Electronics

The coming boom in linear IC's: page 88
Making masks with a laser: page 119
Anticipating disease with electronics: page 125

August 7, 1967
$1.00
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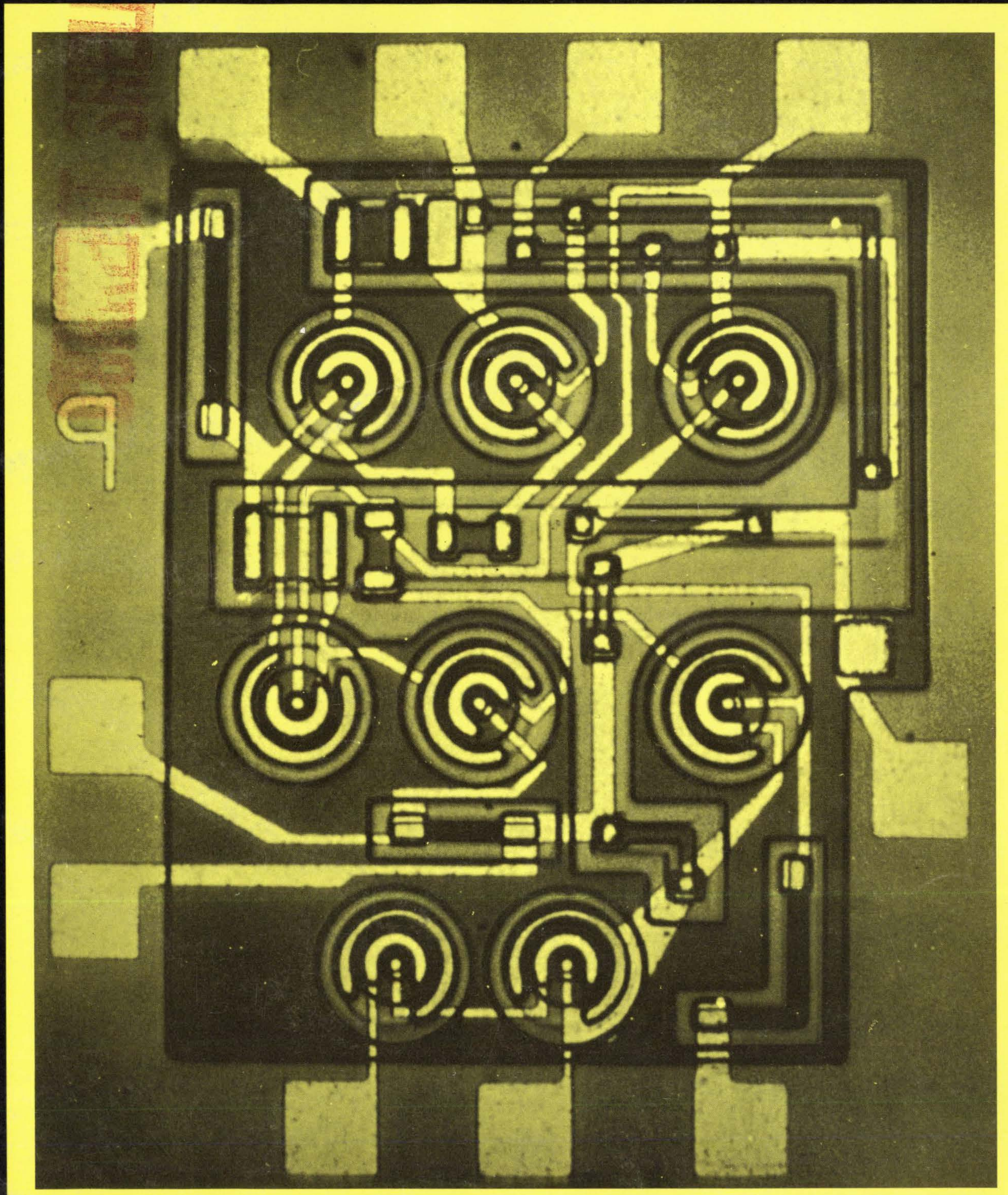
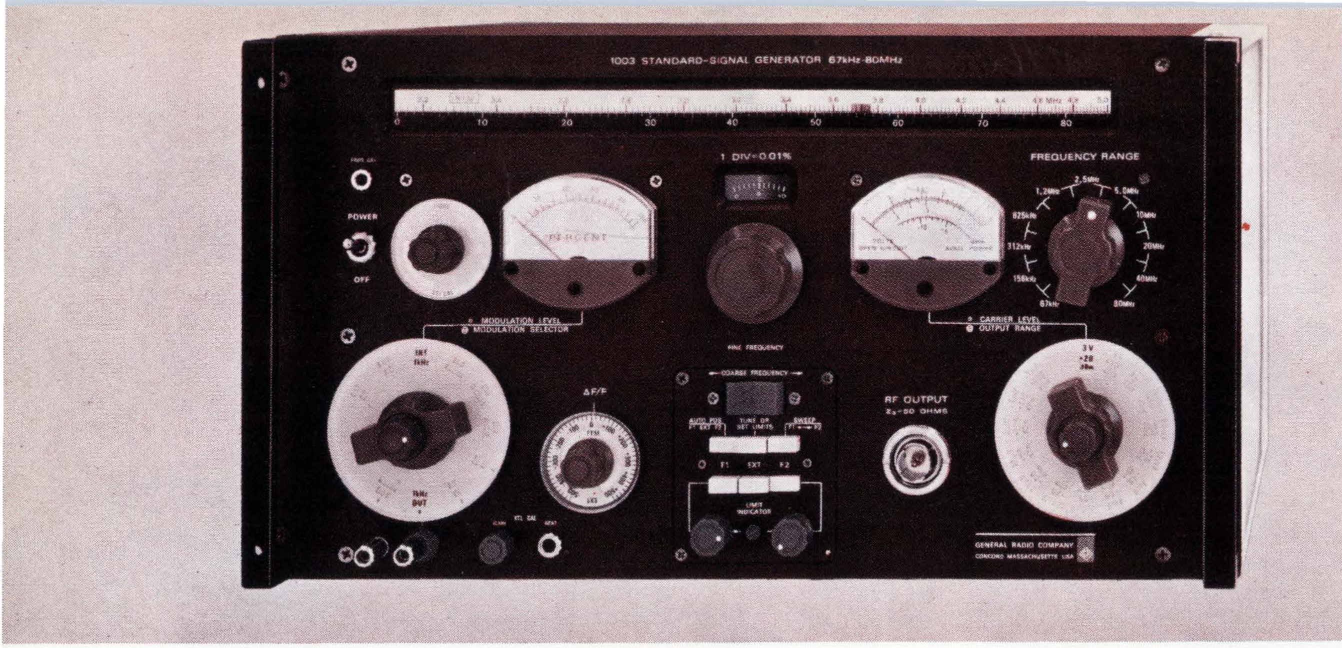
Below: High-frequency amplifier typifies new linear IC's, page 88





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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.

The 1003 covers a 67-kHz-to-80 MHz frequency range, and tuning this instrument is as much fun as it is convenient and fast. You can coarse-tune by motor over the main slide-rule dial to within 0.25% at a rate of about 7% per second, and fine-tune manually with a large control whose dial divisions correspond to 0.01% of the main scale. For greater resolution, a "ΔF" control provides electronic, backlash-free settability to 2 ppm. The motor-driven frequency control is fully utilized in the model containing the auto-control unit, which lets you preset frequencies. The preselected frequencies are useful either as limits for automatic sweeping or for programmed frequency selection (repeatable to 0.1%).

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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.

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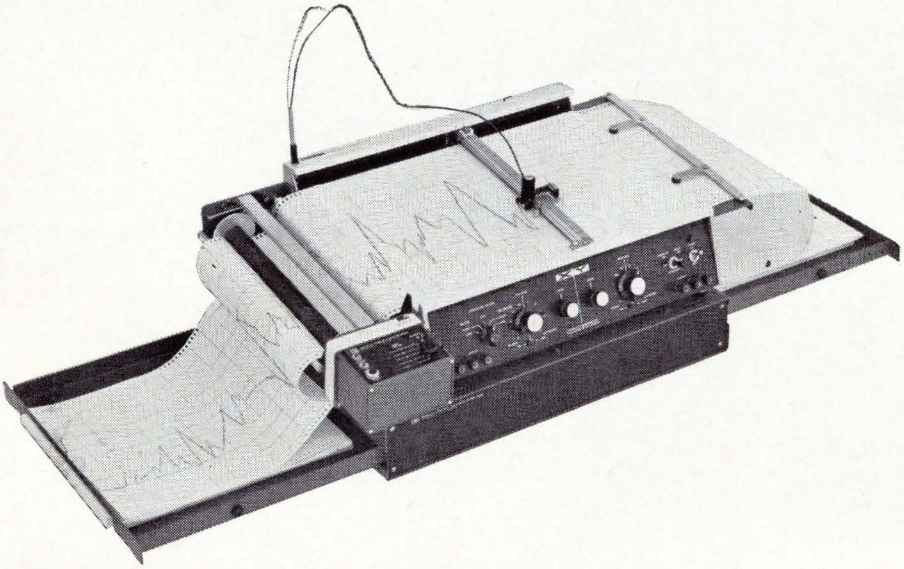
Price of the 1003 is $2995 ($2795 without the auto-control unit and crystal calibrator). For complete information, write General Radio Company, 22 Baker Avenue, W. Concord, Massachusetts 01781; telephone (617) 369-4400; TWX (710) 347-1051.

GENERAL RADIO

See the Type 1003 Standard-Signal Generator at WESCON, Booths No. 3015-3018.

Circle 900 on reader service card

ADVANCE



new X-Y accessory offers unique recorder flexibility

The new 17005A Incremental Chart Advance turns your Moseley X-Y recorder into a more flexible lab and production tool. It provides this added versatility and high performance by converting your X-Y into a strip-chart recorder. It offers incremental advance for multichannel pulse height analysis with resolution between channels—and accepts both positive- and negative-going signals to advance the appropriate increment in the advance mode.

Designed for remote control operation. Will adapt to most 11x17 Moseley Recorders. Powered by the recorder itself. Uses roll chart or Z-fold paper. Price: Model 17005A, $895.

For complete information, contact your local HP field engineer, or write Hewlett-Packard, Palo Alto, California 94304; Europe: 54 Route des Acacias, Geneva.

Visit Hewlett-Packard at Wescon '67
San Francisco, Cow Palace, August 22-25

SPECIFICATIONS:

Incremental advance mode
Plot density (plots/inch):
200, 100, 50, 20, 10

Increment size (in./advance):
0.005", 0.01", 0.02",
0.05", 0.10"

Frame advance mode
Advance distance: 24"
Accuracy:
±0.005" (non-accumulative)
Advance time: <20 sec.

Time base mode
Chart speeds:
1, 5, 10, 50, 100 sec/in.
Accuracy: ±2%

Major division advance mode
Advance distance:
Major divs. in 3" increments
Accuracy:
±0.005" (non-accumulative)
Advance time: 2½ sec.
Other advance increments available

HEWLETT PACKARD MOSELEY DIVISION

11701

Circle 1 on reader service card

Electronics

August 7, 1967

Volume 40, Number 16

News Features

Probing the News

Electronics Review

Electronics Abroad

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Technical Articles

I. Design

II. Application

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Readers Comment

Why not?

To the Editor:

Now that A.J. Williams has developed a new type of chart recorder [June 26, p. 45], he is certainly to be congratulated for his advancement of the state of the art. Having had prior experience with inventions, he is of course prepared for letters of the vein—why didn't you do it his way? My "why not" follows:

Having sampled the wave shape and digitized, there is no advantage taken of coding to reduce the stylics problem. Through the use of binary-coded decimal octal to code each channel, several economic advantages could be achieved:

1. Recording in BCD-octal would permit the use of only three stylics per channel instead of 10.
2. The BCD-octal coding would not require that calibration lines be drawn on the paper.
3. Position accuracy of the recorded data would in no way be critical as described in the article.
4. Paper widths could be narrower.

As the review notes, the use of IC's for electronics will hold down the cost, and the difference between decimal coding and BCD-octal will not be significant.

Edward M. Sawtelle
Federal Aviation Administration
Atlantic City, N.J.

Creativity continuum

To the Editor:

Your story "Second generation" [June 26, p. 45] has prompted me to some observations on engineering obsolescence.

Suppose A.J. Williams, Jr., had been laid off and was looking for a job before he made this discovery. What percentage of company

Indexes of activity

Starting in this issue (page 42), Electronics will publish four indexes measuring the industry's production. The figures will appear in the first issue of every month.

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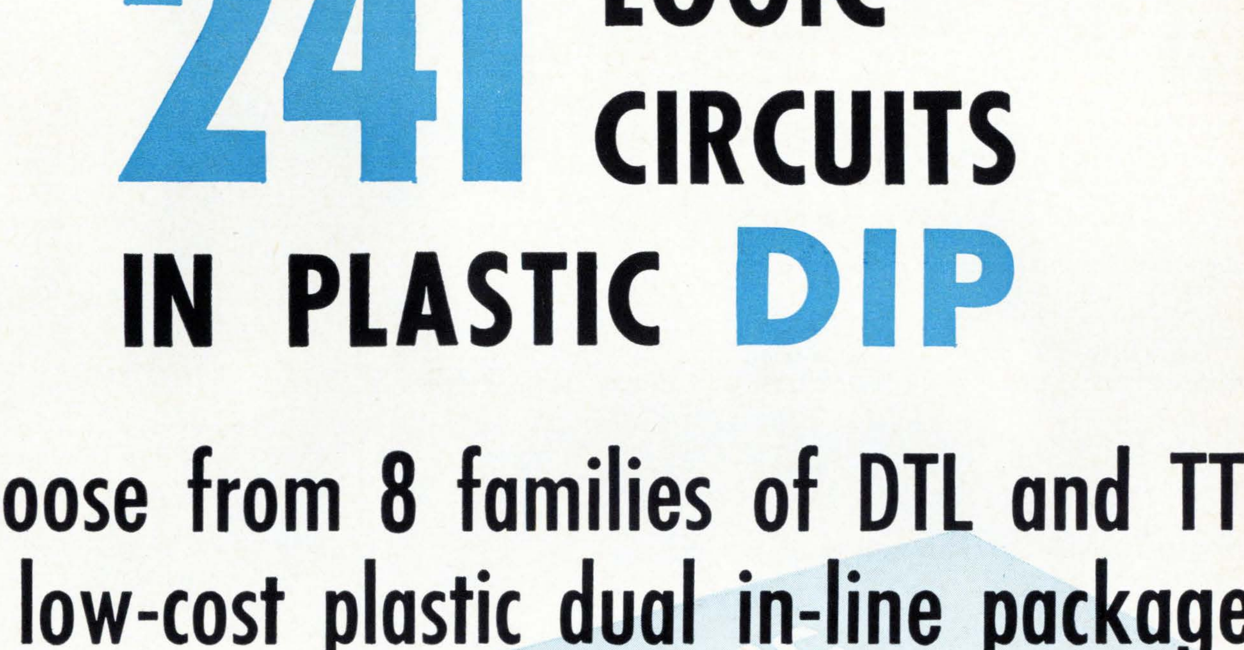

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recruiters do you suppose would have selected him from his resume for an interview in depth? What percentage of such interviews might have resulted in firm job offers? He has offered another of the many proofs that the creativity of the individual does not necessarily dry up with advancing age.

It would be most interesting to learn if Williams had seen any of the "hybrid recording" work done by Dr. John C. Bellamy while he was at the University of Chicago, or later as director of the Cook Research Laboratories. (Here I used "hybrid" to mean "incorporates both analog and digital elements.")

As I recall, Bellamy's displays included both digital and hybrid records. In addition to reading the whole data word from the record, one could inspect one of the significant digits of the record to determine both the trend of the data (its first time derivative) and the changes in the trend (its second time derivative) just as you can in Williams' new recorder.

Perhaps if the engineers and scientists of 20 years ago had had the ability to understand number bases other than 10, Bellamy's work might have found more ready acceptance.

The fact remains that there has not been a general acceptance of continuous digital records that are readily readable by both man and machine for any number base other than 10. So, although from a purely technical standpoint other earlier recording methods were known that could do everything Williams' now does, the fact that they did not win acceptance implies that their essential contributions to the state of the art were not sufficiently distilled and presented in a form readily understandable to potential users.

Charles P. Hedges
Santa Barbara, Calif.

▪ Williams, a 64-year-old engineer with the Leeds & Northrup Co., was instrumental in developing the commonly used strip-chart recorder. Now, 38 years later, he has developed a next-generation instrument, an electronic strip-chart recorder that's based on some new principles. The Williams design provides a resolution 40 times better than conventional recorders and a response time of 250 microseconds, compared with 0.25 second for the earlier model.

Standard sheets

To the Editor:

Over the few years I have collected transistor specification sheets, I have found the only uniformity in these sheets is in size. Since manufacturers obviously have standards in producing transistors, why can't they have standards for producing data sheets? It would be much simpler if a user could look at the same place on each data sheet for the same information. Granted each transistor is individual and should be tested before being put into a circuit, but how many users can afford a Tektronix 575 Curve Tracer?

I believe that standardization could be enforced if the users refused to purchase nonstandard products, and engineer-designers specified only EIA-registered items, and let the manufacturers know this.

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People

The upheaval that elevated energetic **Jerry Sanders,** 30, to his job as marketing manager for the Semiconductor division of the Fairchild Camera & Instrument Corp. will result, according to Sanders, in a more aggressive introduction of new integrated circuit products by the company that is already the industry leader. "We'll continue to support our customers in day-to-day operations," Sanders says, "but we may be less bullish on orders that compete with our new product plans."

Jerry Sanders

Sanders emphatically denies that the reorganization that divided Fairchild into three manufacturing operations [Electronics, July 24, p. 44] will downgrade the marketing department—even though some marketing personnel will be absorbed into operational teams.

Team effort. "Those people will be part of a product marketing support team, with responsibility for field sales," Sanders says. "They will take care of information on prices, delivery, specifications, samples, data, and so forth. They will negotiate prices and handle short-term forecasting.

"Basic pricing responsibility will remain part of the marketing department, which will make strategy and do long-term planning, research and market analysis, and new product planning and introductions.

"Look—as Fairchild grew, many functions that belonged to a support team were usurped by the marketing men, probably because most of them were E.E.'s. The introduction of new products takes a coordinated effort by marketing, operations, and research and development. With the new organization, we can take key men and put them on a particular project to get faster introduction of new products."

Not yet. Fairchild will not say exactly where it will concentrate its new product effort. But Sanders says that the company still con-

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MACHLETT ML-8618 magnetically beamed triode requires 10 to 100 times lower drive

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Filament Power	**2.5 kilowatts**	**4.0 kilowatts**	**2.5 kilowatts**	**4.0 kilowatts**

RESULT: ML-8618 reduces pulse driving power by a factor of 100 or better.

RESULT: ML-8618 reduces rf driving power by a factor of 10 or better.

Machlett's exclusive development, magnetically beamed tubes like the ML-8618 give you these advantages:

- By magnetically controlling the trajectory, electrons from the cathode bypass the grid structure so that nearly all emitted electrons reach the anode.
- Grid current is very low because of the great reduction in grid interception—about 3% as compared to 25% in conventional triodes.
- Low grid current means that grid dissipation no longer limits tube power.
- Parallel plane electrode structure eliminates "shielded" portion of filaments, permits 360° of the cathode surface to face anode surface and complete use is made of the filaments emission surface—result is higher cathode current per watt of heating power.

For details, write The Machlett Laboratories, Inc., Springdale, Conn. 06879.

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People

siders metal oxide semiconductor technology and large-scale integration of bipolar circuits to be remote from the marketplace. "Bipolar LSI will not materialize until there is two-layer metal available for crossovers," Sanders says. "We expect to have a production process for that metal ready to make prototype quantities by year's end."

Functionally, Fairchild will concentrate on high-speed devices, microwave IC's, and bigger memory devices. The target? "One-third of the integrated circuit market," Sanders says succinctly.

"Use of computers is much too important in industry to let it drift as it has in the past," says **William F. Brown.** He is one of the first in a new industrial role: integrating a company's computer activities for its own engineering and business as well as marketing the computer service outside the company.

William F. Brown

At the Atomic International division of North American Aviation Inc., Canoga Park, Calif., he headed one of the first integrated computing operations in the aerospace industry. Last month, he moved to the Avco Corp.'s Missile Systems division, Wilmington, Mass., to head the new directorate of management systems and information sciences.

In addition to controlling the application of computers to scientific and business problems in the division, he will direct the Avco Computer Center, one of the largest in New England. It's now a batch-processing operation that Avco aims to convert to a time-shared center for other Avco divisions and outsiders.

Before going to Atomics International, Brown, who is 43, taught mathematics and computer subjects at West Coast universities, was a staff scientist at the Los Alamos Scientific Laboratory and at General Dynamics Corp.

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Each Series is a carefully designed combination of power, performance and packaging,—to fill your specific requirements. Sorensen's AC regulation capability spans 25 years of experience in the design and production of regulators. Our standard product technology provides the firm basis for an outstanding custom design capability. Whatever your AC regulator problems, – check with Sorensen.

For details on Sorensen AC regulators, or for standard/custom DC power supplies or frequency changes, contact your local Sorensen rep. or: Raytheon Company, Sorensen Operation, Richards Ave., Norwalk, Conn. 06856. Tel: 203-838-6571.

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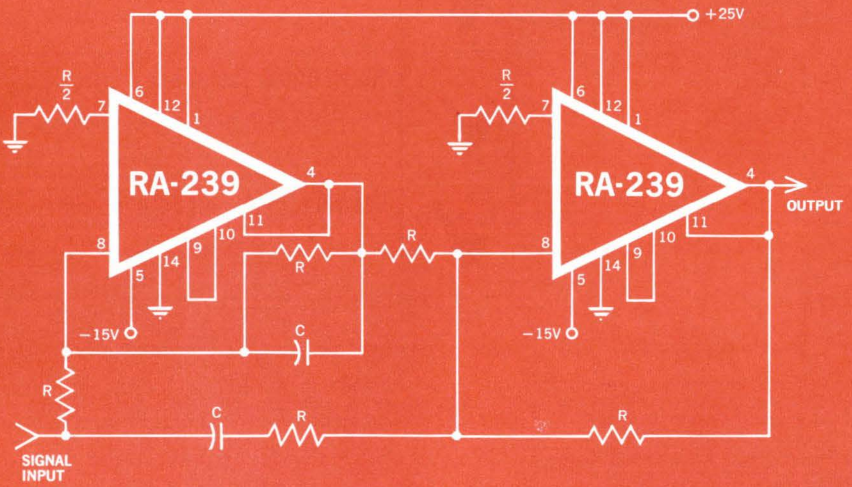
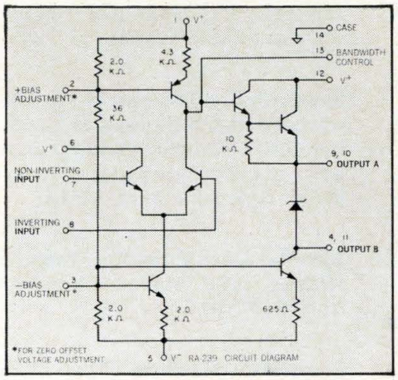
State of the design art



Now...simplify design of phase-delay filters with Radiation's IC Amplifiers



Radiation Operational Amplifiers offer a new dimension in the design of monolithic phase-delay filters. They simplify design, provide unconditional stability without external compensation, and allow accurate determination of phase shift. Only Radiation IC Amplifiers offer the characteristics needed for such an application.

For example, Radiation's RA-239 Broadband Amplifiers are used in the all-pass phase-delay filter shown at left.

Feed-back components are selected to determine the 90° phase-shift frequency, without regard to the active elements in this configuration.

The transfer characteristic is:

$$\frac{E_{out}}{E_{in}} = \frac{1-jx}{1+jx}, \text{ where: } x = \frac{f}{f_o}.$$

90° phase-shift frequency is:

$$f_o = \frac{1}{2\pi RC}.$$

X is the normalized frequency ratio referenced to the 90° phase-shift frequency.

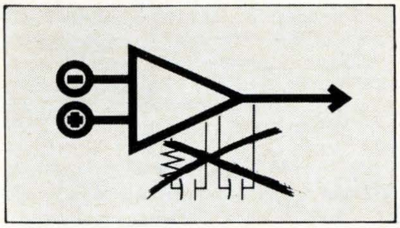
For $f_o \leq 1$ MHz, output voltage is 21.6 V_{P-P}.

A new line of universal building blocks for integrated analog circuitry is now available to design engineers. Radiation supplies three different types of IC operational amplifiers to serve your individual requirements: general-purpose, broadband, and high-gain amplifiers.

These amplifiers provide outstanding performance. Parasitics are eliminated, thanks to our unique dielectric isolation technique. Tighter tolerances and improved temperature coefficients are achieved through use of precision thin-film resistors over the oxide.

Thus, Radiation's technology simplifies system designs which were hampered by limitations imposed by conventional integrated circuit fabrication techniques.

Only Radiation can provide production quantities of inherently stable IC operational amplifiers.



These circuits are stocked for immediate shipment in TO-84 flat packages.

Write or phone for our data sheets, which include *worst-case limits* as well as all information required by design engineers. We'll also be glad to supply our new manual, Operational Amplifier Technical Information and Applications. For your copy, write on your company letterhead to our Melbourne, Florida office.

Radiation IC Operational Amplifiers*

Typical characteristics ($T_A = +25°C$)	GENERAL PURPOSE RA-238	BROADBAND RA-239	HIGH GAIN RA-240	UNIT
Phase margin	60	60	45	Degrees
Bandwidth (unity gain)	7	15	6	MHz
Slew rate	3.2	23	3.2	V/μs
Voltage gain	2,700	2,700	33,000	
Offset voltage	2.0	2.0	2.0	mV
Offset current	80	400	80	nA
Thermal drift	±5 ±1	±5 ±5	±5 ±1	μV/°C nA/°C
Undistorted output swing	21	21	9(11.6)†	V_{P-P}
Power dissipation	90	160	90	mW
Common mode rejection	100	100	100	dB
Power supply rejection	100	100	100	dB
Input bias current	0.4	1.0	0.4	μA

*Standard temperature range: −55°C to +125°C. $V^+ = +25V$; $V^- = -15V$.
†$V^+ = +20V$; $V^- = -20V$.

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Conference on Energy Conversion Engineering, American Society of Mechanical Engineers; Miami Beach, **Aug. 13-17.**

Guidance, Control, and Flight Dynamics Conference, American Institute of Aeronautics and Astronautics; Sheraton Motor Inn, Huntsville, Ala., **Aug. 14-16.**

Conference on Medical and Biological Engineering, Royal Swedish Academy of Engineering Sciences; Stockholm, **Aug. 14-19.**

Cryogenic Exposition, Cryogenic Society of America; Cabana Motor Hotel, Palo Alto, Calif., **Aug. 20-23.**

Cryogenic Engineering Conference, Cryogenic Engineers; Stanford University, San Francisco, **Aug. 21-23.**

International Conference on Phenomena in Ionized Gases, International Atomic Energy Agency; Vienna, Austria, **Aug. 27-Sept. 2.**

Association for Computing Machinery Conference, Association for Computing Machinery; Sheraton Park Hotel, Washington, **Aug. 29-31.**

Cornell Conference on Engineering Applications of Electronic Phenomena, Cornell University and Office of Naval Research; Cornell University, Ithaca, N.Y., **Aug. 29-31.**

Symposium on Automatic Control of Space, International Federation on Automatic Control; Vienna, Austria, **Sept. 4-8.**

Conference on Solid State Devices, IEEE; Manchester, England, **Sept. 5-8.**

Computer Conference, IEEE; Chicago, **Sept. 6-8.**

Electric Propulsion and Plasmadynamics, American Institute of Aeronautics and Astronautics; Colorado Springs, Colo., **Sept. 11-13.**

Technical Meeting on Space Simulation, American Society for Testing and Materials; Sheraton Hotel, Philadelphia **Sept. 11-13.**

Symposium on Computer Control of Natural Resources and Public Utilities, International Federation of Automatic Control; Haifa, Israel, **Sept. 11-14.**

Instrument Society of America Conference and Exhibit, Instrument Society of America; International Amphitheater, Chicago, **Sept. 11-14.***

International Symposium on Information Theory, IEEE; Athens, Greece, **Sept. 11-15.**

Seminar on Mathematical Systems Theory, Pennsylvania State University; Pennsylvania State University's Residence Hall, Pa. **Sept. 11-15.**

International Congress on Magnetism, International Union of Pure and Applied Physics and American Institute of Physics; Boston, **Sept. 11-16.**

Symposium on Materials—key to effective use of the sea, Polytechnic Institute of Brooklyn and Naval Applied Science Laboratory; Statler Hilton Hotel, New York, **Sept. 12-14.**

Biennial Electric Heating Technical Conference, IEEE; Statler Hilton Hotel, Detroit, **Sept. 13-14.**

European Machine Tool Exhibition, European Committee for the Cooperation of the Machine Tool Industries; Hanover, Germany, **Sept. 17-26.**

Short Courses

Modern control theory; Ohio State University's Department of Electrical Engineering; Columbus, Ohio; Aug. 21-Sept. 1; $275 fee.

Modern techniques in signal processing; Massachusetts Institute of Technology, Cambridge, Mass.; Aug. 21-Sept. 1; $400 fee.

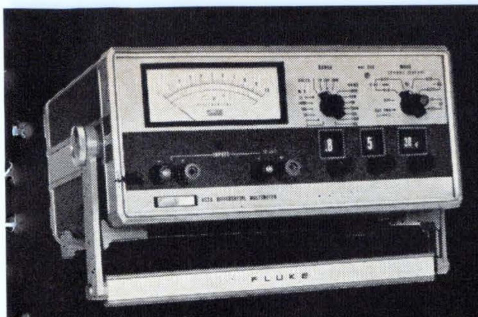
Design and analysis of communications-based systems; International Business Machines Corp.'s Systems Research Institute, N.Y., Sept. 5-Oct. 3; $1,600 fee.

Calls for Papers

Symposium on Remote Sensing of Environment, Office of Naval Research; University of Michigan, Ann Arbor, April 16-19, 1968. **Sept. 15** is deadline for submission of abstracts to Dana C. Parker, University of Michigan, Willow Run Laboratories, P.O. Box 618, Ann Arbor, Mich., 48107.

Symposium on Commercial Application of Ultrasonics, Ultrasonic Manufacturers Association; International Hotel, Kennedy International Airport, New York, Feb. 15, 1968. **Nov. 1** is deadline for submission of abstracts to John N. Antonevich, Blackstone Corp., R&D division, 1111 Allen St., Jamestown, N.Y. 14701.

* **Meeting preview on page 16.**



NEW DIFFERENTIAL MULTIMETER. Model 853A uses differential techniques to measure voltage, resistance and current to high accuracies. Range is 0 to 1100 volts AC/DC, 0 to 10 amps AC/DC, and 0 to 100 meghoms. Price is a low, low $445.

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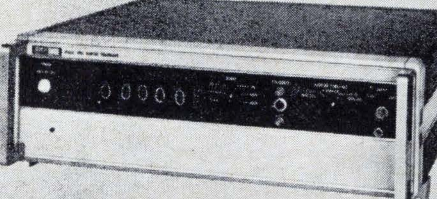
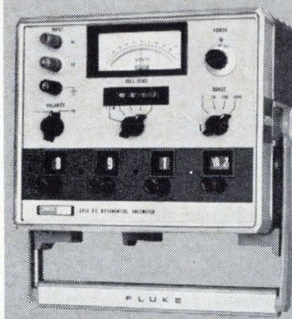
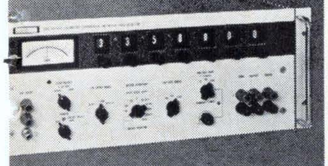


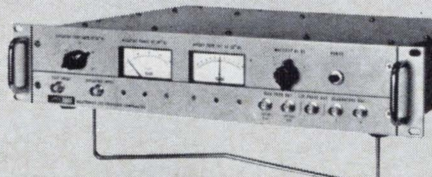


NEW DC DIFFERENTIAL VOLTMETER. Model 891A features infinite input resistance at null over entire 1100 volt range. Accuracy is ±0.02% Light weight and small, the new unit is priced at $595. Battery option $100.

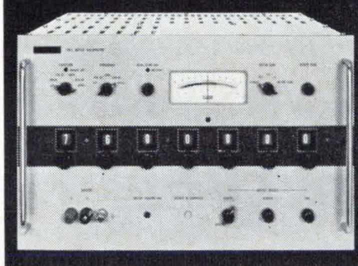
NEW POWER SUPPLY. Model 415A precision high voltage power supply offers up to 3 kv and 20 mils output in a 3½″ panel. Price is modest $495.



NEW DC CALIBRATOR. Model 335A combines a DC voltage standard with a high impedance voltmeter/null detector for ultimate versatility. The instrument performs as a 0-1100 volt ±0.003% voltage calibrator or infinite input resistance differential voltmeter; a 10 microvolt to 1100 volt voltmeter/null detector with 10 megohm and 100 megohm input resistance, or as a precision 50 ma source to drive a calibration system while separately detecting nulls. Price $2,485.



NEW COMPARATOR. Fluke/Monotronics Model 103A performs short term stability measurements with no peripheral equipment. Priced at a low $1,995. The Model 103A costs 40% less than competitive equipment.



NEW METER CALIBRATOR. Model 760A does the work of five separate instruments for about half the cost and much more conveniently too. Use it to calibrate AC and DC voltmeters, ammeters and ohmmeters. Accuracy ranges from 0.1% to 0.25%. Price is $2,485.

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7

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FLUKE

Circle 15 on reader service card

Meeting preview

Sizing up

The 22nd annual Instrument Society of America (ISA) Conference and Exhibit will gauge the progress of instrumentation—from concepts and techniques to products and applications. The conference, in Chicago from Sept. 11 through 14, will be keynoted by J.A. Shannon, director of the National Institutes of Health.

