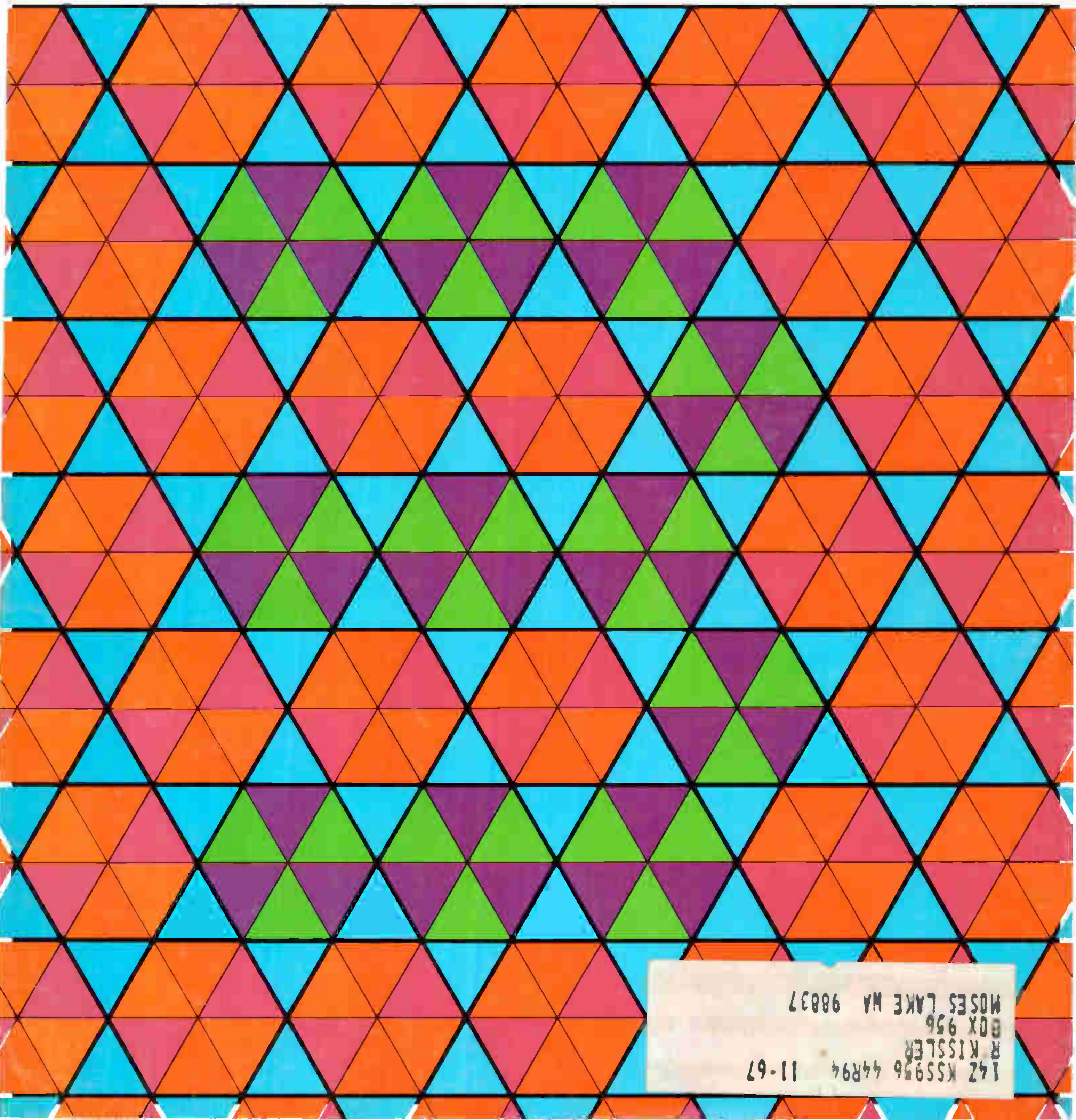
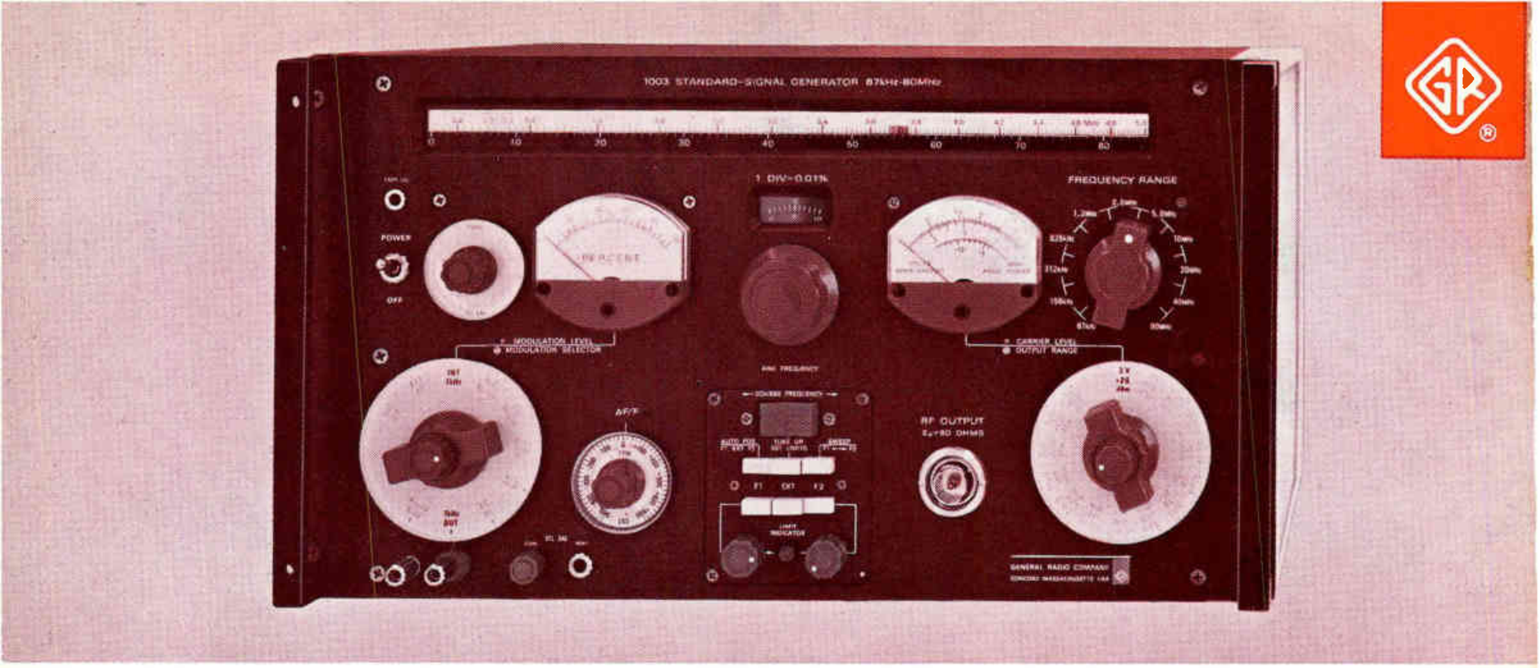
Below: An abstract view of pattern recognition, page 91





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An innovation in signal-generators brings about 10-to-1 better frequency stability and improved accuracy and resolution, without sacrificing other performance features. The key to this performance is the frequency-generating system — a single-range, optimally designed oscillator followed by frequency dividers to provide the successively lower ranges. Thus, the stability of one range is the stability of all, and range switching is accomplished without transient instability. After warmup, drift is typically less than 1 ppm per ten minutes, at least 10 times better than that of any other generator. Because of all-solid-state circuitry, total warmup drift is less than 150 ppm in three hours. Frequency changes caused by band switching or variations in line voltage, load, or level are virtually nonexistent.

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Frequency, incremental frequency, and automatic sweeping can all be programmed, as can output level and modulation-percentage. A crystal calibrator with 1-MHz, 200-kHz, and 50-kHz outputs is also supplied with the model containing the auto-control unit. This calibrator allows you to calibrate to within 0.002 percent.

The 1003 requires only 20 watts and delivers 180 milliwatts of leveled CW power into a 50-ohm load (6 volts behind 50 ohms). Envelope distortion is less than 2% at 70% a-m, with the modulating signal of 400 Hz or 1 kHz provided. Incidental phase modulation is less than 0.1 radian with 30% a-m. The highly accurate, 10-dB-per-step attenuator and a continuously adjustable carrier-level control give an over-all 155-dB dynamic range.

This instrument must be seen to be appreciated. A demonstration will show that very-narrow-bandwidth measurements can be made in 10 seconds with a 1003 signal generator and an oscilloscope. Try that with any other signal generator.

Price of the 1003 is $2995 ($2795 without the auto-control unit and crystal calibrator). For complete information, write General Radio Company, 22 Baker Avenue, W. Concord, Massachusetts 01781; telephone (617) 369-4400; TWX (710) 347-1051.

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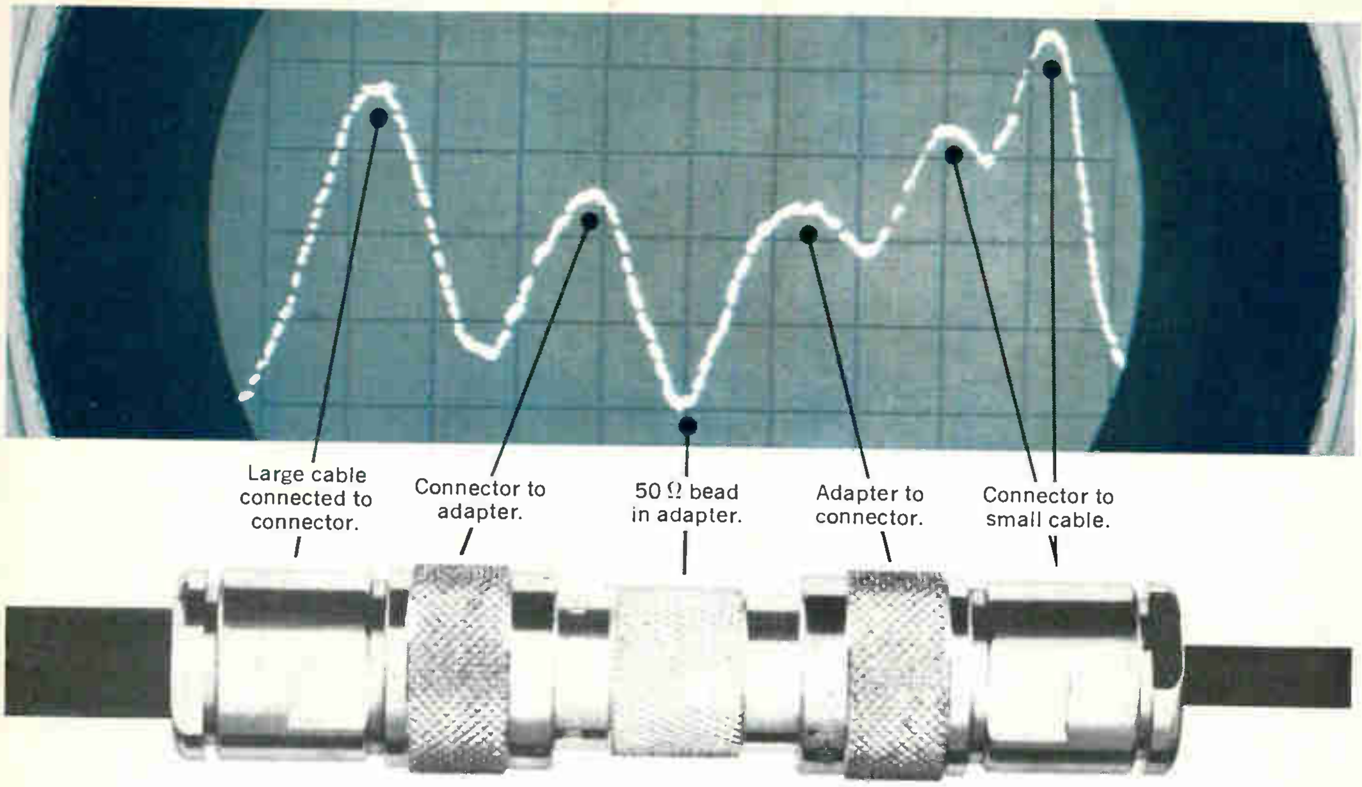

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Minute discontinuities mean reflections and trouble at GHz frequencies. They are also the ones almost impossible to discern in slower TDR systems.

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Electronics

Volume 40, Number 22 October 30, 1967

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Electronics Abroad

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Technical articles

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II. Application

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Readers Comment

Starting point

To the Editor:

The "new laser" described [Electronics, July 24, p. 35] as a development of IBM's Watson Research Center appears to be essentially identical to the first ring-discharge ion laser invented in 1965 by W.E. Bell, then of Spectra-Physics Inc. Mountain View, Calif. The similarities between Bell's device and the IBM device are, in my opinion, too close to preclude, for the record, a mention of Bell's prior work.

Eugene L. Watson
President
Coherent Radiation Labs.
Palo Alto, Calif.

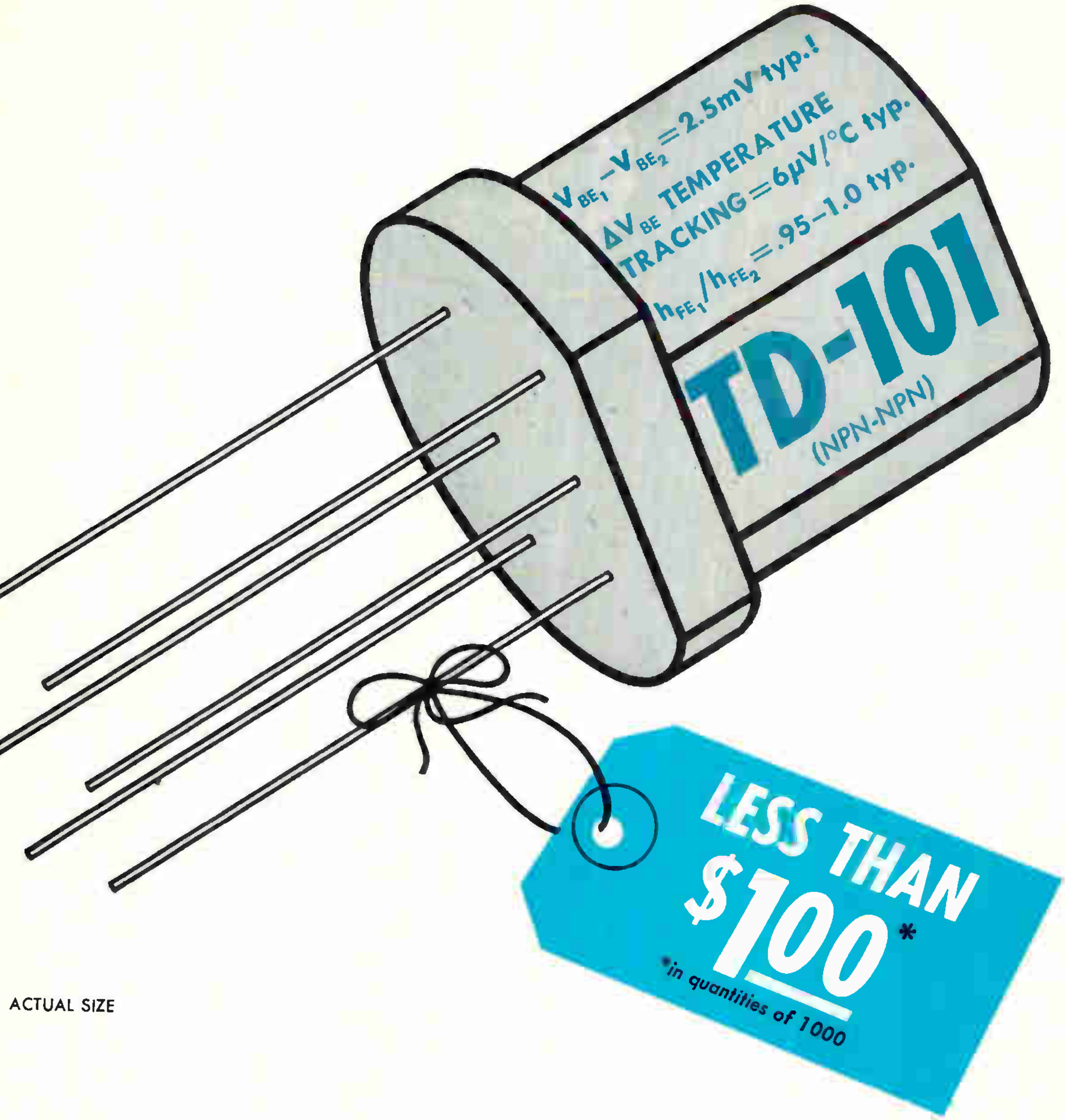
■ The ring discharge ion laser, designed by Bell and his colleagues at Spectra-Physics was, in fact, the starting point for the design of IBM's inductively excited laser, says its developer, physicist Charles Zarowin. But the IBM design differs in several fundamental ways: IBM's laser is squarewave pumped by audio frequencies (about 2.5 kilohertz), whereas the S-P design is pumped by sinewave radio frequencies (about 10 megahertz). S-P had to turn to the higher frequencies to avoid the "on," "off," or flickering effect of the output beam. The IBM design is driven by a small and lightweight (about 150 pounds), solid state power supply, while the S-P unit requires a much larger and heavier (about 1,000 pounds) vacuum tube power supply. In addition, the S-P design involves resonant operation of the inductive coupling, while IBM's unit is nonresonant. As a result of these unique design features IBM's laser provides a high numerical aperture (15 centimeters long by 1 cm in diameter), while the S-P unit is limited to a numerical aperture only about 1/10 that of IBM's.

Mini interference

To the Editor:

In the article "Power grab by linear IC's [Aug. 21, p. 81], I noticed the sentence: "Also, radio-frequency interference is minimal though no rfi filters are used." I think that the authors as well as

First from Sprague Electric!

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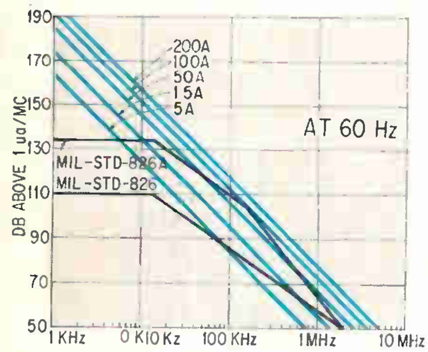
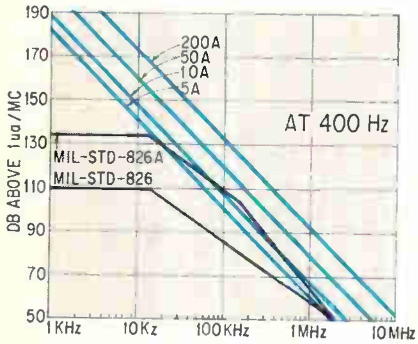
the readers might be interested to know how minimal the minimal rfi is.

Two graphs will predict the conducted interference resulting from zero axis switching at 60 and 400 hz.





Superimposed on each of these graphs are the limits of Mil Std. 826 and 826A per method 3002. The parameter in these graphs is load current in rms amperes. The straight diagonal lines represent the noise generated as a function of frequency for a particular load current. These graphs were prepared as a result of a Fourier analysis of the waveform in question.

Verification of the method used for this prediction is shown on the 400-hz graph in the form of measured data at 10 amperes rms. This data is in good agreement with the prediction.

Steve Jensen
Product development engineer
Genisco Technology Corp.
Compton, Calif.

Toward better standards

To the Editor:

Referring to Lt. John K. Lynn's letter on standard sheets [Aug. 7, p. 7], I should like to point out that standards for data sheets already exist, not only on a U.S. national basis but as international standards.

Technical Committee 47 (semiconductor devices) of the International Electrotechnical Commission (IEC) has been active in this field for 10 years and has succeeded in having several IEC publications issued, the most important being number 147, Essential Ratings and Characteristics for Semiconductor Devices, which contains recommendations regarding data sheets.

An appendix to that publication, to be issued in the near future, will recommend a standard format for the representation of all data.

The main difficulty probably is that these publications are not well known. Moreover, it certainly is deplorable that some manufacturers, although they have knowledge of the existence of such standards, do not pay any attention to them.

Maybe the method proposed by Lt. Lynn—to refuse to purchase such manufacturers' products—could be successful but I should prefer to point out as often as possible that standards do exist and that they should be followed.

H. Oswalt
Laboratorium der
Stiftung Hasler-Werke
Zurich, Switzerland

People

Bunker-Ramo Corp.'s Defense Systems division, formerly a leading maker of coded message systems for electronic warfare communications, is trying to regain the ground it's lost. A first step was taken this week when a manager was named for the communications department, without one for several months. The new man is **Jack J. O'Neill,** who at Airborne Instruments Laboratory oversaw the design and qualification of that company's first group of solid state microwave frequency synthesizers.

Jack J. O'Neill

O'Neill hopes to beef up the sales side of the department and generate new business. He says that the company has a funding program through which ideas can be investigated for three to six months. If an idea looks promising, a "feasibility model" can be built. "Then, when there's a demand for the product, we'll be there with a piece of equipment and not just an idea for development."

With the appointment of **Kenneth G. Harple** as director of development engineering, Systems Engineering Laboratories of Fort Lauderdale Fla., has taken a major step toward strengthening its position in the industrial control and data-acquisition markets, which presently account for 30% of its sales. The 38-year-old Harple is a well-known developer of industrial systems equipment.

Kenneth G. Harple

Systems Engineering, a growing computer firm in existence since 1962, began by developing data-acquisition equipment. It started making its own computers in 1965. Thus, unlike most systems companies, SEL now makes its own com-

People

puters and peripheral equipment, combining them into systems tailored to customer needs.

Harple, believing too much burden has been put on the programer, looks forward to developing instruments designed to simplify programing—in which tradeoffs between hardware and software have been considered—thus resulting in lower net cost to the user.

Harple will be rejoining SEL's Emil Borgers, executive vice president, for whom he worked three years ago at Scientific Data Systems Inc.

H. Brainard Fancher was sent to Paris three years ago by the General Electric Co. to manage GE's takeover of Compagnie des Machines - Bull and to rebuild the French concern's shaky financial base. Now, with Bull-GE on its feet, he has been recalled to Syracuse to become manager of the advanced systems and requirements operation of GE's Defense Electronics division.

H. Brainard Fancher

Fancher will direct the systems coordination of the division's six departments—aerospace electronics, heavy military, armaments, avionics, ordnance, and special information products (military computers)—plus its electronics research and advanced engineering laboratory. He will also supervise the division's operations abroad.

His new job reflects the Pentagon's increasing emphasis on complete systems packages, rather than individual products.

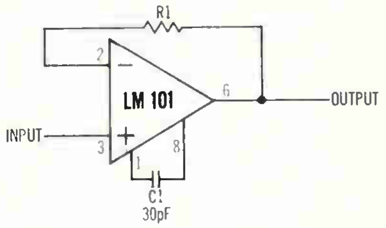
Had GE undertaken a systems engineering effort earlier, he believes, it might have been able to bid on the entire Nike-X system. Instead, the company collected only the order for radar, now being supplied by the heavy military department.

Fancher isn't entirely new to systems coordination. Just before his French mission, he managed GE's Apollo program, and that, he says, "is the biggest system yet."

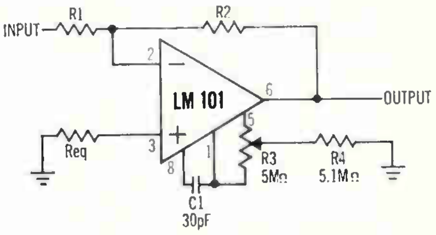
No Comment.

LM 101

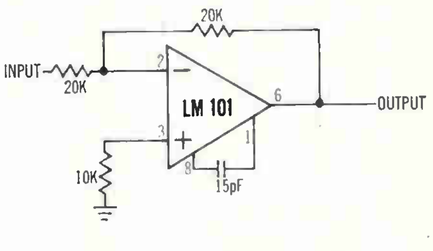
Voltage Follower



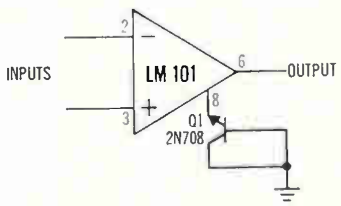
Inverting Amplifier with Balancing Circuit



Unity Gain Inverting Amplifier



Voltage Comparator for Driving
DTL or TTL Integrated Circuits



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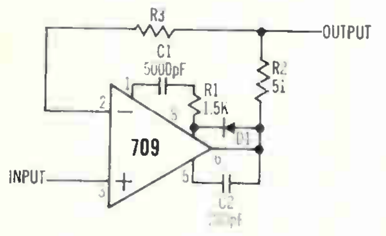
Voltage Follower



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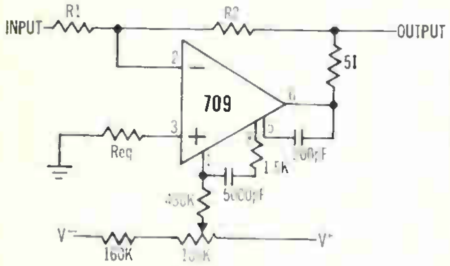
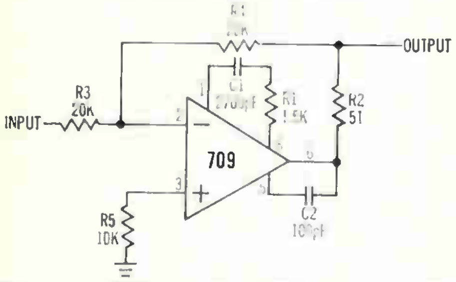


Unity Gain Inverting Amplifier



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Meetings

Meeting on Electromagnetic Compatibility, Society of Automotive Engineers; Dallas Sheraton Hotel, Dallas, **Oct. 31-Nov. 1.**

Nuclear Science Symposium, IEEE; Statler Hilton Hotel, Los Angeles, **Oct. 31-Nov. 2.**

Asilomar Conference on Circuits and Systems, IEEE; Asilomar Hotel, Pacific Grove, Calif., **Nov. 1-3.**

Northeast Research and Engineering Meeting (Nerem), New England Section of IEEE; Sheraton-Boston Hotel, Boston, **Nov. 1-3.**

Product Assurance Conference, IEEE; Waldorf-Astoria, New York, **Nov. 2-3.**

Applied Superconductivity Conference and Exhibition, Atomic Energy Commission and University of Texas; Austin, **Nov. 6-8.**

Conference on Speech Communications and Processing, IEEE; Massachusetts Institute of Technology, Cambridge, **Nov. 6-8.**

Technical Conference, Society of Plastics Engineers, Nevele Country Club, Ellenville, N.Y., **Nov. 6-7.**

Reliability Physics Symposium, IEEE; Statler Hilton Hotel, Los Angeles, **Nov. 6-8.**

Symposium on Automatic Support Systems for Advanced Maintainability, IEEE; Colony Motor Hotel, Clayton, Mo., **Nov. 7-9.**

Analytical Symposium and Instrument Exhibit, American Chemical Society, and American Microchemical Society, Society for Applied Spectroscopy; Statler Hilton Hotel, New York, **Nov. 8-10.**

Western Conference on Broadcasting, Broadcasting Group of IEEE; Ambassador Hotel, Los Angeles, **Nov. 9-10.**

Symposium on the Application of Computers to the Problems of Urban Society, Association for Computing Machinery; New York Hilton Hotel, New York, **Nov. 10.**

Conference on Applications of Simulation Using the General-Purpose Simulation System, IEEE; New York Hilton Hotel, New York, **Nov. 13-14.**

Conference on Thermal Conductivity, Department of Commerce and National Bureau of Standards; Gaithersburg, Md., **Nov. 13-15.**

Engineering in Medicine and Biology Conference, IEEE; Statler Hilton Hotel, Boston, **Nov. 13-16.**

Computer Conference, American Federation of Information Processing Societies; Convention Center, Anaheim, Calif. **Nov. 14-16.***

Short Courses

Precision radiometry—calibration and measurement, University of Michigan's School of Engineering, Ann Arbor, Mich.; **Nov. 6-10; $175 fee.**

Seminar on value engineering, University of New Mexico's State Technical Services, Albuquerque, New Mexico; **Nov. 13-17; $125 fee.**

Institute on the computer and hospital administration, The American University's Center for Technology and Administration, Washington; **Nov. 28-Dec. 1;** $175 fee.

Call for papers

Colloquium in Packaging Electronics and Optics, Rochester Institute of Technology; Manger Hotel, Rochester, N.Y., Mar. 13-15, 1968. **Nov. 22** is deadline for submission of abstracts to A. Robert Maurice, Extended Services Div., Rochester Institute of Technology, P.O. Box 3416, Rochester, N.Y. 14614

Computer Conference, IEEE; International Hotel, Los Angeles, June 25-27, 1968. **Jan. 15** is deadline for submission of digests of papers of Harold Peterson, c/o Rand Corp., 1700 Main St., Santa Monica, Calif.

International Conference on Communications, IEEE; Sheraton Hotel, Philadelphia, June 12-14, 1968. **Jan. 15** is deadline for submission of papers to R.S. Caruthers, International Telephone & Telegraph Corp., 320 Park Ave., New York 10022.

* Meeting preview on page 16.

A state of the art frequency comparator featuring all silicon semiconductor design, the Model 103A makes short term frequency comparisons to 1 part in 10^{11}. Accuracy can be extended to 1 part in 10^{13} under controlled environmental conditions. □ The 103A accepts the widest range of test and reference frequencies of any comparator on the market today. Frequencies of 100 kHz to 5 MHz in 14 discrete increments are acceptable for both inputs independent of one another and in any combination. □ Seven data channels out for ultimate versatility are available. Front panel metering provides "stand alone" operation with no other readout devices required for most measurements. Here's one comparator you can use on the test bench as well as in the standards laboratory.

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FLUKE

Meeting preview

Far-flung, ankle-deep

The fall edition of the American Federation of Information Processing Societies' semiannual Joint Computer Conference will, as usual, include sessions to interest members in all six of the sponsoring organizations. But the trouble is that because the meeting has to satisfy so many people, it cannot please everyone.

Compared to the computer conference sponsored by the IEEE, which provided an in-depth look at recent developments in computer hardware, this conference offers, at best, shallow treatment. Nevertheless, a number of interesting papers and sessions are scheduled for the conference, which will be held Nov. 14-16 in Anaheim, Calif.

Two papers to be given evidence the growing interest in the Fast Fourier transform technique, sometimes called the Cooley-Tukey algorithm. One, by L.B. Lesem, P.M. Hirsch, and J.A. Jordan Jr. of the International Business Machines Corp., describes the technique's applications to computer-generated holograms, and the other, by A.G. Larson and R.C. Singleton of Stanford Research Institute, describes a real-time implementation of the algorithm on a small computer.

In another paper, D.K. Hansom from the Univac division of Sperry Rand Corp., C.F. Chong from Ferroxcube Corp., and R. Mosenkis of Radio Corp. of America will describe a large plated-wire memory containing 100 million bits [Electronics, May 15, p. 101]. Both Chong and Mosenkis worked with Hanson at Univac where the memory was designed, leading to speculation about their present employers' interest in plated-wire technology. Ferroxcube is believed to be more interested in the technique than RCA.

In an attempt to repair the breach between the hardware and software designers, a tutorial session, "Software for Hardware Types," will be offered. The session includes at least one paper, by Albert B. Tonik of Univac, that should interest those familiar with hardware but mystified by software.

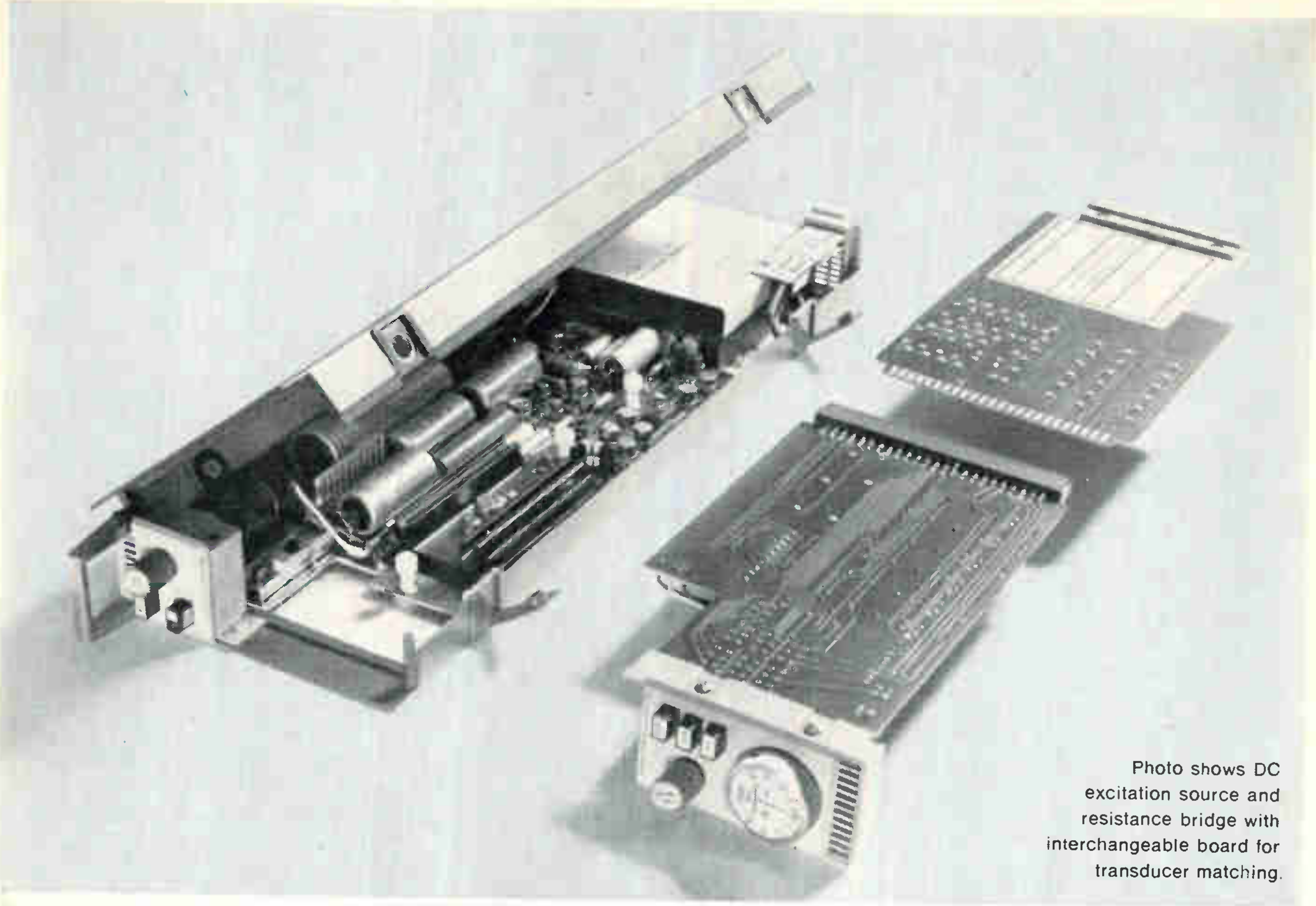
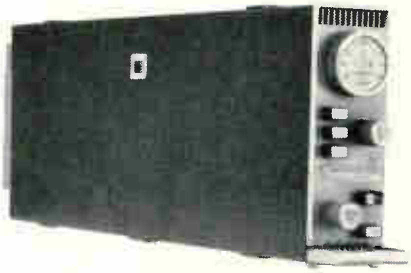


Photo shows DC excitation source and resistance bridge with interchangeable board for transducer matching.

Plug-together Signal Conditioners



with high performance, low-cost adaptability

A floated, guarded DC excitation source provides switch-selectable constant-voltage and constant-current operating modes, plus a unique mode for linear output from single active arm bridges. Exceptional environmental stability saves man-hours maintaining large systems in calibration.

Resistance bridge module provides bridge completion, balancing, calibration and normalizing functions. Minimum cost adaptation to transducers is afforded through a detachable board for mounting components for a specific transducer.

The excitation source may be used on a per-channel basis for maximum isolation, or with up to five transducers using inexpensive excitation couplers for each channel . . . or many transducers can be excited from an external power supply, and you can have local regulated level control. Plug-together design allows change from shared to individual channel excitation.

Price for excitation and conditioning: from $160 to $360 per channel (for rack-mounted, cabled system) depending on configuration.

For information on the 2480 Series or compatible data acquisition instrumentation call your local HP field engineer or write Hewlett-Packard, Palo Alto, California 94306; Europe: 54 Route des Acacias, Geneva.

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SIGNAL CONDITIONERS

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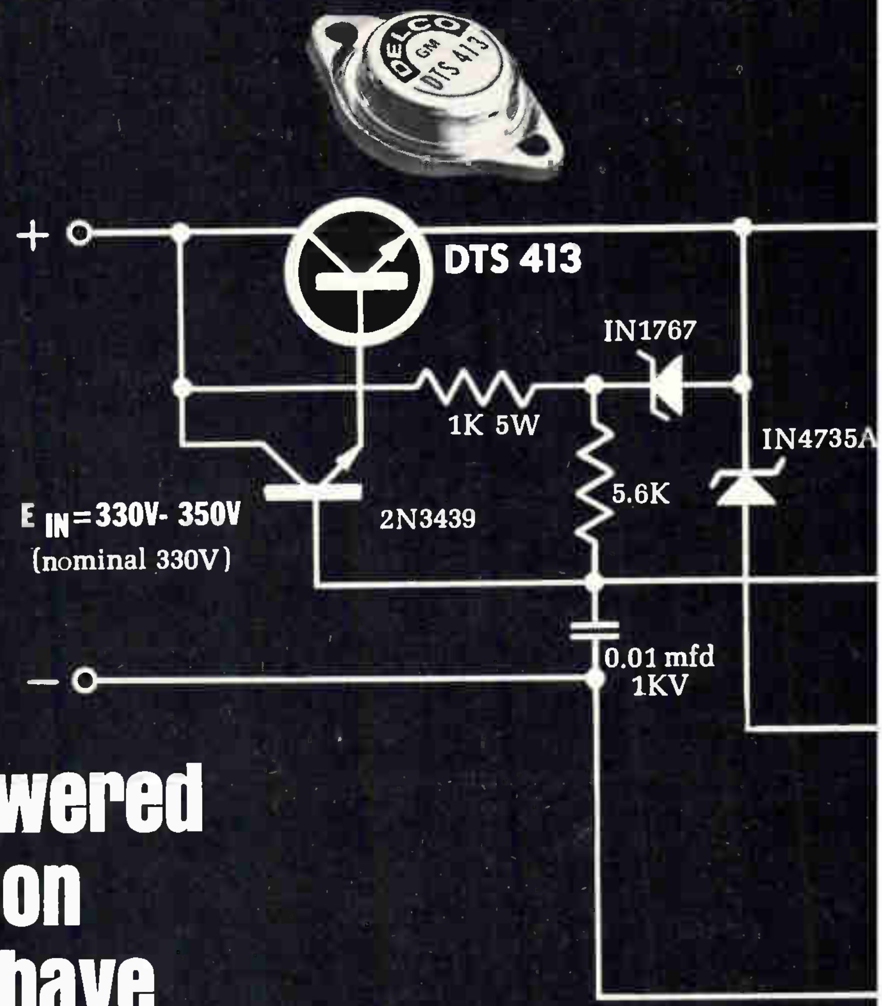


High-powered regulation doesn't have to carry a high-powered price!

The simple DC regulator shown supplies 290 volts to a load of 50 to 600 milliamperes. Regulation is better than ± .05 percent with an input voltage variation of 15%. Delco high voltage silicon makes this possible with just one series transistor—the DTS-413—priced at just $3.95 each in 1000-and-up quantities.

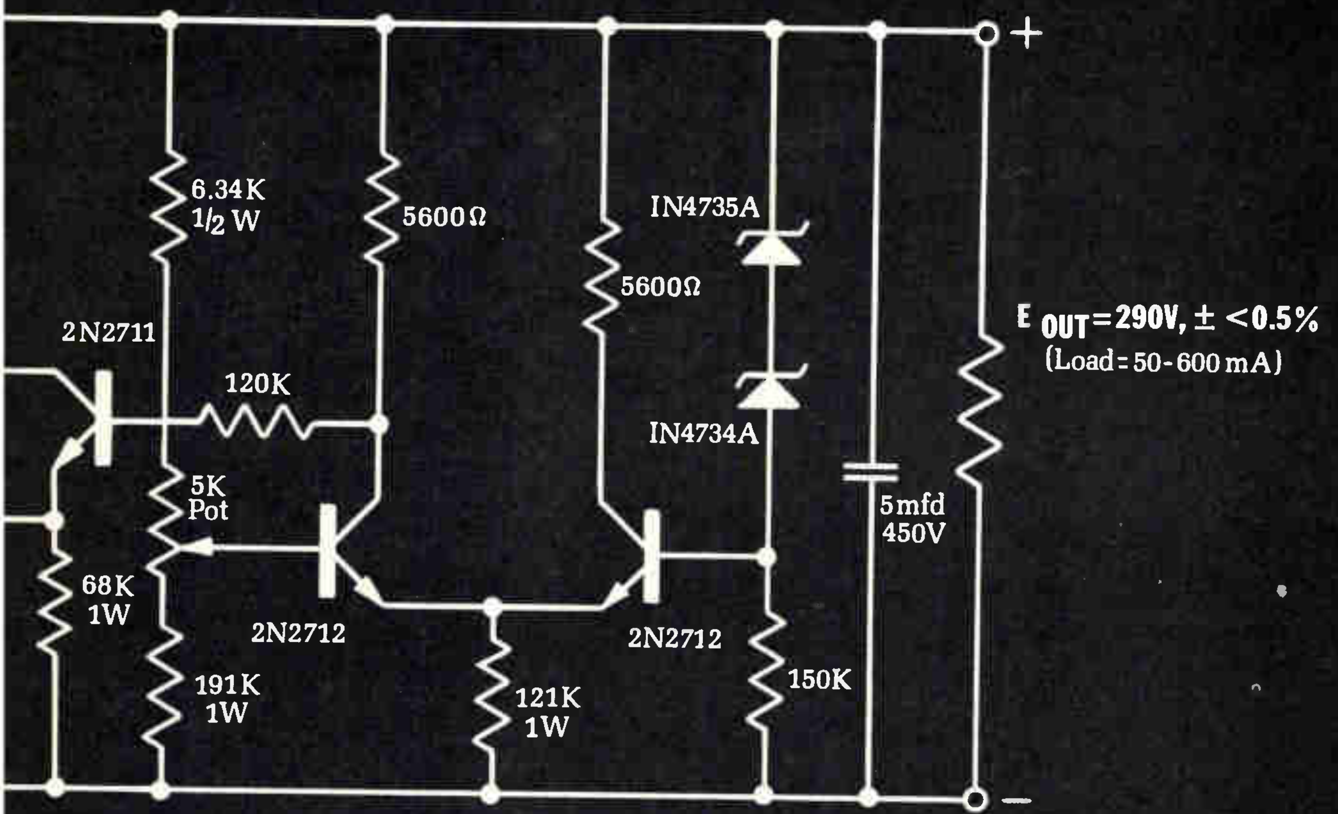
This circuit also can be scaled to the capabilities of any of the other cost saving Delco DTS transistors, including the new DTS-424 and DTS-425. And no matter which Delco high voltage transistor you use, reduction of weight, size, and component cost is part of the bargain. Circuit complexity and number of components are reduced and so assembly costs go down, too. And fewer components mean higher reliability.

Right now, Delco silicon power transistors are adding these benefits in such high energy circuits as: DC-DC converters, ultrasonic power supplies, VLF class C amplifiers, off-line class A audio output and magnetic CRT deflection (several major TV manufacturers use them in big screen horizontal and vertical sweep circuits).

How soon can you get Delco silicon power transistors? How soon do you need them? With our experience and new plant facilities, samples or production quantities can be shipped promptly. Call one of our distributors or a Delco sales office now.

For full details on the DC regulator circuit, ask for application note number 38.

Application of Delco high voltage silicon power transistors: a DC voltage regulator.



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DTS-423	400V	325V	3.5A	10 @ 2.5A	100W	$4.95
DTS-424	700V	350V	3.5A	10 @ 2.5A	100W	$7.00
DTS-425	700V	400V	3.5A	10 @ 2.5A	100W	$10.00
DTS-430	400V	300V	5.0A	10 @ 3.5A	125W	$17.49
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Editorial

The battle lines are drawn

A deafening hue and cry over community antenna television, better known as CATV, is going to be heard during the next 12 months.

Technical men and businessmen now recognize that there is more to CATV than piping commercial television over the mountains to backwoods villages, that the brightest potential comes once the coaxial cable has been laid into every home in the country. Then a whole universe of new possibilities opens up: picturephone, computers in the home, newspaper delivery by facsimile, entertainment retrieval systems, and whatever else—needing large bandwidth for transmission—the imagination can conjure up.

The cacophony is going to come from several different directions. Most broadcasters want to kill CATV because they see it as a face-to-face competitor. They see the new medium as a parasite living off the broadcaster program fare. But the telephone companies see CATV as a superb way to increase their services—via picturephone-type equipment, for one example—and their revenues. And the operators of CATV systems want to take their systems into the 100 major markets the Federal Communications Commission has frozen them out of, to originate their own programs, and to sell advertising on their systems.

Meanwhile, CATV has divided the FCC into a handful of bitterly opposing camps. The FCC's Broadcast Bureau naturally supports the broadcasters' contention that CATV is better off dead because it would change the status quo of broadcasting. At the Common Carrier Bureau, staff members lean towards the telephone companies and support their view that CATV cables are just an extension of wired carrier services.

And the CATV task force, which the agency set up last year to handle a growing backlog of CATV cases, sees itself as the defender of an infant industry that ought to be allowed to survive.

If the staff of the FCC is at odds over CATV, the commissioners are even more sharply divided. Three of them now believe that CATV ought to be given a chance to grow. Two believe that the cable medium should be killed off quickly—as pay television was—before it damages the structure of broadcasting in the U.S. And two others, who are ostensibly noncommitted, wish CATV would go away. Until this summer, the FCC hoped that Congress would solve the problem for the commissioners by passing a copyright law that would put most of the CATV systems out of business.

Now it is clear that even if Congress passes such legislation—and it is doubtful it will come this year—CATV will not die. For one thing, big corporations have moved into it, supplementing or replacing the tiny "momma-and-poppa" systems (so-named because they were often family affairs run by a husband and wife) that started the business. Companies such as Time Inc., Westinghouse Electric, General Telephone & Electronics, and General Instrument have a big stake in CATV these days and these companies are willing to pay a copyright fee to broadcasters for the use of programs and even to pay an additional fee for the right to retransmit broadcasters' signals. But the big CATV operators also talk about wanting the broadcasters to share advertising revenues with them in payment for CATV's extension of a television station's audience.

Broadcasters are the strongest foes of CATV, but there is no unanimity among them about the new medium. Although the National Association of Broadcasters bluntly calls CATV operators parasites, fully 35% of CATV systems are owned by broadcasters—some local and some national—like Cox Broadcasting, Westinghouse, and NBC. CBS has started a study of CATV with the intent of eventually acquiring some systems and the American Broadcasting Co. is only waiting the outcome of its merger plan with ITT, now under scrutiny by the Justice Department and the FCC, before it moves into CATV.

While NAB calls the CATV operators parasites for rebroadcasting television's programs, other broadcasters are indignant about CATV systems' plans to originate their own material. And that leads to another schism at the FCC. The protesting broadcasters have almost convinced the Broadcast Bureau at the FCC to recommend that the agency order CATV broadcasters to stop originating shows. But in October, at a regional meeting of CATV operators, FCC Commissioner Nicholas Johnson urged the CATV men to originate more of their own programs.

The argument that CATV should be relegated to the backwoods communities behind the mountains is also obsolete. The major cities of the U.S. need it even more because reflections from new high-rise buildings are ruining tv reception. In New York City, for example, one wonders why the FCC doesn't oppose the construction of the proposed World Trade Center, which everyone agrees will damage television reception for 2 million to 3 million viewers, if it insists on keeping CATV out of the city.

The rapid acceptance of color telecasting has made cable transmission even more desirable because color tv has tighter requirements. With the new amplifiers, filters and transmitting techniques installed on the cable, CATV systems can produce better quality than the old kind of radiation broadcasting.

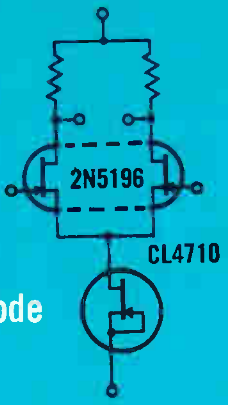
Unhappily, CATV's role as a supplement to television appears to be the best way to pay for the installation of coaxial cable around the U.S.—even though television programing may be the least important user of CATV in the future. So the television aspects have to be pushed. But CATV is too important to be killed off as a sop to broadcasters.

DIFF AMP — HIGH Z_{IN}

Take Two Resistors

Add one Dual FET

Combine with a CL Diode

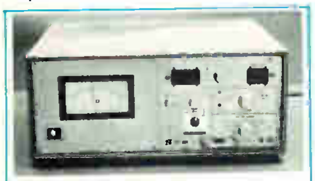


Type	Offset	Tracking	I_G
2N5196	5 mV max	5 μV/°C	15 pA max
2N5197	5	10	15
2N5198	10	20	15
2N5199	15	40	15
[illegible]	5	10	[illegible]

SELECT THE FET DUAL FOR YOUR DIFF AMP

TRACKING FROM 5μ V/°C

A dual matched FET combined with a current limiter diode is all you need for a high impedance diff amp. Input currents are less than 15 pA . . . even with transconductances over 1000 μmhos. The matching parameters of the dual FETs are the most important for diff amp operation—several guaranteed limit ranges are offered for a trade off between cost and performance. Select the optimum dual for your application by using the Siliconix "Diff Amp Designer's Kit." Start with the most closely matched pair, the 2N5196 . . . check operation . . . then downgrade to lesser matched units until the minimum acceptable performance is reached.



NEW LOW COST FET TESTER
The S1200 Semiconductor Tester features plug-ins for expandable test capability, simplicity of operation, and low cost.
Price: S1200 Tester — $960
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The CL diode — a two terminal FET with the source and gate connected — is the constant current supply. This avoids the complexity of the bipolar limiter. These diodes are available for current sources ranging from 220 μA to 4.7 mA. The CL diodes in the Designer's Kit offer typical currents for diff amp designs.

Get your Siliconix "Diff Amp Designer's Kit," DK7, from your distributor. It contains four dual FETs, the 2N5196 through 2N5199, and two CL diodes for $84.50. For literature on these and other FETs, just write or check the inquiry card.

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Electronics Newsletter

October 30, 1967

DOT will build electronics center near Denver . . .

An electronics proving ground for high-speed ground transportation will be built by the Department of Transportation near Denver, Colo. The 60-square-mile facility, site of the Lowry Bombing and Gunnery Range, will be equipped with two or more tracks to study trains capable of speeds up to 250 miles an hour. It is expected to be operational in eight to 12 months.

The range will be fully instrumented—including telemetry systems—to study waveguides for power transmission and distribution, linear induction motors, and the like. Government officials estimate they'll spend $50 million on the facility in the next three years. **An aerospace company is considered likely to win the contract to operate the facility.**

. . . with laser first on test list

First to be tested at the Department of Transportation's Denver center will probably be a laser obstruction detector. A gallium-arsenide injection-laser diode in a sensor warns of obstructions on the tracks. Under the terms of an unsolicited proposal, RCA will install the pulsed infrared devices every 400 yards to give a 200-mph train up to five miles warning. **Obstructions as small as 1 cubic inch can be detected.**

IC's behind slump of discrete devices

Fast selling integrated circuits have been eating into discrete device sales with bigger and faster bites than the semiconductor industry would admit. **Up till now, the slump in discretes has been attributed by industry experts to the general sluggishness of the economy.** But now Patrick E. Haggerty, Texas Instruments board chairman, concedes **"No one really expected IC's to come on so fast, and in such great numbers."**

Fairchild using junction FET's in microwave circuits

Late-starting Fairchild Semiconductor hopes to leapfrog its rivals in the microwave integrated circuit race by using junction field effect transistors. **Its R&D Laboratory has developed an epitaxial FET containing a Schottky barrier gate on a semi-insulating gallium arsenide substrate, which operates to 3.5 gigahertz.**

Most companies active in microwave IC's have dismissed the FET as a usable device—believing maximum operating frequencies too low and fabrication methods too difficult—and have been using bipolar transistors instead [see p. 107].

Going to a GaAs junction FET structure containing a Schottky barrier gate for microwave IC's buys two things, Fairchild says. **The high mobility GaAs permits higher operating frequencies, and the FET structure is easier to fabricate than bipolars and insulated-gate FET's that require intricate diffusions and pose more isolation problems at higher frequencies.** Fairchild believes its FET is usable up to 10 to 14 ghz, offering a flatter high frequency response and possibly better noise performance than the bipolars.

High court to rule on FCC vs CATV

The Supreme Court will decide whether the FCC has the right to regulate cable-television broadcasting. The high court's ruling, the first involving operation of a CATV station, will be based on an appeal by the FCC and two San Diego tv stations of a pro-CATV decision handed down by a U.S. Circuit Court of Appeals in California.

The CATV industry is hoping that the court will not only look into the broad question of FCC regulation but also expand its inquiry to include copyright of over-the-air material. Expected by next spring, the ruling will also cover the FCC's right to suspend CATV growth while the agency ponders how the industry should be regulated. [For more on CATV, see p. 23.]

Now's the time for fast Fourier

Within a year IBM may market a special-purpose computer that calculates Fourier transforms in real time. The machine would be functionally identical to the one designed at Bell Telephone Laboratories [Electronics, Sept. 4, p. 40]. **Applications would include analyzing speech waveforms, radar signals, seismic signals, and data transmission.**

IBM's work reflects the growing interest in developing software and hardware using the fast Fourier transform algorithm. **Sylvania has developed a special-purpose computer that uses the fast Fourier transform to digitize speech signals in real time.** And a research team from Stanford Research Institute will describe at the Fall Joint Computer Conference next month a technique for analyzing radar signals in real time, using the transform technique on a general purpose computer.

Philco tunes up with IC for organs

Philco-Ford is ready to challenge Motorola for a share in the lucrative electronic organ IC market [see p. 45]. The company will introduce an IC containing a seven flip-flop frequency divider developed especially for organs in just four weeks. The monolithic MOS device, a 14-lead dual in-line package, will cost $2.10 each in lots of 1,000. The Motorola device sells for $2 in large quantities [Electronics, July 24, p. 196]. Its operating frequency range extends from d-c to 500 kilohertz; output impedance is less than 1,000 ohms and dissipation is 300 milliwatts. **The device will be available in quantity by the end of the year.**

Stability achieved in thin-film FET

By using a plasma-anodized aluminum oxide for the gate insulator, RCA Laboratories in Princeton, N. J., has come up with what it believes is **the first thin-film field effect transistor that is stable at room temperatures.** RCA researchers say the way may now be open for the use of this type of transistor in IC's made with cadmium selenide. The new material reduces the trapping effects of the insulator-semiconductor interface.

Previous thin-film devices, with silicon monoxide as the gate insulator, showed a drift in threshold voltage when the gate voltage was changed. In RCA's transistor, these voltages are independent of each other.

Addenda

Frank W. Lehan, an engineering consultant long on government and electronic industry experience, has been named to the top research job at the Department of Transportation—assistant secretary for research and development. . . . Victor Comptometer Corp. has finally started delivery of the Victor 3900—the electronic calculator built with Philco-Ford MOS circuits—two years after it was introduced. The 3900 was plagued by technical difficulties that prevented its production as the first calculator made with integrated circuits. Miscalculating the difficulty of building the complex MOS IC's, Philco-Ford had to redesign most of the circuits before making them commercially [Electronics, Mar. 6, p. 231].

Component and Circuit Design

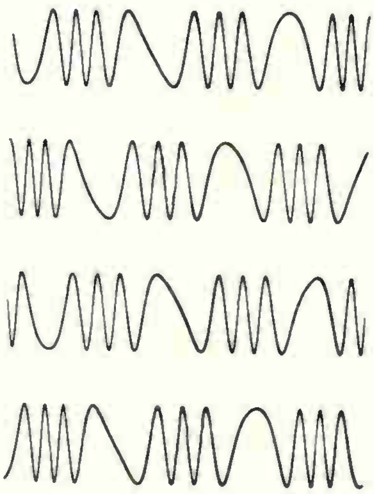
IDEAS

from SYLVANIA Electronic Components Group

CRTs

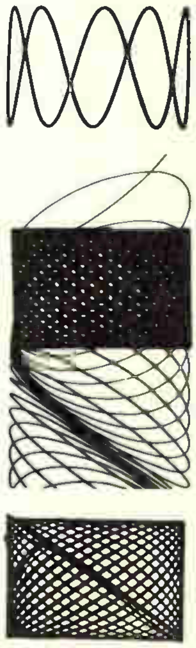
3" x 5" CRT prints out signal records up to 1 MHz

Video pictures printed out in a series of individual frames



Continuous record, transverse signal pattern

Continuous record, longitudinal waveform



Printout of simultaneous X-Y plot and Lissajous pattern

Photos courtesy of Honeywell Inc. Test Instrument Division

Direct printout speeds 100 times faster than previously available in commercial oscillographs . . . Spot resolution of less than 0.008-in. diameter . . . Recording of both black-and-white and halftone data . . . Signal recording and printout from dc to 1 MHz . . . Waveform or alphanumeric printout. . . .

All of these are well within the capability of the Sylvania SC-4082E fiber-optic cathode-ray tube, which has the largest fiber-optic faceplate commercially available today: 3" x 5".

The faceplate consists of more than 35 million light-conductive fibers, each only 10-15 microns in diameter, fused into one bundle about ½-inch thick and coated on the back with Sylvania P16 high-output phosphor.

The small diameter of the faceplate fibers, combined with an improved electron gun, assures extremely fine spot resolution on the output side of the faceplate: 4 to 7 mils as opposed to the 15 to 30-mil range of typical laboratory oscilloscopes.

As shown here, this fiber-optic CRT is used in Honeywell Test Instrument Division's Model 1806 Visicorder, which combines a precision oscilloscope for visual signal monitoring with a high-speed oscillograph recorder.

The Visicorder is a single-channel, 4-axis unit which uses the light output from the fiber-optic CRT faceplate to record continuous transient data directly on standard ultra violet-sensi-

(continued)

This issue in capsule

CRTs *(continued from page 1)*

tive oscillograph paper. Signal variations are recorded as the paper passes over the faceplate. Low-level ultraviolet light develops the paper as it comes out of the Visicorder to give a permanent record within seconds.

Thanks to the speed, light output and resolution of this fiber-optic CRT (and with a well-deserved bow to the ingenuity of Honeywell's design engineering staff), the Visicorder records signal responses from dc to 1 MHz, on either the vertical or the horizontal axis or simultaneously on both, and has continuous or intermittent chart-drive modes.

In addition, video pictures can be recorded as a continuous series of individual 3" x 4" frames on the direct-record paper at the rate of 30 pictures per second.

The SC-4082E fiber-optic CRT uses electrostatic focus and deflection, although Sylvania makes many fiber-optic CRTs with magnetic focus and deflection. Helical-resistor post-deflection acceleration is employed to get a high writing rate, high deflection sensitivity and freedom from pattern distortion.

Unique and specialized as it is, the SC-4082E represents only a tiny part of Sylvania's full capability in fiber-optic cathode ray tubes. Sylvania can make them in circular or rectangular configurations, and with wide, shallow faceplate strips for alphanumeric readout exclusively. CIRCLE NUMBER 300

Honeywell Model 1806 CRT Visicorder

BASIC CHARACTERISTICS OF TYPICAL FIBER-OPTIC CRTS

Tube Type	Fiber Strip Size	Focus	Bulb Size
SC-3304	2 3/4" x 1/4"	magnetic	3" x 1 1/2"
SC-3507	8 11/16" x 1/2"	magnetic	10" x 3 1/2"
SC-3800	8 11/16" x 1/2"	electrostatic	10" x 3 1/2"
SC-3850	4 1/2" x 1/2"	magnetic	5" dia.
SC-3876	8 11/16" x 1/2"	magnetic	10" x 3 1/2"

Sylvania fiber-optic CRT Model SC-4082E as used in Honeywell Visicorder above

INTEGRATED CIRCUITS

You can tailor amplifier response without complex networks

Sylvania's SA-20 series of linear ICs offers more than just an excellent wideband amplifier. The ability to externally control the amplifier's gain and bandwidth means this device can be easily tailored to meet specific system needs. Electrical performance is not sacrificed to obtain this external flexibility. The SA-20 is characterized by stable voltage gain, high output voltage swings, low output impedance, excellent frequency and pulse response, excellent intermodulation product and high linearity.

Now you can get a wideband, bandpass, or notch amplifier simply by changing a simple external network connected between two terminals of an IC. Sylvania's SA-20 integrated circuits (Figure 1) are basically wide band video amplifiers consisting of three direct-coupled linear amplifier stages. Frequency response characteristics are determined by a simple external network connected between the collector (pin 2) and base (pin 1) of the second stage. The complex external networks often needed with other ICs are not required when designers use these Sylvania units.

How the value of a compensating capacitor between terminals 1 and 2 influences broadband characteristics is indicated in Figure 2.

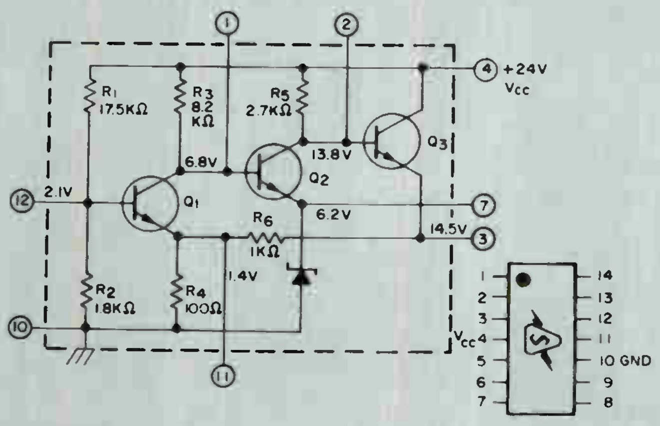
The selective amplifier configurations of Figure 3 show how notch and bandpass characteristics are obtained with simple L-C feedback networks. In the notch configuration, there will be a dip in the gain-frequency characteristics at the resonant frequency. Very narrow notch bandwidth can be obtained by operating in the series resonant mode.

In the bandpass option, maximum gain is obtained at the resonant frequency of L and C. Capacitor C blocks dc. When the SA-20 is connected in this way, the gain approaches the maximum open loop gain at the resonant frequency. The response curves shown were obtained with components listed. Using higher-Q inductors and series tuning L with C_2 at a frequency below F_0 would improve circuit selectivity. Using a crystal operating in a parallel resonant mode will give a more selective bandpass characteristic.

If precise matching of the amplifier gain to a specific application is required, external resistance is added in parallel with an internal feedback resistor R4 or R6. Padding R4 increases the gain, and padding R6 decreases the gain. Padding resistors should be DC-isolated from the circuit with capacitance to prevent a shift in DC quiescent levels.

Figure 1

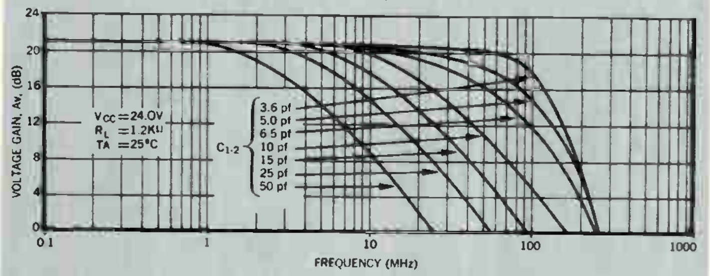
SYLVANIA WIDEBAND AMPLIFIER

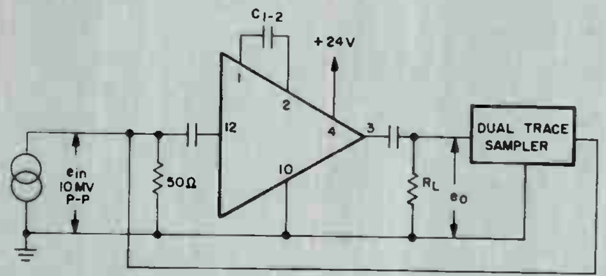


NOTE:
VOLTAGES DENOTED ARE NOMINAL QUIESCENT VALUES AT 25° C, AND ARE SHOWN FOR INFORMATION ONLY

Figure 2

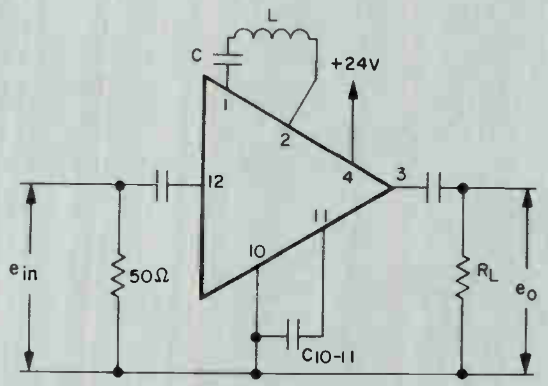
TYPICAL GAIN vs FREQUENCY OF SA-20

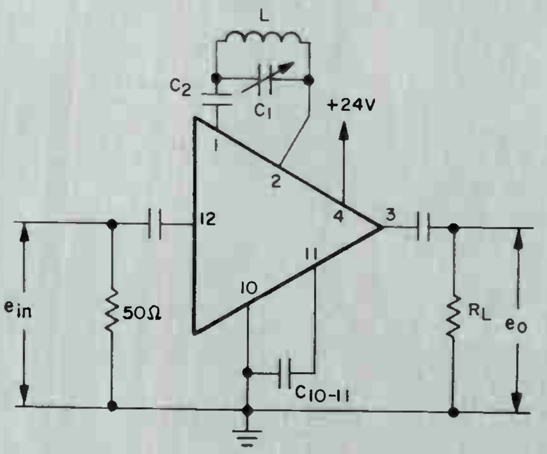




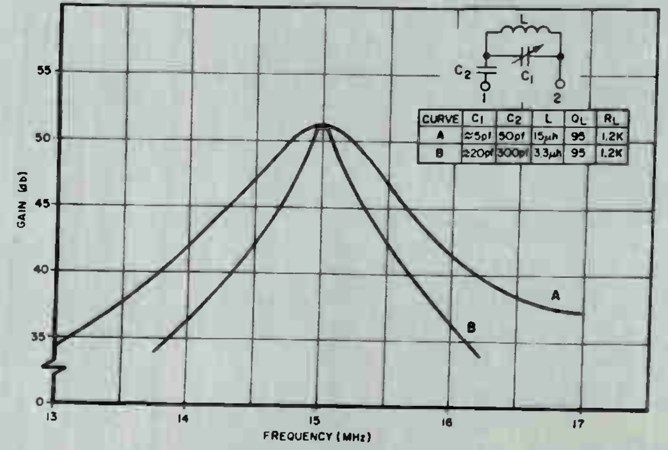
C_{1-2} = INCLUDES SOCKET CAPACITY BETWEEN PIN 1 AND 2

Figure 3





TYPICAL SA-20 BANDPASS CHARACTERISTICS



CURVE	C1	C2	L	QL	RL
A	≈5pf	50pf	15μh	95	1.2K
B	≈20pf	300pf	3.3μh	95	1.2K

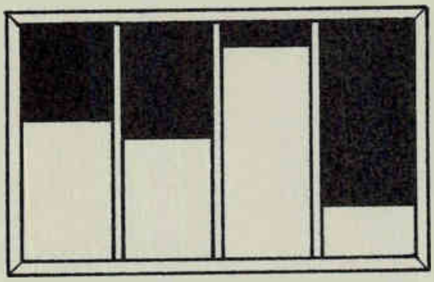
EL "bar-graph" analog indicators, now with resolution to 30 lines per inch

The effectiveness of any analog indicator is measured in terms of how accurately it displays the information and how immediately comprehensible the information is to the viewer. Sylvania has developed a plug-in EL bar-graph indicator which we consider a major advance in instrumentation.

Let's take a typical application for our EL bar-graph indicators: a tachometer array for a 4-engine jet aircraft.

A metered display would look like this:

Our EL bar-graph display of the same input data would look like this:



Notice how much more quickly and easily the comparative speed of the engines may be seen on the bar-graph display.

EL bar-graph analog indicators can be used for general instrumentation, aircraft, spacecraft and shipboard applications—anywhere that quantitatively variable input data must be monitored.

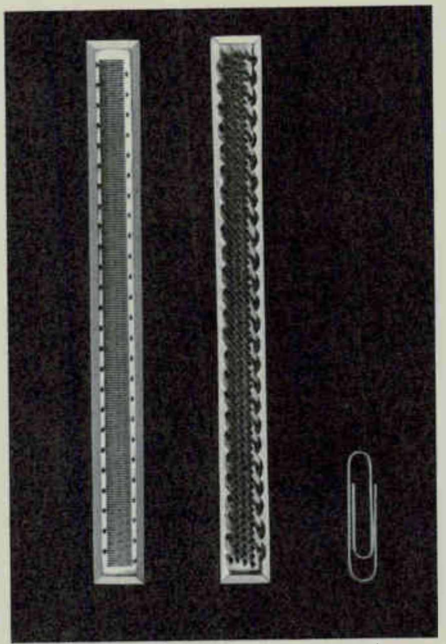
How they work

Each indicator consists of an array of horizontal parallel EL lines deposited on a glass film. The devices—in standard or custom design—can be provided with from 8 to 30 lines per inch, depending on the resolution required. And they are available in hermetically sealed construction. Sylvania bar-graphs offer the inherent design advantages of all EL readout units: solid-state reliability, low power consumption, wide viewing angle, light weight, low reflection, stable performance, freedom from catastrophic failure, and rapid information display.

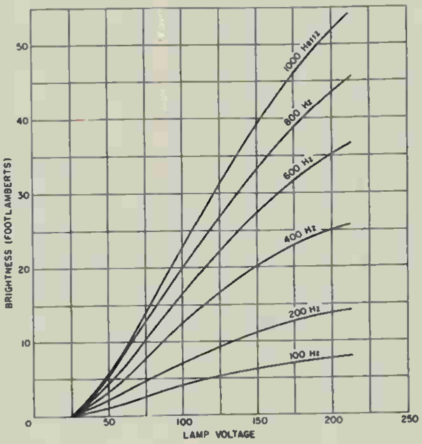
These bar-graph analog indicators are available in 115 V and 250 V versions: our "P" Series and "C" Series respectively.

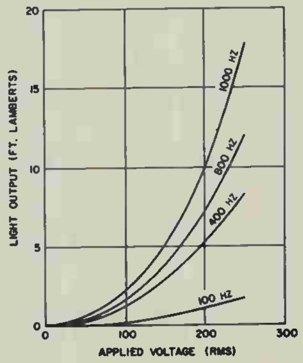
The "P" Series is designed for low voltage operation—115 volts RMS, 400 Hz with a peak voltage rating of 300 volts over the temperature range of −55 to +71°C. This series yields a higher average initial brightness of 15 foot-lamberts at the lower voltage of 115 volts RMS, 400 Hz.

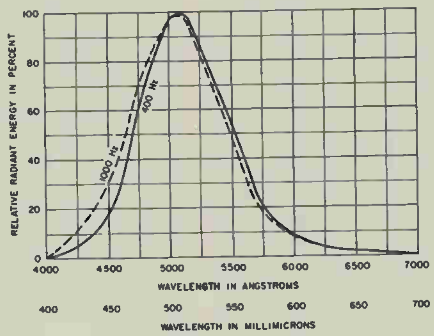
The "C" Series is designed to operate typically at 250 volts RMS, 400 or 800 Hz with a peak voltage rating of 420 volts over the temperature range of −55 to +94°C. This series yields an average initial brightness of 8 foot-lamberts operating at 250 volts RMS, 400 Hz and 12 foot-lamberts at 250 volts RMS, 800 Hz. CIRCLE NUMBER 302

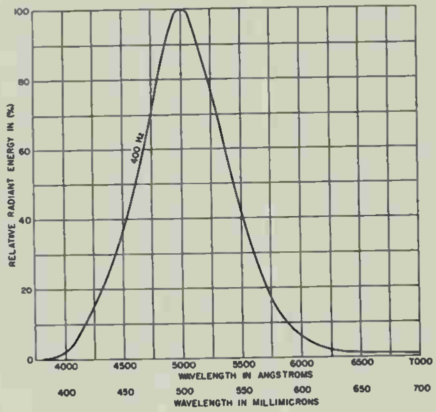


Sylvania electroluminescent bar-graph-type plug-in analog indicators.





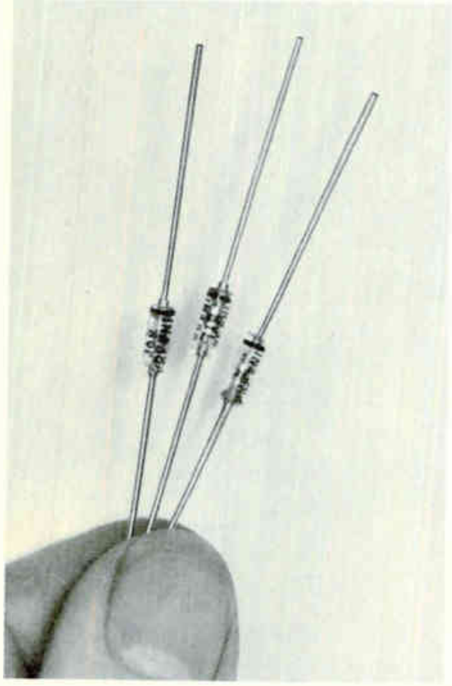


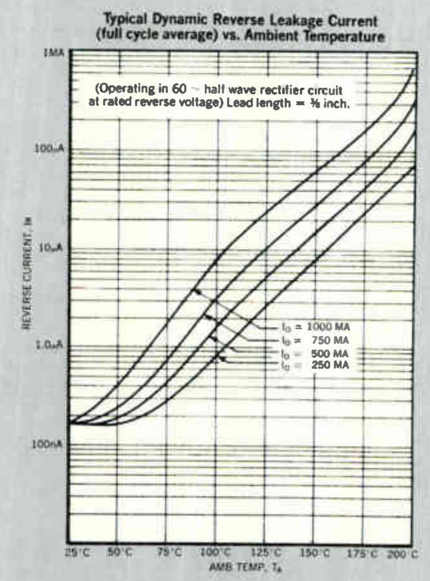


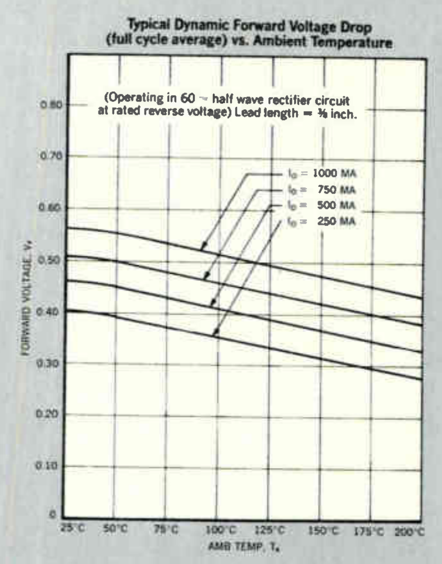
TYPICAL OPERATING CHARACTERISTICS AND MAXIMUM RATINGS (All Segments Lighted)

	OPERATING CHARACTERISTICS							MAXIMUM RATINGS			
	Light Output				Maximums						
Type	Brightness (Initial) FL	Wavelength Angstroms	V-AC RMS	F Hz	I Ma	P Mw	Pf	Peak Voltage	RMS Voltage	Peak Transient Voltage	Operating Temperature Range (°C)
C-Series	6-10	5100	250	400	1.0	50	.50	420	300	500	−55 to +94
	10-14	5100	250	800	1.2	85	.50	420	300	500	−55 to +94
P-Series	12-18	5100	115	400	1.1	55	.85	300	210	350	−55 to +71

Sylvania 50-amp glass rectifiers withstand 1000-watt reverse transients







Circuit designers are finding that Sylvania's glass rectifiers are better than other glass rectifiers. In this instance, the improved characteristics result in enhanced circuit performance and increased device reliability. Sylvania has coupled the inherent advantages of glass encapsulation with superior device design to make these glass diodes rugged enough for military applications. This designed-in dependability also makes this line of glass units an excellent choice for many other uses in computer, industrial and communications equipment. It is the improvements in device design that make Sylvania's glass silicon rectifier line stand out from other glass units.

In the improved devices, a large double diffused junction allows handling of 1000-watt reverse power transients while still maintaining the standard 50-amp forward surge capability. Sylvania's first glass rectifiers can take outputs of up to 1 amp at reverse working voltage of 1000 volts without damage.

Heat dissipation is aided by welding a solid high conduction power lead to an oversized heat conduction stud. This enhances power handling capability while extending device life by keeping the unit cooler. The glass package is electrically neutral and smaller than many metal rectifiers, thus permitting greater stacking and card densities. With Sylvania's sealing techniques, the designer gets the benefits of improved device design without sacrificing any of the advantages of glass encapsulation. Use of a glass package means not only improved insulating characteristics but units that can be hermetically sealed. Radiflo leakage rate for these devices is less than 1 x 10^{-10} cc/sec. Low leak rates extend life and increase reliability. The glass body also enhances the thoroughness of in-process quality control by allowing visual inspection during production.

In addition to the ability to handle high reverse pulses, these rectifiers have low reverse leakage current. Typical rating is 10 na at 25°C ambient and rated reverse voltage. The high voltage rating and wide temperature operating range (−65°C to 175°C) capability of these units can't be matched by ordinary non-hermetically sealed devices.

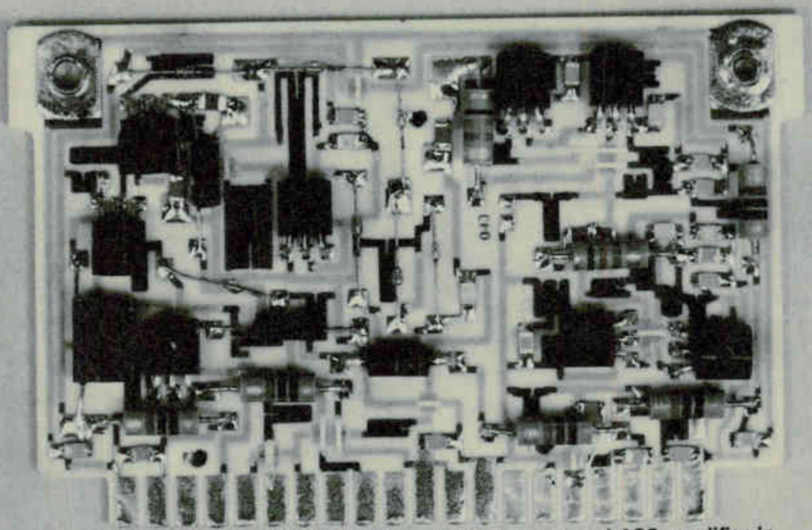
All units in the Sylvania series are packaged in the conventional DO-29 outline. They are replacing existing glass, epoxy or top hat types in applications which demand higher reliability levels. These devices meet or exceed all the standard life and design requirements of MIL-S-19500.

CIRCLE NUMBER 303

ABSOLUTE MAXIMUM RATINGS:
−65°C to + 175°C — Resistive and Inductive Loads — Single Phase, half wave at 60 cps.

	Units	1N4383	1N4384	1N4385	1N4585	1N4586
Continuous Reverse Working Voltage, V_R	volts	200	400	600	800	1000
RMS Input Voltage, V_{rms}	volts	140	280	420	560	710
Average Forward Current, I_o	amps					
@ 50°C		1.0	1.0	1.0	1.0	1.0
@ 100°C		1.0	1.0	1.0	0.6	0.6
@ 150°C		0.3	0.3	0.3	0.2	0.2
Forward Surge Current, 1 cycle — $I_{F\ sur}$	amps	50	50	50	50	50
Forward Surge Current, Recurrent, $I_{F\ sur}$	amps	6	6	6	6	6
ELECTRICAL CHARACTERISTICS:						
Typ. Dynamic Forward Voltage Drop, V_F @ 1.0 amp	volts					
@ 50°C					.56	.56
@ 100°C		.52	.52	.52		
Typ. Dynamic Reverse Current, I_R @ V_R	μa @ 1.0 amps					
@ 50°C					.55	.55
@ 100°C		8	8	8		
Typ. Reverse Current, I_R @ V_R and +25°C	na	10	10	10	10	10
Typical Junction Capacitance — All Types — @ 0 V 80 picofarads; @ 10 V 21 picofarads						

Thick-film microcircuits: Reliability at low cost



Microcircuit combines a broad-band IF amplifier, detector and AGC amplifier in an area only 1.5" x 2.5", using Sylvania thick-film technology. It contains 34 resistors, 26 capacitors, 8 transistors, 8 diodes and 6 chokes. It typifies Sylvania's achievements in creating complex and sophisticated microcircuits on a single substrate.

It's a truism that electronics has had to shrink rapidly in order to grow.

Because as systems became more complex, they grew larger, heavier... and less reliable.

(And slower. What profiteth man to switch in a picosecond when it may take the switching signal a thousand times longer to get where it's going?)

Hence the proliferating technology of microelectronics.

While space, weight and speed are important, no less so is reliability. Most of the many approaches to microelectronics have aimed at improving reliability at the same time they cut bulk and increased speed.

So a major problem facing the design engineer today is the bewildering variety of microelectronic technologies available to him: thick-film circuits, thin-film circuits, monolithic IC's, MOS units and many combinations.

The role of Sylvania

Sylvania has been involved in microcircuit R & D for about 7 years. We've looked into just about every major technology: vacuum-deposited films, sputtered films, active thin-film semiconductors, screened-and-fired or thick-film microcircuits . . . you name it.

But since we can't be all things to all people, we concentrated, starting in 1964, on thick films because this technology is most applicable to automation and low-cost microcircuitry.

Why hybrid microcircuits?

For one thing, they are economical.

They can be packaged in virtually any size or shape.

They make it practical and economical to produce prototype-quantities of modules containing complex circuit configurations.

In addition, they can handle high voltages, currents and frequencies and have capability of producing high resistances and capacitances.

Sylvania has not only demonstrated all these advantages of microcircuitry, but has cut costs enough to make microcircuits competitive with many discrete-circuit components.

Microcircuit capabilities

Sylvania has designed and manufactured microcircuits ranging from simple resistor matrices to complex digital, analog and RF circuits operating up to 250 MHz.

We produce networks of conductors, resistors and capacitors by successively screening and firing conductive, resistive and dielectric compounds onto a single substrate. Our dielectric materials provide 0.001 to 0.5 μfd per square inch; resistive materials cover the range from 10 ohms to 1 megohm.

In the thick-film technique, successive layers are sequentially fired in the temperature range of 600°C to 1000°C. This high-temperature stabilization, combined with the molecular codiffusion that occurs at the layer interfaces, yields microcircuits with high inherent stability, ruggedness and reliability. All film elements are protected by two layers of glass fired in place to assure additional long-term stability.

Reliability standards

Because most of our microcircuits so far have been designed for military use, reliability standards are stringent. Our units have survived (and thrived on) such typical torture tests as:

- Shock—100 G
- Vibration—15 G; 20 to 2,000 cps
- Humidity—95% relative humidity at 85°C
- Drop Test—36 inches onto concrete floor
- Temperature Shock—125°C to —54°C in two minutes
- Low Pressure—3.44 inches of mercury at —54°C
- Accelerated Life Tests—elevated temperatures and voltages used as stresses

Non-military applications

There is now a growing trend toward use of hybrid microcircuits, like the one above, in industrial and consumer applications. We feel that as we continue to bring costs down, hybrid microcircuits will soon be used, for example, in television, hi-fi, automotive and appliance control systems.

And finally—asking for the order

The unit above is unique, custom-built to a specific customer requirement. Par for the course in the microcircuit business.

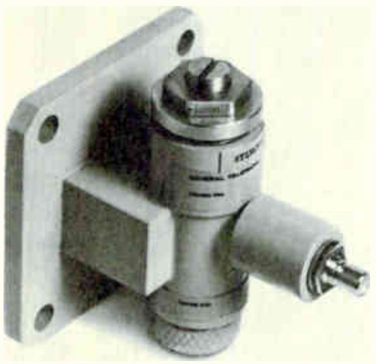
We'd expect to do the same for you.

We offer you a fully systems-oriented design and manufacturing capability, staffed to provide cost-effective microcircuits designed to your specific needs. Whether you need a few prototypes or volume production quantities, we'd like to work with you to develop exactly the microcircuits you require.

I. D. Greenberg

IRVING GREENBERG
PRODUCT MANAGER, MICROELECTRONICS

High power avalanche diode oscillators open new application areas



When Sylvania introduced its SYA-3200 avalanche diode oscillator a few months ago, we said continued development was expected to lead to improved devices with higher output power. We were right. Power levels have now been raised by a factor of five. And there's a total of three units with waveguide outputs, and three to come with coaxial outputs, to make it even easier to convert dc to rf directly at X-band frequencies.

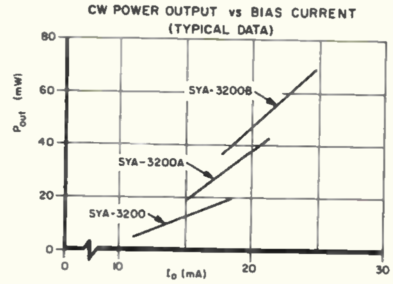
Now there are even more reasons for using solid-state avalanche diode oscillators—with new devices from Sylvania. Our new units have a minimum power output rating as high as 50 mW and are available in waveguide configuration (now) and coaxial (soon). Type SYA-3200A is rated at 25 mW, Type 3200B at 50 mW. Both these units, and the original 10 mW Sylvania avalanche diode oscillator (Type SYA-3200), are for use in waveguide systems.

Soon we'll announce three coaxial versions with electrical characteristics similar to the 3200, -A and -B.

Use of the SYA-3200 series as pumps for parametric amplifiers reduces the size and complexity associated with klystron drivers without degrading performance.

In addition to providing direct dc to rf conversions, other advantages of this line include: only one dc input required, small size and light weight (less than 5 ounces), lower dc power consumption (60 to 90 V, 10 to 20 mA), and no spurious outputs up to twice output frequency. Operating temperature range is —40 to +85° C. These new sources are mechanically tunable by a single screw adjustment over a range of at least 200 MHz and have a typical temperature coefficient of frequency of 200 KHz/° C.

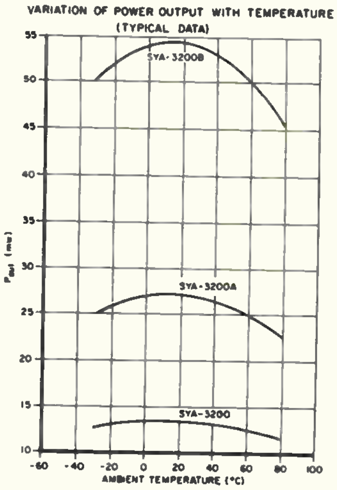
Tests show that parametric amplifiers pumped by these avalanche diode oscillators exhibit performance which is indistinguishable from that obtained with conventional klystrons. In one application, a parametric amplifier operating in L-band was pumped at 11 GHz by a SYA-3200.



The noise figure was 1.8 dB, exactly that obtained using a klystron. Saving in power supply, size, and weight reduced the overall weight and size of the amplifier by fifty percent. Gain, bandwidth, and stability were unchanged from that obtained with a klystron.

Particularly suited for use in doppler radar, these oscillators can function as local oscillators in heterodyne receivers as well as beacon transponder sources.

Continued device development is expected to result in devices with even higher output power and additional frequency-band coverage. Sylvania's application specialist will work with designers in tailoring these new devices to meet specific system requirements. The aim is to be able to use these devices as direct replacements for many of the reflex klystrons now in use. CIRCLE NUMBER 304



SEE OUR SPECIFICATIONS IN VSMF MICROFILM CATALOG FILE

Use Sylvania's "Hot Line" inquiry service, especially if you require full particulars on any item in a hurry. It's easy and it's free. Circle the reader service number(s) you're most interested in; then fill in your name, title, company and address. We'll do the rest and see you get further information almost by return mail.

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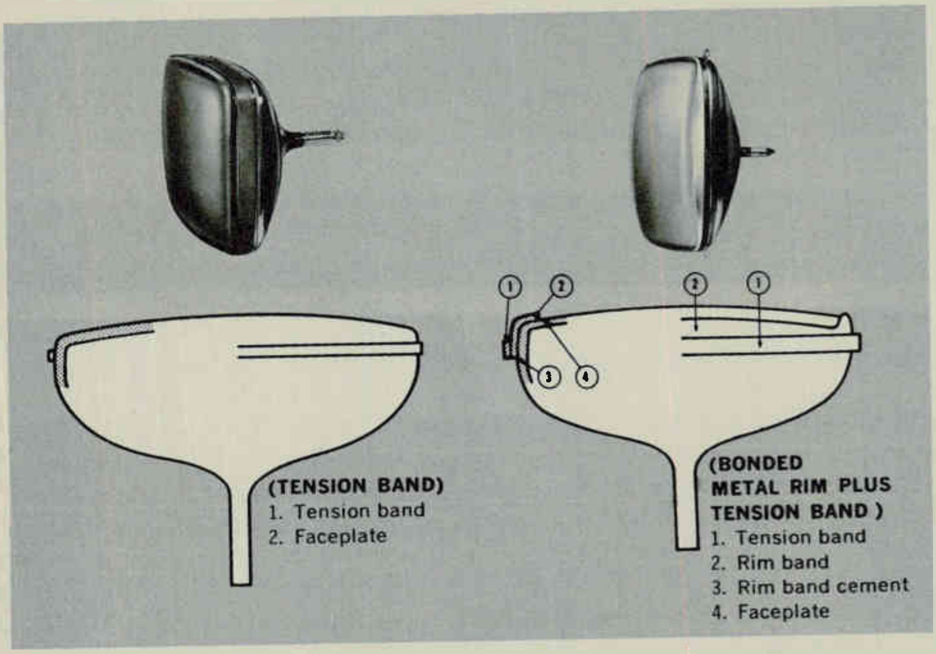
New, more economical 15″ and 19″ color picture tubes



Sylvania offers these two new color picture tubes in the popular 15″ and 19″ shadow-mask styles. Their integral implosion protection systems eliminate the need for separate safety glass in the set chassis or heavy, plastic-laminated bonded-shield tubes.

On the 15″ tube, the weight saving is approximately 1½ lbs; on the 19″ tube, the weight saving is approximately 3 lbs.

Proven through years' use in black-and-white picture tubes, the T-band and Kimcode systems are available now for the first time in Sylvania 15″ and 19″ color tubes. For manufacturers who prefer it, however, tubes will still be available with the familiar PPG safety system.

The RE-ST4561A, for the first time in a shadow-mask color tube, offers a low focus voltage (−75 to +400 volts), and is a 15″ size. This eliminates the need for a separate high-voltage focus rectifier circuit, permitting lower set design costs.

Both new tubes are manufactured with spherical faceplate and have dark-tint glass for high contrast. Each uses three electrostatically focused electron guns spaced 120° apart, with axes tilted to facilitate convergence of the three beams at the shadow mask. Each uses magnetic deflection and convergence, an aluminized screen and is capable of producing high-resolution pictures in both color and black-and-white. The screen incorporates the unique Sylvania screening process and high light-output rare-earth phosphor system.

SPECIFICATIONS

	15″-TYPE RE-ST4561A	19″-TYPE RE-ST4562A
Implosion Protection	T-Band	Kimcode
Glass transmission characteristic	52%	43.5%
Minimum useful faceplate area	11.689 x 9.139 in.	15.585 x 12.185 in.
Deflection Angles (approx)		
Diagonal	90 deg.	89 deg.
Horizontal	79 deg.	78 deg.
Vertical	63 deg.	63 deg.
Minimum projected picture area	102 sq. in.	180 sq. in.
Phosphors	Sylvania P22 Rare-Earth Type	

Sylvania designed these new tubes to help you broaden your set line and cut set costs. Complete specifications are available from your Sylvania representative.

CIRCLE NUMBER 305

NAME ____________________

TITLE ____________________

COMPANY ____________________

ADDRESS ____________________

CITY ______________ STATE ______________

Circle Numbers Corresponding to Product Item

300 301 302 303 304
305

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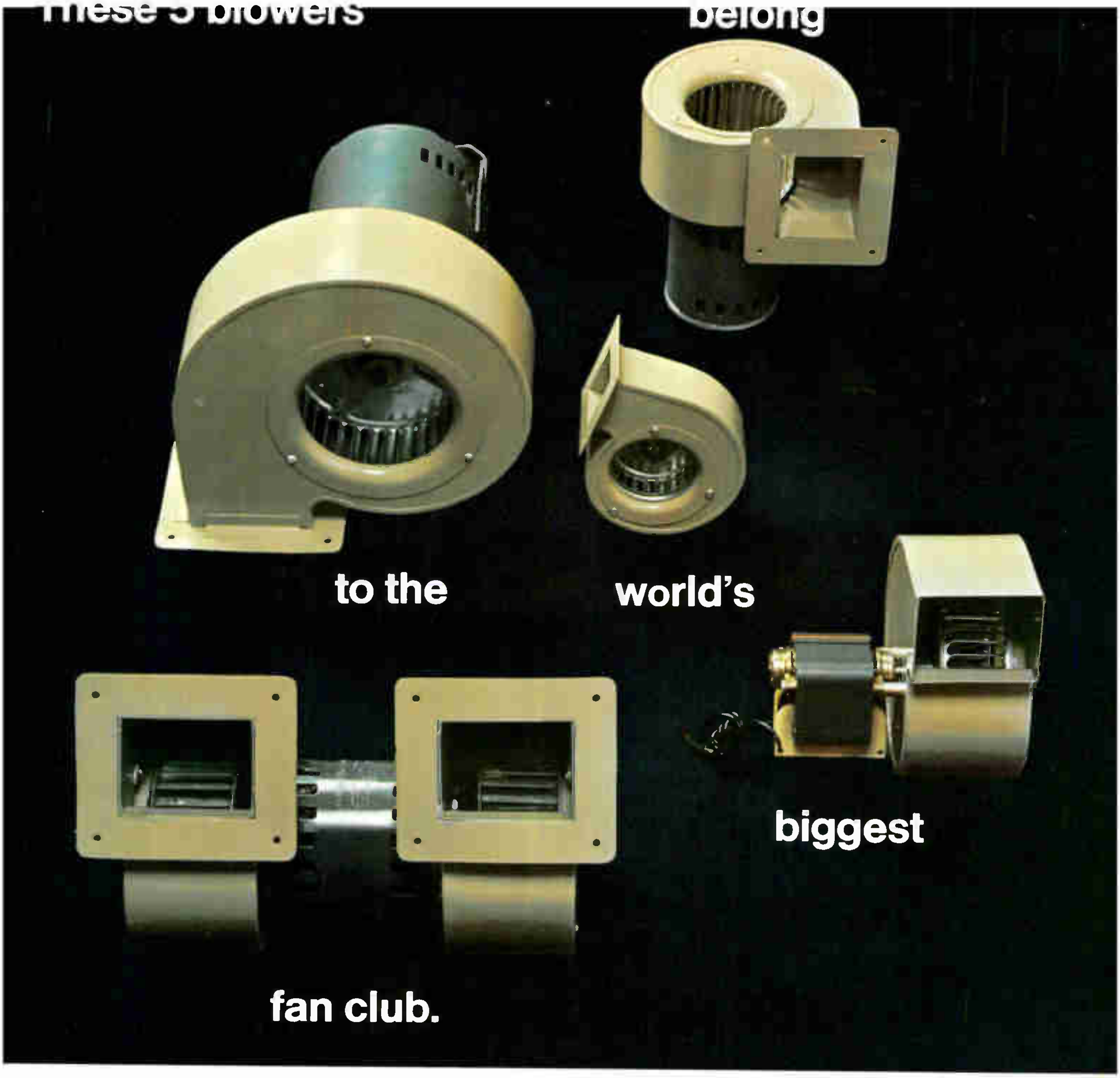


TORRINGTON

Despite any resemblance, no two centrifugal blowers shown above are alike. For that matter, neither are any of Torrington's 67 other in-stock blowers identical. Except for one outstanding fact.

All 72 of these blowers are immediately available "off-the-shelf" units . . . models designed to lend themselves to a variety of adaptations. By merely interchanging standard parts these in-stock units have produced 216 different models for Torrington customers, and the end is nowhere in sight.

Whatever your specifications, whether high or low air flow, A.C. or D.C. motors, high or low resistance, single or double inlet, Torrington can make the centrifugal blower you need — faster, more economically, and in any quantity you desire, from mere dozens to the thousands.

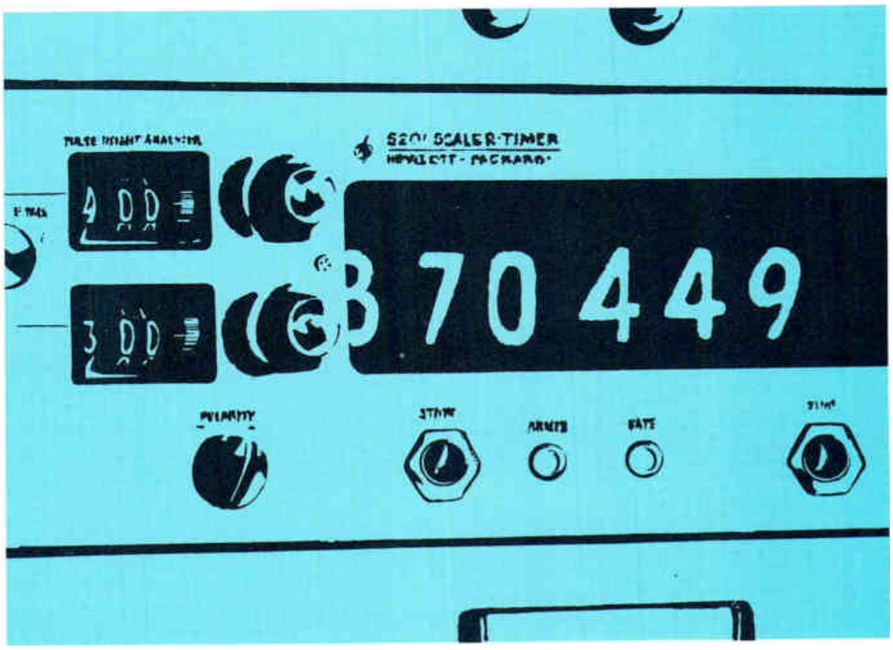
We can't illustrate every type of blower produced in our plant. But if you'd care to see how far we'll go to meet your needs, write today for our catalog "Centrifugal Blowers by Torrington." Address your request to Torrington Manufacturing Company, Torrington, Connecticut.

TORRINGTON MANUFACTURING COMPANY

Circle 35 on reader service card

United States: Torrington, Connecticut/VanNuys, California/Rochester, Indiana **Canada:** Oakville, Ontario **England:** Swindon, Wilts. **Belgium:** Nivelles **Australia:** Sydney

A very discriminating scaler



The Hewlett-Packard 5201L Scaler Timer does more than simply count total numbers of events. Two highly-stable discriminators perform true pulse height analysis which enables the 5201L to totalize the number of times an amplitude lies within an exactly defined (voltage, energy) range. This adjustable "window" makes the scaler valuable for many areas outside of nuclear applications.

The 5201L can be used to count the number of vibrations within a selected range, for damage predictions on mechanical systems. It can—with a sampler—monitor the amount of time receiver signal strength is at a useful level during 24-hour reception. It could even be used to count the number of ocean waves with a given amplitude that roll in during a preset time interval. It can answer many questions that come down to: "How many times over a specified time interval does a signal amplitude lie within a defined range?"

The pulse height analyzer comprises a voltage reference, two discriminators and an anti-coincidence circuit. When an input pulse is within the "window" defined by the upper and lower discriminators, the totalizing circuit receives a pulse. When the pulse lies outside the window no pulse is sent to the totalizing circuit. At the end of a pre-set time, which can vary from 0.1 second to 10,000 minutes, an in-line digital readout displays the count total.

The operation just described is but one mode of three. The discriminators can also totalize all pulses which rise over a pre-set level or to track, stepwise, the narrow "window" over the voltage range for differential counting. This series of high-resolution readings yields an amplitude histogram plot which, with a system including the HP 5552A Spectrum Scanner, can be plotted automatically.

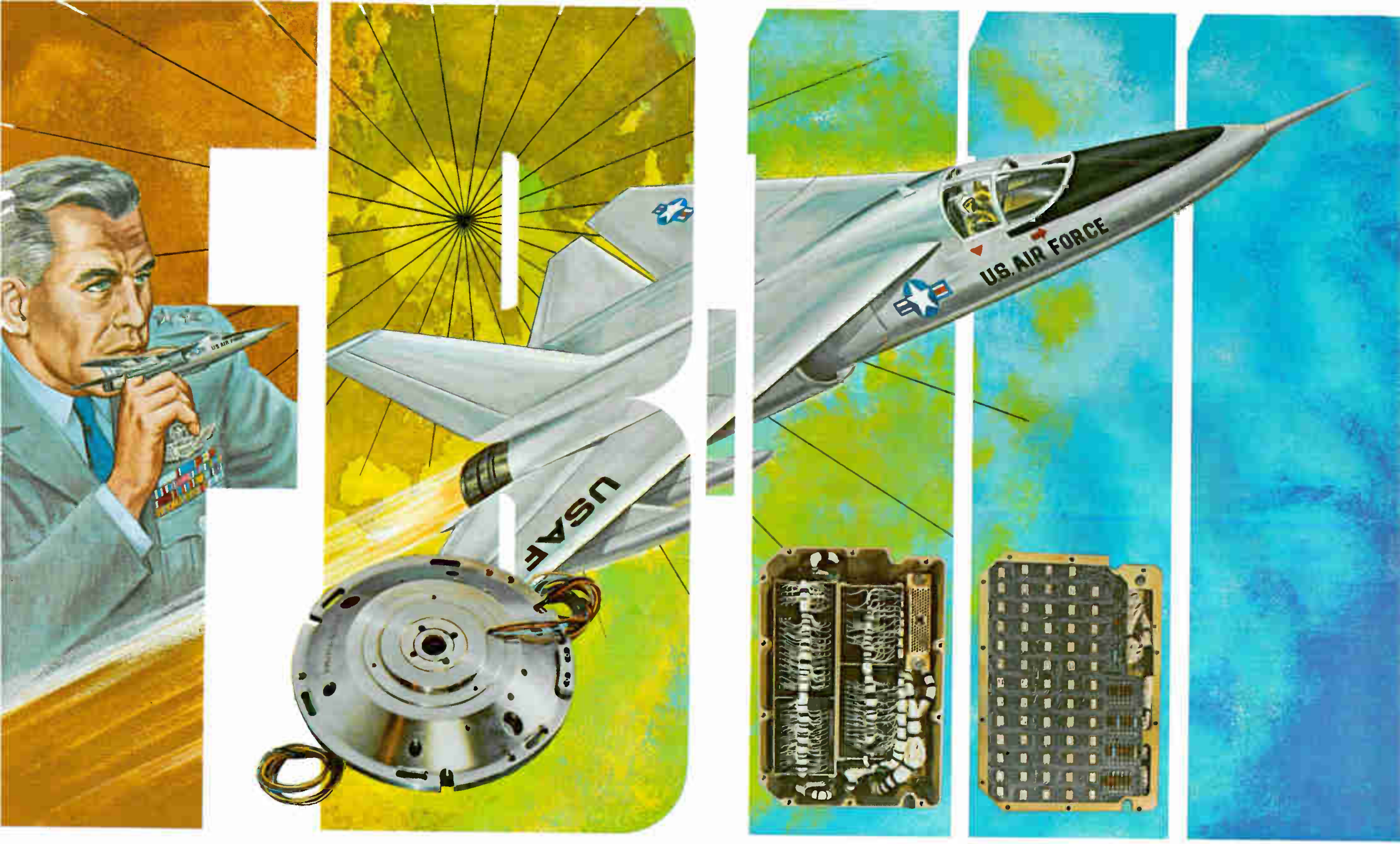
The 5201L, by means of its standard features, can be used with automatic recording equipment in combination with data acquisition instrumentation. It has 200 nsec multiple pulse resolution; 6-digit in-line display capability; automatic recycling with storage.

Price: $1950.

For more information, call or write Jim Sheldon, Hewlett-Packard, Palo Alto, California 94304; Europe: 54 Route des Acacias, Geneva.

HEWLETT hp PACKARD

02715



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Tell us what you're looking for in a X-Y plotter.

We'll set up a test date.

Don't pass it up.

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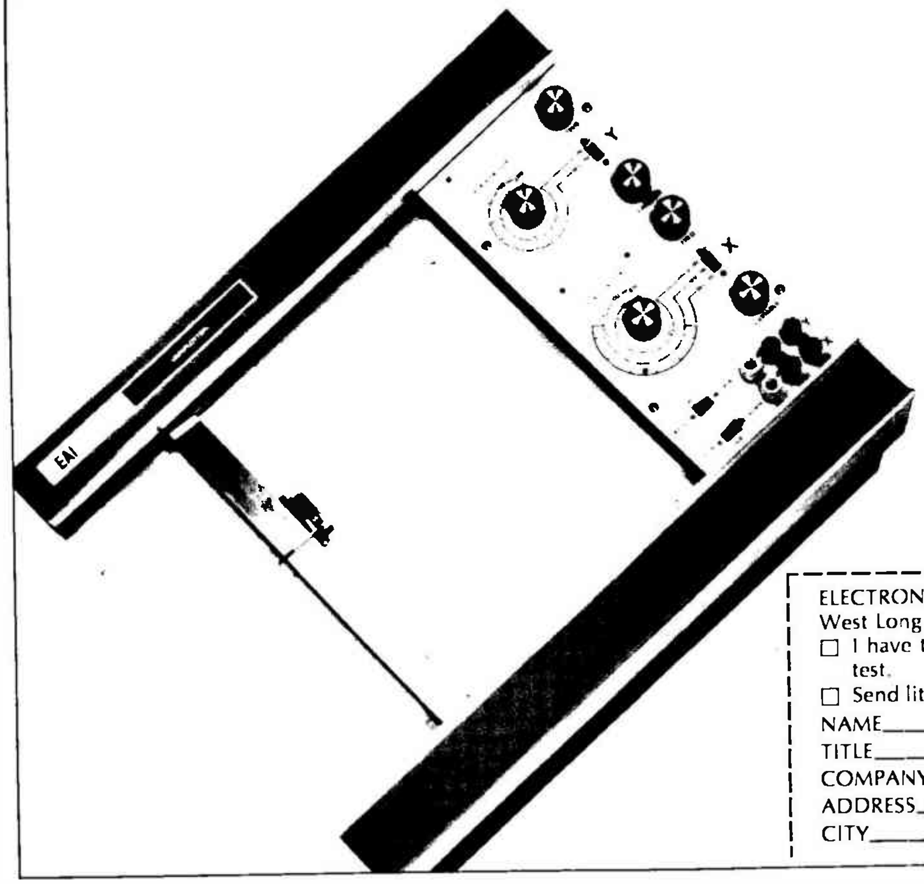
West Long Branch, New Jersey



Here's just one member of the family we'd like to show you. It has the features you want plus a full 10" x 10" plotting area. Check the brief specs:

Series 1125—$1590

- ☐ Accuracy 0.1%
- ☐ 18 calibrated D.C. ranges with variable control
- ☐ ½ mv/inch sensitivity
- ☐ Built-in multi-range time base
- ☐ Rack or bench mount without adapters
- ☐ Inch or centimeter scaling
- ☐ Plug-in disposable ink cartridge
- ☐ Ten-turn zero and scale factor pots

ELECTRONIC ASSOCIATES, INC. E-107
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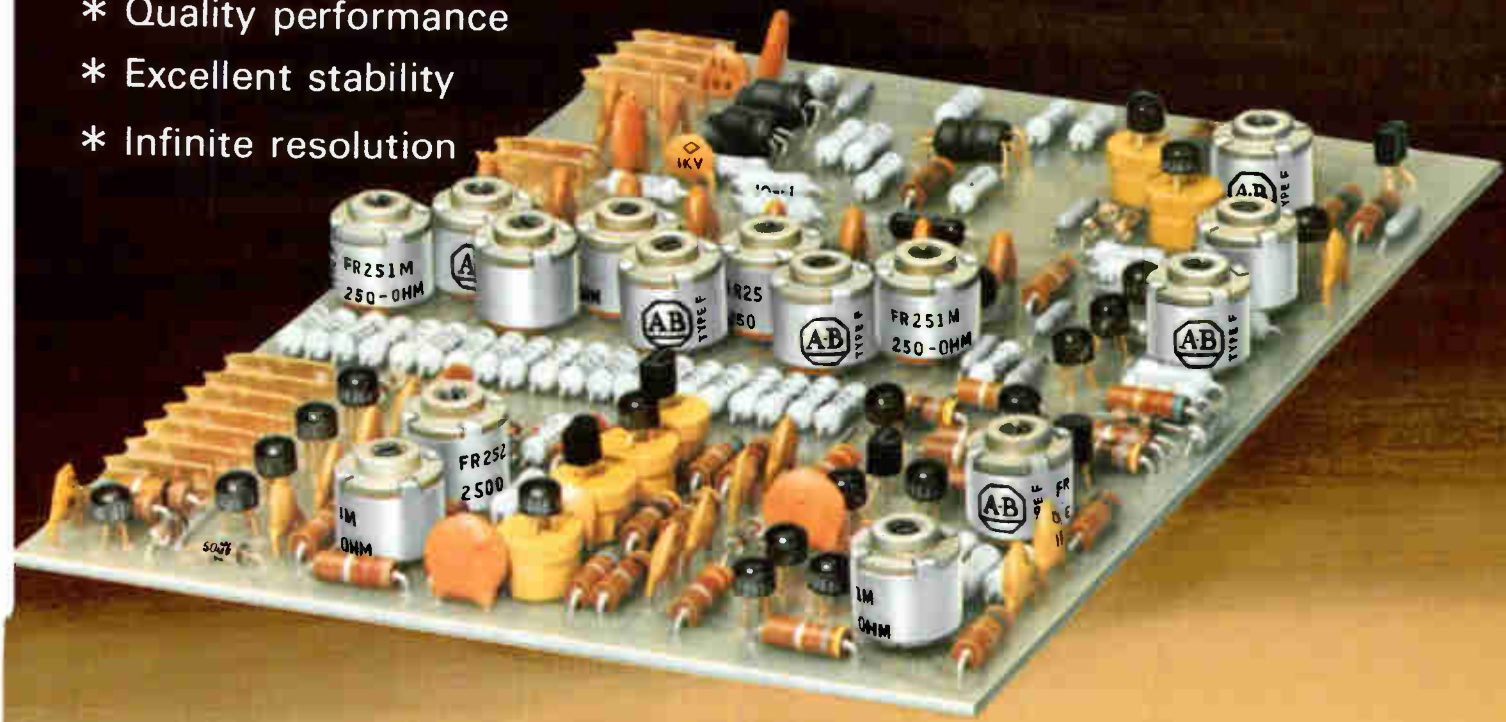
WAVETEK uses Allen-Bradley Type F variable resistors exclusively because of their

* Quality performance
* Excellent stability
* Infinite resolution



One of the 5-inch by 6½-inch Wavetek printed circuit cards, showing 15 of the 25 Allen-Bradley Type F hot molded variable resistors and numerous hot molded fixed resistors used in the Model 111 VCG function generator.

Type F variable resistor with pin type terminals for mounting directly on printed wiring boards. Rated ¼ watt at 70°C. Total resistance values from 100 ohms to 5 megohms.

Actual Size

Wavetek Model 111 VCG generates sine, square, triangle, and ramp waves from 0.0015 Hz to 1 MHz, and offers precision control of the frequency of the waveforms by external voltage.

■ The precision waveforms generated by Wavetek's Model 111 VCG place exacting demands on the large number of variable resistors used to set amplitudes to very precise values and assure symmetry of all functions. They must provide velvet smooth control, and quiet operation. And since this is a Wavetek adjustment, it is essential that the variable resistors, once adjusted, will stay "put".

Allen-Bradley Type F variable resistors satisfy all of these requirements, because they have the same solid hot molded resistance track as the famous Type J and Type G variable resistors. There's velvet smooth control at all times—never the problem of discrete steps common to all wire-wound units. And since Type F variable resistors are essentially noninductive and have low distributed capacitance, they can be used at high frequencies where wire-wound controls are useless.

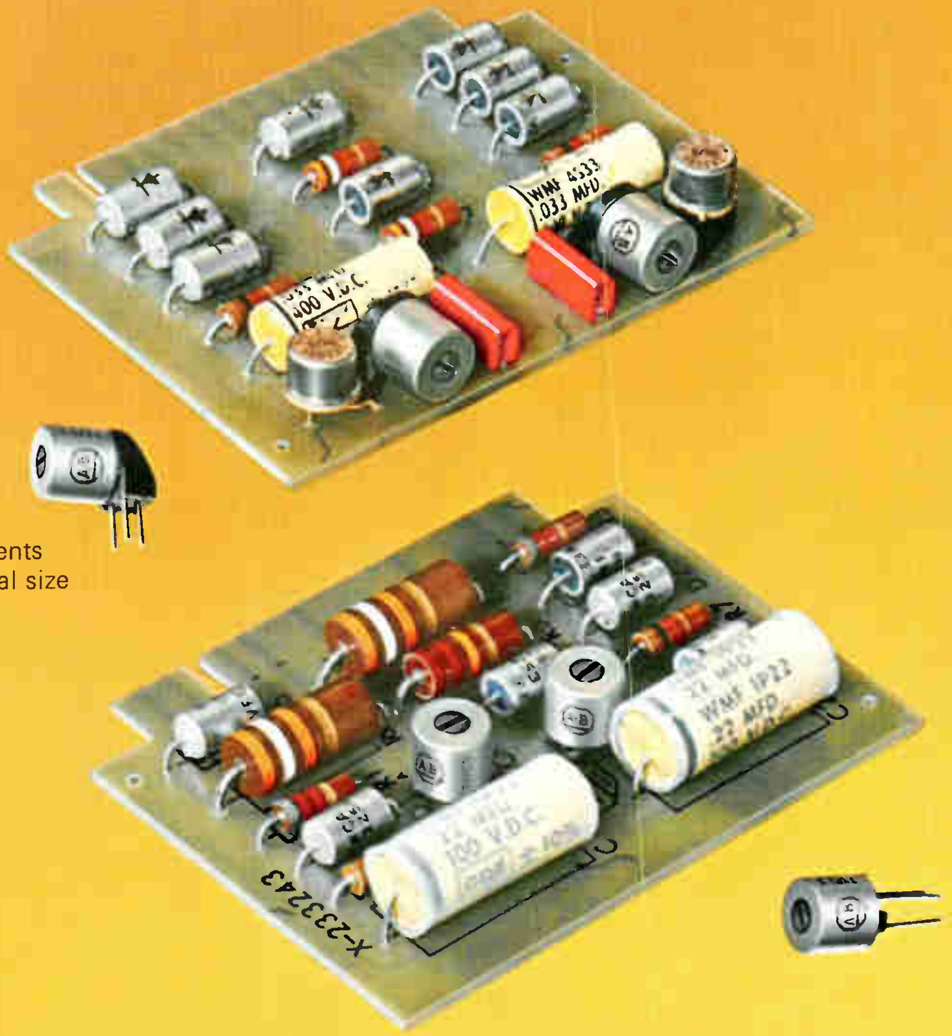
When a manufacturer like Wavetek has standardized on the quality of A-B electronic components, you can be sure of the superior performance of such equipment.

For more details on the complete line of Allen-Bradley quality electronic components, please write for Publication 6024. Allen-Bradley Co., 222 W. Greenfield Avenue, Milwaukee, Wis. 53204. In Canada: Allen-Bradley Canada Limited. Export Office: 630 Third Avenue, New York, N.Y., U.S.A. 10017.

69-01-7E

ALLEN-BRADLEY

QUALITY ELECTRONIC COMPONENTS

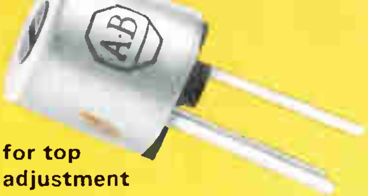


All components shown actual size

Only the new Allen-Bradley Type S cermet trimming resistors have all these features

Type S
shown twice actual size

for side adjustment



for top adjustment

The Allen-Bradley Type S is a one turn cermet trimmer in which you will find incorporated a wider range of features than in any other trimmer now on the market. Here are a few of the more important features.

- **COMPACT**—body is ⅜" dia.
- **BUILT FOR EITHER TOP OR SIDE ADJUSTMENT**
- **50 OHMS THRU 1 MEGOHM**
- **THE SEALED UNIT** is immersion-proof
- **TEMPERATURE COEFFICIENT** less than 250 ppm/°C over *all resistance values* and *complete temperature range*
- **UNIQUE ROTOR DESIGN** provides exceptional stability of setting under shock and vibration
- **SMOOTH CONTROL**, approaches infinite resolution
- **PIN TYPE TERMINALS** for use on printed circuit boards with a 1/10" pattern
- **VIRTUALLY NO BACKLASH**
- **WIDE TEMPERATURE RANGE** from −65°C to +150°C
- **RATED** ½ watt @ 85°C
- **EXCEPTIONAL STABILITY** under high temperature or high humidity
- **MEETS OR EXCEEDS ALL APPLICABLE MIL SPECS**
- **COMPETITIVELY PRICED!**

You'll find the new Type S trimmer equal to the traditional Allen-Bradley quality. You really ought to know more about the Type S. Won't you write for detailed specifications? Allen-Bradley Co., 222 W. Greenfield Ave., Milwaukee, Wis. 53204. In Canada: Allen-Bradley Canada Limited. Export Office: 630 Third Ave., New York, N. Y., U.S.A. 10017.

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QUALITY ELECTRONIC COMPONENTS

75-08-7E

RESOLVER/SYNCHRO INSTRUMENTATION

A very short course for engineers engaged in testing and evaluation of resolvers and synchros as components or as system transducers.

Selecting a resolver/synchro test instrument for any engineering, production or system requirement is remarkably simple from North Atlantic's family of resolver and synchro instrumentation. Because this group has been developed to cover every area of need in both manual and automatic testing, obtaining the desired combination of performance and package configuration usually demands no more than 1) determining what you need and 2) asking for it.

Remote Readout of Angular Position
For remote indication of resolver or synchro transmitters in system testing, North Atlantic's Angle Position Indicators (Figure 1) provide the advantages of low cost and continuous counter or pointer readout. These high-performance instrument servos are accurate to 4 minutes of arc, with 30 arc seconds repeatability and 25°/second slew speed. Dual-mode capability, multi-speed inputs, integral retransmit components and other optional features are available to match application needs. Priced from $895.

Figure 1. Angle Position Indicators are available in half-rack, quarter-rack and 3-inch round servo packages.

High-Accuracy Testing Of Receivers And Transmitters
Measuring receiver and transmitter performance to state-of-art accuracy is readily accomplished with North Atlantic's Resolver/Synchro Simulators and Bridges (Figure 2). Each of these dual-mode instruments tests both resolvers and synchros, and provides direct in-line readout of shaft angle, accurate to 2 arc seconds. Simulators supply switch-selected line-line voltages from 11.8 to 115 volts from either 26 or 115 volts excitation, and so can be used to test any standard receivers. Bridges have constant null voltage gradients, making them ideally suited for rapid deviation measurements. Simulators and Bridges each occupy only 3½ inches of panel height and are available in a choice of resolutions. They are priced in the $1500 to $3000 range.

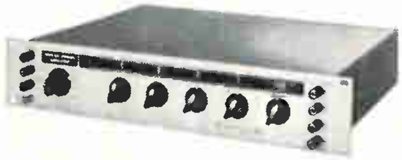


Figure 2. Resolver/Synchro Simulator provides ideal source for receiver testing.

Automatic Measurement And Conversion
Where systems require continuous or on-command conversion of resolver or synchro angles to digits, North Atlantic's Automatic Angle Position Indicators (Figure 3) handle the job without motors, gears or relays. These solid-state automatic bridges accommodate all standard line-to-line voltages and provide both Nixie display and printer output, accurate to 0.01° and with less than 1 second update time. Many variations, including 10 arc second accuracy; binary, BCD or decimal outputs; multiplexed channels and multispeed operation, are available for specific requirements. Ballpark price: $5900.

Figure 3. Model 5450 Automatic Angle Position Indicator. It measures shaft angles, converts them to digital data.

Measuring Electrical Characteristics
Combine a Resolver/Synchro Bridge and a Simulator with a North Atlantic Ratio Box, a Phase Angle Voltmeter and a test selection panel and you have an integrated test facility for determining all electrical characteristics of resolvers and synchros in component production or Quality Control. An example is the North Atlantic Resolver/Synchro Test Console shown in Figure 4. It measures phasing, electrical zero, total and fundamental nulls, phase shift and input current, as well as angular accuracy. Standard North Atlantic instruments are used as modules, making it a simple matter to fill the exact need. The unit shown sells for about $7500.

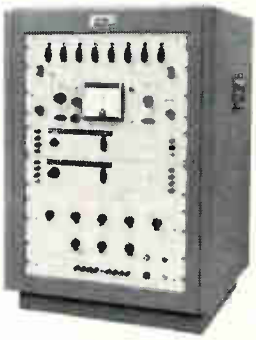


Figure 4. Model RTS-573 Test Console is a complete facility for the production line or in quality control.

If you require performance, reliability and convenience in resolver and synchro testing, we want to send you detailed technical information on these instruments (also on related instruments for computer system interface). Or, if you prefer, we will arrange a comprehensive technical seminar at your plant. Simply write to: North Atlantic Industries, Inc., 200 Terminal Drive, Plainview, N.Y. 11803 • TWX 516-433-9271 • Phone (516) 681-8600.

PRECISION AC INSTRUMENTATION FOR TEST, MEASUREMENT AND DATA CONVERSION

NORTH ATLANTIC *industries, inc.*

Electronics Review

Volume 40
Number 22

Military electronics

Out of the deep

The ocean is the harshest enemy of electronics. Many conventional attempts to develop pressurized packaging for deep-sea operation have run into hot water. But North American Rockwell Corp.'s ocean systems operation borrowed standard aerospace techniques to come up with a new approach: circuit boards sandwiched in a protective honeycomb structure.

Although its new underwater module hasn't been tested, the company is so confident it will work that it has made the module a key part of its design in competing for a contract to develop a Navy swimmer-delivery vehicle.

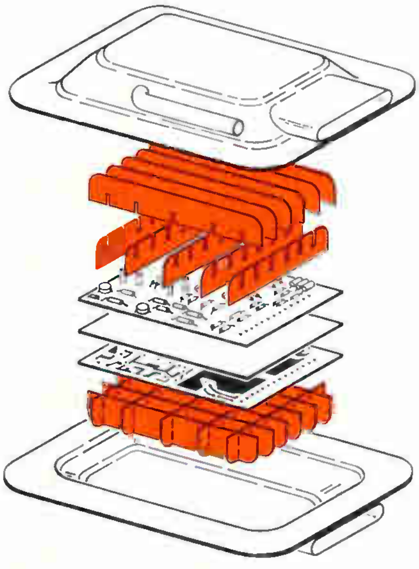
Details are scanty on the two-man delivery vehicle project, except that it is being managed by a new special projects office—PM-12 (program manager for the Office of Naval Inshore Warfare). Among the firms said to be competing with North American are the General Dynamics Corp., the Ryan Aeronautical Co., and the Aerojet-General Corp.

For frogmen. The vehicle will be carried on the decks of submarines for use by underwater demolition teams (UDT). What makes the program particularly exciting to the electronics industry is that the little submersibles will carry a good deal of electronics—comparable to that on a low-flying military aircraft. And it would be a large order—involving between 100 and 200 vehicles. They apparently will contain such subsystems as control, communications, and sonar.

North American's module is a marriage of two in-house technologies that are already proved in aerospace applications—the honeycomb structure used in the B-70 Valkyrie aircraft and the integrated circuits-multilayer board assemblies used in both the Minuteman 2 computer and the Mark 2 integrated-avionics system, which is now under development at the company's Autonetics division for the Air Force F-111A.

Previous approaches to pressurizing electronics fall into three basic types: pressure vessels, circuits packed in oil, and circuits potted in hard plastics. Pressure vessels, which are inefficient in terms of component density, lack standard modules, pay heavy weight penalties, and provide inadequate cooling. Packing circuits in oil exposes components to oil impurities or moisture and unpredictable pressure effects because of manufacturing variations in semiconductor components that alter device pressure sensitivity. Potting circuits in hard plastics such as polymers is limited to applications where high component density isn't needed or where low component power dissipation is.

Sandwich type. The North American module, which measures about 4½ by 5½ inches and has a thickness of 1½ inches, provides pressure isolation of standard microelectronic active and passive elements, says Robert G. Cook, a design specialist who came from the B-70 program. P.F. Godwin, a research specialist moved in from the Mark 2 project, says the modules will house bipolar and metal oxide semiconductor IC's in combinations of linear and digital monolithic and hybrid circuits.



Egg crate. Honeycomb principle is used to protect circuit boards from underwater pressure.

Two standard 3-by-2⅝-in. alumina or beryllia ceramic-circuit boards are mounted back-to-back and separated by a dummy board enclosed by two formed stainless-steel can halves. Two grid assemblies similar to egg crates form the sandwich-type structure that resists high water pressures, thus eliminating the need to pressurize the electronic components. The circuit boards are part of the structure that isolates components from external loads. A standard Mark-2 board was used in a module mockup and the grid, having ¾-in. spacing, doesn't interfere too much with component density.

Wet weight of the module will be 1.64 pounds for a 7,600-foot operating depth and 1.85 pounds for 10,600 feet. For the swimmer vehicle, the module can be made even lighter. Thus, the module can be placed anywhere without affecting trim. Two cans could handle a basic sonar unit, Godwin says, and about 15 watts can be dissipated by one module.

State of the art. Since all technology here is state of the art, North American is predicting high reliability—extremely high for underwater systems. "We're shooting for 10 years," says Godwin. The module can easily be disassembled without destroying the circuit or components.

North American couldn't find a commercial connector suited for the module, so it developed a 24-contact, two-prong insulated connector probe with annular contact rings. Here, O-ring seals serve to pressure-isolate air chambers around pins and sockets, and a squeegee wiping action eliminates all air and water around the contacts. The connection can be made underwater with less than 50 pounds of pressure, Cook says.

Three-in-one mission

Spurred by Vietnam needs, a prototype three-function laser system for forward air controllers will undergo additional tests this week at Eglin Air Force Base in Florida. If the system becomes operational, it will be the Air Force's first laser unit for ground-to-ground ranging [Electronics, July 10, p. 26].

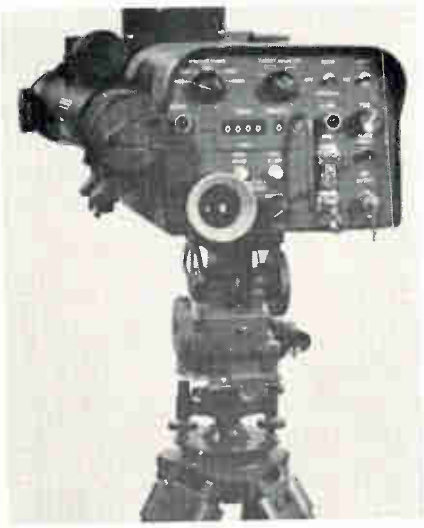
Unlike the Army's laser system, which is limited to ranging, the Air Force's unit is a 3-in-1 package: it locates targets, detects intrusion, and provides secure voice communication. It was developed for the Rome, N. Y., Air Development Center by the Radio Corp. of America's Aerospace Systems division at Burlington, Mass., which also designed the Army rangefinder.

Two for three. The Air Force system uses two lasers—a neodymium-doped, yttrium-aluminum garnet (yag) laser to measure range, bearing, and elevation of the target, and a gallium-arsenide laser to provide high-fidelity, noise-free voice communication up to 2.5 miles and to trigger an alarm when an intrusion interrupts the beam. An optically aligned Starlight scope —a light-enhancement device—can be adapted to the set to improve target location at night. The Army system uses a ruby laser.

According to the Air Force, the yag laser has several advantages over the ruby: it uses one-fifth the input power (40 joules per pulse); it is less hazardous to the eye (by a factor of seven if both lasers are transmitting at the same power level); and its 1.06-micron wavelength is an invisible beam (the ruby laser's 0.7-micron beam is visible). The GaAs laser's 0.902-micron beam is also invisible.

Ruby's plus. The Air Force chose yag over ruby because better and larger crystals are now being produced. Since it settled on its laser design three years sooner than the Air Force, the Army wasn't confronted with a choice between the two; yag hadn't been fully developed at the time. However, the Army claims the ruby lasers offer two advantages—ruby material is relatively low-priced and detectors are extremely sensitive.

Range of the Air Force system is 9,990 feet in clear weather and 5,700 feet in haze, with an accuracy of ±10 feet. The tripod mount can be positioned to true north with an accuracy of ±1 minute of arc by means of a sensitive magnetic compass. Azimuth and elevation accuracy is within ±0.1 degree.



Eyes. Two-laser device for ranging, communications, intrusion alarm.

Output for the rangefinder is 750 kilowatts in a 20-microsecond pulse, and for the communications and intrusion unit, from 10 to 20 watts in a 56-nanosecond pulse. Repetition rate for the rangefinder is six pulses per minute, and for the intrusion unit, 8,000 pulses per second.

Getting warmer

It takes from 20 to 75 minutes to warm up and align the inertial navigation systems of U.S. Navy carrier-based aircraft. During that time, the ship's turning can alter the reference information being fed to the inertial navigators through bulky umbilicals that clutter the flight deck.

The Navy would like to eliminate warmup and the hazardous umbilicals, slash alignment time to five minutes, and allow the ship to turn without affecting the reference data. Toward that end, the Naval Air Systems Command has asked the Naval Air Development Center, Johnsville, Pa., to develop a brassboard or feasibility model of an inertial navigation system that can be aligned by a radio-frequency data link between the ship's own inertial navigation system and the aircraft via computer.

Tests with the feasibility model of the inertial navigator and data link next July or August will establish specifications the Navy can use to buy a preproduction prototype that might undergo sea tests by midsummer of 1969.

SINS and Cains. Lloyd A. Iddings says the intent of the Carrier Aircraft Inertial Navigation System is to produce a standard inertial navigation system that is interchangeable among various Navy aircraft, and which is compatible with the ship's inertial navigation system (SINS). Iddings is section head for gyroscopes and inertial navigation at NASC in Washington. He adds that another aim of the program is to have one maintenance console aboard the carrier to service both the ship's and the aircraft navigation units.

Besides the five-minute alignment time requirement, Iddings says the Navy wants these features in a standardized inertial navigation unit:

- The ability to replace the system in 4½ minutes;
- A purchase price between $45,000 and $80,000 for quantities of 1,500 to 2,000 units, compared with an average of $135,000 for present operational inertial navigation systems.
- A total system weight of about 65 pounds, with no subsystem (inertial platform, power supply, battery and computer) weighing more than 25 pounds.

Iddings emphasizes that the Cains program is not intended to come up with a new inertial navigation system, nor will the Navy try to improve the accuracy of inertial units. The aim is to modify existing hardware so that the next generation of Navy aircraft inertial systems will be compatible with the data-link alignment method. "We examined most of the inertial equipment available from industry. We wanted a system that is the right size, is already in production, and has been flight-tested."

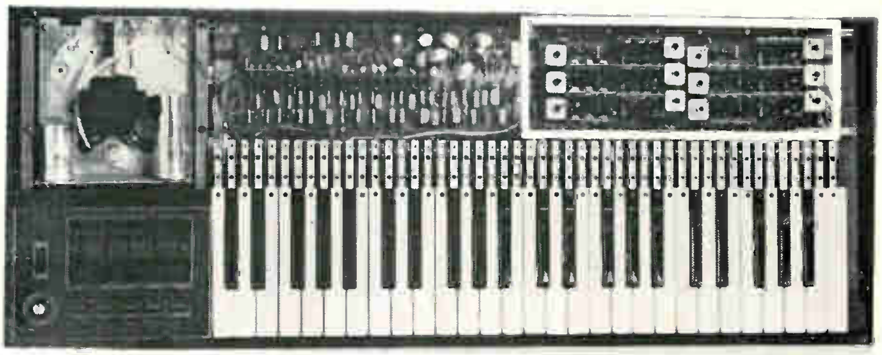
The only platform meeting those requirements is the LN-15 inertial navigation system made by the Guidance and Control Systems division of Litton Industries Inc. It will serve as the inertial navigator in the feasibility model.

The LN-15 is a general-purpose system that weighs 40 pounds without cockpit control and display equipment. It has been flight-tested at Holloman Air Force Base. Warmup time is two to three minutes.

New thinking. The Navy's adoption of an r-f data link to align inertial navigators represents a shift. The Cains program is an outgrowth of an earlier effort called Pinsac (for Portable Inertial Systems Alignment Console). The earlier program concept was to have the aircraft navigation units slaved to the ship's inertial navigation system, then taken to the plane running on battery power and plugged in. Iddings says the Navy abandoned the insertion technique because it imposed too much of a load on flight deck personnel.

The characteristics of the data link and five-minute alignment time are outgrowths of an in-house development program at the Autonetics division of North American Rockwell Corp. Tests last summer of the Autonetics N16 inertial navigator and the data link have been described as successful by both Navy and Autonetics officials. Iddings explained that the Navy was most interested in the fast alignment capability of the Autonetics system, but will use standard hardware based on techniques in the Autonetics data link feasibility model.

Operating frequency of the data link hasn't been determined. Iddings says the Naval Applied Science Laboratory in Brooklyn is about to go shopping for brassboard data processing equipment. The Navy won't say much about signal range, except that it must not be detected beyond short ranges.



IC tone generators. Heart of lightweight organ is printed circuit board, upper right, which mounts 36 digital integrated circuits.

Consumer electronics

Hitting high IC

The giant organ at New York's Radio City Music Hall is famous for its size. Last week the maker of that organ — Wurlitzer — introduced a model it hopes will be famous for its compact size.

What Wurlitzer has done is produce the first commercial electronic organ using monolithic integrated circuits. While there is an IC designed specifically for the electronic organ industry—Motorola's MC-1124P, a four flip-flop frequency divider [Electronics, July 24, p. 196]—Wurlitzer's 24-pound organ employs 36 standard dual flip-flops—Motorola's MC-790L—as frequency generators. Each IC replaces 24 transistors and 32 resistors, reducing the size of the instrument to 4 x 14 x 36 inches while maintaining its seven-octave keyboard. Price: $695, less amplifier.

Now that Wurlitzer has paved the way, other producers can be expected to follow soon. With the organ industry gobbling up transistors at a rate that reached a peak of 26.8 million units last year, every major microcircuit producer can be expected to go after the industry which last year sold 124,000 electronic organs for $192.6 million.

Split. The IC's are used as frequency dividers in the tone-generating circuits, which produce 84 discrete frequencies from 65 hertz to 7,902 hertz. The 12 notes—C through B—are produced by separate Hartley master oscillators.

The output of each master oscillator is buffered and used as the top note of the organ. At the same time, it's coupled to the first flip-flop divider stage which divides the signal to produce two related notes. The output of the first IC is applied to the second IC, which divides the signal again. This frequency division continues.

When a key is depressed the required tone signal is sent through active and passive filters to separate transistor preamplifiers before being switched to a master preamplifier. The output signal from this preamplifier, which is in the order of 5 volts with impedance of 10 kilohertz, is then used to drive any desired power amplifier.

Big play for playback

Electronic Video Recording (EVR) is growing faster than CBS Laboratories thought it would. When the color and black-and-white system was introduced two months ago, EVR was to have been a playback-only unit for educational or home use with standard television sets [Electronics, Sept. 4, p. 25]. Now it appears EVR may be used by tv stations to supplement film or video-tape systems.

A spokesman for CBS Labs says its parent organization, Columbia Broadcasting Systems Inc., will begin on-the-air tests of broadcast

EVR "within the next few months." Picture and color quality are said to equal that of the best 35-millimeter film or video tape. The spokesman also claims that the cost of broadcast-EVR equipment would be about one-third that of equivalent video-tape gear, and that the cost of EVR film would be about one-eighth that of tape.

Since the cost to educational-tv stations for color-tape equipment averages about $75,000 and that of a 1-hour roll of tape about $225, the cost savings predicted by CBS would make EVR attractive to them.

But CBS plans to sell only playback equipment, offering a mastering service itself for any programs that stations or networks would wish duplicated. The service will be available first to educational broadcasters, then to other markets.

Differences. Although the same electron-beam method is used to record picture and color information, broadcast EVR and the system introduced earlier have basic differences. Broadcast EVR masters are made on 16-mm film rather than on 8-mm film. Also, a reel-to-reel rather than a cartridge mechanism is used.

Playback mechanics have also been changed. First an EVR master is used to make a film print with sprocket holes to fit the projection equipment already on hand in most tv stations. This print is then projected into a special-camera system using twin vidicons, one to accept the picture and the other to accept coded chrominance and luminance information.

Companies

Going down

There was nothing but bad news when the board of directors of the Fairchild Camera & Instrument Corp. met recently to review the company's performance in the third quarter. Earnings were $137,000 or three cents a share, compared to $3,061,000 and 71 cents a share in the same quarter last year when earnings had disappointed Wall Street.

When the shock waves subsided, John Carter, chairman of the board, resigned, and Sherman Fairchild, the company's biggest stockholder, had replaced him on a temporary basis as chairman and chief executive officer.

The fortunes of Fairchild are tied closely to the Semiconductor division in Mountain View, Calif., which accounts for more than half the company's sales and probably three quarters of its profits. And so far this year the division has not done well. It has been caught in a slump for discrete components, particularly those used in consumer applications.

Departures. The division has also been hurt by the loss of top level management during the past year, a factor that insiders lay partially to Carter. Earlier this year, when Charles Sporck and four other top executives left to join the neighboring National Semiconductor Corp., a good portion of the blame was attributed to Carter because he opposed a reorganization plan that Sporck had suggested.

During his tenure as chief executive officer, Carter raised Fairchild from a company whose sales were about $30 million in 1957 to more than $300 million last year, primarily because he guessed right in backing Robert Noyce and seven other people when they left Shockley Semiconductor to found the Fairchild Semiconductor division.