More than usual attention will be focused on industrial applications, particularly data handling and computation, ranging from the pulp and paper industry to the food industry. Two sessions will delve into the problems and techniques of programing systems for measurement and control. J.W. Garzanelli, a senior analyst at the Foxboro Co., will describe a process-oriented language for batch sequence control. The new language, predictably called Batch, is designed to simplify programing control systems to start up, run, and shut down most of the various processes in the chemical, petroleum, and food industries.

List the logical steps. A systems analyst at Foxboro, D.C. Kendall, will describe the steps required to develop computer-controlled process systems. Among these steps is the design of sequencing and scheduling logic along with peripheral equipment and associated routines.

Concurrent with the ISA conference will be the fourth annual Measurement Standard Instrumentation Symposium. Various sessions will review such areas as reference voltages, pressures, measurements of temperatures, and signals at high-frequency and microwave frequencies. Several of the papers to be presented will discuss some of the basic problems in metrology and calibration. Among these will be statistical methods for handling measurement data. Others will deal with general measurement techniques.

Another concurrent symposium, the fourth annual Physical and Mechanical Measurement Symposium, will treat such topics as shock and vibration, heat, and strain measurements.

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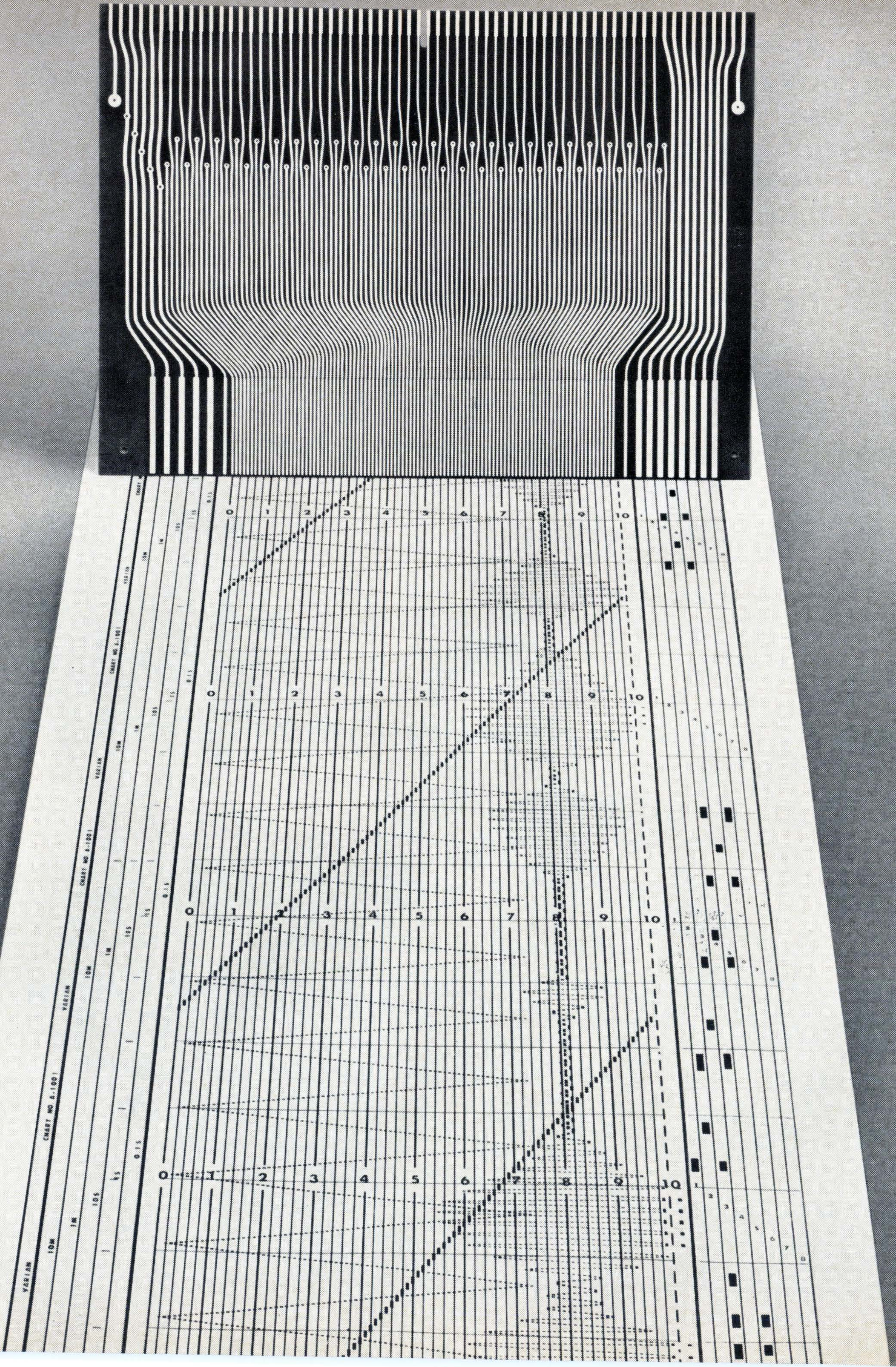


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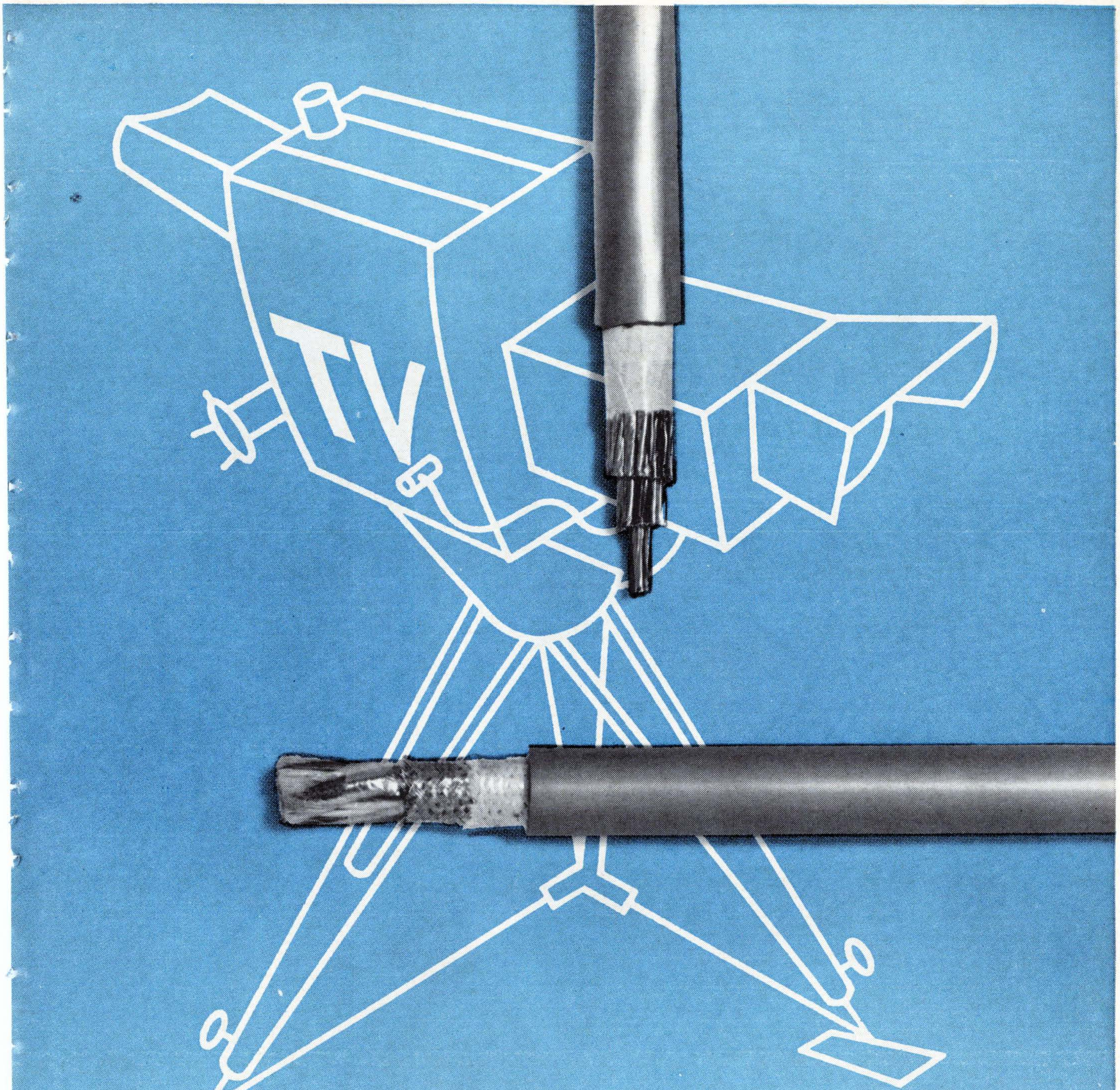

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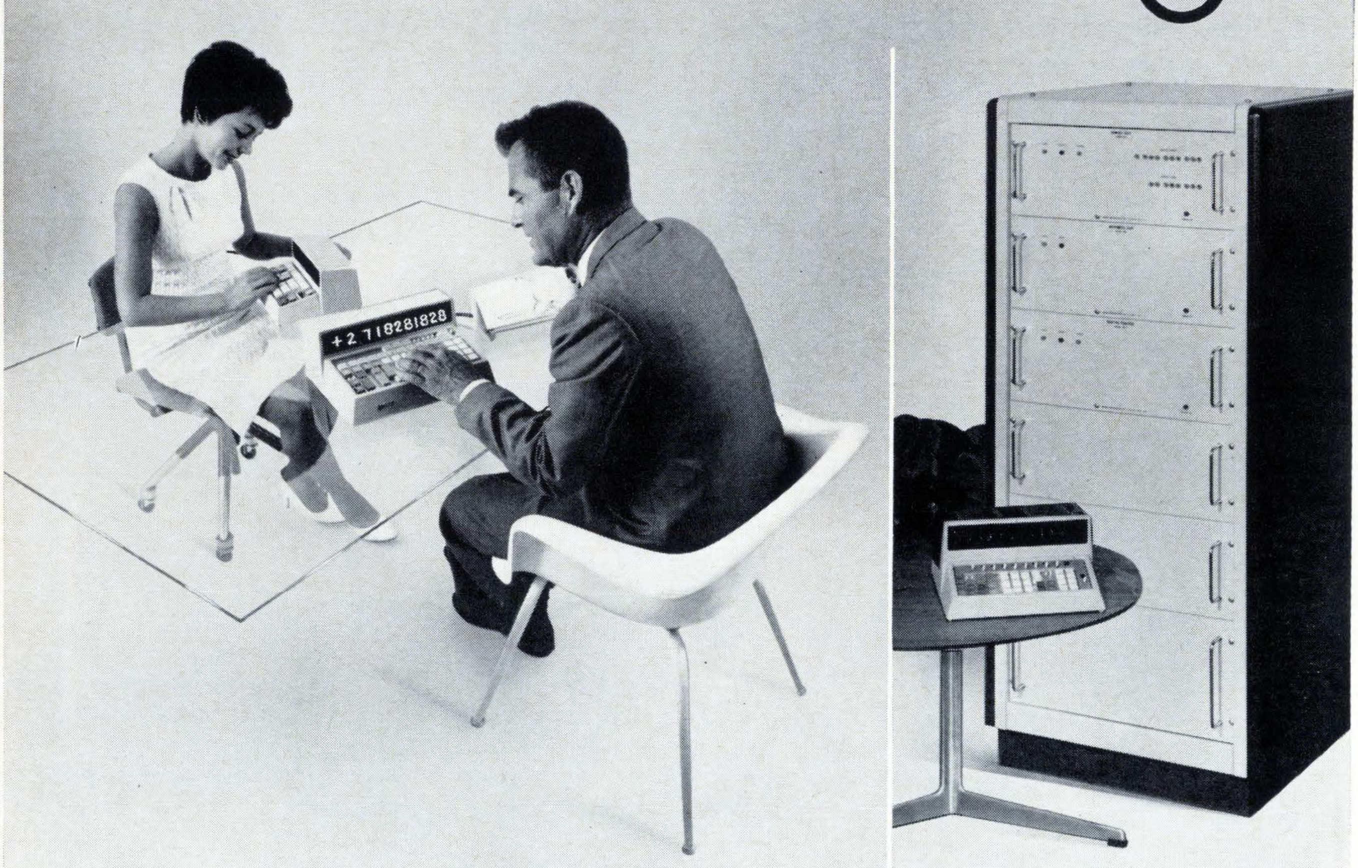

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It's small, quick, quiet and very easy to get along with. You'd never guess, till you get to know it, that inside this trim little keyboard console lurks the most versatile, most advanced electronic desk-top calculating capability ever developed. Among other things, these vital statistics:

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. . then there's the brand new Series 370 programmable calculator

Although it looks like its little Series 300 brother, this new, absolutely unique instrument can do things no other electronic calculator in the world can handle.

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. . . and while you're here, meet the Series 4000 on-line data system

Actually a series of compatible "black-box" data modules, this unusual "system" can be custom-assembled, at low cost and virtually on a plug-in basis, to handle any of a broad variety of on-line data acquisition and reduction tasks.

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Editorial

Frightening testimony

After the midair collision between a private airplane and Piedmont Airlines Flight 22 killed 82 people last month, a Congressional committee began hearings on whether the Federal Aviation Administration, charged with the responsibility for air traffic control, has been doing everything it could. Some of the testimony has been bloodcurdling.

Deputy FAA Administrator David D. Thomas, who is nominally in charge of the agency's air traffic control operations, told the hearing resignedly, "Midair collisions are inevitable as long as people can make mistakes." He considers it fortunate that there haven't been more such tragedies because his agency gets reports of over 400 near-misses a year—better than one a day.

Thomas' resigned attitude is terrifying news for anybody who has to travel by air regularly. It is bad news that will get worse very soon because air traffic is growing at a staggering rate. And the FAA has nothing even in the works to untangle the raisin-pie congestion over and around airports—the most critical situation.

Keeping planes from running into each other is an excruciatingly complex problem. It won't be made any easier by the advent of supersonic transports. And the cost of failing to separate aircraft could mushroom even sooner—in 1970, when the commercial airliners start flying the Boeing 747 with its passenger load of more than 450 people.

But the problem can never be solved as long as two conditions exist:

1. The men responsible for controlling traffic don't know where all the planes in their area are all the time.
2. The FAA refuses to recognize that technology is available today to supply this information to controllers.

It's surprising and alarming to learn that a controller at a busy airport such as New York's Kennedy or Los Angeles's International or Chicago's O'Hare—each of which handle thousands of landings and takeoffs a day —doesn't know exactly where all the aircraft in his area are. He has to assume that planes are where they are supposed to be.

His plan position indicator, displaying blips from a two-dimensional radar, is so crowded with the traces of aircraft taking off, landing, stacked up waiting to land, or flying over the airport that he can obtain little critical information. When he sees two blips on an apparent collision course, he has to assume sanguinely that the aircraft are really flying at different altitudes.

When a TWA airliner crashed into an Eastern Air Lines plane over Westchester County, N.Y., last autumn, on the airspace fringe of Kennedy airport, the impending crash was seen on radar, but the controller thought the planes were at different altitudes. Only an ensuing investigation reported the critical information that one of the aircraft was not at its assigned altitude.

A year earlier, a controller who thought he saw an impending midair collision ordered an Eastern Air Lines plane taking off from Kennedy Airport to make an emergency maneuver. The Eastern plane reacted too sharply and fell into the sea killing all aboard. It turned out that a collision had not been in prospect.

Even scarier is the realization that when a controller gives an instruction to a pilot, the controller usually doesn't know for sure if the instruction has been obeyed. In fact, he doesn't even know if the order has been received. The FAA's Thomas claims that acknowledging such instructions would clog the already overloaded communications system.

Although the investigation of the crash over North Carolina is still under way, early indications are that a controller ordered the private plane, unaware that it was 10 to 12 miles off course, to make a turn that would take it out of the path of the climbing commercial airliner.

Nobody knows if the maneuver was attempted or if the order was received, for the Asheville airport has no radar. It is one of the 434 airports in the U.S. that handle commercial airline traffic without radar—only 113 of the nation's airports have radar coverage.

In fact, the FAA admits that 12 of the 100 busiest airports in the U.S. don't have any radar coverage. And some of the remaining 88 are covered by radar operated at a nearby airport. For example, White Plains, N.Y., the 43rd busiest airport in the U.S. has no radar coverage. Also without any radar coverage are airports at such cities as Madison, Wis., Daytona Beach, Fla., Bridgeport, Conn., Champaign, Ill., Lexington, Ky., and Rockford, Ill. The airport at Opelaka, Fla., surprisingly the second busiest in the U.S.*, is covered by the radar at Miami International Airport, roughly 30 miles away.

When a United Air Lines plane crashed into a TWA plane over Staten Island, New York, in 1960, an investigation revealed that a controller had instructed the United plane to fly a holding pattern, but that the pilot had ignored the instruction and come into the landing pattern. The controller didn't know his order had been ignored.

Just three months ago, when two private planes crashed as they landed at LaGuardia Airport in New York, it was found that a controller had ordered one of the aircraft to pull up instead of continuing its descent, but that the order hadn't been obeyed. Nobody knows for sure if it was ever received.

Such incidents make it clear that the present system is too far from foolproof. It ought to be changed immediately. The FAA is pinning its hopes for preventing midair collisions on a system that has been proposed by the Air Transport Association. The plan calls for installing an atomic clock, transmitter, computer, and display in every commercial airliner. The electronic equipment will weigh nearly 100 pounds and cost about $50,000. Its weight and cost immediately preclude its use in small aircraft, which outnumber commercial airliners roughly 40 to 1. Even if the system works as

Continued on page 284

* Opelaka airport is indeed number two in the nation, after Chicago's O'Hare. It's a base for charter flights to the Caribbean and the Bahamas, for private planes, and for commercial airlines' pilot training programs.

Electronics Newsletter

August 7, 1967

Fight heats up among IC makers for consumer market

Considering the fact that by 1971 some 200 million integrated circuits are expected to be sold annually for the consumer-entertainment market, no electronics firm wants to be left behind. **In the past two months no less than five companies have announced new lines of IC's for this consumer market.** The lastest to join the parade is RCA's Electronic Components and Devices division, which is about to introduce three IC's in its 3000 series that will sell for between 98 cents and $1.75 each.

The most complex of the three—and the most complex of the monolithic linear IC's introduced to date—is the CA3034, a six-function device; it's for automatic fine tuning in television and f-m receivers. The price will be $1.75. Last month Philco-Ford introduced a five-function device for radios [Electronics, July 10, p. 48].

. . . while interest starts growing in industrial field

Meanwhile, a drive is under way to sell IC's in the industrial market.

Fairchild, Motorola, and Texas Instruments are racing for a dominant position with series 700 linear IC's; these IC's are widely used in instrumentation, control, and signal processing and generation.

The Fairchild product, a plastic dual-in-line package (DIP) version of the μA709 operational amplifier, is priced at $6.55. Motorola has been offering sample quantities of a plastic DIP unit, the MC1709, for about $5 and expects to begin filling volume orders by next month. And TI has just started filling volume orders of its 702, 709, 710, and 711 in plastic DIP's; prices range from $2 to $5.

In offering the plastic DIP's, Fairchild and Motorola have, in effect, scrapped a previous market entry, a "C" version of the 709 circuit in a TO-5 can. Reasons: electrical specs were too loose and the package was unpopular with industrial designers. Both firms plan to make remaining 700 series IC's available in plastic DIP form by early fall.

Also in the running is General Electric, which will introduce two operational amplifiers, DIP types, priced at about $2. **While these units are not as sophisticated as the 700 series, their low price may help to convince users to settle for less.**

Budget woes: NASA to feel project squeeze

Though appropriations action by Congress is still some weeks away, the best estimate now is that NASA's funding won't be much over $4.7 billion. **That's about $400 million below the agency's request and will mean some critical reshuffling of programs.** This cut represents a defeat for NASA's boss, James E. Webb, who observers thought could wring more money from Congress [Electronics, June 26, p. 59].

Last week the space agency's budget for fiscal 1968 passed its first hurdle when Senate and House conferees agreed to a $4,865,751,000 authorization for the program. NASA wanted $5.1 billion to carry on the Apollo lunar landing program, and get started on an ambitious round of new projects under the Apollo applications program.

While the cuts were not as deep as had once been feared, the most critical test is still to come and agency officials are frankly worried. **That's because the appropriations committees must still act on the bill and Congress is in a budget-cutting mood.** Space spending ranks low compared with other big spending programs and Vietnam.

No tampering will be done with the $2.5 billion earmarked for Apollo.

But the Voyager program to land instrumented capsules on Mars must be stretched beyond its first planned 1973 launch; the program remains as a line item, totaling $42 million, $30 million less than NASA asked. It also means that some projects within the Apollo applications program will be curtailed, possibly jeopardizing plans to orbit astronauts in space workshops. Almost certainly it will push this program past the planned 1969 date. **Other projects that won't get any money in fiscal 1968 include building two Mariner spacecraft for a Mars mission in 1971 and the initial development of a satellite that would beam radio signals directly to home receivers.**

With sharp paring and stretching out of programs, NASA can still keep the bulk of its planned projects at the reduced funding level. Delays encountered from the Apollo fire was already forcing a slowdown.

Solid state crt

Semiconductors are stepping up their assault on one of the last bastions of the vacuum tube—the cathode-ray tube. IBM's Federal Systems division of Gaithersburg, Md., is **building a prototype radar display for the array consisting of 60 gallium phosphide diodes in a 1- by 2-inch array.** Robert J. Lynch, an IBM engineer, says **the display can be driven either by a digital or an analog signal;** integrated driver circuitry includes an unusual two-transistor-per-line analog-to-digital converter in addition to a conventional decoding matrix for line drive. **Diodes can be latched in the "on" state to hold an image indefinitely for study.**

Laser cane to light way for blind

A new, lighter version of the laser cane for the blind is being delivered to the Veterans Administration by Bionic Instruments Inc. of Philadelphia. Seven of the 20-ounce canes—the VA had rejected earlier versions as too heavy—will be tested at the VA's center for the blind at Hines Hospital in Chicago. The gallium-arsenide laser operates in the far infrared, below the wavelength at which retinal damage might occur.

Laser up in the air

The next generation of heads-up displays may use lasers to paint aiming and navigation patterns in aircraft cockpits. An Office of Naval Research study has already proved the feasibility of a laser-generated avionic display—now the Navy is about ready to select a contractor to develop a prototype system.

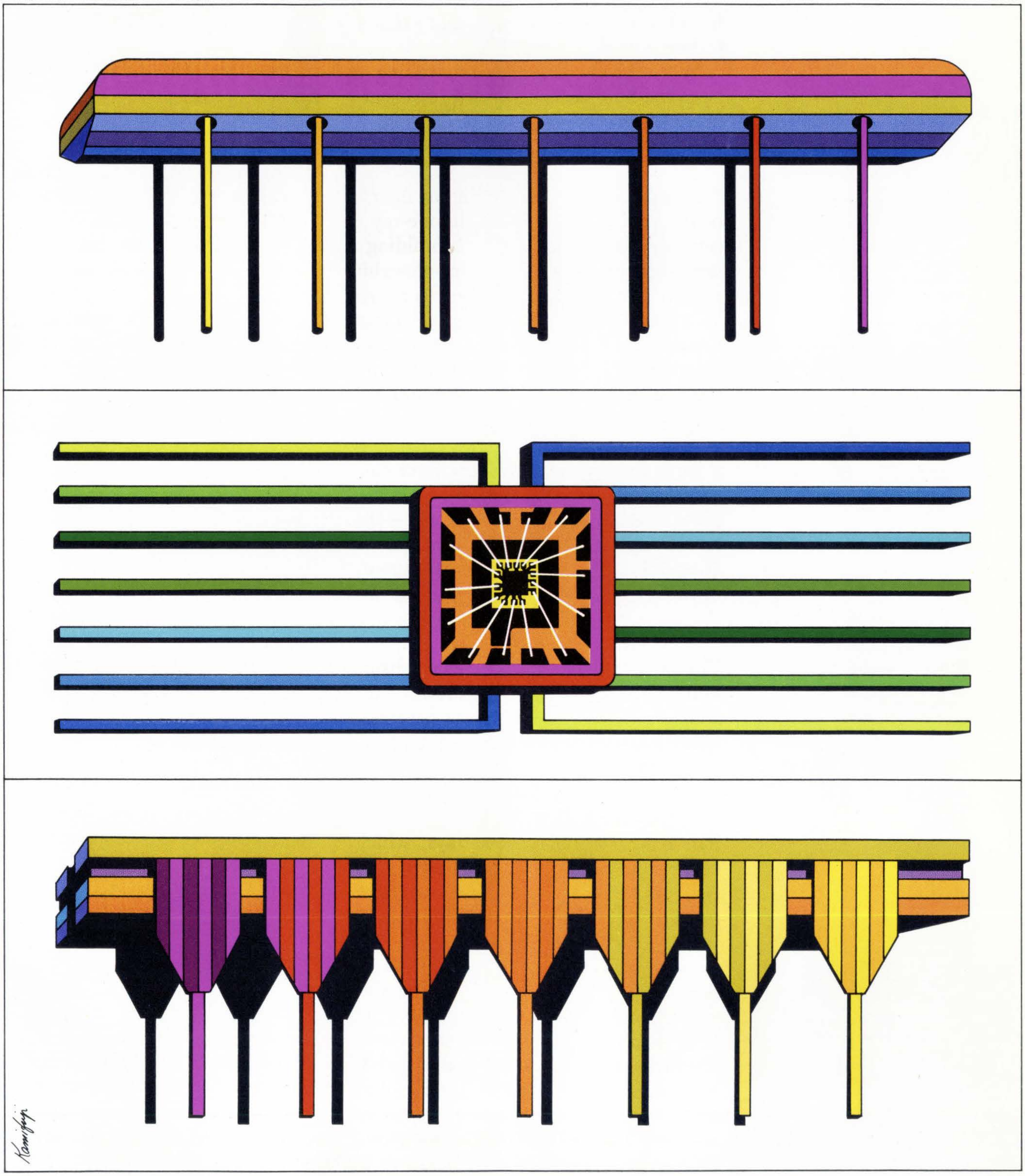
Doppler for Pan Am

Pan American World Airways, which last month gave up on Sperry Gyroscope's SGN-10 inertial navigation system [Electronics, July 24, p. 38], appears to have given up on inertial navigation. **Instead, Pan Am aircraft will be equipped with a Bendix dual-doppler system.**

$695 voltmeter a jack of all trades

A multipurpose digital voltmeter that combines the capabilities of a vacuum-tube voltmeter with the accuracy of a digital instrument has been developed by Non-Linear Systems of Del Mar, Calif. **Made to sell for $695, the voltmeter, called model X-3, measures a-c up to 1 gigahertz, d-c resistance and current.** It can act as a power supply for up to 30 volts at 150 milliamps, has a high-input impedance, and offers a three-digit readout. **The closest thing to the Non-Linear instrument is the Fairchild 7050 digital voltmeter that measures d-c only and sells for $299.**

Circle 27 on reader service card→



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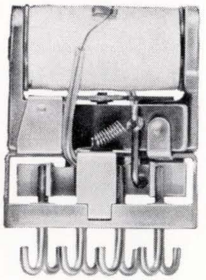

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The rugged Hi-G "T" Series of 10 amp. crystal can relays meet all applicable requirements of Mil-R-5757. Testing has proved more than 25,000 operations typical at 20 amps. They match or out-spec. other 10 amp. DPDT crystal can relays and are priced competitively or lower. Case size: 1.234″ × 1.025″ × .515″. All standard configurations and header styles are available for fast delivery.

Write or call Hi-G for bulletin which provides full details on this high quality line of 10 amp. crystal can relays. Test data and performance capabilities are available on request. Tel: 203-623-2481.

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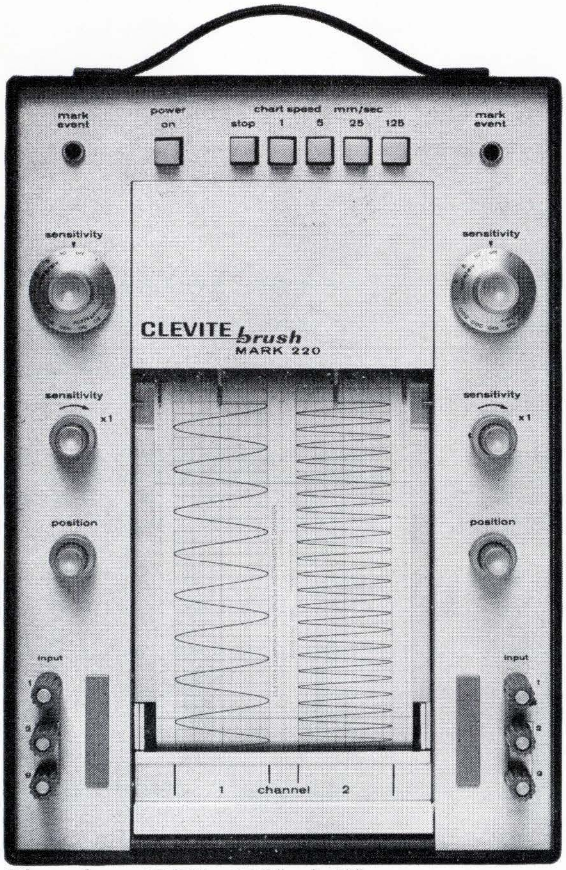
PHILCO Ford

The Innovator: Philco-Ford.

The Product: A 9-way better epoxy transistor. 1. PET TO-18's ambient power dissipation is typically greater than 400 mW (chip dependent). Θ_{JC} is typically 105°C/W. 2. PET TO-5's ambient power dissipation is typically greater than 450 mW. Θ_{JC} is typically 100°C/W. 3. PET packages have reliability factors equal to or exceeding that of metal cans. 4. PET's are immediately available in large volume production quantities. 5. PET's have a special deep-well interlock construction that insures hermeticity and reliability. 6. PET packages are permanently and legibly marked—lettered black on white. 7. PET's are packaged in our low-cost Taiwan production facility—to keep your cost low. 8. PET amplifiers operate on currents ranging from 10 μA to 1 A; PET switches to speeds 8 ns turn on and 11 ns turn off. 9. PET's cover frequencies from 40 MHz to 1400 MHz. Philco-Ford Corporation, Microelectronics Division, Santa Clara, California 95051.

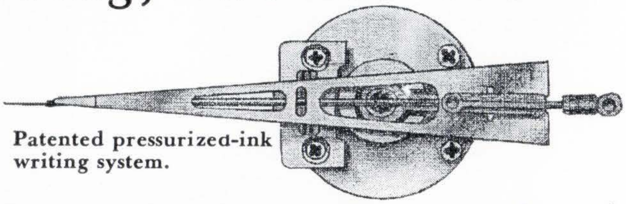
The end of the non-portable portable



Dimensions: 13.06″ x 9.12″ x 7.56″.

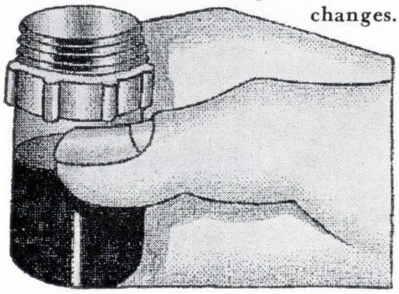
Mark 220 by Brush...

a brand new recorder with a 25,000-channel pedigree. Behaves like its famous granddaddy, the Mark 200, but weighs only 25 pounds. Delivers traces that are unbelievably sharp, 99½ percent accurate. Solid state electronics provide position feedback pen control . . . no springs, no strings. The new Mark 220 has two channels for analog recording, two for events.


Patented pressurized-ink writing system.

Maximum sensitivity is one millivolt per chart division, but the recorder is electrically protected from overloads as high as 500 volts. Pressurized writing puts smudge-proof traces into paper, and there's enough ink in the throwaway cartridge to last for about a thousand miles. Less than $1700 will put you in business with this fine instrument...and it's light enough to take anywhere. Call for a demonstration of the remarkable Mark 220 . . . and if you wish to keep the unit we'll swap it for a P.O. number. Clevite Corporation, Brush Instruments Div., 37th & Perkins, Cleveland, Ohio 44114.