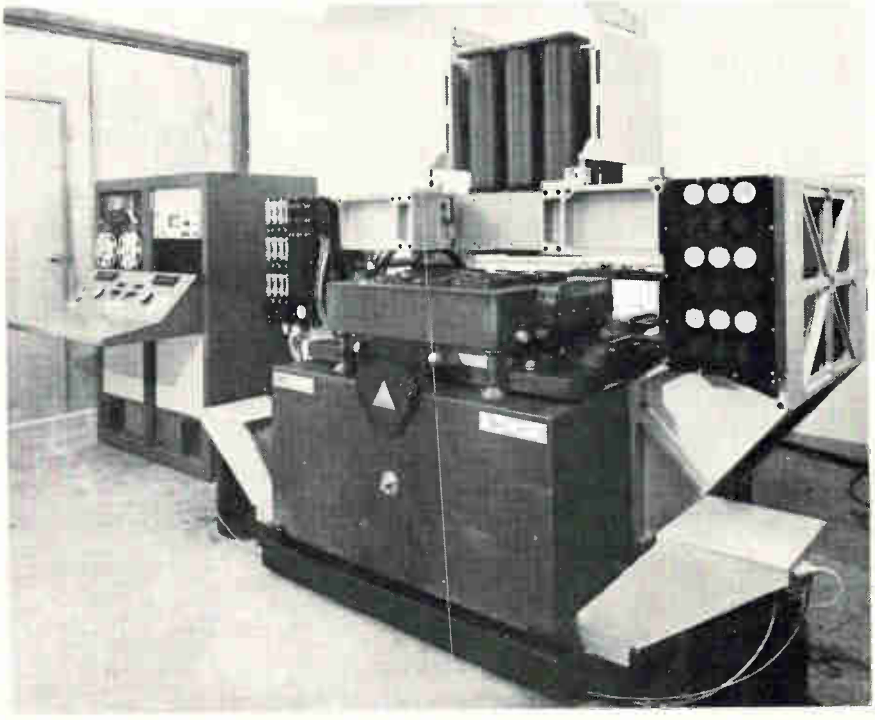
But the financial community has complained that other of Carter's acquisitions have not been so successful. Only three other divisions —Aerospace, Graphic Equipment, and Instrumentation—are thought to be in the black. Some financial men have urged Fairchild to sell the money losers.

Industrial electronics

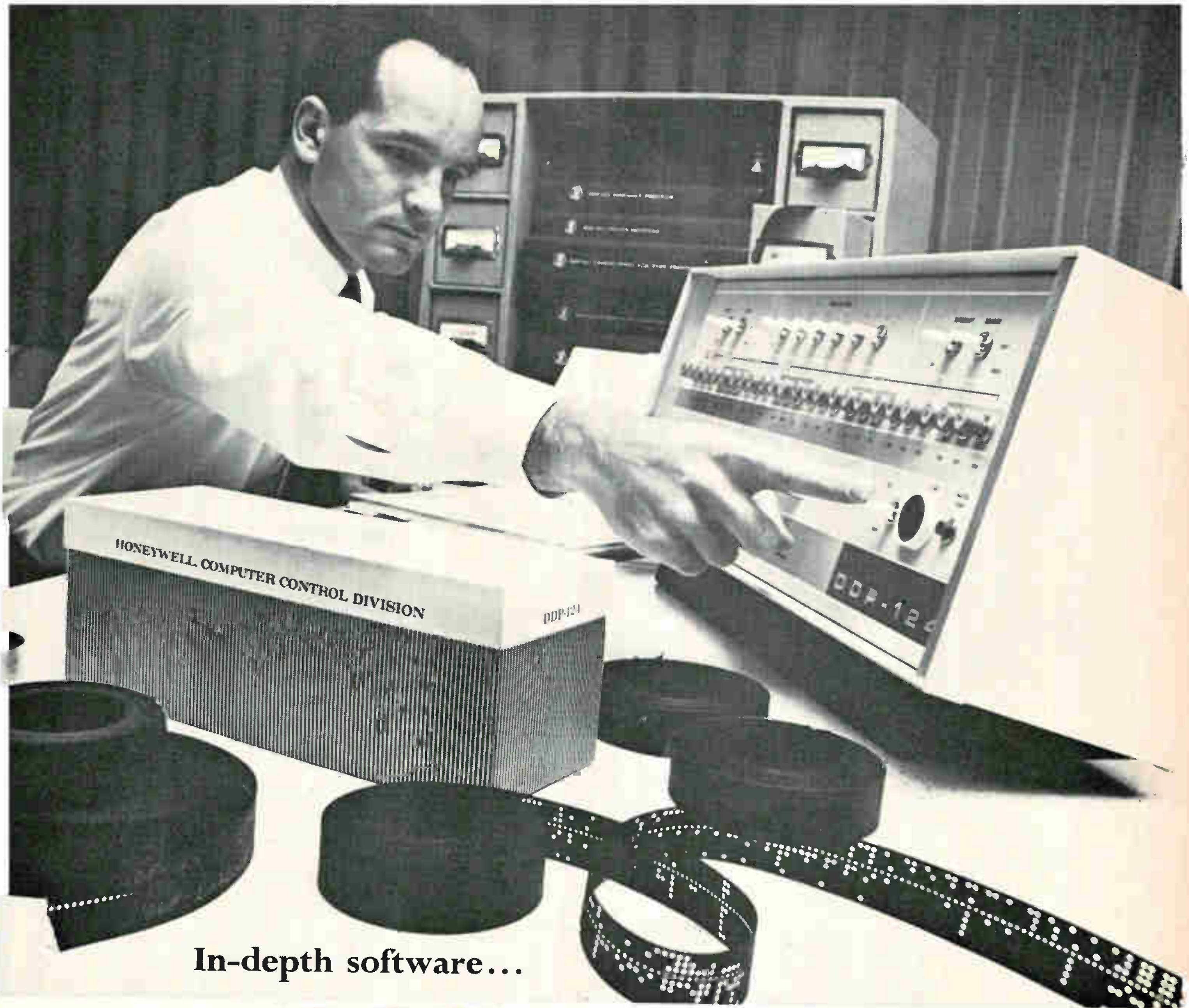
Mix and match

Designers of some industrial electronic equipment have ambivalent feelings about integrated circuits: IC's can be giant helpers or maddening little demons. What brings out the demon in IC's is the high unit cost when they're made in small production quantities for custom applications.

Now, fast photocomposition of a set of masks for making complex IC's is being investigated by ITT Semiconductors as a means of



Step-and-repeat. Once the masters are in the optics of the mask maker, tapes direct and control table position and exposure time.



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breaking through that cost barrier. To try the idea, ITT designed a mask-making machine that assures 3 microinch positioning accuracy between adjacent cells across the mask. Such accuracy—four times better than previous machines—makes it feasible to mix-and-match separate master mask sets for components like transistors and resistors, for simple functions like gates, and more complex functions like shift registers. The sets are then photocomposed side by side to form one mask for each process step in fabricating custom IC devices.

Chips and chunks. If the mix-and-match idea becomes a reality—and machine trials look good—a chunk of the $20,000 to $50,000 now spent for developing a master IC mask set should be eliminated and the lead time to production shortened. Cutting the cost of mask-making will be a boon for industrial electronics designers who have been frustrated in obtaining small quantity custom IC's at prices low enough to justify new and redesigned products for customers.

The lucrative but elusive industrial market for custom IC's is one major reason ITT sought a 3 microinch accuracy in the 11-ton, laser-positioned, tape-controlled machine installed last week at its plant in West Palm Beach, Fla. The other major reason for buying the advanced machine, which can shoot up to nine masks simultaneously, was to increase production to meet growing demand for ITT's present line of IC devices.

Tightening technology. While ITT Semiconductors looks to its new mask-maker to boost IC technology, the machine itself doesn't depend on major innovations. Instead, consultant-designer James R. Nall sought the best in laser interferometry, in table-positioning servos, in machinery design, and in optics to get 3 microinch accuracy.

For example, to position the machine's granite table that rides on Pyrex ways, photodetectors count fringes from a helium-neon laser interferometer emitting light at a 24.34 microinch wavelength. But unlike other similar machines that divide one wavelength by two [Electronics, Aug. 7, p. 119], a special arrangement of beam splitters and photodetectors are positioned to receive fringes from a phase relationship equal to one-eighth the laser wavelength, or 3.08 microinches.

R&D and production. With this one machine, ITT engineers say they have taken mask-making out of the laboratory into the production process. Integrated circuits made from mass-produced masks that can be aligned to 3 microinches should offer a much improved yield, Nall's studies show. And high yields are important to IC makers and their quality-minded customers alike.

Communications

Mallard on the wing

Every designer of tactical communications equipment had better keep close tabs on the Mallard program. Untouched by the squeeze on R&D due to Vietnam spending, the four-nation, integrated tactical trunking and distribution system is moving ahead fast as three contractor teams begin to design the revolutionary system. What they come up with is expected to significantly affect the basic design of all future tactical communications gear.

To make sure that all its tactical equipment under development will be compatible with the international program, the Army has given the Mallard manager, Brig. Gen. Paul A. Feyereisen, a second hat—that of deputy commanding general of the Electronics Command in charge of tactical communications. It won't be easy and there are bound to be some exceptions, particularly since equipment commonality is necessary for all three services.

"We'll have real problems standardizing such things as components and frequencies," says Feyereisen, who will get his second star next spring. Still to be decided, for example, is whether Mallard will use the metric system for measurements—a step that would be costly to U.S. companies [Electronics, May 15, p. 153]. But Mallard is far enough away—now scheduled to be fully operational by the 1975-1977 period—and is a big enough jump in the state of the art that "we can set our own standards," he says.

United. Existing projects, including the tactical communications satellite and the random access discrete address (RADA) system, will continue apart from Mallard, but their designs will be affected by technical constraints emanating from the program so that they can all work together. Mallard will decide such important specifications as frequencies, bit rates, channel allocations, and power levels.

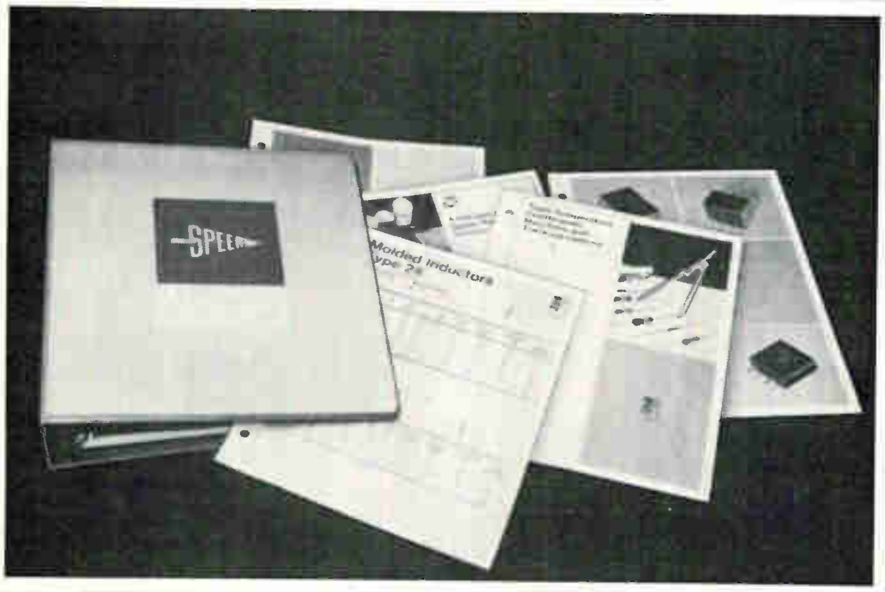
The military services are already working on the commonality problem. An Air Force team of 12 officers will be assigned to Mallard's Fort Monmouth, N.J., headquarters by the end of the year. And the Army is about to start work for the Navy Electronics Laboratory on the interface problems between Mallard and the Navy's new amphibious tactical communications system.

Two U.S. contractor teams are at work on system design. Radio Corp. of America heads one on a $4 million award; Sylvania Electric Products Inc. leads the other on a $3.5 million contract. A third team, from Great Britain, is said to include Marconi Co., the Plessey Co., Standard Telephone and Cables Ltd., and General Electric Co., Ltd. The four governments—Australia, Canada, Great Britain, and the U.S.—will select the system.

Mallard will not go into operation as a full system, but major subsystems, such as switching, trunking, single-channel access, or communications satellite, could be phased in one at a time, possibly beginning as early as 1973. Conceivably, Mallard could cost as much as $1 billion, with U.S. firms expected to get at least two-thirds of the business.

From all directions. Feeding into the three major system studies are some 20 to 25 technique-support efforts, being done in-house by the military and by companies from all four nations. This work will look at such areas as the RADA-Mallard interface, routing, steerable antennas,

SPEER COMPONENT COMMENTS



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Circle 49 on reader service card

and system integration and evaluation. What project people know now is that Mallard will be a secure system, automatically switched, that will digitally transmit voice, teletype, facsimile, and computer data. Cryptographic techniques also will be used.

One particular problem that will be investigated is how RADA will fit into Mallard. Feyereisen says only that "a type of RADA will be used" and that tradeoffs and alternatives to RADA will be explored. At work on the Army's RADA since 1965 is Martin Marietta Corp. The pulse-modulation radio system automatically switches communication channels, utilizing simultaneous transmissions in a common-frequency band. The question is how far into the Army field organization should RADA links be used; if the system is only partially used, new set of converters and buffers will be necessary. Another problem is understood to be the complexity of prototype RADA-switching equipment.

Space electronics

All talk, no money

Remote sensing of the earth from a satellite—to find a wide range of resources—has been discussed for a long time. However, nothing more than discussion seems to be happening. More than one scientist has observed that the recent success of the lunar orbiter program gives us a better knowledge of the lunar surface than the earth's surface.

Earth resources programs seem further from orbit now than ever. The Earth Resources Observation Satellite program announced by the Department of the Interior last year with the prediction of an EROS in orbit in 1969 is now, according to program manager William Fisher, "a concept embodying satellite missions which will serve the needs of the Department of the Interior."

Nothing doing. The department has no satellite or funds lined up for a satellite. But the National Aeronautics and Space Administration has planned earth-sensing missions for the Apollo Applications Program, currently without funds, and several unmanned earth resources satellites for the early 1970's. At NASA headquarters a spokesman says officially that earth resources "are being examined as a possible application of space technology," but admits that nobody seems to know at this point what will happen to the earth resources concept.

A study announced by NASA earlier this year to unify earth missions on one satellite—called USAM (Unified Space Applications Mission)—is not moving because funds are not available for a follow-on. The first USAM study contract now being conducted by the Federal Systems division of International Business Machines Corp. (now running behind IBM's predicted delivery date of mid-October) is coming under fire before it has even been completed. Says EROS manager Fisher, "In this case communality will lead to degradation. Very few sensing missions will be able to use a common orbit."

Avionics

The matchmaker

Maneuvering for midair plane refueling is a ticklish proposition with the hit-or-miss aiming now employed. Microwave radar isn't a useful alternative because the tanker craft and the plane trying to fuel up are too close. But a new laser technique may help effect the coupling.

That's one application for the International Business Machines Corp.'s new rendezvous and station-keeping optical radar (Raskor), a system that employs two gallium-arsenide injection lasers and six solid state optical detectors. The system can pick up a target within an area of 40° azimuth and 10° elevation at a range of up to 60,000 feet.

IBM's Federal Systems division in Gaithersburg, Md., will be sending a prototype to Wright-Patterson Air Force Base, Dayton, Ohio, by the end of the year. Raskor hasn't yet been earmarked for any specific tanker planes.

On the track. Currently in breadboard form, the system ranges and tracks well in ground testing, according to IBM. Its lasers provide optical radiation in fog, darkness, or haze, and are designed to work with a retrodirective reflector attached to the homing aircraft. The optical unit occupies a space no bigger than 6 x 6 x 12 inches.

One laser handles the tracking of planes from 1,000 to 20 feet away, while the other, a high-power device, tracks planes at greater distances. Range is determined by measuring the round-trip time of a transmitter pulse.

Find, fix, fuel. The system's detectors—silicon photodiodes—can receive a laser emission at about 0.9 microns. The center of the detector section is used for "track and acquisition" and the wings for "search and acquisition." The system switches into and out of these phases as it tracks the homing aircraft. If the target is lost during track, for instance, the transmitter is switched to the acquisition mode and servos sweep over a 5° azimuth field to regain contact.

This application of Raskor will be described in detail at the Northeast Research and Engineering Meeting in Boston, Nov. 1.

Instrumentation

Outside looking in

Instead of tearing apart an engine, aircraft mechanics may soon be probing for blade defects from the outside—with the remote sensing of a millimeter-wave interferometer system. Researchers at the Illinois Institute of Technology Research Institute have concluded that such a system is the most promising of several remote inspection methods.

When the millimeter-wave system analyzes the compressor section of a running jet engine, it can see lead-edge defects as small as

0.03 inch and 0.015 inch defect areas caused by foreign objects.

Compare. To take into account the tolerance variations between blades, two beams of energy are focused on adjacent areas of the same blade. After the returning energy from each area is collected by a lens system, it's compared in a bridge circuit. A defect illuminated by one source causes an output from the bridge that locates the defect, while the output's amplitude determines the defect's size.

Illinois Institute researchers think that two modifications may make the system an even better detective. Increasing the operating frequency from 88 Ghz to 220 Ghz and using more sensitive heterodyne detectors could lead to the identification of defects as small as 0.005 to 0.010 inch radius.

Solid state

On the skids

For years, the kingpin of the operational amplifiers has been the 709. But users have started complaining that the 709 is too limited in its potential applications, and at least two companies are doing something about it.

One is Westinghouse. A marketing spokesman in the Molecular Electronics division says: "It's a device that's too limited by its input and output characteristics."

Westinghouse's answer to the problem is the model WC306 [see p. 135]. This unit has both high and low impedance inputs and single-ended as well as differential outputs. To achieve this flexibility, open loop gain had to be sacrificed, but the designers are convinced it's worth it. The 306 sells for $6.60 each in 50-unit lots and is available off the shelf.

Motorola is also introducing a replacement for the 709, along the same lines as Westinghouse—lower gain, higher bandwidth, and differential inputs and outputs. Designated the MC1520, it's for applications requiring high power bandwidth. It will sell for $10 each in quantities of 100 units and distributors are now being stocked.

On the other side of the coin, Fairchild Semiconductor, father of the 709, says that devices like the old 709 are too general. So its engineers have come out with a more specialized unit. They call it a low noise, low drift version of the 709, and it has a higher open loop gain, and a narrower bandwidth. The 709 has a gain of 45,000; by replacing the Darlington configuration in the front end with a single emitter coupled pair, Fairchild has achieved a gain of about 100,000 and a noise improvement of about 30 db.

For the record

White paper. The Government and the Communications Satellite Corp., in a position paper giving the American position on the future of the 59-member International Telecommunications Satellite Consortium, suggests that any nation's voting share be changed regularly to reflect its use of Intelsat services. The paper was sent earlier this month to the Interim Communications Satellite Committee, which is meeting to make recommendations for the 1969 renegotiation of Intelsat. It also recommends that Intelsat expand satellite services to include air navigation, as one example. The paper implies that any nation wishing to operate its own domestic satellite would have to get along without the services of the National Aeronautics and Space Administration in launching and tracking.

Highest. Fairchild Semiconductor has developed what may be the industry's highest voltage-rated transistor, an npn silicon switching device that handles 1,600 volts or more. The device, whose cutoff frequency is 40 megahertz, may lead to eventual displacement of vacuum tubes in the horizontal deflection circuitry of tv sets.

Fairchild expects to have the unit in production by next year for military and industry applications. Pricing isn't expected to be low enough to crack the consumer market until 1969 or 1970.

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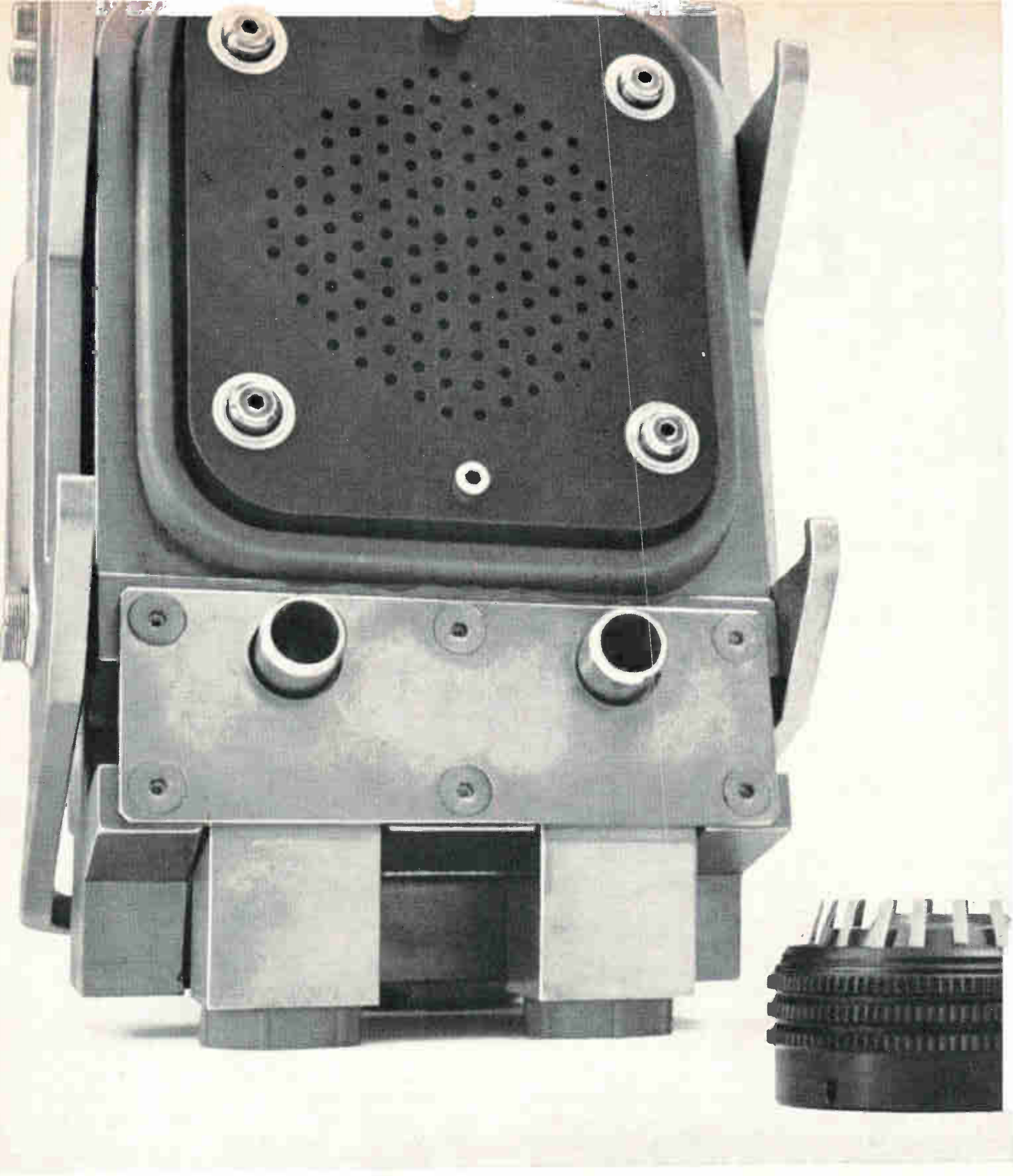

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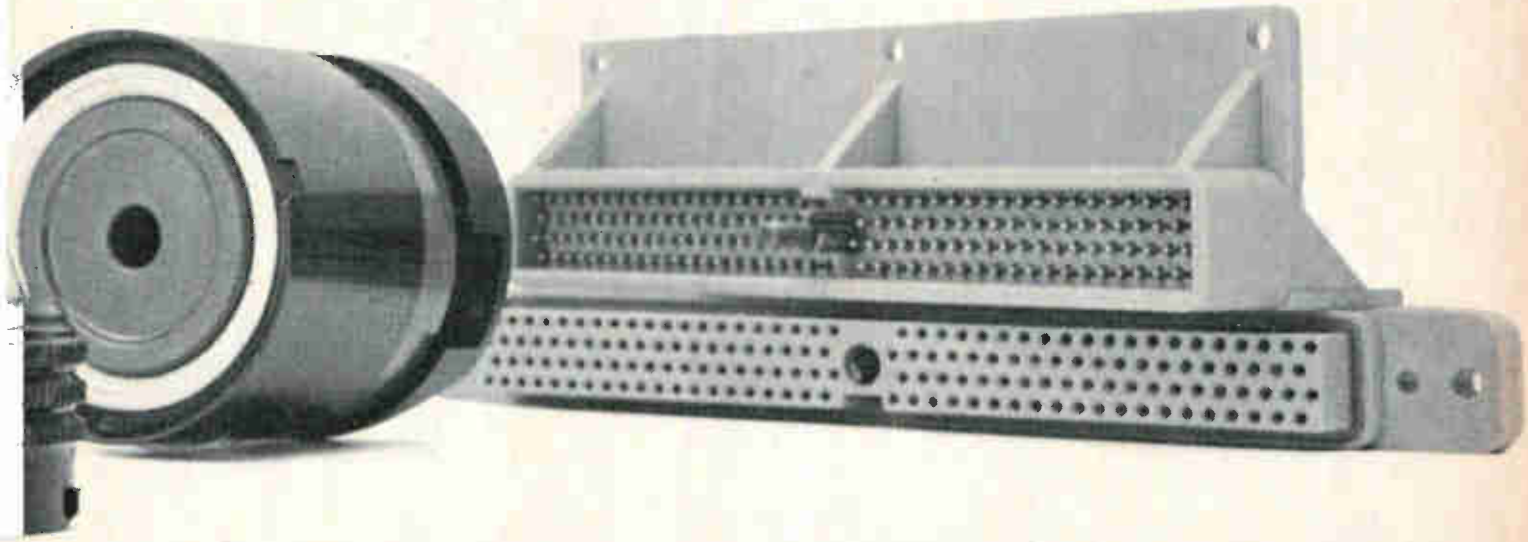

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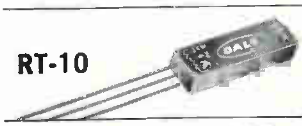
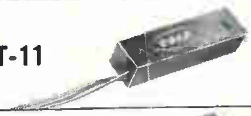
RT-10		Model 691 P.C. Pin Model 697 Flex. Leads
RT-11		Model 1287 P.C. Pin Model 1288 Flex. Leads
RT-12		Model 1680 P.C. Pin Model 1697 Flex. Leads
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Washington Newsletter

October 30, 1967

Double audit trend riles contractors

More Government agencies are expected to follow the Defense Department's lead in expanding double-check audits to sole-source, fixed-price contracts. Making the major contracting-policy change probably will be NASA, the FAA, AEC, and General Services Administration.

The Pentagon made the switch only after heavy pressure from Congress and the General Accounting Office. Previously, it ran two audits only on cost reimbursable contracts. A post-award audit has been added to the pre-award examination of cost data the contractor uses to negotiate the fixed price. If the second study uncovers errors or false cost data leading to undue profit, the Government can demand an adjustment.

About 12% of Pentagon procurement—close to $5 billion a year—will start getting the double audit.

Satellites require less space to park

It now looks like there'll be room to park more stationary satellites along the equator than originally estimated. Preliminary data from an experiment being conducted by Comsat indicates that two communications satellites can function without interfering with one another at less than 2° separation in a 23,000-mile-high orbit.

Previously, separation estimates ranged from 6° down to more than 2°; a degree at stationary orbit is about 500 miles. Comsat, which started the experiment this month by gradually moving its Pacific-2 satellite closer to Pacific 1, will issue detailed data in a few weeks.

Navy salvage job on Ilaas subsystems

Now that the Sperry-developed integrated light attack avionics system is almost certain never to go into production as a system, the Navy is trying hard to salvage some of the subsystems. The Naval Air Development Center in Johnsville, Pa., is considering Garrett AiResearch's inertial-navigation system and Elliott Automation's head-up display, among others, for possible jobs on their own.

Adding to Sperry's woes is the postponement of the first R&D flight tests of Ilaas until Vietnam spending tapers off. This delay comes even though $5 million has been budgeted, an A-6A Intruder aircraft is available and Sperry has a prototype Ilaas in final assembly.

Comsat plans push for Intelsat 4

The Communications Satellite Corp. will do some hard selling of its 10,000-channel, Intelsat 4 satellite at the November meeting of the International Telecommunications Union in Mexico City. Its pitch will be made to member nations of the International Telecommunications Satellite consortium. Comsat's first attempts to move ahead with the big satellite flopped earlier this month when it failed to convince the Intelsat interim committee that Intelsat 4 was economically justified.

The FCC, which also has to approve the satellite plan, has asked Comsat to answer 24 questions by early November. The FCC wants to know, among other things, how the new satellite affects the 1,000-channel Intelsat 3 due to go up next year, and how it contrasts economically with the TAT-5, the 720-circuit transistorized cable proposed for 1970 operation. Two years ago, the situation was reversed: Comsat pushed the Intelsat 3 while the FCC wanted a bigger satellite.

Washington Newsletter

Weigh second job for Navy's F-111B

The Navy may give its overweight and overpriced F-111B another mission in an attempt to get more for its money. It is considering equipping the fighter with a stand-off missile system for air-to-ground attack—**possibly North American's television-guided Condor now being developed for the Navy's A-6 and A-7 attack craft.** The Navy still plans to use the F-111B primarily as a platform for the Hughes Phoenix missile system, an air-to-air weapon.

Hams on television

Hams are about to get a new dimension. **By the end of the year, the FCC is expected to approve the transmission of slow-scan television by some 40,000 radio amateurs** now holding advanced or extra-class licenses. Needing only the bandwidth now used for ordinary single sideband voice transmission—up to 3,000 hertz—a standard 525-line picture can be transmitted in about eight seconds.

Although no company now offers amateurs the required equipment, at least one firm, Ball Bros. Research Corp. of Boulder, Colo., is considering marketing a camera and monitor unit priced at about $1,000. It would include either a Westinghouse or General Electric slow-scan vidicon.

MOL on target

The Manned Orbiting Laboratory (MOL) will remain on schedule despite the Pentagon's heavy slashing of non-Vietnam spending. Air Force project officials plan to spend the entire $430 million appropriated for 1968. They say $400 million to $500 million annually is required to keep the program on target. Insiders say MOL has been untouched because of the enthusiastic backing it has always received from Congress. The nation's only military manned-space effort will cost at least $2.2 billion before its seven R&D flights are finished early in the 1970's. First flight is now scheduled for 1970.

Reducing plan for sensor unit

NASA's Goddard Space Flight Center is using large scale integration to develop by 1971 a two-pound earth sensor package for its interrogation recording and location system (IRLS). The sensor would be small enough to attach to animals for migration and biological studies. It might also permit the use of smaller and cheaper buoys and balloons for world-wide oceanographic and meteorological studies in the 1970's. So far, 18 elements—shift registers, gates and demodulators—of the sensor have been put on a single chip.

IRLS packages weighing 30 pounds will communicate with next year's Nimbus B satellite, and work is proceeding on a 10-pound package for the Nimbus-D satellite tests in 1970. Balloons, aircraft, buoys and icebergs will carry the sensor packages in the two Nimbus experiments.

Addenda

Surprised by Congressional allocation of more money than the FAA requested for facilities and equipment for fiscal 1968, **agency officials say they don't know at this time how they will spend the money.** FAA originally asked for $28.4 million and Congress gave it $54.5 million . . . **The General Services Administration is increasing efforts to sell its mounting surplus of electronics gear.** The GSA will display communications, radar, and navigation equipment in a show next month at its Washington headquarters.

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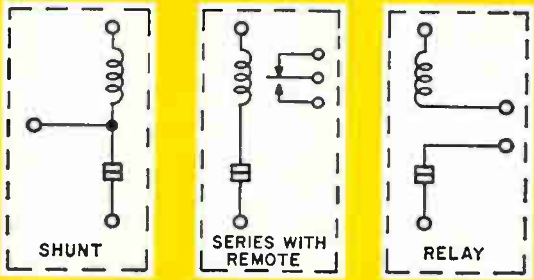

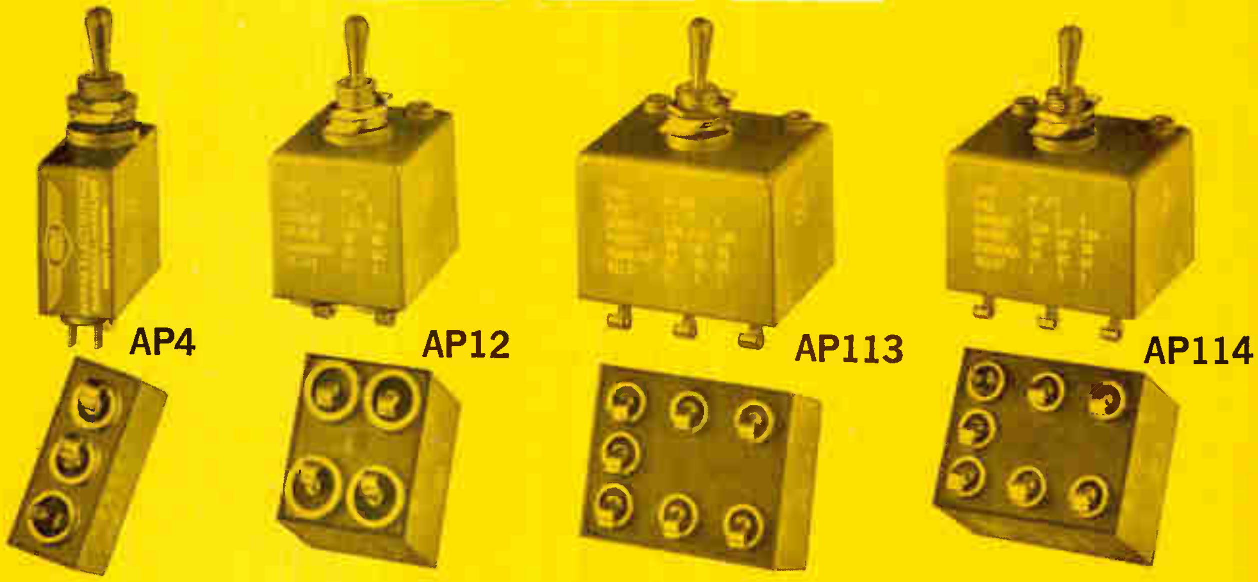

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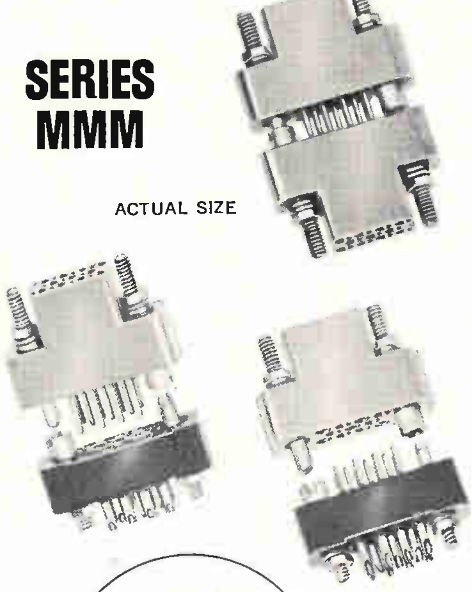

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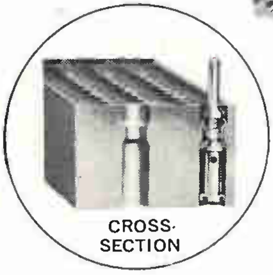

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INSERTION TOOL NO. 2558

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microminiature removable contact connectors with wire crimp termination

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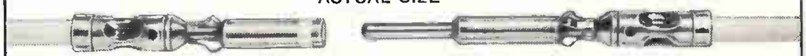

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Resistance Tolerance	±5% standard
Resolution	0.08 to 0.88%
Power Ratings:	
40°C Ambient	0.5 watt
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Temperature Coefficient	70 PPM/°C
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Technical Articles

It's not how much an IC costs . . . but how much it can save
page 66

Although the use of integrated circuits holds out the promise of lower costs, there are no guarantees that savings will accrue to every user. If an engineer chooses the wrong circuit, he can end up paying a penalty for using IC's rather than saving money. The critical item is special testing that an IC may require before it is incorporated into equipment.

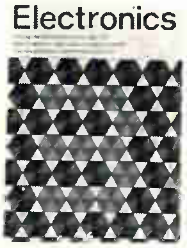
Equivalent circuits estimate damage from nuclear radiation
page 73

The formulas of physicists, explaining what happens to semiconductors when they are exposed to nuclear radiation, don't help engineers design radiation-resistant circuits. More useful are radiation-equivalent circuits. Using them increases the confidence in a circuit's survivability when it's exposed to nuclear radiation.

Computer aid on the ocean floor
page 85

The only way communications engineers could lay a cable between Vietnam and the Philippines in less than the two weeks the military demanded was to design the equalizers and calculate the position of repeaters as the cable was laid, and thus keep the operation continuous. Using a computer, the engineers devised techniques that can be applied to any communication system where on-the-spot adjustment of signal strength is required. That would include: high-speed data transmission, computer-controlled relay, missile range testing, satellite tracking, and missile detection systems.

Machine looks, listens, learns
page 91



Electronic equipment that can respond to written or oral commands could find wide acceptance in military and industrial applications, so there is a huge amount of effort aimed at developing such gear. A new machine just built can learn to identify both graphic and spoken inputs. It demonstrates the feasibility of three previously untried techniques. Because the machine is adaptive, it can learn to respond to commands like "up" or "down" or—without any redesign—their foreign equivalents such as "montez" or "descendez" in French or "suba" and "baja" in Spanish. For the cover, art director Saul Sussman symbolized the pattern recognition problem by picking out a numeral from a color pattern.

Coming November 13

- Special report: a survey of gallium arsenide technology
- Faster testing of r-f devices
- A computer with a suitcase memory
- Battery charging for consumer products

It's not how much an IC costs . . . but how much it can save

By carefully selecting the right integrated circuit for the job, designers of an r-f amplifier were able to cut costs in half because they avoided special tests that are time consuming

By D.W. Ford, M.M. Gutman and W.F. Allen Jr.
Philco-Ford Corp.

At first glance, the use of integrated circuits holds out the promise of lower costs. But savings don't necessarily come about. If an engineer chooses the wrong integrated circuit, he can end up paying a penalty in unexpected costs for special testing.

An example of what the right circuits can do in a design is a 70-megahertz intermediate-frequency amplifier that goes into a communications receiver. The use of three IC's as automatic gain control (agc) stages reduced the cost to about half that of an all-transistor version. Although the cost of components for the IC version was greater, it was offset by the simpler assembly. The higher costs of a transistor version stem from the complexity of discrete circuitry—assembling its associated biasing and decoupling networks, and external agc circuitry.

Not only does simpler circuitry cut costs, but it clears the deck of some knotty design problems. With discrete components, the yeoman effort usually goes into the circuit layout to minimize interactions of the components. If the amplifier is to remain stable at the maximum gain condition, special precautions are needed to prevent feedback currents through ground paths, which can cause oscillations. Problems like this are taken into consideration in the original design of IC's.

With only three IC's making up the heart of the amplifier system, each in effect, becomes a subsystem. As a result, the IC's require systems-type tests that go beyond the circuit-type tests normally performed by the manufacturer. But such tests would pare the IC's cost advantage. The trick is to find circuits that would work in the system based on their usual parameters—gain, bandwidth, and noise figure.

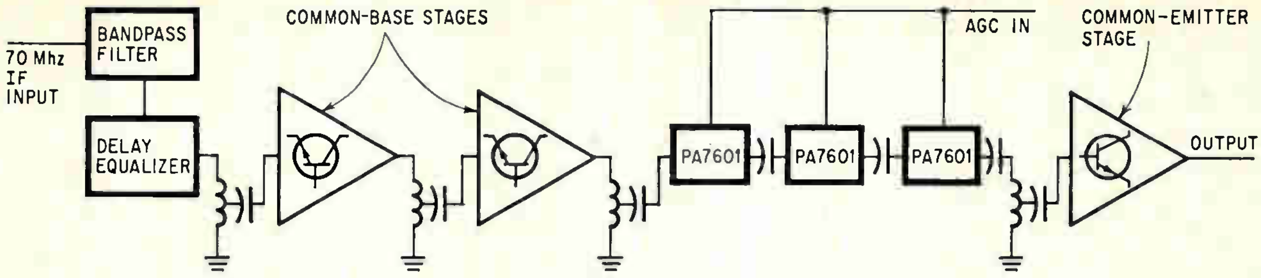
At the Philco-Ford Corp.'s Communications and Electronics division, designers were seeking an IC for the 70-Mhz i-f amplifier used in the receivers in the microwave- and troposcatter-equipment product line. Specifications called for a 1-decibel bandwidth of 20 Mhz, a gain of 80 db, an automatic gain control range of 60 db when the agc voltage varies from —6 to —2 volts d-c, and an output of 0.5 volts across 75 ohms. And, since the application was for frequency-division multiplex systems with several hundred voice channels, the amplifier had to have low intermodulation distortion.

With an over-all bandwidth of 20 Mhz, the bandwidth for each stage had to be much wider—in the neighborhood of 80 Mhz. Of the commercially available r-f integrated-circuit amplifiers, used mostly in television and frequency-modulation broadcast tuners, none approached this.

However, a broadband IC had recently been developed for an electronic countermeasures (ECM) receiver designed at Philco-Ford's Aeronutronic division. The IC characteristics and design were set by Earl Johnson of that division, and the mask and final design were done at the company's Microelectronics division. The circuit, the PA7601, offered a good possibility of fulfilling the system needs since it also had the proper agc scheme.

Gain control

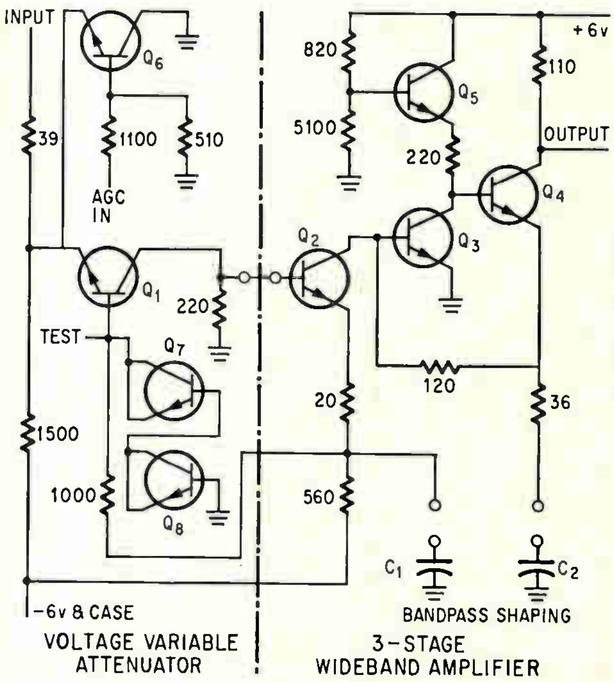
Unlike narrowband i-f amplifiers, agc can't be achieved on wideband systems by simply varying the bias on a transistor because large variations adversely affect the bandpass characteristic. This problem was solved in the PA7601 integrated amplifier by using the input stage of the IC as an electronically controlled attenuator. The input stage



Greater flexibility. Designed as a universal broadband circuit with an interchangeable bandpass filter setting the over-all bandwidth for specific applications, Philco-Ford's 70 Mhz i-f amplifier uses three PA7601 integrated circuits as automatic-gain-control stages. Two common-base stages serve as broadband amplifiers and a common-emitter stage is the power amplifier.

is a common base amplifier with the emitter of a second transistor connected across the input to shunt some of the signal to ground when the gain-control voltage is applied. Frequency response then remains unaltered, even with the required wide range of agc. This scheme also minimizes input-impedance changes since the input signal is not changed, but only redirected.

The amplifying portion of the IC, at right, which follows the agc stage, uses an input transistor with emitter degeneration to obtain broad bandwidth and a shunt-series feedback pair, Q_3 and Q_4. Transistor Q_5 serves as a variable load resistance that increases as the frequency increases. This unloads the amplifier and compensates for droop in the gain characteristic at high frequencies. The bandpass characteristic, extending from 45 to 130 Mhz at the 3-db points, can be controlled externally with emitter bypass capacitors. No inductances are required with this circuit.



Basic circuit. The PA7601 integrated amplifier uses a voltage-variable attenuator for gain control to preserve frequency response.

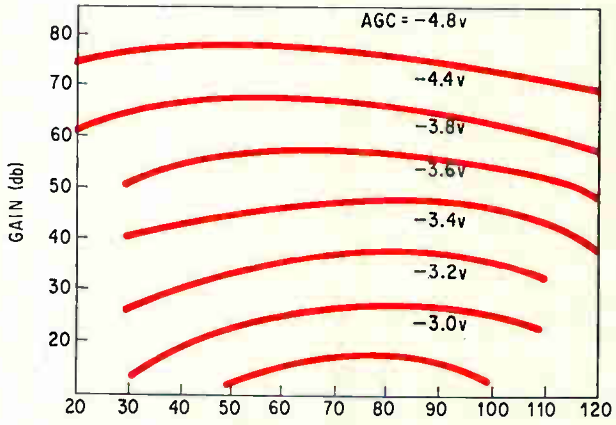
Distortion requirements

In an r-f application in which a large number of voice channels must be transmitted, it is common practice to use frequency-division multiplex, where each voice channel is frequency modulated onto a subcarrier and then the assembly of subcarriers is frequency modulated onto the r-f carrier. Because intermodulation affects quality, it must be minimized. The distortion stems from the multiplexed frequencies passing through the amplifier with different time delays. To overcome this, the i-f amplifier must have a linear phase response.

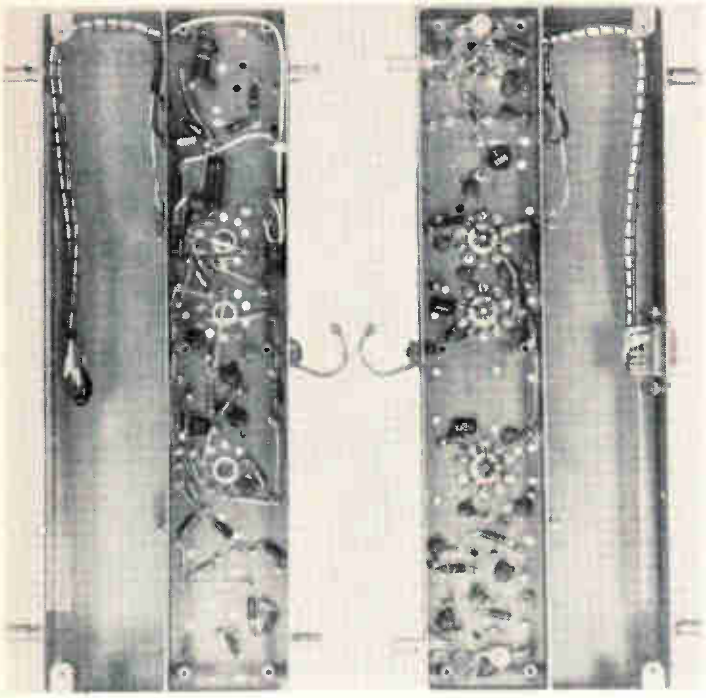
One test for intermodulation distortion—prescribed by the International Radio Consultative Committee—is to generate a wide band of noise, notch out a narrow range free of noise, pass the band through the amplifier, and then measure how much noise has appeared in the notched-out portion of the spectrum at the amplifier's output. If no distortion has occurred, the notch appears at the output noise-free. However, when the amplifier produces distortion, it adds noise across the entire spectrum, the notch included.

Intermodulation is expressed in terms of noise power ratio—transmitted noise to amplifier-generated noise. A high ratio is desirable; in this case, at least 55 db for the receiver system and 60 db for the i-f amplifier.

The test for determining this ratio, though not difficult to perform on a receiver, would be time-consuming and costly if it had to be performed for



Variable gain. The amplifier's bandpass characteristic continues to be broad despite wide changes in agc voltage.



Package. The commercial version of the amplifier has the three integrated circuits in the center and the discrete transistor stages above and below.

each IC. A better method is to make the specifications of the circuit tight enough to meet the requirements.

Since the over-all passband was held flat to within 1 db across the range of 60 to 80 Mhz, the flatness specification was extended to the individual IC's—each circuit had to be flat to within 1 db across the range of 50 to 120 Mhz.

Although unrelated to phase response, the noise figure also entered into the intermodulation specification. If the noise figure was too high, the noise level would mask the intermodulation noise and, in effect, degrade the noise power ratio. Because the noise figure of the chosen IC was 15 db, two transistor stages—to provide enough gain to mask the noise—preceded the IC's in the r-f amplifier.

Widening the applications

To provide a wider range of applications, the amplifier was designed as a broadband unit without tuned circuits. A separate filter—built with lumped passive elements whose delay and gain properties can be closely controlled and compensated for with delay equalizers—is used in front of the amplifier to set bandpass characteristics. A simple change in the filter can suit the amplifier to any system within its frequency band. The advantage of this approach is that the amplifier has no tuned circuits that require extreme care in alignment.

A typical filter is a three-section Butterworth. Phase equalization networks are used to minimize the time-delay distortion of the filter and to improve the noise power ratio characteristics.

Positioning of the agc circuits is critical in enabling the amplifier to handle high-level signals without saturating. If the agc is placed too near the receiver input, its output might be less than its input, and it will contribute to the noise in the amplifier. The thermal or shot noise may become greater than the intermodulation effects.

The complete i-f amplifier is a hybrid combination of three PA7601 IC's, three conventional transistor-amplifier stages, and the bandwidth-determining filter. Two of the transistors, at the amplifier input, are common-base broadband-amplifier stages. Broadband transformers are used for interstage coupling of the transistors.

The output of the second transistor-amplifier is transformer-coupled to the first of the IC amplifier stages. The IC's are broadband gain-control stages, each producing 20 db gain with —6v agc voltage, decreasing to 0 db for —2v agc voltage. The three IC's control the gain from 80 db down to 20 db. The output of the third IC is transformer-coupled to a common-emitter power amplifier stage, which delivers 0.5 volt rms across an output load resistance of 75 ohms.

Capacitive coupling is used between successive IC stages. The over-all 3-db bandwidth of the amplifier, exclusive of the bandpass filter, is greater than 40 Mhz. The nominal 1-db bandwidth is 20 Mhz.

Some tilt in the amplifier's passband characteristics occurs as the gain is reduced from maximum. The tilt, which could cause a nonlinear phase response, can be held within ±1 db across the 60-to-80-Mhz frequency range with capacitive tuning of the emitter circuit at the output of the integrated-circuit amplifiers.

The authors

David W. Ford is an engineer in the advanced engineering and research group at the Communications and Electronics division in Blue Bell, Pa. He is presently working on wideband communications systems. He has a master's degree from the University of Iowa.

An engineer in the transmission equipment laboratory of the Communications and Electronics division in Philadelphia, Michael M. Gutman is working on the development of i-f amplifiers for microwave and troposcatter equipment.

A project engineer with the Microelectronics division in Blue Bell, Pa., William F. Allen is responsible for design and applications of linear IC's. He holds a master's degree from the University of Pennsylvania.

Circuit design

Designer's casebook

Designer's casebook is a regular feature in Electronics. Readers are invited to submit novel circuit ideas, packaging schemes, or other unusual solutions to design problems. Descriptions should be short. We'll pay $50 for each item published.

SCR takes bounce out of switching

By Roy A. Wilson

Hycon Manufacturing Co., Monrovia, Calif.

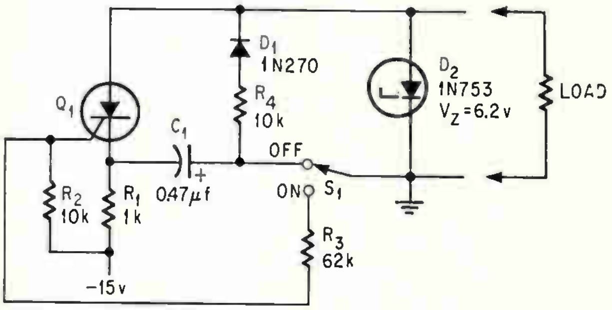
Logic-level signals generated by a pushbutton or toggle switch may be followed by a false triggering signal or noise voltage if the switch contact bounces. Turning on a silicon controlled rectifier with the switch makes it bounceless. The SCR circuit consumes no quiescent power, unlike the flip-flops and one-shots customarily used to overcome contact bounce.

With the switch, S_1, in the off position, capacitor C_1 charges to −15 volts through resistor R_1 when power is first applied to the circuit.

If S_1 is toggled to the on position, the silicon controlled rectifier also turns on, and stays on, regardless of any bounce S_1 may have. The 2 volts applied to the SCR gate, Q_1, through the voltage divider, R_2 and R_3, is positive with respect to the cathode.

When Q_1 is conducting, C_1 discharges through the SCR, diode D_1, and resistor R_4. The zener diode, D_2, clamps the voltage across the load. When S_1 returns to the off position, a shunting path for the SCR current is provided through C_1, momentarily dropping the current below Q_1's holding value. Therefore, the SCR turns off and stays off, since R_2 and R_3 have been switched out.

Now, D_1 prevents the capacitor from being charged through the load during the time that the switch contact might bounce on again. The chance of the circuit generating a false transient signal is eliminated.



Tandem switch. Silicon controlled rectifier turns on and off with switch positions, but not with contact bounce.

Unijunction improves timing-circuit accuracy

By Arthur J. Lim

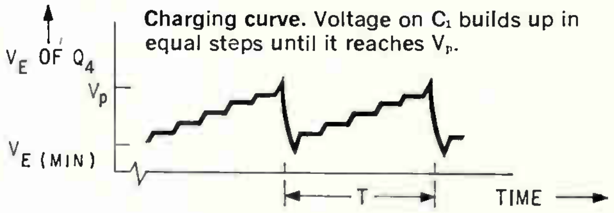
University of California, Brain Research Institute, Los Angeles

An inexpensive timer that maintains 2% accuracy over a wide variable range is accomplished by driving a unijunction trigger pulse generator with an astable multivibrator. The circuit consists of conventional components including a metalized-paper timing capacitor having an epoxy transistor current source.

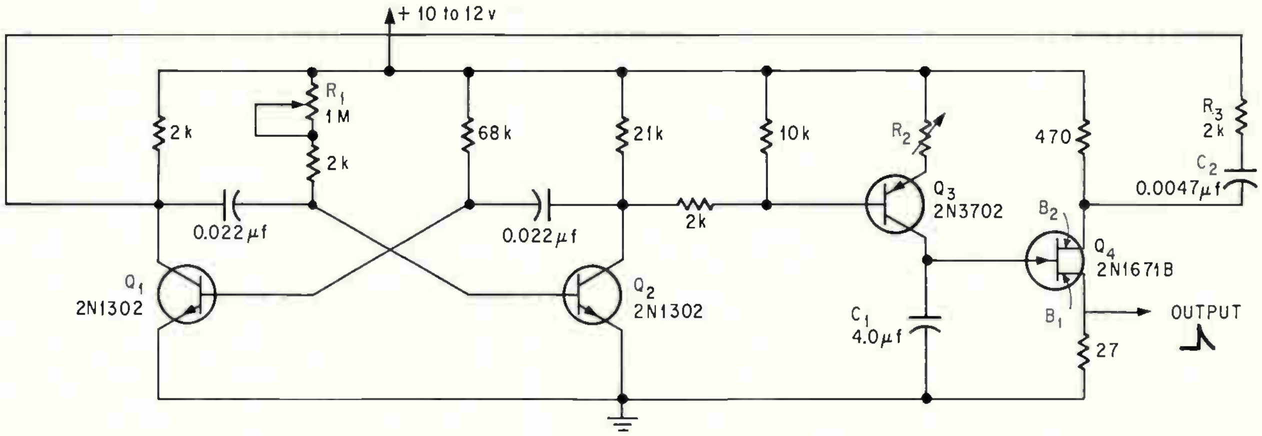
In the circuit, the astable multivibrator formed by Q_1 and Q_2 operates as a variable-frequency pulse generator whose alternate half-cycle pulses turn on transistor Q_3. Transistor Q_3 places a small charge on capacitor C_1. The charging curve shows how the voltage steps on C_1 builds up until they reach V_p, the peak point of unijunction transistor Q_4. Then Q_4 fires, generating a timing pulse.

Leakage currents discharge some voltage on C_1 when the current source, Q_3, is not conducting. At a given multivibrator frequency, the off-times for Q_3 are equal; thus, V_p is always reached by the accumulated voltage steps on C_1. Since the timing period T is the sum of the fixed identical voltage steps, this period remains constant despite leakage and the timer's accuracy is not impaired.

The voltage on C_1 need not equal V_p to trip unijunction Q_4. Before the voltage on C_1 reaches V_p, the pulse's negative trailing edge at the base of Q_2 is transmitted to base 2 of Q_4 via R_3 and C_2. This negative voltage lowers V_p momentarily so



Charging curve. Voltage on C_1 builds up in equal steps until it reaches V_p.



Timing circuit. Multivibrator Q_1-Q_2 drives Q_3 until C_1 charges up V_P and trips Q_4 generating a triggering pulse.

that a voltage on C_1, which is less than the previous V_p, is sufficient to trigger Q_4.

Varying R_2 from 1 kilohm to 10 megohms gives a range from about 4 milliseconds to 32 minutes. Fine adjustment is handled through rheostat R_1, which provides a linear variation of about a 100:1. The breadboard model had a timing accuracy of $\pm 2\%$ for a temperature range of $+15°$ to $+35°C$ and for a voltage range of 10 to 20 volts.

The timing period, T, can be expressed by

$$T = \frac{C_3\,[V_p - V_{E(min)}]}{nI_3 - I_L}$$

where n is the duty cycle of Q_2, I_3 is the on current from Q_3, I_L is the sum of leakage currents, and $V_{E(min)}$ is the minimum emitter voltage of Q_4 in repetitive operation.

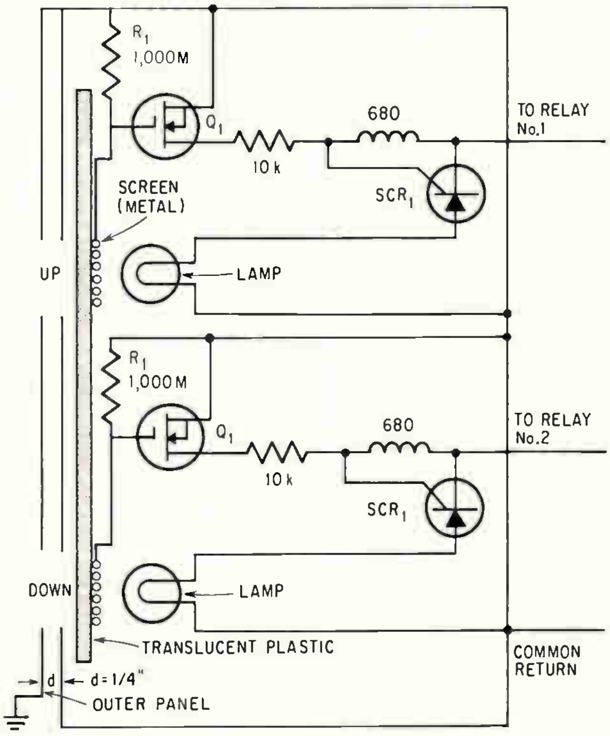
MOS FET takes the push out of elevator push button

By Fred G. Geil

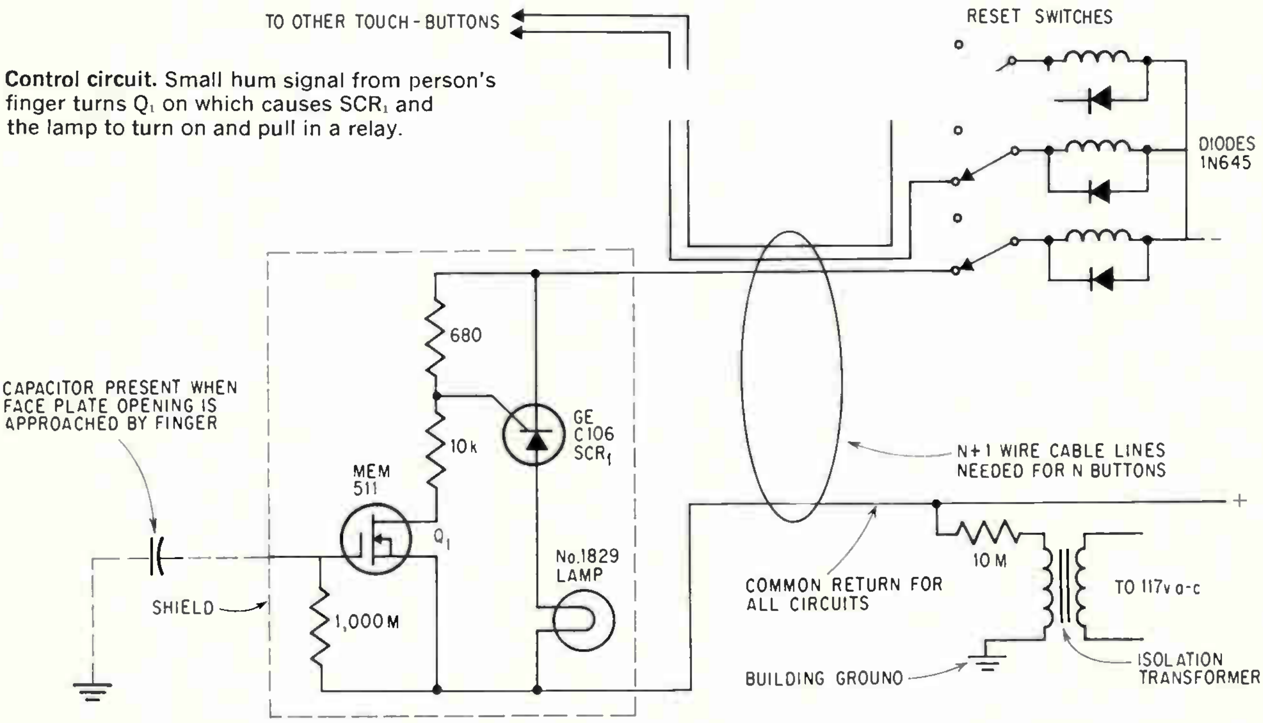
Westinghouse Electric Corp., Pittsburgh

Because modern elevators are automatically controlled, buzzer systems are no longer used to bring the vehicle up or down. Instead, the signaling is accomplished with a field effect transistor and capacitor coupling. As an elevator rider places his finger near the up or down button, a hum signal from the building ground, which has been capacitively coupled through his body, is picked up by a sensing screen. The screen passes the signal to a MOS FET lamp driver that turns on a lamp behind the direction selected and fires the appropriate elevator command relay. Since the system operates capacitively, the control can be triggered by a person wearing gloves.

The metal sensing screen is connected to the gate of Q_1, MEM511. Because the input impedance of Q_1 is extremely high, the tiny 60-cycle hum signal coupled to the screen by the person's finger is sufficient to saturate and cut off Q_1 60 times per



Physical layout. Metal screens placed opposite the two openings in the face place (and behind the translucent plastic slab) are connected to the gates of the MOS FET's Q_1 and Q_1'.



Control circuit. Small hum signal from person's finger turns Q_1 on which causes SCR_1 and the lamp to turn on and pull in a relay.

second. The first time Q_1 turns on, the silicon controlled rectifier SCR_1 also turns on and lights the lamp. The resulting lamp current is sufficient to pull in a relay in the control center and hold it in until the circuit is reset. The MOS field effect transistor, Q_1, provides its own internal protection against excessive gate voltage; this protection is important because a person may be carrying a relatively high charge when his finger approaches the elevator control.

The circuit is mounted in a shielded box, as shown, to prevent stray capacitances from tripping the control. Circuit's sensitivity is varied by changing the value of R_1, a 680-ohm resistor.

Capacitors sensor monitors stored liquid levels

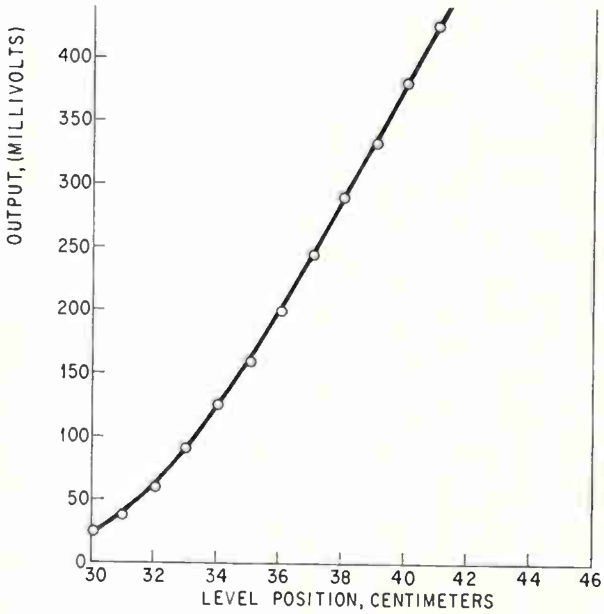
By P. K. Mital

Division of Applied Physics, National Research Council, Ottawa, Canada

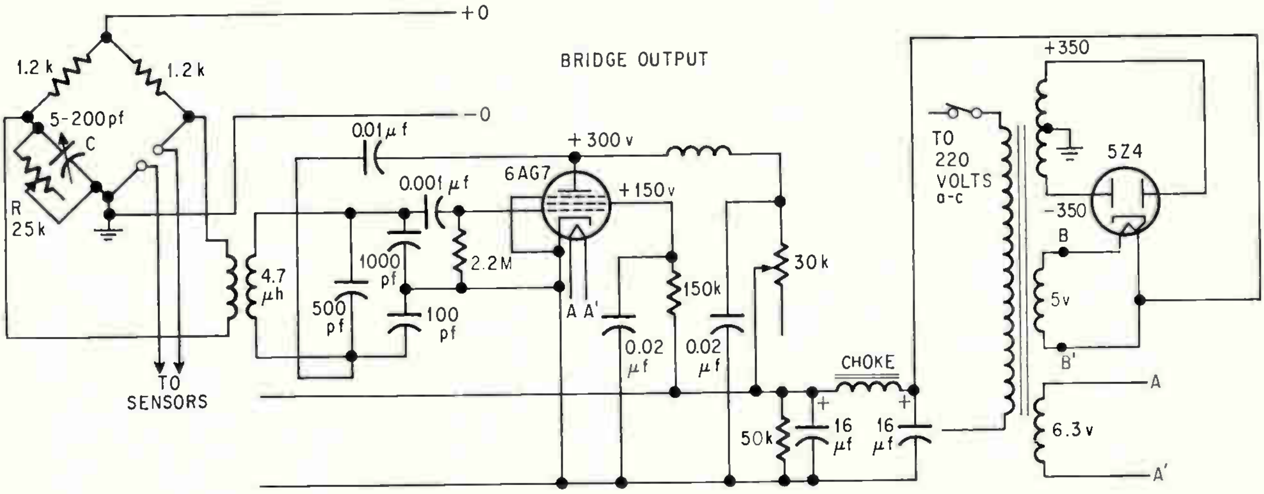
A simple variable-capacitance sensor connected in a bridge circuit monitors the level of liquid stored in a tank. The sensor is placed around a glass gauge outside the tank. As the liquid's level changes, so does the capacitance across the sensor and the output of the bridge.

The sensor consists of two electrodes, 1 millimeter thick, made of either brass or stainless steel and held by clamps.

A coaxial cable connects the electrodes to one arm of the bridge and a 3.2-megahertz oscillator supplies the bridge with 10-volt excitation. To prevent stray fields, an aluminum shield is placed



Bridge output. For ordinary water, bridge output varies linearly over 450-millivolt range as liquid level rises from 34 to 44 centimeters. Electrode size is 15.5 cms.



Bridge circuit. Sensors, whose capacitance depends on liquid level, being monitored, are placed in one arm of bridge circuit. As capacitance varies, so does the output of the unbalanced bridge.

over the electrodes and protected leads carry the signal from the oscillator to the bridge.

The bridge is first balanced for minimum output —a few microvolts—by adjusting C and R when the liquid is at the top of the electrodes. Tests were run with three lengths of electrodes—4, 7 and 15.5 centimeters—placed around the guide tube, whose outside diameter was 1.5 cm. The longer electrodes had the greatest detection sensitivity as the level of liquid changed—5 millivolts rms per millimeter change of level, compared with 2.6 and 3.4 mv per mm for the 4- and 7-mm long electrodes.

Liquids tested	Detection sensitivity (RMS) mv/mm
Double distilled water	4
Potassium hydroxide solution, pH 10	4.9
Potassium hydroxide solution, pH 8	4.9
Methyl alcohol	3.2
Ethyl acetate	0.7
Acetone (commercial)	2.3
Amyl acetate	0.7
Aml alcohol	1.9
Methyl ethyl ketone	2.5

Time delay stretched with new bias scheme

By Arthur L. Plevy

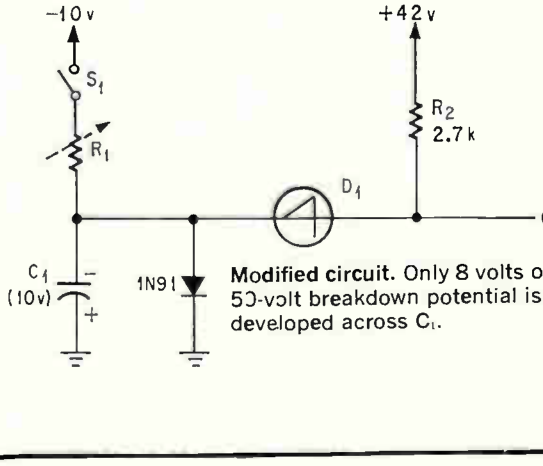
East Brunswick, N.J.

Time delays as long as half an hour occur when a Schockley diode is biased with small voltage-rated capacitors and large resistors. Incorporated in the power supply of a computer's printer, for example, this circuit delays the operation until the character drum reaches synchronous speed.

In conventional circuits, large capacitances produce the desired RC time constant because the timing resistor's size is limited by the holding current for the Schockley diode, D_1. Capacitor size is further reduced by biasing the diode so that only 8 volts of the 50-volt breakdown potential is developed across the timing capacitor; usually, the the entire breakdown voltage is across the timing capacitor, requiring high-voltage capacitors.

The modified circuit, however, does not require a large capacitor to produce long time delays. When the anode of D_1 is tied to a 42-volt supply, C_1 need only supply the remaining portion (−8 volts) of D_1's 50-volt breakdown voltage.

Resistor R_2 provides ample holding current and fixes the size of timing resistor R_1; hence, R_1 may be made as large as necessary to obtain the desired R_1C_1 time constant and C_1 may be made proportionally small. Diode D_1 is a 4E50.



Modified circuit. Only 8 volts of D_1's 50-volt breakdown potential is developed across C_1.

Equivalent circuits estimate damage from nuclear radiation

Using device models, circuit designers can calculate the effects on components and then compute the over-all response of a circuit

By Joseph T. Finnell Jr., David D. Bertetti and Fred W. Karpowich

Missile System Division, Avco Corp., Wilmington, Mass.

Radiation from a nuclear weapons explosion can make even a simple, one-transistor amplifier behave as though gremlins were on the loose in the circuit. Although the effects can be explained by physicists' formulas, radiation-equivalent circuits give engineers a better picture of what happens.

The schematic representations are also in tune with the times. Until recently, the many studies of radiation effects on components were primarily research efforts. Now, the emphasis has shifted to practical circuit development, particularly when it comes to aerospace systems. Design times can be shortened and confidence in a circuit's survivability increased when an analysis is made of radiation models, in conjunction with radiation-effects tests.

Breadboards vs computers

Experienced designers of hardened circuits often find that breadboarding a design idea and testing it with a radiation simulator is more effective than doing rigorous design analysis, which can be so complex that a computer is required.

But it must be kept in mind that there is no laboratory substitute for the mix of radiations in a real weapons environment. Instead, the effects of neutrons and gamma radiation must be checked out in separate test facilities. Special pulsed reactors are used to simulate the brief but strong fluxes of fast neutrons, and flash X-ray machines or linear electron accelerators are used to simulate gamma-ray doses.

Because the designer's chief concern is over-all circuit response to the radiation mix, a great deal depends on the designer's ability to correlate the data from the separate tests. Each type of radiation causes a variety of effects—some transient, some permanent—and a variety of responses. Over-all response stems from the interaction of the effects on different components.

In the analytical approach, the effects on each component are first estimated and then represented as components, current generators, and perturbations to existing components in the equivalent circuit. These estimates can sometimes be based on radiation-effects data gathered in previous research programs. But, for the most part, they must be based on new radiation-simulated experiments.

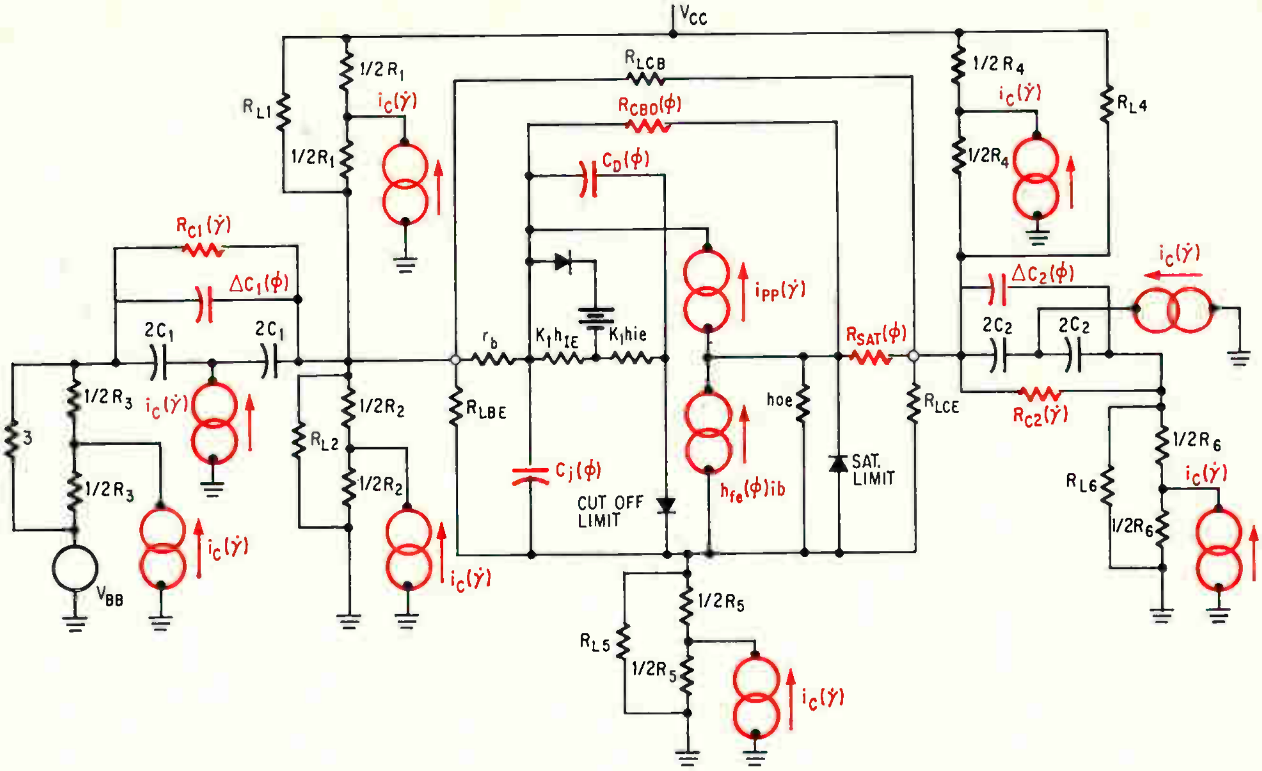
Since a circuit is a matrix of components, radiation effects represented in the components' equivalent circuits add up in matrix fashion. The complexity of a radiation equivalent circuit is evidenced by the schematic on page 74 of a common-emitter amplifier. This circuit shows how equivalent circuits for transistors, resistors, and capacitors can be combined.

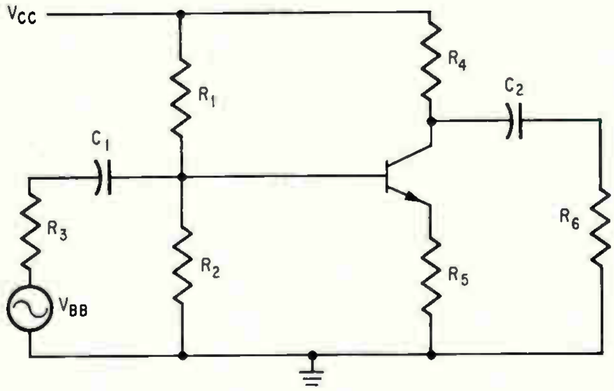
Such a schematic can be rendered into a set of nodal or state-variable equations. The equations must be solved with analog or digital computers—a pencil and paper attack on the problem is a hopeless task, because inhomogenous and nonlinear elements crop up in the 20 or more simultaneous equations used in the solution.

Despite careful component selection and use of

A closer look

"Designing for the worst of worst cases—nuclear war" [Electronics, Aug. 21, p. 99] detailed the nature of a nuclear weapons environment. It also summarized the effects of radiation on electronic circuits and some of the techniques employed to offset them. In this article, a more detailed picture is presented of what has been learned about these effects on all types of electron components, and how they disrupt the operation of solid state circuits.





Radiation amplifier. Complex equivalent circuit, above, is needed to explain the effect of gamma radiation and neutron bombardment on the simple common-emitter amplifier, at left. Circuit parameters shown in color are functions of radiation. The radiation-induced photocurrents and Compton electron replacement currents cause components to act as miniature generators.

good design practice, such an analysis might indicate that a circuit could not withstand the expected radiation environment. In that case, other measures can be taken, such as the use of circumvention redundancy, gamma-ray sensing circuit desensitizers, or complete redesign—perhaps even to consider a different approach to the problem and eliminate certain types of circuitry.

Transient and permanent effects

High-energy gamma rays and neutrons—those with energies above 1 million electron volts (Mev)—are the most troublesome radiations in the weapons environment. Either kind can cause transient or permanent alteration of component characteristics, rendering a circuit inoperable.

Permanent change, of course, is an irrecoverable alteration in properties, such as occurs with dislocation of the crystal lattice in semiconductor devices. A typical transient effect is the generation of photocurrents. Some designers loosely define any effect lasting longer than a required recovery time as permanent degradation—in a practical sense, a circuit that doesn't recover in time to do its job on a mission has failed.

The radiation spectrum from a nuclear explosion is rich in gamma rays with energies above 1 Mev. At that level, transient changes due to ionization of materials in and near the components can be severe. The gamma rays give up energy in the materials through formation of electron-hole pairs, photoelectric effects, and Compton effect (freezing, or scattering, of electrons). These effects generate photocurrents in semiconductors, change the conductivities of conductors and insulators, and create leakage paths in component packages. The absorption of large doses of gamma energy by the materials can severely overheat the components.

The charge imbalance created by the Compton effect can cause passive, as well as active, components to generate spurious current pulses in the circuit. Most of the freed electrons have energies in the million-electron-volt range, and many of them escape from the body of the component part. They are replaced by electrons drawn from ground, generating a current pulse called the Compton replacement current. The shape of the Compton current pulse depends on circuit impedance to ground and the shape of the gamma pulse—that is, the rapidity with which the radiation intensity rises and falls.

Furthermore, destructive secondary effects often arise from the transient primary effects. For example, transistors will amplify the primary photocurrents, often to saturation. The circuit can be driven into a mode of operation that raises current or temperature levels beyond the safe operating margins of the components.

Bombardment of the materials with neutrons more energetic than 1 Mev can cause all the ionization ailments and then some. As the neutrons hit the atoms in the component materials, they produce crystal dislocations and other irrecoverable forms of damage. Only a portion of the neutron energy is lost in this fashion. Studies at the Sandia Corp. show that the degree of ionization depends on the energy given up by the neutrons.[1] As can be seen in the curve for silicon at the right, the percentage of neutron energy that goes into ionization rises with neutron energy.

Transients in transistors

Production of numerous hole-electron pairs in and near carrier depletion regions make each transistor and diode act like a tiny, additional power source in the circuit. The pairs are excess carriers whose net effect is generation of a primary photocurrent, I_{pp}, at the diffused junctions.

In transistors, I_{pp} is produced by the charge-segregating action of the base-to-collector and base-to-emitter junctions. If this occurs while the transistor is drawing normal circuit-operating power, the transistor amplifies part of the primary photocurrent, giving a larger, secondary photocurrent, I_{sp}.

As long as circuit operation remains linear, I_{sp} is roughly proportional to I_{pp} times transistor gain, β. The photocurrents are incremental changes in the transistor operating currents, I_{CO} and I_{BO}.

The primary photocurrent splits into two parts, as in the simplified model, at the right, of a transistor in a radiation environment. One part, I_{pp1}, flows into the circuit outside the transistor. The second part, I_{pp2}, flows into the transistor's emitter and is treated by the transistor as a base-drive current. Therefore, I_{sp} is a collector-to-emitter current

$$I_{sp} \approx \beta I_{pp2} \quad (1)$$

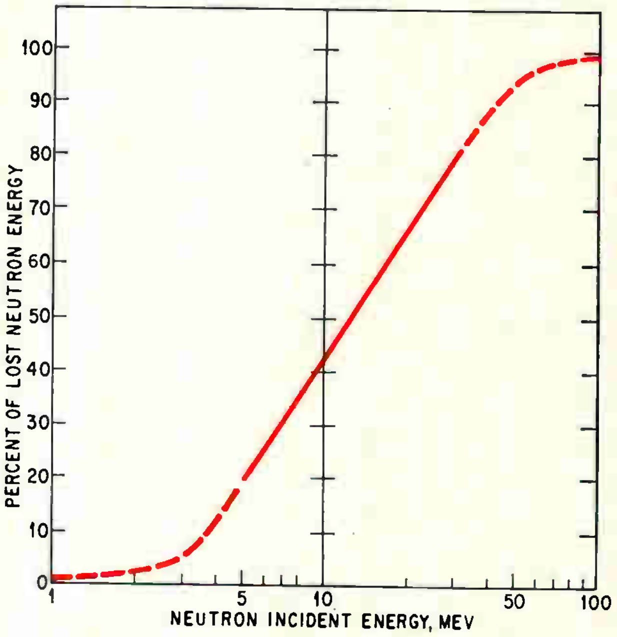
and total collector current, I_C', is

$$I_C' \approx \beta I_{pp2} + I_{pp} + I_C(0) \quad (2)$$

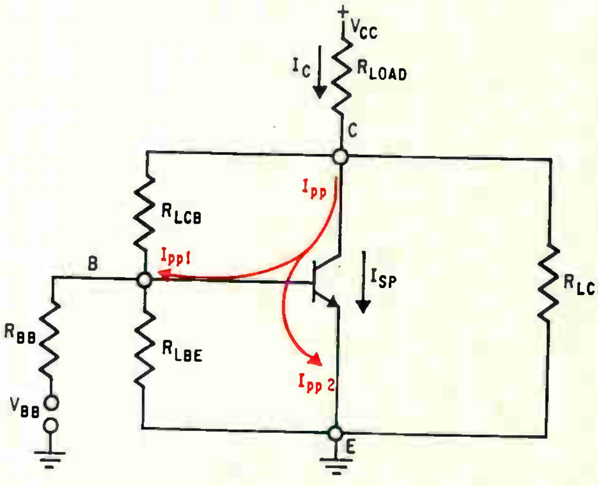
This relationship fails to hold true if the transistor current rises to saturation and no longer operates linearly. Intense ionizing radiations tend to drive transistors into saturation, where they remain for some time after the radiation pulse ends.

Creation of leakage paths in the transistor packaging (or in the passivation oxide on the silicon crystal) is of less significance. Experience has shown that, as a practical matter, leakage won't make circuit operation worse if the transistors have already been driven into saturation by the photocurrents. The leakage varies with packaging materials. It is shown as three resistances in the transistor model, since it shunts the emitter, base, and collector connections, E, B, and C.

Primary photocurrent levels in nonsaturated transistors fall in the ranges tabulated on the following page. The ranges are not clear-cut; there are isolated cases of overlap. The values were measured while transistors were irradiated by linear electron accelerators. Generally, direct measurement using



Silicon vs neutrons. Some of the energy lost by neutrons in silicon acts as ionizing radiation. The percentage of energy causing ionization increases with the incident energy of the neutrons.



Irradiated transistor. Photocurrent produced in a transistor by ionizing radiation is amplified. The primary photocurrent splits two ways.

Primary photocurrents in transistors

Transistor class	Approximate photocurrent (μa per megarad/sec)
High-frequency switches	
low-power	1 to 10
medium power	10 to 100
High-frequency power switches	
P_c between 1 and 10 watts	50 to 500
P_c between 10 and 150 watts	500 to 5,000

a gamma-ray simulator (flash X ray or linear electron accelerator) is needed to determine how much primary photocurrent will be produced in a given transistor.

Further information on transient effects in transistors and diodes is contained in the TREE Handbook (transient radiation effects on electronics).[2]

High fluence, low gain

Bombardment is a good term for neutron irradiation because these atomic particles can break up a crystal lattice structure, causing displacements in crystals, called cluster defects. Neutron damage in solid state circuits usually shows up as a decrease in the forward current gain of transistors.

When neutrons collide with atoms in a crystal, energy is transferred from the neutrons to the atoms. If the energy transferred exceeds the level that normally binds the atoms into the crystal lattice, the atom will break free and move about. Some of these atoms move to interstitial positions, leaving vacancies at positions normally occupied in the lattice. In silicon, the interstitial atoms act as weak n-type doping, while the vacancy clusters act as stronger p-type doping (electron traps). In effect, the transistor is doped in a manner not anticipated by the device processors, and gain and other characteristics suffer.

The gain variation with neutron fluence is given by[3, 4]

$$\frac{\beta}{\beta_0} = \frac{1}{1 + \frac{1.22}{2\pi}\frac{\phi\beta_0}{f_2\,k}} \qquad (3)$$

Ideally, the damage constant, K, would depend entirely on the semiconductor material, and the alpha cutoff frequency, f, would account for device geometry, doping levels, and material variations. In practice, K varies slightly in transistors of the same type, and widely in transistors of different types. Experimental measurements in reactors generally yield K values between 10^5 and 10^7. Typically, a transistor will begin to lose gain rapidly when neutron fluence exceeds about 10^{12} n/cm^2 and will cease amplifying at about 10^{15} n/cm^2.

However, some specially made transistors are guaranteed to retain 15% or more of their initial gain at 10^{15} n/cm^2. These hardened transistors are doped so that minority carriers in the base have very short lifetimes, and the base width is made small enough to provide gain. Such devices have an f in the gigahertz range. Since carrier lifetime is shorter than in conventional transistors, creation of lattice vacancies during neutron bombardment results in markedly less relative change in average lifetime. Therefore, the damage constant is high—about 10^7 n-sec/cm^2.

If the gain of such a hardened transistor is initially 100, one can predict with equation 3 that gain will be 34 at fluence of 10^{15} n/cm^2.

The gain loss due to dislocations is more or less permanent. At first, there is considerable chaos just after the pulse passes its peak. If in this state the transistor has any gain at all, it indicates the pulse of neutrons wasn't very powerful. The process of the lattice coming to equilibrium is called fast annealing.

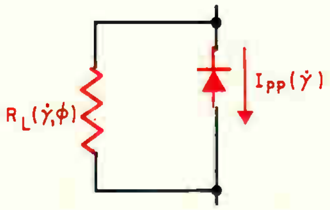
The transient loss of gain may be many times as great as the permanent loss, and annealing time can be as short as 100 microseconds or as long as many milliseconds. Designers worry more about the transient than the permanent losses when a circuit must operate during or immediately after neutron exposure. The loss and recovery is difficult to calculate, so it is generally measured in a pulsed reactor whose neutron pulse output (of a few hundred microseconds) approximates the anticipated weapons environment.

Neutrons also cause permanent degradation of cutoff-collector current, collector-to-emitter voltage, collector-saturation voltage, and the equivalent circuit base resistances. Often, the changes are small and the effect on circuit operation inconsequential. But some transistors undergo large changes, so these characteristics, too, are generally checked out in a nuclear reactor.

Gamma heating

Gamma rays cause essentially the same lattice-displacement effects as neutrons, but these are far less troublesome in semiconductor devices than the heat generated by gamma irradiation. In fact, they are negligible in the mixed environment of a nuclear explosion.

The most dangerous gammas are the prompt ones —those emanating in less than a microsecond from the explosion rather than those radiating from the fireball or caused by neutron capture in atmospheric nitrogen. A circuit must be very close to an explosion to receive a million-rad dose of prompt gammas—so close that often the dominant damage mechanisms will be neutron bombardment, shock from the blast, and thermal radiation. Likewise, the direct heating of a semiconductor device can be fatal when the gamma dose exceeds 10^7 rads in less than a microsecond—but the size of the dose will be of no consequence if the circuit has already been destroyed or rendered inoperable by the other transient



Diode model. Photocurrent generation and insulation leakage are the main effects of radiation on diodes.

Definitions of terms

Term	Definition	Units
I_{pp}	Primary photocurrent in transistors and diodes	amps
$\dot{\gamma}$	Gamma-ray dose rate	roentgen/second or rads/second (Si)
γ	Gamma-ray dose	rads
ϕ	Neutron fluence	n/cm^2
fluence	Time-integrated flux	$particles/cm^2$
flux	Rate of flow of particles or energy per unit area	$particles/cm^2/sec$
I_{sp}	Transistor secondary photocurrent	amps
β, h_{fe}	Transistor small signal forward current gain	(dimensionless)
β_o	Initial current gain	(dimensionless)
$f\alpha$	Transistor α cutoff frequency	hertz
K	neutron-damage constant	$neutron\text{-}seconds/cm^2$
I_{CBO}	Transistor cutoff collector current	amps
V_{CE}	Collector-to-emitter voltage drop	volts
V_{BE}	Base-to-emitter voltage drop	volts
$R_{(sat)}$	Collector saturation resistance	ohms
γ_b	T equivalent circuit base resistance	ohms
γ_e	T equivalent circuit emitter resistance	ohms
rad	Radiation absorbed dose (100 ergs/gram) referenced to the material in which absorbed eg. 10^5 rads (silicon)	rads
roentgen	Radiation dose unit (83.8 ergs per gram deposited in dry air at STP)	roentgen
Curie	Radioactive source strength 3.7×10^{10} disintegrations per second	curie
$i_c(\dot{\gamma})$	Compton scattering current from electronic components as a function of gamma-dot	amps
Δ E	Energy absorbed from a gamma-ray field by a slab of material	ergs
E_o	Incident energy in gamma-ray field on surface of slot of material	ergs
γ (E)	Normalized gamma-ray spectrum—function of energy	fraction/unit E/cm^2
σ (E)	Material absorption cross-section—function of energy	cm^2
R_s	Capacitor shunt resistance	ohms
$\epsilon\epsilon_o$	Absolute dielectric constant	farads/meter
C	Capacitance	farads
σ	Conductivity	mho/meter
R_s $(\dot{\gamma}, \phi)$	Leakage or shunt resistance	ohms
i_b	Transistor base current	amps
h_{ie}	Hybrid parameters (common-emitter transistor)	ohms
h_{oe}	Hybrid parameters (common-emitter transistor)	mhos
h_{re}, h_{fe}	Hybrid parameters (common-emitter transistor)	(dimensionless)

and permanent effects. A prompt gamma dose of 10^7 rads will heat silicon to 130°C.

What is of primary concern to the designer is the cumulative heating of the semiconductor. Gamma energy that is converted to thermal energy, ambient temperature, normal power dissipation, and abnormal power dissipation as the result of transient photocurrents, can quickly add up to an operating temperature higher than the component was built to withstand. Or, in any event, it can produce the operating degradations generally associated with high component temperatures.

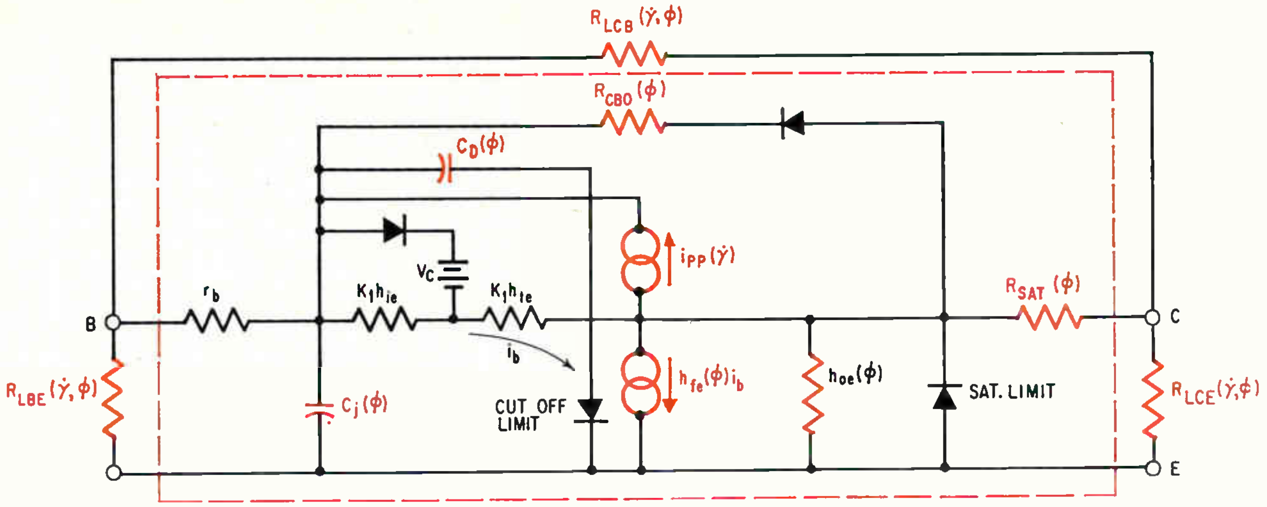
When the gamma pulse lasts a microsecond or less, the heating is assumed to be adiabatic—that is, the device's temperature rises instantaneously and there is no opportunity for heat to flow from the device to a heat sink. In the adiabatic case

$$\Delta T = \frac{\text{rads} \times 10^{-5}}{2.39 \times \text{specific heat}} \qquad (4)$$

In the preceding equation, ΔT represents the temperature rise and specific heat of the semiconductor material.

In most cases where the gamma dose is intense enough to cause overheating, the circuit will also be driven into saturation by photocurrents and Compton currents. Therefore, the gamma heating in an operating circuit is augmented by I^2R heating at saturation.

As the duration of gamma pulses go beyond a microsecond, heating becomes less and less adiabatic. The temperature rise will be less severe at a given gamma dose since some of the heat will have time to flow out to the heat sink while the component is being irradiated. How much less heat depends on the width of the gamma pulse, flow rates of heat in the silicon, and the conductivity of the thermal path to the heat sink. Likewise, heating due to photocurrents will be more severe at saturation if the tran-



Transistor equivalent. Common-emitter equivalent circuit of npn transistor (dashed area) sorts out changes in characteristics caused by radiation and is accurate enough to be used in circuit-analysis applications.

sistor's storage time is much longer than a microsecond.

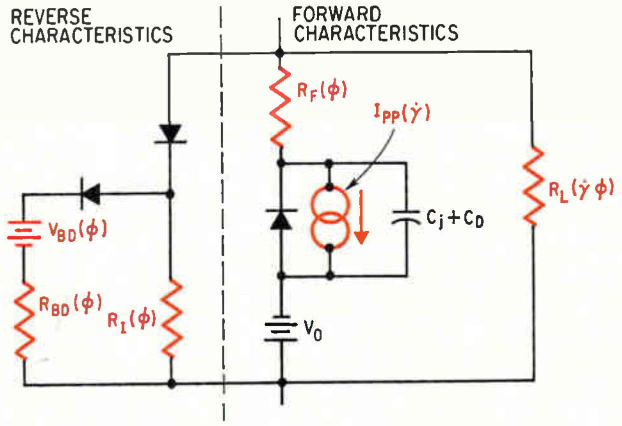
Semiconductor diodes are damaged in much the same ways as transistors.

During gamma irradiation, a primary photocurrent is produced by the charge-segregating action of the p-n junction, as indicated in the model on page 76. Of course, there is no secondary photocurrent—since diodes do not amplify—but diodes are subject to the secondary photocurrents generated by transistors in the circuit. And, as in transistors, leakage paths arise in the diode insulation.

Damaged diodes

Permanent damage from lattice displacements shows up mainly as shorter carrier lifetimes. The resulting changes in reverse characteristics are not well behaved. It has been observed in some cases that identical diodes, tested side by side in a reactor, exhibit increases or decreases in avalanche- or zener-breakdown voltage, reverse-leakage current, and breakdown or zener resistance.

Forward saturation resistance and leakage both increase. Slight changes may occur in junction capacitance and diffusion capacitance, but these changes have negligible effects unless capacitance values are critical to circuit operating stability.



Diode equivalent. Forward and reverse characteristics of diodes are represented in this circuit-design model.

Semiconductor equivalent circuits

Although simplified models of transistors and diodes are sufficient to visualize effects, they aren't precise enough for design work. The equivalent circuits on this page are adequate engineering models for most cases.

The transistor is shown in a common-emitter configuration, with the primary photocurrent between the collector and base. K_1 is a dimensionless constant that mixes "hybrid" and "T" parameters for this application. It is found with

$$K_1 = \frac{(1 + h_{fe})\, r_e}{(1 + h_{fe})\, r_e + r_b} \qquad (5)$$

After the variations in the conventional transistor parameters are found by experimentation in radiation simulators, the voltage and currents can be solved with the equivalent circuits.

Integrated circuits

Ionization-current effects are an order of magnitude greater in monolithic integrated circuits than in discrete circuits. The primary photocurrents, it must be remembered, arise in the junction area in discrete devices. Besides acting as junctions in transistors and diodes, p-n junctions are used for element isolation, for separating the elements from the silicon-crystal substrate, and for forming resistors and capacitors.

Moreover, as the photocurrents are generated, the combinations of isolation and substrate junctions create parasitic diode and transistor elements in the IC. Sometimes the substrate junction makes a nearby transistor act like a pnpn switch—a device that is very sensitive to ionizing radiation. The photocurrents can turn on the transistor and keep it on, a condition known as latchup.

A linear IC's transient response to radiation is dominated by secondary photocurrents. So the greater the gamma-dose rate (rads per unit time), the longer the time that IC's are saturated and operate nonlinearly. Digital IC's also saturate, but the major concern is whether they change state falsely during irradiation. Flip-flops sometimes reset in a symmetrical manner—that is, regardless of the control signals applied during saturation, there is an equal probability that they will be in either of their two states when they come out of saturation.

Transistor gain loss due to neutron bombardment is about equal for a transistor in an IC and a discrete transistor with a similar geometry, base-region design, and cutoff frequency. The diffused resistors and capacitors used in IC's are much more vulnerable than their discrete counterparts because they are formed with p-n junctions. Leakage and other surface effects, however, are less pronounced in IC's than in discrete components—perhaps because the protective oxide on the silicon is more carefully controlled during the production of the circuit than during production of a discrete semiconductor device.

Fairly hard IC's are being produced by the silicon-dioxide isolation technique. Essentially, this separates the elements into discrete devices surrounded by dielectric. Radiation photocurrents are reduced by an order of magnitude back to the discrete-transistor range by elimination of isolation and substrate junctions. Without the extra junctions, parasitic elements and latchup cannot occur, and digital IC's are less likely to change state.

No significant further progress in IC hardening can be expected without more basic research in IC production techniques. For example, initial tests indicate that replacing silicon dioxide with silicon nitride for surface passivation and dielectric isolation substantially improves resistance to ionizing radiation. Both the International Business Machines Corp. and the Sperry Rand Corp. are developing techniques for silicon-nitride isolation.

Ionization increases a material's conductivity in most cases, so the obvious effect of irradiating a resistor is a lowering of resistance values. But don't count on it. The conductivity increases and the formation of leakage paths in the resistor package may be offset by other changes that add to bulk resistivity.

Carbon and resistive wire, for example, lose resistivity. Yet, some carbon-composition, carbon-film, and even some wirewound resistors show slight over-all increases in resistance. Perhaps the increases are due to structural changes. The damage mechanisms in resistive materials are not as well understood as those in other materials. This is partly because the effects are inconsistent and partly because resistors have been studied less than other components.

Resistor shunts

In a circuit, a decrease in a resistor's value has the effect of placing a shunt resistor in parallel with the actual resistor, as in the equivalent circuit at the right. Shunt values of 1 to 100 megohms have been observed at gamma-ray dose rates of 10^7 rads/second. Since parallel resistances lower than

Neutron tolerance of resistors

Resistor type	Mild damage threshold (n/cm²)	Severe damage threshold (n/cm²)
Carbon composition	10^{13}	10^{16}
Metal film	3×10^{16}	5×10^{17}
Carbon film	10^{15}	10^{17}
Oxide film	2×10^{12}	2×10^{16}
Precision wirewound		
ceramic	5×10^{17}	10^{19}
epoxy	10^{15}	10^{19}

a megohm can crop up in a circuit at higher dose rates, the designer should consider how they would affect circuit operation. If the shunts could cause problems, the resistor characteristics should be measured in a gamma-ray simulator.

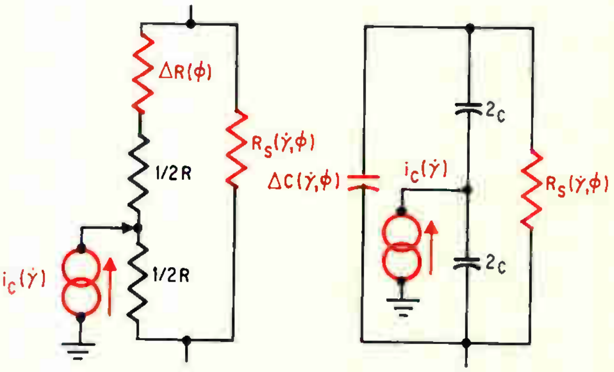
In the equivalent circuit, the series resistor $\Delta R (\gamma\phi)$ accounts for any resistance increases that gamma or neutron radiation may produce. $R_S (\gamma\phi)$ represents increase in conductivity of the resistive material and leakage through the insulating material of the resistor substrate or packaging materials.

Neutron bombardment will permanently change resistor values, but the change is generally small or negligible at fluences below 10^{15} n/cm². Even so, a circuit requiring precise resistor values could be in trouble at fluences less than 10^{14} n/cm².

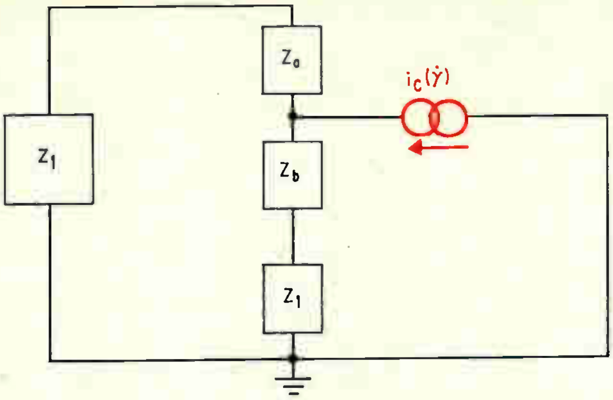
The permanent-damage thresholds tabulated above were obtained by measurements in fission-neutron flux, rather than a real fusion-fission neutron mixture, but are helpful in component selection. Insufficient data has been gathered on resistance variations to predict absolute changes in resistor values, so the designer must again measure changes experimentally and weigh the effect upon circuit operation.

Compton current

Absolute changes in the values of resistors—or capacitors, coils, and other passive components such as cables, batteries, etc.—generally perturb circuit operation less than the transient currents that can be generated in such components by the Compton effect. Like photocurrents, the Compton replacement currents are amplified by the operating



Resistor, capacitor. Changes in conductance and leakage, and Compton currents alter characteristics of resistors and capacitors.



Compton currents. The replacement-current model of resistor indicates how electrons are drawn from ground to replace Compton electrons escaping from component.

transistors and contribute to nonlinearities in circuit outputs, saturation, and latchup (in monolithic transistors).

Assuming that the scattering of Compton electrons is uniform, the Compton current, $i_c(\gamma)$, is considered to be injected from ground into the center of the component, as in the resistor equivalent circuit and in the Compton current model shown above. Similar models are used for components other than resistors. In the model, V_1, V_2, V_3 are nodal voltages, Z_a and Z_b are the impedances of the two halves of the component body, and Z_1 and Z_2 are the circuit's impedance to ground from both ends of the component.

A ballpark estimate of the Compton current in resistors can be obtained with

$$i_c(\gamma) \approx 10^{-12}\gamma \qquad (6)$$

where γ is the dose rate in rads per second.[2] One rad equals 100 ergs of absorbed energy per gram. Energy absorption varies with the material; hence the amount of gamma radiation in a rad also varies. The energy absorbed is calculated with

$$\Delta E = E_0 \int_0^\infty \gamma(E)\,\sigma(E)dE \qquad (7)$$

Terms are defined on page 77.

To determine Compton current in capacitors, one can multiply γ by 10^{-11} to 10^{-10}. Precise evaluation of Compton currents in any component requires experiments in gamma-ray simulators.

Changes in the conductivity of irradiated materials can cause greater leakage in capacitors than in resistors.

Conductance and annealing in capacitors

Capacitor Type	Maximum leakage conductance mho/μfd/ megarad/sec.	Dielectric long-time annealing time constant (seconds)
Aluminum oxide	3×10^3	unknown
Tantalum oxide	10^2	10^{-4}
Ceramic ($BaTiO_3$)	2	1
Glass and mica	10^4	1
Mylar	10^5	10^{-2} to 10^{-3}

A resistive material is essentially a conductor while a capacitor dielectric is essentially an insulator. Even though both might undergo an equal change in absolute conductivity, an insulator's relative change in conductivity could be many orders of magnitude greater, since its initial conductivity was nearly zero. Little ionizing radiation thus produces significant change in capacitor conductivity.

Conductive capacitors

The increase is considered by the circuit designer in much the same fashion as resistor leakage, and is shown as a shunt resistance, R_s, in the equivalent circuit on page 79 (R_s also includes radiation-induced leakage in the capacitor package). To calculate R_s as a function of gamma-dose rate, use

$$R_S = \frac{\epsilon\epsilon_0}{C\sigma} \qquad (8)$$

The radiation-induced conductivity, σ, is found by measurement in a gamma-ray simulator. A thorough discussion of this transient effect and much data useful for capacitor selection has been published in the TREE Handbook.[2] The edge effects are assumed negligible in this equation. Radiation effects in the types of capacitors employed in solid state circuits, along with the effects on other components, are given on the facing page.

Conductivity rises approximately as fast as intensity rises in the radiation pulse. However, it doesn't drop immediately when the radiation subsides. The time required for conductivity to drop to an acceptable level is determined experimentally —it may be as long as 1 second.

Over-all recovery—or annealing—time depends on the dielectric's chemical purity and other factors that determine which recovery time constant predominates. Typical values are given below left, along with leakage conductance. Total maximum conductance per megarad of radiation is obtained by multiplying the tabulated conductance by the capacitance in microfarads.

Blowouts

Much of the data on permanent damage to capacitors was obtained in reactors providing a mixture of fission neutrons and gamma rays[6]. In some instances, reactor-caused damage was found in capacitors exposed only to gamma rays, but the reasons for the damage aren't clear. Some capacitors have failed spectacularly, with minor explosions or eruptions of the cans or cases of certain types of oil-filled, oil-impregnated, and wet electrolytic capacitors. The radiation decomposed the liquid and caused a buildup of gas pressure.

Test results indicate:

- Glass, mica, and ceramic capacitors are highly resistant to damage. After exposure in a reactor pile to 10^{15} n/cm^2 of fast neutrons and more than 10^8 rads of gamma rays, capacitance and dielectric loss factors show slight—only a fraction of a percent—permanent changes, or none at all. In addition, the thermal-neutron level in the reactor pile may be

Principle effects of nuclear radiation on components

Component	Change	Damage	Primary cause
Transistor			
Operating currents	Increase, due to photo-currents	Transient, but could contribute to permanent damage	Production of hole-electron pairs by gamma rays
Gain	Decrease, due to change in minority carrier lifetime	Transient and/or permanent	Crystal dislocations by neutrons, some of which are annealed
Temperature	Increase	Transient and/or permanent	Heating by gamma rays, R_{SAT} by neutrons
Leakage	Increase	Transient	Insulator conductivity changes from ionization and neutron damage
Diode			
Reverse characteristics	Shift	Transient and/or permanent	Due at least in part to neutron damage
Forward saturation resistance	Increase	Transient and/or permanent	Neutron damage
Leakage	Increase	Transient and/or permanent	Same as transistor
Integrated circuit			
Transistor and diode characteristics	Same as discrete components, generally larger	Same as discrete components	Same as transistors and diodes, larger photocurrents in monolithic IC's because of additional junction areas
Spurious effects	Transistor turn on (latchup) can occur, due to photo-currents	Transient	Substrate junction forms pnpn switch with nearby transistor
Resistor			
Resistance	Generally decreases (sometimes increases)	Transient, generally	Materials conductivity changes, due to ionization and neutron damage
Spurious effects	Compton current generation	Transient	Electron scattering by gama rays
Capacitor			
Leakage	Increase	Transient, generally	Same as resistors plus electron trapping in dielectric
Spurious effects	Compton current generation	Transient	Same as resistors
Operation	Physical damage	Permanent	Gas evolution in liquid dielectrics by gamma heating
Vacuum tube			
Plate current	Increase	Transient	Secondary effect of Compton current generation by grids

10^{18} to 10^{20} n/cm^2 (a thermal neutron moves slowly and may have kinetic energy as low as 0.025 electron volt).

- Mylar capacitors and some types of polystyrene capacitors suffer little or no permanent damage from exposures to as much as 10^{15} n/cm^2 and 10^8 rads.
- Dry electrolytic aluminum and tantalum capacitors show minor permanent changes in capacitance and dissipation factors at 10^{14} n/cm^2 and 10^8 rads. The effects may possibly be caused more by the gamma dose than neutron fluence.
- Paper and some types of plastic capacitors can be severely damaged by gas evolution and dielectric changes. The tests exposed them for several days to approximately 10^{15} n/cm^2 of fast neutrons, 10^{18} n/cm^2 of thermal neutrons, and 10^8 rads. Long-time, gamma-ray soak tests in cobalt-60 piles, adding up to 10^8 or more rads, produce similar damage in some cases.

It is very difficult, if not impossible, to correlate accurately such test results with actual exposure to a nuclear explosion. Extent of the damage is apparently a function of the long exposure times. In contrast, an explosion would produce high-intensity gamma rays and fast neutrons for only a brief time.

Another significant difference is that the explosion spectrum outside the fireball contains hardly any thermal neutrons in comparison with the number of fast neutrons[7]. The number of thermal neutrons in conventional reactor piles exceeds the number of fast neutrons—at least in some of the cases cited. Thermal neutrons' low kinetic energy makes it unlikely that they will do any serious structural damage. However, thermal neutrons are readily absorbed by the nuclei of materials, making the materials radioactive. The half-lives of radioactive-insulating materials range from seconds to years. Emission of beta particles and gamma rays within the insulator keeps its conductivity higher than normal during that period. Since the conductivity change is persistent, it may be measured as permanent damage.

Vacuum tubes

Extensive studies have not been made of the vulnerability of vacuum tubes to ionizing radiations. However, degradation appears to be mainly transient effects of the Compton replacement current.

The grids are the chief source of Compton electrons scattered from the tube elements, so plate current increases as though a positive bias were applied to the grid. The higher conduction state persists until the replacement current can flow through the grid-bias network in the circuit. The amount of plate-current increase varies primarily with grid resistance and tube gain.

The Compton effect occurs whether the tubes are conventional glass-envelope types or ceramic-metal types. Much has been made of the radiation resistance of miniature ceramic-metal receiving tubes to radiation but this resistance shows up primarily in less damage from heat, neutrons, and physical shock.

Inductors and transformers, like resistors and capacitors, exhibit leakages and Compton currents.

The gamma-ray leakage effects in insulators, potting compounds, and printed circuit boards are similar to those in capacitor dielectrics. These effects are usually neglected by designers of hardened circuits in the early stages because they are negligible in comparison with other circuit perturbations caused by gamma rays. Fast neutrons also produce some leakage of a fairly permanent nature, and thermal neutrons produce the type of conductivity change discussed under capacitance.

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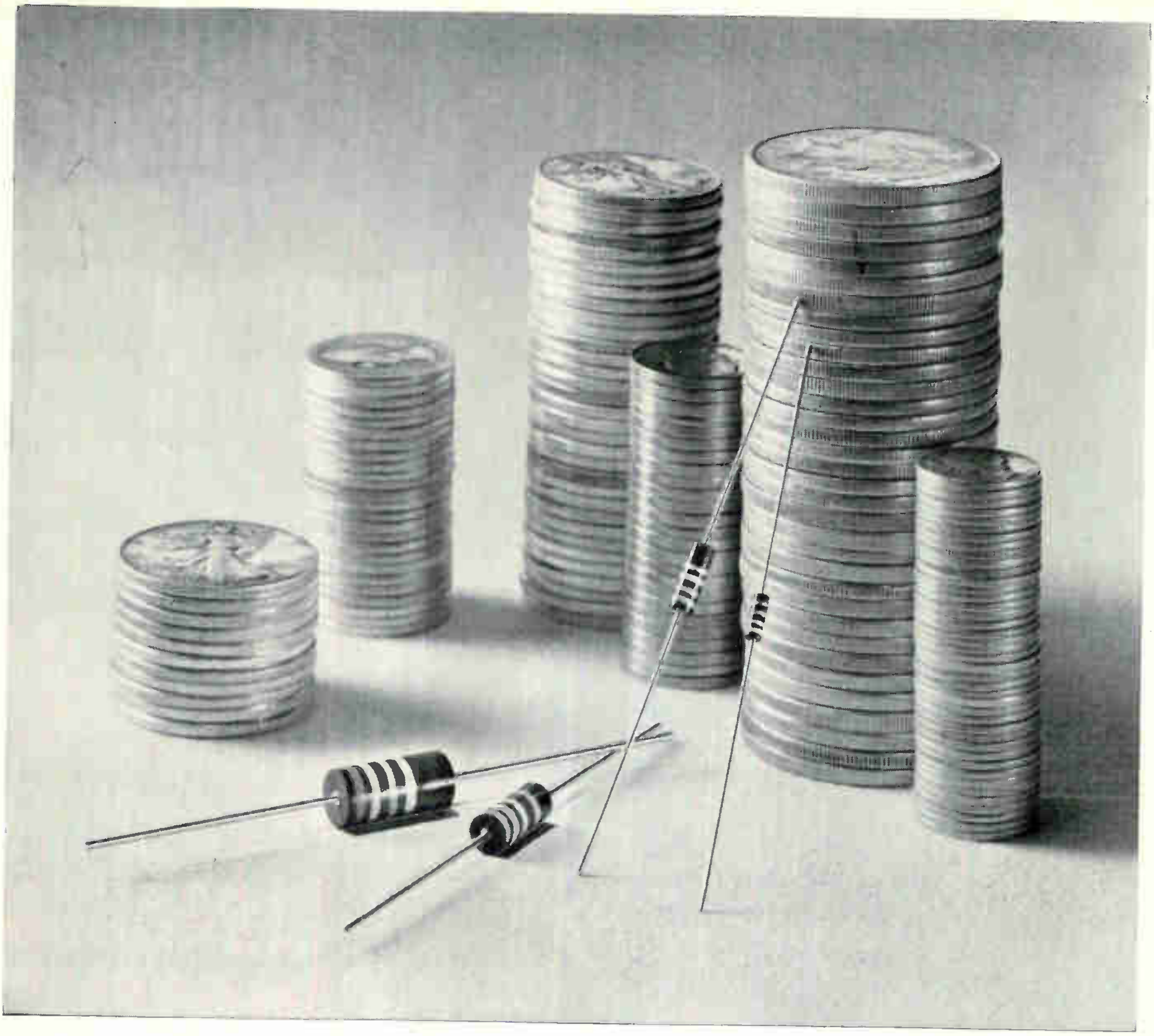
The authors

Joseph T. Finnell Jr., a 17-year veteran in military electronics, heads the section at the Avco Corp. that determines nuclear vulnerability of missile systems.

David D. Bertetti joined Avco's nuclear-effects section four years ago. He now heads the circuit design, analysis, and evaluation group of the section.

Fred W. Karpowich is studying transient-radiation effects. He designed hardened circuits at the Hughes Aircraft Co. and the Philco-Ford Corp. before joining Avco as a senior staff engineer.



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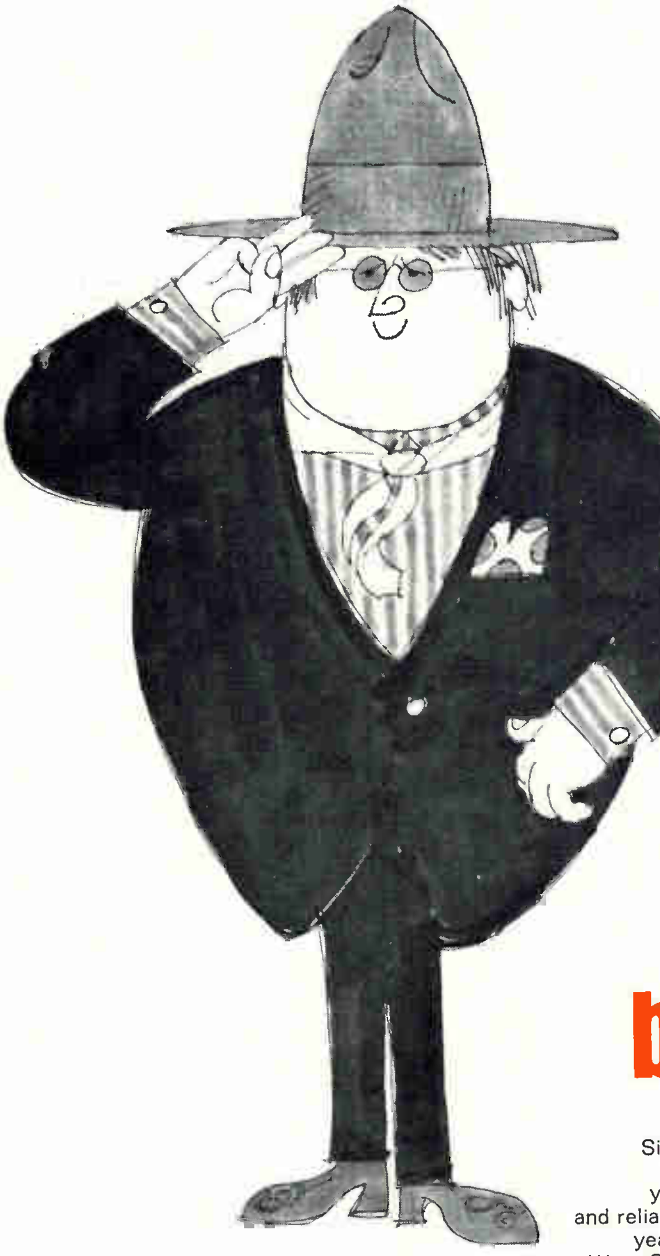

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Computer aid on the ocean floor

A 700-mile underwater telephone cable, linking Vietnam and the Philippines, was laid in eight days as a shipboard computer calculated critical equalizers spliced between repeated cable points

By Oswald R. Reh

U.S. Underseas Cable Corp., Washington

Typhoons twice howled across the cable ship's route, causing rough seas for many days, and once there was a hurricane, but the computer clicked merrily along, performing its programed calculations despite the rolling, pitching, and yawing of the ship Neptun. A telephone cable had to be strung along the bottom of the South China Sea that would connect South Vietnam and the Philippines.

The war in Vietnam, with its increasingly heavier communication requirements between Saigon and the Philippines, placed a heavy premium on speed, and any technique that could save months in cable-laying was happily seized by the U.S. Underseas Cable Corp., assigned the task by the Air Force.

During the eight days of the mission, the computer solved two big problems. First, it determined the component makeup for the equalizers needed to counteract the electrical loss of each 10-part cable section. And it determined the component values for each equalizer.

The experience gained in laying the much-needed voice link between Vietnam and the United States' friendly ally, produced a technique that can be applied to any communication system where on-the-spot equalization, adjustment of signal strength and a delay-time equalization of a wide frequency band are required: high-speed data transmission, computer-controlled relay systems, missile-range testing, satellite tracking, missile and submarine detecting, and tracking and destroy systems.

The cable link provides 60 telephone channels in each direction, making possible 60 simultaneous phone conversations. Each channel has a 4-kilohertz bandwidth. Multispeech transmission requires a wide frequency band but such a frequency range causes large electrical losses. Loss of signal strength is proportional to cable length; in a sea cable the problem is complicated by different ocean temperatures, water pressures, and cable stresses.

In laying sea cables such as this one, repeaters are spliced into the cable at specified intervals to compensate for the loss in signal strength. In the Vietnam-Philippines link, it was necessary to use 41 repeaters. The losses are adjusted against a predetermined figure based on an examination of the ocean terrain. Deviations from the expected values can be ascertained accurately during the cable laying. After every 10 repeaters, defined as an ocean block, an equalizer containing passive filters is inserted to compensate for any losses not overcome by the repeaters.

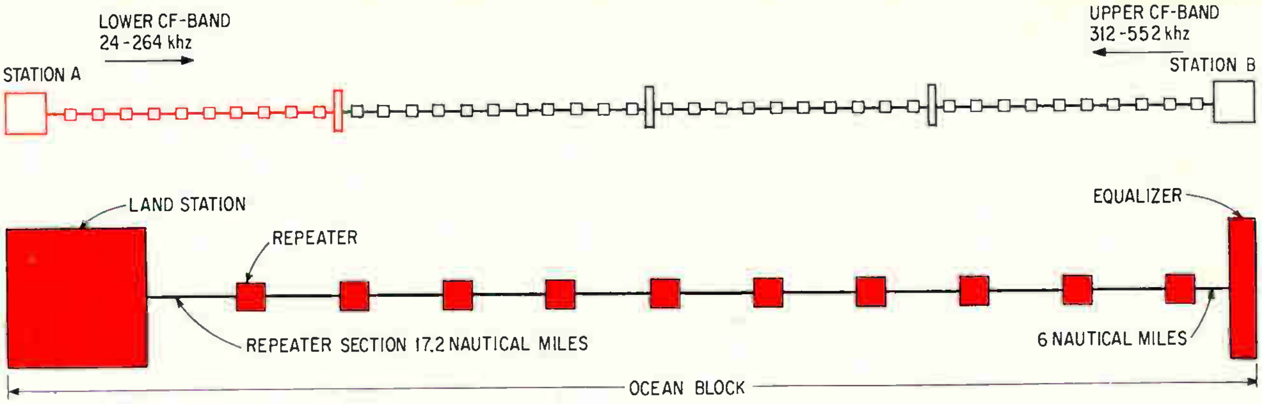
Splicing points

Determining the complicated equalizer circuits and equalizer component values is a time-consuming task if calculated with manual techniques, or even with the help of electrical calculators. In conventional cable-laying operations, adjustments of the equalizer must be determined by stopping the cable-laying operation while the calculations are being made. Besides slowing progress, halting the ship endangers the success of the entire installation, especially in the face of hazardous weather conditions.

The only way to meet the short schedule for laying the Vietnam-Philippines link, colorfully labeled the Wetwash A cable system, was to accomplish the entire equalization process aboard ship. Compli-

The author

Oswald R. Reh heads the technical center of U.S. Underseas Cable Corp. He supervises the electronic computer and data retrieval centers, and the electronic laboratory. He has had 10 years experience in the design and development of carrier-frequency equipment and underwater repeaters and equalizers.



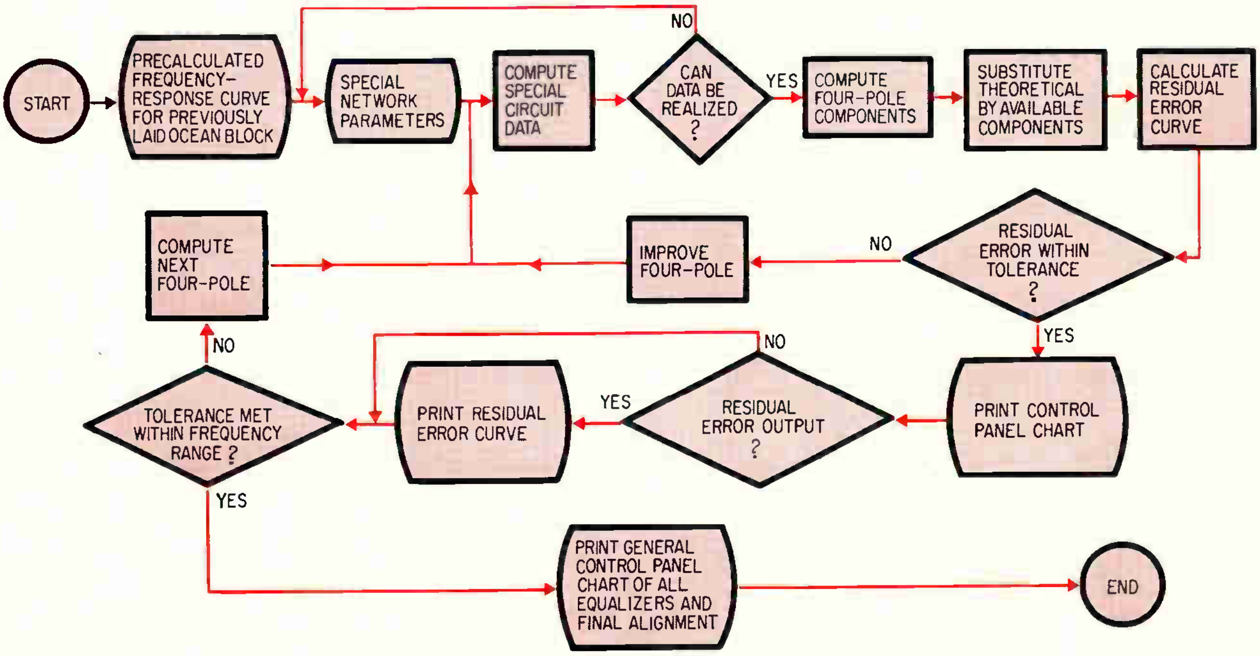
Battle plan. Between South Vietnam and the Philippines, the two land stations, 41 repeaters and three equalizers were laid in four ocean blocks.

cating the problem was the extra-ordinary length of the cable, twice any previously laid. It was obvious that a computer, small in size but capable of withstanding all sorts of weather-produced rigors, was an absolute necessity. It had to work with the utmost precision even as the ship rolled, pitched, and yawed in a typhoon, if need be. Equally important was the availability of a manufacturer's repair and adjustment services on a worldwide basis. Furthermore, the computer had to be easily programed to operate from special programs.

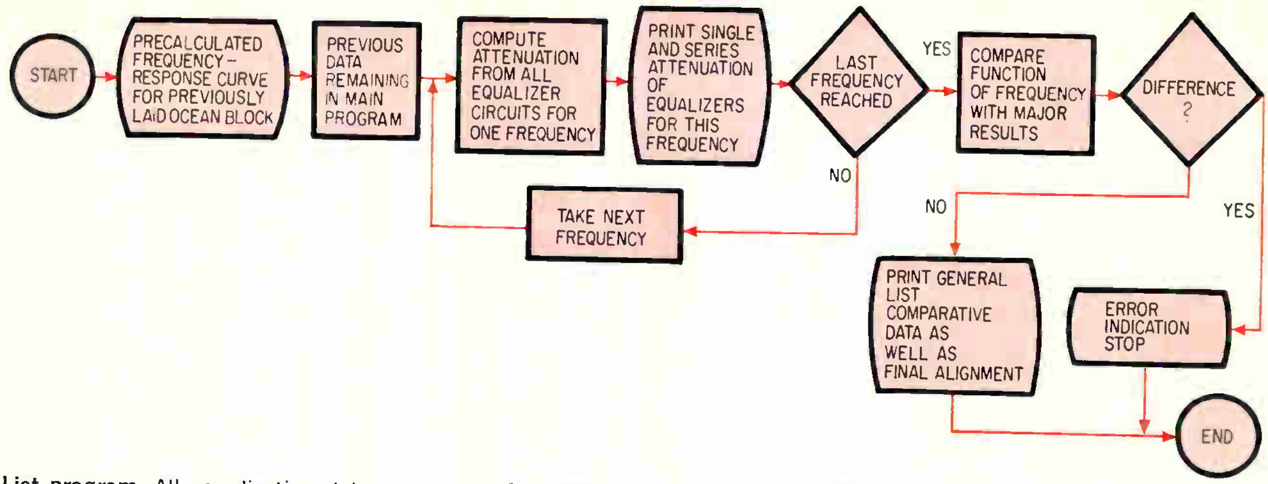
Many tried, one chosen

Many computers were carefully considered before an IBM 1620 was finally chosen. At the end of August 1964 the cable ship Neptun was berthed at Nordenham, Germany, and the 1,320-pound computer was installed in a test room in the ship's fore bridge, one deck above the main level, and secured against the stormy seas by bottom plates firmly screwed into the steel deck. Its output-typewriter, with its movable carriage arranged to operate along the longitudinal ship's axis, had been checked while in operation to determine whether it would continue to function in heavy seas. A similar test was made on the paper tape read and the punch unit. There was no malfunctioning or interference in any of the three units.

The computer manufacturer established a frequency-stability requirement of ±0.5 hertz for the power supply. But previous experience with a-c motor-alternators—the ship board supply source—indicated that a frequency stability of only ± 1.0 hz could be met. Fortunately, tests showed that the re-



Equalization program. Component values for the bridged-T networks within each equalizer are computed by following this computer routine. To start, a frequency-response curve is prepared for the first ocean block laid. This is then compared with a desired frequency-response curve for the section. Special network parameter data is added to the deviations between the two curves and the computer determines whether the bridged-T networks can be made with the available components. If they can, the computer determines their values. If they can't the parameter data is readjusted. Process is repeated for each ocean block as it is laid.



List program. All equalization data not erased from the main program when it concludes is compared against the desired frequency-response curve. Values are determined for the components based on the deviation.

quirement set by the computer manufacturer was conservative; the computer was found to calculate precisely even with frequency variations of ±2 hertz.

The cable was divided into 42 parts, based on the best solution for noise factor and overload. Each part, called a repeater section, measured 17.2 nautical miles. Repeaters were connected between each section of the previous 17.2-mile cable length. At the end of 10 repeaters an equalizer was connected. Each 10-block repeater grouping formed what was designated an ocean block. There were 41 repeaters, three equalizers and four ocean blocks.

Computer aid

To design the equalizers, part of the cable already laid was tested continuously and the test data immediately stored in the computer and on punched tapes. Partial tests were performed on the block every half hour and a full test every two hours.

Two substantial curves were evaluated. One contained the measured data representing the frequency response curve of the entire ocean block just laid; the other specified the desired frequency response for the block. Then the computer processed the two curves to determine the necessary compensation. The compensation data was then used to synthesize the passive bridged-T networks that accomplish the equalization. Characteristics of the available passive components were also stored in the computer, so that the machine could compare the synthesized data with the characteristics of the components.

The complete equalizer contains about 20 bridged-T networks in cascade, the line and power separating filters, and two prefabricated adjustable cable-building-out networks. Each T-network is built with a similar design but has different component values. Because the equalizer contains no active networks, an equalizer section is shorter than a repeater section—12 instead of 17.2 nautical miles. Using the main computer program the engineer is able to simulate the frequency response of a bridged-T section.

Adding these sections in cascade between two ocean blocks compensates for the loss in the previously laid block. A typical comparision of an uncompensated and compensated ocean block is at the bottom of page 88. The bottom curve represents the final residual deviation. A list of the calculated component values for all individual networks is typed out from the data provided by the computer. In addition, the frequency response of each bridged-T network can be obtained with the aid of the list program which calls upon the stored data available from the main program.

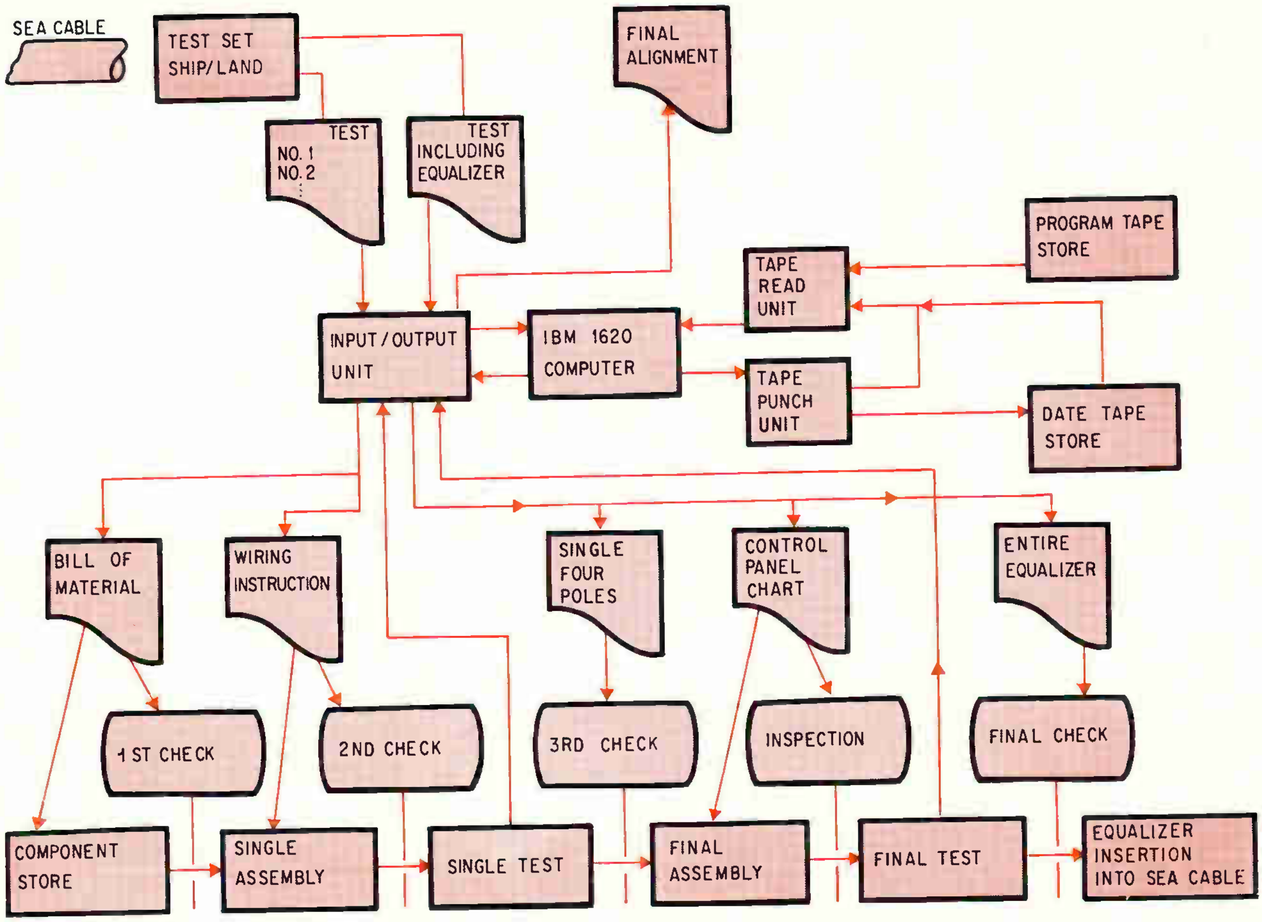
A correction program was prepared in the event the network components had to modified or, an equalizer had to be changed. All previously calculated data was stored in the correction program so that it was not necessary to refeed this information or repeat calculations of the whole program.

The laying of the South Vietnam-Philippines sea cable started on November 19, 1964, at which time telecommunication was established over the cable between the terminal station and the test room aboard the cable ship. As the cable was laid out, it was tested from both sides from the ship and from the terminal land station.

Time to calculate

During the laying of the cable, the ship reduced its speed from six knots to three when reaching the

Cable ship. Neptun during the cable-laying operation. Cable is laid continuously from the front end of the ship.



Testing procedure. Equalizers are run through a series of tests before they are inserted into the cable.

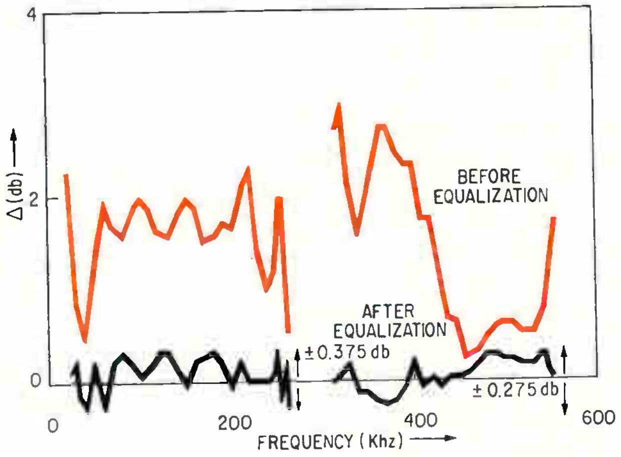
last third of the first ocean block. Thus there was enough time in which to make the calculations, assemble the equalizer, and test and splice it into the cable. At the beginning of this period of reduced speed, the computer successively processed the extrapolation, evaluated the tests, calculated the block characteristics on the ocean bottom and then set up the nominal equalizer curve.

The prefabricated repeaters were flown to all ports of call of the cable ship. As each repeater arrived, it was tested, spliced into the cable and stored in the holds of the ship. Subsections of the cable—the ocean blocks—were successively assembled and precise tests taken at every stage. All these tests—a series of attenuation measurements after the splicing in of each repeater—were stored on the paper tapes and evaluated by the computer.

As soon as a block containing 10 repeaters was completed, further information on the temperature of the subsection was determined. On several occasions the shipboard tanks, which contained the particular ocean block, were flooded and the block tested.

The ocean block completed first was tested at different temperatures by using water from the Atlantic, the Caribbean and the Pacific. When the water temperature was constant, the tank was flooded and the cable was allowed to reach a stable temperature. Then a variety of test data was taken. All evaluation of the test data was performed by the computer. This made possible a more precise calculation of the loss of signal strength in the cable after it had been laid.

When the Neptun reached the Philippine coast on November 27, 1964, eight days after it started, it had laid 700-nautical miles of sea cable without any interruptions and had written a new chapter in the history of computer-aided design for communications.



Achieving equalization. Upper curve represents the frequency response for the entire sea-cable link before equalization. Adding the equalizers results in the desired lower curve.

Machine looks, listens, learns

It employs a matrix-expansion technique, five-state memory units, and a "don't know" capability, to identify spoken or graphic inputs, differentiate between similar patterns, and eliminate any guesswork

By G. L. Clapper
International Business Machines Corp., Raleigh, N. C.

Capable of learning, responsive to the spoken word, but requires patient repetition to retain lessons—these phrases might have been lifted from the report card of some slow but willing student. They also describe a fast and willing machine that can learn to identify both graphic and spoken inputs, and that demonstrates the feasibility of three new techniques in adaptive pattern recognition.

Because the unit is adaptive, its organization makes no allowance for prior knowledge of the input data's exact nature. For example, if the design were used in a voice-controlled milling machine, it could learn to obey commands like "up," "down," "left," "right." But it could also, without any redesigning, learn to obey a Frenchman's "montez," "descendez," "à gauche," "à droite," or a Spaniard's "suba," "baja," "a la izquierda," and "a la derecha."

The machine is not designed to recognize any particular kind of inputs—be they 10 decimal digits, up to 16 arbitrary patterns, or 16 different syllables in any language. Rather it is shown the sequence of patterns or syllables one at a time, together with the desired outputs for each one. It then sets up its own decision criteria upon which to base recognition of further inputs.

The present model is limited in size and capability, but the principles embodied in it could be incorporated in larger versions that might, for example, permit a computer to be programed by spoken instructions, or an unmanned spacecraft to be directed to alter its operation upon commands from a ground station.

To recognize both written and verbal inputs, the demonstration model employs:

- A relatively simple expansion of the input patterns that heightens the differences between similar patterns.
- A bank of five-state adaptive memory units that stores patterns for comparison with inputs.
- A parallel summation technique that enables the machine to make a "don't know" response, as well as "yes" or "no."

In the demonstration model, the input patterns are stored in a 3-by-5 matrix of flip-flops. This stored pattern is then expanded into a 7-by-5 matrix, with a technique independent of the size of the matrix. The same technique could be used to differentiate among more complex patterns in the input matrix of a larger machine.