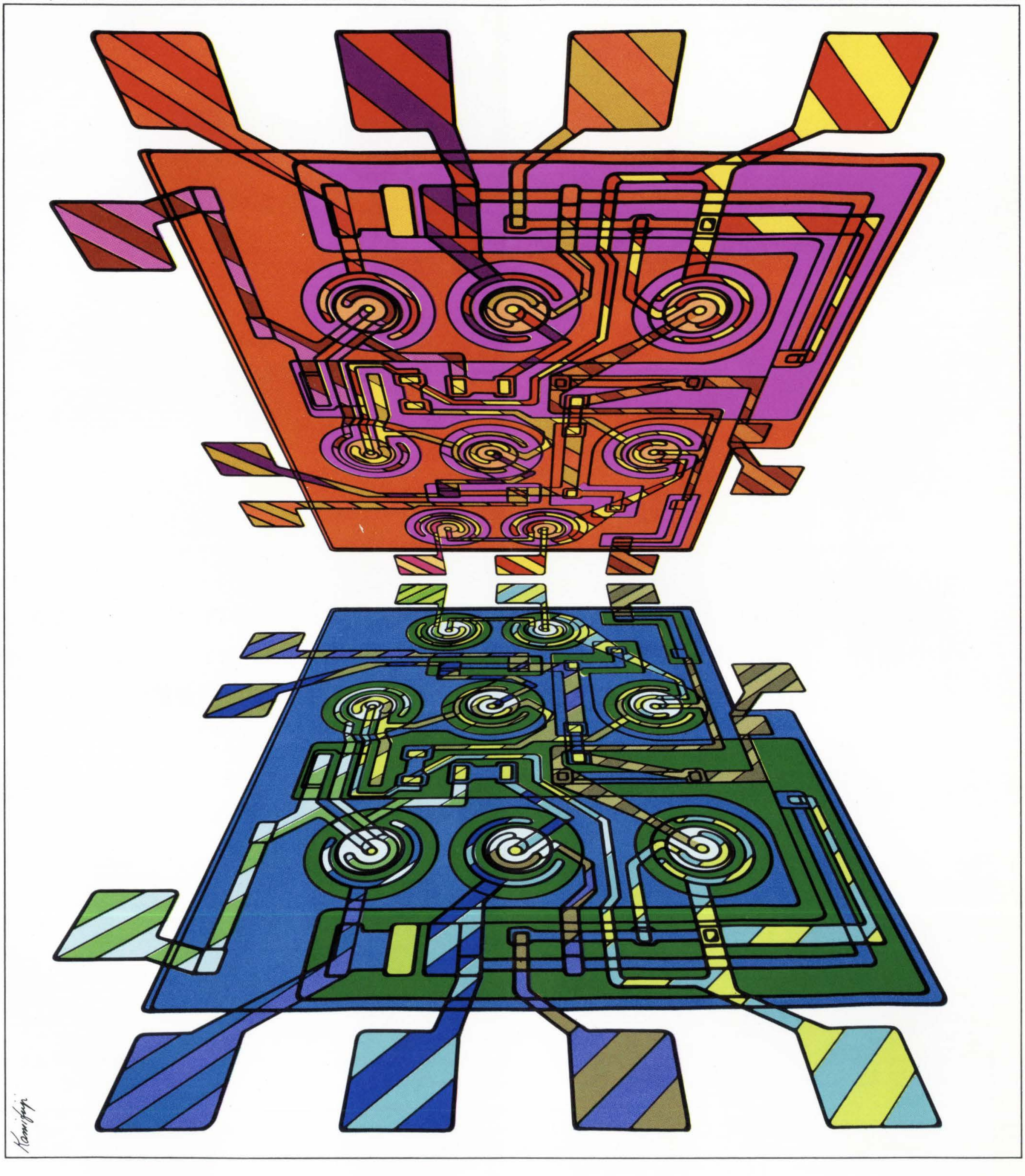
Throw-away ink cartridge–1000 mi. between changes.



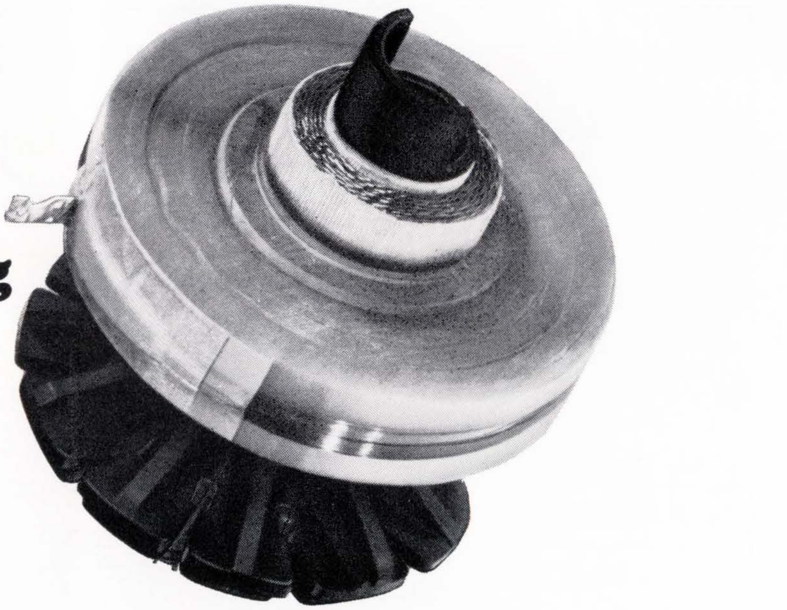
PHILCO Ford

The Innovator: Philco-Ford.

The Product: A 5-way better linear IC line. 1. Only linear line that covers the entire frequency spectrum from DC through VHF. 2. Our PA 7600 RF/IF video amplifier offers the highest gain bandwidth available in the industry (passband to 9000 MHz). 3. PA 7601 RF/IF bandpass amplifier offers extreme linearity with AGC. 4. PA 7713 RF/IF video amplifier: a special linear circuit featuring high gain bandwidth at low power (500 MHz at 18 mW). 5. Immediate delivery. Philco-Ford Corporation, Microelectronics Division, Santa Clara, California 95051.

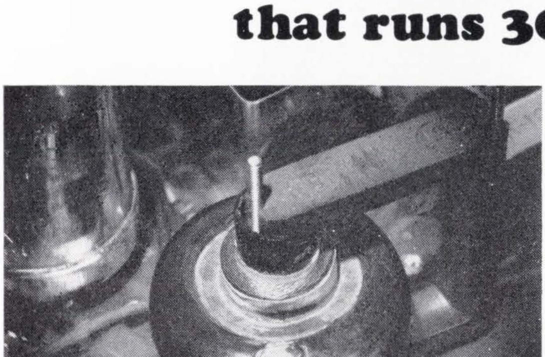


How a TV maker boosted picture power 25%



simply by switching insulation

Scotchpar® BRAND Polyester Film insulation permits a smaller sweep transformer that runs 30% cooler, lasts longer



Elimination of the metal can saves money and permits better transformer location.

"SCOTCHPAR" IS A REG. T.M. OF THE 3M CO.

General Electric recently redesigned the sweep transformer for many of their TV models. They changed from a wax impregnated paper coil insulation to "Scotchpar" polyester film. They benefited by *25% more transformer power,* greater *reliability* and *cost savings.*

The specific differences are: (1) Metal can around the transformer is no longer required. U.L. approved elimination of the can because "Scotchpar" polyester film won't burst into flames. (2) The coil is smaller because "Scotchpar" film has seven times more dielectric strength than paper. The transformer can now be mounted on the printed circuit board in some designs where it gets better air circulation so it runs cooler. (3) This contributes to a greater power output for color — 0.3 m.a. more at 25,000 volts. (4) Cost savings come from elimination of the can and six connecting wires, less assembly labor and greater reliability.

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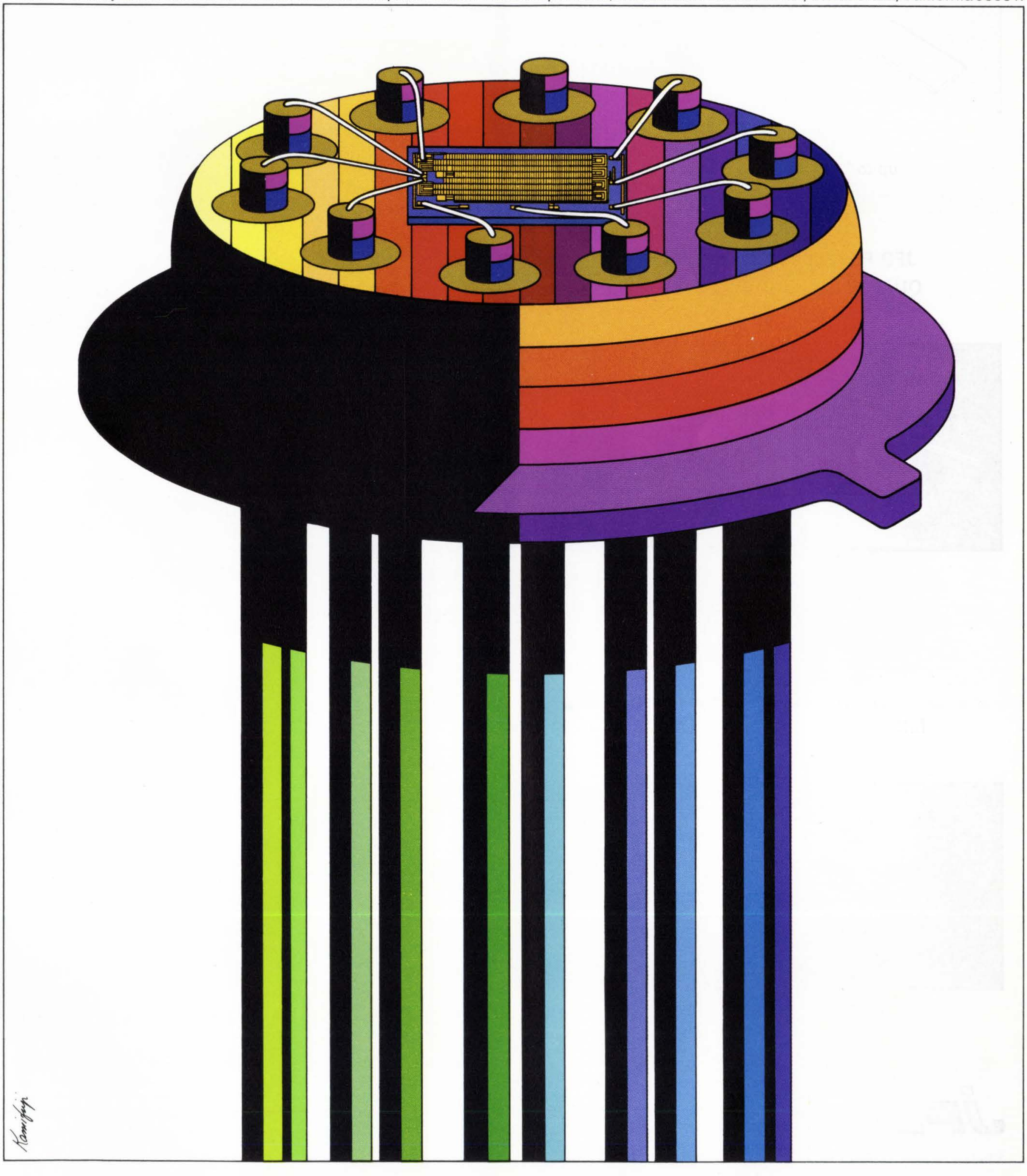

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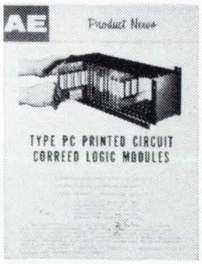

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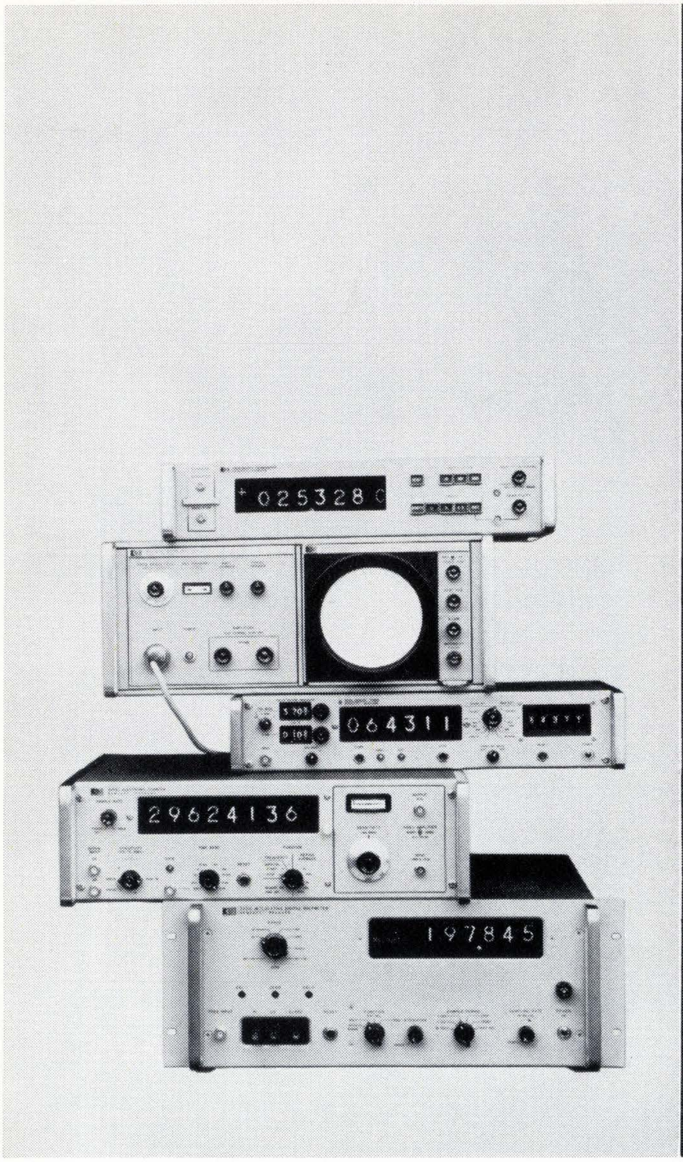

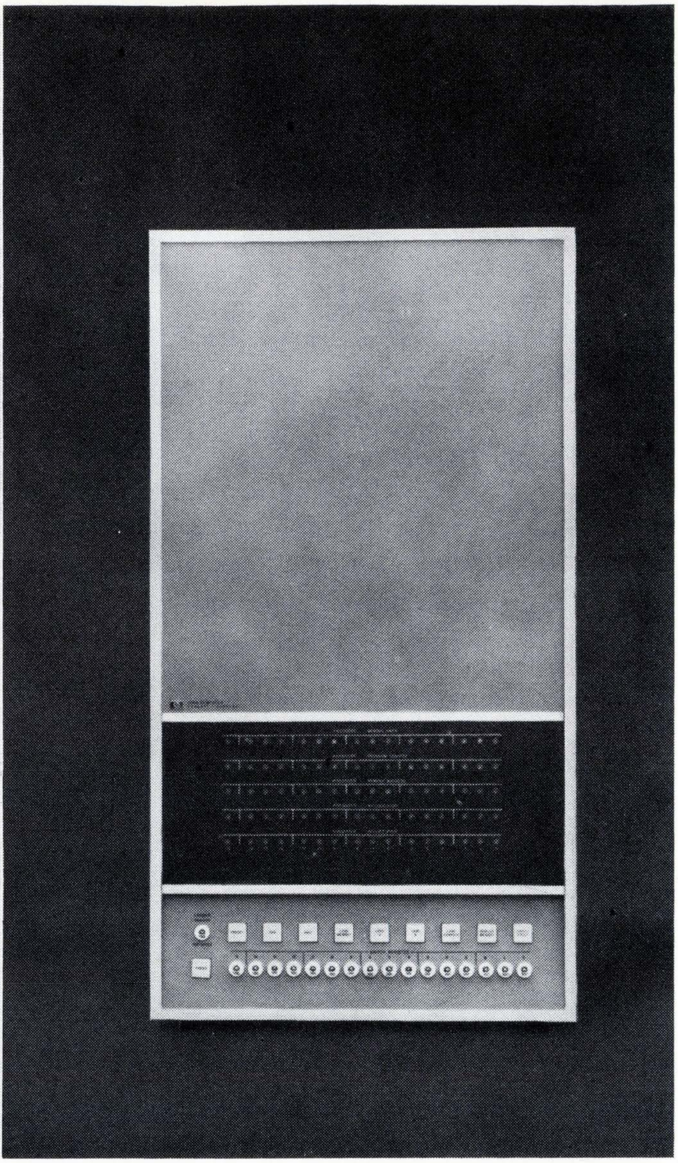

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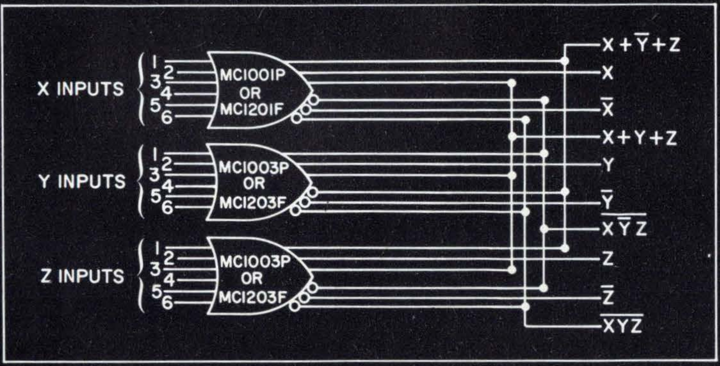

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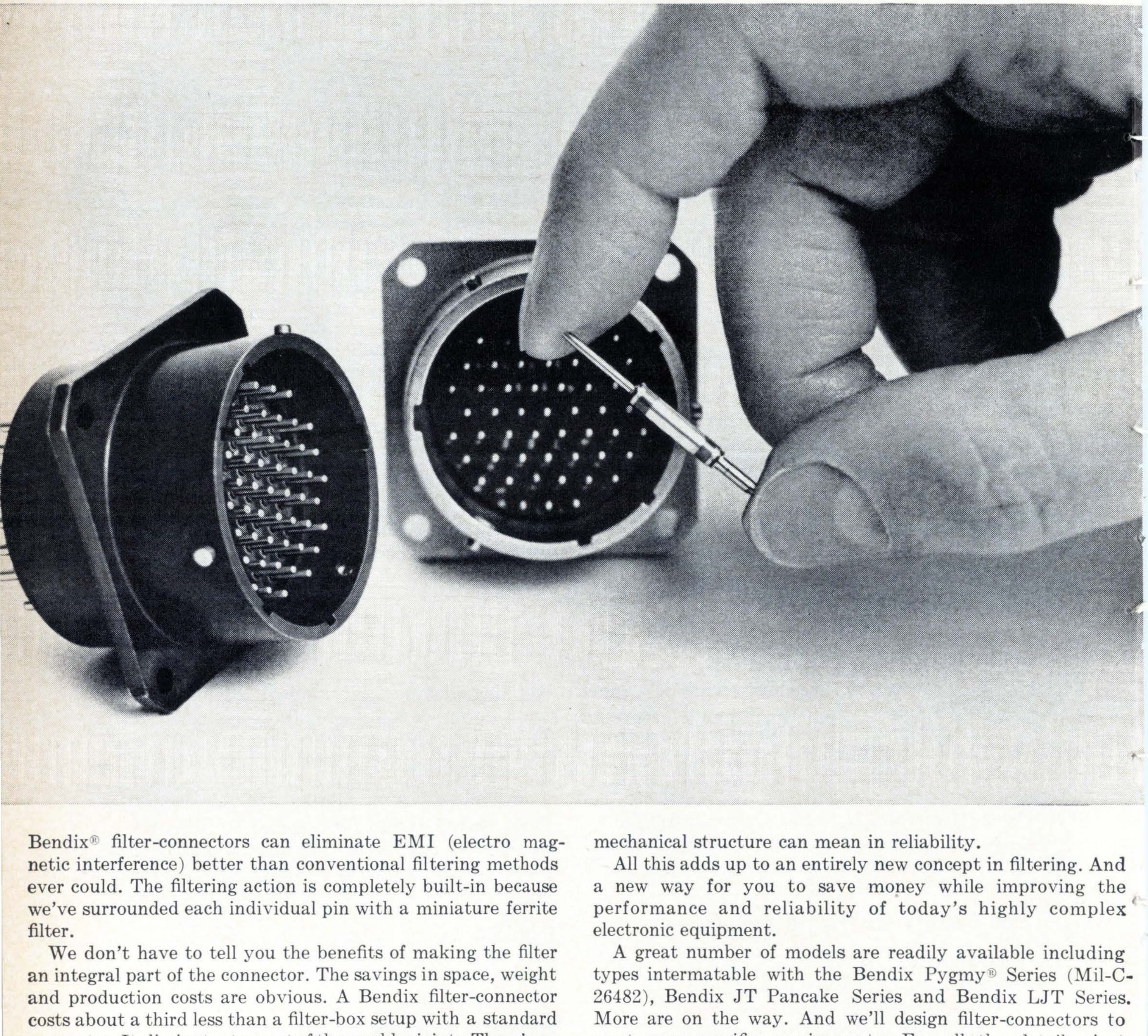

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Circle 40 on reader service card

Bendix Electronics

Electronics Review

Volume 40
Number 16

Consumer electronics

The sweet sound of IC's

Just when it seemed that hi-fi set makers were chiefly concerned with outwatting each other—producing solid state receivers and audio amplifiers that could shatter glass and burst eardrums—they changed their tune. Now the emphasis is on building better receivers by designing them with integrated circuits.

When Fisher Radio introduces its 1968 line at the High Fidelity Show in New York this fall, it will unveil two home-entertainment firsts that capitalize on the advantages of IC's. Although others are also using IC's, Fisher will show a receiver that's the first to have as many as seven of the circuits (six in the intermediate-frequency and limiter stages, the seventh in the meter and muting circuit) and the first to be built around easily removable modular plug-in circuit boards (there are seven of them).

Clean sounds. As Fisher research chief, Fred Mergner, points out: "Using IC's, it's now possible to design a high-gain linear i-f section without worrying about neutralization or damping on tuned output circuits. The over-all result is better adjacent- and alternate-channel selectivity, better amplitude-modulation suppression, and less distortion. These factors depend entirely on the design of the intermediate frequency section."

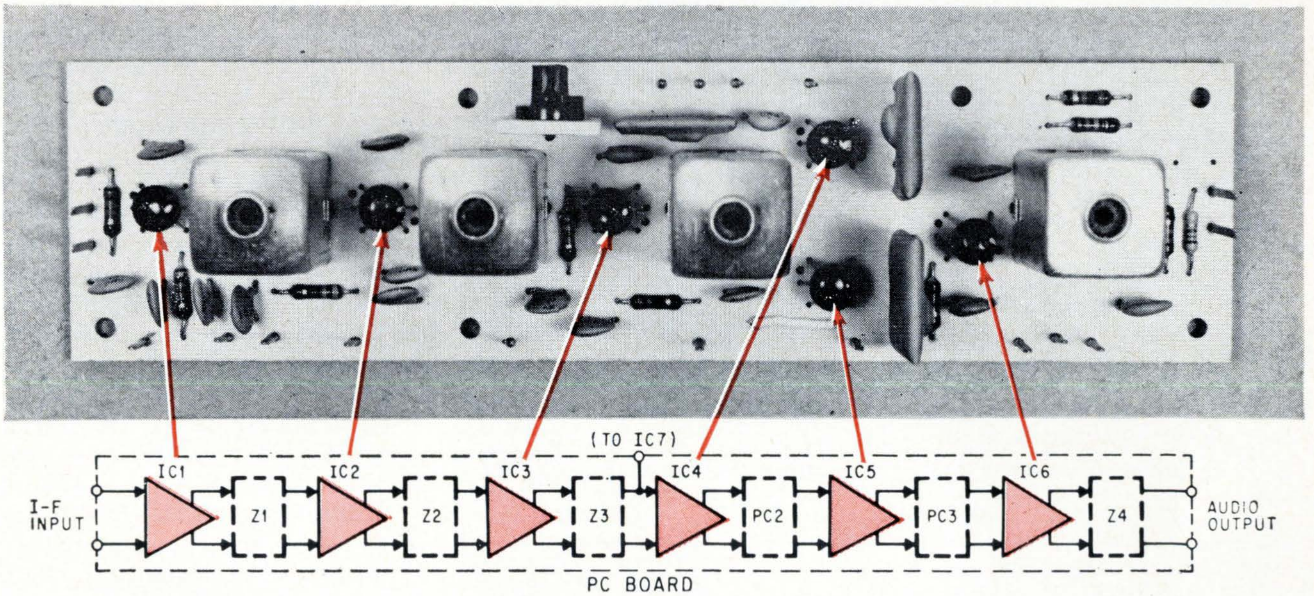
Still another advantage is that IC's permit a better capture ratio: the ability of a receiver to null unwanted f-m stations that are on the same frequency but at a lower signal level than the one desired.

At the top of Fisher's new line is the model 550-T a-m/f-m stereo receiver priced at $450, which is a bit lower than comparable receivers. It has the extremely low capture ratio of 1.5 decibels and an alternate channel selectivity of 60 dbs. The reason: extremely low impedances in the limiter stage and a 5-megahertz i-f bandwidth, and circuitry in which four of the six IC's in the i-f and limiter stages operate as straight amplifiers while the other two function as limiters in the presence of low-level signals. In the presence of strong signals, one amplifier switches to the limiter function.

For openers

When word recently leaked out that Arvin Industries was about to produce color-television set with a built-in tv tape recorder for under $1,000, not only was the industry caught by surprise, but there was openly expressed doubt that such a product could be available within 5 or 10 years. Realizing that it might have prematurely tipped off the competition, Arvin quickly tightened all security and declined to discuss the project.

Meanwhile, back in Chicago, the company was delighted with the results of secret field tests of a



Hi-fi IC's. Fisher Radio will introduce a high-fidelity receiver this fall that uses seven integrated circuits: six in the intermediate-frequency and limiter stages and one in the meter and muting circuit. The receiver will sell for a little less than comparable high-fidelity receivers. Aside from cutting costs, the application of IC's produces better sound, Fisher maintains. Also, the IC's improve the receiver's capture ratio.

fully developed prototype of the set. In fact, Arvin was so confident that it had finally produced the industry's first consumer tv tape recorder, that it immediately applied for a patent and is preparing to preview the unit at a full press conference in New York. Furthermore, the Columbus, Ind., based firm plans to have the unit ready for its 1969 product line.

Less tape. Technical details are still hush-hush. The recorder also will be offered separately, without a monitor. Besides the price breakthrough, Arvin's color video recorder will offer a dramatic reduction in tape consumption by operating at a much slower speed than present video recorders. Picture definition will be close to that of professional recorders.

At present, the only color video recorder outside broadcast studios is the Ampex VR-7500C, which sells for $4,500, less the $695 monitor. However, since a color camera cannot be purchased for under $50,000, all color video tape recorders must be slaved to a color-tv receiver. Also holding back widespread use of video recorders is the price of the recording tape: it costs about $60 to record a one-hour program. An hour's worth of sound tape costs an average of $3.

Communications

Visual aid

To be sure, a picture is worth a thousand words, but the cost of transmitting a picture and producing hard copy is expensive. Now a cost-saving solution may be in sight. EG&G Inc. of Bedford, Mass., a company not known for its expertise in graphic communications, has a digital facsimile system that cuts by a factor of five the time it takes to transmit a picture over a regular telephone line.

The name of the fast system, PDQ, is no accident; in fact it took some imagination to find words to fit the acronym: predictive differential quantizing.

Time to send. What makes PDQ unique is its use of redundancy-elimination techniques. Conventional facsimile units are slow because they scan and transmit each and every line of the picture; the higher the resolution, the more lines and the longer it takes to send, boosting the phone bill.

PDQ, on the other hand, uses line-to-line correlation techniques to squeeze out most of the line-scanning redundancy. It quantizes and transmits only the line-to-line difference information. The recorder remembers the previous scan and prints a corrected line. Off-the-shelf integrated circuits perform memory and logic functions at both ends of the link. It uses a flatbed scanner and coated paper, similar to office copier techniques.

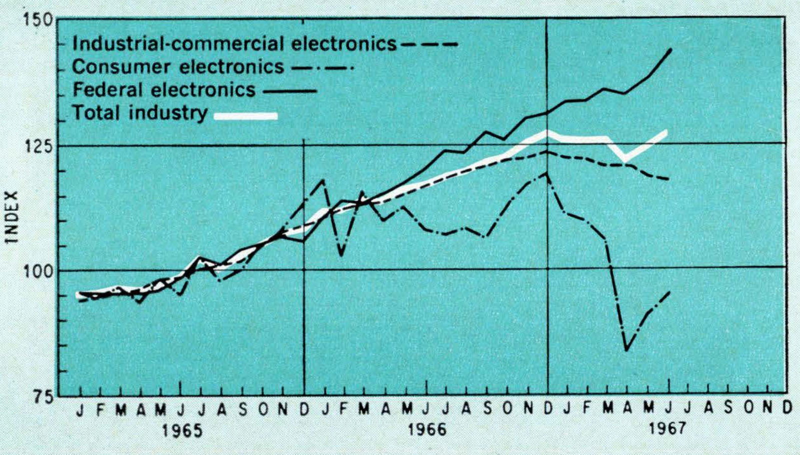
First marketing targets are the big Government facsimile networks. Prototype equipment has been built for both Navy and Weather Bureau feasibility tests.

EG&G took its initial prize in the facsimile market when it won a $3.5 million Air Force contract to re-equip bases with weather plotter transmitters and receivers. After 30 months of development and tests, EG&G will deliver 20 transmitters and 125 receivers. This is part of the 433L program managed at Hanscom Field, Mass., for updating the Air Force's global weather network. The company won the facsimile contract over the United Aircraft Corp., the Litcom division of Litton Industries, and Cardion Electronics Inc.

Transmitting maps. The contract calls for equipment to transmit Air Force weather maps and charts from forecast centers to bases five times faster than with current equipment. Today, it takes 10 minutes to send an 18-by-12 inch

Electronics Index of Activity

August 7, 1967



Segment of Industry	June 1967	May 1967	June 1966
Consumer electronics	95.0	87.3	108.0
Defense electronics	144.1	139.5	119.9
Industrial-commercial electronics	118.3	119.2	116.4
Total industry	128.2	125.2	116.8

Volume of electronics production rose 3 points in June to a record. Production of consumer electronics began a recovery after a spring slump had pushed this index down 28 points. Even after an 8-point increase in June, the index of consumer electronics activity is still nearly 25 points below its December peak, when output hit a record 119.1. Over the year, defense electronics production rose over 20 points.

Indexes chart pace of production volume for total industry and each segment. The base period, equal to 100, is the average of 1965 monthly output for each of the three parts of the industry. Index numbers are expressed as a percentage of the base period. Data are seasonally adjusted.

weather map over a voice-quality telephone circuit. PDQ takes less than two minutes per map, providing comparable resolution. In other models, being developed by EG&G for commercial and Government networks, 10 pages of standard business paper will be sent per minute over the 48-kilohertz channel of the telephone company's Telpak A circuits.

"This will mean a businessman can talk for two minutes and also transmit a letter, all in a three-minute call on a dial-up Dataphone channel," points out Victor M. Tyler 2nd, manager of EG&G's graphic systems department.

PDQ gains speed by bandwidth-compression techniques. "We don't send any information about white space, just about the black lines," says Tyler. "People have been playing with bandwidth compression for a decade, mostly for television applications. They usually end up by saying their techniques don't work for tv, but they ought to be great for facsimile. We checked them all out, found they weren't any good for facsimile either, so we came up with our own line-to-line correlation technique."

Nothing new. In line scanning, Tyler reports, there is inherently a high redundancy: "The next line has to be almost the same as the last one." The PDQ receiver predicts that the next scan will be the same as the last. The transmitter knows this, measures the difference, quantizes this, and sends only that information. The receiver uses this correction information, sent once every 100-milliseconds, to keep updating its prediction. If no difference information is received it will print the previous line again.

The system can be started by a generic scan, such as a line, or coded information from the transmitter. This latter technique lends itself to secure communications. "Unless you know what the first scan was," says Tyler, "the difference information actually means nothing."

The modems (modulator-demodulator) for the Air Force equipment will handle 4,800 bits per second. A 6,400-bps modem is being developed for Weather Bureau tests. Critical feature of the special modems is the design of precisely matched filters for a low-error ratio.

EG&G's new graphic systems department is looking for new markets to apply the PDQ, such as the Defense Department Autovon communications system, the Federal telecommunications system, the space agency's meteorological networks, and for police fingerprint identification and railroad communication systems. In addition, says Tyler, the company is investigating markets in document storage and retrieval systems and in corporate communications networks.

Air traffic control

On the spot

Developers of the air traffic control equipment that the Federal Aviation Administration was cool to or rejected outright have pretty much kept their grumbling to themselves. But they'll soon be given the chance to tell publicly, before the House Committee on Interstate and Foreign Commerce, just what equipment they have and what it can do. And the FAA is going to have to do a lot of explaining to Congressmen unhappy about the agency's snail's pace in air traffic control development [Electronics, July 24, p. 141].

The FAA got a taste of what's to come at the committee's first hearing on air safety held a few days after the midair collision over North Carolina that claimed 82 lives. Rep. Richard L. Ottinger (D., N.Y.), who charged the FAA with being derelict in "not aggressively pursuing equipment development," wants the committee to bring industry representatives into the air safety hearings to determine the state of the art.

Ottinger wants facts and figures on equipment. And he wants to have committee members get into the field to see the equipment function or else the hardware demonstrated in the committee room itself.

Answers wanted. "We want to see why the FAA rejected some of this equipment or failed to investigate it," says an Ottinger spokesman. "And if the reasons don't hold water, this should be brought out."

The hearings could result in legislation giving the FAA power to segregate commercial and private craft, control which the agency had never sought. Hearings could also lead to larger FAA budget requests for equipment. Even if no specific legislation emerges, Congressmen feel the hearings will serve to focus attention on the need to shake the FAA out of its lethargy.

Ottinger isn't the only committee member unhappy with the FAA. Rep. Fred B. Rooney (D., Pa.) charged that the agency has at least $25 million in unexpended funds left over from fiscal 1966, out of a $49 million appropriation for facilities and equipment. Rep. Paul G. Rogers (D., Fla.) sharply rapped the FAA for not requesting funds in its 1968 budget for additional radar installations, while at the same time giving "lack of budget" as a reason for not having radar at six airports that qualify for it.

Although no date has been set for the resumption of the hearings, committeemen expect them to be held by this fall.

Do it now. One bill has already been filed by Rep. Dante Fascell (D., Fla.) that specifically directs the agency to "develop and make available as soon as possible a proximity warning device for use on all U.S. aircraft." Fascell points out that although the FAA already has such authority, "this bill enunciates a Congressional directive to immediately carry out specific objectives." Noting that FAA's studies into collision-avoidance systems up to now came up with equipment at prohibitive costs, he says, "the time has come to renew and redouble our efforts in this regard and embark on a crash program to prevent midair collisions."

"I am convinced that American technology can substantially reduce, if not totally remove, the threat of aircraft collision," he said.

Echoing Fascell's sentiments is Sen. Howard H. Baker (D., Tenn.).

Says the Senator: "I am certain that in the scope of the exotic control facilities available to the industry that midair collisions can be severely reduced or eliminated." Speaking of the North Carolina collision, where both aircraft were under "positive control," he says, "positive control was disastrously unpositive."

Advanced technology

Sputtering diodes . . .

On paper, the concept of using arrays of diodes for displays, light-sensitive receivers, or memories is excellent—but applying the concept is another thing. Pack the diodes too tightly and the system shorts out; attach a lead to each device and the system is a maze of wires. At TRW Systems in Redondo Beach, Calif., researchers have solved some of these problems. They have developed a sputtering technique for producing silicon diodes with a width of less than 0.2 micron.

Such diodes would be impossible to produce by photoresist techniques, according to Murray Bloom, a member of the technical staff and project engineer for the sputtering work.

"We proved we could do an epitaxial process this way and we have also proved that we can make an emitter," he says.

When operated as avalanche photomultipliers, the diodes have shown quantum efficiencies as high as 5,000 at a 1-micron wavelength, Bloom says, against a reported maximum of about 1,000 for germanium avalanche diodes and about 250 for silicon.

Where they'd go. Possible applications for the sputtered diodes are high-speed photosensors of high packing density and fixed memories.

"We could make memories with a packing density of 4 by 10^6 bits (diodes) per square inch," Bloom says. "This is about two orders of magnitude greater than the density of silicon-on-sapphire that are currently being produced."

Breakdown voltages are sharp, he says, corresponding to the impurity concentration of the least doped element. For example, breakdown voltage is about 1,200 volts at a resistivity (lowest impurity concentration) of about 100 ohm-centimeters.

Sputtering produces a mosaic of submicroscopic diodes on a silicon wafer, Bloom explains. A major advantage of the process is that it produces these tiny, dielectrically isolated diodes without the involved photolithographic process.

TRW has produced diode mosaics both by triode and diode sputtering. Sputtering is done at around 1 micron (1 millitorr or 10^{-3} torr) in an environment of commercial-grade argon at 400° to 500°C. The argon is ionized and the positive ions are accelerated to the cathode (a silicon substrate). En route, they strike a silicon target between the anode and the cathode, knocking off silicon atoms that then hit the substrate.

The company has deposited p-type layers on n-type silicon and vice versa in this way. Bloom says sputtering results in better adhesion than evaporation and that it isn't necessary to clean the substrate as carefully. This is because the atoms strike the substrate with 40 times more energy than in the evaporation system, in which atoms leave the filament with only thermal energy.

Making connections, he points out, is simply a matter of taking a 0.1-mil connector and putting it down at any desired point on the substrate. All the diodes touched by the connector are wired in parallel. Those which are not touched are isolated out of the circuit.

In contrast, the conventional process requires the leads be attached to each diode. The disadvantages of this are isolation, Bloom notes, spacing between diode centers must be at least 0.7-mil (usually they are several mils).

Pick and choose. TRW's method of making connections is to deposit an oxide layer on the wafer after sputtering. This may be deposited by sputtering or ethyl-silicate pyrolysis. Photoresist techniques are then used to etch 0.1-mil holes for the connections.

"Once you have etched the holes you have decided which of the crystallites will be in the circuit and which won't," Bloom says. "This process is the same as the conventional process, except that you etch more or less where you want to."

. . . and selling them, too

TRW isn't alone in working on diodes. At Monsanto Co., for example, work is also progressing on developing a monolithic array of diodes on a single chip. In the meantime, however, Monsanto is now offering for sale a small array (5 by 7 inches) for alphanumeric display that is made by photolithographic techniques.

The only hitch is the price—starting at $500 for a single array. But the device does have some advantages: it needs no drivers—which are needed for Nixie tubes—to turn it on and off, it works on low-voltage sources, has higher reliability than Nixies, and is easy to read.

Monsanto can provide diodes that produce brightnesses of from 50 foot-lamberts to almost 600 foot-lamberts; the brighter the array, the higher the price.

Tuning a laser

Tunable pulsed lasers select the colors within the optical spectrum somewhat as a radio dial selects frequencies, but up until now continuous-wave lasers have been more like a pushbutton radio: they can generate several discrete wavelengths but can't get anything in between.

With simple laboratory equipment, a young Stanford University professor produced the first c-w tunable source and considerably brightened the picture for achieving truly tunable c-w lasers.

Stephen Harris, a professor of electrical engineering, beams c-w laser light through a crystal and gets monochromatic light that can

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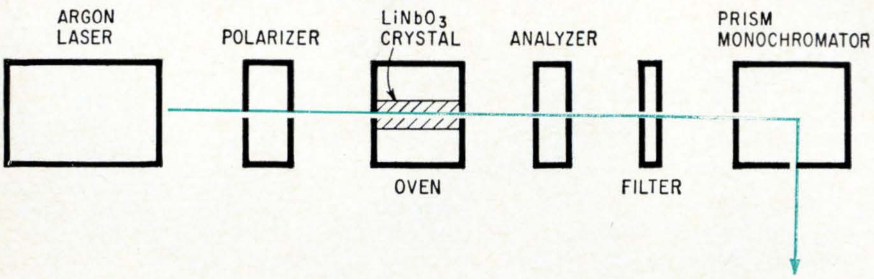


Temperature tuning. Laser goes from infrared to blue-green.

be tuned from infrared to deep green-blue by changing the temperature of the crystal.

Nearly as pure. While the light he receives now is weak (10^{-10} watt with linewidths probably less than 1 angstrom), Harris claims it is nearly as pure as laser light. In effect, he says, "it will be a tunable laser and every bit as good as one," even though the laser light is being used as a pump.

The discovery is important for several reasons. It will aid in the construction of higher power c-w optical parametric oscillators by allowing researchers to look at low-level emissions and determine at what temperatures to set the crystals. Also it will permit studies of different materials to determine which fluoresce strongly enough to make the best oscillators.

It also promises benefits in other fields. In underwater communications, the tunable light will allow selection of the best wavelength (usually in the blue-green) to match the medium.

Harris' experiment uses a principle called "parametric fluorescence," which was predicted theoretically six years ago by several people, including Stanford professor Anthony E. Siegman, Harris' mentor when he earned a doctorate in 1963.

Such fluorescence occurs when laser light passes through certain nonlinear crystals causing parametric (time varying) amplification or oscillation at two lower optical frequencies, often called the "signal" and "idler" frequencies.

Harris uses a weak (300 milliwatt) c-w argon laser and beams it through a crystal of lithium niobate 1 centimeter long that rests in a small open oven. The crystal is placed with its optic axis in its face and parallel to the polarization of the incoming laser beam. The parametric fluorescence emerges from the crystal in a direction parallel with the pumping laser and is orthogonally polarized.

From red to green. Due to phase-matching conditions, which require the pump, signal, and idler waves to travel at related velocities in the crystal, the wavelength of the fluorescence is changed from deep red to green-blue as the crystal is heated from 100° and 350°C.

The fluorescence occurs between 5,400 and 6,600 angstrons. With the crystal temperature between 75°and 100°, the emission is in the far red and between 100° and 125°, plain red. As the temperature rises above 125°, the emission moves progressively toward the green.

Because the outgoing beam is not a coherent oscillation but only an incoherent noise-light emission, it does not need a complicated set of aligning mirrors. Though not coherent, it is one wavelength and fairly pure in color, and can be seen by using filters to protect the eye from the laser beam.

Although the idea had been around for six years, Harris was the first to demonstrate it. Surprisingly, it was easy to do. Harris said he set it up in four days after giving it a little thought.

Military electronics

Who goes there?

After the Rome Air Development Center asked for intrusion detection devices for Vietnam, a flood of ideas and hardware poured in from 92 companies. The center has bought a number of devices to test here and in Vietnam, and will buy more.

Weed and Seed. Almost any sensor Rome is testing gives more information when teamed with a second. One, for example, called Weed, a radar that uses a 5-foot whip antenna, will trip an alarm if an object comes within its range. But the unit can't tell whether it's an animal, a man, or a jeep. When the impedance of the antenna's field is disturbed by the entry of a new object, a telemetry device radios the news to a monitor.

The unit, built by General Dynamics Corp. in San Diego, can detect an object the size of a man at 100 feet and a vehicle at 300.

A seismic device is being teamed with Weed; the combination is called Seed. With Seed an experienced operator can tell the difference between the steps of a man and those of an animal; both are distinguishable from the steady shaking of a jeep. Two seismic devices are being tested; one by Research Inc. and one by Sandia Corp. The Sandia system stores information for later examination.

Center stage. Two infrared systems under test show promise. When, for example, the lead man of a small group of Vietcong breaks an infrared pencil beam transmitted along the perimeter of a camp, a circle of Roman candles explodes. The intruders are on stage center with every light in the house turned on.

One of the infrared systems is active, consisting of a transmitter pointed toward a receiver that will note the interrupted transmission and set off an alarm. The other, a passive detector, consists of two receivers placed side by side that monitor nearly identical areas in the distance; a sudden disparity in heat between them sets off an alarm. Two receivers are used instead of one to avoid false alarms caused by natural changes such as the sun's going behind a cloud, rainfall, or other normal phenomena that would affect both areas in the same way.

The active device is built by

If your blip is a blooper, you'll know it in 10 seconds.

Once you start using Polaroid Land film, you'll wonder how you and your oscilloscope ever got along without it.

In 10 seconds, you get an on-the-spot record. You can study it, attach it to a report, send it as a test record along with a product shipment, or file it for future reference.

You have a choice of 5 films for oscilloscope recording.

The standard film has an A.S.A. equivalent rating of 3000. You can get it both in pack film [Type 107] and roll film [Type 47]. They both give you 8 pictures 3¼ x 4¼ inches. This emulsion is also available in 4 x 5 sheets [Type 57].

And for extremely high-speed oscilloscope recording, there's Polaroid PolaScope Land film [a roll film, Type 410].

It has an A.S.A. equivalent rating of 10,000. It can discover traces too fleeting for the human eye: such as a scintillation pulse with a rise time of less than 3 nanoseconds.

Because these films are so sensitive, you can use small camera apertures and low-intensity settings. Every shot is a sharp, high-contrast image that's easy to read.

To put these films to work on your scope, you need a camera equipped with a Polaroid Land Camera Back.

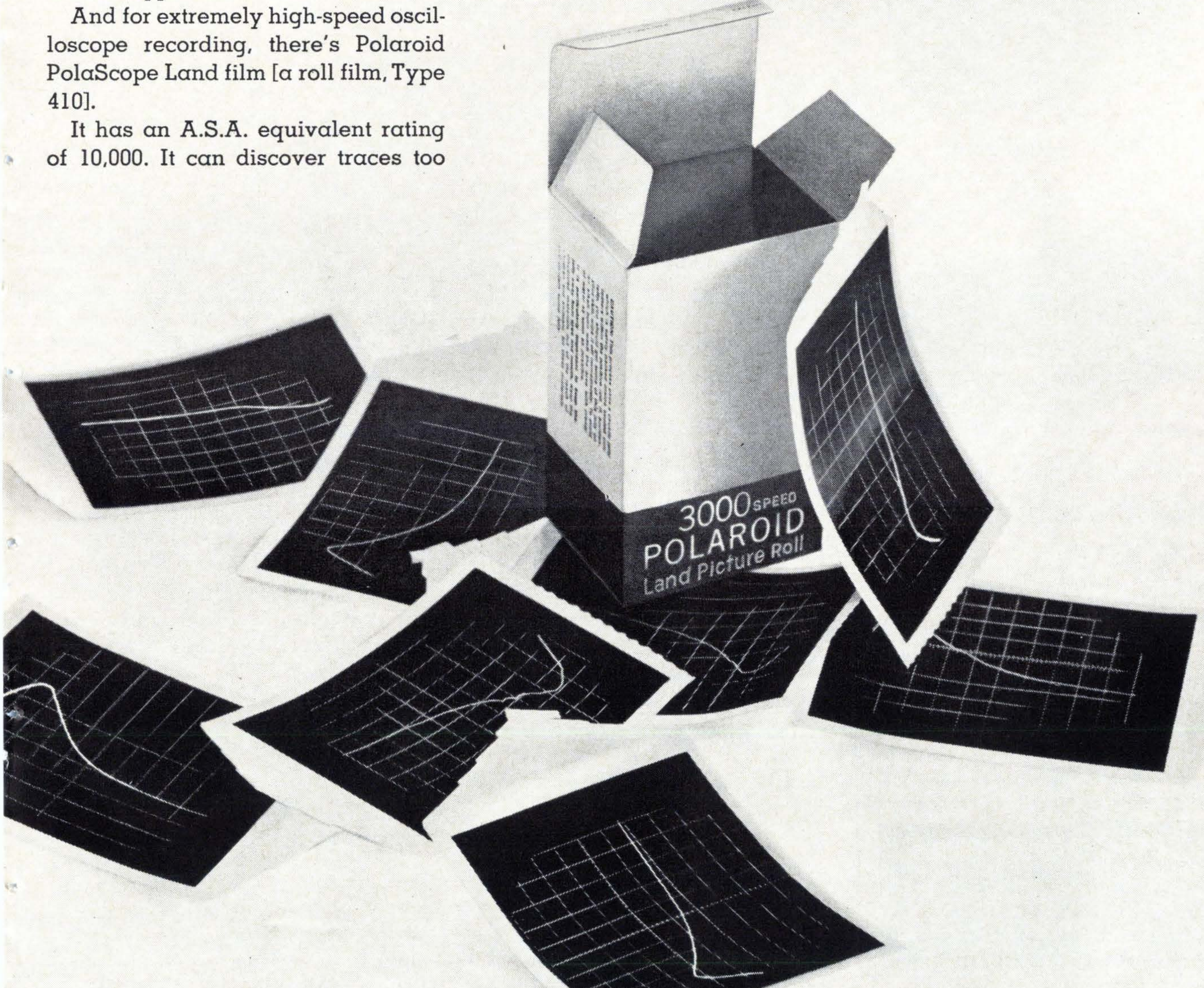
Most oscilloscope camera manufacturers have one.

For instance: Analab, BNK Associates, Coleman Engineering, EG&G, Fairchild, General Atronics, Hewlett-Packard and Tektronix.

You can get the full story by writing to Polaroid Corporation, Technical Sales Department, Cambridge, Massachusetts 02139 [or directly to the manufacturers mentioned above].

About the only thing we can't tell you is how to keep your blips from being bloopers.

"Polaroid" and "PolaScope" ®



Polaroid Land Film for Oscilloscope Trace Recording.

Santa Barbara Research Center, a division of Hughes Aircraft Co.; the passive system by Barnes Engineering Co.

Sensors. To check on the reaction of the infrared set, several more sensors could be used. A magnetic strip, developed by Honeywell Inc., can be buried under ground to detect metal passed above it. Or a pressure device can measure the approximate weight of the object pressing down on it. This sensor consists of an ordinary garden hose, filled with water, buried in soft dirt. When someone steps on the hose, the pressure change is measured by a transducer and converted to an electrical signal which is transmitted by wire or radio to the guard on duty.

Rome is testing an acoustic receiver that is tuned to receive only ultrasonic frequencies made by a man brushing past foliage or rustling through weeds. The device, built by Westinghouse Electric Corp., was sponsored by the Army Limited War Laboratory at Aberdeen Proving Ground, Md.

Two personnel detection radars are being tested at Rome now. One is a two-pound radar built by the Radio Corp. of America with a 500-meter range for people and 1,500 meters for a vehicle. The other is a jeep-mounted version of the AN/PPS-5 radar, built by Airborne Instrument Laboratories, a division of Cutler-Hammer Corp. The PPS-5 detects personnel at 5,000 feet and a vehicle at 10,000 feet.

Industrial electronics

Going commercial

The U.S. invitation—which may eventually go to foreign ships—to use the Navy's navigation satellite will open a $50 million market for the shipboard receivers.

The satellite system, launched in 1964 as Transit, was designed to sharpen the navigational fixes of submarines carrying Polaris ballistic missiles. Under the U.S. proposal, it will be available to fix the positions of survey ships, tankers, freighters, and oceanographic research vessels.

Unless other companies get into the receiver field quickly, sales will be divided among Magnavox, International Telephone & Telegraph, and Honeywell.

Tooling up. The three have been primarily concerned with building military or research units in limited quantities, but they have also been preparing for heavy commercial sales. Depending on the size of production runs, a complete commercial unit consisting of a receiver data processor, and computer may eventually sell for as little as $30,000—the current cost of military units without a computer.

ITT has already made the first commercial sale, delivering two units last week to a survey company that searches for undersea oil. And it is building units for a geodetic survey company and an oil concern. The company's main business in this area, however, is still its contract with the Navy for 67 units, two of which will go to the National Aeronautical and Space Administration for range tracking ships.

To date, Magnavox has built four versions for the Scripps Institution of Oceanography—two of which could be marketed commercially, the company says.

Honeywell hasn't built a commercial unit yet, but in October it will deliver an 18-pound airborne unit to the Applied Physics Laboratory of Johns Hopkins University, where the entire satellite system was designed. The airborne system, Honeywell says, could also be used on ships, and will be suitable for commercial use. All three companies use silicon transistors, integrated circuits, and diode switching.

Opening floodgates. The overseas market is expected to be good. Since the two navigation satellites in the system went up in 1964, Magnavox and ITT have been besieged with requests from West Germany, Britain, and France for

Circle 49 on reader service card

shipboard units. But because the system was "military," they couldn't sell to foreign customers. Now that the lid may be taken off, a further flood of requests is expected from abroad.

Japan, however, may not be one of the buyers. According to the Japanese government's science and technology agency, the surface gear needed to work with the Navy's satellites is too expensive. Japan currently plans to put up a satellite of its own in the spring of 1971 to test communications or navigation concepts. If the cost of receivers for the U.S. system drops much more, these plans could change.

Medical electronics

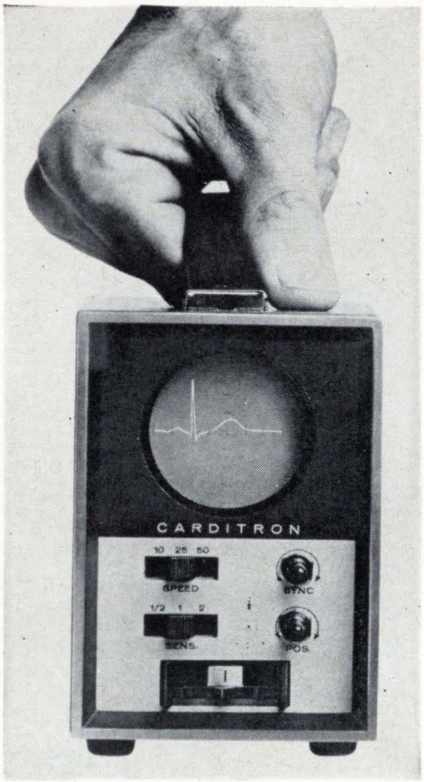
New wave

Since their inception, monitors for medical electronic systems have been built around conventional large-screen oscilloscopes that display low-frequency electrocardiographic (EKG) tracings as a train of waves. Each heartbeat is typically represented as four, five, or six waves chasing across the screen in succession. Comparing one moving wave with another is no easy task, and doctors generally complain that no rhythm shifts but those gross enough to cause heart-rate changes can be detected.

Now a small medical electronics firm in New York, Datascope Corp., has developed a scope monitor, called the Carditron, that displays only one complete cycle of a patient's EKG, not five or six. Each cycle is "painted" over the one before it, so that even the slightest change in the waveform can be easily detected.

Life and death. This feature could save lives. Early detection is essential in the case of such problems as ventricular fibrillation, where the heart beats out of control.

Conventional scope monitors don't provide this heart rate data; for such information the doctor must turn to a heart rate meter,



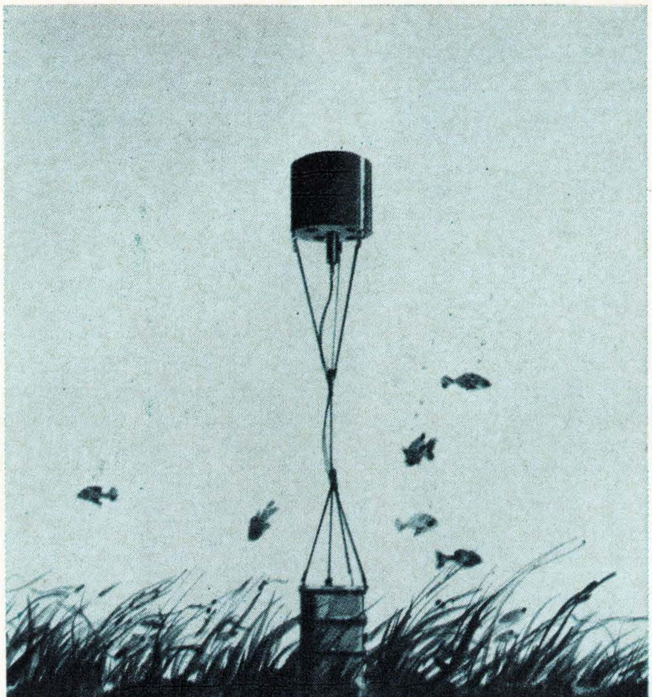
Handy meter. Checking the heart.

which averages many heartbeats. The Carditron, on the other hand, performs the job itself by measuring intervals between peaks of a patient's EKG; the peaks chosen are called R waves, typically the largest in a complex EKG signal.

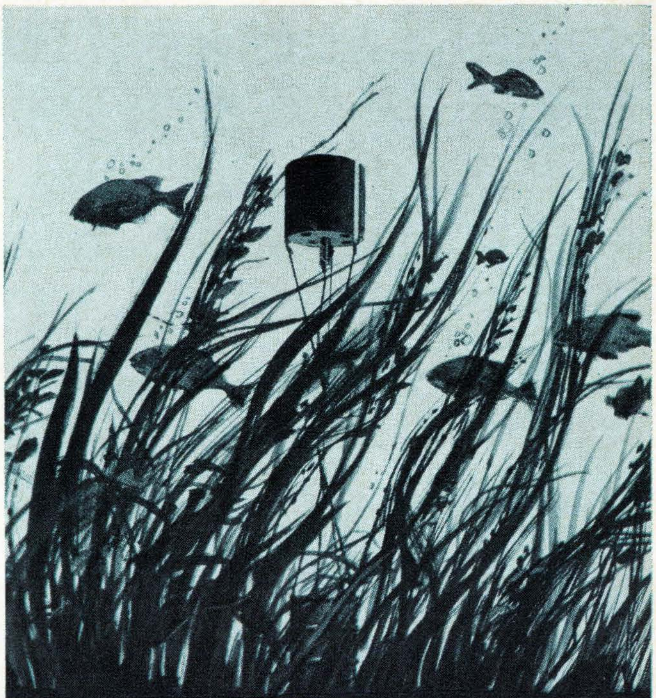
To synchronize the scope to the heartbeat, the Carditron's sensing circuitry reacts to the prominent R wave. When an R wave is detected, a delay gate is generated, initiating a sweep. The trailing edge of this gate terminates the sweep and triggers a new one.

Complete picture. The delay gate also creates a window for the T wave, a waveform that generally follows the R wave, so that the entire EKG complex can appear in the correct physiological sequence. The delay gate is adjustable from 0.15 to 0.5 second to accommodate the range of the T wave.

Aside from being easy to read, the single wave can be displayed on a scope with a very small diameter—1½ inches in the Carditron. The whole unit measures about 15 cubic inches, weighs only 3½ pounds and consumes about 7 watts; this compares with the con-



April 6, 1963 the AT052 Transponder placed in operation 6025 feet below the ocean surface.



April 6, 1967 still going strong!

That's Bendix reliability!

Designed for a minimum life of 12 months, the first Bendix AT052 acoustic transponder was still operating well within limits after 48 months of uninterrupted service. That's 35,064 hours *without* failure. Associated shipboard equipment installed on July 16, 1963 has proven equally reliable. Similar results are being obtained with other AT052 transponders, some of which operate at depths to 20,000 feet.

A wide variety of acoustic transponder systems are available for accurate ship positioning in survey and salvage work and for oil well position markers.

Please write *Electrodynamics Division, The Bendix Corporation, North Hollywood, California 91605.*

Bendix Oceanics

Attend WESCON and visit the Electrodynamics Booth 2815

Circle 51 on reader service card

ventional scope's volume of more than 1,500 cubic inches, weight of about 25 pounds, and consumption of 100 watts.

For the record

What's new? Everyone knows it, and now the Federal Power Commission has said it: computers could help prevent electric power failures like the Northeastern blackout of Nov. 9, 1965. In its report on the blackout, the FPC urges the power industry to use computers for more than accounting.

Space travelers. Joseph F. Shea, manager of the Apollo space program office at the Manned Spacecraft Center in Houston at the time of the Cape Kennedy fire that killed three astronauts, has joined the Polaroid Corp. in Cambridge, Mass., as a vice president. Walter D. Smith has been appointed general manager of Martin Marietta's Apollo applications program.

Last word. A 1,206-foot antenna is getting final tests as a focal point of the nation's last-ditch-survival communications system. The tower, in the Mojave Desert at Hawes, Calif., is atop the first of four transmit-receive stations for the 487L very-low-frequency network, capable of communication through nuclear fallout during and after an attack. Others are being built in Nebraska, Puerto Rico, and Virginia. Also, there will be 200 receive-only sites that can be reached by the fixed stations or flying command posts.

Happy landing. The Army has awarded Airborne Instruments Laboratory a $635,732 contract to develop a manpack tactical landing system. To be called A-SCAN, the system will use technology already developed for AIL's Flarescan series of landing systems.

Tooling up. Transitron Electric Corp. is readying a full line of off-the-shelf linear IC's. The company, heretofore a large supplier of digital IC's, plans to offer operational amplifiers, differential amplifiers, and comparators. Also planned are complex linear IC's, including dual analog circuits and sense amplifiers.

low cost

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NPN SILICON TRANSISTORS

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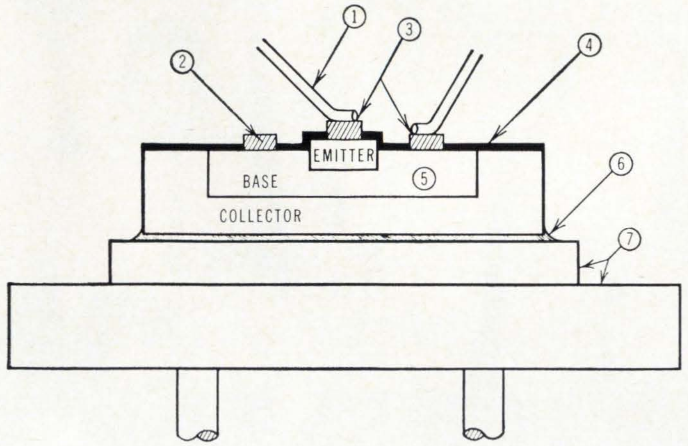
PROVE THEIR HIGH RELIABILITY!



ISOLTAXIAL
(Oxide Passivated Single Diffused Transistor)
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1. Aluminum Leads
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7. Moly Pedestal silver brazed to nickel plated copper package for improved thermal expansion matching

Initial customer response to Solitron's ISOLTAXIAL NPN Silicon Transistors has proven the wide acceptance of these devices for high reliability applications. Their special construction innovations and processing techniques have resulted in a combination of high secondary breakdown resistance and low leakages never before achieved. As shown in the cross-sectional drawing, the key is in the planar surface and the uniform base. Available in a TO-3 or TO-61 case, the ISOLTAXIAL may be used in power supplies, audio amplifiers, inverters, converters, relay drivers and series regulators.

All types include these specifications:
Gain 20-60 @ 5 A
V_{CE} (sat) 0.5 V Max. @ 5 A
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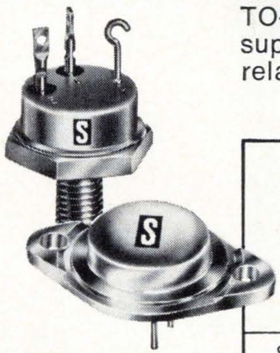
ft. 1.0 MHz Min.



Type Number	Pkg. Size	Type Number	Pkg. Size	DESIGN LIMITS			PERFORMANCE SPECS.	
				BV_{CBO}	V_{CEO} (SUS)	BV_{EBO}	I_{CEX} @ V_{CE}	
				Volts	Volts	Volts	(V_{EB} = 1.5V)	
				Min.	Min.	Min.	μA (Max.)	Volts
SDT9801	TO-3	SDT9901	TO-61	60	40	12	100	40
SDT9802	TO-3	SDT9902	TO-61	80	60	12	100	60
SDT9803	TO-3	SDT9903	TO-61	100	80	12	100	80
SDT9804	TO-3	SDT9904	TO-61	120	100	12	100	100

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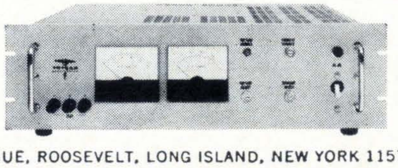
So far, he's had problems with our Super-Mercury series. Because there haven't been any problems.

The Super-Mercury is a brand new series of fully programmable, wide range power supplies—the new generation of the industry-accepted, field-proven Trygon Mercury Series. And Marshall and friends make sure that the new Super-Mercuries maintain Constant Voltage/Constant Current with precision performance from 0 to 160 volts, and up to 100 amps. Panel heights range from 3½ to 10½ inches. .005% regulation and 0.015% stability are standard (.005% stability optional). Total ripple and noise is less than 1mv rms and 10mv P-P (to 10MHz).

Master–slave tracking, automatic load share paralleling and dozens of other features make Super-Mercury make sense for you. And we'll guarantee that the only person who's ever disappointed is "Bulldog." How many shall we send?

Trygon Power Supplies



TRYGON SUPER-MERCURY SERIES
CONSTANT VOLTAGE/CONSTANT CURRENT

MODEL	VOLTS	AMPS	HEIGHT	PRICE W/METERS
M3P 8-25 OV	0-8	0-25	3½	$525
M5P 8-50 OV	0-8	0-50	5¼	650
M7C 8-100 OV	0-8	0-100	7	995
M5P 15-30	0-15	0-30	5¼	660
M5C 15-50	0-15	0-50	5¼	845
M7C 15-80	0-15	0-80	7	1250
M5P 36-15	0-36	0-15	5¼	575
M5C 36-30	0-36	0-30	5¼	690
M7C 40-50	0-40	0-50	7	975
M5P 60-10	0-60	0-10	5¼	645
M5C 60-15	0-60	0-15	5¼	695
M7C 60-30	0-60	0-30	7	1070
M5C 160-5	0-160	0-5	5¼	995
M7C 160-8	0-160	0-8	7	1250
M10C 160-16	0-160	0-16	10½	1550

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Here, clearly, is the most economical and most compact black and white tube kit yet offered. Only 5 tubes are needed to perform all necessary tube functions except the tuner and picture tube. This new idea in electronic tubes is designed to help lower the price of monochrome sets.
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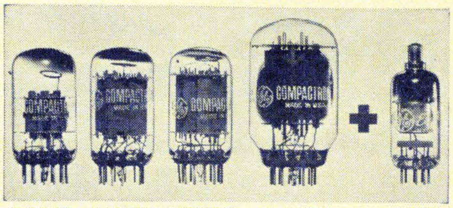
Y-1607B 17BF11 Y-1699B 33GY7A 1BC2

GE THICK-FILM MODULETRON . . . A BOLD NEW PACKAGING CONCEPT
Up to 75% of the passive elements in your TV receiver can now be included within this new compactron. Yet no circuit redesign is necessary; active tube elements remain unchanged. The GE Moduletron may offer savings as high as 50% on passive elements and installation costs.
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Takes passive elements off the circuit board and puts them inside the compactron

Need Black Hawk capacitors in a hurry?

Now you can specify Black Hawk capacitors for immediate delivery in 7 different case sizes and in 5 different voltage ratings—50, 100, 200, 400 and 600 VDC. Black Hawk capacitors feature molded encapsulation to provide a hard moisture-resistant shell around the capacitor roll and strengthen the welded leads. Other advantages include extended foil construction and very precise dimensions (±0.005).
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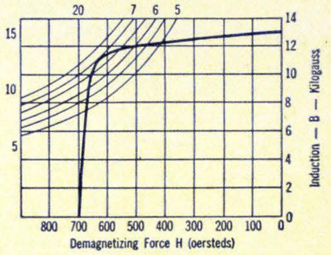
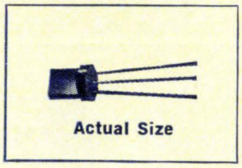
Maximum energy product: 7,000,000 gauss-oersteds with GE Alnico 5-7

At 7,000,000 minimum gauss-oersteds, Alnico 5-7 gives you a 25% increase over conventional Alnico 5 . . . permits either greater magnetic performance in the same size material, or equal performance in a smaller and lighter magnet. High-energy premium priced Alnico 5-7 is excellent for applications requiring superior performance such as high-density meter movements, large dc motors and sophisticated speakers. GE engineers will gladly help you discover how to make the most efficient use of its properties. **Circle Number 93.**



Demagnetization vs. energy output

New 2-transistor Darlington amplifier costs as low as 35¢*



Use GE's new D16P NPN device (in monolithic structure) to simplify your audio amplifier circuits in pre-amps for phonographs and tape recorders. One D16P actually costs less than its discrete counterpart in these applications—two 2N3394's. D16P's provide single stage input impedance over 2 megohms with a 6-to-1 voltage gain at negligible distortion (less than 0.1%). For more information. **Circle Number 94.**

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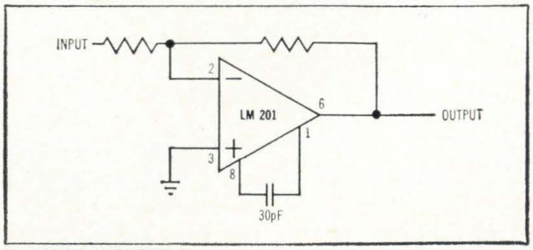

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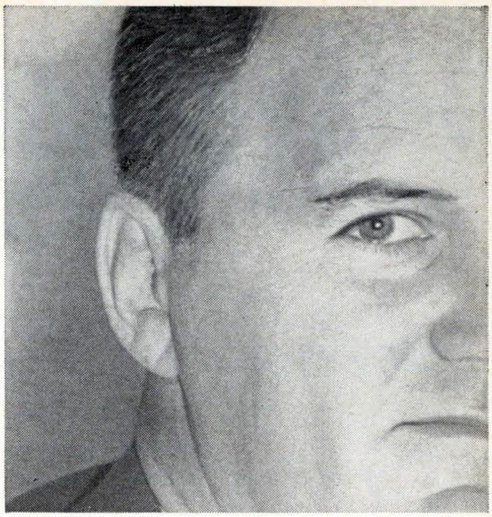

Cheap son-of-a-101 market discoverer, Dugan.

of-a-101

reduces your chance of burnout from overload. It also has a class-B output — with continuous short-circuit protection — giving at least a ± 10V output swing with a 2KΩ load. And, operation's specified from ±5V to ±20V, with power dissipation less than 100 mW at ± 20V supplies.