Longer memory

The five-state, or quinary, adaptive memory units [see "Five states of learning," p. 98] learn faster and retain information longer than the infinite-state arrangements used in some previous adaptive pattern recognizers.

The decision techniques used elsewhere involve a threshold upon which a "yes" or "no" response must be made for every input pattern. But with the parallel summation method used in the demonstration model, all the previous experience of the machine is available instantaneously to decision circuits that can generate any one of the three possible outputs [see "Three-way decision," p. 101].

One earlier adaptive pattern recognizer, the Perceptron developed at Cornell University, contains

The author

Gene Clapper holds the title of IBM Fellow, the company's highest technical rank. Currently studying adaptive systems and speech recognition techniques, he has been with IBM since 1934, and has developed a large number of circuits, subsystems, and machines. He holds 60 U.S. patents.

an array of motor-driven potentiometers controlled by the difference between the actual output and the desired output. In another earlier unit, Stanford University's Adaline, a chemical cell's resistance is varied by plating or deplating metal on a carbon electrode.

Because both the potentiometers and the chemical cells, called Memistors, can have any resistance between their minimum and maximum values, they have, in effect, an infinite number of states. They therefore have an easy time learning the difference between two similar patterns, U and V, for instance, but a hard time discerning that A and ᴀ are two versions of one pattern.

Also, the Memistors take several seconds to change from one state to another, and can't be depended on to stay in a given state for longer than an hour or so. The quinary memory units, on the other hand, change states in a microsecond or less and will retain a state as long as electric power is available.

Third choice

In a pattern recognizer that depends on a single "yes-no" threshold, the machine must either discern or not discern a resemblance between every pattern presented to it and a learned pattern. Such an arrangement leads to somewhat arbitrary decisions when the input is near the threshold. And if the threshold has a tendency to drift, as is the case with the Memistor, these close decisions are more likely to be wrong even though the basic pattern has been thoroughly learned.

But in the present machine, the adaptive quinary memory units store all the previous experience of the machine. Input patterns gate weighted sums from the memory units to four three-way decision circuits, which indicate whether the summation is substantially positive ("yes"), negative ("no"), or nearly zero ("don't know"). The three states aren't stable, but simply indicate a sum of several stable states of the adaptive memory units.

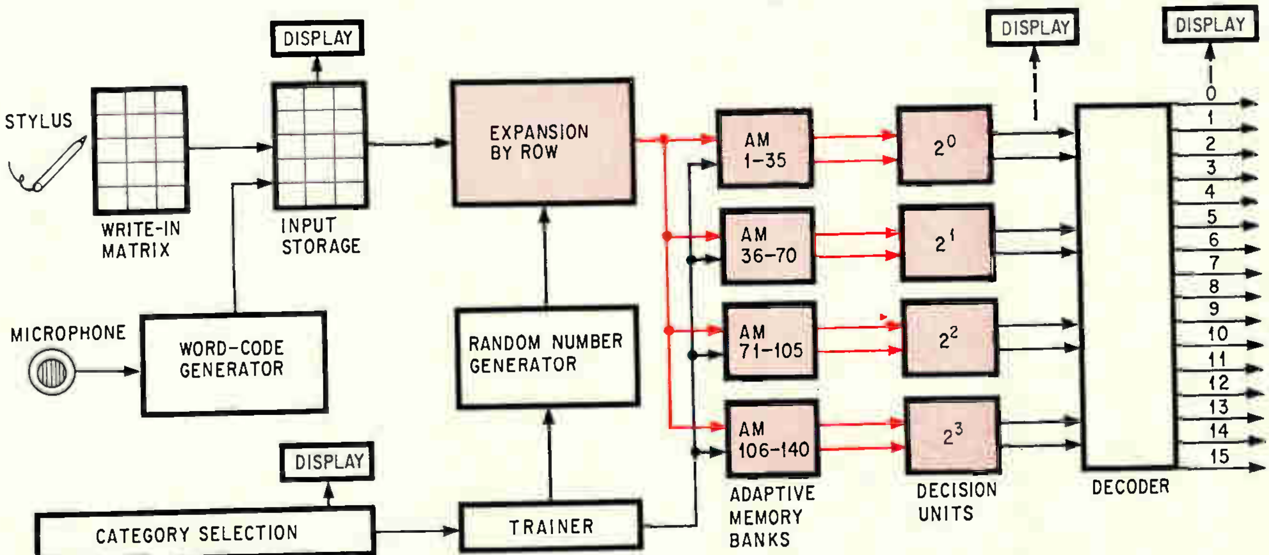
In contrast, an adaptive system using a serial-search method looks through records of all its past experience, one record at a time, before responding to any input. An example here would be the well-known checkers-playing computer program developed at the International Business Machines Corp. during the 1950's. Before making any move, the computer reviews prior games stored on magnetic tape or in a disk file to see if it ever encountered a similar situation, what it did at that time, and how the move turned out. As it plays more games, it accumulates more data; the searching time could eventually make the computer an exasperating slow player.

Spoon feeding

The demonstration pattern recognizer accepts graphic data written by stylus on a 3-by-5 front-panel array, and verbal inputs spoken into a microphone and passed to a binary encoder, or word-code generator. After the input is recorded as a pattern in the smaller internal flip-flop matrix and expanded in the larger one to show up in greater detail, it is applied simultaneously to four banks of memory units. Four decision units compare the enlarged pattern with previously learned patterns in the memory banks, and generate four binary signals that are decoded into one of 16 possible outputs identifying—or not identifying—the input.

To train the machine, the operator presents each input pattern in turn, manually selects the desired output for that input, and presses a button that conditions the memory banks.

With the memory completely cleared, as it is when power is first turned on, the operator might first trace a 1 on the write-in matrix, set a rotary switch to the appropriate output—putting a binary-coded decimal 1 on four lines to the four memory banks—and press the "condition" button. The operator can handle the figure 2 in the same way, and



Graphics and voice. Both kinds of input set up patterns in the 3-by-5 input storage, which is expanded into a 7-by-5 matrix row by row. The expanded pattern gates weighted sums from the corresponding adaptive memory units to the decision units, which produce a binary output if they recognize the pattern.

Pattern recognizer. Double row of lights at top show desired output and actual output. The author has entered the digit 3 on the write-in matrix at lower right; it appears in the matrix display at center right. He has also set the trainer at 3 and pressed the conditioning key, thus matching the actual to the desired output. The same signals are displayed in binary form at the left of the meter. The encode key blocks out the background noise when the microphone is not in use, the reset key clears the input matrix, and the clear terminal wipes out all previous training.

if he goes back to input 1, the machine will probably recognize it at this point without being further conditioned.

If, however, he then teaches a 3 to the machine, it may become confused when it again sees either the 1 or the 2, and the operator must then go back and retrain it for the earlier inputs.

For each new pattern presented during training, the machine generally has to be retrained for two or three previously learned patterns, particularly if they resemble the new input in some way. Distinguishing between 0 and 8 is always troublesome, for example, because when traced out on the 3-by-5 matrix the figures differ only in the presence or absence of the center bit—the cross-over of the 8. Three or four iterations are usually sufficient, though, to train the machine to differentiate between such pairs reliably thereafter, and a few more iterations can teach it all patterns in a set.

The input set can include variations of some or all the patterns if these are known in advance. And the machine can handle considerable variation from the original set once its training is complete.

In the case of sets without variations—the 10 decimal digits, for example, where a 2 always looks like a 2, a 6 like a 6, and so on—arbitrary small

Other expansions

The row-by-row technique was chosen from a number of alternative methods of expansion as the most economical in terms of hardware and yet sufficient to identify the digits and similar patterns that the machine should recognize.

The 15 bits, considered as a group, can be arrayed in 2^{15}, or 32,768, different combinations—too large a number to implement at any reasonable cost. Furthermore, no two of these could be recognized as being "almost" alike, so that a system using this expansion could not generalize.

If the 15 bits are considered individually, the set of 10 decimal digits would require 150 descriptors, each of them either on or off, as shown below left. The diagram indicates that bits 1 and 15 are of no value in identifying any digit because they appear for all digits. Bits 2 and 9 aren't much better; they appear for all but one digit. And bits 3, 8, 12, and 14 appear in all but two representations. Furthermore, bits 5 and 11 uniquely describe the digit 1; no other digit has any unique descriptors. This leaves only five bits, or descriptors, out of 15 to identify nine of the 10 digits, and these five—4, 6, 7, 10, and 13—aren't sufficient to identify all those nine.

An expansion by column is analogous in every way to the expansion by row, except for its direction. In the diagram below right, the columns of the smaller matrix are numbered 0, 1, 2, and the rows are given the binary values 1, 2, 4, 8, and 16 to identify combinations. Three 3-digit descriptors are associated with each input pattern; the first digit identifies the appropriate column of the matrix and the second and third identify the bits turned on.

Thus the digit 1 is represented by descriptors 017, 131, 216. This means that in column 0 bits 1 and 16 are turned on, giving the combination 17; in column 1 all five bits are turned on, so that their binary identifiers add up to 31; and in column 2 only bit 16 is turned on. The rest of the diagram lists the descriptors in the column-by-column expansion—three for each of 10 decimal digits.

The column expansion includes 11 unique combinations, as opposed to nine in the row expansion; but these 11 still appear in only seven of the 10 digits, the same number as in the row expansion. The descriptors 121 and 231, both appearing for six of the 10 digits, have the least descriptive power. This is somewhat better than in the row expansion, but that small advantage is offset by the three descriptors per digit in the column expansion, as compared to five for the row expansion.

The most important practical disadvantage in column expansion is that the technique would require more than twice as many of the adaptive quinary memory units—$3 \times 31 = 93$—for each of the four banks than does row expansion—$5 \times 7 = 35$.

There are various other ways to expand the small matrix. A combined row and column method for example, is entirely possible; each digit would have eight descriptors, and the expanded matrix would provide very good discrimination and generalization. But it would require 128 memory units, and would thus be that much more expensive. Or the matrix could be expanded along its diagonals, or in a pattern similar to the knight's move in chess—relating cells that are one row and two columns apart, or two rows and one column.

1	2	3
4	5	6
7	8	9
10	11	12
13	14	15

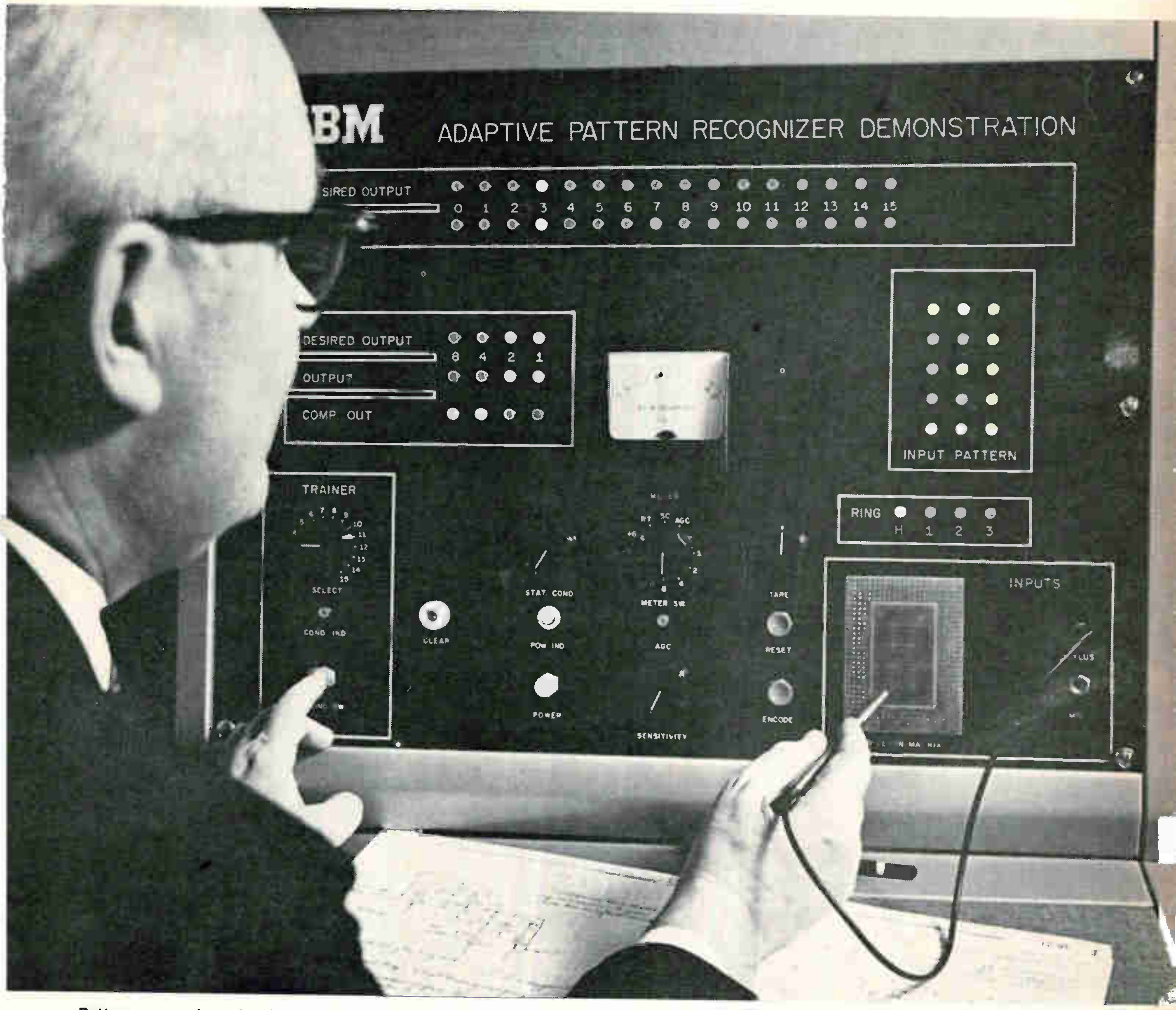
1	1	2	–	–	5	–	–	8	–	–	11	–	13	14	15
2	1	2	3	–	–	6	7	8	9	10	–	–	13	14	15
3	1	2	3	–	–	6	–	8	9	–	–	12	13	14	15
4	1	–	3	4	–	6	7	8	9	–	–	12	–	–	15
5	1	2	3	4	–	–	7	8	9	–	–	12	13	14	15
6	1	2	–	4	–	–	7	8	9	10	–	12	13	14	15
7	1	2	3	–	–	6	–	–	9	–	–	12	–	–	15
8	1	2	3	4	–	6	7	8	9	10	–	12	13	14	15
9	1	2	3	4	–	6	7	8	9	–	–	12	–	14	15
0	1	2	3	4	–	6	7	–	9	10	–	12	13	14	15

Expanding by element. If each flip-flop were treated individually in matrix expansion, the various patterns would be difficult to distinguish because so many would share the same elements.

0	1	2
1	1	1
2	2	2
4	4	4
8	8	8
16	16	16

1	017	131	216
2	029	121	223
3	017	121	231
4	007	104	231
5	023	121	229
6	031	121	228
7	001	101	231
8	031	121	231
9	007	121	231
0	031	117	231

Expanding by column. A five-bit binary number represents each column of the matrix. Three numbers thus describe the pattern in the three columns; each number specifies the column and the binary number in that column.



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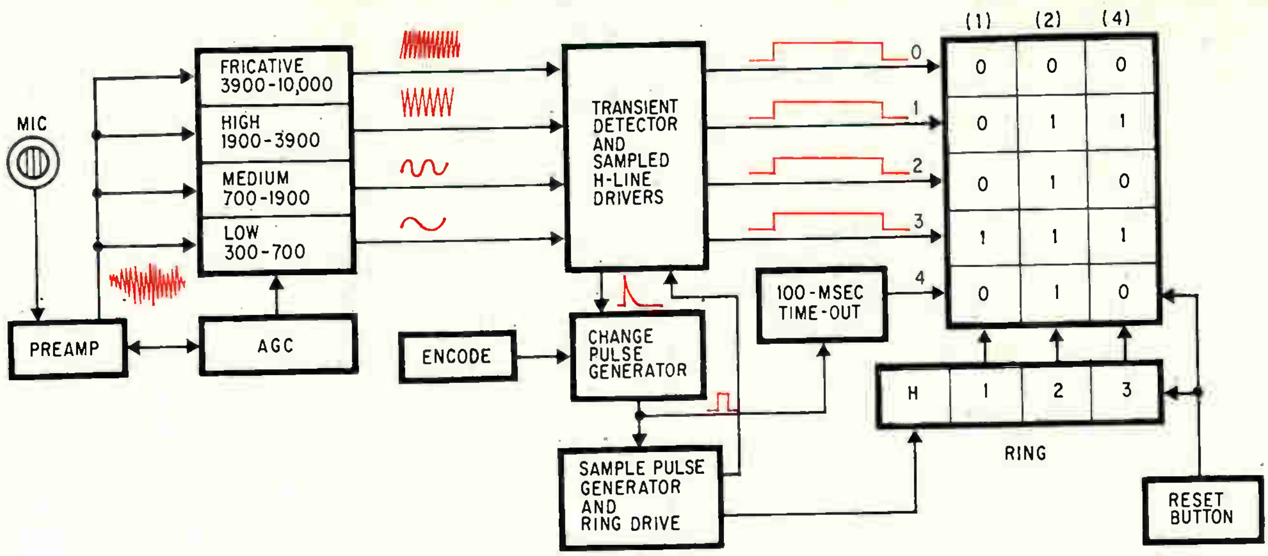
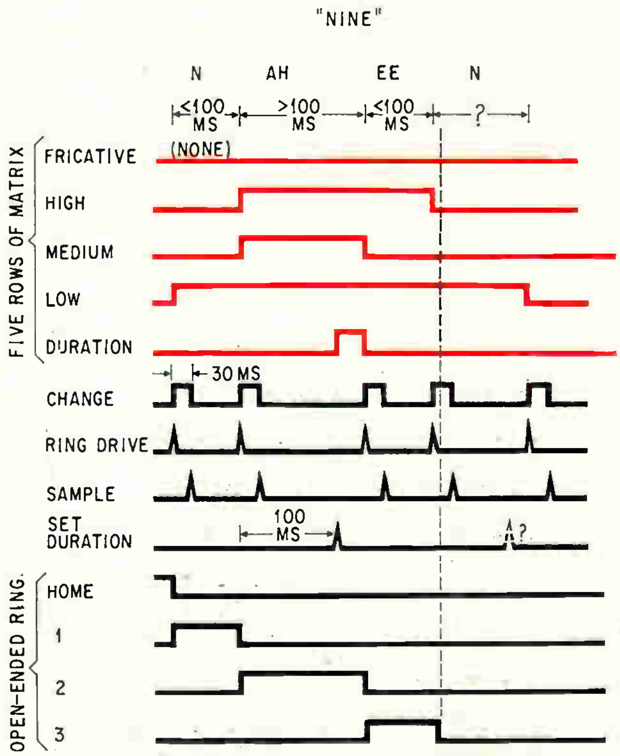


Four frequency bands. The spoken input "nine" sets up a pattern in the 3-by-5 matrix through a set of four filters. A timing circuit determines whether a speech segment exceeds 100 milliseconds.

differences between successive inputs of the same pattern are introduced. Without this technique, called statistical conditioning, the machine would have to learn the full set of input patterns without seeing anything less than the complete characters, a difficult task. With this conditioning, however, it learns that each digit is represented by one of several sets of identifying features, each set smaller than the one describing the complete character. Thus, the demonstration model could identify a pattern as a 1 just from seeing part of the down-stroke and perhaps the base of the figure.

Statistical conditioning isn't necessary when dealing with verbal patterns, which are varied enough even when the same person does all the speaking.



Binary frequency signals. The change pulse controls the setting of successive segments of the word "nine" into successive columns of the matrix, and is generated by the turning on and off of the various filter outputs.

Clipped sounds

Spoken inputs are encoded by the word-code generator; a set of four broadband frequency selectors generate on or off signals to indicate the presence or absence of speech components in each of the four frequency bands. Only the first three discrete sounds in a word are encoded—the rest of the word is ignored. On or off signals for the first three sounds in each of the four bands are stored in four rows of the 3-by-5 flip-flop matrix; the fifth row of flip-flops indicates whether the sound was short or long, turning on if the interval between "change" pulses exceeds 100 milliseconds. A change pulse indicates that at least one of the frequency selectors is detecting the beginning or end of a speech sound.

Input information stored in the matrix is expanded row by row by considering each row as a three-bit binary number. Each of seven combinations of three bits (all 0's are excluded) corresponds to a single bit in the expanded matrix, which therefore again has five rows, but with seven positions, or flip-flops, in each row. No more than one flip-flop in any row can be turned on at any one time.

During training, the states of the flip-flops in the 7-by-5 matrix adjust the states of the four banks of memory units to generate the desired output. After training, the expanded pattern causes the memory units to gate different amounts of positive or negative current onto common buses in accordance with their respective states; these states may therefore be regarded as current-regulating weights.

The buses, one pair for each of the four memory banks, transmit the total current to the four decision units, which then generate the signals that represent whichever of the 16 patterns the machine recognizes. If it doesn't recognize the pattern, one or more of the four outputs will remain in a "middle" state halfway between the two binary levels, indicating indecision or lack of comprehension.

The four signals are decoded in a conventional decoding circuit to turn on an indicator lamp identifying the input pattern, if it's recognized. If the pattern can't be identified, two or more decoder outputs will be produced, but no lamp will turn on because the outputs' current comes from a constant source that is not sufficient for two lamps.

The input to the four frequency selectors is the amplified complex speech waveform from the microphone. An automatic gain control (agc) circuit keeps the amplitude of the signal within reasonable limits, and a sensitivity control screens out background noise.

The agc circuit also generates an interlock signal that squelches the fundamental excitation impulse at the beginning of each syllable. The speech waveform is a sort of reverse sawtooth, one peak to a syllable, with a fast rise time, slow decay, and a pulse train under each peak. Initial impulses are among the characteristics by which a person's voice can be recognized, but they add nothing to the meaning of what's said.

Its master's voice

The frequency selectors contain bandpass filters in four ranges. The highest-range filter is sensitive to fricatives—sounds formed when air passes through a small opening such as between the tongue and the roof of the mouth ("s"), or between the teeth and the lower lip ("f"). Fricatives may be voiced ("z," "v") as well as unvoiced. The next band covers the "high resonance" portion of the speech spectrum, differentiating "f" from "s" and aiding vowel discrimination. The other two bands cover the medium and low resonance portions of the speech spectrum, picking up the voiced part of fricatives and other vocal sounds. The low-frequency cutoff is the average fundamental frequency of the female voice and the average second harmonic of the male voice.

Unlike some more sophisticated speech analyzers, the word-code generator, a simplified version of an earlier design, doesn't distinguish or track formants, which are peaks of intensity plotted against frequency and which vary with time.

Consider the machine's handling of the spoken word "nine." Of four sound segments—n-ah-ee-n—the first three are retained in the matrix, as shown on the opposite page. The first sound, "n," is normally short and contains only low frequencies. The sound "ah" is long and contains low, medium, and high resonance, but no fricatives. The third sound is short, with high and low resonance; it's actually only a transition from "ah" to the fourth segment, "n," which is lost. If the word is pronounced "nnnnnine," the same pattern would appear except that the bottom flip-flop in the first column would turn on, reflecting the prolonged "n" sound.

Before the operator speaks, he must reset all the flip-flops in the 3-by-5 matrix with a pushbutton; the same reset pulse also returns an open-ended three-stage ring counter to its home position. The transitions at the rise and fall of the four binary signals generate square change pulses about 30 milliseconds wide, as in the timing chart at the bottom of the opposite page.

The rise of the change pulse as the first segment "n" is spoken generates a ring-drive pulse that advances the ring to its first position, gating the first segment into the first of the three columns in the matrix. The change-pulse fall generates a sample pulse that stores the state of each frequency selector output in the corresponding flip-flop of the first column.

The rise of subsequent change pulses advances the ring to its second and third positions, so that later frequency samples are stored in the second and third columns of the array.

Drawn or quoted

For graphic inputs, each of the 15 segments of the write-in array is wired to a flip-flop in the 3-by-5 internal matrix. A constant-current source connected to the stylus turns on the flip-flops as the stylus contacts the corresponding segments of the write-in matrix. A momentary contact with the wrong segment creates a spike in that segment's line to its flip-flop, a spike that a low-pass filter in the line suppresses.

The patterns produced in the 3-by-5 flip-flop matrix by corresponding graphic and spoken inputs—

0	1	2	4
1	1	2	4
2	1	2	4
3	1	2	4
4	1	2	4

03	12	22	32	47
07	14	27	31	47
07	14	26	34	47
05	15	27	34	44
07	11	27	34	47
03	11	27	35	47
07	14	24	34	44
07	15	27	35	47
07	15	27	34	46
07	15	25	35	47

Expanding by row. Each row of the matrix is treated as a binary number; the pattern in five rows thus is described by five numbers, each specifying the row and the appropriate binary number.

Other expansions

The row-by-row technique was chosen from a number of alternative methods of expansion as the most economical in terms of hardware and yet sufficient to identify the digits and similar patterns that the machine should recognize.

The 15 bits, considered as a group, can be arrayed in 2^{15}, or 32,768, different combinations—too large a number to implement at any reasonable cost. Furthermore, no two of these could be recognized as being "almost" alike, so that a system using this expansion could not generalize.

If the 15 bits are considered individually, the set of 10 decimal digits would require 150 descriptors, each of them either on or off, as shown below left. The diagram indicates that bits 1 and 15 are of no value in identifying any digit because they appear for all digits. Bits 2 and 9 aren't much better; they appear for all but one digit. And bits 3, 8, 12, and 14 appear in all but two representations. Furthermore, bits 5 and 11 uniquely describe the digit 1; no other digit has any unique descriptors. This leaves only five bits, or descriptors, out of 15 to identify nine of the 10 digits, and these five—4, 6, 7, 10, and 13—aren't sufficient to identify all those nine.

An expansion by column is analogous in every way to the expansion by row, except for its direction. In the diagram below right, the columns of the smaller matrix are numbered 0, 1, 2, and the rows are given the binary values 1, 2, 4, 8, and 16 to identify combinations. Three 3-digit descriptors are associated with each input pattern; the first digit identifies the appropriate column of the matrix and the second and third identify the bits turned on.

Thus the digit 1 is represented by descriptors 017, 131, 216. This means that in column 0 bits 1 and 16 are turned on, giving the combination 17; in column 1 all five bits are turned on, so that their binary identifiers add up to 31; and in column 2 only bit 16 is turned on. The rest of the diagram lists the descriptors in the column-by-column expansion—three for each of 10 decimal digits.

The column expansion includes 11 unique combinations, as opposed to nine in the row expansion; but these 11 still appear in only seven of the 10 digits, the same number as in the row expansion. The descriptors 121 and 231, both appearing for six of the 10 digits, have the least descriptive power. This is somewhat better than in the row expansion, but that small advantage is offset by the three descriptors per digit in the column expansion, as compared to five for the row expansion.

The most important practical disadvantage in column expansion is that the technique would require more than twice as many of the adaptive quinary memory units—$3 \times 31 = 93$—for each of the four banks than does row expansion—$5 \times 7 = 35$.

There are various other ways to expand the small matrix. A combined row and column method for example, is entirely possible; each digit would have eight descriptors, and the expanded matrix would provide very good discrimination and generalization. But it would require 128 memory units, and would thus be that much more expensive. Or the matrix could be expanded along its diagonals, or in a pattern similar to the knight's move in chess—relating cells that are one row and two columns apart, or two rows and one column.

1	2	3
4	5	6
7	8	9
10	11	12
13	14	15

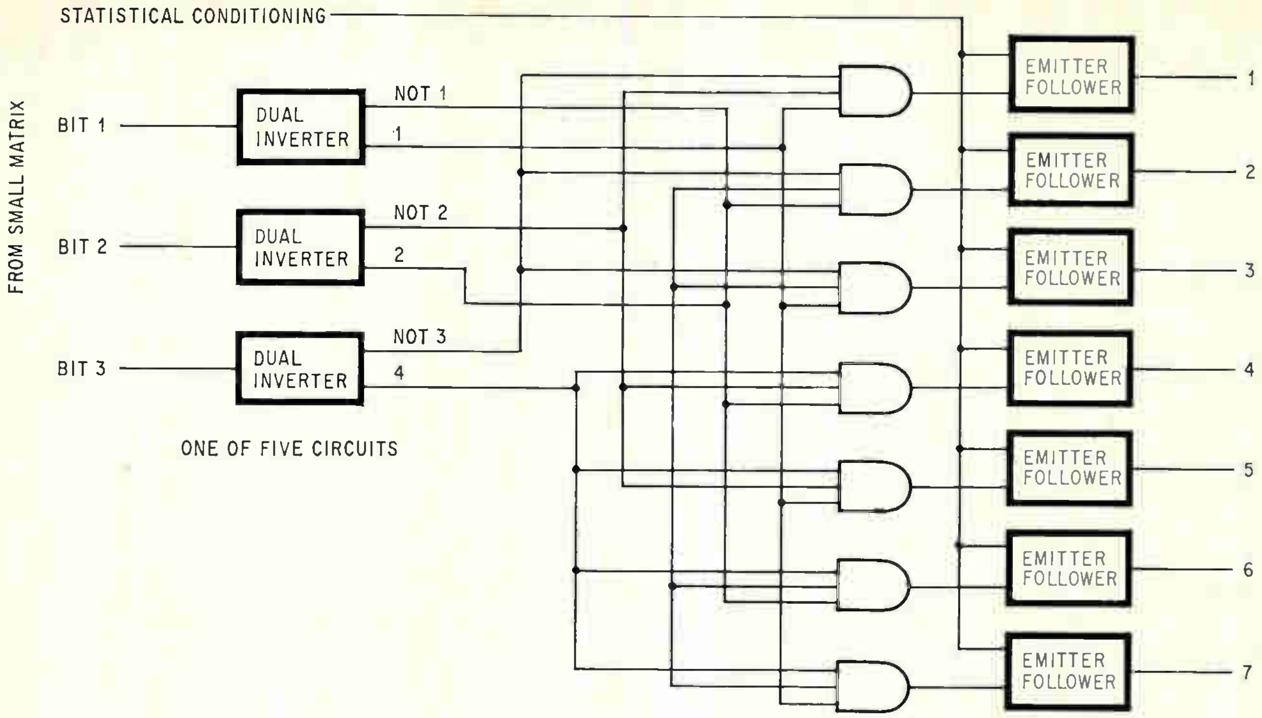
1	1	2	–	–	5	–	–	8	–	–	11	–	13	14	15
2	1	2	3	–	–	6	7	8	9	10	–	–	13	14	15
3	1	2	3	–	–	6	–	8	9	–	–	12	13	14	15
4	1	–	3	4	–	6	7	8	9	–	–	12	–	–	15
5	1	2	3	4	–	–	7	8	9	–	–	12	13	14	15
6	1	2	–	4	–	–	7	8	9	10	–	12	13	14	15
7	1	2	3	–	–	6	–	–	9	–	–	12	–	–	15
8	1	2	3	4	–	6	7	8	9	10	–	12	13	14	15
9	1	2	3	4	–	6	7	8	9	–	–	12	–	14	15
0	1	2	3	4	–	6	7	–	9	10	–	12	13	14	15

Expanding by element. If each flip-flop were treated individually in matrix expansion, the various patterns would be difficult to distinguish because so many would share the same elements.

0	1	2
1	1	1
2	2	2
4	4	4
8	8	8
16	16	16

1	017	131	216
2	029	121	223
3	017	121	231
4	007	104	231
5	023	121	229
6	031	121	228
7	001	101	231
8	031	121	231
9	007	121	231
0	031	117	231

Expanding by column. A five-bit binary number represents each column of the matrix. Three numbers thus describe the pattern in the three columns; each number specifies the column and the binary number in that column.



Decoder for expansion. The binary number in each row of the small matrix is decoded to set an individual flip-flop in the corresponding row of the expanded matrix. Statistical conditioning blocks some outputs at random.

for instance, a drawn "9" and a spoken "nine"—will generally differ. But with sufficient training the machine can learn to recognize both patterns as representations of the same thing, because both patterns are expanded and establish weights in the memory banks in the same way. The stored weights, however, will differ among sets of graphic digits, sets of spoken digits, and sets of both graphic and spoken digits.

The expansion of patterns from smaller to larger matrix is done row by row in the demonstration model. In the diagram on page 95, the rows of the smaller matrix are numbered 0 through 4, and the columns are given the binary values 1, 2, and 4 to identify combinations. Five two-digit descriptors are associated with each input pattern; the first digit identifies the appropriate row of the matrix and the second identifies the bits turned on.

Thus the digit 1 is represented by descriptors 03, 12, 22, 32, 47. This means that in row 0 bits 1 and 2 are turned on, giving the combination 3; in rows 1, 2, and 3 only bit 2 is turned on; and in row 4 all three bits are turned on. The rest of the diagram lists the descriptors in the row-by-row expansion—five for each of 10 decimal digits.

The total of 50 descriptors includes many that occur more than once, plus nine, shown in color, that are unique. These nine can describe seven of the 10 digits, namely 1, 2, 3, 4, 7, 9, and 0. All the descriptors are of some value in identifying digits; least valuable are 07 and 47, which each apply to seven out of the 10 digits—2, 3, 5, 7, 8, 9, 0 and 1, 2, 3, 5, 6, 8, 0, respectively.

Physically, the expansion process involves the driving of five three-bit decoders from the rows of the smaller matrix. The decoded outputs set the flip-flops in the rows of the 7-by-5 matrix.

The expanded matrix contains fewer descriptor bits in a larger area, reducing the probability of descriptor overlap between patterns. The adaptive memory units are driven by the flip-flops in the expanded matrix on a one-to-one basis, a factor that combines with the wider separation of patterns to provide reliable recognition with relatively simple memory units.

Conditioned reflex

The inputs to the 35 units in the memory bank, top of page 99, are the 35 descriptor lines from the expanded matrix. The two condition drivers, for 0 and 1, are each driven by a three-way AND whose inputs come from the trainer input, the statistical conditioning unit, and from the opposing output of the balanced decision unit. For example, if the desired output from the bank is 1, the Condition 1 driver is activated only if the 0 output appears at the decision unit. The 0 output is on for either 0 decisions or "don't know" conditions.

The pressing of the condition key on the console sets off a chain of events. First, a small current increment, or tare weight, is subtracted from all lines. The tare assures that additional weight beyond the minimum is added to the memory units as a margin of safety. If the total weight presented to the decision unit during training is just barely out of the "don't know" condition, it will be substantially positive or negative during actual operation with the tare disconnected.

A gated multivibrator next produces master conditioning pulses to all eight condition driver gates—only four of which are open, under control of the input from the operator—adding weight to all banks until the desired output appears. The feedback from the decision-unit output closes the condition driver gates when the correct output appears, automatically terminating the conditioning process.

If the operator desires, he may turn on the statistical conditioning unit for random conditioning. When he presses the condition key, a random-number generator gates two or three of the five descriptors into the expanded matrix. For any given conditioning pulse, it is not known which descriptors are effective, or how many; but all descriptors appear with approximately equal probability over a full training period.

The random-number generator is based on a zener diode biased just to the point of breakdown. As the bias voltage fluctuates slightly, the diode continually breaks down and recovers, generating a random voltage fluctuation that is amplified, integrated, and shaped. The result is a train of pulses with random widths and spacings. The pulse train is applied to a six-position shift register driven and sampled by a 1-kilohertz clock pulse. Because the pulse-train input is random, the contents of the register are random; when sampled at any time, the last five positions of the register gate a random selection of descriptors into the expanded matrix.

The graph on page 102 indicates the number of trials required in a test during which the machine tried to attain 100% learning of a rigid (without variations) set of graphic symbols. The first test (black line) was made with the random-number generator switched off. After 12 runs the machine got into a vicious circle that prevented 100% learn-

Continued on page 100

Training logic. Trainer opens one of the two gates feeding the condition drivers. If the decision unit has made no decision or a wrong one, its output will also drive the gate. The statistical conditioning unit then feeds pulses through the open gate, adjusting the weights stored in the bank memory units until the correct output appears at the decision unit, at which point the gate automatically closes. The tare guarantees a margin of safety in the stored weight.

Five states of learning

The units of the pattern recognizer are novel two-transistor circuits with five stable states. An input line from one of the 35 flip-flops in the larger matrix is common to the four corresponding units in the four memory banks, and two conditioning input lines and two summation output lines are common to all the memory units in a single bank of 35.

The input line gates conditioning pulses that change the state of the quinary memory unit, and it also admits varying amounts of current to the summation lines, depending on the state of the unit.

Diodes D_3 and D_4 are associated with the conditioning gates, and diodes D_9 and D_{10} with the summation gates. The quinary trigger is a modified Eccles-Jordan flip-flop with three additional stable states created by diode pairs D_1/D_2, D_5/D_6, and D_7/D_8, in color.

Reset. Momentarily turning off the –12-volt power resets the circuit; it therefore automatically assumes the reset state when power is first turned on. In this reset state, the middle one of the five, the two transistors have equal collector currents, so that A and B are at the same voltage—about –4.2 volts. The two emitters are at a higher level—about –1.6 volts—and the 36-ohm resistors establish a still higher level at the diode cathodes, so that D_1 and D_2 are reverse biased.

There is, therefore, no cross-coupling between emitters, and each emitter impedance provides degenerative feedback. As the gain of each stage is somewhat less than unity, the circuit is stable. The net output weight is zero, because equal current flows to the summation lines, which are assumed to be at approximately the same voltage level.

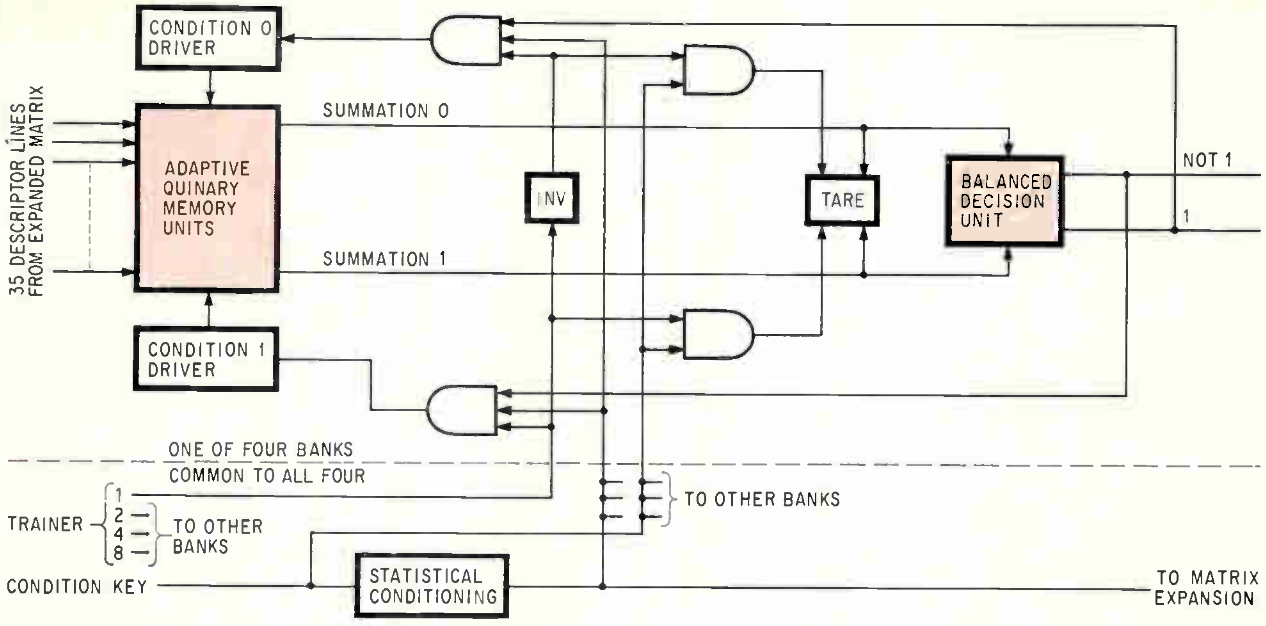
The state of the input line alone has no effect on the balance of the summation lines. When the input line is at –11 volts, diodes D_9 and D_{10} decouple points A and B, so that equal resistances connect both summation lines to the input voltage. When the input rises to ground, diodes D_9 and D_{10} maintain the voltage at their anodes at a slightly higher level than that at A and B, so that equal currents again flow to the summation lines.

Adding weight. The leading edge of the pulse on the Condition 0 line, when the input gate is at ground, generates a positive transient at the base of Q_1 through conducting diode D_3. This reduces the collector current in Q_1, and the voltage at point A becomes more negative.

Simultaneously, the emitter voltage of Q_1 becomes more positive and D_1 turns on, cross-coupling the emitters through the 36-ohm resistance. The voltage at A falls, and the voltage at B rises until it equals the voltage at the cathode of D_8. Diodes D_7 and D_8 then both conduct, and a low-impedance inverse feedback path is established from collector to base of Q_2. This feedback stabilizes the trigger with point A at –6.5 volts and B at –2.8 volts—a state designated as weight –1. The higher level at B reverse biases diode D_9, so that when the input line rises, current flows to the W_0 summation line. But D_{10} is forward biased, taking current from the input through A to the –12-volt supply.

Another pulse on the Condition 0 line in the presence of an input gate reduces the current in Q_1 still further. Point A then drops to its lowest level, –9.5 volts, as Q_1 approaches cutoff and Q_2 approaches saturation, raising point B to –1 volt. The circuit is again stable, and the weight is –2. Maximum current flows to the W_0 lines, and minimum current to W_1.

Opposite path. In the same way, applying pulses to the Condition 1 line in the presence of an input gate steps the circuit the other way. The first pulse passes through conducting diode D_1, cutting off Q_2. A increases while B drops until D_7 and D_8 again stabilize the circuit. A second pulse on the Condition 1 line brings the circuit to the reset state, and a third boosts A and drops B until D_5 and D_6 stabilize the circuit at another state

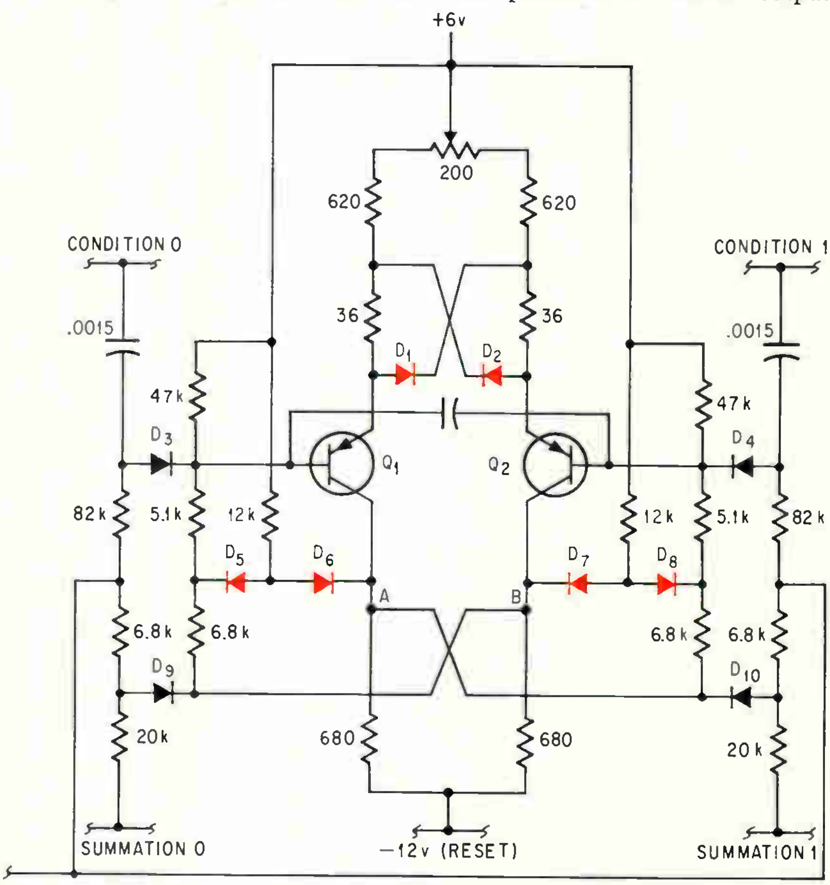


with weight +1. Finally, a fourth pulse on the line causes Q_2 to approach cutoff and Q_1 to approach saturation, stabilizing the circuit in its fifth stable state, in which the weight is +2.

NODE	N1	N2	N3 (RESET)	N4	N5
V_A	−9.5	−6.5	−4.2	−2.8	−1.0
V_B	−1.0	−2.8	−4.2	−6.5	−9.5
ΔV	−8.5	−3.7	0	+3.7	+8.5
WEIGHT	−2	−1	0	+1	+2

$\Delta V = V_A - V_B$ = DIFFERENCE BETWEEN COLLECTOR VOLTAGES

Thus, the quinary memory unit can be adapted through its range and reversed as often as necessary. Conditioning pulses are applied to the whole bank of units during training; those units that are activated by inputs from the matrix expansion will respond. As these units change state, the weights change and the summation lines' balance is altered in the direction that produces the desired output.



Quinary memory unit. The three diode pairs [color] give this modified Eccles-Jordan circuit three extra stable states for a total of five. The basic circuit connects the base of each transistor to the collector of the other through the 5.1K and 6.8K resistors.

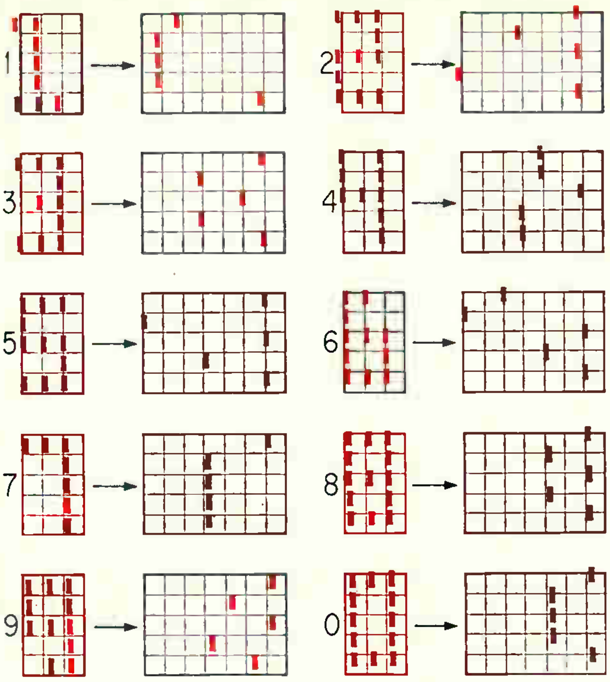
ing. It had most of the 16 patterns down pat, but was continually confused by a few similar pairs. The memory was then reset—the machine was made to forget everything. The random-number generator was switched on, and the same patterns were presented again, in the same order. This time as shown in color, the machine learned all of them perfectly in six trials.

A weighted answer

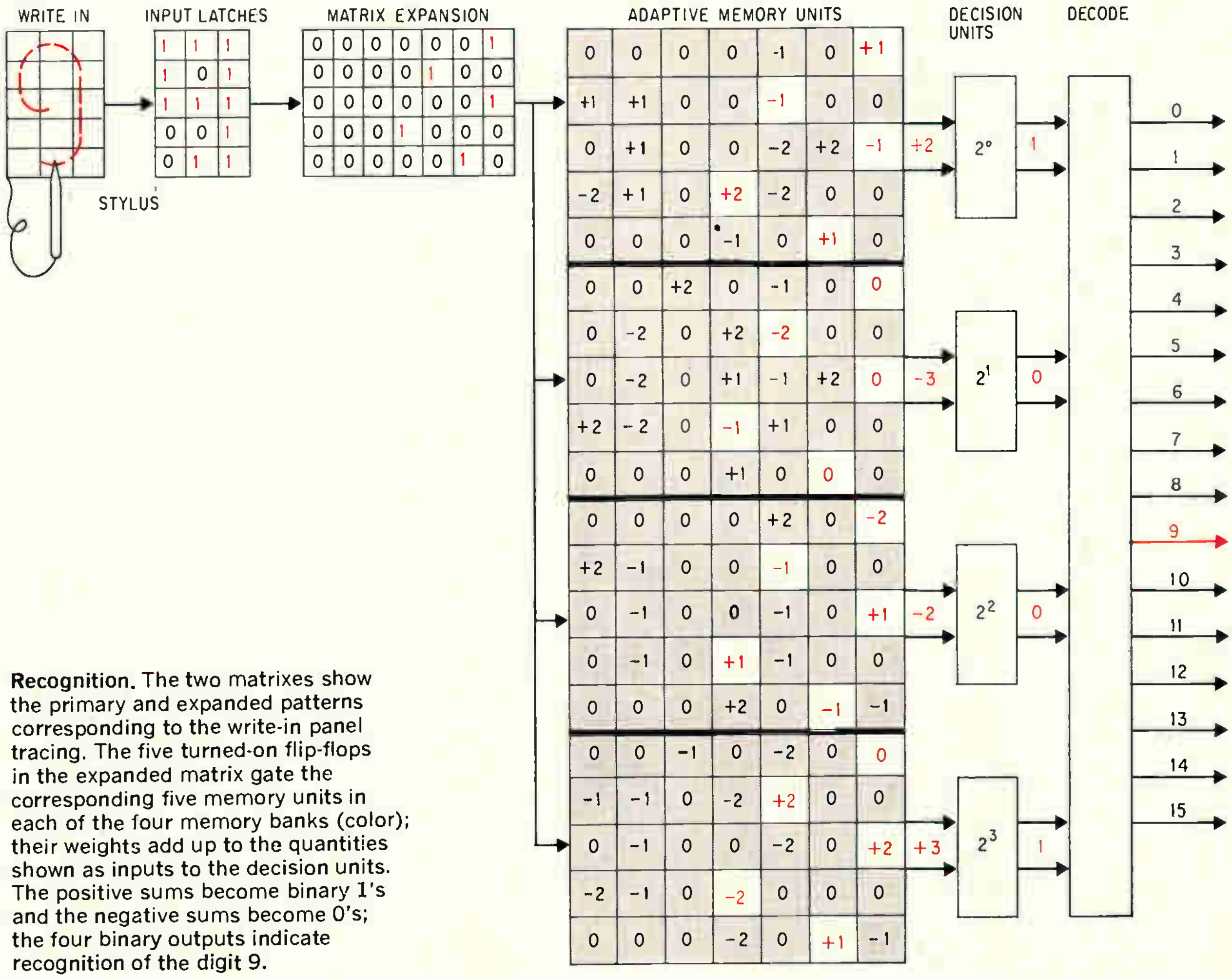
The diagram below shows the steps taken when the machine is presented with the digit 9 traced on the write-in matrix. Each segment touched by the stylus sets a flip-flop in the 3-by-5 matrix, so that the pattern of 1's in that matrix duplicates the traced-out pattern.

In the small matrix, the top row has a 1 in all three positions; the binary number 111 corresponds to the decimal number 7, so the seventh flip-flop in the top row of the large matrix (contains a 1) is turned on. Likewise, the second row contains the binary number 101, or 5, and the fifth flip-flop is set in the large matrix. In the same way, in the other rows, the seventh, fourth and sixth flip-flops are turned on. The descriptors for the input pattern are 07, 15, 27, 34, and 46.

The five flip-flops that have been set in the large matrix gate the corresponding five memory units



Expanded patterns. Each of the 10 decimal digits, entered graphically here, expands into a different, more distinguishable pattern in the large matrix. The distinction between 8 and 0 is the only one not much improved by expanding.



Recognition. The two matrixes show the primary and expanded patterns corresponding to the write-in panel tracing. The five turned-on flip-flops in the expanded matrix gate the corresponding five memory units in each of the four memory banks (color); their weights add up to the quantities shown as inputs to the decision units. The positive sums become binary 1's and the negative sums become 0's; the four binary outputs indicate recognition of the digit 9.

Three-way decision

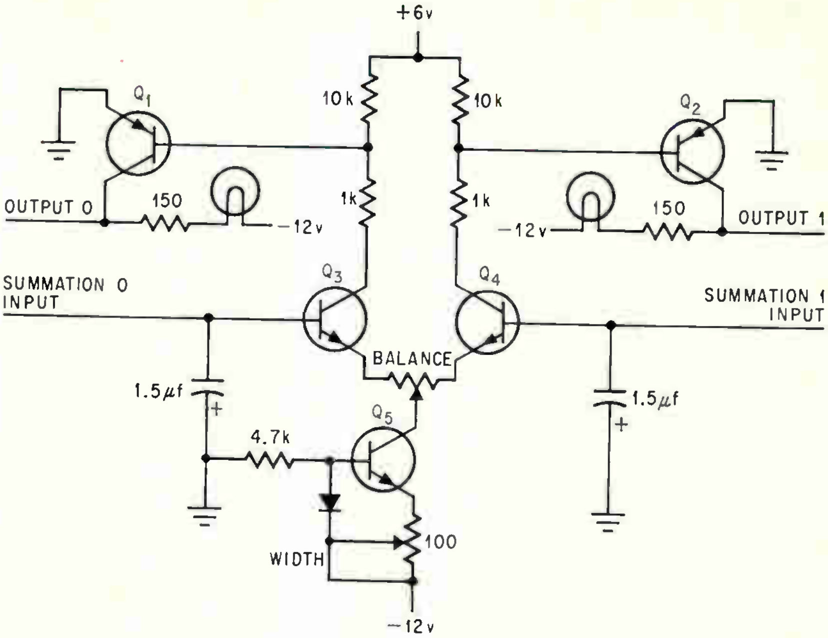
The inputs to the balanced ternary decision unit are summation lines from the quinary memory units that the decision unit compares for balance or imbalance rather as a differential amplifier would. The circuit determines the relative voltage levels for the two lines without referring to a fixed threshold; the line with the more positive voltage determines the output.

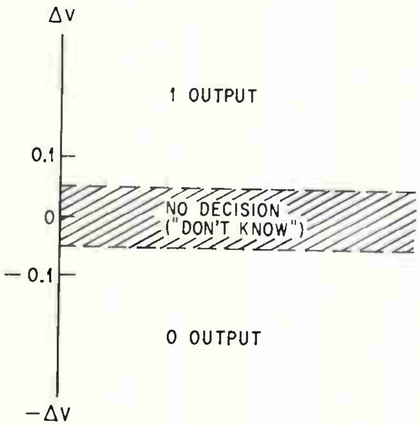
No guess. When no input pattern is present, or when the descriptors don't fully describe the pattern, the voltages on the summation lines are equal. Transistors Q_3 and Q_4 both conduct equally, and the current in each is about 1.5 milliamperes, since Q_5 maintains the total current at about 3 ma. About 0.9 ma then flows in the base circuits of both Q_1 and Q_2, saturating them.

Equal inputs turn on both the 0 and 1 outputs to indicate the "uncertain" or "don't know" condition. The positive and negative tolerances of the zone of equality are adjusted by the width potentiometer and the balance adjustment.

No hedging. A difference as small as 0.05 volt between the summation lines eliminates the uncertainty and generates a solid 0 or 1 output. If the voltage on the W_0 summation line is 0.05 volt more positive than the voltage on the W_1 summation line, Q_3 takes over nearly all the 3 ma. Because this maintains conduction in Q_1 and turns off Q_2, a true indication for 0 is given.

A single unit of weight difference from the memory bank provides a voltage difference of at least 0.1 volt, assuring a correct decision. Furthermore, the balanced summation lines ensure that variations in power supply and other parameters will have little effect on the determination of the decision-unit output.





Ternary decision unit. Like a differential amplifier, this circuit measures the difference between two signals and produces a signal on one output or the other depending on the sign of the difference. If the two inputs are the same, both output signals are on.

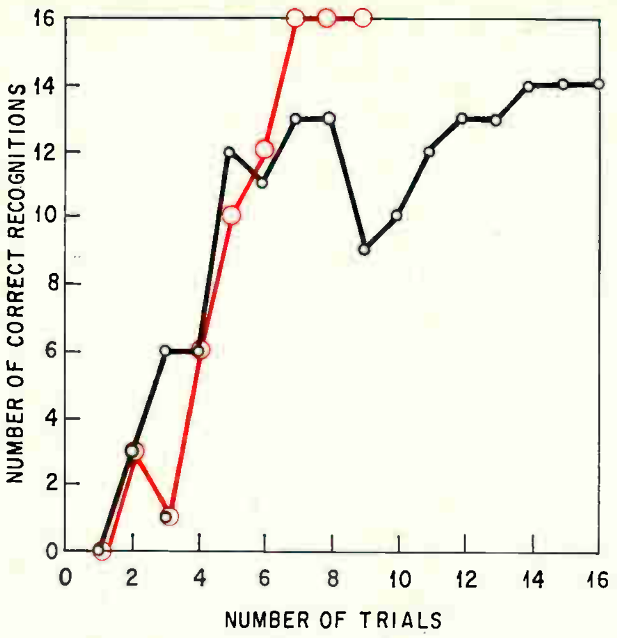
in each of the four memory banks. These units are shown unshaded in the diagram, with their respective weights—relative current-gating capabilities—in color.

Current corresponding to the weights of these memory units is added up on the summation lines common to all the memory units in each bank, and the sum is shown between the two lines leading to the decision units. Where the sum is positive, the output of the decision unit is 1; where the sum is negative, the decision unit produces a 0. The four outputs taken together present the binary number 1001, which, decoded, turns on the output 9.

In this example, the recognizer has been well trained; none of the memory banks produce zero current, or equal current on both buses of a pair. If any did, the decision unit would produce a "don't know," for that memory bank, and there would be no recognition.

The operation can be outlined in a small table like that at the bottom of page 102. The left-hand column contains the descriptors for the digit 9; the entries in each row of the left half of the table are the weights from the unshaded squares in the diagram at the bottom of page 100, reading from bottom to top. These weights can then be added up column by column and the correct value of the input pattern deduced from the distribution of plus and minus signs in the sums, corresponding to 1's and 0's.

The right half of the table contains the weights for the digit 3. Similar tables can be made up for other digits, using the proper weights from the shaded squares. The same digit shapes are em-



Statistical conditioning. The machine learned a set of graphic symbols perfectly in only six trials when it was statistically conditioned (colored line). With the random-number generator switched off (black line), it never got more than 14 of 16 right in this test.

ployed as were used in training the machine to arrive at the weights shown in the memory banks; these are indicated in the diagram at the top of page 100, along with their corresponding expansions.

Some confusion

Different shapes will be correctly recognized if they aren't too far removed from the original. For example, a 1 drawn as a single vertical line through the center column of the matrix will be recognized as a 1 using the weights in the diagram; but a similar line through the right-hand column looks more like a 7, and one through the left hand column looks like a 6, believe it or not, and the machine will identify it as such.

Tests with the demonstration model indicate the feasibility of building a similar device with a larger input matrix to handle more complex data, and with more binary decision units that can handle more patterns.

07	0	-2	0	+1	07	0	-2	0	+1
15	+2	-1	-2	-1	14	-2	0	+2	0
27	+2	+1	0	-1	26	0	0	+2	+2
34	-2	+1	-1	+2	34	-2	+1	-1	+2
46	+1	-1	0	+1	47	-1	-1	0	0
	+3	-2	-3	+2		-5	-2	+3	+5
9=	1	0	0	1	3=	0	0	1	1

Summing up. The stored weights shown in the diagram at the bottom of page 100 add up to produce the proper outputs for each digit.

A linear increase in the number of decision units would represent an exponential increase in the number of output categories. The present model, with four decision units, produces 16 outputs (recognizes 16 patterns). A machine with twice as many decision units would have 16 times 16, or 256, output categories.

Quadrupling the size of the input matrix would require perhaps four times as much logic hardware as the demonstration model contains, but less than four times as much control circuitry, power-supply volume, and mounting hardware. Assuming—conservatively—that a machine with twice as many decision units and four times as large an input matrix as the present unit would be eight times its size, such a machine could be packaged in a box no more than twice as high, wide, and long as the present system's. And the employment of the latest miniaturization techniques could doubtless fit the more complex system to the space occupied by the demonstration unit. For that matter, the present model includes lots of empty space.

Obviously the signals that turn on the indicator lights in the demonstration model could easily punch a card, print a figure, or close a relay. Or they could interrupt a computer program, and in so doing initiate some response by the computer to the input pattern.

Further, the machine's adaptive organization allows for component failure, a particularly important feature in systems that may incorporate large-scale integration techniques. A working version could be built with batches of LSI devices of which 10% were marginal or imperfect, and could learn to bypass those devices that fail.

Speech processing opens possibilities beyond computer programing, of course. Besides being able to adapt to any speaker, regardless of his language, dialect, or peculiar pronunciation traits, an identifier or verifier system based on these adaptive principles could learn to recognize a speaker by his individual vocal characteristics.

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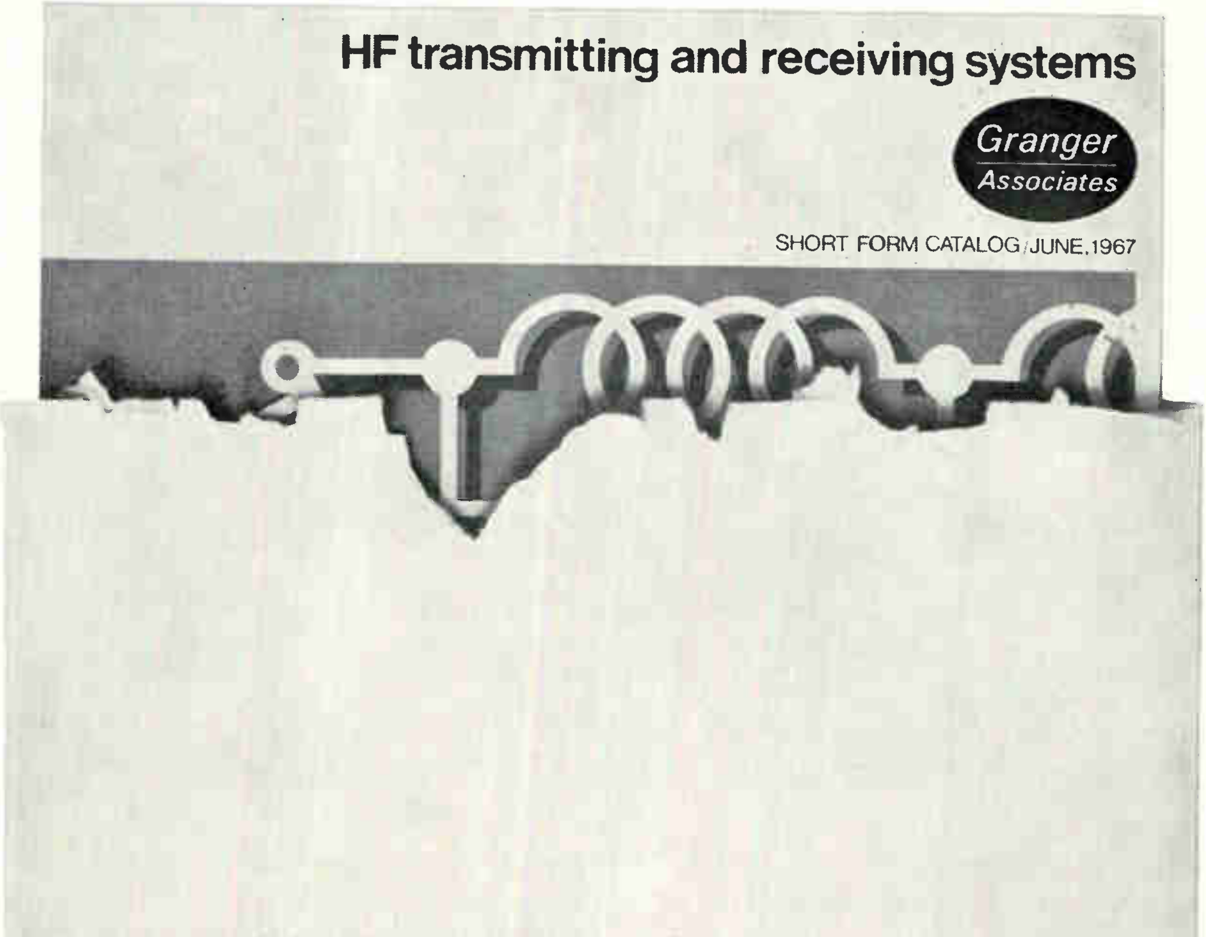

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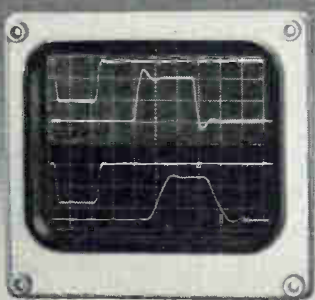

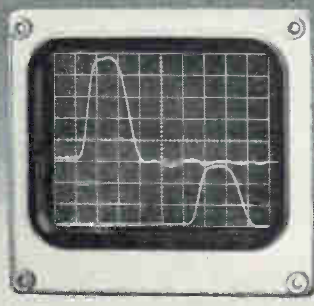

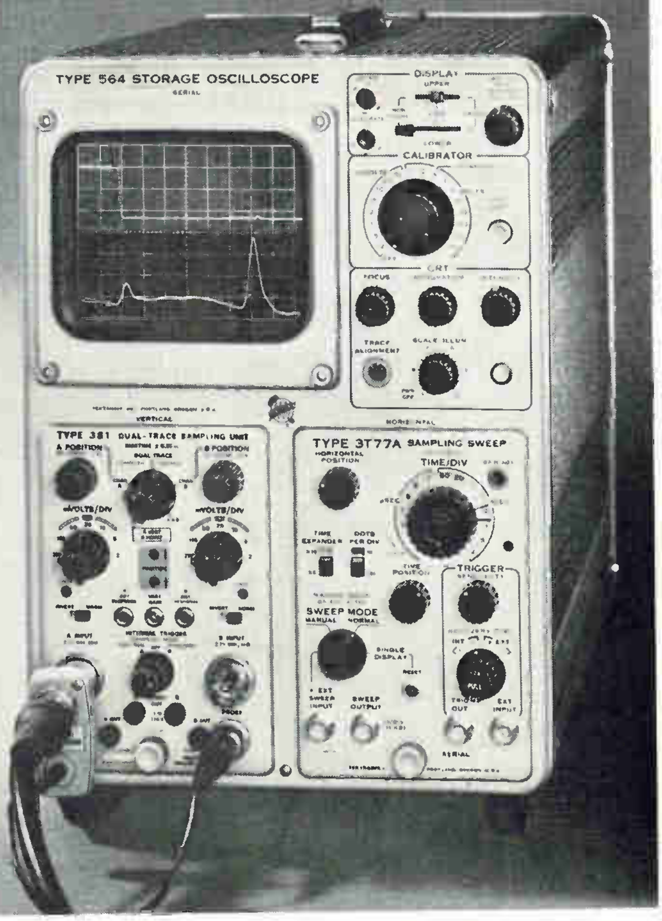

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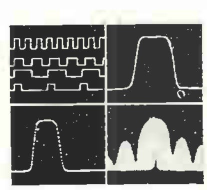

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Integrated electronics

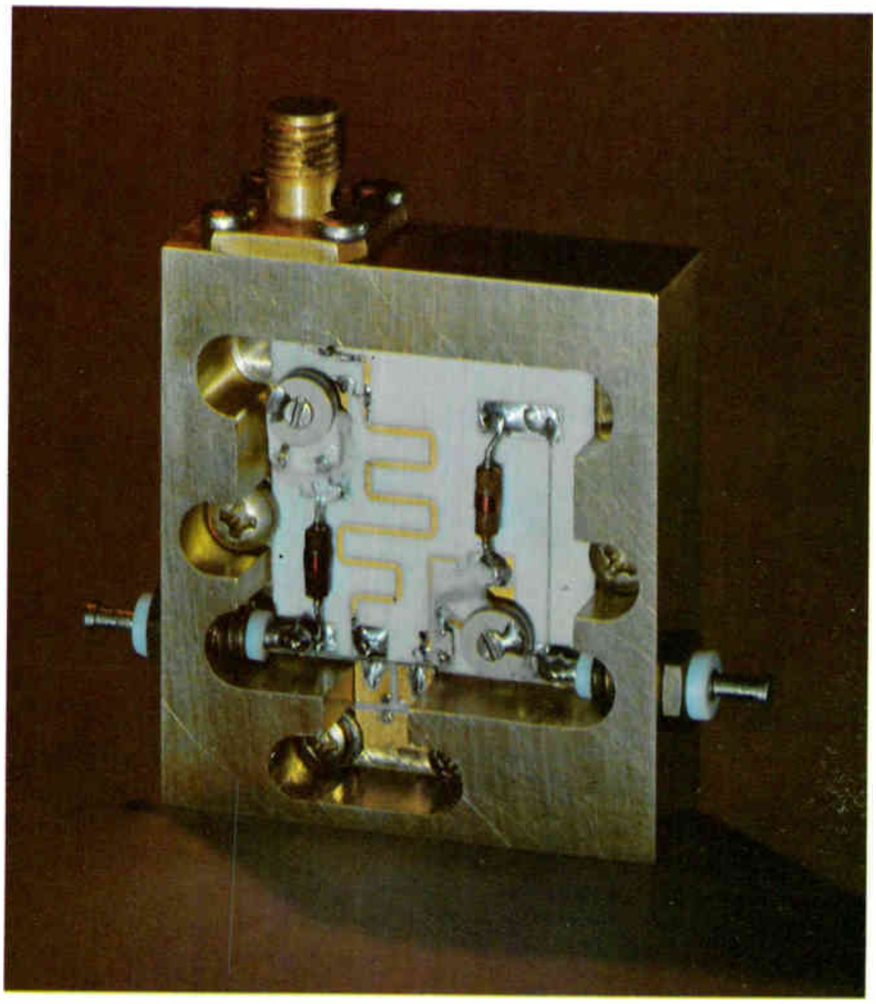
Microwave IC's come of age

Industry is gearing for volume applications in military, space, and commercial outlets; hybrid technology will give way to monolithic as mass markets develop

By Mark B. Leeds
Solid state editor

Integrated circuits are chipping away at the private preserves of microwave and other high-frequency tubes and components. And a number of IC trends are becoming increasingly apparent:

- Military and space systems, especially radar, are the biggest potential outlets at the moment, but consumer and commercial applications will be increasingly in evidence by the 1970's.
- Lower costs and greater reliability are the principal reasons for the IC push. However, the multifunctional characteristics of these assemblies promise a variety of additional operating advantages that should enhance their appeal.
- Hybrid techniques are now dominant, but monolithic technology is gaining ground and will eventually prevail as mass markets open.
- More and more systems manufacturers will compete directly with IC houses as erstwhile suppliers seek a share of development projects leading to prototype microwave equipment.