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National Semiconductor

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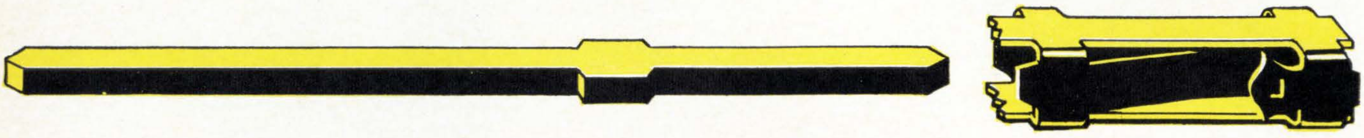

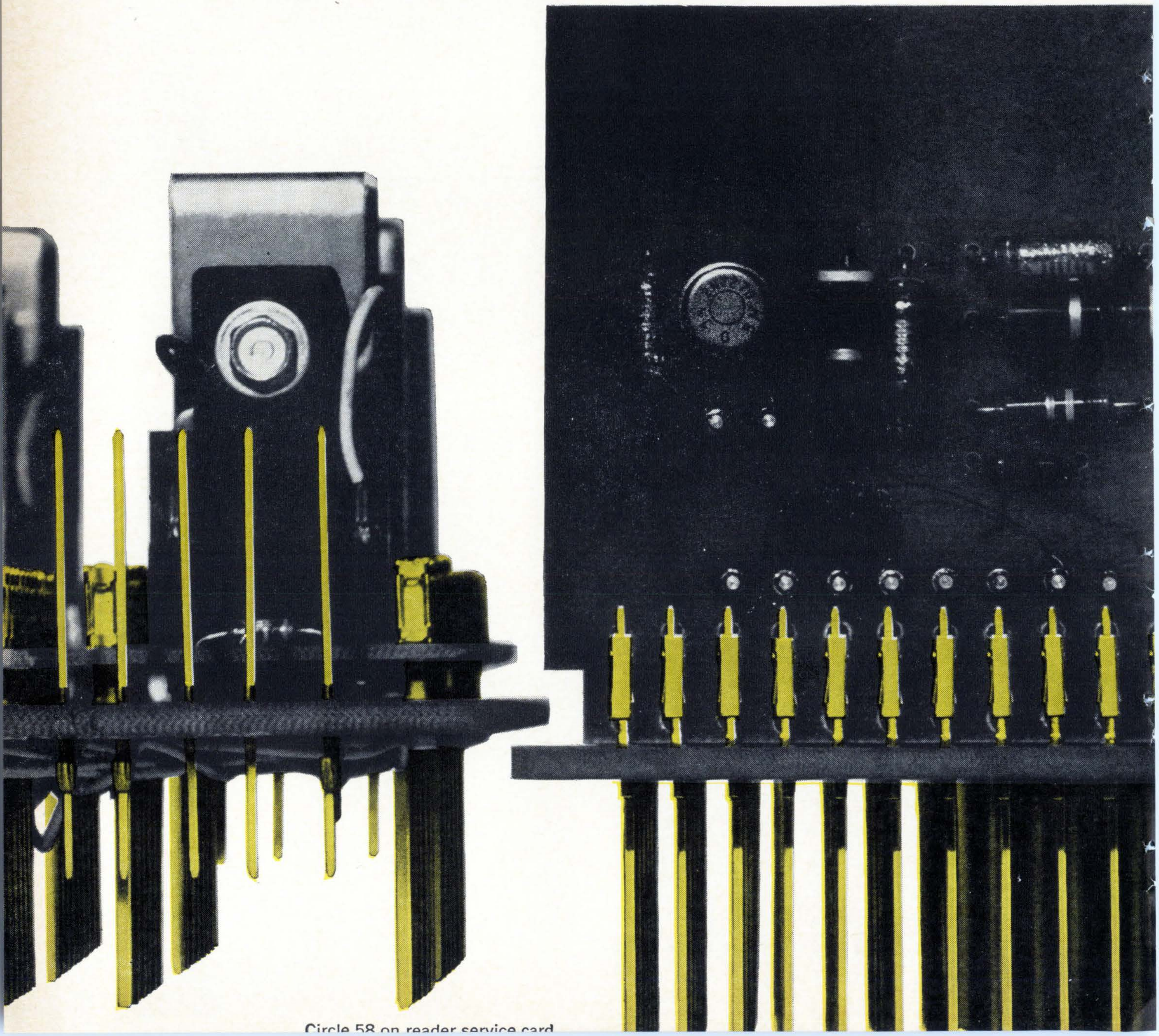

Circle 58 on reader service card

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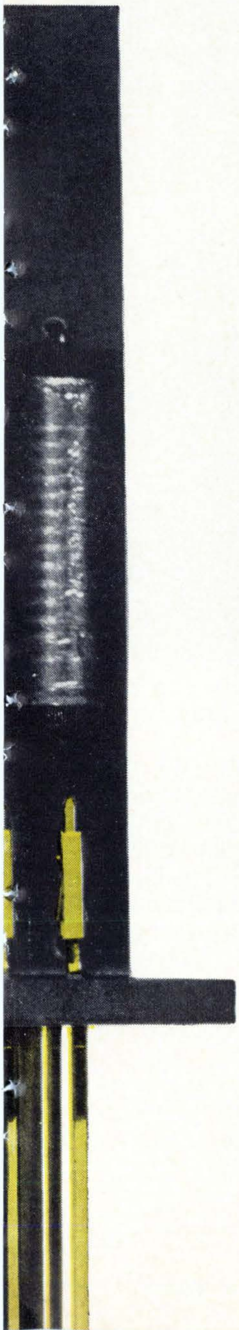
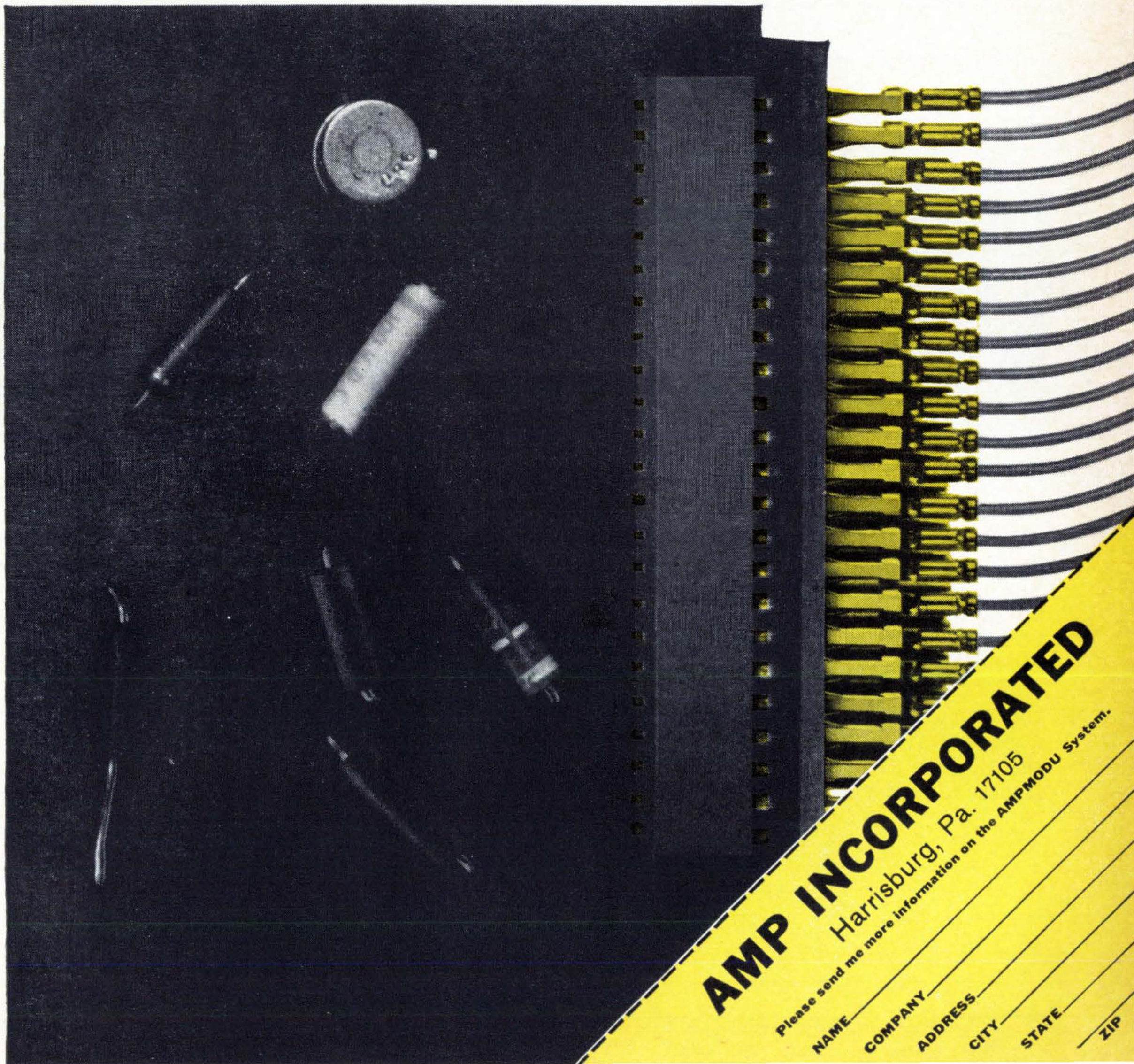
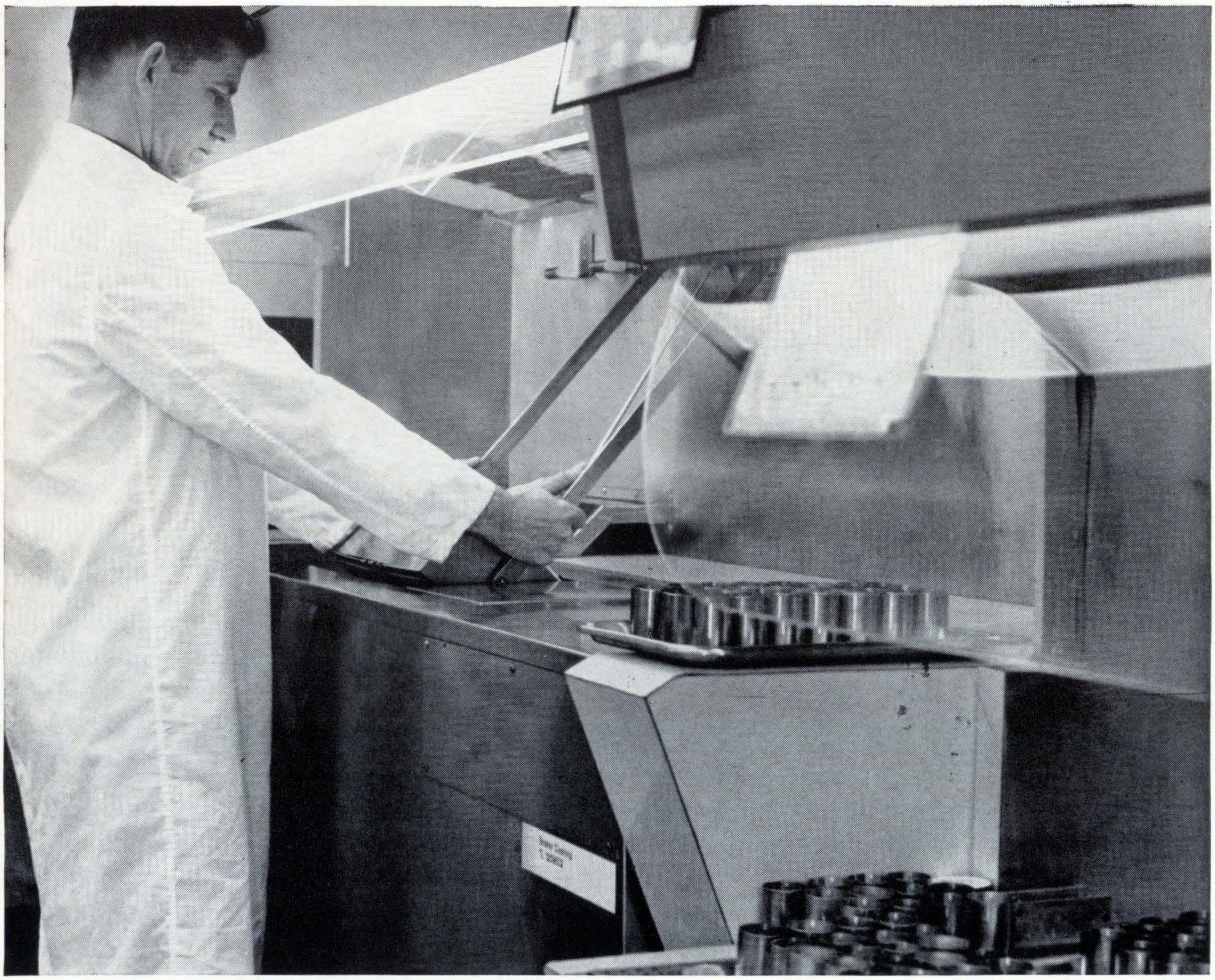




If FREON® is the "high-priced" cleaning agent ...how come it saves IBM $19,000 a year?



In their new East Fishkill plant near Poughkeepsie, N.Y., where IBM makes microminiature circuits for their newest lines of computers, System/360, engineers made this discovery:

They could save *big* money by spending *more* for the cleaning agent used to decontaminate stainless-steel beakers.

These steel beakers are used in the process of manufacturing semiconductors... and they must be completely free of contamination or be rejected. This care is vital because each beaker holds a wafer that is later made into a transistor. The slightest degree of contamination to the wafer makes it unusable.

The former 3-step method—water ultrasonic, acetone, hot plate—required 6 minutes for each step. Even then, a sizable number of beakers was rejected. When the East Fishkill plant switched to FREON*, cleaning time decreased 30% and rejections were cut to 5%. Overall labor was reduced from 27 to 13 hours. Annual savings totaled $19,000.

One way FREON saves money is by combining cleaning and drying—formerly two operations—into one. Another way is through the re-use of FREON many times a day. Even at the end of a workday, FREON is still free from contamination. The former cleaning agent was contaminated after one use.

How much can FREON, the "high-priced" cleaning agent, save you? Your first step in finding out is to write: Du Pont Co., Room 5296, Wilmington, Del. 19898. (In Europe, write: Du Pont de Nemours International S.A., FREON Products Div., 81 route de l'Aire, CH 1211 Geneva 24, Switzerland.)

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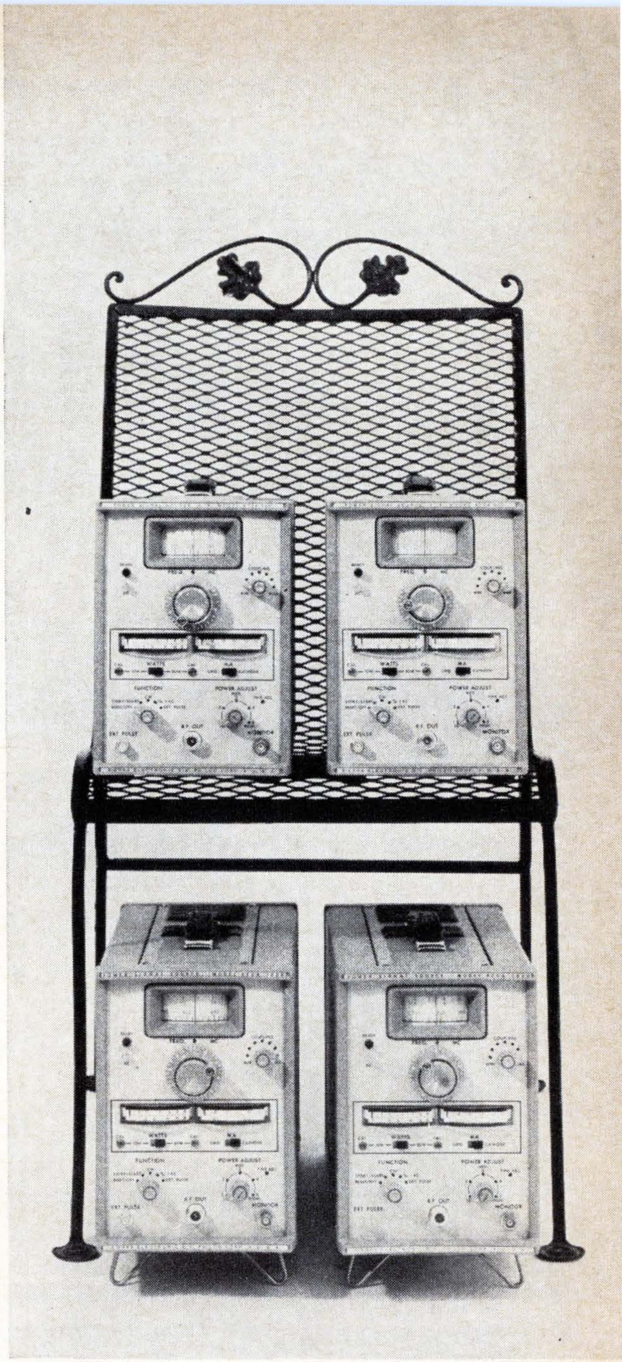
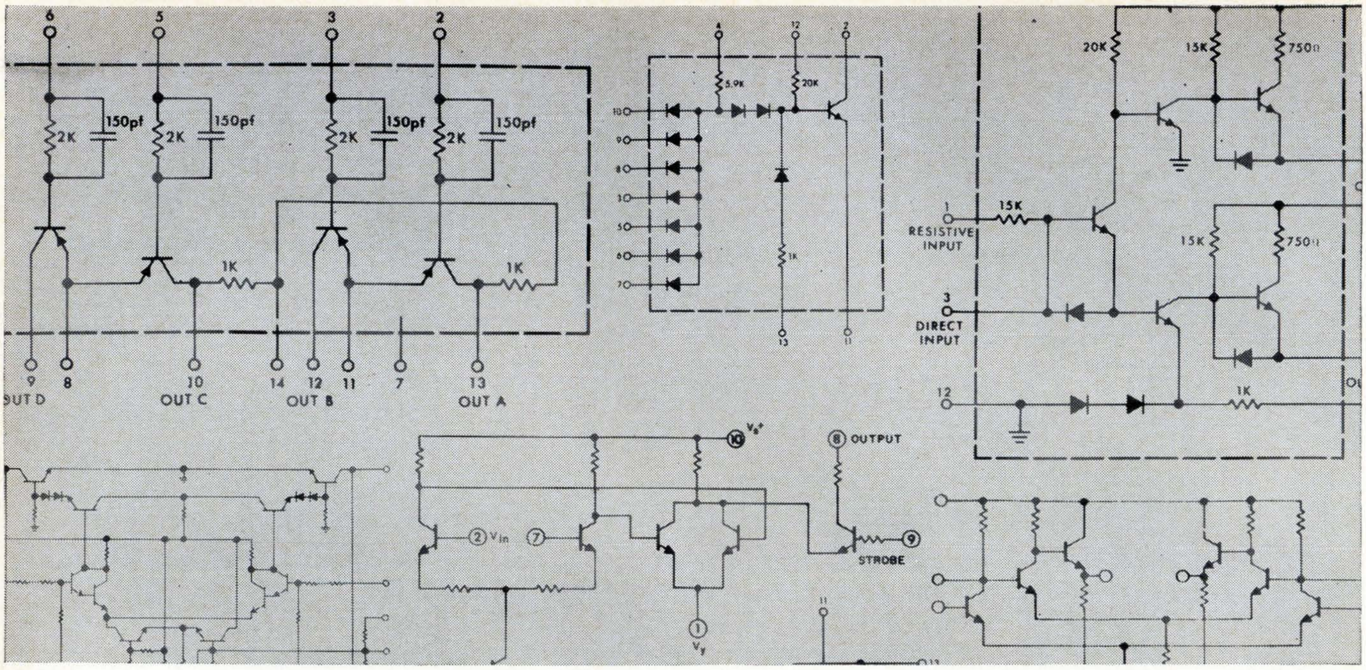
... through Chemistry

*Du Pont registered trademark for its fluorocarbon cleaning agent.





Now available from Norden **Analog and digital microcircuits with Glastrate dielectric isolation**

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- NM 1038 Driver switch
- NM 4013 RS Flip flop
- NM 4014 Dual 4-input clocked DTL NAND/NOR gate
- NM 4015 Dual 4-input DTL NAND/NOR gate
- NM 4016 Driver amplifier
- NM 4017 7-input clock DTL NAND/NOR gate
- NM 4018 Triple high-level DTL NAND gate

Norden announces off-the-shelf availability of high-performance, dielectrically isolated analog and digital microcircuits produced to Minuteman specifications, guaranteeing you highest quality and reliability.

Norden's *Glastrate* process of dielectric isolation reduces leakage current and capacitance to substrate, prevents unwanted PNP action, eliminates "latching," and improves radiation resistance.

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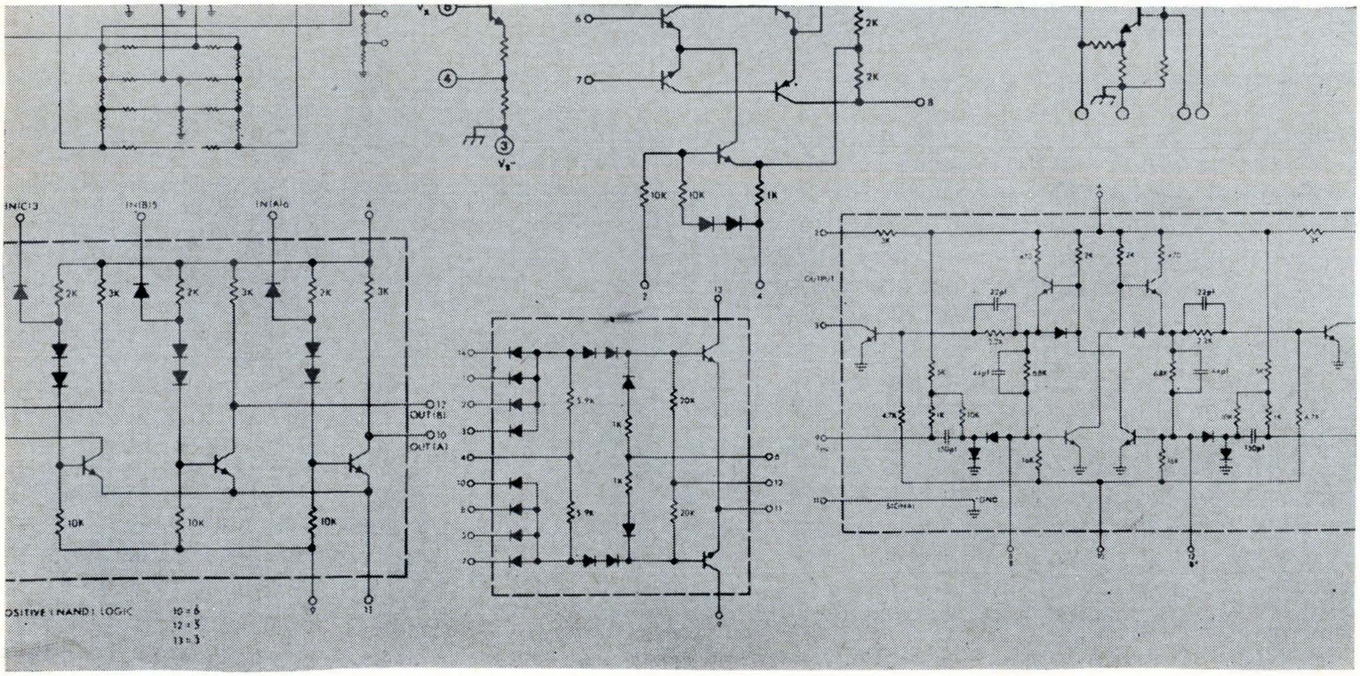
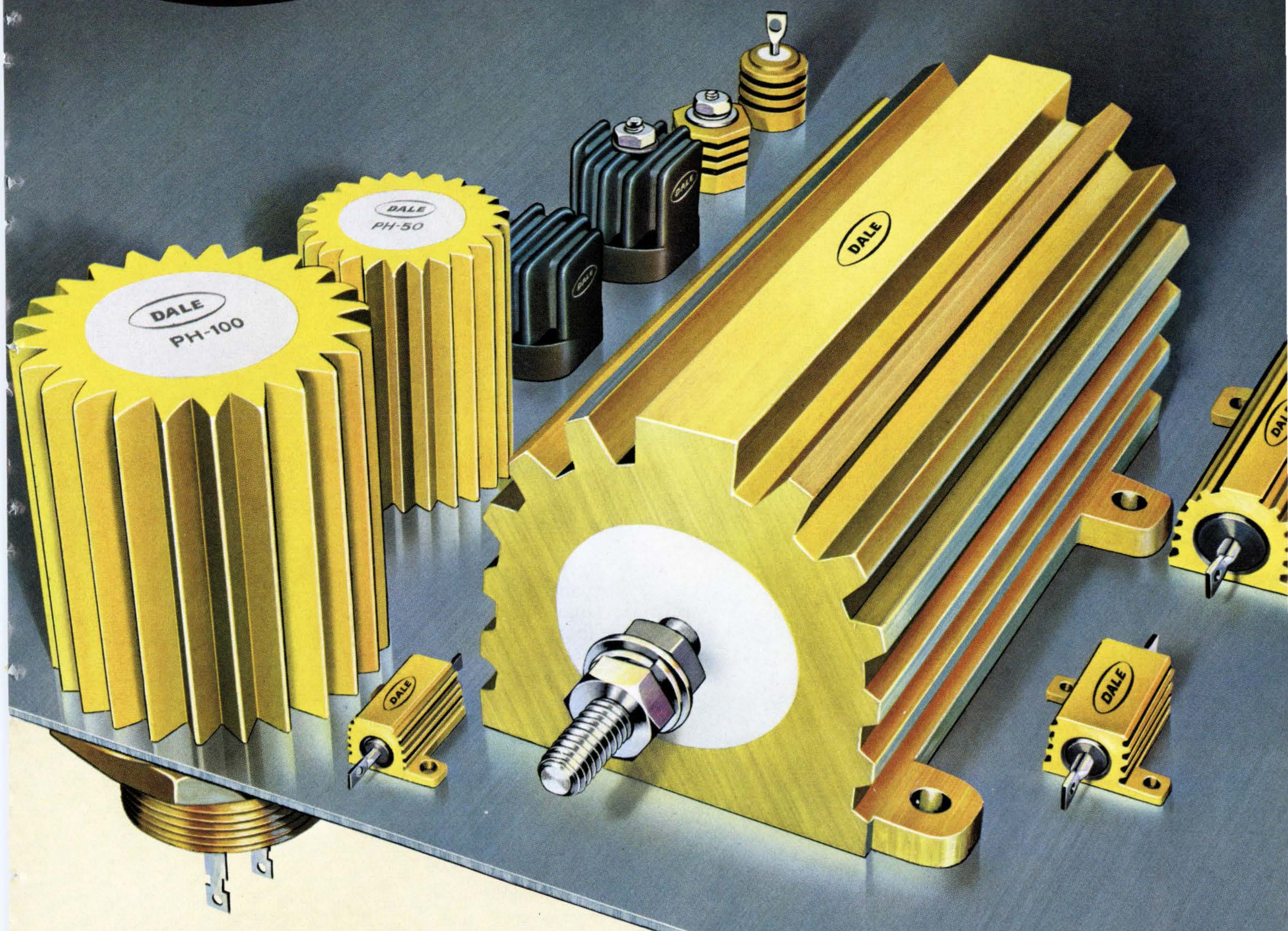


DALE®

heat handlers!



Precision housed power wirewounds from Dale meet your power requirements with ease!

When circuit design calls for mounting *to* or *through* the chassis—specify Dale RH or PH housed wirewounds. In a range from 5 to 250 watts they give you bonus capacity to handle any power or stability problem. And they are available in precision tolerances down to .05%.

In chassis-mounted styles the RH Series offers two choices within MIL-R-18546D dimensions: (1) Full power operation 25% to 108% above mil levels. (2) Derating to mil levels for exceptional long-term stability.

Dale's patented PH Series is also made to MIL-R-18546 specifications but offers the versatility of through-chassis mounting. Both double and single terminals are available. Single terminal models have non-inductive winding to allow fast cycle time. For faster assembly, particularly in modules, they are designed to ground through the housing to the chassis.

For mounting *to* or *through* the chassis, you have a choice of 12 standard RH and PH models plus dozens of easily-produced special variations.

For prompt delivery: Phone 402-564-3131

For more information: Turn the page

DALE

TOTAL CAPABILITY IN PRECISION RESISTANCE

DALE ELECTRONICS, INC.
1300 28th Avenue, Columbus, Nebraska
In Canada: Dale Electronics Canada, Ltd.

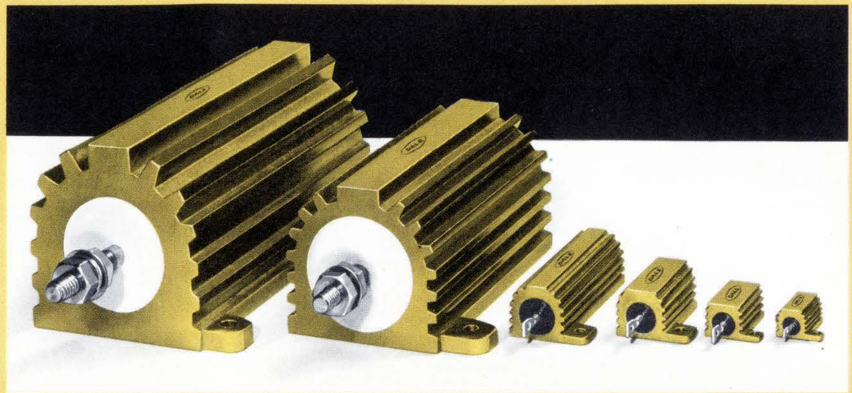
DALE®

QUICK REFERENCE GUIDE

PRECISION HOUSED WIREWOUND RESISTORS

TYPE RH
CHASSIS MOUNT

- Six models, 5 – 250 watts
- Exceeds MIL-R-18546D for high stability at conventional ratings
- All models available with non-inductive winding (Type NH)
- Screw mounts on chassis
- Flat marking surface on top for easy identification



RH-250 RH-100 RH-50 RH-25 RH-10 RH-5

RH RESISTOR SPECIFICATIONS

DALE TYPE	EQUIV. MIL. TYPE	DALE RATING*	MIL. RATING	RESISTANCE RANGE (OHMS)	STANDARD HEAT SINK
RH-5	RE-60	7.5 (5)	5	.1 – 24K	4x6x2x.040 Aluminum Chassis
RH-10	RE-65	12.5 (10)	10	.1 – 47K	
RH-25	RE-70	25	20	.1 – 95K	5x7x2x.040 Aluminum Chassis
RH-50	RE-75	50	30	.1 – 273K	12x12x.059 Aluminum Panel
RH-100	RE-77	100	75	.1 – 50K	12x12x.125 Aluminum Panel
RH-250	RE-80	250	120	.1 – 75K	

Electrical & Environmental Specifications

Tolerance: .05%, .10%, .25%, .5%, 1%, 3%

Load Life: 1% max. Δ R (RH-5 – 50) 3% max. Δ R (RH-100 – 250) in 1000-hour load life.

Operating Temperature: –55°C to +275°C

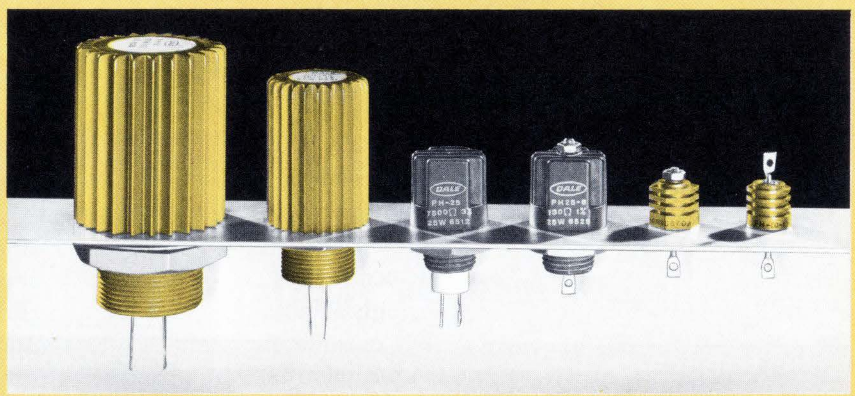
Overload: ±.5% max. Δ R per MIL-R-18546D

*Power Rating based on 275°C max. internal hotspot temperature with resistor mounted on standard heat sink. Figures in parentheses indicate wattage printed on RH-5 and RH-10. New construction allows higher ratings as shown, but these resistors will be printed with the higher rating only on customer request.

TYPE PH
THROUGH-CHASSIS MOUNT

- Six models, 10 – 100 watts
- Versatile terminal arrangements
- Non-inductive models available (PH-10-5, PH-25-8)
- Patented design

Mounting Information: Non-inductive models. PH-10-5, PH-25-8 need only one connection since housing grounds to chassis. Others require two connections as shown.



PH-100 PH-50 PH-25 PH-25-8 PH-10-5 PH-10-1

PH RESISTOR SPECIFICATIONS

DALE TYPE	DALE RATING* WATTS	RESISTANCE RANGES (OHMS)		STANDARD HEAT SINK
		.05%, .1%, .25%	.5%, 1%, 3%	
PH-10-1	10	1 to 12.7K	.1 to 47.1K	4x6x2x.040 Aluminum Chassis
PH-10-5	10	.5 to 6.3K	.1 to 23.5K	
PH-25	25	.5 to 25.7K	.1 to 95.2K	5x7x2x.040 Aluminum Chassis
PH-25-8	25	.25 to 12.8K	.1 to 47.7K	
PH-50	50	3 to 52K	.1 to 75K	12x12x.125 Aluminum Panel
PH-100	100	5 to 35K	.1 to 50K	

Electrical & Environmental Specifications

Temperature Coefficient: ±50 PPM, ±30 PPM, ±20 PPM, depending on value and tolerance

Operating Temperature: –55°C to +275°C

Construction: Extruded aluminum housing with steatite or alumina core and tinned copperweld or 180 alloy terminals, depending on physical size. Covered by U.S. Patents.

*Power Rating based on 275°C max. internal hotspot temperature with resistor mounted on standard heat sink.

For complete information circle 181, or call DALE, Columbus, Nebr. 402-564-3131

Literature available:

- **CATALOG A** (the complete Dale resistor line) *REV. 8-66*
- **CATALOG B** (Wirewound Trimmer & Precision Pots) *REV. 4-66*

DALE ELECTRONICS, INC.
1300 28th Ave., Columbus, Nebr. 68601
In Canada: Dale Electronics Canada, Ltd.

SEE OUR SPECIFICATIONS IN VSMF THE MICROFILM CATALOG FILE

Washington Newsletter

August 7, 1967

Bypassed for job as science overseer, Commerce aide quits

Chalmers W. Sherwin, who as number two man was considered most likely to succeed J. Herbert Hollomon as assistant secretary of Commerce heading up science and technology [Electronics, June 12, p. 47] has quit the Government because he didn't. Sherwin comments, "I've been a Democrat for a long time but I'm not enthusiastic about going back to work for the government."

Having bypassed Sherwin, the Commerce Department is having trouble filling the post. It has named Allen V. Astin, director of the National Bureau of Standards, to take over Hollomon's duties temporarily. Astin, who wants to get back to his old job as soon as he can, isn't expected to embark on anything new or make any significant changes.

Price tag may slow airlines' satellite

High costs threaten to scuttle plans to launch a satellite for relaying vhf communications from transoceanic airliners by 1970. Stopped once before by technical and cost problems, the Communications Satellite Corp. promises a "firm systems proposal" to the FAA in the immediate future to meet the latest target date. But a Comsat official admits there are still "basic issues to be resolved."

As far as the FAA is concerned, the only issue is cost. The agency is still reeling from a Comsat proposal earlier this year pricing such communication services at $5 million per channel per year; the FAA told Comsat it was not interested at that price. To make matters worse, one FAA official says current estimates from hardware makers are even higher.

Congress may plug X-ray leakage

Three Congressional probes this month on excessive X-ray leakage are likely to produce more than scare headlines. **Insiders consider it probable that the hearings—triggered by the Surgeon General's appeal to find 9,000 unaccounted-for GE television sets that might be unsafe—will result in legislation.** A new law could direct the Public Health Service to set and enforce radiation safety standards, or could establish a National Commission for Product Safety.

Tests on 185 shunt regulator tubes (6EF4 and 6LC6), the types used in the recalled GE sets, showed that 77% produced X rays above the safe level of 0.05 milliroentgens an hour. The faulty tubes emitted from 500 to, in one case, more than 50,000 milliroentgens an hour.

Army wants radar within 18 months to find enemy guns

The Army, which still hasn't been able to get what it wants in a mortar-locating radar despite a top-priority R&D program, is now seeking a quick solution to a much tougher problem. The service will request industry proposals for the first-ever system to pinpoint enemy artillery and rocket batteries; further it wants the system in Vietnam in 18 months.

The simpler task of quickly detecting enemy mortar locations has long defied designers despite the arching trajectory of the shells. One reason: no 360° radar. With a field of less than 25°, as in the AN/MPQ-4A counter-mortar system, radar can't get a good fix until three or four rounds have been fired. A new system with 360° radar, the AN/TPQ-28, is still in the development stage.

Washington Newsletter

So far, so good for AWACS radar

Tests to date, including flight tests that began last month, have satisfied the Air Force that the overland surveillance radar technique, now being considered for the airborne warning and control system (AWACS), is feasible. The advantage of overland radar is that it will reject ground clutter and reflection. The feasibility tests cover radars from four companies: Hughes, GE, Raytheon, and Westinghouse. The Westinghouse version began flight tests in July on an EC-121 piston craft; tests of the Raytheon and Hughes systems will start this month. The GE system, which is also feeding data to the test, is being flown on an E2A Hawkeye. Once all the data is in, the Air Force will write the proposal package for the AWACS radar, which is aimed at detecting and tracking low-flying aircraft. Boeing and Douglas are now in a runoff for AWACS and the winner will be selected in about a year. The prime contractor then will conduct a competition to build the AWACS radar.

Big city cops want more air

Watch for a major push by police departments of riot-torn U. S. cities to get more radio frequency space. At a meeting in Toronto this month, the Associated Public Safety Communications Officers will ask its 1,800 members to cite riot problems in appealing to Congressmen to press for FCC action. Says an official of the group: **"The FCC realizes something must be done, but it won't do anything."** Police have their eye on the ultrahigh-frequency television spectrum and the lower channels in the very-high-frequency tv spectrum.

Westinghouse bid for torpedo order boosted by tests

Westinghouse is feeling better about its chances to get the production contract for the Mark 48 torpedo. The company's development of the top-priority, wire-guided torpedo ran into such severe technical and managerial problems earlier that the Navy named the Clevite Corp. to develop a backup model [Electronics, July 10, p. 45]. **But late last month, the Westinghouse model went through a successful series of Navy tests at Keyport, Wash., according to an in-house memo circulated among top Westinghouse executives.**

Pentagon may try to bar awards on bids below cost

The Pentagon may tighten contract regulations in an attempt to eliminate awards to companies that bid at less than anticipated cost. Some firms do this with the intention of making up the loss on subsequent orders of the same system. Consideration of the change is prompted by an angry report from a House Armed Services subcommittee that the Army bungled in awarding a contract for light observation helicopters to the Hughes Tool Co. Hughes admits it bid below cost but says it hoped to make up the difference on civilian sales.

Congress weighs arms credit curbs

One outcome of the Arab-Israeli war may be a U.S. clampdown on arms credit to underdeveloped nations. Congressional critics of easy credit terms are pushing hard for tighter controls. **Such a move would hit the electronics industry's pocketbook hardest in the area of missile and aircraft equipment sales.**

In the past two years, 14 countries have purchased weapons on credit. And in the last six years, one-third of the $12 billion in arms exports has been sold on the cuff. Sales to the Middle East, Africa, and Asia could be crippled by a credit squeeze.

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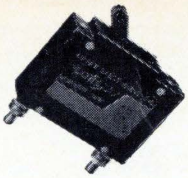
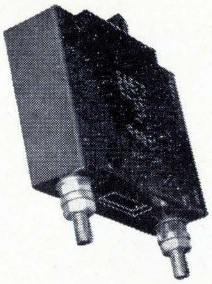
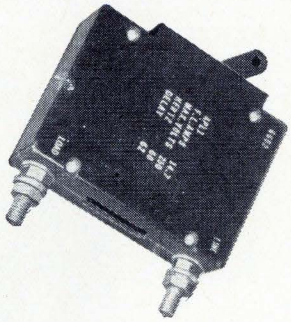


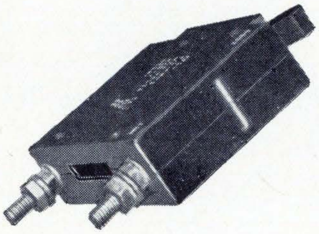


Sensitive - trip levels as low as 50 milliamperes

Rugged - withstand shocks of 50 g while operating

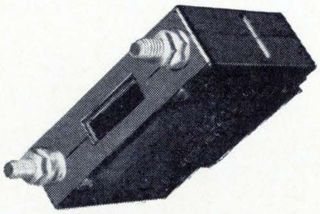
Powerful - trip levels as high as 50A at 50 v dc or 250 v ac



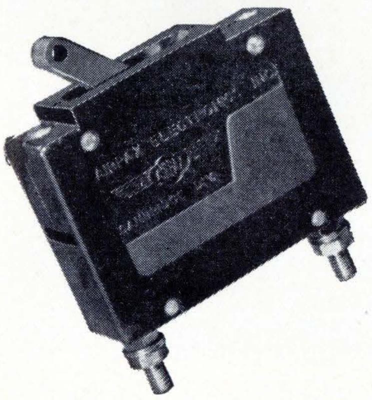


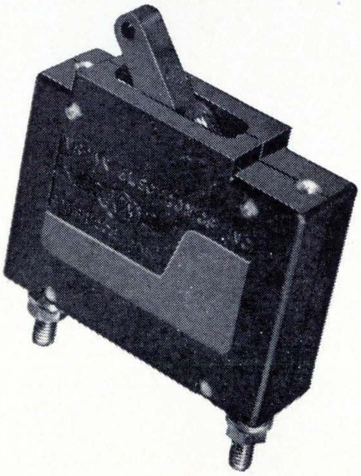
Reliable - rated for at least 10,000 operations

Stable - trip level unaffected by ambient temperature or past current history



Safe - handle is trip free so that a protector cannot be manually held closed in presence of overload





Versatile - instantaneous trip for protection of sensitive circuits – time delays of normal surges without tripping

Adaptable - units can be stacked for mechanical interlock, auxiliary contacts permit remote electrical interlocking and signalling

Dependable - designed and manufactured by Airpax

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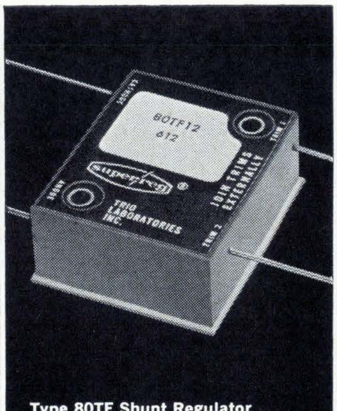
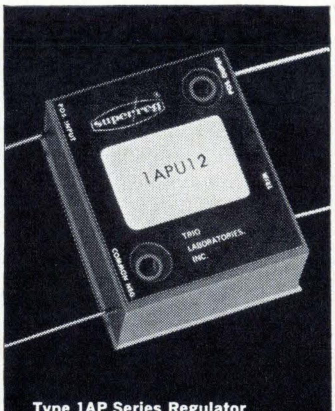
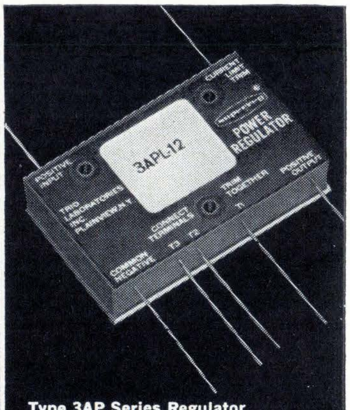
- .01% Regulation – output Z from .002 ohms
- Hermetically sealed TO-36 case



Type 80TF Shunt Regulator
- 80 Watt or 3 Amp capability
- Output voltage from 3.9-56 Volts
- .01% Regulation – output Z from .002 ohms
- Encapsulated construction



Type 1AP Series Regulator
- Economy priced
- Output voltages from 5-24 Volts
- 1% Regulation – output Z from .06 ohms
- Full 1 Amp load capability



Type 3AP Series Regulator
- Full 3 Amp load capability
- Output voltages from 2-33 Volts
- .01% Regulation – output Z from .002 ohms
- Adjustable overload protection

1 μV Full Scale 10 kHz to 30 MHz

Wave Analyzer

TYPE USVH

SELECTIVE MICROVOLT/AMMETER

FEATURES:

- Wide frequency range covers 10 kHz-30 MHz
- Measure Voltage: 1μV to 1V, f.s.d. (—118 dB to +2 dB)
- Measure Current: Clip-on current probe (optional, 0.1 — 30 MHz) 1μA to 1 A, f.s.d.
- Dynamic Range: 60 dB
- Fine Frequency Adjustment: ±2.5 kHz
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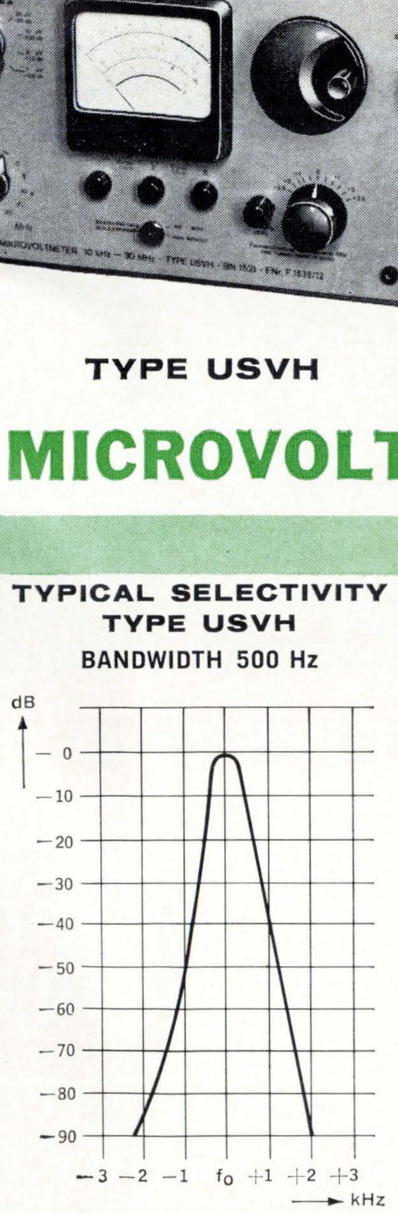
- Noise Level: 0.5μV
- Input Impedances: 50, 60, 75, 150, 600Ω and 500kΩ || 20 pF High impedance probe available.
- Internal reference makes unit self-calibrating.
- Demodulated phone output.
- Economically priced.

TYPICAL SELECTIVITY TYPE USVH

BANDWIDTH 500 Hz



Type USVH Selective Microvolt/ammeter is continuously tunable over the wide frequency range of **10 kHz to 30 MHz.** High sensitivity and selectivity are outstanding features of this superheterodyne receiver with direct readings in volts and decibels. Voltage measuring range covers from 1μV to 1 V f.s.d. with an accuracy of ±3% referred to 1 MHz & 1 V. Measurements can be made to 0.25μV. Frequency response is ±0.5 dB from 20 kHz|— 10 MHz, and ±1.0 dB from 10-20 kHz and 10-30 MHz. Type USVH also can be used for selective current measurements using Clip-On Current Probe, BN 150013. Instrument features selectable bandwidth of 500 & 5000 Hz, and provides six switchable input frequencies.

Applications Include:

- 30 MHz Wave Analyzer
- Attenuation and frequency response measurements on networks up to 140 dB
- Null indicator for high frequency bridges
- Measurements of RF distortion as low as —60 dB
- Inter-Channel cross-talk attenuation measurements on carrier systems

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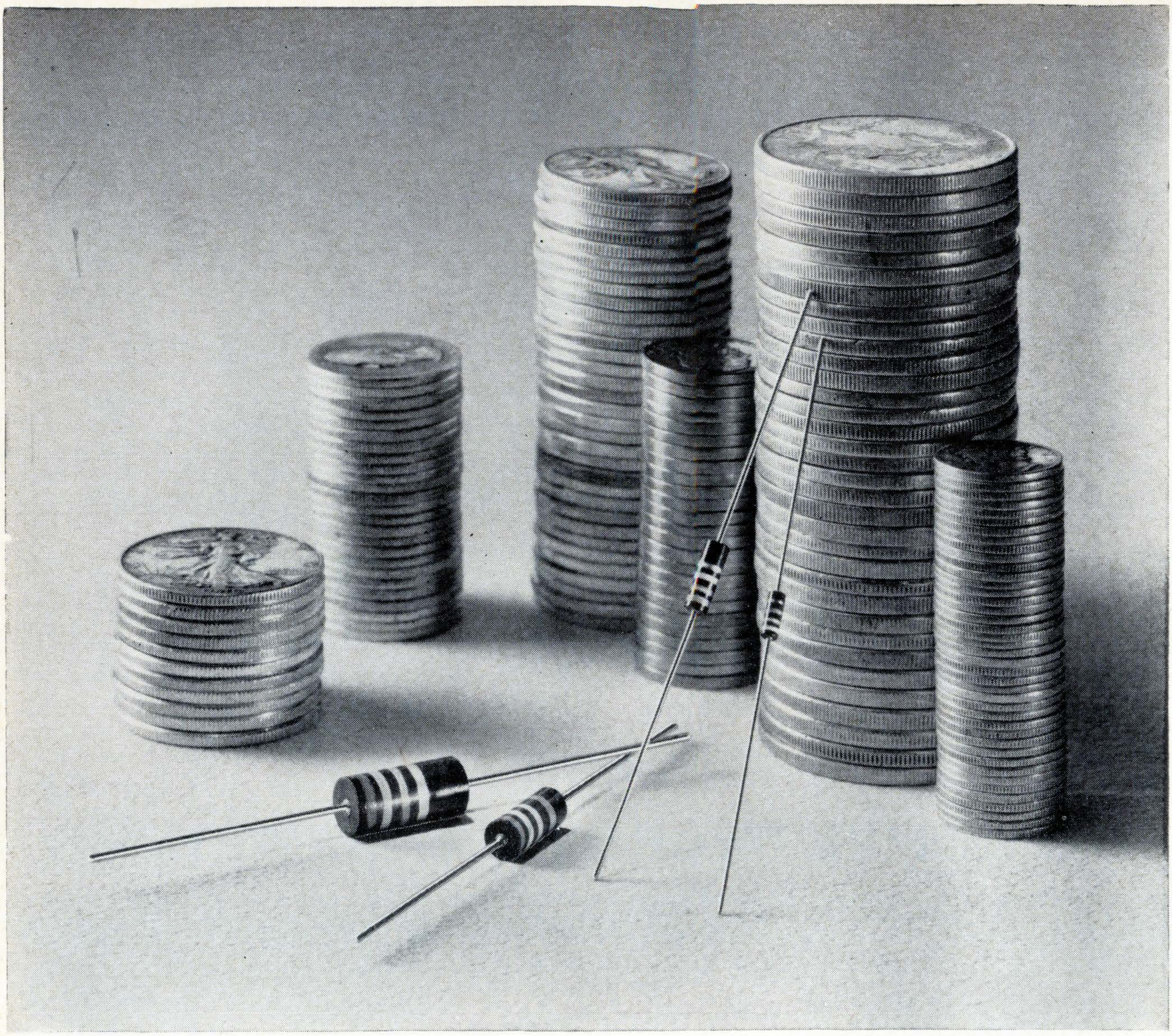

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Some people would have you believe that to buy the best, you must pay the most. This is not necessarily true. Price is only a measure of value—never a substitute for it.

At Stackpole, the real value of any resistor is determined by a combination of its performance record and its price. Perhaps this is why so many of our customers continue to specify Stackpole resistors year after year to maintain top performance for established products and for their new ones, too. Such confidence and loyalty cannot be based on price alone.

Uniformity has become the accepted characteristic of Stackpole resistors. Unique production methods, coupled with in-depth experience in manufacturing and testing are your assurance that Stackpole resistors will give you absolute performance. The resistors you order today will be identical in every way to your last order.

Most leading manufacturers of electronic equipment have long recognized Stackpole resistors for reliability. Whether it be the rugged demands of portable television or the critical tolerances of space age communication and tracking equipment, Stackpole resistors deliver the performance you expect—the kind of dependability that builds a reputation for your products.

Why continue to pay a premium for quality? Let us prove that you get value from Stackpole. Quality resistors, economically priced, are delivered promptly and backed up by our complete corporate facility. Next time, specify Stackpole. There's a family of fine resistors available in sizes of 2, 1, ½ and ¼ watts. For samples and additional information, write: Stackpole Carbon Company, Electronic Components Division, Kane, Pa. Phone: 814-837-7000 — TWX: 510-695-8404.

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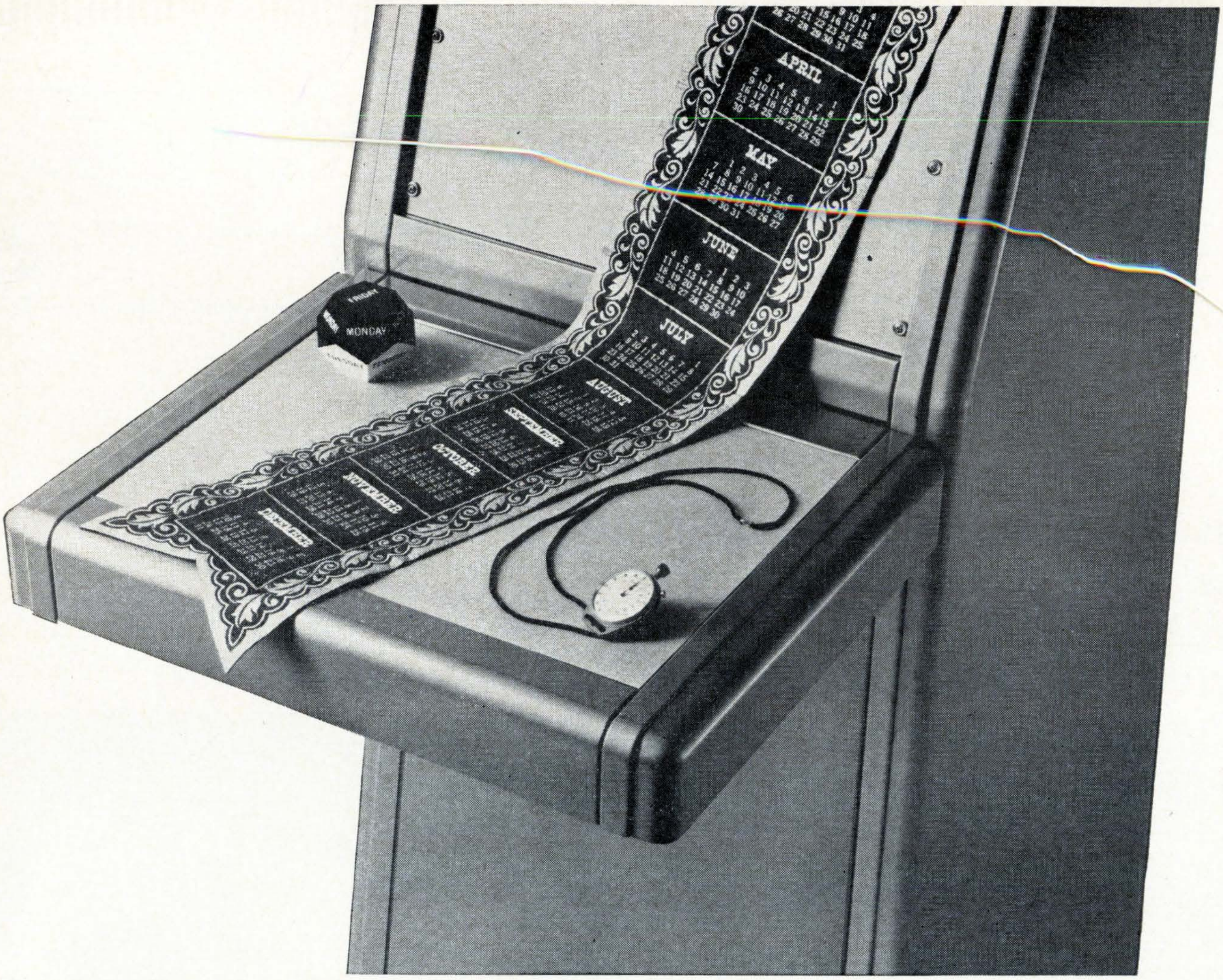

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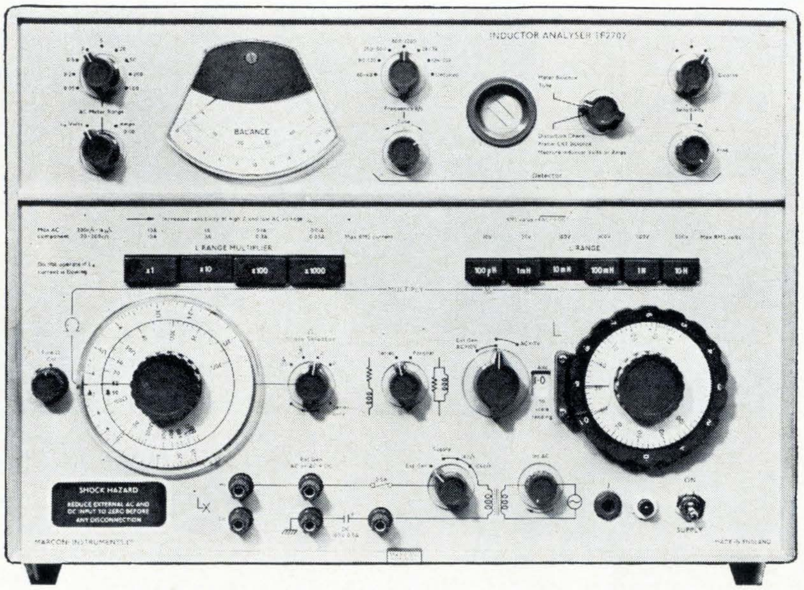

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Our new TF 2702 answers any inductance analysis problem you are ever likely to meet; it does more than any other bridge at any price—and yet it costs only £490. A remarkably low price for the first true *inductor analyser*—both a self-contained low and medium current inductance bridge and the nucleus of a complete high-power inductor test assembly.

Its inductance range (0.3 μH to 21,000 henries) is twenty-one times wider than its nearest competitor's. It can be used at any frequency from 20 Hz to 20 kHz—internal frequencies: 10 kHz, 1 kHz, and 50 Hz. And it switches to Maxwell or Hay configuration for equivalent series or parallel inductance, with loss resistance indicated directly in ohms.

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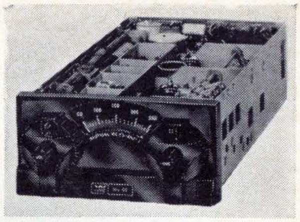
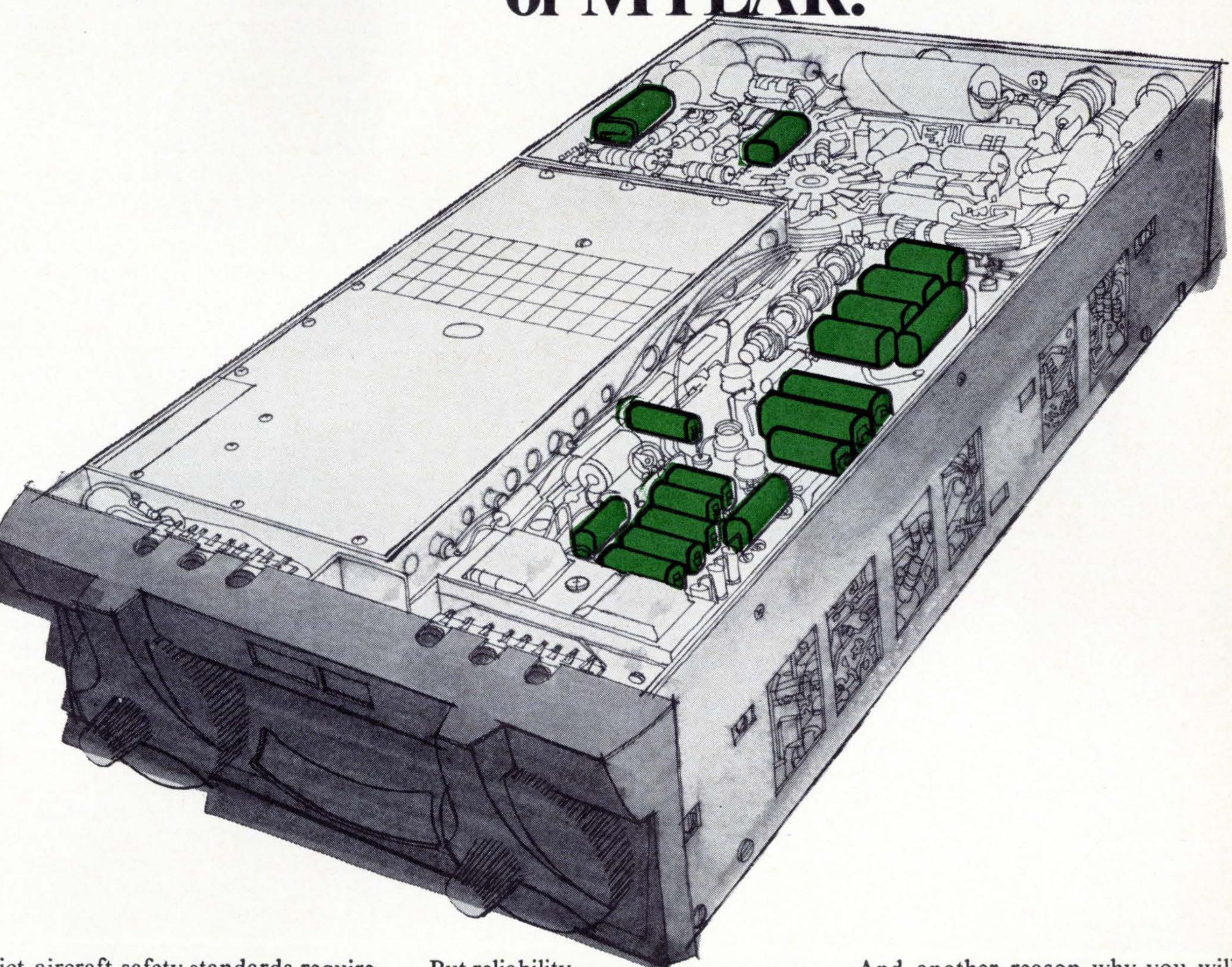


King Radio needed: capacitors that stay reliable even with extreme cold, humidity and vibration.

So King Radio chose: capacitors of MYLAR.



Strict aircraft safety standards require the most reliable navigation equipment available. That's why King Radio Corporation uses capacitors of MYLAR* for their Distance Measuring Equipment. MYLAR can take temperature extremes from −60° to +150°C; MYLAR remains constantly stable under humid conditions.

But reliability isn't the only reason King Radio chose MYLAR. The extremely high dielectric strength of MYLAR permits its use in thinner film, thus helping King Radio to build the lightest and most compact distance measuring unit on the market. MYLAR is available in films as thin as 15 gauge.

And another reason why you will want to investigate using capacitors of MYLAR: they usually cost no more than others. Write for complete technical data to DuPont Company, Room 4960A, Wilmington, Delaware 19898. (In Canada, for information write Du Pont of Canada Ltd., Post Office Box 660, Montreal, Quebec.)