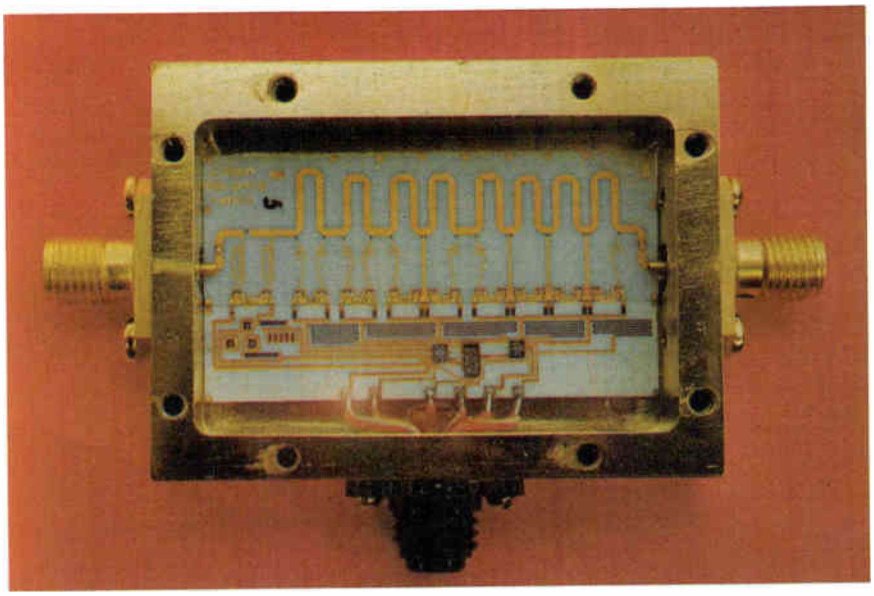


High powered. A hybrid 500-Mhz oscillator built by Motorola produces a 2-watt power output. The device is mounted in a brass test fixture.

I. Something of value

Most of the money now being spent in the microwave field is on subsystems and equipment, rather than parts. Industry sources say outlays for discrete semiconductor components, hybrid and monolithic IC's, and integrated-equipment modules are running at an annual rate of $40 million to $60 million, with IC's accounting for only $2 million to $3 million of this total. But, as assemblies improve, the semiconductor portion of the microwave market could reach $350 million a year by the mid-1970's, according to Virgil L. Simmons, manager of microwave products at Texas Instruments Incorporated. He believes IC's will get an 85% slice of this pie.

As a result of its three years of experience on the Air Force's MERA® (microelectronics for radar applications) program, TI has a headstart on other semiconductor makers in the race for microwave IC markets. On the systems side of the fence, Microwave Associates Inc., which



Complex. A four-bit S-band phase shifter made by Texas Instruments incorporates high-frequency driver and logic elements—the monolithic chips seen at the top center—as well as microwave switching diodes.

has a solid IC capability, holds a commanding lead. But coming up fast to give the top two a run for their money are Sylvania Electric Products Inc., a subsidiary of the General Telephone & Electronics Corp., and the Radio Corp. of America. Also in the running are such outfits as the General Dynamics Corp., TRW Inc., the Hughes Aircraft Co., the Bell Telephone Laboratories, and Motorola Inc. Overseas, Japan's Nippon Electric Co., Germany's Siemens AG, and France's Compagnie Française Thomson Houston-Hotchkiss Brandt are among the firms that have assigned microwave IC's a high priority.

Role call. Circuits developed by TI for MERA are typical of the microwave assemblies being produced. Among these devices are S-band pulse power modules, transmit-receive switches, frequency quadruplers, X-band balanced mixers, local oscillator multipliers, and pulse modulators.

Other state-of-the-art microwave assemblies include radio-frequency and video amplifiers, circulators, and impedance-matching networks. Operating frequencies of microwave IC's run from as low as 300 megahertz through 94 gigahertz [Electronics, Aug. 21, p. 44]. Most devices work between 1 and 12 Ghz; power levels vary from the submilliwatt range to 1 or 2 watts.

II. Market profile

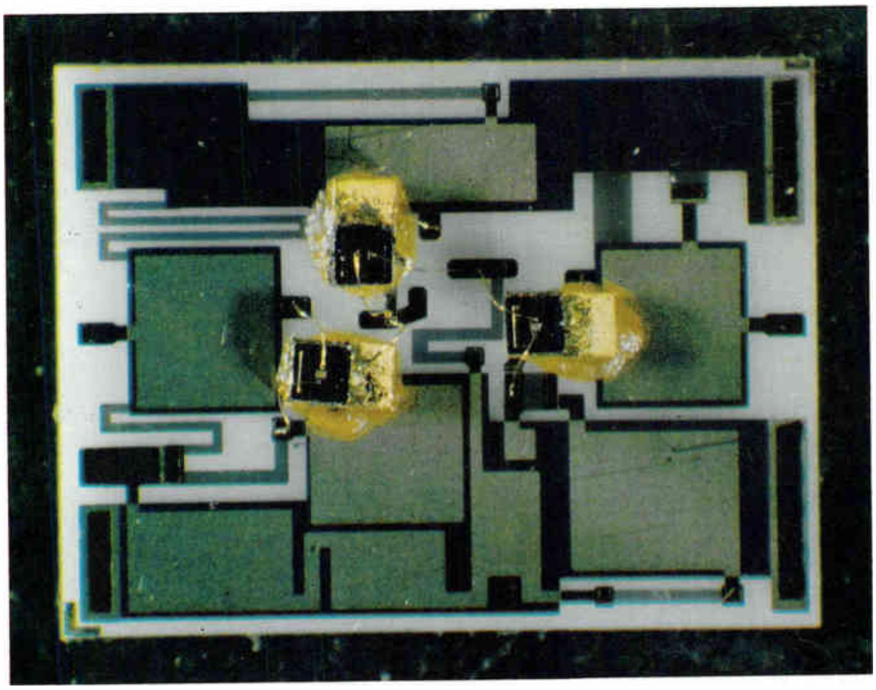
Military and space projects in general and radar systems in particular provide the largest outlets for microwave IC's. "Radar will do for microwave IC's what computers did for digital devices," says Roger Webster, who heads Texas Instruments' microwave research and development program.

The outlook for phased-array systems is especially promising, says Richard Alberts, chief of the integrated avionics task force in the Electronic Technology Division of Avionics Laboratories at Wright-Patterson Air Force Base. He predicts that by the mid-1970's some 10,000 military aircraft may be equipped with phased-array radars, each using as many as 1,000 microwave IC modules.

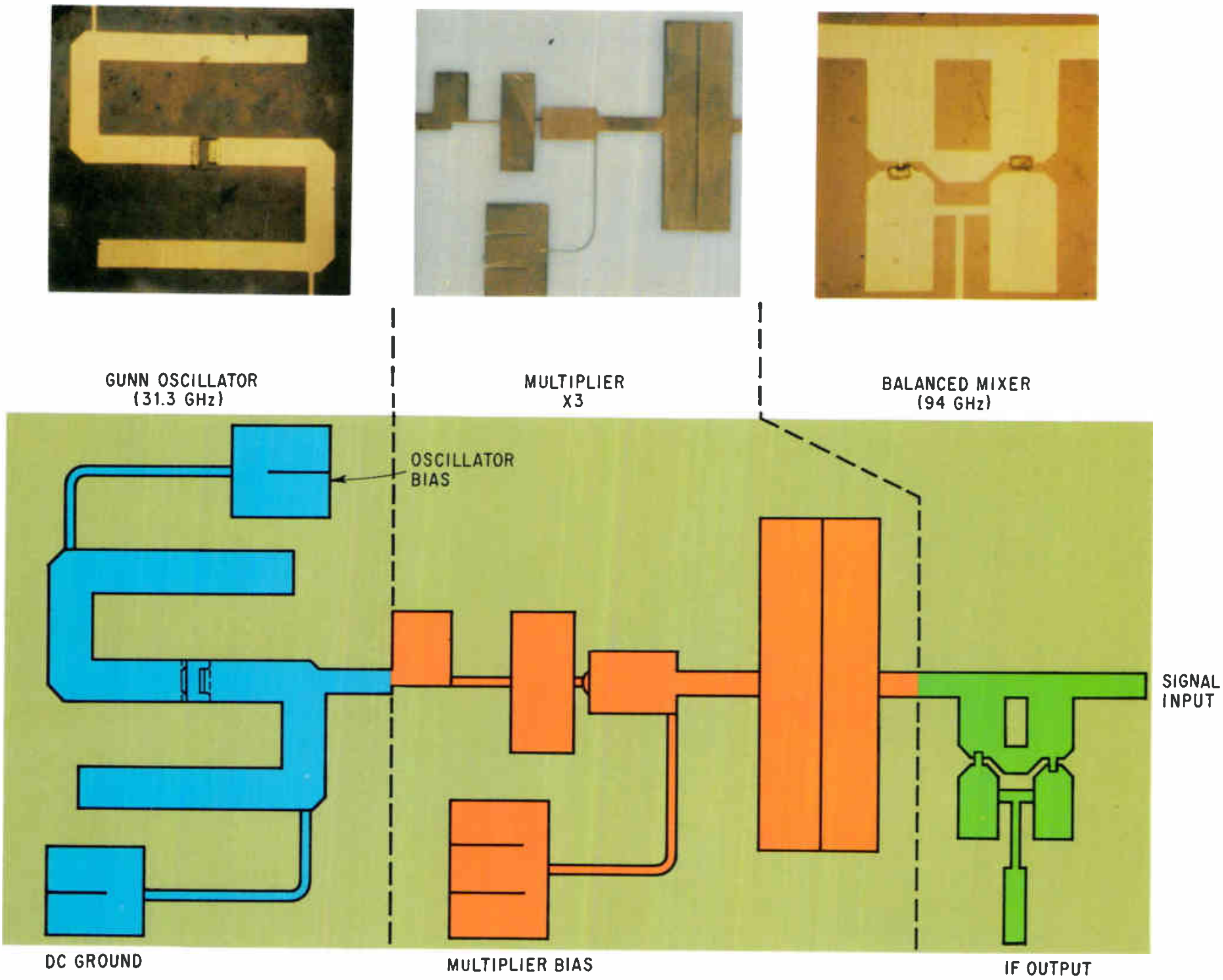
Alberts also considers navigation satellites, global-communications systems, missile-guidance equipment, and electronic-countermeasures apparatus potential volume outlets. William Edwards, technical manager for microwave devices in the avionics labs at Wright-Patterson, says telemetry systems—most of which operate below 1 Ghz—will be designed upward for the 1.5 to 2.3 Ghz range, opening up another vast outlet for microwave IC's.

Thomas Hyltin, manager of advanced microwave development at TI, sees microwave IC's eventually supplanting infrared and ultrasonic devices in measurement systems.

Fallout. The MERA project has been good to TI. The company is now marketing some of the IC's and discrete components developed for the program to systems firms. In addition, as a result of early success, TI has snared a number of new development contracts. Among these awards are a solid-state transmitter and altimeter for the National Aeronautics and Space Administration, a portable radar for the Army, an airborne-intercept radar for the Navy, a communications satellite for the



Starting point. Devices like the 500-Mhz preamp from TI are bringing the Air Force's integrated phased-array radar program close to reality.



Three in one. This state-of-the-art device developed by TI for a 94-Ghz receiver for the Air Force has three functions on a single monolithic chip. The circuit is fabricated on a 40-by-80-mil semi-insulating gallium-arsenide substrate.

Air Force, and advanced radar systems for the Marine Corps.

Executives at Microwaves Associates agree with the rosy assessment of the market potential for microwave IC's. But Richard T. Dibona, vice president for sales, cites telephony, industrial-surveillance gear, and airborne systems for commercial aviation as other applications. A. T. Botka, who heads the company's microwave-development effort, is optimistic about tying microwave IC assemblies to computers in high-speed data-processing applications like aerospace navigation and air-traffic control.

Motorola's Semiconductor Products division is tooling up to produce as many as 10,000 microwave IC's a week by 1969. Karl Wolters, who heads microwave development at the company's Government Electronics division, pinpoints collision-avoidance equipment and high-frequency commercial-communications systems as potential outlets for the devices. At Sylvania, Arthur H. Solomon, chief of the microwave-components section, believes that point-to-point relay communications, data transmission, and closed-circuit television applications will prove lucrative. "The first extensive use of microwave IC's by nonmilitary customers will occur in Europe at telephone companies that don't have microwave links. The devices will be used for low-power, short-hop, low-density traffic voice channels," he says.

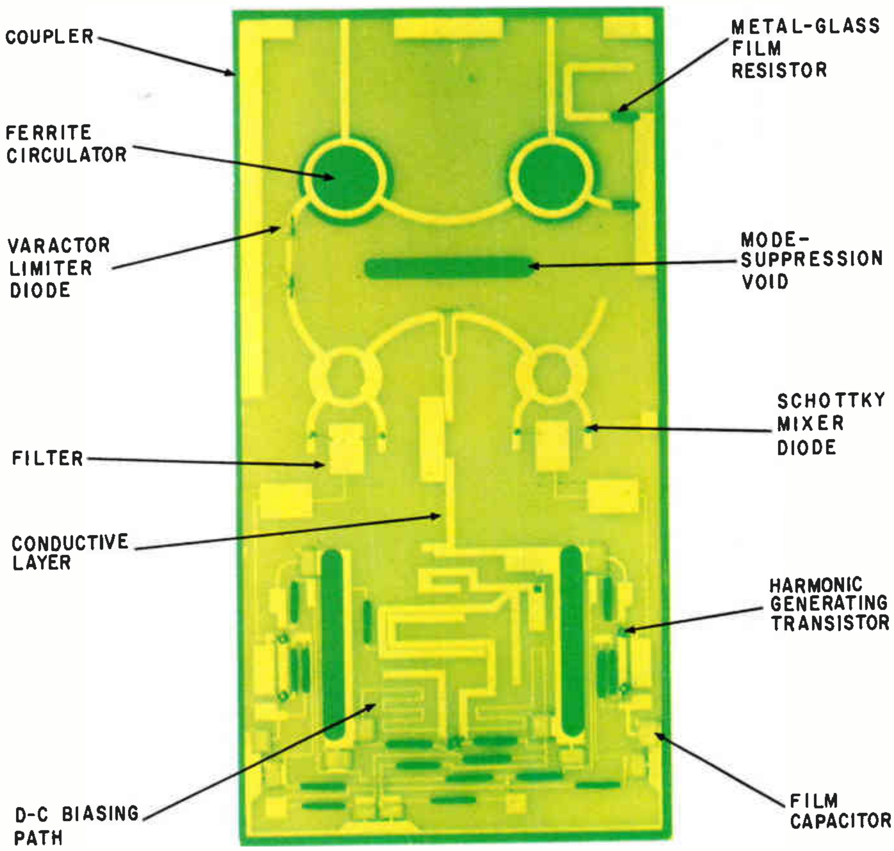
Overseas. But European interest in microwave IC's is not confined to telephony. Marcel Palazo, microwave manager at Thomson Houston's Radar and Aerospace division, says his company is working on devices for a variety of applications, including ground-based phased-array radar stations. In West Germany, Siemens is turning out circulators, frequency multipliers, attenuators, and directional couplers with an eye to expanding its share in the communications business.

Despite the potential, a great deal depends on the course of action a company decides to take. A source at RCA, who anticipates "tremendous opportunities in such areas as marine radar, collision-avoidance systems, garage-door openers, and railroad-car identification systems," is disturbed that his company has not centralized its efforts.

"We have microwave IC facilities in a half-dozen areas," he says. "A decision on centralization is due soon, but I wish it had been made earlier since our technical capabilities rank us with the leaders."

III. Savings

"The prime motivation for going to microwave IC's is economy. Mini-



Multifunctional. Built by Microwave Associates, this hybrid device performs preamplification, mixing, and local oscillator functions.

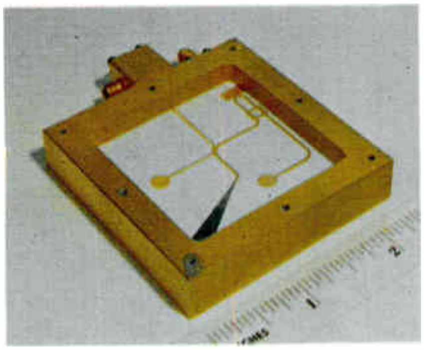
aturization is a secondary consideration," says Motorola's Wolters. "The economics of integrated design mean that IC's will constitute up to 70% of all our microwave equipment in the next few years."

Maintenance and troubleshooting costs have proved the biggest headaches with radar. Systems that operate for only 10% of the lifetime of the equipment containing them are considered working wonders. As a rule of thumb, conventional radars break down an average of 100 times during their life span; each failure requires upwards of 10 hours of repair work.

A Government study, says TI's Simmons, pins the blame for 50% of all radar failures on less than 10% of the electronic and mechanical components. Among the weakest links are magnetrons, klystrons, connectors, and coupling. An integrated-design approach could circumvent critical shortcomings; TI's Hyltin claims that mean time between failures of microwave IC's will outstrip that of aircraft carrying the radar system.

Extras. Integrated design provides additional advantages. Simmons cites phased-array radar that can both track and beam with the same IC elements. Steering is easily accomplished and such systems can furnish over-all area, rather than zone, coverage.

Since semiconductors don't have the narrow-response characteristics of tubes, broader bandwidth is possible. This, in turn, makes systems more versatile. In phased-array radars, IC modules are closer to the radiating element, thus minimizing power losses. Arthur S. Robinson, technical director of RCA's Missile and Surface Radar division, says that when tubes are used, losses occur in the waveguide, duplexers, feeds, and phase shifters.



Test case. Experimental hybrid built by Sylvania has beam-lead diodes and ink-like film passive elements; it is designed for doppler-radar systems.

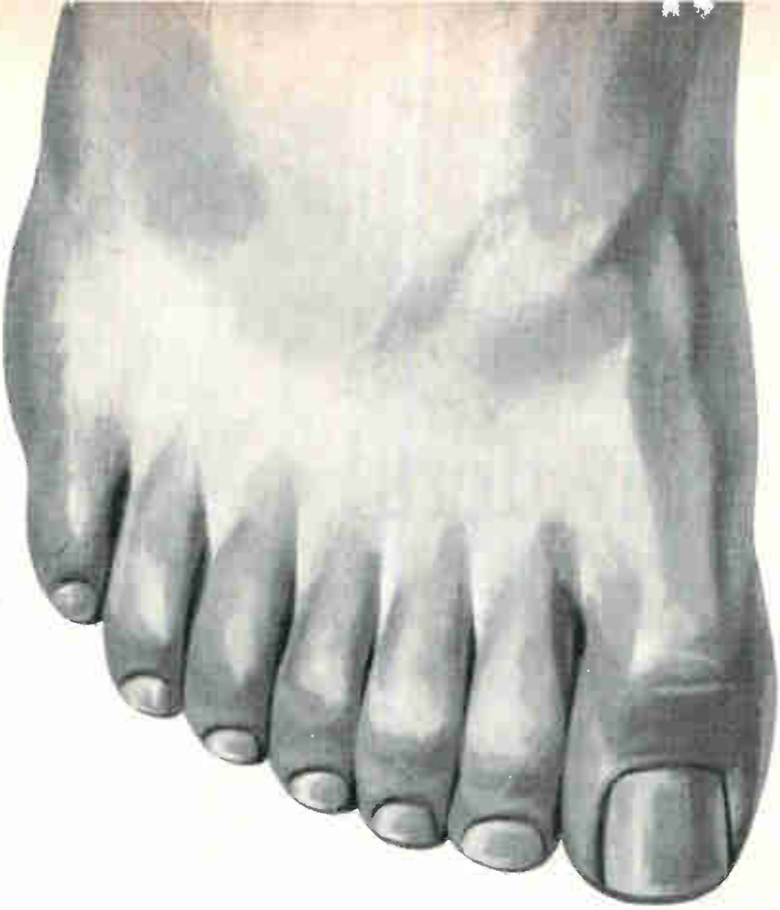
"Low-cost fabrication in quantity is a key consideration," says Marvin E. Groll, Sylvania's marketing manager for microwave products. "Automated production is, to a great extent, a reality with IC's. This isn't true, however, of waveguide systems." Size savings are also possible with microwave IC's. But TI's Hyltin points out that such gains are realized only in systems operating above S band.

IV. Way to go

Most of the microwave IC's now either in the works or still on the drawing boards are hybrid rather than monolithic. The main reason is that virtually any microwave function can be realized comparatively easily through hybrid techniques. The monolithic approach still doesn't lend itself to low-cost batch fabrication [Electronics, Sept. 4, p. 25]. Also, power dissipation represents a problem. Troublesome now, such difficulties are not considered insurmountable and the industry expects to be turning out volume quantities of monolithic devices probably as soon as the early 1970's.

Aid program. Webster at TI says computers are being used as extensively for microwave IC design as for digital circuits. "We know the characteristics of the materials and geometries at high frequencies, so it's a snap to design the patterns and figure out the types, ingredients, dimensions, and location of the elements," he says.

"Even though microwave IC's are generally considered custom jobs," says Webster, "there are many similarities. Impedance levels as well as switching and amplifying requirements, for example, are common to most circuits. We know how specific materials and combinations of certain lengths will behave. We also know that to modify a function, we simply change a length or increase a doping level. There is getting to be less and less of the trial and error and adjustment that characterized past circuit design. And each design and element that is finalized becomes a sort of master print to be used again and again. Under the old rules, every circuit had to be dealt with ad hoc, even when off-the-shelf devices were



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. . . both IC and systems firms are now playing dual roles . . .

being used."

Keys. Development of solid state discrete elements like microwave transistors, diodes, passive film networks, and related items that could be integrated, has opened up the field in the past few years. Transistors operating at 4 Ghz, for example, are now common. This is also true for mixing and switching diodes operating at even higher frequencies, permitting the use of multiplication techniques. Power-handling capacities are still lower than those of tubes, but combinations of active elements provide acceptable levels. Then, too, semiconductor elements are not as thermally limited as tubes. Thus, such devices can withstand proportionately greater average power levels and tolerate wide pulses.

Moving ahead. Microwave IC technology continues to gain ground rapidly. Typical of what's ahead is Microwave Associates' integrated Ku-band doppler-radar program for the Air Force. The project is exploring the feasibility of using large-scale-integration techniques in microwave applications. At RCA, engineers are paralleling Gunn diodes with an eye to achieving kilowatt outputs at 1 to 2 Ghz. Bell Lab researchers are on the verge of getting 1-watt outputs at 150 Ghz with limited space-charge accumulation devices. Interdigitated transistors handling 1 watt at 3 Ghz are being developed at TRW and the company expects to have a 25-watt, 1-Ghz unit operative before 1970.

At TI, Hyltin believes the millimeter range above 30 Ghz is ripe for IC conquest. He also predicts a new breed of digital elements operating at microwave frequencies for up to subnanosecond switching.

V. Power struggle

As a result of the heightened interest in microwave IC's, there is an inevitable blurring of the traditional roles played by systems manufacturers and IC makers. Eventually, there must be a direct confrontation. But for the moment, despite occasional skirmishes, an uneasy truce prevails. Perhaps the main reason for the status quo is the Government, which is underwriting research and development efforts at both the systems and semiconductor levels.

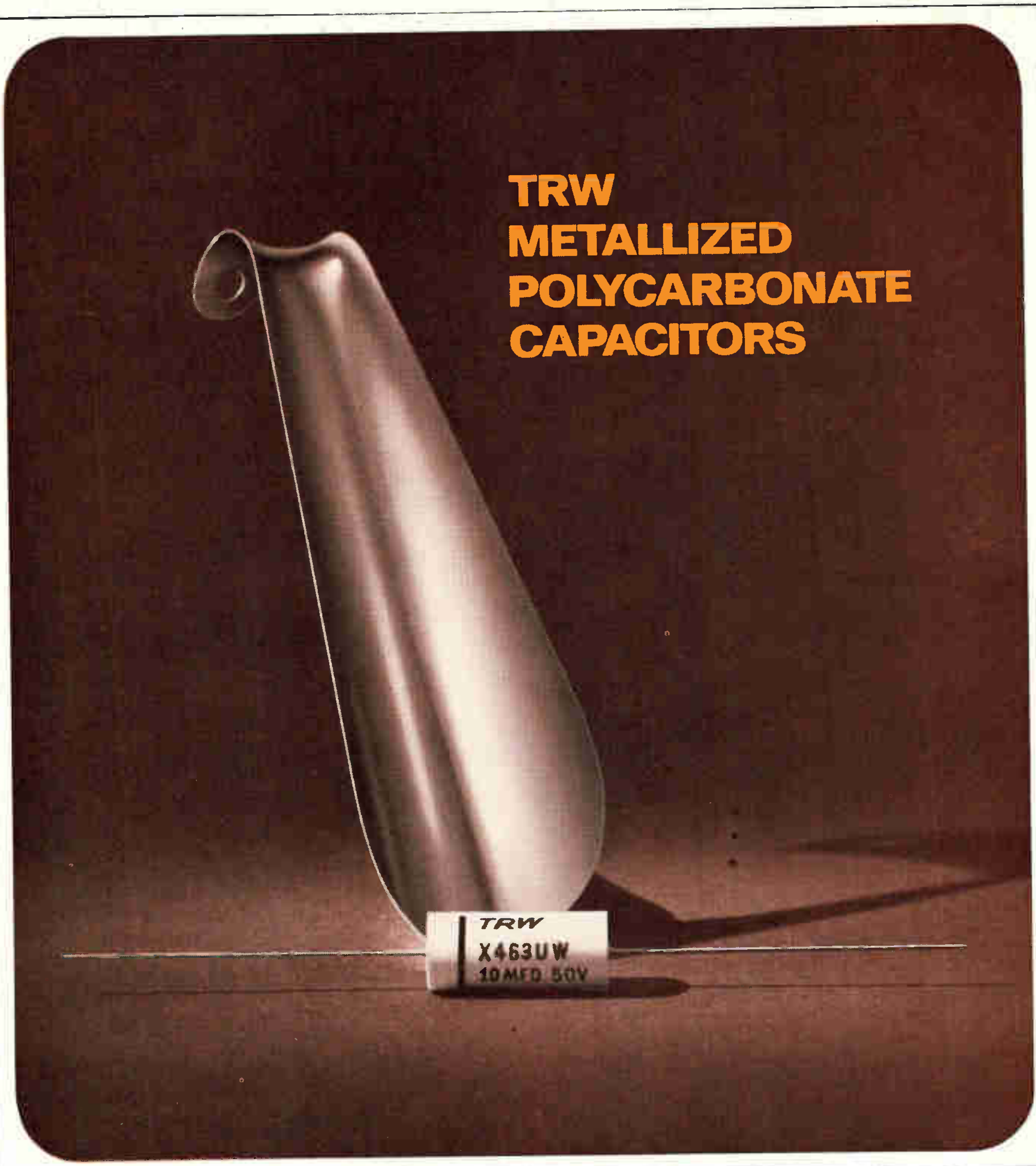
When it comes to assembling functional blocks to build working equipment, the systems makers have the edge. But at the device level, the IC makers have the advantage. Although developments in the microwave area are generally linked to devices, the systems makers seem to be more skillful in exploiting the possibilities of new circuits. In effect, they have successfully reduced the component makers' edge.

As a rule, IC houses delay releasing the newest device developments until their own engineers have thoroughly grounded themselves on the ins and outs involved. This effectively serves to keep the state of the art at home base.

Systems firms can produce their own IC's, and their hybrid units are on a par with anything delivered by semiconductor outfits. But when monolithic devices become a fact of life, IC houses should be able to open a lead on the basis of both economy and technology. Monolithic production is an expensive proposition, beyond the reach of all but the most affluent corporations. Systems makers would have to develop volume markets to justify the vast outlays needed to get into production. It's unlikely that the microwave field can support any mass business until the 1970's.

Playing it cozy. The IC houses that don't have a background in systems work and lack operating units in the radar and communications fields generally avoid competing with their customers—both actual and potential. But the microwave field lacks giant customers like the International Business Machines Corp. that can create markets by themselves.

It is not unlikely that marketing and merchandising prowess may ultimately dictate which firms get the biggest slice of the microwave pie. For the moment, however, IC houses and systems makers appear content to quietly upgrade their competence in the others' specialties. Some companies are even reorganizing along marketing and production lines so they can work both sides of the street.



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In the vanguard of this upheaval are two companies not normally considered dominant figures in the data processing field—the Digital Equipment Corp. with an integrated-circuit takeoff on its PDP-8 series and the Hewlett-Packard Co. with its model 2115A, a stripped-down, economy version of the 2116A [Electronics, Sept. 18, p. 43].

Probably the main reason that small computers have captured the fancies of both users and manufacturers is the extreme difficulty experienced in programing the large, third-generation machines. Moreover, both groups are waking up to the fact that there is a place—and a growing one—for small computers that can do specific tasks efficiently at a reasonable cost. Adding further impetus is a year-old Air Force resolve to use off-the-shelf machines rather than custom designs for all but a few mobile and airborne applications [Electronics, Sept. 19, 1966, p. 201]. And integrated circuits have helped bring the cost of general-purpose computers below $20,000.

I. Diminishing returns

Until now, the major trend in computer design has been to reduce the cost per calculation by increasing the size and speed of the computer. The International Business Machines Corp., for example, says it cost $1 to process 35,000 program instructions in 1950; today, 35,000,000 instructions can be processed for $1. Theoretically, this gives machines the capacity to work on several problems at the same time. But the bigger the machines grew, the more important became precision scheduling of peripheral gear, such as tape transports, printers, punched-card input and output devices, and data transmission apparatus. Moreover, exactness must be automatic—a situation requiring complex operating-system programs that have proved difficult or impossible to write.

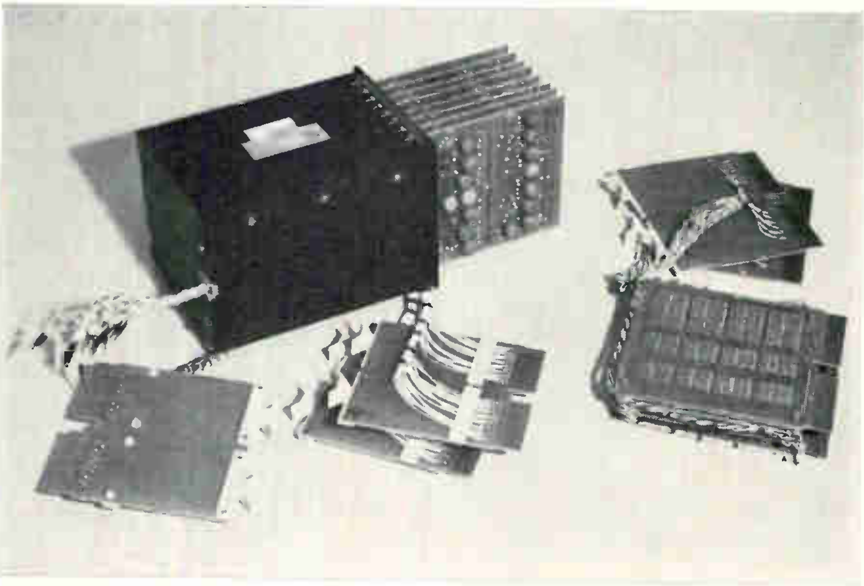
IBM Corp. has suffered the best publicized woes with software for the larger models of System 360. The program was completed at least two years late. At one time, the company had nearly 1,000 people writing it. When finally delivered, the program still didn't satisfy everybody, and it has already been changed two or three times. Regular revision will be necessary, probably as long as System 360 machines are in use.

Programs for operating systems have grown so big—IBM's has one million instructions — that they choke the computer memories, cutting down on the machine's ability to perform useful tasks. For example, the 360's operating system occupies almost 32,000 bytes of memory all of the time.

Identity crisis. As another source of discouragement, a big computer takes a lot of programing to make it a scientific problem solver for one user, a payroll accounting machine for another, an information retrieval system for a third, and a language translator for a fourth.

Time-sharing has further complicated programing by introducing complex coding and programing requirements to assure each user's privacy.

As a result of such difficulties, users have begun asking if it wouldn't be more economical to buy several small-sized general-purpose computers, each of which



Squeeze play. Core stack memory for new Digital Equipment Corp. computer built with IC's is shown at right; it replaces the hardware at the left.

. . . the trend to time-shared systems will boost small computer sales . . .

could concentrate on a single problem, such as circuit design, payroll preparation, or inventory checks. More and more customers are saying yes, particularly since the availability and use of integrated circuits has brought the cost of small machines with acceptable speeds and capacity into the $10,000 to $20,000 range. Moreover, these smaller processors are comparatively easy and inexpensive to program.

Charles D. Ettinger, manager of small computer marketing at the General Electric Co., says that the trend to time-shared systems and remote batch processors will mean more rather than less business for the mighty mites. He believes that multiplant companies will want small machines for remote access to central systems as well as for use as principal processors at outlying locations. Ettinger estimates that perhaps 5,000 new commercial users will be buying such equipment between now and 1970.

Job shopping. Other analysts peg the dollar value of the 1967 market in small computers at more than $200 million. In addition to taking over conventional computer chores in scientific and research applications, the small new machines have created their own openings in process control, test instrumentation, and communications. Small computers are also being employed as satellites—either as controllers or buffers—in larger data processing systems.

II. Dead aim

With such a lure, the market, which is expected to grow to nearly $1 billion by 1970, is attracting new suppliers. For example, Hewlett-Packard, an instrument maker, was prompted to introduce a small general-purpose computer, the 2115A, that costs $16,500 with a teleprinter. The company's new machine, which will be unveiled at Anaheim, is an adaptation of the special-purpose computer, designed for instrumentation systems, that was introduced last fall. The 2115A was intended to compete head-on with a small machine already doing very well—the PDP-8, an $18,000 unit made by the Digital Equipment Corp., self-styled "IBM of small computers." The H-P machine uses the same kind of input and programing and produces the same kind of output as Digital Equipment Corp.'s model 8.

With the PDP-8 and another small machine—the PDP-8/S, a slower model of the 8 which carries a bargain-basement price tag of $10,000—DEC claims a healthy percentage of the small-computer market. The company considers Honeywell Inc.'s Computer Control division, whose models DDP-416 and -516 sell in the $20,000 range, and Hewlett-Packard its principal competitors.

Big deals. Unlike orders for large machines that typically dribble in one at a time, bookings for small machines can come in bunches. Theodore Helweg, vice president for marketing at Honeywell's Computer Control division, says his firm recently received an order for 150 machines from a communications concern. About the same time, the Digital Equipment Corp. reported an order for 200 machines from one of its customers in the communication field.

One-upmanship. Both Honeywell and Digital Equipment Corp. are looking worriedly over their shoulders at Hewlett-Packard because of the instrument company's traditionally strong marketing organization. Barely had H-P announced its plans to enter the general-purpose computer business with the 2115A when DEC hustled to trump its rival's ace with a new version of the model 8 that is faster, more powerful and costs only $12,800 with teleprinter. [For a closer look at this new machine, the PDP-8/I—I for integrated circuits—see the box on this page.] The new machine

Family plan

Stockholders at the Digital Equipment Corp.'s annual meeting at the end of October were treated to a preview of the company's first computer built with integrated electronics: the PDP-8/I. The new machine is compatible with the company's model 8: it runs on the same programs and operates the same input-output equipment at about the same speed. But with a price tag of $12,800, it costs $6,000 less than the model 8 and $4,000 less than the new machine announced this fall by the Hewlett-Packard Co.

The company started its family of small computers four years ago with the PDP-5 machine. It followed up with the PDP-8, which was faster and cheaper. The PDP-8/S, a slower, less expensive version of the PDP-8, came next.

The design of the 8/I typifies the new breed of small computers. It has minimal architecture. For example, the basic instruction set does not include multiply or divide instructions; instead, program subroutines perform these operations. If a buyer needs such capability, he can get the hardware at extra cost. In addition, the machine has no index registers except for a single special address in the main memory.

Until the model 8/I, DEC had stayed away from integrated electronics on the grounds that IC's were neither economic nor reliable enough. What changed the company's mind was the availability of transistor-transistor logic (TTL). The high speed of TTL allows the new computer to equal the performance of a PDP-8 machine—which operates on register-to-register transfers so that two or more transfers take place at the same time—even though the PDP-8/I uses a common bus for transfers, allowing only one transfer at a time. The common bus is necessary because of the limited number of inputs available in an individual TTL circuit.

Compared to the PDP-8 or the PDP-8/S, the new machine has somewhat greater capability. In operation, it is more serial than the 8 and more parallel than the 8/S. The 8/I has built-in controls for a paper-tape reader and plotter—something the earlier machines lacked.

And, although both the PDP-8 and the PDP-8/I have a basic memory of 4-k bits, the new computer has built-in wiring to handle an extra 4-k memory that can be plugged in. The earlier machine requires an external module.

Satisfied with the performance of the PDP-8/I, DEC may redesign the cheaper PDP-8/S with IC's to produce a no-trimmings computer that could sell for about $6,000.

. . . with LSI, an entire processor may be built on a single chip . . .

will also make its official debut at the Fall Joint Computer Conference.

III. Best of the rest

Although virtually all other computer makers say they too are interested in the small computer business, most do not make equipment that meets the tough specification of very low cost. Scientific Data Systems Inc., for example, makes the Sigma 2, which comes close to being a small general-purpose machine. But while its price tag is only $30,000, a company executive cautions that adding peripheral equipment can run the cost up to $70,000 or $80,000 for an installation. Other small computer makers contend the Sigma 2 has not been tough competition and say it accounts for less than 2% of the market. General Electric's model 115 "small computer" has a starting price of $55,000; installations cost as much as $275,000.

The Radio Corp. of America has a machine, the 1600, which meets the requirements for a small computer, but the company does not yet sell the machine as a separate product. The 1600 is used as a controller in other data processing systems or as a buffer in communications systems.

The Control Data Corp. which has always concentrated on the largest and fastest computers, typically those run by aerospace companies which have large staffs or computer experts to write their own programs, has also eschewed this part of the market. And IBM, which bestrides the worldwide computer market, has only fielded one entry that meets the low-priced limitation.

IV. New ballgame

But the three major outfits—DEC, CDC, and H-P are not likely to keep their preserve private for very long. During the next decade, the development of large-scale integration—the incorporation of thousands of gates on a single chip—will change not only the organization and shape of the next generation of computers but also the structure of the industry. It's conceivable that an entire processor could be built on a single slice of silicon the size of a half dollar.

Dan E. Cota, a member of the product planning staff at Scientific Data Systems, says large-scale integration may well be one of the technologies that will lead to small systems even cheaper than those now available. "Large-scale integration is suitable for logic and it may also be useful for memories," he says. "If this proves out, we could take a total design approach to new systems." Combining memory and logic in the same package, or even on the same slice, would distribute memory throughout the computer instead of restricting it to one portion.

But even before that happens, medium-scale integration—50 to 100 gates on a single IC—will radically affect computer designs. In addition, medium-scale integration products, some of which are already being marketed or built on pilot lines, will cut the costs of small computers even more sharply.

Logical contenders. It's inevitable that some of the semiconductor companies that build large arrays will enter the small computer field. Texas Instruments Incorporated has already built an experimental machine in its laboratory and is weighing its market potential. The Fairchild Camera & Instrument Co., which has pushed IC instrumentation in its instrument division, has a bevy of computer experts and could launch a line of equipment to follow Hewlett-Packard's lead.

Finally, some of the aerospace firms like the Autonetics division of the North American Rockwell Corp. with inhouse capabilities in both IC's and computer technology, are studying the possibilities of the small machines as diversification vehicles. What makes this area so much more attractive than the large general-purpose computer business is the premium placed on hardware. There is no need to develop the complex, expensive software packages which tripped a lot of earlier entries in the computer market.

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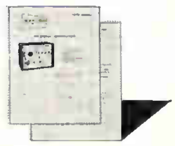

TECHNICAL DATA SHEETS

Technical Data Sheets on the Model 1066B/1 and Model 1066B/6 Marconi FM Signal Generators detail all specifications, operation, applications, features and accessories available.

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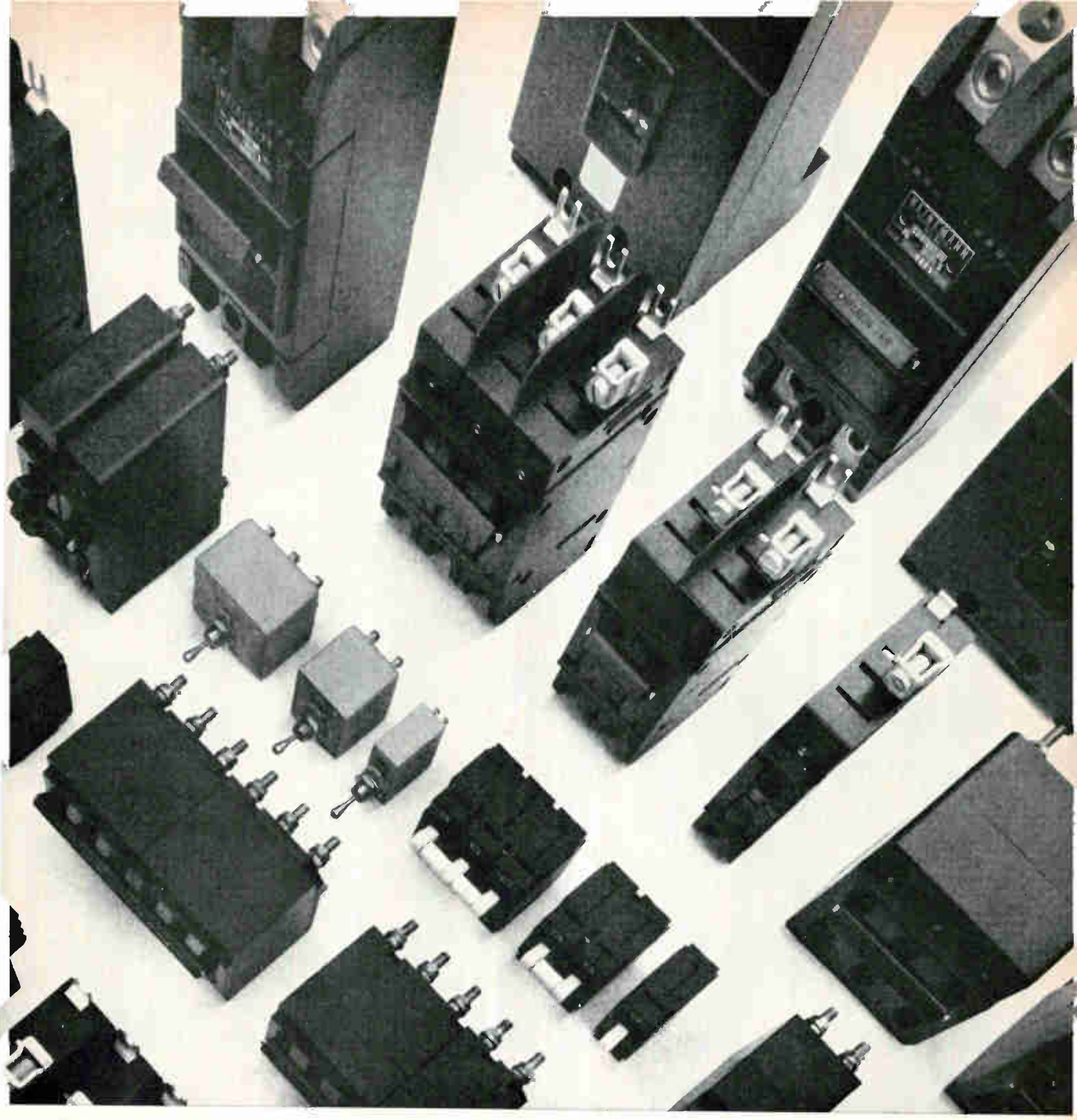

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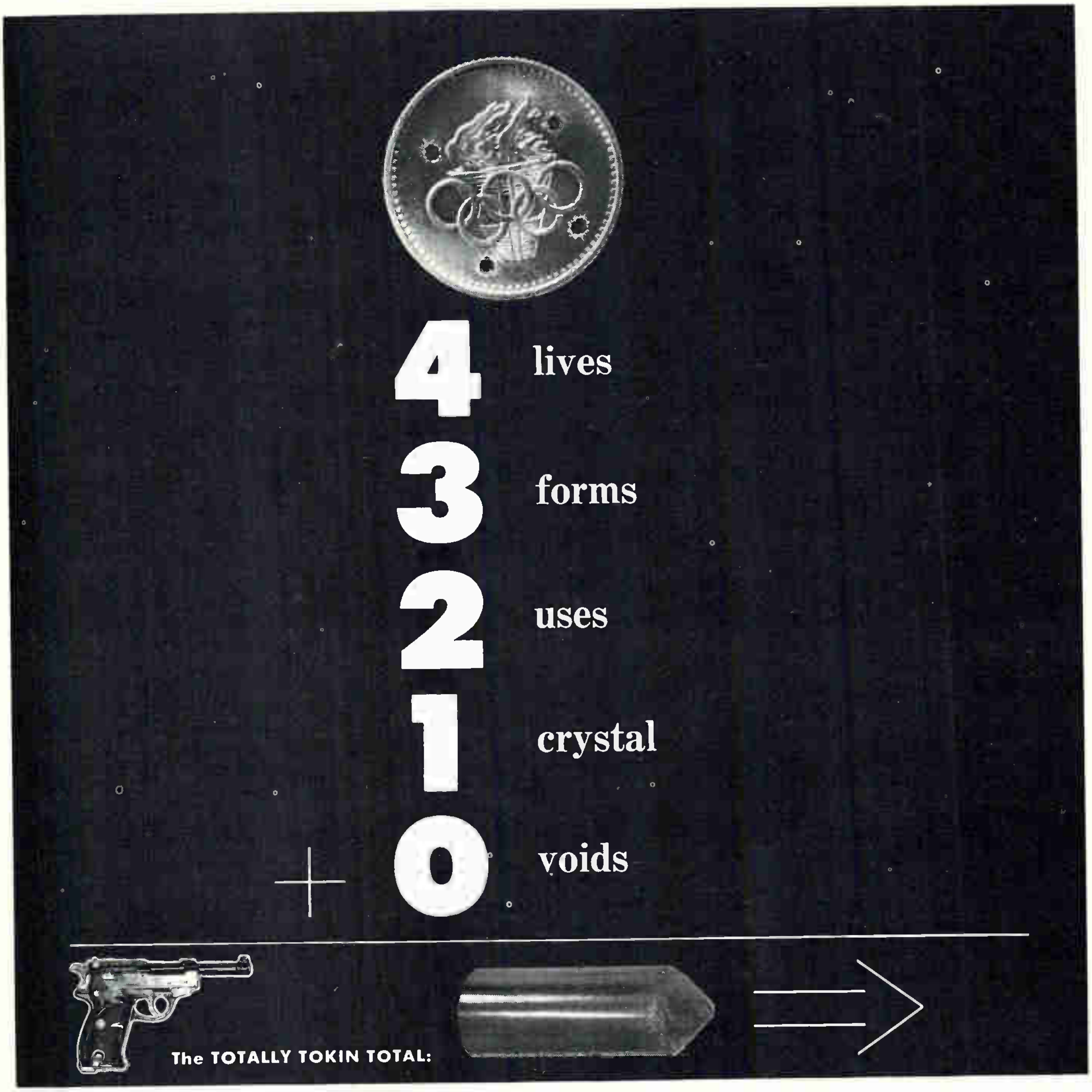

The Olympic Winner–

watchers were headed by TOKIN.

1. '64 Olympics: Japan Broadcasting Corporation developed unique slow-speed video tape recorders to catch the winning moments beyond doubt. To get long life and super-sensitivity for their VTR recording heads, they chose **TOKIN** to make the tips. Just last year **TOKIN** began to produce them internationally.
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Tokin

New Products

New television equipment

Tape, disk recorders make wider color splash

Companies aim at new industrial markets, medical research and education with simpler, smaller units; black-and-white set is $600 under firm's prior low

By Christmastime, the Ampex Corp. will be marketing two new video-tape recorders for industrial, medical, and educational applications. Still too costly for the consumer market—one machine is priced at $995 and the other starts at $8,000—the VTR's are beginning to rival the familiar audio tape units in both size and simplicity of operation.

In addition to the Ampex entries, the MVR Corp. has unveiled a video-disk recorder for slow-motion playback. Based on equipment developed for instant replay of sports highlights on television, the new recorder is billed as a valuable tool in heart research, psychiatry, physics, highway-safety studies—anywhere events can be monitored continuously and data used for special analysis.

I. Priced lowered

The $995 price for the Ampex VR-5000 is $600 below the company's previous low for a black-and-white recorder. The company's other entry, the VR-7800, a sub-broadcast-quality color recorder, will be offered for $8,000 to $12,000, depending on optional features. It is intended primarily as a production machine for making master black-and-white or color tapes, and can be used in any closed-circuit tv application.

The VR-5000 includes deck, base, and video-control center, which enables the recorder to be connected to the antenna terminals of any tv set. Thus, the set can be used as a playback monitor. The recorder has its own built-in audio monitor and speaker system. With a 20 hertz-to-2.5 megahertz bandwidth, the recorder has a playback resolution of better than 280 lines.

Servotracked. It is equipped with a new servosystem to control timing and tracking of the rotating head. This system employs a d-c motor, which has a printed-circuit permanent-magnet field and is driven by a pulse-duration modulated source. This is a departure from the hysteresis-synchronous motor normally used to drive the capstan and accounts for a time-base stability of 2 Mhz.

The VR-5000 weighs just under 65 pounds, and will record and play back a 1-hour program using a 10-inch reel of special 1-inch video tape.

The VR-7800 color recorder is by far the most sophisticated helical-scan recorder introduced to date. It is the first unit priced under $50,000 that meets the Federal Communications Commission's 2,-500-Mhz transmission requirements for black-and-white and for National Television Standards Code (NTSC) color, and the Electronic Industries Association standard covering broadcast requirements.

New generation. The 7800 is the first video recorder in the Ampex family to use monolithic integrated circuits—more than 70 circuits for servocontrol and video processing. Its four-motor transport system—one for drum, one for capstan, and one for each of the two reels—is

For the record. Ampex VR-5000 tape unit, smallest in the company's line, weighs 64 pounds, can be used with any standard monitor or television set.

automatically switched by solid state circuitry. Unlike lower-priced VTR's, the 7800 has separate capstan and drum servos. The recorder can operate independently of the power-line frequency. It can also be synchronized to the line frequency externally, or internally by a 50- or 60-hz oscillator.

Editing circuits enable tapes to be electronically spliced, allowing any number of tape strips to be combined on a continuous reel. Another new feature is an electronic tension servo, which senses the tape condition and automatically takes up the slack or eases tension.

A color-correction feature that, until now, was used only on the $100,000 VR-2000 studio recorder, has been included in the 7800 design. The customary separate audio and control channels, variable speed slow motion playback, and full remote control capabilities are included.

Like all recorders in the Ampex line, both the 5000 and 7800 have a video writing speed of 1000 inches per second, and a reel-to-reel tape speed of 9.6 ips. They both use 1-mil polyester base video tape and have a maximum recording time of one hour.

II. Football and psychiatry

The medical research market is a prime goal for the MVR Corp.'s 222S slow-motion playback unit, which was developed for football telecasts. The Mayo Clinic in Rochester, Minn., will use one unit to study fluoroscopic X rays of dogs' hearts. John T. Phan, designer of the unit, says the stop-action equipment can also create a three-dimensional effect. It would record a series of focused X-ray pictures in planes, each image taking eight fields or four frames. By progressively focusing the X ray from front to rear of a tumor it could record up to 100 frames. Since the eye retains an image for a split second, the recorder could play these frames back at a speed in which the eye would see a 3-D picture.

In psychiatric analysis, says Phan, instant playback would enable a patient to see his actions on a monitor.

Slow to slower. The 222S offers four modes of operation: real time of 26 continuous seconds; stop action; four forward slow-motion speeds; and reverse motion at either full speed or any or all of the four slow-motion speeds.

The 222S also permits field-by-field analysis by holding an individual frame upwards of 100 hours. In this way, events can be recorded, held and analyzed, and then erased or transferred to another record such as a strip chart or x-y recorder.

The 222S has a price tag of $25,000 for the basic black-and-white machine. With color capability added, the 222S will be priced about $35,000 higher.

New tv equipment

Little Shaver convention-bound

Color television camera of broadcast quality weighs in at 23 pounds

All three major television networks will be sending Little Shavers to cover next year's political conventions. The Little Shavers aren't baby-faced reporters, but portable color-tv cameras developed by the Philips Broadcast Equipment Corp., a subsidiary of North American Philips Co. (Norelco).

Moving color. Optical simplicity helps make portable camera possible.

Called the PCP-70, Little Shaver is the first portable color camera of broadcast quality to be marketed. It uses the same optical and electronic equipment as its full-size studio counterpart, the PC-70. In their studio cameras, other manufacturers use four image tubes —one for each of the three primary colors and one for color registration. To split the incoming light four ways, requires four lenses, five mirrors, and a beam splitter. The PC-70 and the Little Shaver use one prism assembly and three Plumbicon image tubes. The fourth tube isn't needed, because of an unusual technique called contours out of green. The output of the green tube serves two functions: it supplies the green video signal and feeds a circuit that enhances the boundaries between colors, eliminating registration problems.

Like big brother. Because the PCP-70 has few parts in its optical path, the unit requires less light to produce a high-quality video signal. And because of its optical simplicity, Norelco engineers were able to repackage big brother into the Little Shaver.

The PCP-70 has a smaller lens than the PC-70. The automatic, servocontrolled zoom and focus systems are omitted in the portable model. The lens, image tubes, and first preamplifier are contained in the 23-pound, shoulder-carried camera, with the rest of the electronics mounted in a 10-pound backpack. Total system weight is 44 pounds, with a cathode-ray tube viewfinder and a wiring harness making up the additional 11 pounds. With a longer harness the camera can be up to 75 feet away from the backpack electronics.

Compatible. What makes the Little Shaver particularly attractive to broadcasters is that it uses the same control equipment as the bigger, studio cameras. Capable of being operated up to 3,000 feet from the control console, using standard TV-81 cable, the Little Shaver is a natural for sporting events. The American Broadcasting Co. has ordered the camera to cover the 1968 Winter Olympic games. It is priced at $41,450 minus control console. All three networks now use PC-70 consoles.

Philips Broadcast Equipment Corp., Paramus, N.J. [338]

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TO-72

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This new full insulated-gate, N-channel, depletion type MOS transistor can offer performance advantages of mechanical choppers with none of their drawbacks. The inherent zero offset voltage (see chart) means that you have none of the tracking problems of matched bipolar devices, caused by temperature changes and extended operation. Compared to a mechanical chopper, the 3N138 offers the additional features of solid-state reliability, superior frequency response, lower driving power, and small size.

Among other important advantages, the insulated gate provides a very high value of input resistance (10^{14} ohms typ.). Forward transconductance is also exceptionally high (6000 μmho typ.). So for outstanding performance and reliability in chopper and multiplex applications and industrial instrumentation and control circuits, ask your RCA Field Representative for complete information on the 3N138 MOS field-effect transistor. For additional technical data, including Application Note AN-3452, "Chopper Circuits Using RCA MOS Field-Effect Transistors," write RCA Commercial Engineering, Section FN10-2. Harrison, N.J. 07029. See your RCA Distributor for his price and delivery.

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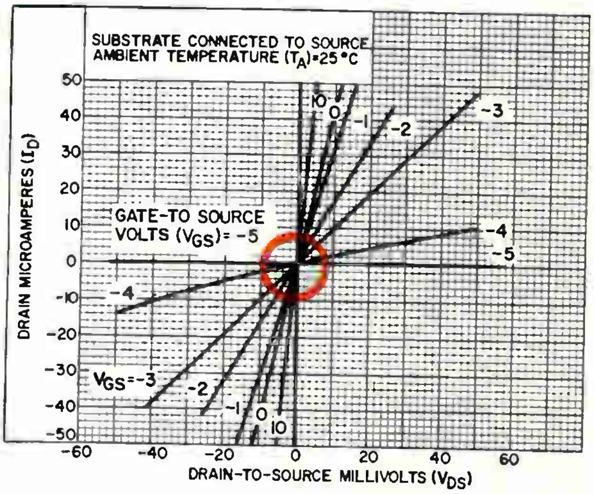

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Gain control range	50 dB (min)
Attenuator	
Range	0 to 100 dB
Insertion loss	18 dB (max)
Accuracy	± 0.05 dB/10 db, ± 0.3 dB (max for 100 dB change)
Resolution (½ smallest division)	0.01 dB

Overall Instrument	
Measurement range and accuracy	
IF	100 dB ± 0.4 dB
RF	60 dB ± 0.3 dB
Scale resolution (½ smallest div.)	Normal 0.05 dB Expanded 0.005 dB
Video output	0.5 volt (100-ohm load)
Rise and fall time	1.5 usec (max)
Power required	115/230 vac, 50 to 400 Hz, 20 watts

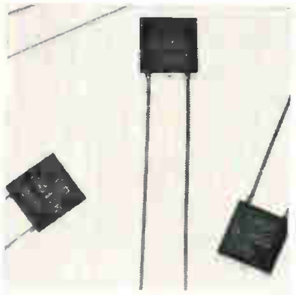
CONTROL
CUTLER HAMMER
AIL DIVISION

AIRBORNE INSTRUMENTS LABORATORY
DEER PARK, LONG ISLAND, NEW YORK

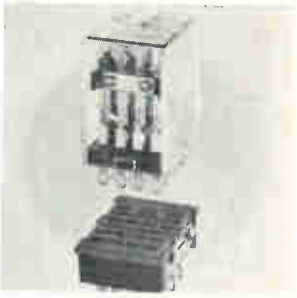
New Components Review

Single-turn pots 3103 and 3203 have 7/8-in. and 1 1/16-in. diameters, respectively. Essentially infinite resolution cermet elements come in resistance values of 1 meg, with resistance tolerance of ±5% and independent linearity of ±0.5%. At +50°C power rating is 1.25 w for the 3103 and 1.5 w for the 3203. Beckman Instruments Inc., 2500 Harbor Blvd., Fullerton, Calif. [341]

One-half-cubic-inch crystal oscillator model XO-105 is designed for industrial and military applications on p-c boards. Frequency range is 2 Mhz to 100 Mhz. Frequency stability versus temperature varies from ±0.0005% (in the range of +20° to +30°C) to ±0.005% (for −55° to +85°C). Electronics Div. Bulova Watch Co., 61-20 Woodside Ave., Woodside, N.Y. [342]



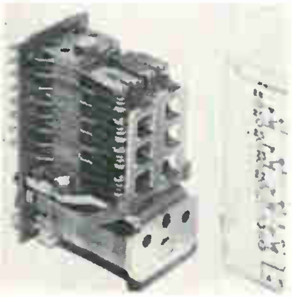
Molded ceramic capacitors TMM5 and TMM6, through advanced multilayer technology, are available from 10 to 100,000 pf. Units meet MIL-C-11015/18 and 19 for MIL Styles CK05 and CK06. They exceed the BX temperature characteristic requirement (±15% at zero v d-c; +15%-20% at 100 v d-c). Cornell-Dubilier Electronics, 50 Paris St., Newark, N.J. [343]



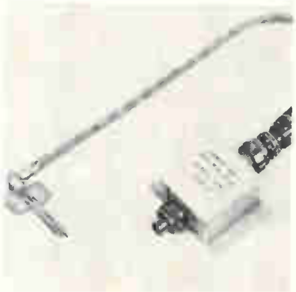
Four-pole relay series 67 is slightly more than 1 cu in. Each pole switches low-level to 3-ampere loads at least 100,000 times. In-line contact arrangement assures mechanical life to 100 million operations d-c, and 50 million a-c. The unit is suited for use in computers and data handling equipment. Sigma Instruments Inc., 170 Pearl St., Braintree, Mass. 02185. [344]

Hermetically sealed time delay relays rated to 60 kw have factory preset or adjustable delays on "make" of from 100 msec to 300 sec in 1-, 2-, and 3-pole models. Operating temperature is 10° to 65°C. Repeatability is ±2% at stated voltages and temperature range. The 50-amp TD-B-1 unit is illustrated. Ebert Electronics Corp., 130 Jericho Turnpike, Floral Park, N.Y. [345]

Metalized polycarbonate capacitors in the MPCW series are for filter and timing circuits. Ambient operating temperature range is −55° to +125°C. Retrace after full-range temperature cycling is typically less than 1.5%. The series is available in 0.001 to 10 μf, in 50, 100, 200, 300 and 400 v d-c. Capco Capacitors, 5262 W. 34th St., Lubbock, Texas. [346]



Multipole relay model R10 features an 8 Form C contact arrangement. Five different contact styles are offered, ranging from a crossbar dry-circuit type to a heavy-duty 5-amp type. Coil operating voltages range from 3 v d-c to 115 v d-c. Actuator displacement is 0.045 in. minimum with overtravel of 0.010 in. Parelco Inc., 16239 Colorado Ave., Paramount, Calif. [347]

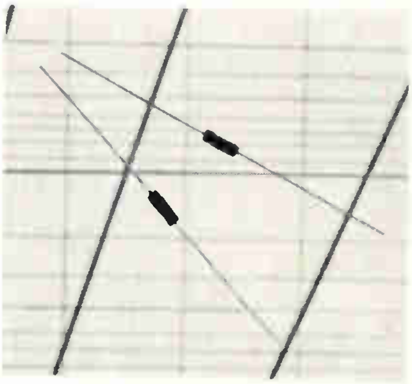


A high-temperature switch for airborne use is 1.25 x 2 x 2 in and weighs approximately 8 oz. The standard units will switch up to 1.5 amps. Response time for 63% of step change is better than 100 msec. The unit operates under temperatures of −65° to +250°F. It is rfi free per MIL-I-6181D. Scientific Engineering & Mfg. Co., 11505 Vanowen St., N. Hollywood, Calif. [348]

New components

Logarithmic diodes for analog computers

Operating on the same principle as a slide rule, diodes perform multiplication, division, and power functions



Nonlinear. Diodes with logarithmic I-V characteristics multiply in analog computers.

Development of analog computers has lagged behind that of digital machines largely because of the demands for accuracy and predictability placed on transistors. In analog computers, multiplication is carried out by the addition of the logs of the numbers that are to be multiplied—much like a slide-rule approach. Transistor circuits that are used to accomplish this are very sensitive to temperature, interstage inaccuracies, and resistor ratios. Until recently, the same could be said about diodes.

Now the Computer Diode Corp.,

by exercising unusually tight control over the alloying area, is producing units with logarithmic characteristics that are accurate and reproducible.

If the output of a diode is plotted on a semilog scale with forward voltage on the horizontal axis and the log of the current on the vertical axis, a curve is generated that is described by the equation: $V = A \log I + BI \pm C$, where V is the forward voltage and I is the forward current. The coefficient A determines the slope of the voltage versus log current output of the diode, B describes the ohmic component of the diode, and C is the point at which the curve crosses the horizontal axis.

The new diodes, designated the CODI LD series, bear out the equation to within ±2 millivolts. The coefficients are repeatable from batch to batch.

To verify the accuracy of the diodes, a specialized computer is used to check the I versus V relationship at 800 points on the curve. These outputs are then reduced to provide the exact equation generated by the diode to determine deviations from the theoretical values. The temperature characteristics are also checked at three points: −55°, +25°, and +125° C. Since the output of the diodes varies with temperature, performance must be determined for a specific temperature. If desired, diodes can be made to conform to a given curve across a specified temperature range.

Operating over a three-decade range from 10 to 10,000 microamps, the diodes are available in chip form, plastic packages, and DO-7 glass packages. They cost about $1 each.

For applications requiring more complex equations, the engineer can request additional diode data. Upon request, the manufacturer will supply the deviation from the original equation. This data is obtained with the help of a computer whose output is fed to an automatic printer or data logger. During production the manufacturer uses an analog computer to obtain data on a go or no-go basis for a minimum of 1200 different current values along the log curve.

Computer Diode Corp., Fair Lawn, N.J. **[349]**

Here's a switch —with resistors

Circuit-deck combines both in package for scopes, plotters, dvm's

It's an old story. A company's engineers find they can make a better component than they can buy. Once they've acquired the new capability they decide to market the component.

The Helipot division of Beckman Instruments Inc., best known for its potentiometers, got into the switch and resistor business after replacing a commercially available switch, to which discrete resistors were soldered, in a Beckman strip-chart recorder. The switch deck and discrete resistors were replaced with what the firm calls a circuit-deck, a combination of switch and resistor networks packaged in one small preassembled unit designated the Series 1390 precision cermet switch.

John Doering, Helipot's chief engineer for product design, says the circuit-deck can be used in any instrument in which resistors are used in connection with switches—such as oscilloscopes, x-y plotters, or digital voltmeters.

Spinoff. In developing the 1390, Beckman applied its experience in thick-film microcircuits, to switching applications. Elimination of discrete resistors, with their associ-

Switch plus. Wafer can have as many as 10 resistors screened on each side.

. . . permits variety of switch logic . . .

ated individual design, assembly, and testing allows a cost reduction of at least 25%, Doering says.

Switches in the 1390 series consist of screened cermet resistors, switch pads, and interconnections fired on an alumina wafer that replaces the conventional switch deck. Screened capacitors are also offered in the series. A typical wafer may have five to 10 ¼-watt resistors screened on each side of the wafer; 10 wafers take up only 2½ inches behind the instrument panel.

Other advantages claimed for the circuit-deck are long life and good high-frequency performance.

According to the company, principal initial applications will be in digital voltmeters. The biggest attraction is the cost-saving achieved by eliminating discrete resistors, "plus the concentration of responsibility a user gets by buying an assembled package," says Doering. Custom designs, with specific ratios, capacitance values, resistance values, and logic are being offered.

No limit. Beckman says the ability to connect contacts on opposite sides of the rotor, plus the use of feedthroughs on the wafer, make just about any switch logic possible. Resistance ratios will remain stable within 0.01% after 1,000 hours of load life at 65°C, according to the company.

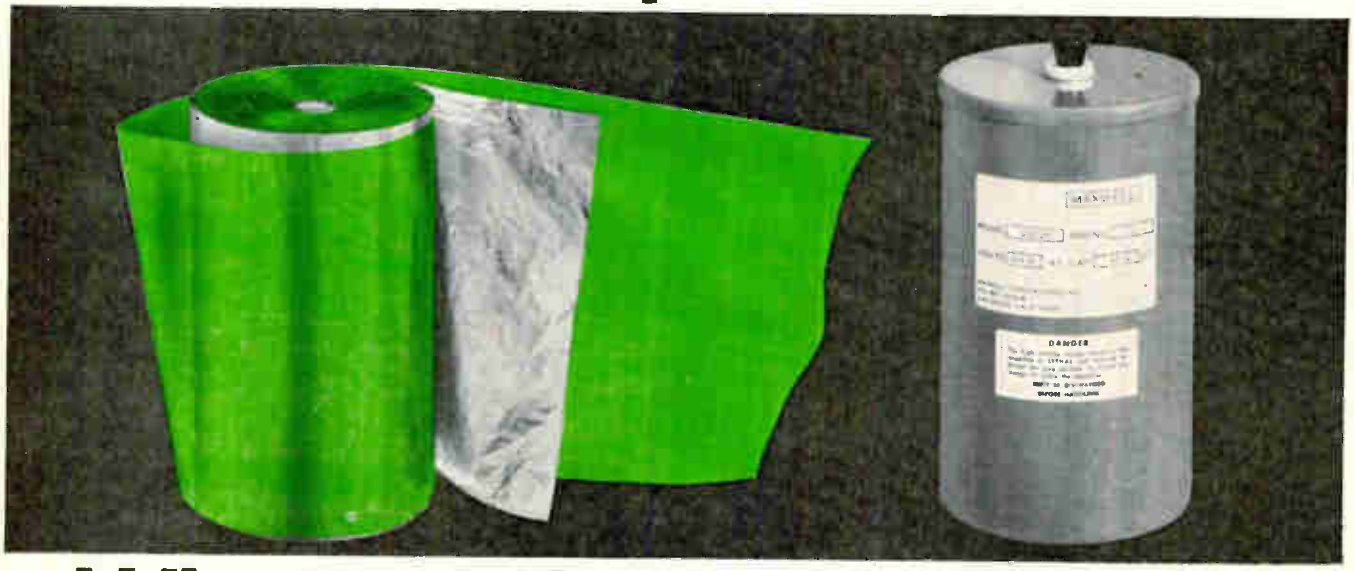
The circuit-deck can be provided with pin-type terminals to which flexible cables may have to be connected. Round pins coming off the switch can be made for direct mounting on a printed-circuit board. The switch can be wired in when the board is put through its solder operation.

Specifications

Range of resistor values	10 ohms to 1 megohm
Resistance tolerance	±5% to ±0.2%
Ratio range	10,000:1
Ratio stability over temperature range	5 ppm/°C
Temperature coefficient of resistance	±300 ppm/°C
Power rating	2.5 w per side at 65°C
Range of capacitor values	10 pf to 270 pf
Contact rating	125 ma
Dielectric strength	1,000 v rms
Insulation resistance at 100 volts d-c	1,000 megohms

Beckman Instruments, Inc., Helipot Division, Fullerton, Calif. [350]

Mylar® helped Maxwell Labs save 75% on size and weight in its new 5KV capacitor.



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Capacitor manufacturers in the past have frequently relied on paper impregnated with chemicals as a capacitor dielectric material. These units were often up to four times as large and bulky.