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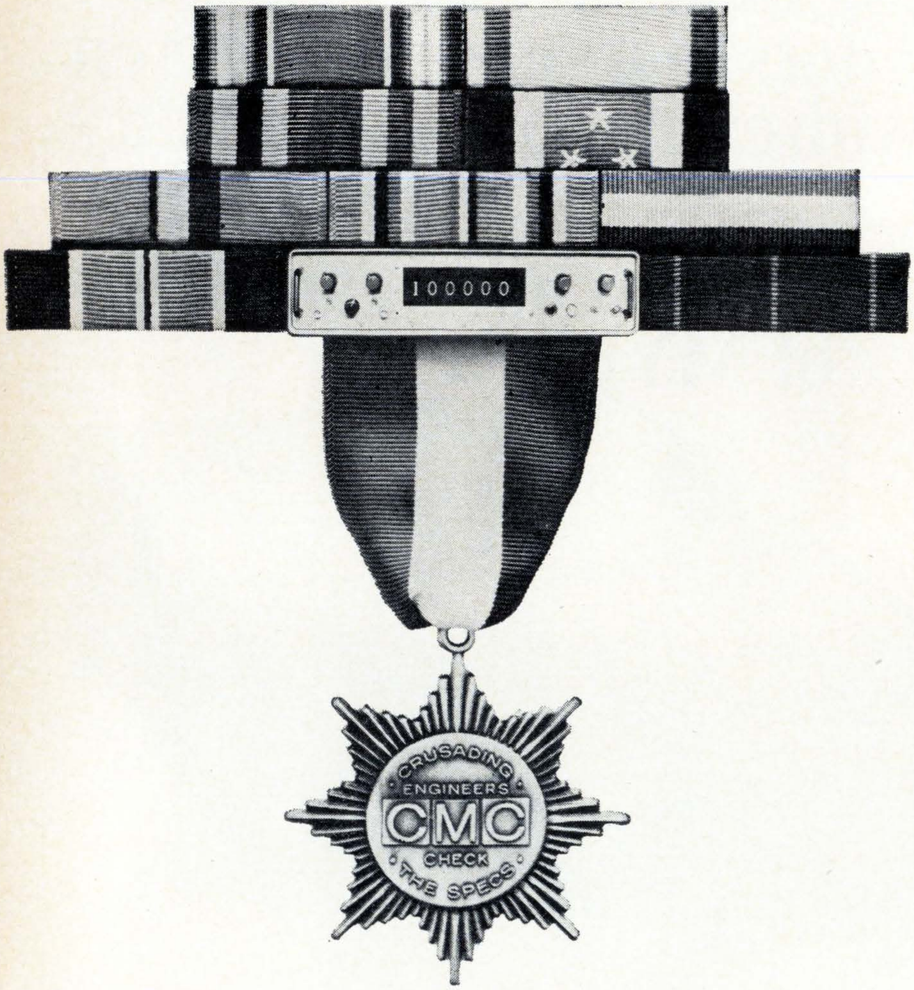
Circle 77 on reader service card



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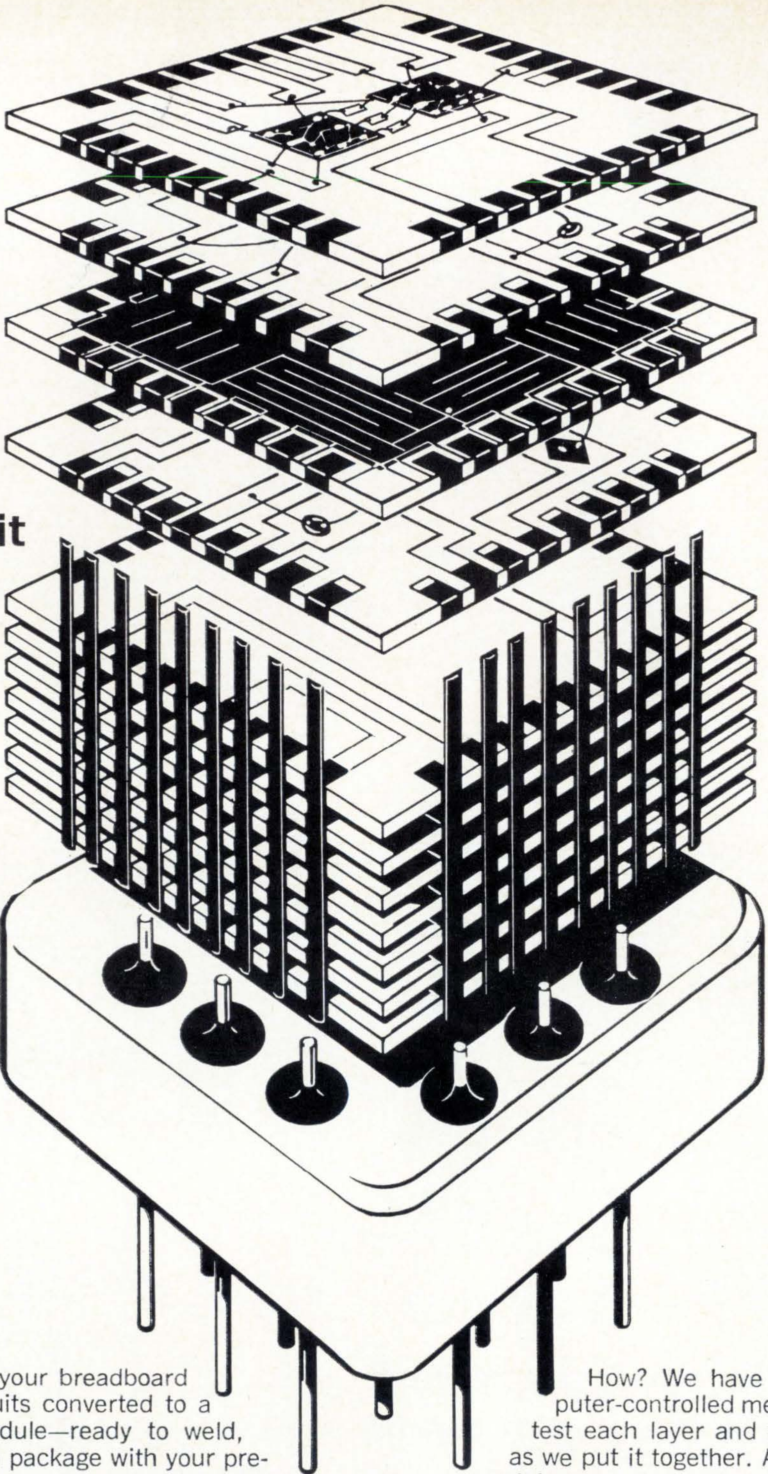

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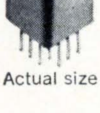

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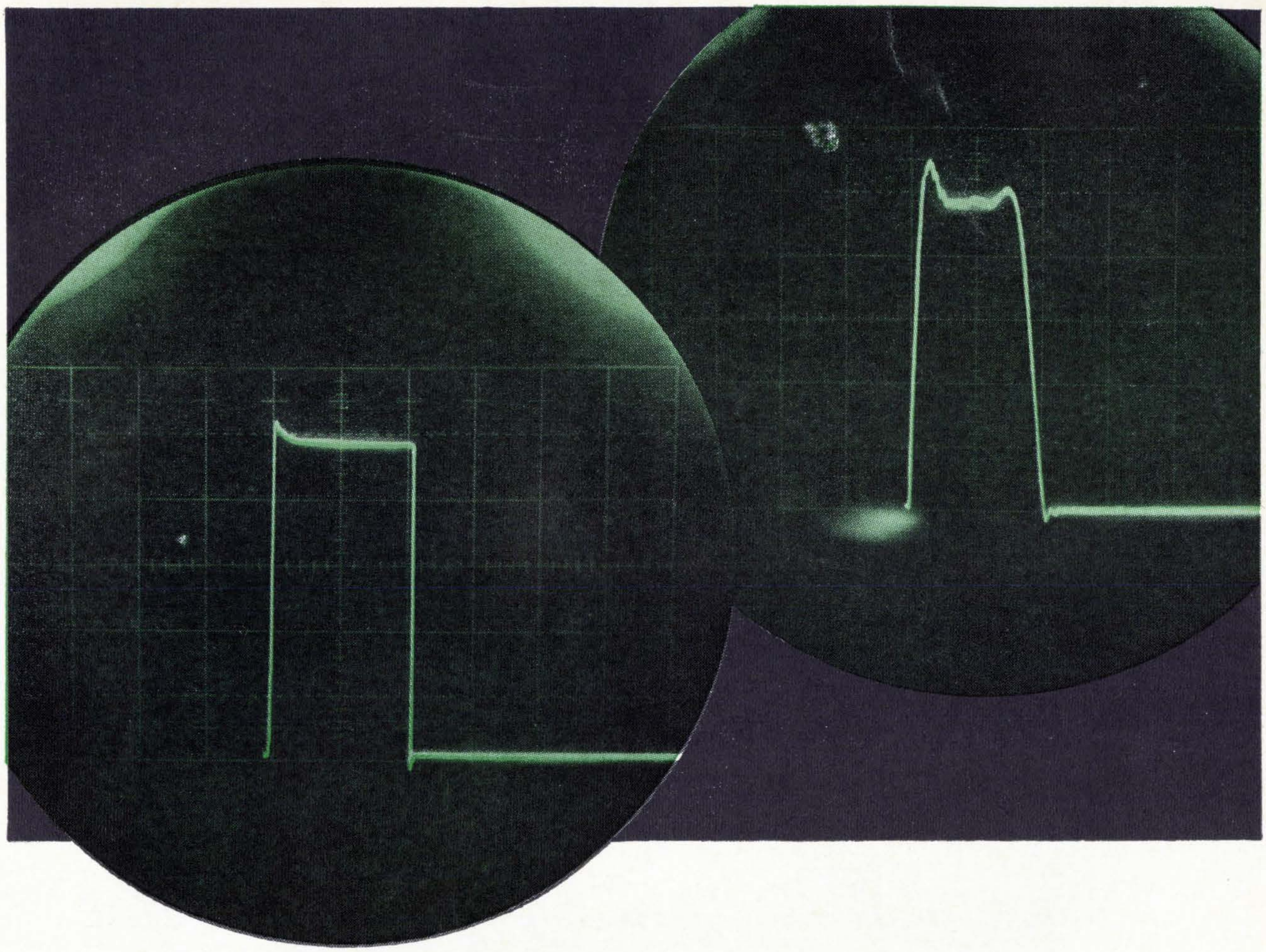

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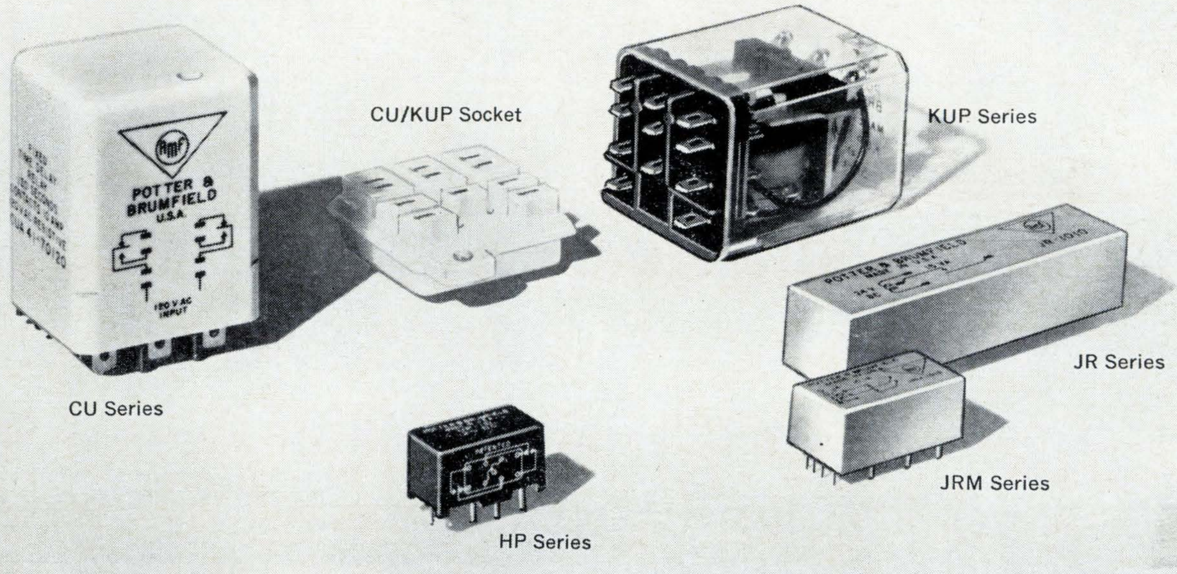

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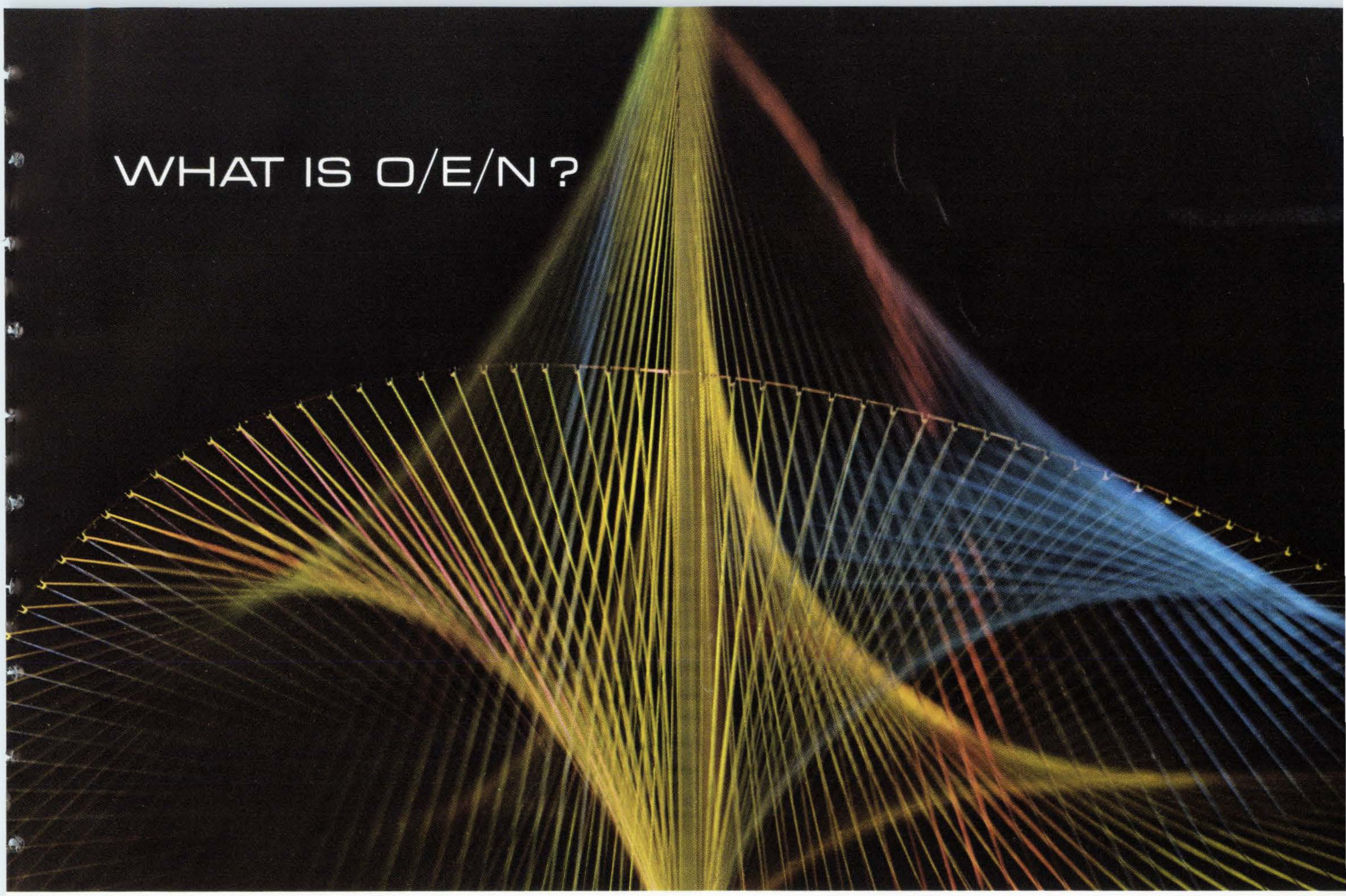

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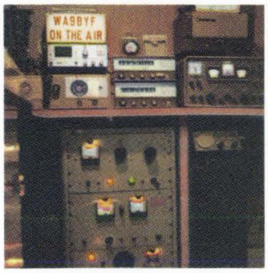

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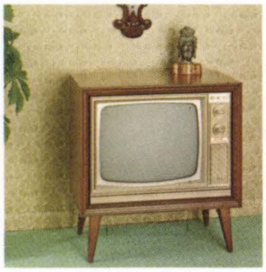

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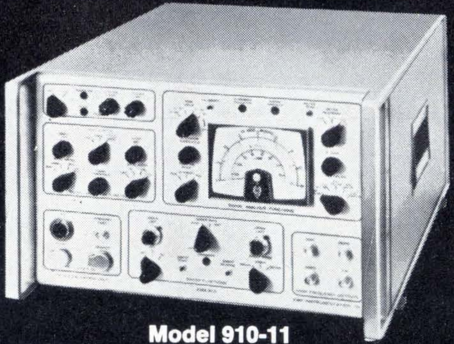

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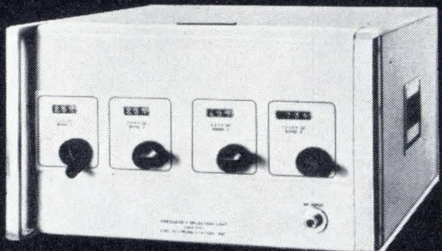

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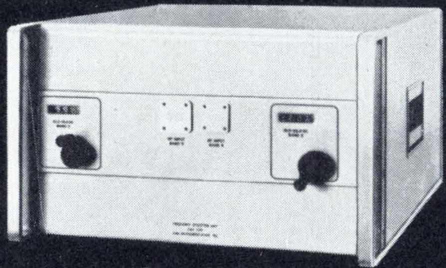

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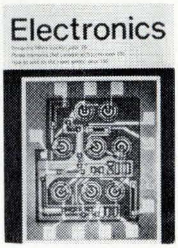
Technical Articles

Overview: Linear integrated circuits page 88



The concept of integrated circuits has been accepted by most electronics engineers because they have been impressed by the success of digital microcircuits in computers and military applications. Now, the use of tiny integrated circuits is spreading to analog functions. In this overview article, the first in a series on linear circuits, an examination is made of the potential market, the approaches that suppliers are taking, the role of monolithic and hybrid circuits, the limitations of linear IC's, and the ways to use them. On the cover is a high-frequency amplifier, typical of the new linear circuits being introduced in increasing variety. It was fabricated by the Microelectronics division of the Philco-Ford Corp.

Laser brightens the picture for IC mask-making camera page 119

For several years now, engineers have talked about the promise of the laser for making the masks that are needed to fabricate integrated circuits. The reason for the interest is the high resolution that a laser instrument would allow. This article describes a step-and-repeat camera that is controlled by a laser interferometer. Its resolution is 600 lines per millimeter; its repeatability is 12.5 microinches.

Special report: Medical electronics, Part III, page 125

This final part of a special report on medical electronics explores three areas:

6. Helping hands (p. 125). An examination of how electronic components and signal-processing techniques help build better prosthetic devices for amputees.

7. Vigilant machines (p. 132). Electronic monitoring equipment that can watch critically ill patients continuously has already dramatically reduced the mortality rate among such patients. The need is particularly crucial in the case of victims of heart attacks.

8. More than an ounce of prevention (p. 134). The goal among one segment of doctors is to predict the onset of illness by repeatedly measuring certain important body variables and then comparing their values over months or years. The belief is that most illnesses do not happen suddenly, but build up over a period of time.

Coming August 21

- **An examination of linear IC's: operational and differential amplifiers**
- **Designing circuits to protect against radiation**
- **A multiple winding choke simplifies filters**
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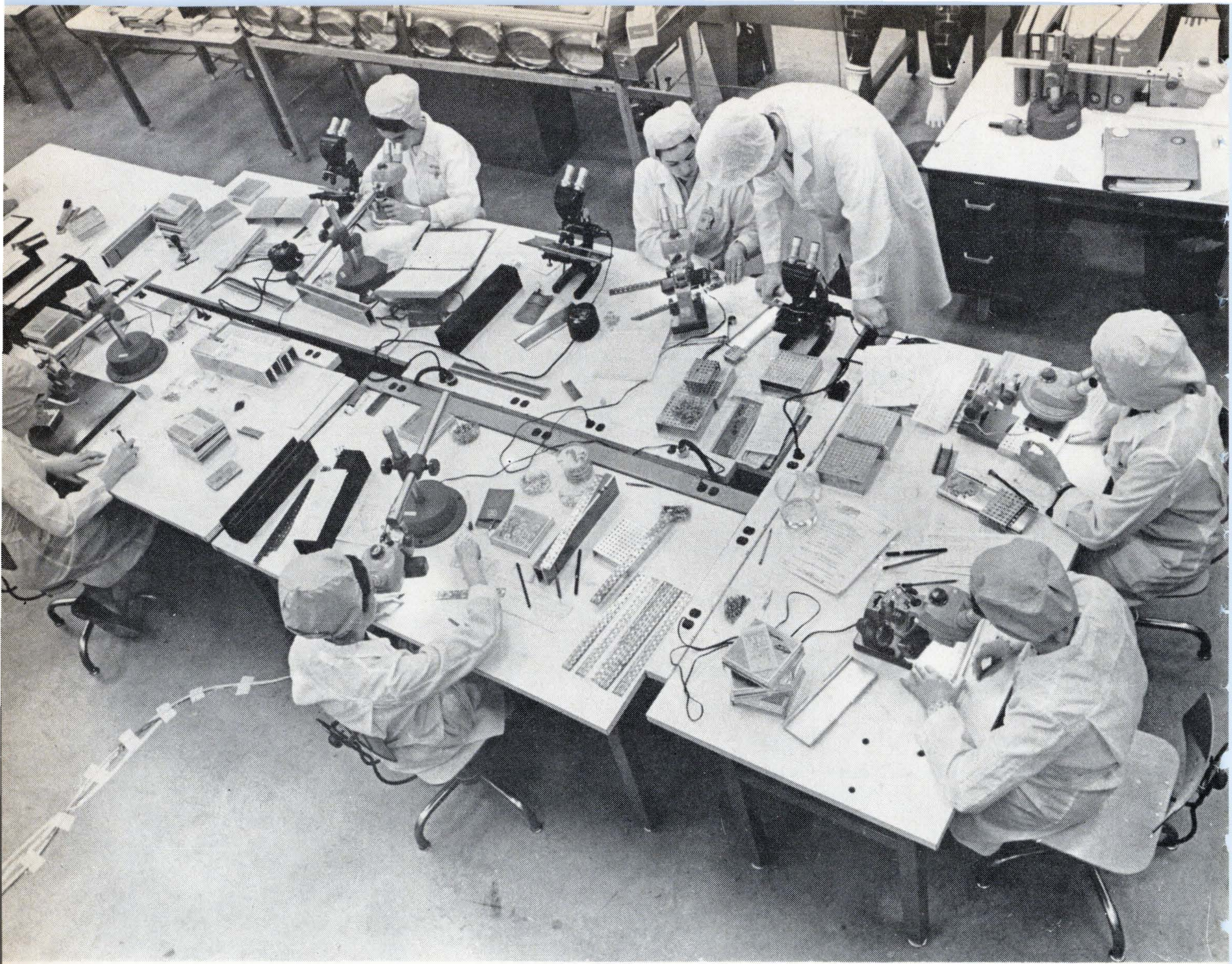


Line up. Inspection workers examine linear integrated circuits prior to sealing and shipment at Westinghouse's Molecular Electronics plant.

Special report

Linear integrated circuits are coming into their own and will affect every segment of the electronics industry.

In this overview, the first in a comprehensive series on linear IC's, Electronics examines the market (page 89), the monolithic technology (page 100), the hybrid technology and the relation of linears to the rest of the IC world (page 107). Covered are the evolution of linear IC's, the shape of the market, product and merchandising trends, a profile sketch of the makers, and projections of linear growth into the 1970's. In addition, the article describes the how and why of linear IC design, compares the linear IC with competitive devices and networks, and demonstrates where they can be and should be used.

Future reports will probe the integral parts of the linear IC spectrum —operational amplifiers, communications circuits, etc.

Scrambling for linear IC business

Although the linear integrated circuit push has only begun, the growth rate exceeds that of digital IC's; as sales boom manufacturers jockey for position

By Mark B. Leeds
Solid state editor

Asked about the boom in linear integrated circuits, an executive at Motorola Semiconductor Products Inc. replied: "Linears have arrived because the technology is sound, the pricing is economic for most users and there are more applications for analog IC's than there are for digital. As the technology improves, cost per function will drop, new, mass-outlet markets will emerge, and I doubt if anyone will design a television set better and more economically using digital IC's."

This opinion reflects the sentiment of the semiconductor industry as it watches sales of linear IC's expand at rates higher than any other major semiconductor product. There will still be a place —and a large one—for digital IC's. Even the most optimistic prophets of linear IC achievement expect them to account for no more than 40% of total IC sales, with that peak percentage not occurring until the early 1970's.

Part of the success of linear integrated circuits is due to a recent, extensive merchandising effort by the makers. Another factor is user acceptance of the IC concept, made possible by the digital IC. But in the main, linears are winning approval because they cost less than discrete semiconductor and vacuum tube networks in a wide variety of applications.

Production and sales are up

Production is up tenfold over last year, sales are climbing fast and the average price per chip is down. Mass outlets have been defined and penetrated; the technology is already yielding products for further market conquests; and makers are scrambling to increase their market share.

Last year digital IC's dominated the microelectronics scene; linears accounted for less than 20% of the total IC sales volume in dollars and about 8% of the number of units sold. This year, linears are accounting for 25% of the dollars and 10% of the units.

Linear IC growth rates have risen to nearly triple that of digital units. In the first half of 1966, linear volume and sales were 600,000 pieces and $11.6 million; for the same period in 1967, the figures are approaching 2,300,000 units and $25 million, increases of 350% and 106%, respectively. The comparable half-year figures for logic units show increases of 125% and 45%.

Estimates of linear IC sales for 1968 indicate they'll hit $90 million; by 1970, the volume may reach $155 million. Ben A. Jacoby, the Radio Corp. of America's marketing manager for IC's, expects the volume to approach 150 million units a year by then, despite the fact that automotive and consumer industries won't be using IC's in large quantities. And by the early 1970's, linear IC's are expected to saturate these enormous markets.

The lines were drawn

Just a few years ago, the linear IC was not accorded much of a chance to become an equal working partner of the digital integrated circuit. Makers and would-be users doubted that linears would ever become widely used semiconductor products. Technological limitations, the marketing situation, and the specter of direct digital control (DDC) posed nearly insurmountable barriers; linears appeared destined for special-purpose, small-volume applications.

Technologically, it was said, linears couldn't provide the same electronic functions as discrete semiconductor circuits and vacuum tube networks. Passive elements were tough or impossible to fabricate and were more costly than active elements; high-performance pnp devices to work with npn elements were costly and hard to make.

There were other drawbacks. Signal-handling levels in analog systems were too high for linear IC's. Frequency needs were similarly too high. And how far could a linear IC go in the way of functioning, with its innate d-c operation [see "Design ingenuity is the key to success," page 100] facing the biasing, filtering, and other a-c requirements typical of analog applications?

Logic IC's had a ready-made market in the computer industry which encouraged and awaited them. But linears were not equally sought after. The only high-volume estimates were being made for the automotive and consumer entertainment equipment markets—both extremely cost-conscious industries and both with little need for the $40 operational amplifiers that typified linear IC products. These industries wanted voltage regulators, sound-processing strips, audio drivers, and other basic IC's—costing a dollar or two each.

Linear IC development didn't get much help from the Government. Of the funds available, the lion's share went into digital IC's. The small sums for linears went into microwave phased-arrays and other subsystems that couldn't easily be translated into industrial and consumer products. In industry, investment capital was already earmarked for logic IC's and large-scale integration (LSI), so linear IC efforts were hamstrung.

Additionally, experts were predicting the steady replacement of analog methods with direct digital control, so manufacturers held back on analog product improvements.

Despite these portents of a small demand, analog IC's have come on strong. Nearly every major technological limitation has been solved—in many cases by ingenious design. Linear IC's costing under $2 are on the market and the manufacturers of tv sets and other consumer products have resisted DDC; they're still using linear techniques.

Consumer market ahead

The bulk of the dollar volume until now has been for operational amplifiers and differential amplifiers, largely because they can be used in a variety of applications. Signal-processing, signal generation, control, and instrumentation are but a few of the roles these IC's fill.

While other linear types have enjoyed relatively small sales success, this picture is changing. Also, the overwhelming majority of IC's—at least 75%, according to a Texas Instruments Incorporated spokesman—have thus far been for military and aerospace applications; industrial and consumer usage has been minimal. In the latter, instrumentation engineers have used linear IC's; makers of tv sets, radios, and the like are evaluating them.

Yet the semiconductor industry believes that by 1970, linear IC success will be shared by a number of different product types. Operational and differential amplifiers will still command a substantial share of the business, but communications circuits, units for computer periphery applications (sense amplifiers, interface networks, etc.), IC's for timing and control, and other types will be widely used. And by that time, the amount going for military and space systems is expected to be less than 50% of the total linear volume.

Experts predict that by the early 1970's, the use of linear IC's in automotive and consumer products will outpace all other markets. Some 90% of the electronic functions in tv sets, radios, phonographs, recorders, and nearly all present electrical functions in automobiles, as well as some new ones concerning safety and maintenance, will be performed by linear IC's—most of them complex, multifunction types.

Linear IC's are also going into applications formerly impractical with discrete components. In medical electronics, for example, new devices are small enough to be implanted in the body. Coupled to appropriate transducers, such items as detectors, amplifiers, and pulse generators—on tiny hybrid chips—will be used for diagnosis and treatment.

Follow the leader

There is no clear-cut leader in sales or technology, but most makers grudgingly concede that Fairchild Semiconductor, a division of the Fairchild Camera & Instrument Corp., has probably sold more off-the-shelf monolithic linear IC's than anybody else. The success of Fairchild is due mainly to its early introduction of a number of operational amplifier products and other low- and medium-frequency analog units. Almost universal in terms of application, these devices, with their attendant size, reliability, and cost-savings advantages, initiated the linear IC success story.

One, the μA709 premium operational amplifier, has established a dominance like that of the 2N697, the semiconductor industry's most popular transistor. Today, nearly a dozen firms make 709-type units, most of which are second-source items. These firms call their IC's 1709, 809, SN52709, etc.—some use 709 prefixed by a letter identifying the maker. Others have recently introduced operational amplifiers—with claims of higher gain, less stringent

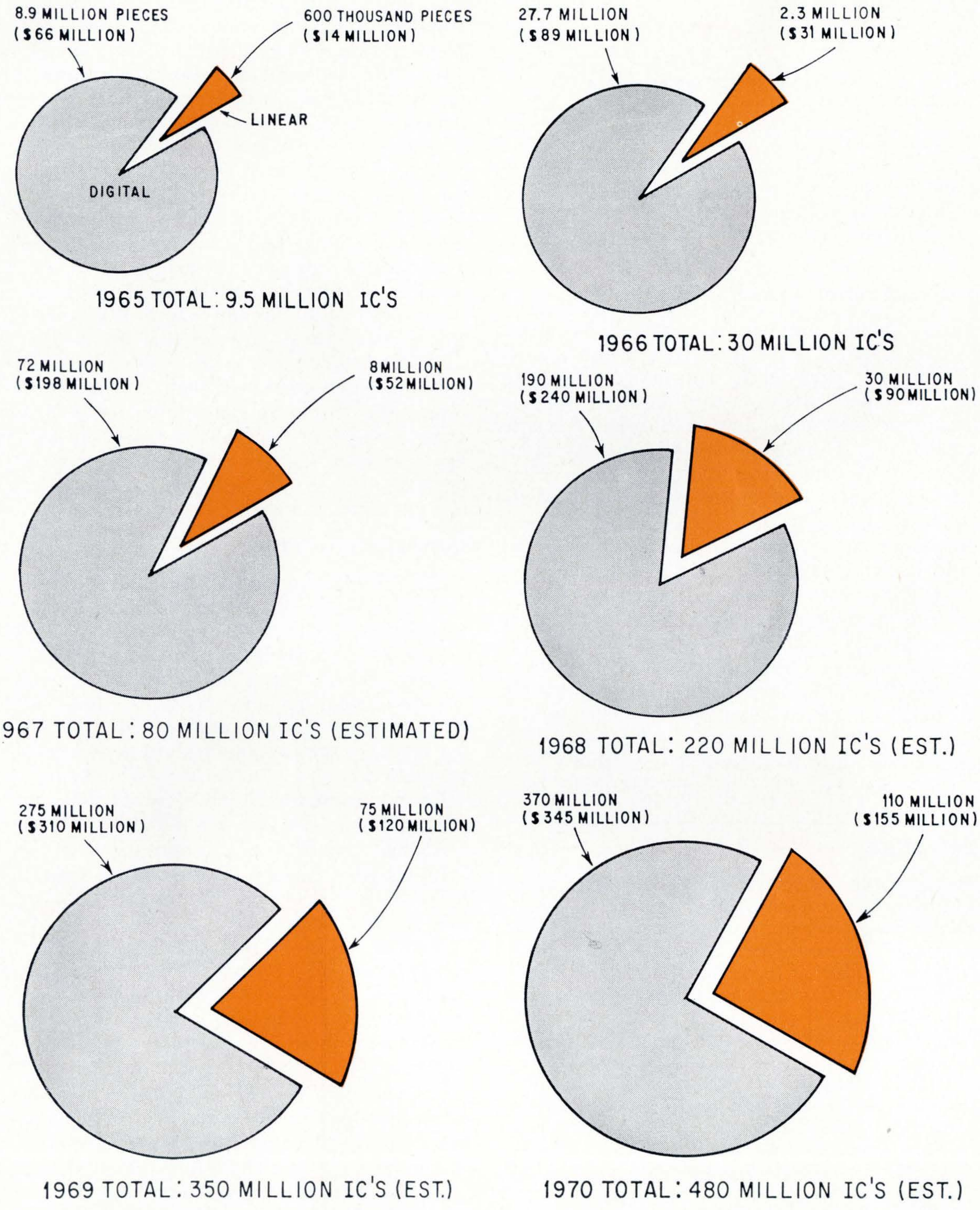
Definitions: drawing the lines

To the electronics engineer, linear integrated circuits—also called analog IC's—mean any IC's that aren't digital. But that clear-cut definition becomes muddled; the application of analog IC's is not always analog and linear IC's often have nonlinear characteristics. The traditional straight-line relationship, $y = mx + b$, doesn't necessarily express the operation of all linear chips—good examples are logarithmic amplifiers and demodulators.

The difference between digital and linear IC's is this: the logic unit operates with a discontinuous response; the analog unit produces a continuous, proportional response.

Jack Gifford, manager of linear IC marketing at Fairchild Semiconductor, suggests that linear IC's operating at frequencies below 10 Mhz be called analog types and those functioning at 10 Mhz and higher be called communication units. Acceptance of the terms may place them in the IC lexicon.

The IC sales picture: linears become a major shareholder



Pieces of the IC pie. Linear integrated circuits continue to chip away at the digital IC's. A few years ago linears accounted for less than 8% of the number and less than 20% of the dollar volumes of all IC's. This year the respective chunks will reach 10% and 22%; by 1970, the linear portion is expected to account for 24% of the number sold and 31% of the dollar volume. Why?—because mass-outlet markets have begun to realize that linear IC's are technically equal to and more economical than discrete component circuits.