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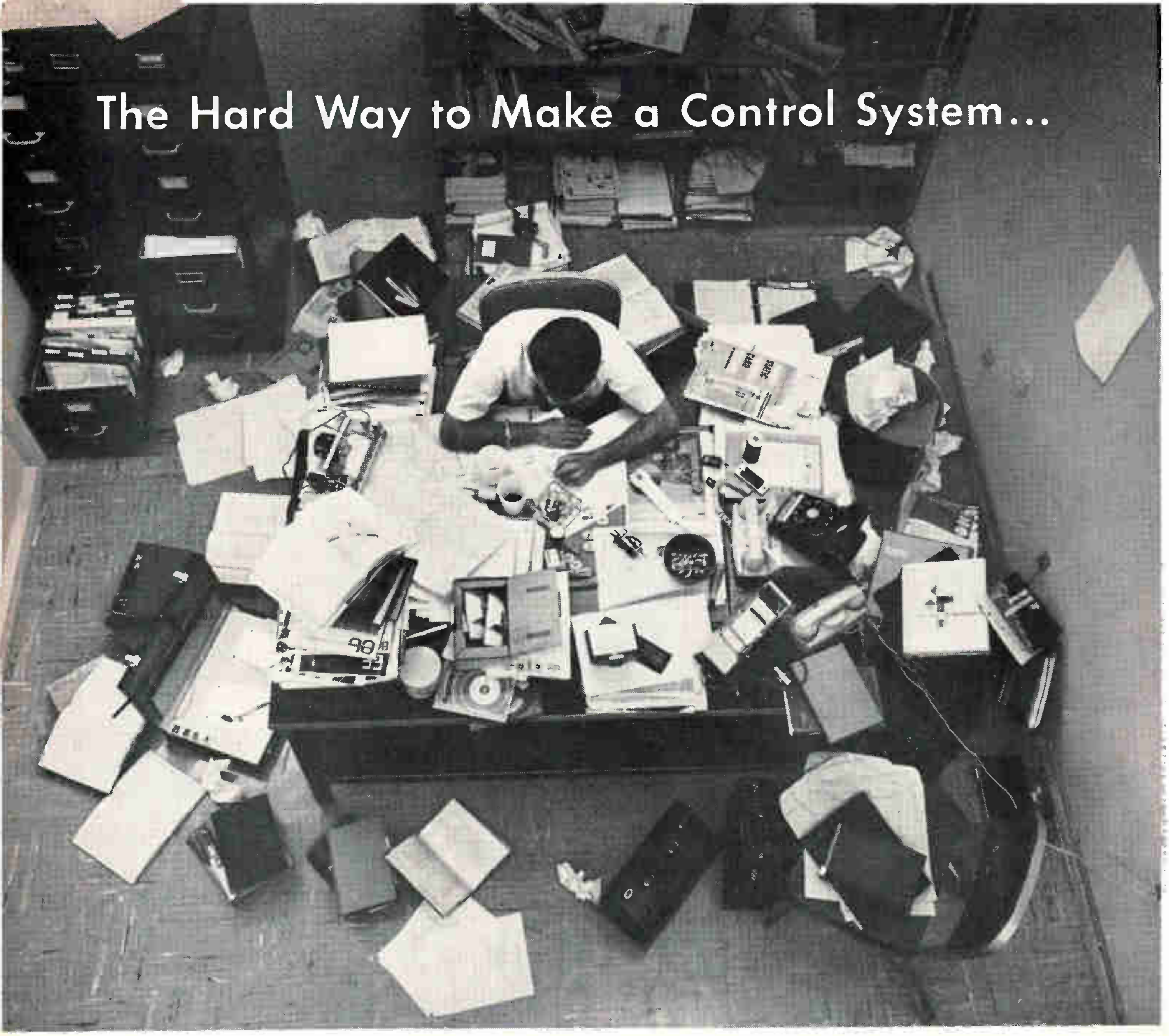
Circle 133 on reader service card



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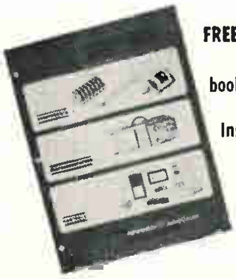

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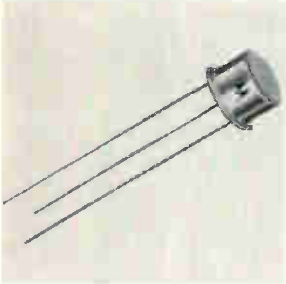
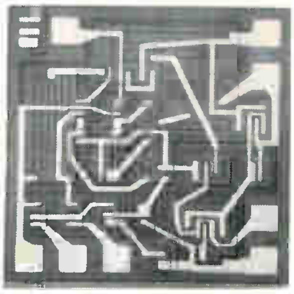
Circle 134 on reader service card

New Semiconductor Review



Eight germanium mesa transistors, manufactured by the selective metal etch process, provide direct replacement for Philco MADT devices in military and industrial communications equipment. All are in the TO-5 case. Frequencies range from 100 to 980 Mhz. Price (100 and up) ranges from $1.05 to $3.05. Motorola Semiconductor Products Inc., Phoenix, Ariz. [436]

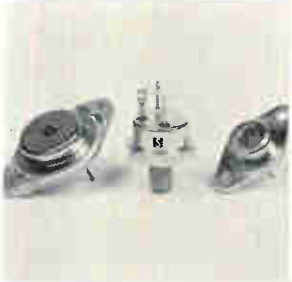


Improvements in major parameters of the μA709 standard operational amplifier are found in the μA709A, a direct plug-in replacement. Input offset voltage is 2 mv max.; input offset current, 50 na max.; input offset voltage drift, 10 μv/°C max.; input offset current drift, 0.5 na/°C max. (+25° to +125°C). Fairchild Camera and Instrument Corp., Mountain View, Calif. [437]

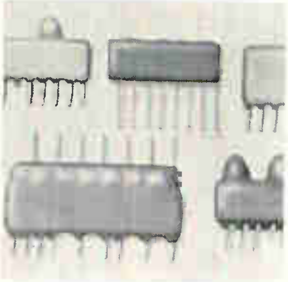
A 25-amp germanium power transistor, the HST3080 series, packaged in a TO-3 or TO-4 case, provides a low-cost, high-current unit capable of 106 w. Specs include: minimum gain of 10 at 25 amps, breakdown voltage (V_{CBO}, V_{CEX}) is 40-80 v. It is for use in military and industrial inverters, switches, etc. Hughes Semiconductors, 500 Superior Ave., Newport Beach, Calif. [438]

Four low-level, high-speed switching transistors—2N2432, 2N2432A, 2N3153, and 2N4138—are npn complements to the 2N2944. These devices feature low offset voltage (0.5 mv max.) and high emitter-base breakdown voltage (15 v min.). Unit prices start at $12 in 1-99 quantities; from $8 each in 100-999 lots. Crystalonics Inc., 147 Sherman St., Cambridge, Mass. [439]

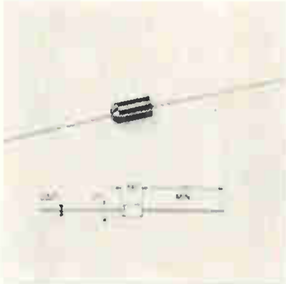
Photodetector PIN-8LC is designed for high speed and for applications requiring a good spectral response at a laser wave length of 1.06 microns. The unit has an active area of 1 cm² and a minimum capacitance of 40 pf. Rise time to a light pulse is less than 5 nsec. Quantum efficiency is 30% at 1.06 microns. United Detector Technology, Box 2251, Santa Monica, Calif. [440]



High-voltage npn silicon power transistors are offered up to 700 v in 3 different packages. The TO-3, TO-61, and TO-66 are characterized at current levels of 1, 2, and 3 amps. The TO-3 and TO-61 are rated at 100 w at 75° C case temperature. The TO-66 is capable of 50w power dissipation at 75° C. Solitron Devices Inc., 1177 Blue Heron Blvd., Riviera Beach, Fla. [441]



Hybrid circuit modules custom designed for the consumer, industrial, and military markets. Besides thick film deposition of resistors, capacitors, and circuitry on ceramic substrates, silicon transistors, and germanium and silicon diodes are included in the units. Costs start at less than 20 cents in quantity. Centralab Div., Globe-Union Inc., 5757 N. Green Bay, Milwaukee. [442]



Silicon rectifiers with piv's of 1,600 to 6,000 v and a forward current of 150 to 500 ma—depending on piv—are in a 0.2 x 0.38 in. transfer molded package. Series RF160A-RK600A and RF-160B-RK600B offer a choice of 200 or 250 nsec recovery time. Price of the RJ400B (4,000 piv) is $2.67 in 100 lots. Electronic Devices Inc., 21 Gray Oaks Ave., Yonkers, N.Y. [443]

New semiconductors

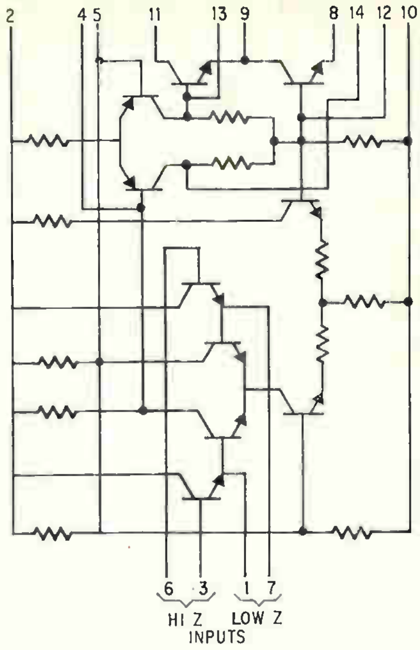
Jack-of-all-trades op amp

Multifunction unit challenges conventional devices; needs no extra circuitry for complex operations

The closest thing yet to a universal operational amplifier appears to be the Westinghouse Electric Corp.'s WC 306. A monolithic op amp, it was designed, not for high gain, but for versatility. Unlike other op amps—such as the popular 709—which are designed for a single function, the new unit can perform complex operations without additional circuitry.

Instead of increasing gain or bandwidth, the 306 has both high and low impedance inputs and differential as well as single-ended outputs. The output flexibility is achieved by using a vertical pnp transistor in a complementary pair configuration in the last stage. According to Bill Williams, head of Westinghouse's linear integrated-circuit group, "In many applications, one 306 will replace two or more 709's."

In recording instruments, where it's desirable to isolate a signal from ground, the 306 can be connected with both differential inputs and outputs to drive a recorder directly. In zero-cross detection, where a pulse output is required whenever a signal swings from plus to minus—or vice versa—only one 306 is needed. The amplifier satur-



Real thing. Vertical pnp transistors are used in the output stage.

ates, causing it to switch, when its output is a few millivolts above ground.

Because the 306 has external connections that are not available on other op amps, it performs unusual functions. Pin **11** can be used as a sense-and-control amplifier input for series-voltage regulation. If pin 9 is grounded, the 306 can drive a low-current relay directly by connecting the relay power supply to pin **11**. This operation between pins 9 and **11** is independent of the regular power supply, which is connected to pins 2 and 10.

If a wideband amplifier is needed, the low impedance input is used, providing 30 decibels of gain at 10 megahertz. Other circuits, such as a voltage comparator, and a window detector, can be implemented by the addition of an external resistor.

Packages include flat packs and dual in-line plastics, and the units are priced at $6.60 each in lots of 50.

Specifications

Power supply	±15 v
Input voltage	±6.25 v
Operating temperature	−55° to +125°C
Differential gain	2,000
Input offset voltage	10 mv max.
Frequency response	500 khz
Input impedance	300 kilohms
	4 kilohms
Output impedance	40 ohms
Power dissipation	450 mw

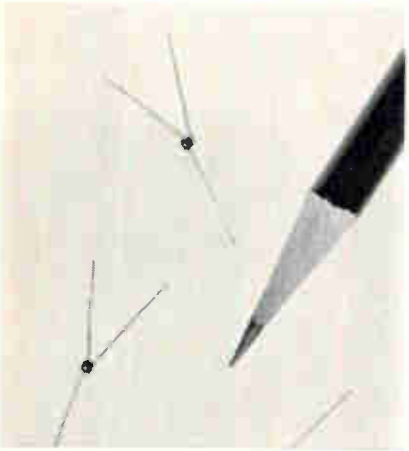
Westinghouse Electric Corp., Box 7377, Elkridge, Md. [444]

New semiconductors

Channel protects leads from bending

Hybrid transistor chips for microwave equipment operate up to 2.5 Ghz

A line of channel-packaged silicon transistors for thin- and thick-film, and stripline circuit applications has been developed by the KMC Semiconductor Corp. The units are available for uhf and vhf microwave circuitry in both amplifiers and oscillators. The transistor chips are mounted in a ceramic channel and then encapsulated in epoxy to avoid lead bending—at high frequencies, bent leads cause the device inductance to increase.



Protected. The three sides of the channel form a mold for epoxy.

The amplifier group consists of 27 transistors that operate over a frequency range from 60 to 1,000 megahertz. Twelve of the units are low-noise devices with a maximum system noise figure of 1.4 decibels at 60 Mhz. All of the amplifiers are supplied with gold-plated Kovar ribbon leads.

The oscillator transistors consist of eight types, ranging in output power from 20 milliwatts at 2 gigahertz, to 60 mw at 2.5 Ghz. These are supplied with nonmagnetic silver leads for applications where yttrium iron garnet tuning is used.

KMC Semiconductor Corp., Parker Rd., Long Valley, N.J. **[445]**

New semiconductors

Tv transistor handles 1,400 v

New device may help clear way for low-cost, all-solid-state sets

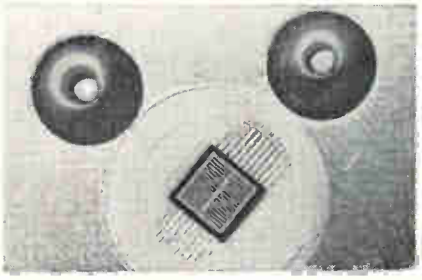
The first step in designing a low-cost, large-screen, all-transistor tv receiver would be to eliminate the power transformer, which accounts for a disproportionately large part of the set's cost. But this step can be taken only when semiconductor houses come up with cost-competitive high-voltage devices that can operate from a 120-volt supply.

The major problem here is that the horizontal output transistor should have a breakdown voltage rating of about 1,500 volts, but the highest voltage rating of currently available transistors, selling for $6 each, is 700 volts.

However, in what appears to be a significant advance in fabrication technology, the Amperex Electronic Corp. has developed a transistor, designated the A705, with a collector-base voltage of 1,400 volts—something of a record. The company attributes the rating to special profiling of the crystal edges, plus a mesa collector structure.

Amperex is demonstrating its device to tv manufacturers in a line-operated, 23-inch, all-transistor feasibility model that employs the A705 as a power source to drive the flyback transformer directly. When operated at its maximum power, the transistor dissipates 8 watts with a maximum mounting base temperature of 95°C.

Amperex Electronic Corporation, Slatersville, R. I. 02876 [465]



Minimight. Transistor handles high voltage in crucial television circuit.

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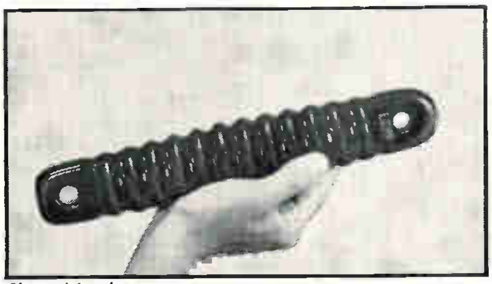
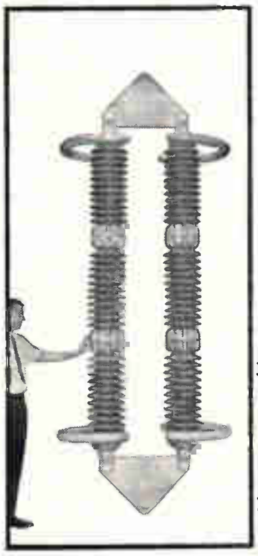


Shaped insulator



Double strain assembly

Rod-type with rain shield and corona ring

Special antenna insulator assembly with corona rings.

Lapp has been designing and producing antenna insulators for nearly a half century. We have delivered short ones, long ones, little ones, big ones, giant ones. Each met the customers' electrical and mechanical specifications with "room to spare".

Examples? The double-strain insulator assembly shown here tested to 240,000 lbs. ultimate strength. A similar triple yoke assembly tests to 360,000 lbs. Lapp has a compression cone guy insulator already designed that tests to 750,000 lbs! We also have many smaller units and rod-type and shaped insulators.

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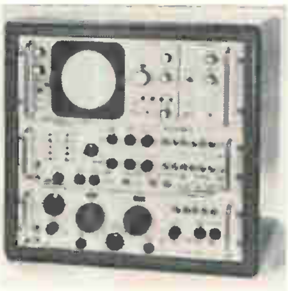
Dynamic range of better than 70 db distinguishes the LA-40A ssb spectrum analyzer. The unit uses a single tuning control to search for signals and has plug-in tuning heads with easy-to-read, digital type dials. Sweep rates and resolution are automatically optimized for calibrated widths from 0.5 to 100 khz. Specialty Electronics Development Corp., 70-31 84th St., Glendale, N.Y. [361]

Strain gauge pressure transducer RV22 uses IC techniques. Featuring a built-in amplifier, the unit gives a repeatability of 0.2%, hysteresis of 0.25%, and linearity of 0.25%. Maximum output at full scale pressure is 4 v into 400 ohms. Twelve ranges are available: from 0-15 lbs to 0-1,500 lbs. Price is under $325. Dentronics Inc., 60 Oak St., Hackensack, N.J. 07601. [362]

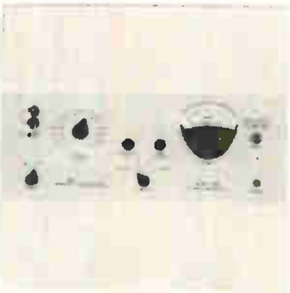
Frequency selective voltmeter 3111, covering a range of 20 hz to 150 khz, is for use in telemetered supervisory control systems. Features include restored frequency and recorder outputs, 100-kilohm input impedance, and 600-ohm input circuits. Accuracy is ±0.5 db over input levels of −100 db to +22 db. Rycom Instruments Inc., 9351 E. 59th St., Raytown, Mo. [363]

D-c voltage calibrator and electronic galvanometer VS11-G has a range of 0 to ±11.1110 v d-c, resolution of 100 μv. Input impedance is infinite at null and 200 kilohms off null. The output mode has an absolute accuracy of ±0.01% of setting. Output current is 30 ma; output impedance, 30 milliohms. Electronic Development Corp., 423 W. Broadway, Boston, Mass. [364]

Digital volt-ratiometer model 4651 features 5-digit display and a sixth digit overrange, externally programable front-panel controls, and accuracy within 0.001% of full scale +0.005% of reading. Input impedance is greater than 10,000 megohms on a 10.9999 volt range. Balance time averages 50 msec. Cimron Division, Lear Siegler Inc., 1152 Morena Blvd., San Diego, Calif. [365]



Sweep instrumentation test set TS-102 provides a lab-type 5-in.-scope display system, besides solid state sweep generation functions. The display unit provides vertical sensitivities of 1 mv/cm with band pass to 500 khz. Four sweep outputs are offered: video, 0 to 10 Mhz; i-f, 35 to 50 Mhz; vhf, 50 to 250 Mhz; uhf, 450 to 920 Mhz. Sweep Systems Inc., Box 616, Indianapolis. [366]



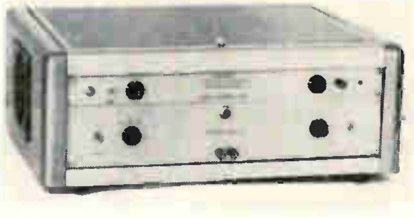
Current integrator model 1000 is for use with low energy particle accelerators. A wide span of input currents can be accommodated by its 15 scales that range from 2 na to 20 ma full scale. Accuracy is 0.02%. A chopper-stabilized input amplifier with a gain of 10^8 provides extremely low input impedance and eliminates drift. Brookhaven Instruments Corp., Box 212, Brookhaven, N.Y. [367]

High-voltage test set 4030 has an output of 4,000 v a-c for dielectric strength testing and leakage current measurement. It is suited for manufacturing and quality control checks of components, wiring harnesses and motors. It has a 2-range kilovoltmeter and 3-range microammeter, both accurate to within ±3%. Associated Research Inc., 3777 W. Belmont, Chicago. [368]

New instruments

Transceiver expands sonar jobs

Device designed to match variety of transducers for underwater ranging, sea-bottom profiling



Sound center. Modular transceiver can match virtually all existing transducers.

Echo-sounding equipment aboard ships was—until quite recently—considered adequate if it merely told where the ocean bottom was at a given time.

More demanding tasks like acoustic ranging have now emerged—for expanded oceanographic studies, cable-laying projects, antisubmarine warfare research, and harbor and river navigation.

As an aid to navigation, such as following a channel with the help of a recorder profile of the river bottom, acoustic ranging "is more reliable than radar—there's less clutter to contend with," says George Lehsten, chief engineer of Alpine Geophysical Associates.

The company, which developed a series of acoustic transceivers for its own ocean study projects, has decided to sell the devices to other

. . . records deepest water known . . .

research groups.

Static field. "Outside of changing from tubes to solid state, very few design improvements have been made in this field since World War II," says Lehsten. "That's why we had to develop our own transceivers."

Called the Series 495, the transceivers can accurately match almost any acoustic transducer, regardless of impedance level, within a wide range. The company considers this feature especially attractive to companies retrofitting marine equipment because it means that transducers already mounted on ship hulls can be used and given additional power for underwater ranging.

According to the company, the versatility of the new transceivers will help to refine acoustic echo ranging as a form of navigation.

Lehsten, designer of the transceivers, says they will correctly match any device between 50 and 400 ohms, and yet deliver the full rated power automatically with no control or tap selection needed. This is accomplished in the transceiver by sensing the impedance match between it and the transducer. An error signal is fed back to the biasing networks of the driver transistors, to change the drive level applied to the output. This changes the drive impedance, which also affects the secondary impedance and thus matches the transceiver output impedance to that of the transducer.

Depth power. Another design feature is the use of a single frequency receiver section operating at the transmitted frequency, which can be set at a wide range. The bandwidth of the receiver section determines in part the actual transmitted frequency. This assures the maximum transfer of reflected energy without envelope distortion so prevalent with the more common heterodyning type systems currently in use. By using power levels of 1,000 watts or more, these units could record the bottom of the deepest water known.

The Series 495 devices are precision bathymetric transceivers, designed for standard sonar transducers and precision bathymetric recorders. There are four transceiver models—ranging from 800 to 1,400 watts output. The transducers should be capable of transmitting 12-kilohertz pulses or—for one of the models only—any other frequency between 3.5 khz and 39 khz. The transceivers may be used with any commercially available precision recorder requiring an input level of approximately 1 volt.

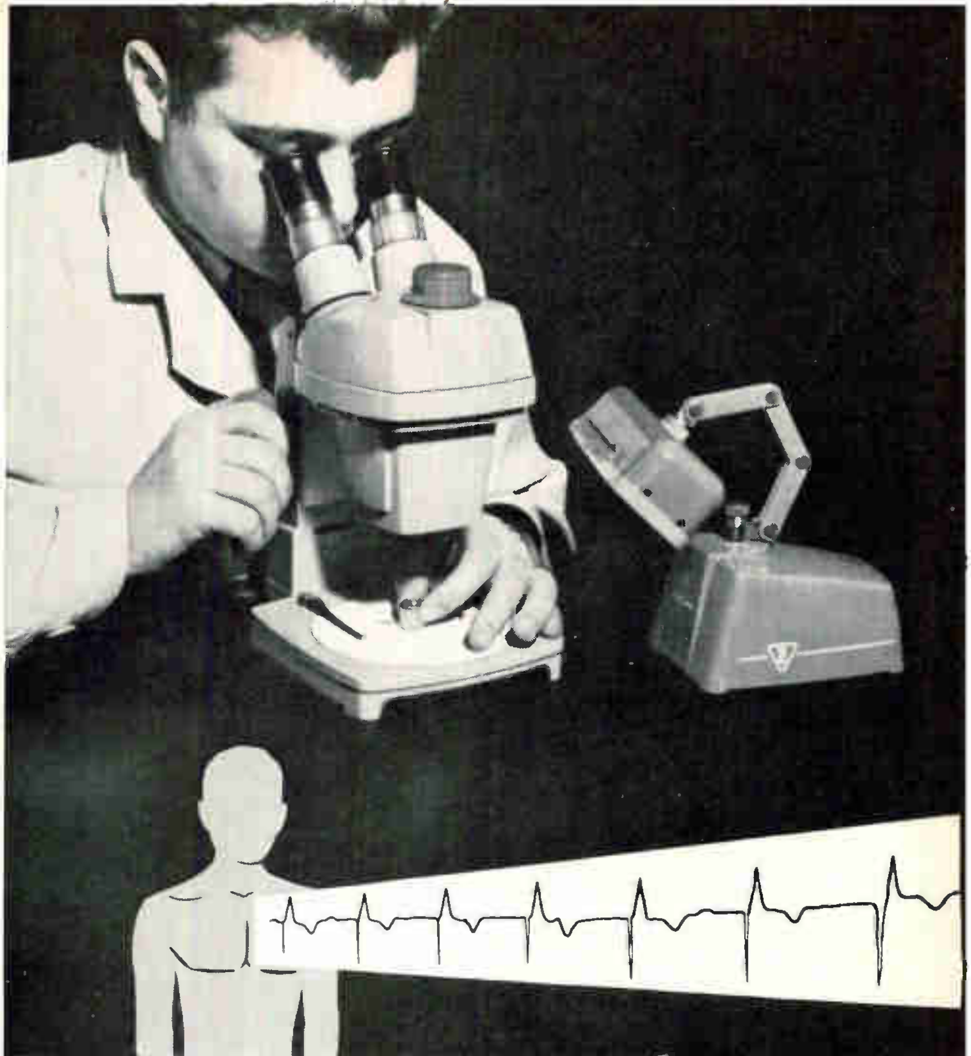
The Alpine transceivers are packaged for either bench or standard 19-inch rack installations. They are also available in self-enclosed cabinets for other types of installations. Only four cable connections are necessary to hook up the transducer and recorder.

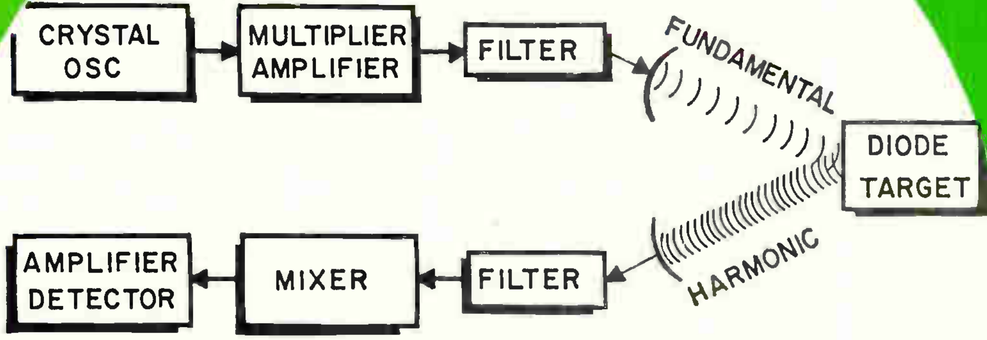
All models operate on 117 ±15 v a-c, 50-60 cycles. All have an input sensitivity of approximately 10^6 volts. They are convertible for use with other sound sources and detecting systems by means of plug-in, interchangeable amplifiers. A separate, balanced signal input connector is supplied for external signal sources of any characteristic impedance between 50 and 1,000 ohms. No bandwidth limitations exist between this signal source and the recorder, within the range of 5 hz to 50 khz, depending on the amplifier model.

Specifications

Model number 495	
Power consumption (w)	300
Power output (w)	800
Bandwidth	12 khz ±1%
Nominal frequency (khz)	12
Frequency stability (hz)	10
Pulse lengths (ms)	0.2 to 15.0
Model number 495A	
Power consumption (w)	350
Power output (w)	1,200
Bandwidth	12 khz ±1% 34 khz ±2%
Nominal frequency (khz)	12 34
Frequency stability (hz)	10 at 12 khz 30 at 34 khz
Pulse length (ms)	0.2 to 15
Model number 495A2	
Power consumption (w)	350
Power output (w)	1,400
Bandwidth	12 khz ±1% 34 khz ±2%
Nominal frequency (khz)	12 34
Frequency stability (hz)	10 at 12 khz 30 at 34 khz
Pulse length (ms)	0.2 to 15
Model number 495B	
Power consumption (w)	350
Power output (w)	1,400
Bandwidth	12 khz ±1%
Nominal frequency (khz)	12
Frequency stability (hz)	10
Pulse length (ms)	0.2 to 10 (to 20 with external capacitor)

Alpine Geophysical Associates Inc., Norwood, N.J. **[369]**





Can a diode in free space generate harmonics?

YES—and it's the basis of Dinade—a new communications & navigation system from Microlab/FXR!

Everyone knows that diodes generate harmonics—in a circuit! But perhaps you didn't know that diodes can be made to do this in free space—without any attached circuitry or power source.

Microlab/FXR has applied this principle to a new Diode Interrogation, Communication and Navigation System*. This is a harmonic radar system, consisting of a Diode Exciter/Receiver plus a passive diode antenna—or a self-focusing phased array where increased range is required—either modulated or unmodulated.

This new Microlab/FXR system can thus detect and communicate with any object (or person) to which the diode is attached. Perhaps even more important, it can positively *single out and identify* any particular target from all others. Microlab/FXR's new system can well be the answer to heretofore unyielding problems connected with air/sea navigation, flight traffic control, rescue and recovery operations, IFF systems, etc. In other areas, the system can be used for everything from automobile traffic control to aircraft blind landing systems; from bird and animal migratory studies to human medical diagnostics.

Maybe these applications whet your appetite — maybe they fit in neatly with a project you're working on— maybe they give you a new idea for something we haven't thought of. If so, you'll want more information. Just circle the Reader Service Card. Better still, write us directly, at Dept. E-61.

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*patents pending

Delay lines in the SM series conform to applicable portions of MIL-D-23859A. Standard items range from 10 to 1,200 nsec at impedance levels of 100, 200, and 500 ohms. Operating temperature is −55° to +125°C. They come in 2 sizes: 1 x 0.32 x 0.32 in. and 2 x 0.32 x 0.32 in., both with ½-in. leads. ESC Electronics Corp., 534 Bergen Blvd., Palisades Park, N.J. [381]

Model 10BP1 a-d converter employs IC logic. Bipolar inputs over a ±5-v range are converted to 9-bit, plus sign, binary output in 11 μsec. The maximum conversion rate is 90,000 words/sec with an accuracy of ±0.1% of full scale ±½ least significant bit. Input impedance is greater than 2,000 ohms. Houston Magnetics Div., A.I.C. Corp., Box 207, Bellaire, Texas. [382]

Battery-operated, FET operational amplifier model KM46 is suited for integrators; sample and hold circuitry; isolation amplifiers; low-noise, high-impedance a-c amplifiers; and general instrumentation amplifiers. Quiescent current at ±9.5 v is 1.5 ma maximum; input impedance at d-c, 1 x 10^{12} ohms; offset current, 30 pa. K&M Electronics Corp., 102 Hobart St., Hackensack, N.J. [383]

Transistor amplifier G260 has a frequency range of 55 to 65 Mhz. It can deliver 1 watt to a 50-ohm load with an input of 20 mw for a gain of 17 db. A single negative-ground power supply furnishing +28 v at 150 ma maximum is the only external d-c requirement. Size is 1.13 x 1.38 x 3.85 in. Somerset Radiation Laboratory Inc., 2060 N. 14th St., Arlington, Va. [384]

Power modules have been developed to meet the regulation, ripple and rfi requirements of all commonly available integrated circuits. Model IC5-25, measuring only 5¼ x 3½ x 7½ in. and weighing only 6 lbs., delivers 5 v d-c at 25 amps with regulation of 125 mv and rms ripple of 15 mv. Transistor Devices Inc., 65 Route No. 53, Mt. Tabor, N.J. 07878. [385]

Differential d-c amplifier A524-14 offers solid state design plus encapsulated construction for virtual immunity to severe airborne or missile-borne environments. Performance includes a zero stability of better than 0.5 μv/°C, linearity within ±0.1%, and noise of 1 μv peak-to-peak. Common mode rejection is 120 db at 60 hz. Ectron Corp., 8070 Engineer Rd., San Diego, Calif. [386]

High-voltage d-c/d-c converter PS115 is a 3-w unit with an average efficiency of 75%. Conversion frequency is approximately 30 khz, which lends itself to good filtering for low output ripple (0.1%), and low conductance interference is less than 10 mv across a 1-ohm resistor in series with the input. Price is $90. Crestronics, Box S, Crestline, Calif. 92325. [387]

Bipolar, transistor, differential operational amplifier model 1726 features low voltage offset drift coefficient vs temperature of 5 μv/°C. It has high full-power bandwidth of 200 khz and high slewing rate of 12 v/μsec. The unit is applicable in control instrumentation, computation, and data logging. Melcor Electronics Corp., 1750 New Highway, Farmingdale, N.Y. [388]

New subassemblies

IC servo loops control tape transport

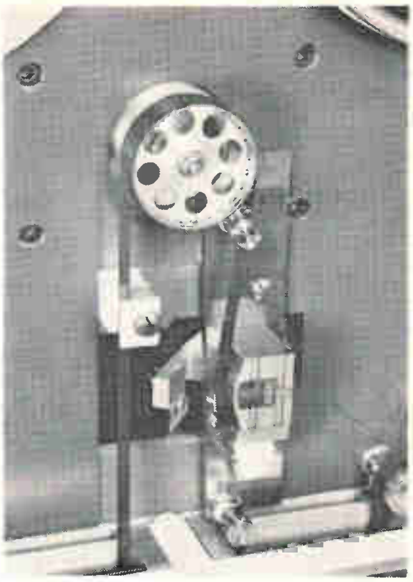
Semiconductor techniques eliminate mechanical complexity; head remains stationary in automatic loading procedure

Semiconductor technology has revolutionized computers, but the revolution hasn't been drastic enough as far as computer tape transports are concerned.

That's the reasoning behind the decision of Texas Instruments Incorporated to bring out a new line of tape transports. The major tenet of the design philosophy was to take advantage of TI's expertise in semiconductor electronics, and apply it to the transport.

"Central processors have been reduced perhaps 10 times in cost, 10-20 times in size, and speed has been increased 10 times in the past decade, mostly by improved semiconductor techniques," says Project Manager Norman Gruzcelac. "Meanwhile, too much that is mechanical has remained in the tape transport, keeping complexity high and reliability low." Also, says Gruzcelac, mechanical systems cannot take advantage of upcoming advances in electronics.

In the new line, designated Model 959, no belts, gears, clutches, or brakes are used, and TI says no mechanical adjustments are needed for the life of the transport. Linear integrated circuits are employed in the capstan drive and reel electron-



The unmoved. Tape head stays put, crosstalk shield swings away for loading.

ics, and digital IC's in the read-write electronics.

The design includes single-capstan drive, automatic loading, and quick-release transport hubs. There is no oxide contact except at the recording head, and the reel servosystem controls torque, to eliminate excessive tightening of the tape.

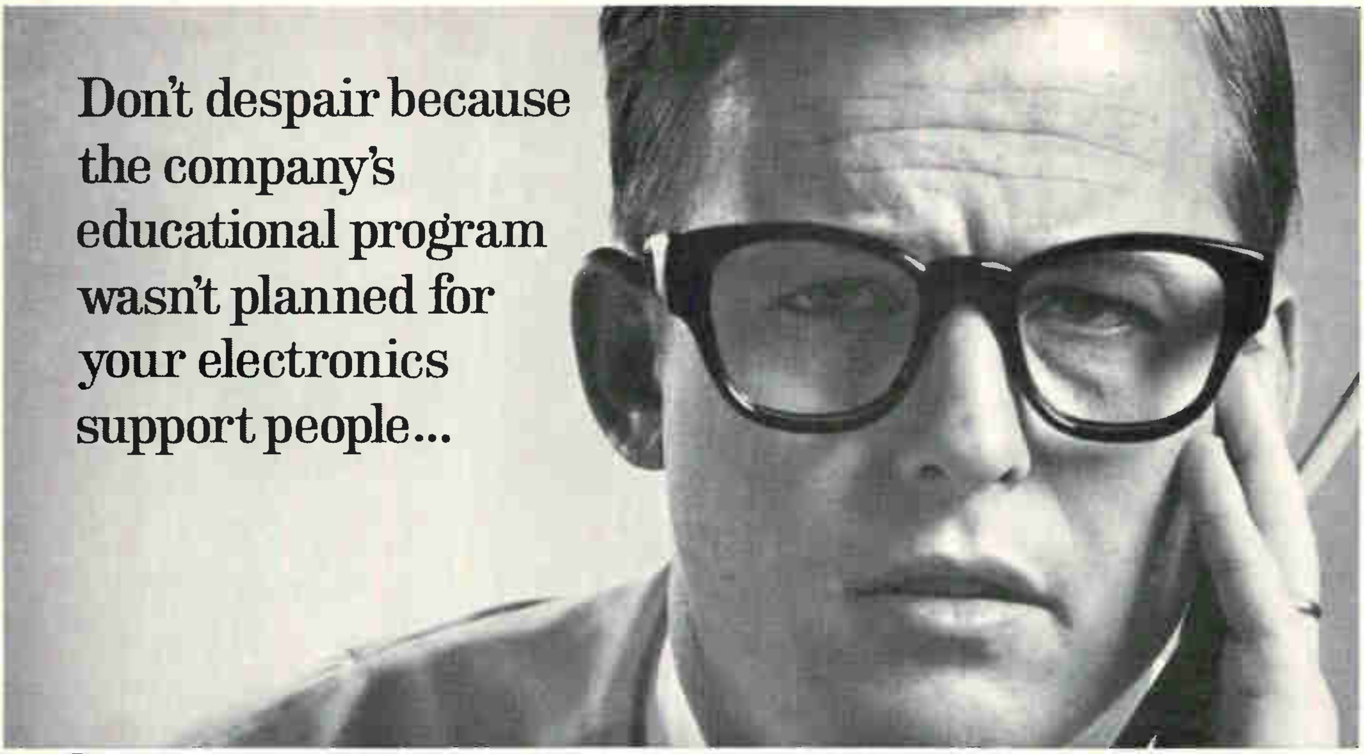
The two reel drives and the capstan drive are direct-coupled to d-c motors by operational amplifiers in IC form and by semiconductor circuitry in feedback loops.

Violin string. The use of operational amplifiers and servo loops coupled to the drive motors make for a smooth start for the tape. "Tape tends to act like a violin string," says Gruzcelac. "You can easily set up a standing wave in it, and get into all kinds of problems with lifting and twisting."

In the Model 959, the head need not be moved out of the way for tape loading. "Instead, we move the read-write crosstalk shield," says Gruzcelac. "This eliminates critical and complex mechanisms for accurately repositioning the head."

The tape must be accurately guided over its entire path from reel to reel, so that the tracks of data on the tape precisely match the individual magnetic air gaps on the head. Meeting these tolerances with a movable head is difficult. Repositioning of the crosstalk shield is much less critical.

Texas Instruments Incorporated, Industrial Products Group, P. O. Box 66027, Houston, Texas 77006. [389]



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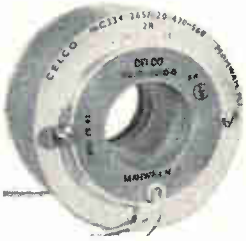

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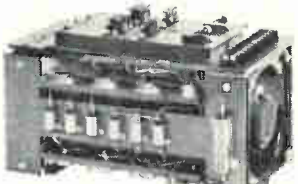

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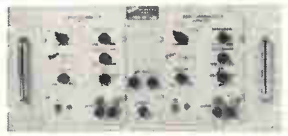
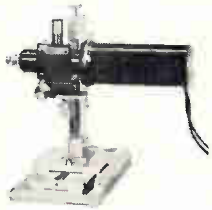


Two Ramp Units in one panel. Ramps from 20 μsec to 100 msec. Adjustable dc offset. Compatible with CELCO Drivers.

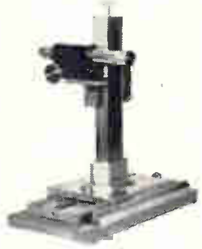
INSTRUMENTS

DISPLAY MEASUREMENT LAB



Two-Slit CRT Spot Analyzer on X-Y Traverse quickly ascertains spot size, line width, and X-Y coordinates. Easily determines linearity and positional accuracies as well as phosphor characteristics.

X-Y TRAVELING MICROSCOPE
Mounted on X-Y Traverse.



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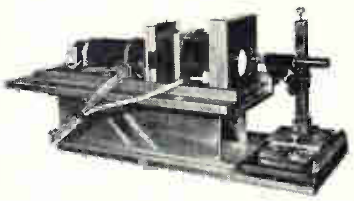
CRT DEFLECTION SYSTEM



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New Microwave Review

Compact Ka-band diode switch MA-8319-1Q3 is designed for positive receiver protection in radar systems or as a variable attenuator in agc systems. The unit operates from 33 to 35 Ghz over a bandwidth of 0.5 Ghz. Insertion loss is 1 db max. at +50 ma and isolation is 20 db min. at −50 v. Microwave Associates Inc., Burlington, Mass. 01803 [401]

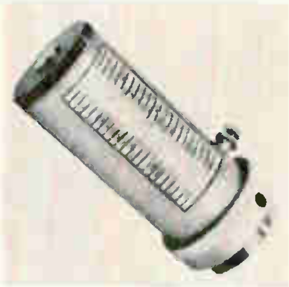
A shunt-mounted chip switch/attenuator is offered in the circular SO-30 style and the rectangular SO-31 case. Typical insertion loss at zero reverse voltage, 2 to 4 Ghz, is 1 db max.; 4 to 12 Ghz, 1.5 db max. Isolation at 50-ma forward current, 2 to 4 Ghz, is 50 db minimum; 4 to 12 Ghz, 55 db minimum. Alpha Industries Inc., 381 Elliot St., Newton Upper Falls, Mass. [402]

Coaxial slotted line 2400-04 has an outer conductor that is an accurately machined metal block with a 0.1378-in.-diameter bore. It is suited for precision measurements in miniature and subminiature connectors up through 36 Ghz. Over-all dimensions are 2.7 x 7.5 x 3.5 in. Weight is 1.5 lbs. Price is $1,200. Alford Manufacturing Co., 120 Cross St., Winchester, Mass. 01890. [403]

Bandpass coaxial filter G859 features one-knob tuning. A calibrated knob is directly coupled to a low-torque precision gear train to minimize backlash. The unit's range is 5.5 to 5.8 Ghz. Its 3-db bandwidth is 33 Mhz; 55-db bandwidth, 85 Mhz. Max. insertion loss is 2.9 db; vswr, 1.5:1 at output frequency ±10 Mhz. Gombos Microwave Inc., Webro Road, Clifton, N.J. [404]

Octave-band limiters hold peak power of 250 w to 100 mw at 2 to 4 and 4 to 8 Ghz. They handle an average power of up to 5 w. Insertion loss across the bands is under 2 db. Recovery time is 100 nsec. Units measure 1½ x ¾ x ¾ in. Uses include protection of tunnel diode amplifiers and mixers. Micro State Electronics Corp., 152 Floral Ave., New Providence, N.J. [405]

Pulsed magnetron BLM-143A, designed for use in ground radar systems and beacons, delivers a peak output of at least 1 kw over the range of 16 to 16.5 Ghz. Peak anode voltage is 3 kv; peak anode current, 1.6 amps; average input power (including heater), 8 w; load vswr, 1.3:1. Over-all dimensions are 2.625 x 2.375 x 3.422 in. Varian Associates, 8 Salem Rd., Beverly, Mass. [406]



Direct-reading frequency meter 410-A12, for use with WR-75 waveguide, covers a range of 10,450 to 13,350 Ghz. It provides a 20% nominal absorption dip, with a loaded Q of greater than 7,000. Accuracy is 0.06% of dial reading, or 0.01% with correction chart. Price is from $500 to $600, depending on quantity. Microlab/FXR, Ten Microlab Road, Livingston, N.J. [407]

Miniature mixer preamps in the LMP series have an input frequency up to S band with a maximum noise figure of less than 6.5 db. Units measure 1 x 1⅛ x 2¼ in. The r-f bandwidth is up to 10% of the input frequency. Output frequencies are up to 90 Mhz. Microwave Products Div., Consolidated Airborne Systems Inc., 115 Old Country Rd., Carle Place, N.Y. [408]

New microwave

Getting specific about frequencies

Improved circulator-isolator features specs that allow engineers to choose frequencies

An improved design for its Isoductor line of isolator-circulators allows Melabs of Palo Alto, Calif., to list absolute specs for both characteristic resistance, r_o, and characteristic inductance, l_o—enabling the design engineer to pick the operating frequency. The latest device in the line will operate at any frequency from 200 to 400 megahertz depending on the type of external capacitor used.

The Isoductors were introduced several years ago as circulators minus their tuning capacitors. Melabs reasoned that users might want

Mounting. The Isoductor must be kept 1 inch or more from ferrous materials.

. . . device specified by its admittance . . .

to choose their own values for the capacitors.

Circulators are three-port devices in which inputs to port 1 are outputs at port 2, but inputs to port 2 are blocked from port 1. Traditionally, these units are characterized by insertion loss and isolation, but the company found it difficult to draw up specifications on these parameters without knowing what external capacitors would be used; frequencies of operation could only be assured if the company specified a capacitor and it was used.

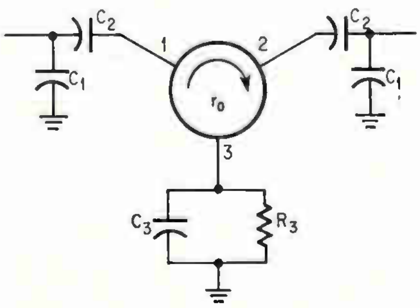
Easing doubts. Perry Vartanian, executive vice president of Melabs, says the new specs eliminate this constraint and make the device more understandable to designers, who apparently were somewhat wary of a component that could only be characterized in terms of something else. The new Isoductor, designated the LB-1, is completely characterized by its admittance,

$$Y = \frac{1}{r_o} + \frac{1}{j\omega l_o}$$

An external capacitor will resonate at the frequency of interest; adding a resistor (R_3 in the diagram) will define r_o, which is equivalent to the resistance that will provide maximum isolation between the ports.

Internally, the Isoductor consists of a permanent magnet, a ferrite disc of low-loss material originally developed for microwave isolators and circulators, and a set of windings designed to give the desired nonreciprocal coupling to the electron-spin system of the ferrite-disc substrates.

Wide separation. The device can be used as a nonreciprocal phase



Tuning. External components R_3 and C_3 determine the operating frequency.

. . . 25-db isolation with only 0.6-db power loss . . .

shifter in feedback loops, or as a duplexer capable of separating signals 1 kilohertz apart. To date, however, the Isoductor has been employed principally as a load isolator. It provides 25-db isolation between a transistor amplifier and the following circuit, with a forward power loss of only 0.6 to 0.8 db. The designer can thus lay out individual transistor stages without worrying about interaction between the stages.

In another application, terminated Isoductors can be used as load isolators on each of two communications transmitters to reduce intermodulation distortion. Because of unwanted coupling between the two transmitters, energy from one gets into the other, producing undesirable third-order intermodulation products. Isoductors reduce these products by as much as 25 db, Melabs says, with negligible forward power loss.

The device could also act as a circulator or duplexer capable of separating signals on the basis of the direction of power flow. Thus it replaces the receive-transmit switch that is a large source of power loss in microwave systems. If transmitter, antenna, and receiver are connected to the three terminals, there is low loss from transmitter to antenna and about 20-db isolation from receiver to transmitter; for received signals the loss from antenna to receiver is only 0.6 to 0.8 db. Therefore, if any power is reflected from the antenna, it will not harm the receiver.

The LB-1 is the first of a series. Melabs plans other models to cover the 100-600 Mhz range at higher powers than the LB-1's rated 10 watts.

Specifications

Frequency	200-400 Mhz
r_o	250 ohms nominal
l_o	26.5 nanohenrys nominal
r_d (dissipation loss)	2,500 ohms minimum (corresponds to 1 db insertion loss)
Power	10 watts average (higher power available on special order)
Temperature	—35°C to +85°C
Price	$89 in sample lots, lower in production quantities

Melabs, Stanford Industrial Park, Palo Alto, Calif. [409]

New Books

Switched on

Large-signal transistor circuits
Donald T. Comer
Prentice-Hall Inc., 268 pp., $10.50

Unlike many textbooks that describe transistor circuitry, this one is aimed at practical applications, and even an engineer familiar with the field can benefit from it. The reader can review, or learn for the first time, the basic elements of transistor physics, equivalent circuits, and graphical analysis that are needed to work with large-signal circuits. The author defines these as pulse, digital, or sweep circuits. They are also referred to as nonlinear, or nonsinusoidal circuits and find wide application in radar and digital computing. Only a few circuit design equations are given, but the book does offer a good physical insight into the circuit's operation.

To provide a broader base for studying practical switching circuits than the more conventional piecewise-linear, black-box, or graphical approaches, the author emphasizes an analysis of the transistor in the act of switching. Detailed static- and transient-switching characteristics of the transistor are considered, independent of particular circuit application.

In describing static-transistor switching the author uses the Ebers and Moll equations to define transistor operations in the cut-off, active, and saturated regions. These equations are often used in computer-aided transistor design.

For transient switching, the hybrid-pi high-frequency circuit is described. This circuit enables the engineer to successfully predict active-region switching times.

Making use of the past

Modern Control Systems
Richard C. Dorf
Addison-Wesley Publishing Co., 387 pp., $12.50

Too many books offer cut-and-dried, cookbook solutions to classical problems and reduce the adventure of discovery to a dusty heap of theorems. Richard C. Dorf believes that the best way to learn is to reexamine the classical problems first, then consider new ways of solving them.

Dorf's book is primarily concerned with the control-system theory in the frequency and time domains. He deals mainly with linear systems but also describes some nonlinear systems. Each topic he treats, as well as the systems decribed in the examples, is dealt with in the light of the latest technology. Many of the topics, such as signal-flow graphs, sensitivity analysis, performance indices, the time domain, optimum control systems, and state variables are not usually found in a first text on control theory.

State variables, a relatively new technique for analyzing systems with equations that describe the system's stored energy, is a powerful tool because the equations are speedily solved by either an analog or digital computer. In an analog computer, only one integrating network is required for each first-order differential equation. Furthermore, state techniques are not restricted to systems that are described only by differential equations; they may also be used to analyze and design sequential machines, switching networks, and sampled data systems.

Several practical problems are given from electrical, mechanical, chemical, or industrial engineering areas, as well as from sociology, biology, and economics.

Recently published

Electronics for Scientists and Engineers, R. Ralph Benedict, Prentice-Hall, Inc., 635 pp., $12.95

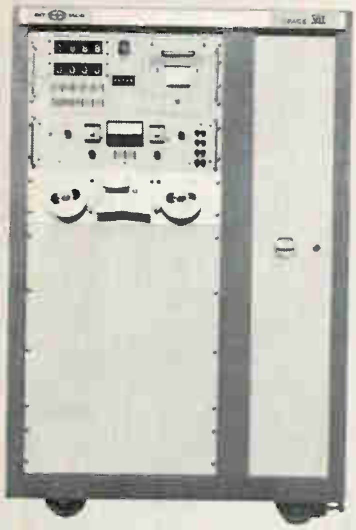
Basic instrumentation and control topics such as d-c amplifiers, servos, analog computers, feedback theory, data acquisition, recording and processing are described for scientists and engineers not in the electronics field.

Theory and Applications of Holography, John B. DeVelis and George O. Reynolds, Addison-Wesley Publishing Co., 196 pp., $12.95

A probing description of various systems for those engaged in holography and related industrial research. Mathematics of holography is presented in a separate section for engineers not familiar with this field.

Handbook of Filter Synthesis, Anatol I. Zverev, John Wiley and Sons, Inc., 576 pp., $19.95

This handbook explains filter performance to the electronics engineer. Design charts for crystal filters, coupled resonators, helical filters, and basic inductance-capacitance types are featured.



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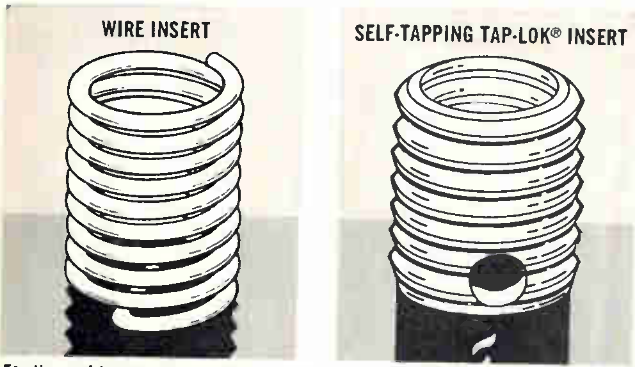

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Drill Hole	.070¢	______	Drill Hole	.070¢
Tap Hole	.090¢	______	Tap Hole	Not Req.
Gage Hole	.030¢	______	Gage Hole	Not Req.
Install Insert	.080¢	______	Install Insert	.080¢
Remove Tang	.050¢	______	Remove Tang	Not Req.
Per Finished Hole	.370¢	______	Per Finished Hole	.194¢

*Estimated cost for wire-type 4-40, .224" long, 25,000 quantity; Tap-Lok 4-40, .234" long, case-hardened steel, 25,000 quantity. Estimated average costs will vary with user, equipment, overhead, and labor rates.

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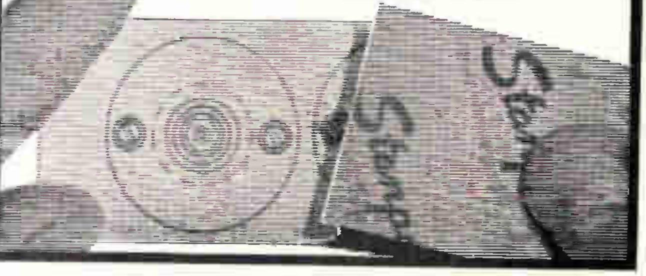

Circle 153 on reader service card

Technical Abstracts

MOST colorful

A developmental 15-inch transistorized color receiver
W.E. Babcock
Radio Corp. of America, Somerville, N.J.

Field effect transistors that can directly replace vacuum tubes, plus a high-voltage, developmental bipolar transistor, are the keys to an experimental solid state color tv set built around a new 15-inch picture tube. Though the transistors were chosen for performance rather than attractive prices, they could become low-cost items within a few years.

The design is based on standard vacuum-tube circuits where the substitution of metal oxide semiconductor transistors for the tubes requires only a reduction in supply voltage and minor adjustments in component values.

Commercially available dual-gate MOS transistors with regions of nearly constant gain for a wide range of bias voltages are used in an automatic gain control system in the radio-frequency and intermediate-frequency amplifiers. The r-f amplifier is set at a bias for constant gain, while the i-f amplifiers are biased at points where the gain changes rapidly with bias. As agc voltage increases, the i-f gain drops rapidly but the r-f gain remains constant. The amount of agc delay can be varied over a wide range by adjusting the resistors in the network.

The vertical-deflection circuit is a four-stage multivibrator that includes feedback from the output circuit to trigger the multi. The horizontal-deflection circuit uses an advanced bipolar transistor that can withstand a collector-to-emitter pulse of 1,000 volts and normally operates with 750-volt pulses.

Presented at the 1967 International Electronics Conference, Toronto, Sept. 25-27.

Multiplicity

A PCM telemetry system utilizing multiple IC technologies
D.C. Fox
Autonetics Division, North American Aviation, Inc.
Anaheim, Calif.

Integrated circuits of all types—metal-oxide semiconductors, thin-film resistive networks, hybrids, and linear and digital monolithics—each doing the job it does best, were used in an experimental pulse-code modulation telemetry system. The system, small enough to fit into an attache case, uses IC's exclusively and promises to be more reliable and less costly than existing systems.

The telemetry module can handle 48 channels of information and provides 10 bits of magnitude information for each channel. It is divided into three sections: multiplexer, amplifier, and analog-to-digital converter. Both differential and singled-ended inputs are used, and multiplexing is controlled by random or sequential addressing.

The system accepts positive or negative voltages on two different ranges: ±5.11 volts and ±51.1 millivolts full scale. After multiplexing these voltages by sequential switching, it amplifies, samples and holds, and then converts them to digital values for transmission on the data channel.

Metal-oxide-semiconductor IC's were picked for use in the multiplexer; the choice is excellent for low-level, low-offset multiplexing. The multiplexing section consists of five identical MOS circuits: four wired to perform an analog multiplexer function and the fifth to provide sequence or selection of the other four IC's.

Hybrid IC techniques were needed to achieve performance levels in the amplifier that are impossible with monolithics. The amplifier has an input impedance of 100 megohms and a common-mode rejection of 120 decibels. Nichrome resistors provide good tracking of resistance-ratios and temperature-coefficients. The hybrid process also results in lower costs for prototype development of the amplifier.

The third section of the system, the analog-to-digital converter, uses a 10-bit thin-film ladder network built with high-accuracy nichrome resistors, monolithic digital (transistor- logic) and dielectrically isolated linear IC's.

Presented at the International Telemetry Conference, Washington, Oct. 3-4.

New Literature

Foam flux. Alpha Metals Inc., 56 Water St., Jersey City, N.J. A technical bulletin describes Reliafoam No. 811-13 flux, a rapid, high-rising foam flux for printed circuits and other electronic assemblies.
Circle **446** on reader service card.

Amplitude distribution analyzer. B&K Instruments Inc., 5111 W. 164th St., Cleveland, Ohio 44142, has available an eight-page bulletin on the model 161 amplitude distribution analyzer for statistical analysis of complex, random, nonperiodic, and transient waveforms from d-c to 20 khz. **[447]**

Memory modules. Electronic Products Division, Corning Glass Works, Raleigh, N.C. 27602. Reference file CE-5.03 provides applications and specifications for a line of digital glass memory modules. **[448]**

Indicating lights. General Electric Co., Schenectady, N.Y. 12305. Bulletin GEA-8266 details the CR103 type G transistorized indicating lights. **[449]**

Thermistor housings. Fenwal Electronics Inc., 63 Fountain St., Framingham, Mass. 01701, has published a 28-page catalog describing over 55 typical thermistor housings and compatible thermistor elements. It is available on letterhead request.

TR-limiter. Microwave Associates Inc., Burlington, Mass., has released a technical bulletin describing a TR-limiter that combines a gas TR tube and a solid state limiter in a single package to provide positive protection for standard crystal receivers. **[450]**

Tin-oxide resistors. Electronic Products Division, Corning Glass Works, Raleigh, N.C. 27602, offers a data sheet listing characteristics and applications for its half-watt, flame-proof tin-oxide resistors. **[451]**

Power supply. Borg-Warner Controls Division of Borg-Warner Corp., 825 Nash St., El Segundo, Calif. A data bulletin covers the model 50-7 general purpose a-c/d-c power supply. **[452]**

Wire and cable. Belden Corp., P.O. Box 5070A, Chicago 60680. A complete line of electronic wire and cable is illustrated and described in catalog 867. **[453]**

Time delay circuits. Potter & Brumfield Division of American Machine & Foundry Co., Princeton, Ind. 47570. A 12-page booklet features a variety of circuit diagrams for time delay relay applications. **[454]**

System power supplies. RO Associates, 917 Terminal Way, San Carlos, Calif. 94070, has issued a four-page brochure covering a line of system power supplies for digital IC and analog applications. **[455]**

Coaxial components. Microlab/FXR, 10 Microlab Road, Livingston, N.J. 07039. Catalog 17A describes a line of miniaturized and 18 Ghz coaxial components. **[456]**

Turns-counting dials. Helipot Division, Beckman Instruments Inc., 2500 Harbor Blvd., Fullerton, Calif. 92634. Miniature digital turns-counting dials are described in data sheet 671074. **[457]**

Computer control cables. Gulton Industries Inc., 212 Durham Ave., Metuchen, N.J. 08840, has issued a comprehensive brochure that facilitates specifying of complex computer control cables. **[458]**

Microwave anechoic chambers. Emerson & Cuming Inc., Canton, Mass. 02021. A four-page folder, seventh in a series, describes recent advances in the design and construction of microwave anechoic chambers. **[459]**

IC logic cards. Datascan Inc., 1111 Paulison Ave., Clifton, N.J. 07013. A 115-page technical catalog on series 200 IC logic cards is available to qualified design engineers requesting on company letterhead.

Operational amplifier. National Semiconductor Corp., 2950 San Ysidro Way, Santa Clara, Calif. 95051, has published bulletin SC-104 describing and illustrating its LM201, an operational amplifier for commercial and industrial applications. **[460]**

Junction circulators. Raytheon Co., Foundry Ave., Waltham, Mass. 02154. A four-page bulletin describes a line of 12 basic high-power, waveguide junction circulators. **[461]**

Temperature controller. InstruLab Inc., 1205 Lamar St., Dayton, Ohio 45404. Data sheet 9500-34 describes the specifications for a miniaturized temperature control system. **[462]**

Color electrolytics. Cornell-Dubilier Electronics, 50 Paris St., Newark, N.J. 07101. A six-page brochure lists more than 250 wide-range color electrolytics by capacitance value. **[463]**

Attenuator set. Weinschel Engineering, Gaithersburg, Md., has issued a data sheet on precision attenuator set model AS-4 with a frequency range of d-c to 12.4 Ghz **[464]**

Microwave equipment. Narda Microwave Corp., Plainview, N.Y. 11803. A 152-page catalog covers a complete line of coaxial and waveguide devices and systems. Useful design information is included. Copies are available on letterhead request.

Circle 157 on reader service card

Newsletter from Abroad

October 30, 1967

Russians hint shrouded antenna silenced Venus-4

Western space experts now are largely convinced that a partly blocked antenna prevented the Soviet Union's Venus-4 instrument capsule from transmitting back to earth after it had landed on the planet.

The Soviet Academy of Sciences maintains that the soft landing—with parachutes—was successful. Data telemetered from the 843-pound capsule while it was dropping through the dense Venusian atmosphere indicated the rate of descent was 10 feet per second just before impact. **Thus the Russians feel sure the package would have kept on transmitting after it landed had the highly directional main antenna been clear.**

For telemetry, the Soviets used a pencil antenna working with a parabolic reflector 7.5 feet in diameter. The transmitter operated in the decimeter waveband.

Although Venus-4 went silent as it hit the planet, the shot rates as a stunning space achievement. As a result, Western observers say it's almost certain that the Russians will not mount a manned space spectacular next week to celebrate the 50th Anniversary of the Revolution. They may, however, try a recovery at sea with a Soyuz spacecraft carrying an animal. The Soviets presumably have been redesigning the Soyuz since its first test flight this spring ended in disaster [Electronics, May 1, p. 161].

Ground stations tender subject in Great Britain

Some sort of fuss now seems inevitable when Britain's Cable & Wireless Ltd. finally names—probably next month—a contractor for satellite communications terminals in Hong Kong and the Persian Gulf island of Bahrain.

The government-owned but commercially run communications company called for bids on two stations 16 months ago and insiders say the best tender came from the Nippon Electric Co. British telecommunications makers, though, apparently put strong pressure on the government to throw the business to one of them. Their pitch: export sales of British ground-station hardware would suffer if a Japanese company won the Cable & Wireless contract.

It's a good bet that Cable & Wireless, as a result, reworked its specifications so that it could pick a British contractor. The Marconi Co. most likely will get the job. Officials at Nippon Electric may ask the Japanese government to protest if the disguised "Buy British" maneuver costs it the job.

Matsushita readies 1,500-V transistor

Look for line-operated, all-transistor Japanese television sets with no power transformer sometime next year. Matsushita Electronics Corp. will have the kingpin component for such sets, a high-voltage transistor for the horizontal output stage, in quantity production by next February.

The horizontal output transistor has a collector-base rating of 1,500 volts. It has the same mesa-collector, planar-emitter structure found in the high-voltage transistor introduced earlier this month by the Amperex Electronics Corp. [Electronics, Oct. 16, p. 47]. Both Companies are affiliates of Philips' Gloeilampenfabrieken and both based their high-voltage transistors on a Philips' design.

Matsushita Electric Industrial Co., partner with Philips in Matsushita Electronics, already has prototypes of 19-inch sets designed around the

Newsletter from Abroad

1,500-volt transistor. The sets also have an 800-volt transistor in the vertical output stage and a 300-volt transistor in the audio output stage. Both are triple-diffused silicon mesa units developed by Matsushita.

Matsushita has yet to set a price for its 1,500-volt transistor. But company officials say they'll at least match Amperex's price of "about $2.50."

German MD's to try computer network

A nationwide computer network to aid West German doctors in making diagnoses may be in the offing.

The country's medical association will start trials with one computer early next year. If **the tryout is successful, the association will expand the system to include as many as 24 computers spotted throughout West Germany** so that all its 50,000 member doctors could be tied into the network. In the U.S. thus far, computer diagnosis has been evaluated in hospitals and medical research centers but has not been used in actual practice.

Besides helping doctors make diagnoses, the computers will prepare diets for patients suited for their specific ailments. The system also will be used to evaluate data generated by mass medical checkups.

Consortiums form for Symphonie

French and German electronics companies have teamed up on a strictly national basis in their quest for the prime contract in the $40 million binational Symphonie telecommunications satellite project [Electronics, Sept. 4, p. 208]. About two-thirds of the money will go for electronics hardware.

The French group vying for the lead role in electronics consists of Compagnie Francaise Thomson Houston-Hotchkiss Brandt, its subsidiary-to-be CSF-Compagnie Generale de Telegraphie sans Fil, and the Societe Anonyme de Telecommunications. German companies that will act in concert for Symphonie are AEG-Telefunken, Siemens AG, and Rohde & Schwarz.

No matter who wins, the losing group figures to pick up considerable business in Symphonie subcontract work. The French and German governments agreed that the project's work would be farmed out equally in the two countries. So the losers will have an inside track—although not an absolute guarantee—for their country's share of the business.

Symphonie's airframe, however, looks like a winner-take-all proposition. The two competing consortiums are binational so there'll be no need for subcontracts.

Britain may build 400-foot antenna

Britain's famed radio astronomer Sir Bernard Lovell quite likely will get his 400-foot fully steerable antenna [Electronics, May 1, p. 162]. **Funds for the design of the dish—which will be the world's largest—were earmarked this month by the government's Science Research Council.**

H.C. Husband, the consulting engineer picked by the council to design the antenna, says it will cost about $14 million. The site of the big dish—still not selected—will be "far" from Jodrell Bank. The two antennas will be linked by microwave so that they can operate as an interferometer.

Jodrell Bank's 250-foot antenna is now the world's largest. It will be eclipsed, though, in about 2½ years by a 328-foot antenna now under construction near Bonn. The big British dish could be in service in about five years if the council decides to fund it.

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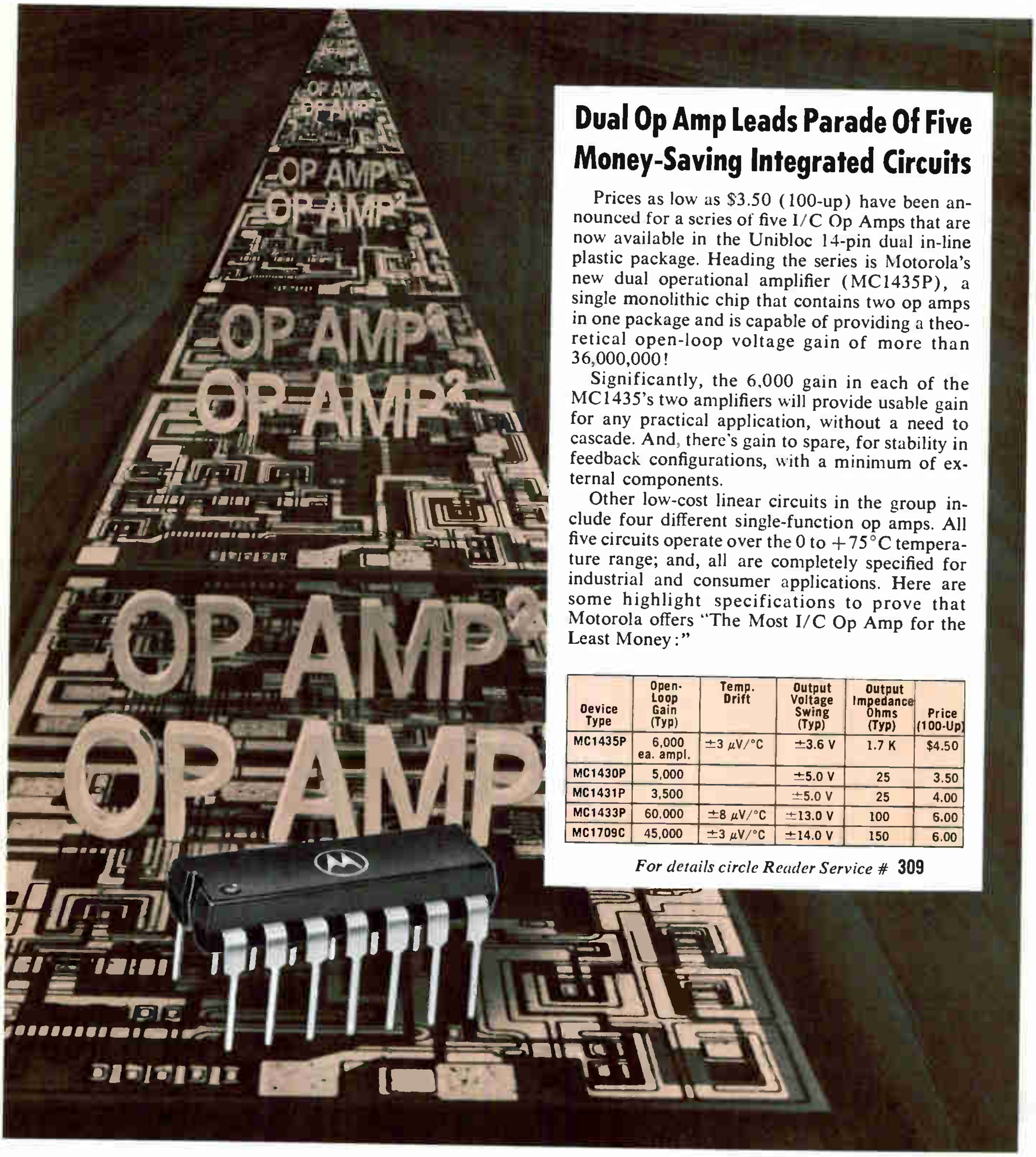


Dual Op Amp Leads Parade Of Five Money-Saving Integrated Circuits

Prices as low as $3.50 (100-up) have been announced for a series of five I/C Op Amps that are now available in the Unibloc 14-pin dual in-line plastic package. Heading the series is Motorola's new dual operational amplifier (MC1435P), a single monolithic chip that contains two op amps in one package and is capable of providing a theoretical open-loop voltage gain of more than 36,000,000!

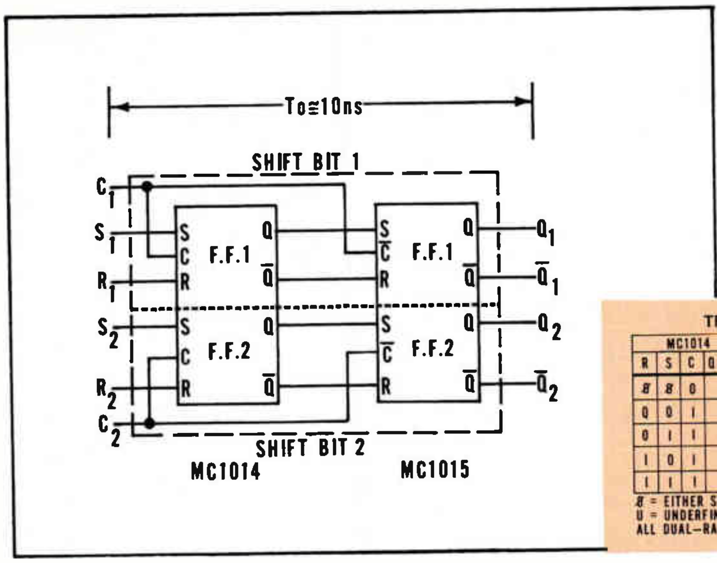
Significantly, the 6,000 gain in each of the MC1435's two amplifiers will provide usable gain for any practical application, without a need to cascade. And, there's gain to spare, for stability in feedback configurations, with a minimum of external components.

Other low-cost linear circuits in the group include four different single-function op amps. All five circuits operate over the 0 to +75°C temperature range; and, all are completely specified for industrial and consumer applications. Here are some highlight specifications to prove that Motorola offers "The Most I/C Op Amp for the Least Money:"

Device Type	Open-Loop Gain (Typ)	Temp. Drift	Output Voltage Swing (Typ)	Output Impedance Ohms (Typ)	Price (100-Up)
MC1435P	6,000 ea. ampl.	±3 μV/°C	±3.6 V	1.7 K	$4.50
MC1430P	5,000		±5.0 V	25	3.50
MC1431P	3,500		±5.0 V	25	4.00
MC1433P	60,000	±8 μV/°C	±13.0 V	100	6.00
MC1709C	45,000	±3 μV/°C	±14.0 V	150	6.00

For details circle Reader Service # **309**

Featured In This Issue:



Logic diagram and truth table show how MC1014 and MC1015 are connected to form two Master-Slave shift register elements.

TRUTH TABLES

MC1014			
R	S	C	Q n+1
ø	ø	0	Q
0	0	1	Q
0	1	1	1
1	0	1	1
1	1	1	U

MC1015			
R	S	C	Q n+1
ø	ø	1	Q
0	0	0	Q
0	1	0	1
1	0	0	1
1	1	0	U

ø = EITHER STATE MAY BE PRESENT
U = UNDERFINED LOGIC STATE (COMMON TO ALL DUAL-RAIL INPUT R-S FLIP FLIPS)

MECL II Dual R-S Flip-Flops Combine To Achieve Two Gating Levels; 2 ns Prop. Delay Increase

Two new additions to the growing MECL II line of integrated circuits MC1014 and MC1015P, may be used as positive-gated and negative-gated R-S Flip-Flops, respectively. The two levels of gating are accomplished with only 2 ns increase in propagation delay. As a result, a single phase, clocked Master-Slave type of shift register may be obtained as shown.

The MC1014P, in addition to teaming with MC1015P for shift register functions, is also useful as a dual storage element. It contains two dc Set-Reset Flip-Flops with a positive clock input provided for each flip-flop. The counterpart, MC1015P, operates with a negative clock input. Both circuits exhibit a typical propagation delay of 5.0 ns, operating over the 0 to +75°C temperature range. Both provide typical power dissipation of 125 mW at an operating frequency of 80 MHz. Minimum dc fan-out of 25 for each output is guaranteed. Prices for the MC1014P and MC1015P are $4.25 (1,000-up), in the 14-pin dual in-line plastic package.

The MECL II family of logic integrated circuits now includes 27 functional elements in the limited temperature range MC1000P series and a comparable number in the full temperature range MC1200F series. All of these circuits are fully compatible with the MECL 300/350 series types.

For details, circle Reader Service # **310**

MDTL Presettable Decade Counters Feature 20 MHz Operation

A new series of MDTL circuits, types MC938F, MC838F and MC838P, all offer individual direct-sets for each stage as well as a common reset and buffered inputs (a standard MDTL loading factor of 1). These monolithic ripple counters operate in excess of 20 MHz at ± 20% of the nominal 5.0 V power supply.

The three new devices are composed basically of four MC950 pulse-triggered binaries. All have standard MDTL inputs and use active pull-up devices in the outputs to increase capacitive drive capabilities. Typical dc noise immunity is better than 1.0 volt.

All three new circuits are fully compatible with the Motorola MC930/830 series MDTL and Motorola MC500/400 series MTTL.

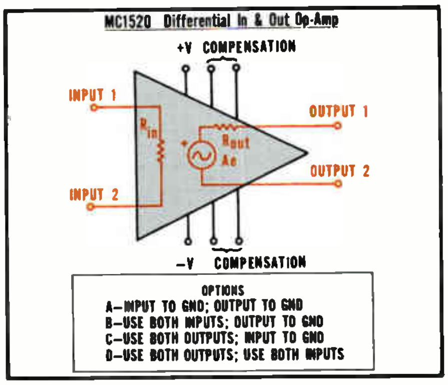
Circuit Type	Package	Temp. Range	Price (100-Up)
MC938F	14-Pin Ceramic Flat Pack	(−55 to +125°C)	$18.00
MC838F	14-Pin Ceramic Flat Pack	(0 to +75°C)	10.00
MC838P	14-Pin Unibloc Plastic	(0 to +75°C)	6.70 (1,000-up)

For details, circle Reader Service # **311**

Differential "In" and "Out" I/C Ideal For Wide-Band Amplifier Applications

Motorola's new MC1520, a monolithic Op Amp integrated circuit, provides both differential input and differential output characteristics. Because of the latter capability, this new circuit exhibits an extremely good common-mode rejection ratio of 90 dB (typ) — making it ideal for use in instrumentation, communication and computer equipment.

The MC1520 also provides a high differential gain of 74 dB (max) — numerically 7,200 — and, as a result, is also a good general purpose operational amplifier. It is particularly useful in wide-band applications requiring large output-voltage swings at high frequencies, especially those calling for differential outputs. The MC1520's gain of 7,200 compares with gains of less than 1,000 for comparable circuits.



New linear I/C boasts differential outputs as well as differential inputs . . . making it a good universal operational amplifier.

Other outstanding typical characteristics of the MC1520 are:

- Wide Closed-Loop Bandwidth — 10 MHz
- High Input Impedance — 2 MΩ
- Low Output Impedance — 50Ω
- Full Output Voltage Swing to Greater than 1 MHz

Available in both the TO-99 10-pin metal can and TO-91 ceramic flat pack, the MC1520G is 100-up priced at $10.00; and the MC1520F is $15.00 (100-up).

For details, circle Reader Service # **312**

One ounce of ZenGard protects against kW "spikes"

New ZenGard Transient Suppressors Provide 12 kW Surge Protection

Electrical Characteristics for MPZ5 Transient Suppressors (At $T_C = 25°C$):

Type Numbers	Nominal Operating Voltage $V_{OP(DC)}$	Nominal Operating Voltage $V_{OP(RMS)}$	Clamping Factor C_F*	Maximum Zener Voltage PW = 1 ms V_Z	@ I_{ZT}	Minimum Zener Voltage V_Z	@ I_Z
MPZ5-16B MPZ5-16A	14	10	1.25 1.5	20V 24V	200A	16V_{DC}	0.4A_{DC}
MPZ5-32C MPZ5-32B MPZ5-32A	28	20	1.25 1.4 1.56	40V 45V 50V	100A	32V_{DC}	0.2A_{DC}
MPZ5-180C MPZ5-180B MPZ5-180A	165	117	1.14 1.25 1.39	205V 225V 250V	20A	180V_{DC}	0.03A_{DC}

$$^{*}C_F = \frac{V_{Z(MAX)}}{V_{Z(MIN)}}$$

The MPZ5 series of ZenGard suppressors are designed to protect transistors, SCR's, rectifiers and other sensitive components in danger of destruction from circuit transients above their ratings. They can easily absorb up to 12 kW for 0.1 ms in applications as 14 V military automotive ignition, 28 V aircraft equipment and 110V ac line-operated circuits. They are more-than-equal replacements for mechanically or electrically-limited selenium cells, silicon carbide varistors, RC networks and electro-mechanical relay systems.

Besides providing sharp, controlled reverse breakdown characteristics, the new series exhibits clamping factors as low as 1.25 — a figure of merit which means lower overshoot voltages and less chance of component degradation and burn-out — and is less temperature and age-sensitive than conventional stacked cells. Costs can also be reduced by allowing the safe use of lower voltage-rated rectifiers.

Weighing only 1 ounce and occupying less than 2 cubic inches, the devices feature low leakage (50 μA max @ V_R) which affords negligible power losses. They are oxide-passivated for top reliability and performance and will operate over a −65 to +175°C range.

Non-standard voltages, tight-tolerance and higher power units (200 kW units have been supplied) can be developed for specific requirements.

For details, circle Reader Service # **313**

SME Transistors Replace "Old-Workhorse" MADT Types

Eight new germanium SME (Selective Metal Etch) mesa transistors – including 2 popular JAN types – are now available in volume quantities to provide a leading second-source for MADT® devices in military and industrial communications equipment.

The SME process, an exclusive Motorola development, is considered a breakthrough in germanium mesa devices. Higher-frequency, lower-noise performance is obtainable due to complete freedom of transistor geometry and much better definition and closer spacing of emitter/base areas to gain optimum device performance.

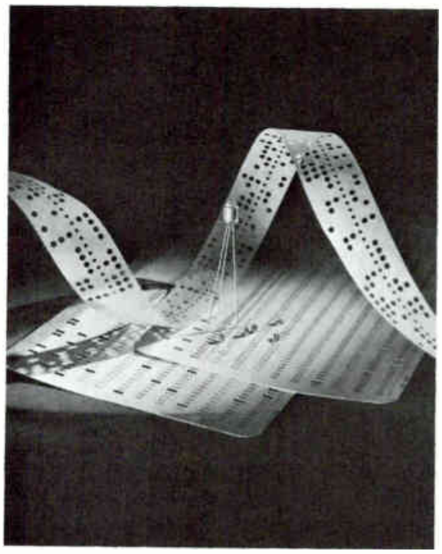
In addition to meeting *exact* parameter-by-parameter specs, the inherent flexibility of the advanced SME process makes it possible to achieve nearly identical key MADT *parameter distributions.* Thus the user can now count on second-source *direct replacement* availability for essentially all MADT-type sockets.

Motorola's MADT replacement types are furnished in the popular TO-5 case (with "tab" removed) which meets all EIA-specified dimensions of the older, TO-9 package, including exact lead configurations.

Type	Use	Power Gain @ 200 MHz (min)	NF (max)	$V_{CE(sat)}$ @ I_C = 10 mA (max)	F (max)
2N502	VHF ampl	8 dB	10 dB	N.A.	500 MHz
2N502A JAN2N502A	VHF ampl	10 dB	7 dB	N.A.	620 MHz
2N502B JAN2N502B	VHF ampl	10 dB	7 dB	N.A.	620 MHz
2N1499A	HF switch	N.A.	N.A.	0.20 Volt	100* MHz
2N1742	VHF ampl	14 dB	5.5 dB	N.A.	980 MHz
2N2048	HF switch	N.A.	N.A.	0.14 Volt	150* MHz

*f_T (min)

For details, circle Reader Service # **314**



Fast Photo Sensors Aid Light-Activated Designs

A tiny photo detector—type MRD200 — and a sensitive photo-transistor — type MRD300 — now provide opportunities to simplify light-activated designs!

Functional and compact (only 0.060″ diameter), the MRD200, two-terminal unit serves where small size and high density positioning is required such as high-speed tape and card readers and rotating shaft information encoders.

It displays linear characteristics over the dynamic range — ideal for reading film sound tracks. Maximum t_{on}/t_{off} is only 6.5 μs allowing faster reading than any mechanical contacts. And, its extremely narrow field of view minimizes cross-talk.

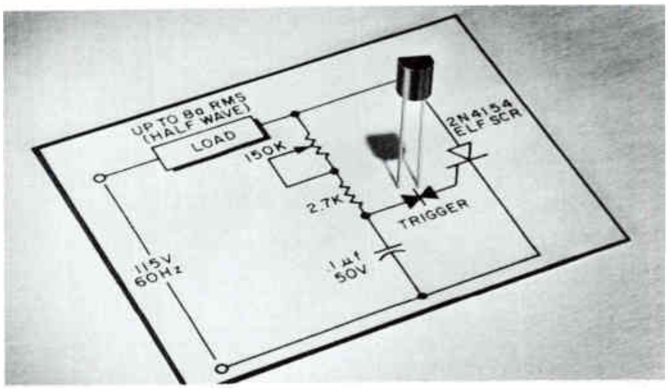
With equally fast rise/fall time, the MRD300 utilizes a TO-18 case with external connections for added control and excels in applications where high sensitivity is essential. It responds to modulation well above the audio spectrum providing a useful means of data transfer from laser light sources.

Both units operate from 1 to 50 Volt power supplies and are compatible with most transistor circuits. Low leakage permits use in direct-coupled designs for low-signal-level operation.

Type	Radiation Sensitivity mA/mW/cm² (typ)	Illumination Sensitivity μA/lum/ft² (typ)	Dark Current μA (max)
MRD200 MRD300	0.5 1.6†	5.0 10†	0.025

†Base open

For details, circle Reader Service # **315**



Low-cost MPT28/32/36 silicon plastic bilateral triggers now make it possible to use all solid-state design in economy power control circuits.

New Bilateral Triggers Trigger New Low-Cost Power Control Designs

Another layer of cost has been peeled from already-economical, all-solid-state power control circuitry with the introduction of the MPT 28/MPT32/MPT36 series of silicon bilateral triggers.

These 28-, 32-, and 36-volt (nom) devices are housed in the Unibloc plastic package — well-known for its rugged,

Trigger Type	V_{BR}† (nom) Volts	I_{BR}‡ (typ) µA	ΔV‡ (typ) Volts	I_{pulse} (max) Amps
MPT28 MPT32 MPT36	28 32 36	20	10	2

†±4 volts, both directions
‡Both directions

void-free case integrity that has consistently withstood 3,000-hour severe environmental testing. The new series furnishes symmetrical switching characteristics, low 50 µA (max) switching current, which reduces capacitor size . . . and a large, 10-volt (typ) switchback voltage which allows higher energy pulses-to-gate for faster "turn-on," lower switching losses and reliable thyristor operation.

In addition, use of these lower voltage, solid-state devices in place of short-lived, high-breakover-voltage neon triggering devices affords broader conduction angle control plus easier triggering of less sensitive thyristors through higher pulse current.

And exclusive Annular construction ensures stable operation over a −40 to +100°C operating temperature range.

How can you best use them in consumer/industrial designs . . . *at below-25¢ volume prices?*

Tie this new bilateral trigger series together with more than 270 different thyristors now available from the industry's broadest up-to-35-Amp line including these preferred 8-Amp Motorola favorites: 50 to 400-volt TRIACS, 50 to 600-volt THERMOPAD plastic SCR's and the ever-popular, metal "can," 25 to 600-volt ELF SCR's.

For details, circle Reader Service # **316**

Low-cost, Complementary Chopper Designs With New Plastic MOSFETS

Low-level, low-frequency complementary chopper designs at a low, low cost . . . that's the essence of the story about Motorola's new plastic-encapsulated MOSFET types — MPF159-160. But then, what more could one want?

Low-level (low-power) complementary chopper applications? They've been almost impossible to accomplish with bipolars because bipolars exhibit excessive leakage. MPF159-160 boast an I_{GSS} value in the picoamp region. Low-cost? The 100-up price for these devices in the Unibloc plastic package (that meets MIL standards) is just $2.75 — about one-third the cost of comparable metal "can" types.

The two new devices are both silicon, type C, triode-connected field-effect transistors that utilize the MOS process. MPF159 offers an R_d "on" rating of 100 ohms, while the complementary p-channel device, MPF160, provides 200 ohms of drain-source resistance in the "on" condition. Both are 15-volt devices that provide 200 mW of continuous power dissipation.

Other ratings for the two devices are:

Characteristic	Symbol	Max. Rating	Unit
Gate Reverse Current	I_{GSS}	100	pA
Zero-Gate Voltage Drain Current	I_{DSS}	10.0	nA
Input Capacitance	C_{iss}	3.0 4.0	pF (MPF159) pF (MPF160)
Reverse Transfer Capacitance	C_{rss}	1.0	pF (Both)

For details, circle Reader Service # **318**

800 mA SCRs Spark New Economy Designs

With prices pegged substantially below 40¢ in volume quantities, the 2N5060-63 SCR series is sure to be a boon to the designer of low-level, power controls.

Housed in the rugged Unibloc plastic package, these 30 to 150-volt units can be plugged directly into existing TO-18 pin circles without confusing lead crossing. Only 200 µA is necessary to trigger these devices — making them ideal for low-level sensing and triggering designs.

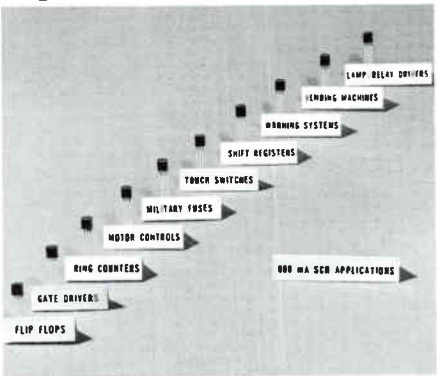
Low-power consumer/industrial/military applications are virtually limitless: military fuzes (squib-firing and safety circuits), flame detectors, automatic warning systems, lamp and relay drivers, fractional H.P. motor controls, sensing, detecting and process controls, vending machines, touch switches, ring-counters, shift registers, flip-flops, gate drivers for larger SCR's, ad-infinitum!

The exclusive Annular construction affords stable, reliable operation over a wide −65 to + 125°C operating temperature range.

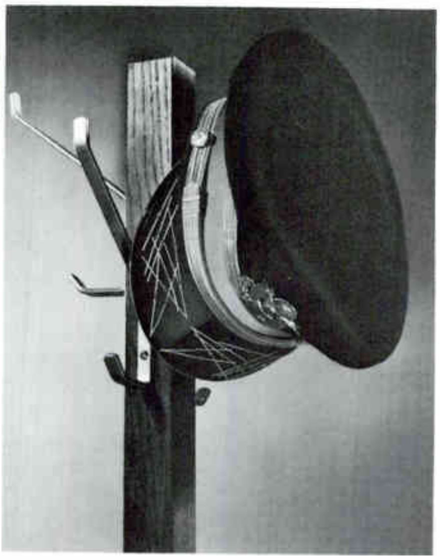
Other features are: 6-A peak surge rating, 1.7-V peak forward "on" voltage and 5 mA max. holding-current, at 25°C.

TYPE	I_F (AMPS)	V_{FXM}/V_{RXM} (VOLTS)	PRICE (100-Up)
2N5060 2N5061 2N5062 2N5063	0.8	30 60 100 150	$.51 .55 .64 .85

For details, circle Reader Service # **317**



When you think "low-level power control," think 2N5060-63 SCR's. They're naturals for virtually all low-cost, high-volume designs.



"Surmetic" First Plastic Rectifier To Count Cadence To MIL-S-19500/228D

Now — the most popular, industry-accepted standard in plastic rectifiers — the Surmetic — is the first of its kind to meet rigid military requirements! . . . an above-and-beyond "call to *reliability* duty" that you can expect in your consumer/industrial designs, too.

Motorola doesn't have a special production line for mil-type Surmetic rectifiers . . . Rather, identical devices for both military acceptance as well as *your* particular requirements are from the same production runs — your assurance that all quality designed into the Surmetic is available to all users.

You get these important design advantages too:

- Improved HV avalanche characteristics through advanced die fabrication
- Superior lead and seal capabilities through double nail head construction
- Excellent reliability through high-temperature passivation

And a minimum guard-band of 20% on all voltages means that I_R will be maintained at 120% of PIV — an automatic safety factor which assures you that units rated at 400 volts, for example, are actually capable of 480 volts operation!

The complete line of Surmetic rectifiers covers a reverse voltage range of 50 to 1000 volts. They are rated to carry a full amp at 75°C and 30-amp surges.

Type	V_{RM} (Volts)	I_O @ 75°C (Amps)	I_R (A)	I_{FM} (SURGE) (Amps)	Prices (100-up)
JAN1N3611	200	1	5	30	$ .99
JAN1N3612	400	1	5	30	1.30

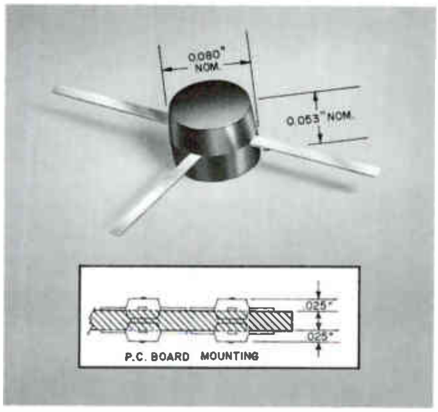
For details, circle Reader Service # **319**

Unibloc "Micro-T" Debut Spurs New High-Density Concepts

The advent of Motorola's Micro-T molded Unibloc plastic transistors now provides the ultra-small devices you've needed to make those high-density, miniaturized equipment design dreams come true. Besides being roughly only one-tenth the volume of standard plastic or TO-18 transistors, the Micro-T's leads radiate from the center of its body, making it particularly well suited to "drop in" automatic strip-line PC board mounting.

The new Micro-T also lets you design circuits having discrete device performance while achieving the component densities and space reductions approaching that of integrated circuits. In addition, its unique structure allows for a wide latitude of mounting flexibility and circuit-layout design. For example, it makes an ideal device for use in thick-film and unitized circuit assemblies.

The first Micro-T transistors available are Motorola PNP/NPN complementary MMT3903-06 silicon Annular switching and amplifier types. They feature a host of premium specs including BV_{CEO}'s of as high as 40 V min., C_{ob} of only 4.0 pF max., current gain speced in two ranges — 100 μA to 1 mA, and 1 mA to 10 mA — with saturation voltages as low as 0.2 V at I_C = 10 mA. They dissipate a full 225 mW at T_A = 25°C and operate over a wide junction temperature of from −55 to +135°C.



Micro-T Unibloc plastic transistors make high-performance ultra-miniature designs economically practical.

Prices are moderate *too* — only $1.60 for the MMT3903 and MMT3905 and $2.00 for the MMT3904 and MMT3906 — in 100-up quantities.

For details, circle Reader Service # **320**

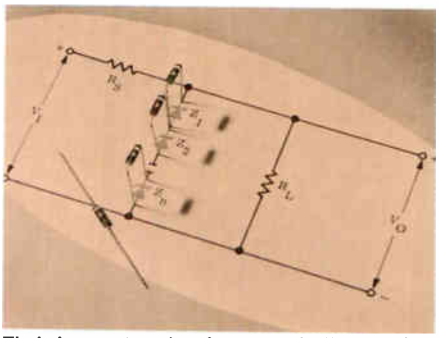
Surmetic-20 Gives Body Blow To Zener Diode Prices

The new ½-watt Surmetic 20 zener diodes now place reliable, economical, voltage regulation within the reach of every circuit designer.

Priced as low as 36¢ (10% tolerance, 5,000-up), the 1N5221-81 units will replace more than 450 older, more costly DO-7 devices from 2.4 to 200 volts . . . and give an extra "capability cushion" besides.

Surmetic-20's are conservatively rated at 500mW under normal mounting conditions. Production-line units have demonstrated "no-failure" resistance to greatly overstressed, 1-watt, 1,000-hour testing. In addition, nanoampere reverse leakage current ratings indicate cleanliness of the passivated junctions and assure low-power drain and sharper knees in all applications.

As a result of flame and distortion-proof silicone polymer packaging, a 200°C operating temperature and repeated defiance of 50-day moisture resistance tests (5 times the exposure period required in standard mil-type case integrity tests), it can be designed with more confidence — and less heat sinking — into virtually all high-temperature, high-humidity environments.



Their low-cost makes it economically practical to employ Surmetic-20 zener diodes in multiple arrays ("strings") to provide greater design flexibility.

Both demanding industrial and military circuits which require solid-state devices to be completely spec'd (Surmetic 20's are 100% oscilloscope-tested and characterized at 4 critical points including $i_{z(surge)}$), or non-critical commercial-type applications are a natural for ultra-economical Surmetic-20 types.

For details, circle Reader Service # **321**

NEW PRODUCT BRIEFS

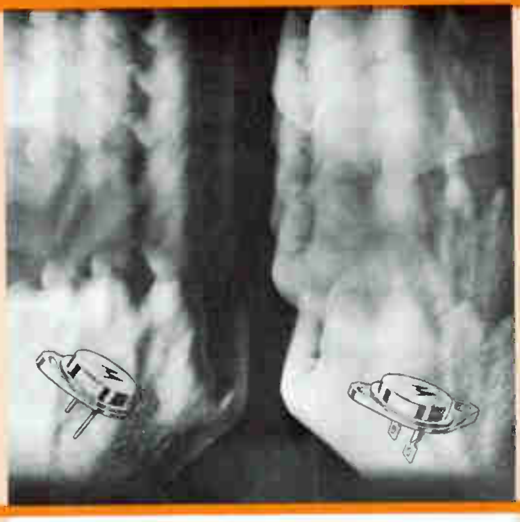
ADE GERMANIUM POWER-SWITCHING TRANSISTORS

— Double "Brute-Power" Capability Over Alloy Types

It's almost like having two power transistors for the price of one! Motorola's new Alloy-Diffused-Epitaxial (ADE) die structure boosts peak power-switching capability to nearly twice that of conventional alloy units, yet carries a low price tag.

The MP2200A-2400A switching transistors are ideal for core driver, power conversion and HV switching applications where high power capability — 80 to 120 V min @ 8 A — is needed at low cost. In addition, high current/gain (25 min @ 8 A), low saturation voltage (0.6 V @ 25 A) and good switching speed (9 μs t_{on} @ 10 A typ) advantages rank them as efficient, solid-state servants in "brute-power" designs. They are available in TO-41 or TO-3 all-aluminum cases.

Type	V_{CE} Volts (sus)	I_C Amps (Cont)	$V_{CE(sat)}$ Volts (max)	h_{FE} @ I_C (min)	Price (100-up)
MP2200A	80	25	0.6	25 @ 8 A	$2.25
MP2300A	100				2.45
MP2400A	120				2.60



For details circle Reader Service # **322**

TIGHT-VOLTAGE-TOLERANCE REFERENCE DIODES

— Spec'd To ±2% Limits, 0.0005%/°C; Yet Cost 30% Less!

You can now specify *either* a ±0.2 V ("A" type, ±2%) or a ±0.4 V (non-suffix, ±4%) tolerance over the nominal 9.4-volt rating for tight voltage range considerations in critical test equipment, meter, satellite and instrumentation designs with Motorola's 1N2163 reference diode series. And where economy is a factor (where *isn't* it!) you can realize savings up to 30% over published prices for comparable units. These 750 mW units feature maximum voltage change spec'd over test temperature range and temperature coefficients guaranteed over three operating temperatures.

For details circle Reader Service # **323**

DO-13

Type Number	Max ΔV_Z (Volts)	Test Temperature (°C)	Temperature Coefficient (%/°C)	Price (100-up) Std.	Price (100-up) "A" Types
1N2163,A	0.033	0, +25, +70	0.005	$ 2.50	$ 2.60
1N2164,A	0.086	−55, 0, +25, +75, +125	0.005	3.40	4.15
1N2165,A	0.115	−55, 0, +25, +75, +125, +185	0.005	4.25	5.50
1N2166,A	0.007	0, +25, +70	0.001	5.10	6.10
1N2167,A	0.017	−55, 0, +25, +75, +125	0.001	6.50	8.30
1N2168,A	0.023	−55, 0, +25, +75, +125, +185	0.001	8.95	12.00
1N2169,A	0.004	0, +25, +70	0.0005	12.75	18.80
1N2170,A	0.009	−55, 0, +25, +75, +125	0.0005	18.00	27.80
1N2171,A	0.012	−55, 0, +25, +75, +125, +185	0.0005	26.20	33.50

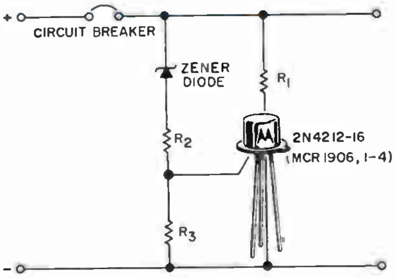
SENSITIVE GATE SCR's

— Reduce Triggering Requirements to μA Levels

Only 100 μA (@ $T_C = 25°C$) is needed to turn on the new 2N4212-16 series of SCR's — a current level many orders of magnitude less than that needed by conventional SCR's and one that virtually eliminates the necessity for elaborate pre-triggering (using transistors or high output triggers). This low-level sensing capability also minimizes the complexity of amplifier stages needed to fire larger power SCR's. The 1.6 amp family is packaged in the space-saving, hermetic TO-5 case and includes both premium and economy units.

Type	V_{RXM} Volts	$I_{FM (Surge)}$ Amps	Max at 25°C I_{GT}	Max at 25°C I_{HX} (R_{GK} = 1 k)	Prices (100-up)
2N4212	25	15	100 μA	3.0 μA	$1.80
2N4213	50				2.00
2N4214	100				3.30
2N4215	150				4.10
2N4216	200				5.40
MCR1906-1	25	15	1 mA	5.0 μA	1.05
MCR1906-2	50				1.10
MCR1906-3	100				1.25
MCR1906-4	200				1.35

For details circle Reader Service # **324**



SCR Crowbar Over-Voltage Protection for DC Operation

UNIBLOC PLASTIC UNIJUNCTION TRANSISTORS

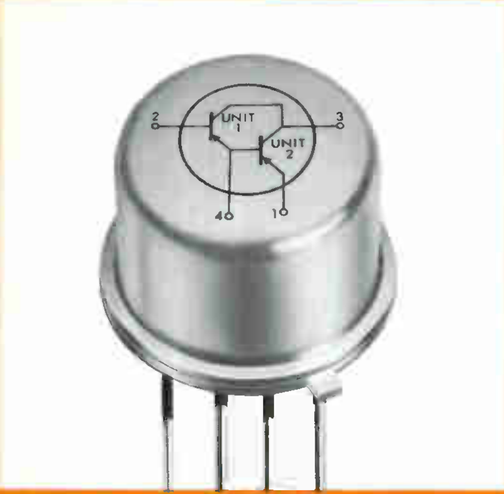
— Combine Low Price And High Performance . . . With Availability

You can select from *two* narrow-range eta spreads with the 2N4870-71 series UJT's, reducing the necessity of tight tolerance resistor/capacitor selection and *two* valley current characteristics, allowing wider latitude in sawtooth oscillator and frequency divider circuit design. And, ultra-low leakage, resulting from the Annular structure, reduces pulse-width variations. In addition, their low (2.5 V) typical emitter saturation-voltage allows greater output to the following circuit stage — particularly useful in triggering applications.

Use them in consumer/industrial applications such as timers, lamp dimmers/flashers, sawtooth generators, motor-speed controls, fuse circuits, pulse generators, multivibrators, oscillators . . . ad infinitum!

Type	Package	Peak Point Current (Typ)	Emitter Reverse Current (Typ)	Intrinsic Standoff Ratio Min.	Intrinsic Standoff Ratio Max.	Price (100-up)
2N4870	TO-92 UNIBLOC PLASTIC	1 μA	0.05 μA	0.56	0.75	$ .64
2N4871				0.70	0.85	$ .68

For details circle Reader Service # **325**



1-AMP PNP DARLINGTON AMPLIFIERS

– Provide High Current Gain Even at Cryogenic Temperatures

The designer is assured of a minimum gain of 15,000 at −55°C and gains up to 60,000 at +25°C (typ) with two new PNP Darlington amplifiers—making them highly suited for very-low-temperature designs—types 2N4974 and 2N4975. They operate over a wide dc current range from 1 μA to 1.0 A with characteristics specified at 8 separate points over the complete operating current range. Both units carry a high P_D rating of 800 mW at 25°C.

Motorola's patented annular semiconductor structure assures unusually low leakage currents—I_{CBO} = 10 nA(max) at V_{CBO} = 30 V. They have a maximum noise figure of only 6.0 dB at 1.0 mA and a typical f_T of 275 MHz at 20 mA. Typical gain specifications for these PNP Darlington amplifiers are:

TYPE	−55°C	+25°C
2N4974	15,000	60,000
2N4975	10,000	30,000

For details circle Reader Service # **326**

HIGH-GAIN 2N4416 — VHF/UHF JFET

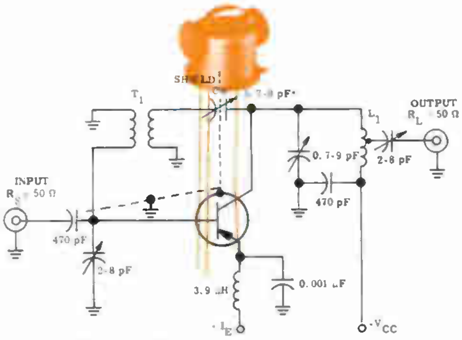
– Fits 8 Out Of Every 10 Sockets!

There's little doubt that most designers will find this new n-channel JFET so versatile that it will soon become the most useful device in the "designer's tool box."

Even though the 2N4416 is characterized as a VHF/UHF amplifier, it will work equally well in low-noise, high-gain amplifiers from dc to above 400 MHz. At 100 MHz, noise figure is specified at 2.0 dB and power gain is 18.0 dB at the same frequency. In addition, the device features input capacitance of 4.0 pF at 1 MHz and transconductance of 4,000 μmhos at 400 MHz.

Motorola's 2N4416 JFET is available now in the TO-72 (4-lead TO-18) package, with isolated chip. The 100-up price is $3.35.

For details circle Reader Service # **327**



MM5000-MM5002 - POWER GAIN AND NOISE FIGURE TEST CIRCUIT

GERMANIUM VHF AMPLIFIER TRANSISTORS

—Break 2 dB Noise-Figure Barrier — 1.6 dB max. at 200 MHz!

Low-noise, low-price and high power-gain make the MM5000 PNP VHF amplifier transistor series a natural choice for the value vs. performance conscious engineer. The units also feature an f_T of 800 MHz min., and a collector-base capacitance of only 0.6 pF max. They are fabricated using Motorola's exclusive Selective Metal Etch process, which permits greater freedom of geometry design. The result . . . better definition and closer spacing of emitter/base areas to provide optimum performance chracteristics. Case type: TO-72.

Type	Low Noise @ 200 MHz	Power Gain @ 200 MHz	Prices (100-up)
MM5000	1.6 dB max	24 dB min	$4.75
MM5001	2.0 dB max	22 dB min	2.80
MM5002	2.2 dB max	20 dB min	2.00

For details circle Reader Service # **328**

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NEW PRODUCT BRIEFS

NPN/PNP HIGH-VOLTAGE SILICON HIGH-FREQUENCY TRANSISTORS

— Offer An Outstanding Combination of Key Parameters

Combining leakage currents in the nanoamp range with low saturation voltages and dc betas (h_{FE}) up to 200 at $I_C = 10$ mA — all this at very high f_T's — Motorola's NPN 2N4924-27 and PNP 2N4928-31 complementary high-voltage silicon Annular transistors provide the peak-efficiency parameters you need to avoid expensive "overspecing" often encountered with devices of this type.

Packaged in the TO-39 case, they dissipate up to 5 watts at $T_C = 25°C$. Both polarity types are available in production quantities to serve a broad scope of high-voltage, high-frequency amplifier applications.

NPN 2N4924-27 and PNP 2N4928-31 Silicon Annular Transistors

Types		BV_{CEO} @ 10 mA (V)	I_{CBO} @ V_{CB} (A)			$V_{CE(sat)}$ @ 10 mA max. (V)		f_T @ 20 mA; 20 V (MHz)		Prices (100-up)	
NPN	PNP		NPN	PNP	(V)	NPN	PNP	NPN min/max	PNP min/max	NPN	PNP
2N4924	2N4928	100	0.1	0.5	50	0.25	0.5	100/500	100/1000	$1.35	$2.70
2N4925	2N4929	150	0.1	0.5	75	0.25	0.5	100/500	100/1000	1.65	3.30
2N4926	2N4930	200	0.1	1.0	100	1.00	5.0	30/300*	20/200	1.95	3.95
2N4927	2N4931	250	0.1	1.0	150	1.00	5.0	30/300*	20/200	2.10	4.50

*f_T @ $I_C = 10$ mA

For details, circle Reader Service # **329**

HIGH-EFFICIENCY POWER VARACTOR MULTIPLIERS

— Boost Frequencies Eight Times in a Single Step!

With the advent of four new step-recovery power multipliers (varactors), the microwave designer can say goodbye to the expensive prospect of two, three, and sometimes four multiplication steps in order to reach regions as high as 6 GHz. Motorola types MV1816B-17B . . . and their tighter tolerance "1" versions (with superior thermal resistance) multiply a frequency 8 times — e.g. from 800 MHz to 6400 MHz — in a single step, with a minimum 20-25% efficiency. Other significant parameters for the MV1816B-17B are:

Device Type	P_{in} (W)	Eff. % (min)	f_{in}/f_{out} (MHz)	θ_{JC} (°C/W max)	C_r @ 6 V 1 MHz (pF)	BV_R @ 10 μA (Volts, min)
MV1816B	3	20	300/2400	23	2.4 - 3.6	75
MV1816B1		25		15	2.7 - 3.3	
MV1817B	1	20	800/6400	35	0.8 - 1.2	35
MV1817B1		25		25	0.9 - 1.1	

These universal devices can be employed in a wide range of local oscillator and transmitter designs requiring a variety of frequencies and multiplication steps. Both types are available in "pill" and "pill/prongs" packages.

For details, circle Reader Service # **330**

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Electronics Abroad

Volume 40
Number 22

West Germany

Horning in

The West Germans, it turns out, have a decided knack for satellite communications ground terminals.

Three years ago, they put into service at Raisting in Bavaria their first satellite ground station. The antenna at the time was rated as the most-advanced design in commercial use [Electronics, Nov. 16, 1964, p. 175]. Now for their second satellite terminal, scheduled to be completed in mid-1969, the Germans again will try something new.

All large satellite ground stations built so far carry transmitting and receiving equipment on the moving structure that keeps the massive antenna aimed at the satellite. The new Raisting installation will have its transmitter and receiver mounted in the pedestal, off the moving antenna structure.

Double-jointed. Like its predecessor, Raisting II has a combined Cassegrain-and-horn design. But instead of a single bend in the horn, there will be two so that the horn can handle antenna movements in both azimuth and elevation. In one bend, radio-frequency energy bounces off a flat reflector onto a parabolic reflector. It focuses the energy onto the director of the big antenna dish.

Two bends mean two rotating joints; but the antenna designers say this complication is more than offset by the advantages of fixed receiving and transmitting equipment. Maintenance, obviously, is easier on fixed gear. No slip rings are needed to feed power to the transmitter and the receiver. And keeping the helium-cooled receiver supplied with helium becomes less of a problem.

Home made. To build Raisting I, West Germany had to lean heavily on hardware supplied by U.S. manufacturers. But Raisting II will have little not made in Germany. Siemens AG, which is managing the project for the government-run West German telecommunications system, will build about 70% of the electronics for the new ground station. Some 30% will come from AEG-Telefunken. About the only noteworthy hardware that may have to be imported is the refrigeration system to cool the receiver.

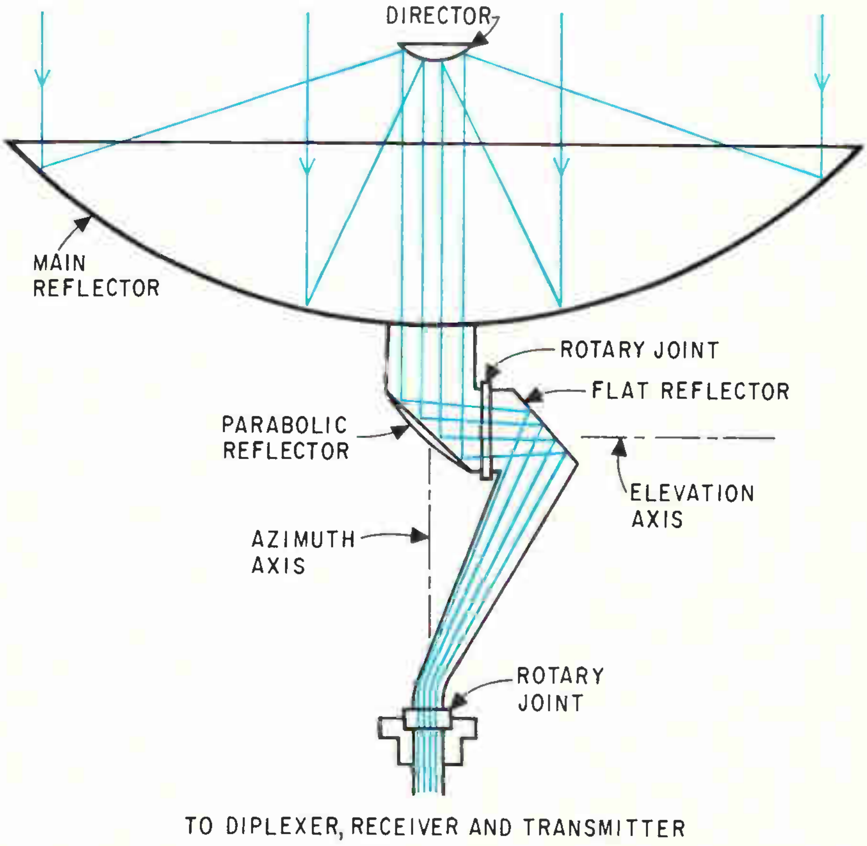
Fried. Krupp will build the dish and its support structure.

For the receiver, Siemens designed a parametric amplifier cooled with gaseous helium rather than liquid helium. This makes for a less-expensive receiver although the noise temperature is rather high—about 15°K. Receiver gain will run about 58.5 decibels over a band from 5,925 to 6,425 megahertz.

For the transmitter, Siemens has decided on a water-cooled traveling-wave tube with output power of between 2 and 3 kilowatts. Antenna gain in the transmit direction will be just under 62 db.

De-iced. After their experience with Raisting I, government telecommunications officials decided to forego a radome for the new antenna. In rainy weather, a film of water forms on the Raisting I radome and makes for poor reception.

Bavarian winters being what they are, though, an unprotected dish would ice up. So Siemens



Around the bends. Horn that feeds Cassegrain antenna has two bends and two rotating joints. The double-jointed layout makes it possible to keep the transmitter and receiver off the moving portion of the antenna for a satellite communications ground terminal.

plans to fit the underside of the dish with infrared heaters. They'll radiate between 250 and 300 kw of heating power to keep the antenna reflecting surface free of ice.

Besides doing away with the radome to hold down attenuation, Raisting II's designers increased sensitivity by setting the dish diameter at 91.5 feet, 9.5 feet more than for Raisting I. The second terminal was designed to work with Intelsat-3 satellites, which will have slightly lower power flux per channel (although more channels) than the predecessor satellites that the older terminal was built for. Raisting I, however, is currently being modified so that it can handle communications via the Intelsat-3 satellites scheduled to be launched next year.

Simple answer

Any time a television repairman has to fiddle with the video intermediate-frequency amplifier in a set, the bill runs high. Changing a component means realigning the coils in the video i-f strip, a tedious job that can take a skilled technician 20 minutes or more to do.

Some set designers say crystal filters are the answer. Unlike the coils commonly used in i-f circuits, the filters need no tuning. Others maintain that integrated circuits, because of their low stray capacitance, are the way to i-f amplifiers that need no adjustment. A third approach, now being tried at the applications laboratory of Standard Elektrik Lorenz AG, is simply to lower the i-f frequency.

Less critical. Hansjuergen Mosel, who's heading the work at the West German subsidiary of the International Telephone & Telegraph Corp., points out that the lower frequency makes the ratio of the bandwidth to the center frequency much higher than usual. As a result, variations in the parameters of key amplifier components—particularly the transistors—have little effect on the i-f response curve.

At Standard Elektrik, the experimental video i-f amplifiers have a center frequency of 14 megahertz. The video carrier is at 17 Mhz and the sound carrier at 11.5 Mhz. Conventional i-f amplifiers in West German sets operate at 36 Mhz and have the same 5.5-Mhz separation between the video and sound carriers. (In the U.S., the i-f center frequency is 45 Mhz and the bandwidth 4.5 Mhz.)

Stagecraft. In the three-stage, 14-Mhz i-f amplifier, only the first stage has a feedback input for automatic gain control; the other two use plastic-encapsulated transistors with high internal shielding. The capacitive feedback is so low that neutralization is not necessary, says Mosel.

At the amplifier input and in the second and third stages, the frequency-selective elements are symmetrically damped two-circuit bandpass filters. Because of the symmetrical damping, frequency detuning between the two circuits of each filter has a negligible effect on the response curve. And because of the loose capacitive coupling between stages, small variations in the characteristics of the input and output transistors have practically no influence on the shape of the curve.

The result is an i-f amplifier that needs no adjustment if close tolerances are held on the capacitors, coils, and damping resistors in the filter circuits. Printed coils, rather than adjustable ferrite core types, are used in the amplifier. Total amplification is about 80 decibels and the output voltage across the 2.7-kilohm load resistor is roughly 2 volts.

Interference. Mosel, who last year devised a circuit that does away with coils in the i-f and discriminator stages in tv sound channels, says some further work must be done before the new video i-f amplifier can be designed into tv sets. The 14-Mhz center frequency lies in a shortwave broadcast band used, among others, by ham radio operators, and this raises the problem of shielding the i-f circuit.

If the shielding isn't onerous, Standard Elektrik expects to develop a hybrid-circuit package combining both a tv tuner and a video i-f amplifier.

Great Britain

IC time at ICT

Britain's biggest computer maker, International Computers and Tabulators Ltd., has compiled an admirable track record in recent years. Among West European computer firms, ICT stands out as the sole company that, in its domestic market, has managed to best the International Business Machines Corp.

The company turned the trick with second-generation transistorized computers. But ever since IBM started delivering third-generation integrated-circuit machines in 1965, the industry has wondered when ICT would follow suit. The answer came this month as ICT announced it would be ready to deliver a large multiaccess computer—designated the 1906A—by late 1969.

The machine's central processor —built around emitter-coupled-logic (ECL) packages—will handle up to 1 million instructions per second, and transfer up to 5 million characters per second to the peripheral equipment. System prices will range from $1.5 million to $4 million. Performance and price puts the 1906A in much the same class as IBM's 360/65.

Officials at ICT predict 40 sales in the domestic market, plus another 40 or so overseas.

Fast logic. The company opted for emitter-coupled-logic because it felt ECL's speed would make possible a massive computing capacity at the right price. About three years ago, ICT developed thick-film hybrid ECL circuits with a switching time of 3 nanoseconds. Using these circuits, it put together a prototype processor to prove out the design. Later, ICT scouted around for a volume producer of ECL, settling on Motorola Inc.

Motorola developed a monolithic equivalent of the hybrid logic that has the same switching time. Although the monolithic's noise margin is somewhat lower than the hybrid's, it isn't enough to affect the machine's performance. The

British firm describes the first production IC's as "superb" and says they'll be much cheaper than hybrids in the long run.

At the outset, the IC packages will be imported from the U.S. However, ICT will undoubtedly line up a British supplier as a second source, most likely Ferranti Ltd. Motorola and Ferranti are negotiating for British production of the ECL packages.

The central processor circuits are so fast, says ICT, that they could be paired with a memory having a 100-nsec cycle time. But a memory this fast would be too costly, so the 1906A core memory will have a 750-nsec cycle time. The memory will be arranged for multiple access for up to eight words at a time, however, to get an effective cycle time close to 100 nsec.

The store width is 50 bits and its capacity will range up to 4 million words.

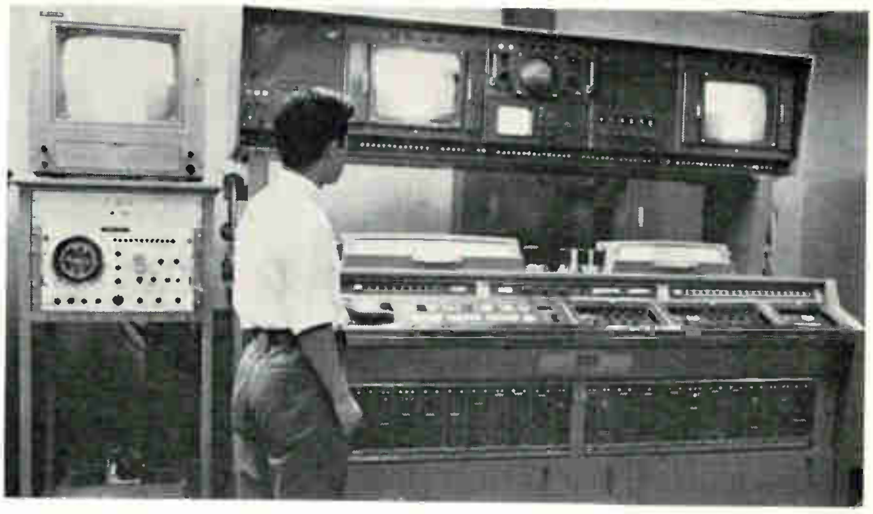
Curbed crosstalk. The company says that despite the high speed, some computer makers have shied away from ECL because of troubles with crosstalk in the densely packed wiring of the circuit. This was solved at ICT by integrating ground lines and logic transmission lines in multilayer printed-circuit boards.

The processor will be made up of from 60 to 70 boards, each carrying up to 200 IC packages. Only about 0.1-inch thick, the boards will contain up to a dozen layers, two of them carrying ground connections.

Japan

Slow color

Thirty seconds is more than enough to show a pro football quarterback tossing a touchdown pass to a sure-handed receiver. And so U.S. television networks aren't bothered at all by the 30-second limit on the disk-recording equipment they use for playback of colorcast sports events in slow-motion [see story p. 125].



Fast or slow. Color video tape recorder plays back at normal speed or one-fifth speed for slow-motion.

But 30 seconds isn't long enough for Nippon Hoso Kyokai (the Japan Broadcasting Co.), whose viewers like long slow-motion replays of sumo matches, the stylized wrestling contests popular in Japan. So NHK has come up with a color video tape recorder that can play back at normal speed or one-fifth speed. The slow-motion playback by the recorder can start anywhere on the tape and last for hours. But NHK of course doesn't go to extremes.

Adapted. The slow-motion recorder is a standard four-head broadcast-type unit, to which two sets of playback heads and additional circuits are fitted. The standard playback heads operate in the usual manner for normal speed.

Both standard and slow-speed heads rotate at 240 revolutions per second. But the slow-speed heads are slightly offset so that four consecutive tracks of the tape are reproduced during one revolution of the head assembly. During the next four revolutions, the heads are electronically switched off, and on the sixth revolution they reproduce the next four tracks on the tape.

Two auxiliary memory units are used for slow-motion operation. Each has a stationary drum wound with enough tape to reproduce one field. Inside the drum are heads rotating at 60 revolutions per second for recording and playback. The units are similar to helical-scan home-video recorders, except that the tape doesn't move.

Quartets. The two memory units are for even and odd scan fields of the tv signal. Four groups of four tracks from the original tape are recorded as one field on one memory. The next group of four tracks is recorded as one field on the other memory. Each field is reproduced five times while the other field is being recorded.

The color subcarrier is separated from the brightness of the reproduced slow-motion signal by passing it through the resolver circuit, which corrects the phase of the signal, and is then again added to the brightness signal. Correction of the phase of the color subcarrier signal only, without processing the brightness signal, provides broadcast-quality color reproduction, Japan Broadcasting says. In this respect, the unit differs from other color video tape recorders, which process the entire color signal.

By the numbers

Controls makers in Japan find themselves in much the same situation their American counterparts suffered through some three years ago. The agonizing is over when to go to market with direct digital control equipment.

At the automation show put on this month by the Japan Electric Measuring Instruments Association, it became clear that most of the country's controls makers think the age of direct digital control is nearly at hand. Yokogawa Electric Works Ltd., Fuji Electric Co., Tokyo Shibaura Electric Co. (Toshiba), and Hitachi Ltd. all had DDC hardware to show. But DDC equipment was conspicuously missing at the precinct of Hokushin Electric Works Ltd. At the previous automation show two years ago, Hokushin had the competition agape with a display of DDC hardware developed jointly with the Fischer & Porter Co.

Too much too soon. Hokushin, competitors say, leaped into the market too soon. Although the DDC equipment worked, a field test at a refinery of the Mitsubishi Oil Co. proved more than anything else that Hokushin's DDC hardware could replace conventional analog controllers. But limited to proportional-integral-derivative control (PID)—known as Type 1 DDC—the Hokushin approach turned out to be an expensive way of doing what analog equipment can do.

In the U.S., Fischer & Porter has had mixed success with the Hokushin DDC hardware. One system was tried out first at a Canadian paper plant and later moved to a New England rubber plant. In both cases, the equipment was turned back to Fischer & Porter.

Meanwhile, the Union Carbide Corp. tried a system and found it worked well in a pilot plant having 75 control loops. A full-fledged system to control "more than 200" loops will go on-stream in a month or so at a Union Carbide plant. Fischer & Porter built the equipment, based on Hokushin's design.

Sophisticated. Hokushin currently is querying potential DDC customers to find out what they really want. Meanwhile, the company's competitors have decided that the future for DDC lies in Type 2 systems, a decision most American DDC makers and users arrived at two to three years ago. In these, the computer not only handles PID control but also implements advanced control schemes like feed-forward that can signal changes long before conventional PID equipment could react. Thus with Type 2 DDC, the payoff comes not from lower initial control system cost but from gains in output of plants and improvements in product quality.

At the moment, Yokogawa Electric rates as the front-runner among Japanese DDC systems makers. The company has two systems in operation at chemical plants, plus orders for a half-dozen more. Fuji Electric has two systems—both small—in operation. Hitachi and Toshiba still are looking for their first DDC customers. Only Yokogawa and Hokushin have special-purpose DDC central processors. The others have based their entries on small general-purpose computers.

Backup. Yokogawa's system relies heavily on integrated circuits in the arithmetic and logic circuits. All-in-all, there are about 1,600 diode-transistor-logic packages, supplied by the Nippon Electric Co.

Although a prototype system with no backup equipment stayed on-line 99.90% of the time during a nine-month field test at a pilot fermentation plant, Yokogawa engineers added some partial duplication to cut the down time for subsequent systems. They have standby arithmetic control circuits, memory current drivers, and amplifiers. In Yokogawa's view, complete duplication would be a waste of money.

France

Traffic talk

The automobile telephone has not achieved wide popularity either in Western Europe or the United States. So far it has been used chiefly by business executives or government officials. In all of Paris, for example, only 225 mobile phone subscribers are tied into the government-run system. And in the New York metropolitan area, the figure is a mere 800.

Significant strides, though, seem imminent in Western Europe. A system that can handle 400 subscribers is about ready to go into service in Madrid. Barcelona expects to have a 400-subscriber system on the air by the spring of 1968. And West German telephone officials are thinking about a nation-wide automobile telephone network that could handle up to 100,000 subscribers.

Credit Le Matériel Téléphonique, a French subsidiary of the International Telephone & Telegraph Corp., for the spurt of activity. The company's new automatic mobile telephone equipment has been selected for Madrid and Barcelona and probably will be the West German choice.

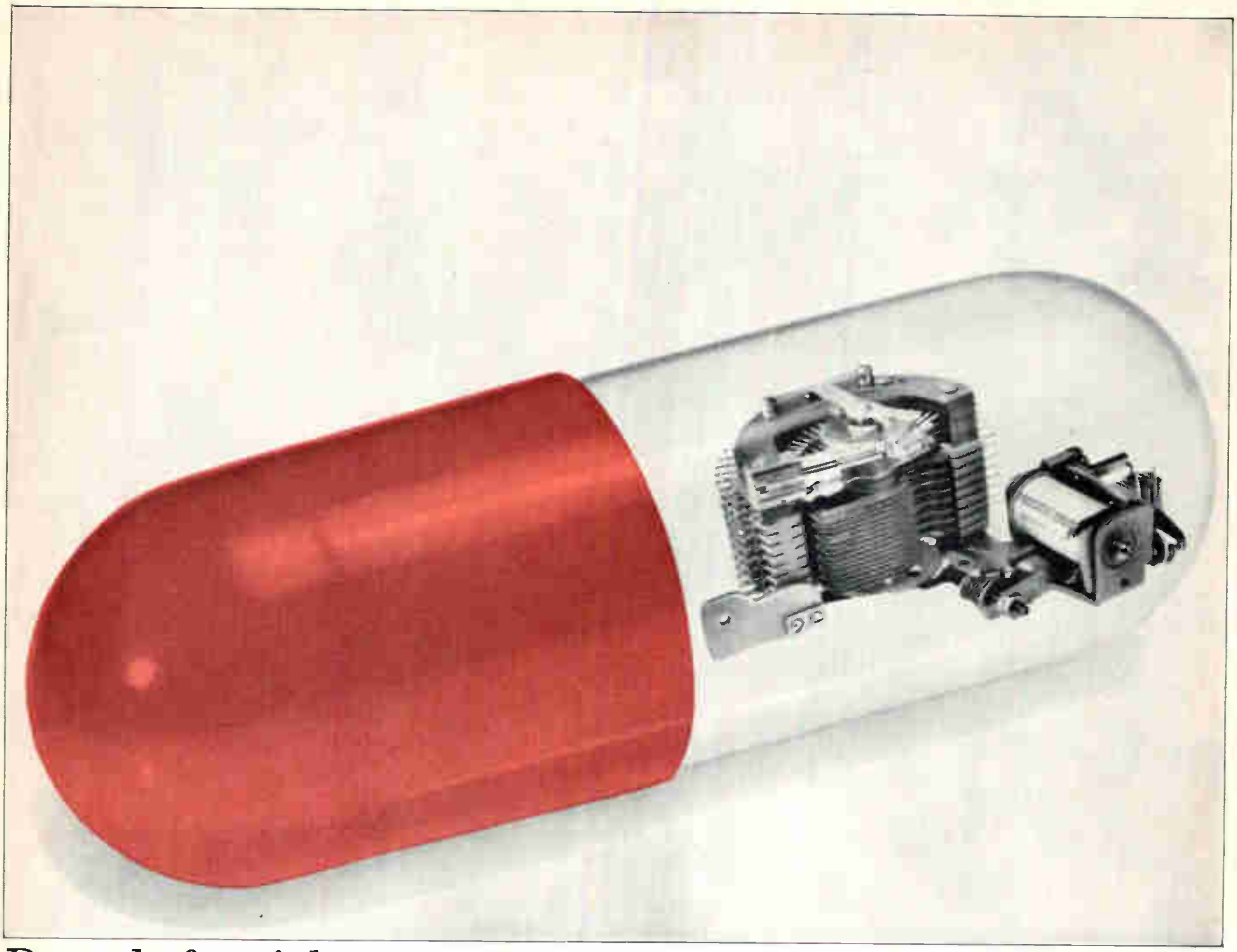
Grouped. Like the improved mobile telephone service equipment used by the Bell System in the U.S., LMT's equipment ties automobile phone subscribers into the telephone network by microwave radio. The main difference between the two lies in the terminal equipment that links the transmitter-receiver to the telephone switching circuits in the central exchange. The U.S. equipment acts as a number of independent subscriber circuits. The French equipment functions as a group of four trunk lines, one for each radio channel.

The advantage over independent circuits, LMT says, is that a terminal operating as a group of trunk lines doesn't have to duplicate line-concentrators, registers, and translators that exist in the central exchange. However, the trunk-line arrangement alone doesn't cover call metering and special services, so LMT adds to the trunk switch a pseudo line switch.

Well spaced. In the Madrid installation, calls to cars are broadcast from a central station with a 250-watt transmitter for each of the four channels. Calls from cars are picked up by five receiving stations spotted to cover the city. The system operates in the 156—174 megahertz band. Transmissions are frequency-modulated and the channels are spaced 20 kilohertz apart.

The transceivers in subscribers' cars have 10-watt transmitters. When a subscriber lifts the phone off the hook to call, the transceiver unit searches automatically for a free channel.

LMT's vehicle equipment is less complex than Bell's, which can handle eight radio channels. Also, the LMT equipment has no provision for making calls through an operator, as Bell's does.



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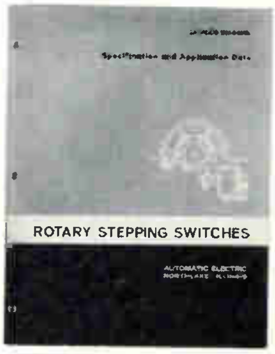

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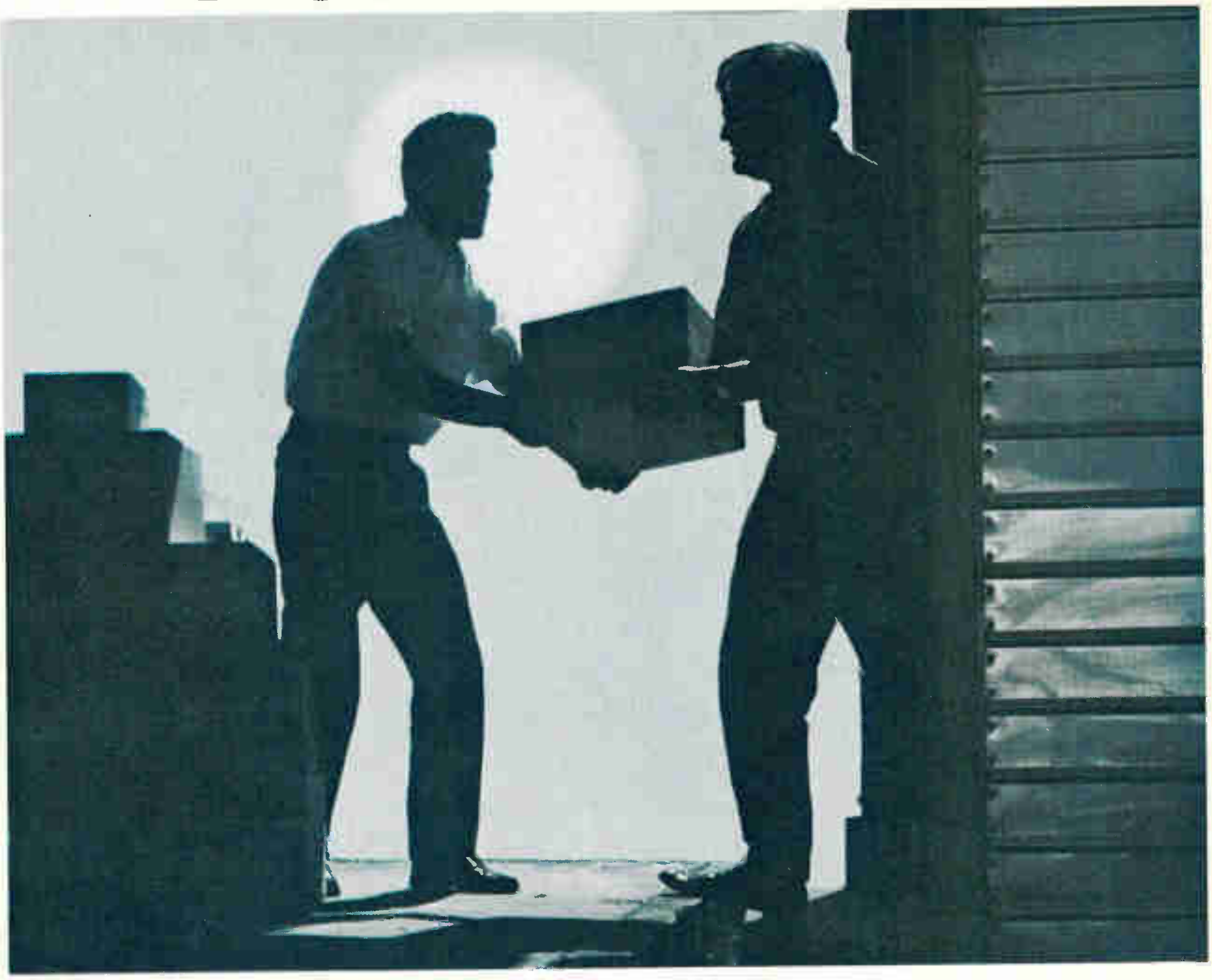

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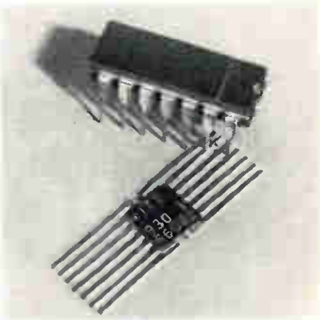

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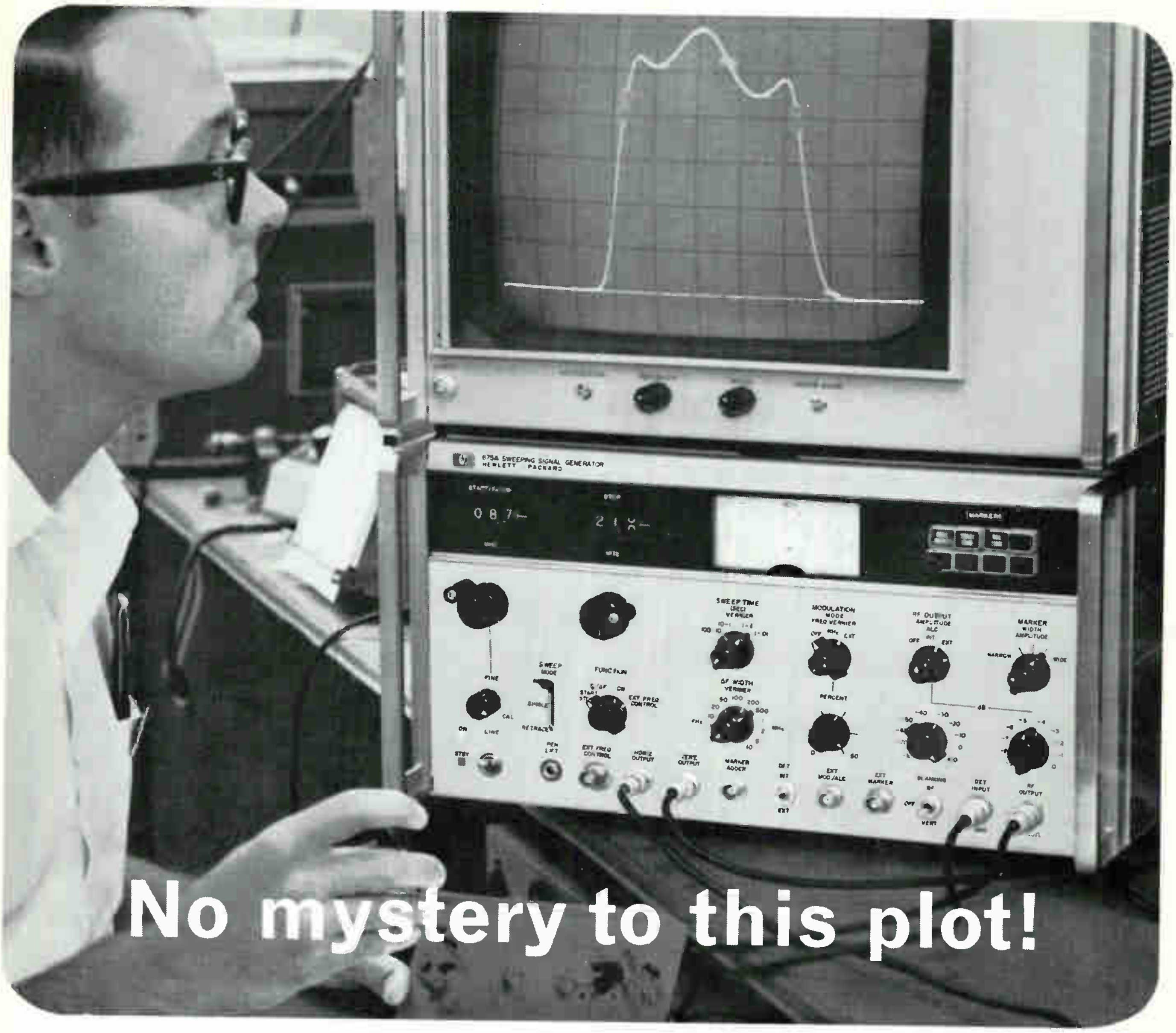

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