Comparison of average prices

	Linear	Digital
1965	$25.06	$7.25
1966	13.37	4.33
1967	7.50	3.00
1968	3.00	1.50
1969	1.60	1.25
1970	1.40	1.08

(figures for 1968-1970 are estimates)

compensation needs, more bandwidth—and entire lines of specialized operational amplifiers, all intended to chip away at the 709. Fairchild has recently introduced linear IC's for consumer applications, and plans to broaden its communication IC product lines.

Substantial custom market

Close behind Fairchild is Texas Instruments. TI has enjoyed its biggest success in the custom-circuit market, particularly with military and aerospace customers. Since custom linear IC sales account for 40% of all the units sold, TI had a healthy market to tap. During the last few months TI has added a dozen new linear IC's to its product line, including general- and special-purpose operational amplifiers, high-frequency circuits, and basic communications subsystems, of the monolithic and hybrid varieties, all off-the-shelf items.

TI is also about to market dual-in-line, plastic-packaged versions of the basic operational amplifier series—types 702, 709, 710, and 711. The company has stockpiled large quantities of these items. Pricing will be 40% below existing cost structures, and both a military-temperature range version (—55° to +125°C) and an industrial temperature range version (0 to 70°C) will be available.

During the last nine months Motorola Inc.'s Semiconductor Products division has pushed forward with bread-and-butter linear circuits and some which advanced the state of the art. Among the former are operational amplifiers, audio amplifiers, sense amplifiers, and narrow-band amplifiers; in the latter are ultrahigh gain-bandwidth types, r-f amplifiers, dual operational amplifiers, and complex communications circuits. The firm has also won major contracts of several years duration, including a multimillion dollar order from the General Dynamics Corp.'s Pomona division for linears for the Redeye [Electronics, Oct. 17, 1966, p. 77].

Other firms are making extensive efforts to capture large chunks of the expanding market. The General Electric Co., a relative latecomer to the field, is pushing linears harder than digital IC's. The firm has introduced low-cost amplifiers, communications circuits, and a variety of brand new types—such as IC's for power control systems [Electronics, May 15, p. 26 and June 26, p. 10]. GE's big advantage is its strong position in industrial and consumer areas. GE engineers point to the company's new $7.5 million IC center in Syracuse as an example of the firm's resolve. The company has started an extensive effort to mechanize production so it can also build low-cost hybrid linear IC's for mass markets.

Communications thrust

RCA's Electronic Components and Devices division is considered the leader in linear IC's for communications applications. Like GE, RCA is using linears as the spearhead of its integrated circuit activity. The firm isn't neglecting the operational and differential amplifier products either and has low-cost items in these and related areas, including multifunction communication networks selling for under $2.

RCA's current product line, series 3000, is one of the industry's largest, with 36 different items.

At the Molecular Electronics division of the Westinghouse Electric Corp.—in the game early and considered a technology leader—the strength thus far has been in low- and medium-frequency amplifiers and associated circuitry. The firm had concentrated on serving military and aerospace needs, but is now shifting part of its emphasis to industrial and consumer quarters. Westinghouse recently introduced IC's containing SCR elements for control applications.

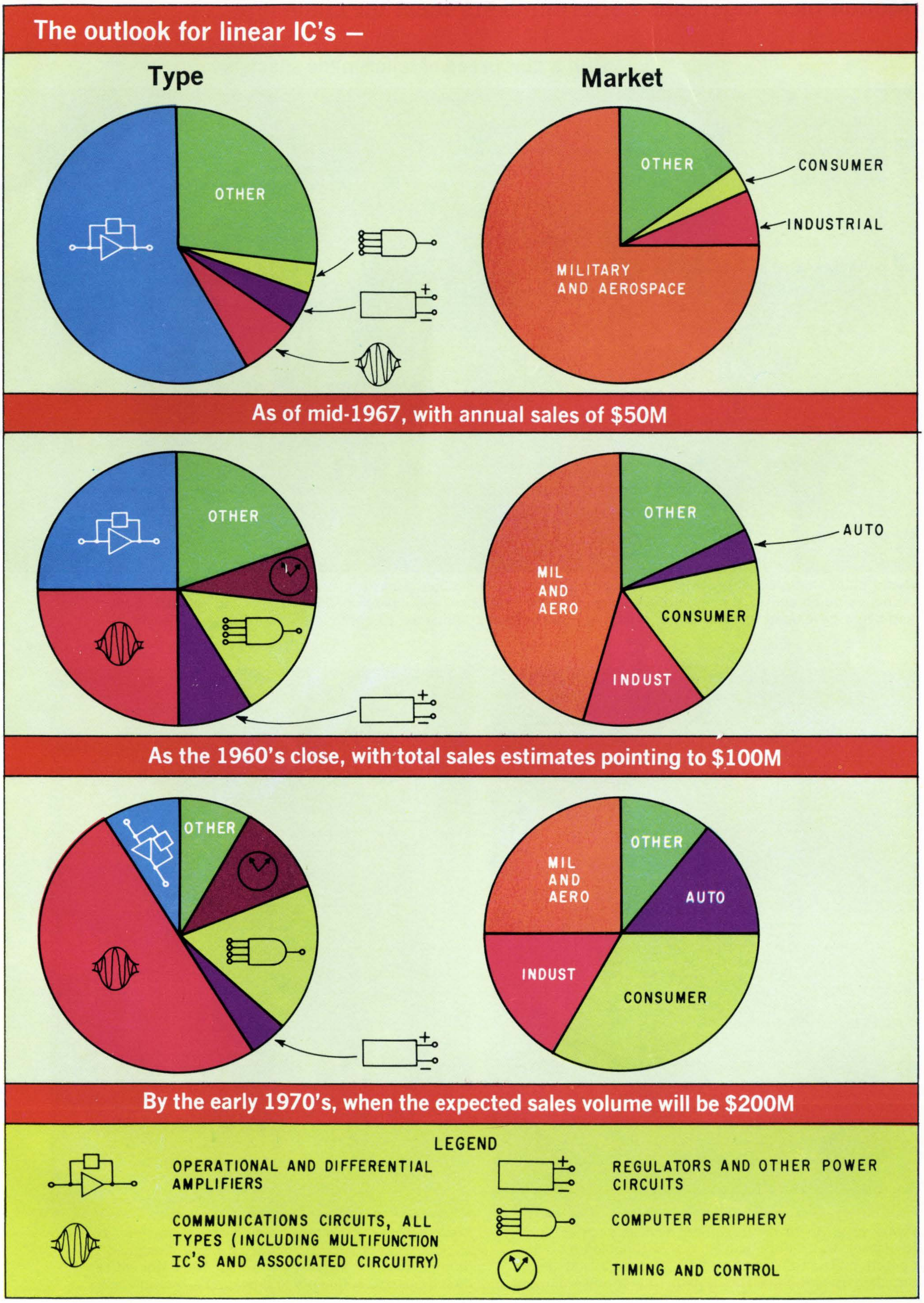
Product emphasis at Westinghouse has centered on medium-frequency operational amplifiers, general-purpose differential amplifiers, preamplifiers, and audio amplifiers. The firm is extending its high-frequency linear IC product line, and is currently developing complex communications types.

The Microelectronics division of the Philco-Ford Corp. has been active in the communications area, particularly with high-frequency IC's and products for consumer and auto applications [Electronics, May 1, p. 26 and July 10, p. 50]. It is also making operational and differential amplifiers on a second-source basis. Philco-Ford's production during the

Slow start

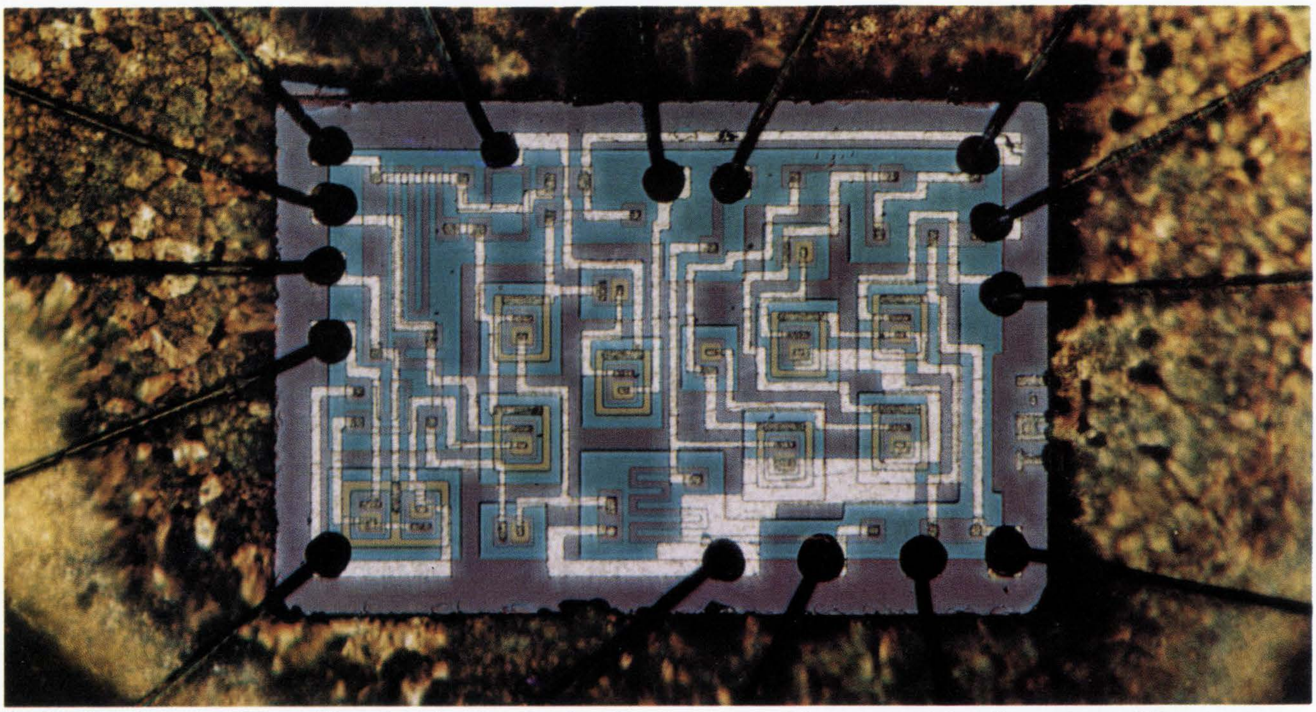
The first linear integrated circuits that were more than laboratory curiosities came from Texas Instruments, which developed the very first IC, a flip-flop, back in 1959. The linears, along with digital units, were then called solid circuit semiconductor networks. Linear IC activity remained fairly dormant until 1962; then TI received a contract from the North American Aviation Inc.'s Autonetics division for linear IC's in the Air Force's Minuteman program. It introduced the first off-the-shelf monolithic linear IC's, series-52 devices, in December of 1962. These were operational amplifiers with npn and pnp transistor elements; the gain of each was a modest 62 db and the half-power frequency point was 60 kilohertz.

The first linear IC's that were widely accepted, units that are now industry standards, were Fairchild Semiconductor's μA700 family, launched in 1965—in particular the 702 and 709. These amplifiers parallel the prominence of the 2N404 and 2N697 bipolar transistors, kingpins of the discrete technology. More μA709 operational amplifiers have been sold than any other linear IC product.

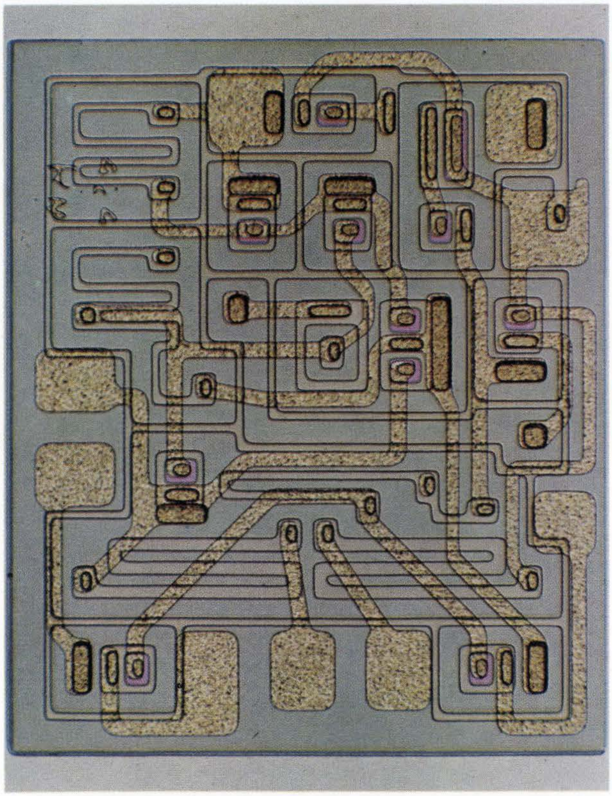

The outlook for linear IC's —
Type
Market
OTHER
OTHER
CONSUMER
INDUSTRIAL
MILITARY
AND AEROSPACE
As of mid-1967, with annual sales of $50M
OTHER
OTHER
AUTO
MIL
AND
AERO
CONSUMER
INDUST
As the 1960's close, with total sales estimates pointing to $100M
OTHER
OTHER
MIL
AND
AERO
AUTO
INDUST
CONSUMER
By the early 1970's, when the expected sales volume will be $200M
LEGEND
OPERATIONAL AND DIFFERENTIAL AMPLIFIERS
REGULATORS AND OTHER POWER CIRCUITS
COMMUNICATIONS CIRCUITS, ALL TYPES (INCLUDING MULTIFUNCTION IC'S AND ASSOCIATED CIRCUITRY)
COMPUTER PERIPHERY
TIMING AND CONTROL

Monolithics: ingenious pattern-makers meet the challenge . . .

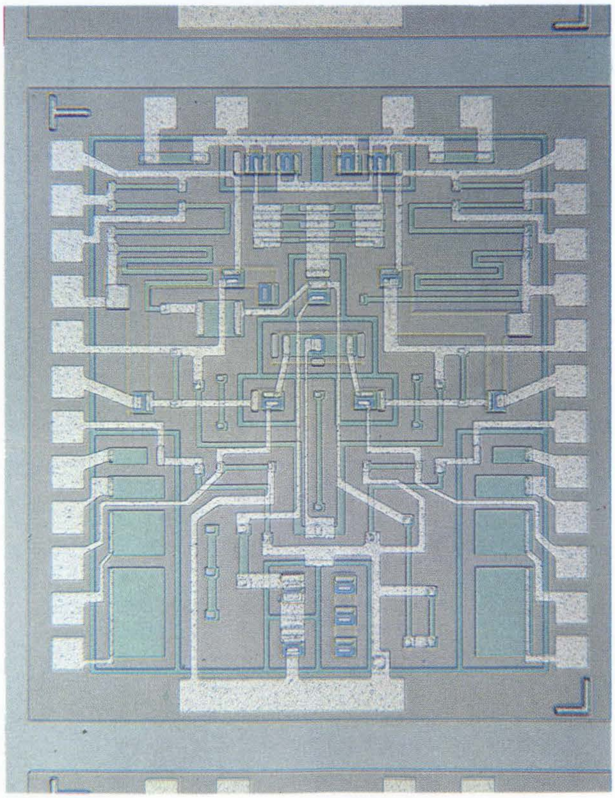
. . . with a new breed of tailor-made specials . . .



Radio chip. Complex IC providing five signal-processing functions is used in commercial radio-receivers. Chip amplifies audio and i-f signals, provides agc, detects envelopes, and has temperature-stabilizing network. Sony engineers developed the unit rather than use three or four commercial IC's with one or two functions each.

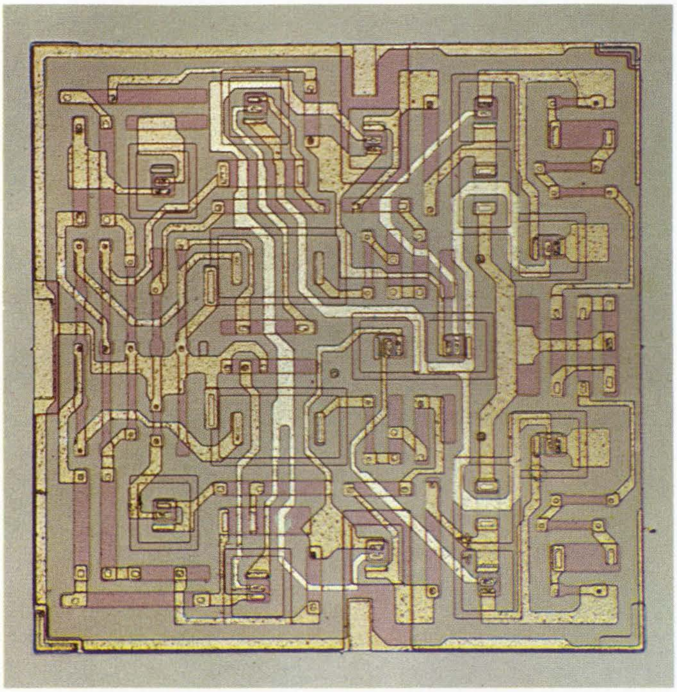


Power play. IC for driving-power devices such as thyristors, transistors, and relays, is capable of a-c line operation. The GE unit, type PA424, detects voltage, unbalances and generates timed, trigger-pulse outputs.

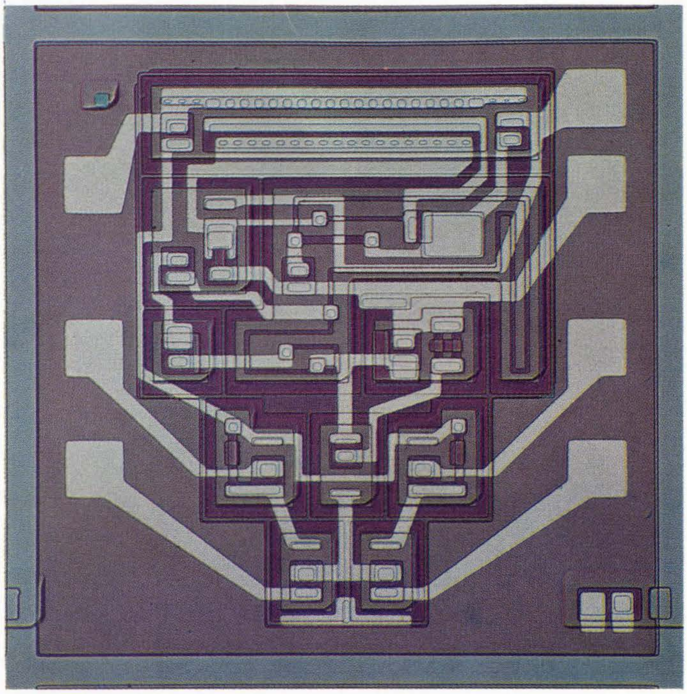


Citizen-soldier. Elaborate gain-control circuit can be used in both color-tv sets and radar i-f strips. Designed by Sprague Electric, variable electronic attenuator works directly with IC amplifiers to provide the agc function.

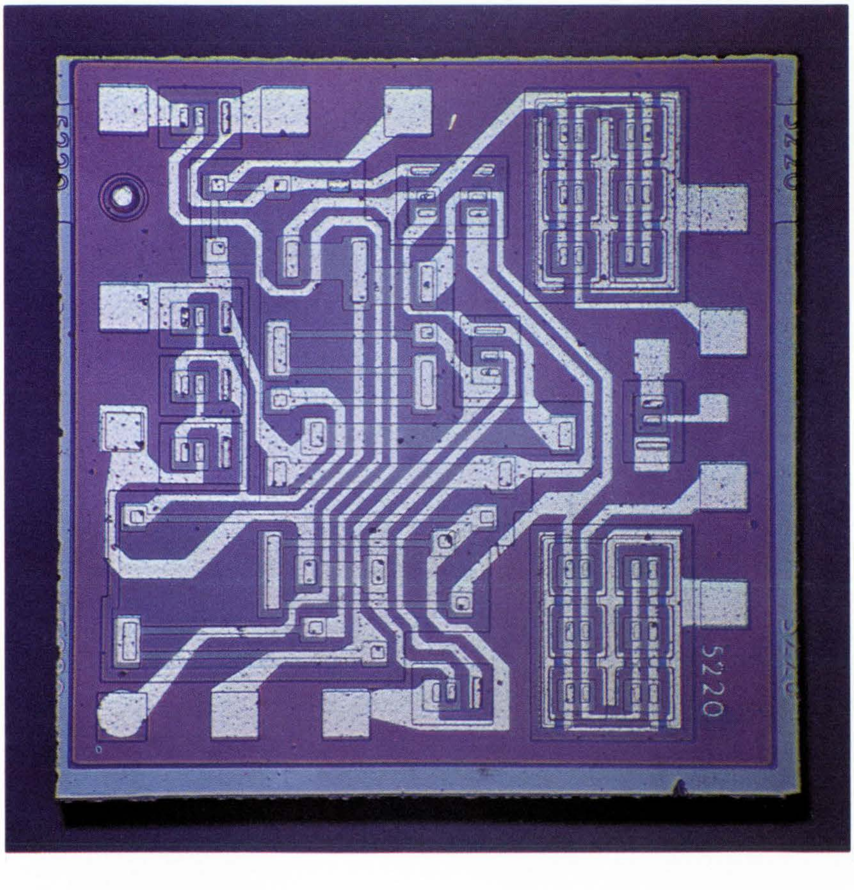
. . . and improved versions of standard IC types



Wide screen. High-gain video amplifier from TI is improved version of earlier wideband differential amplifier. The SN5511's stages have a three-octave spread in frequency breakpoints; additional elements on chip help maintain 30 db of gain over a 35-Mhz bandwidth.

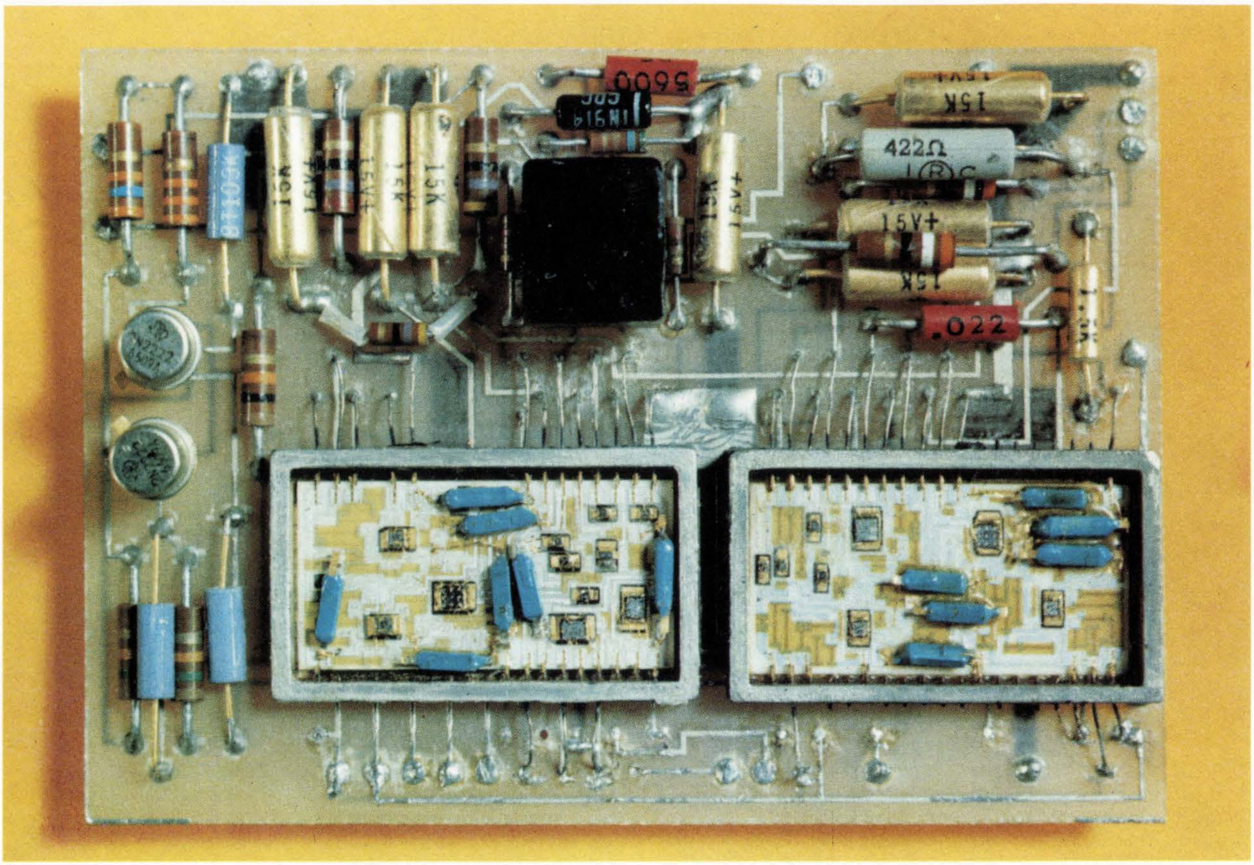


Stable IC. Self-tracking preamplifier mitigates performance variations caused by temperature change. An offshoot of an earlier linear amplifier, this Fairchild μA726 contains a two-stage feedback amplifier which senses chip temperature and regulates current supply accordingly.

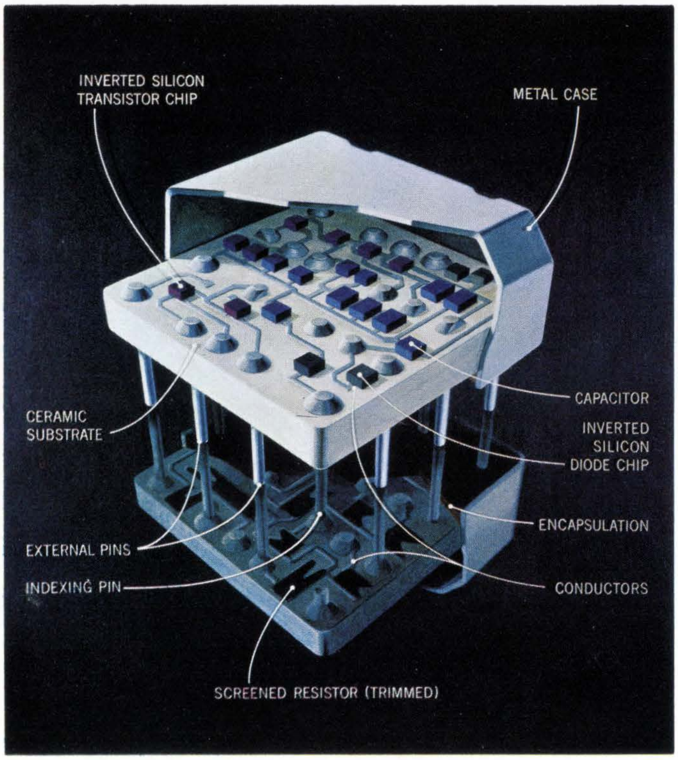


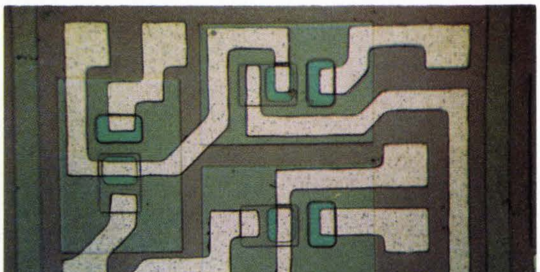
Universal IC. Wideband multistage circuit, RCA's CA3020, is outgrowth of simple audio-frequency differential amplifier. Modified chip contains additional stages and elements, and is configured for general-purpose applications. Unit may be used for communications, control, cable-driving, and even as a quasi-operational amplifier.

The hybrid IC world: sophisticated subsystems to economy packages



Super card. Video-processing subsystem, a radar range gate filter, contains two complex IC's having about 150 elements each. The 40-lead flatpacks, developed by GE Aerospace engineers, contain both monolithic and thin-film elements. The range gate filter consists of input, clutter rejection, amplifier, detector, integrator, and output circuits in a space less than one-sixth that of previous discrete semiconductor cards.





Active pattern. Monolithic dual common-emitter pairs provide the active functions in hybrids. Access to each of the four transistor elements gives users the option of any or all devices and bypassing of substandard units.

Tv fade-in. IC combines diverse elements not mutually amenable to monolithic fabrication for use in television sets' f-m sound system. TI developed this chip as a direct replacement for existing discrete and tube circuits.

first quarter of 1967 was up 15 times over the same period in 1966; through other divisions of the company, the Microelectronics division reaches the entertainment equipment market and the automotive industry. The firm has developed some of the most complex monolithic linear IC's now available [Electronics, July 10, p. 50], and is working on a number of linear IC subsystems for the Government in radar and communications equipment.

In the black

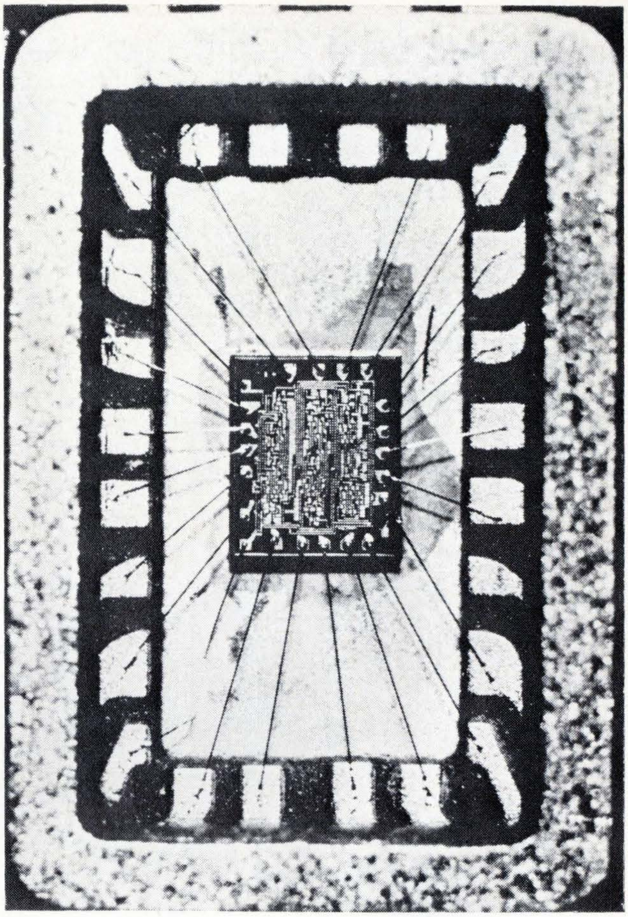
The Signetics Corp. which boasts that its total IC effort, nearly all digital thus far, has already reached the profitable stage, is expanding its linear IC lines. It has plans for dual operational amplifiers, dual i-f and r-f amplifiers, and IC's for motor-control and voltage regulation. Signetics currently makes a few operational and high-frequency amplifiers. The firm is also developing linear hybrids for Touch-Tone dialing, monolithic function generators, and interface circuitry for computer applications.

The Norden division of the United Aircraft Corp. has been carving out a place in the linear IC field with premium-type products, particularly with high-power handling units. The company has a number of IC's for applications in the 10- to 40-watt area and has introduced basic operational and differential amplifiers and preamplifiers. Soon to be introduced, says Eugene Tatom, engineering manager of the microcircuits department, are active filters, function generators, bigger and more sophisticated operational amplifiers, and linears for computer-periphery applications. Among the latter are sense amplifiers, line receivers, analog-to-digital converters, and level shifters.

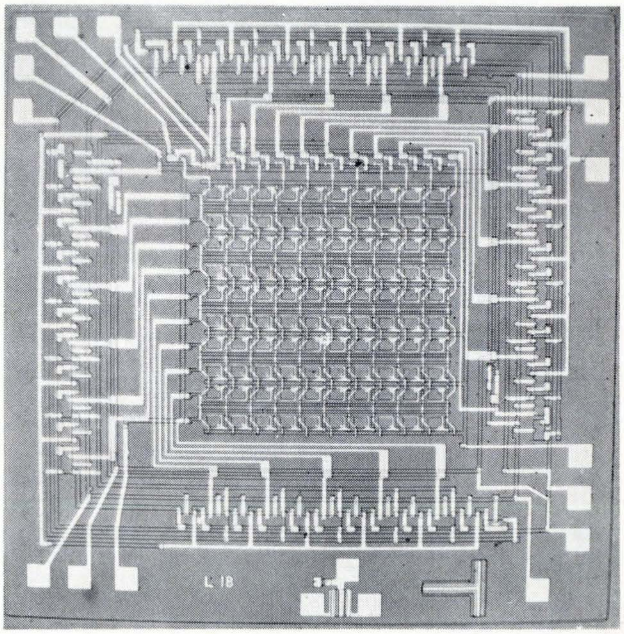
The Raytheon Co.'s Semiconductor Devices division, the Amelco Semiconductor division of Teledyne Inc., the Union Carbide Corp., and the Sperry Semiconductor division of the Sperry Rand Corp., are concentrating on fundamental items—operational and differential amplifiers, and basic communications circuits. Union Carbide and Sperry are both enlarging their hybrid operations; the former is converting some operational amplifier modules into IC form. Amelco is selling operational and high-frequency amplifiers, including sophisticated premium types as well as general-purpose units. Radiation Inc. is concentrating on operational amplifiers —premium types combining monolithic and thin-film technologies, and with dielectric isolation. Amperex Electronics Corp. has evolved audio amplifier and preamplifier linear IC products. The firm intends to introduce operational amplifiers this fall. General Instrument Corp., a leader in the MOS technology, has developed hybrid linear operational amplifiers, and intends to expand into other product areas this year.

Other makers moving in

The Transitron Electronics Corp. already a sizable digital IC maker, just introduced operational amplifiers, its first linear IC's. According to R. Edward Shaut, IC product sales manager, the firm will

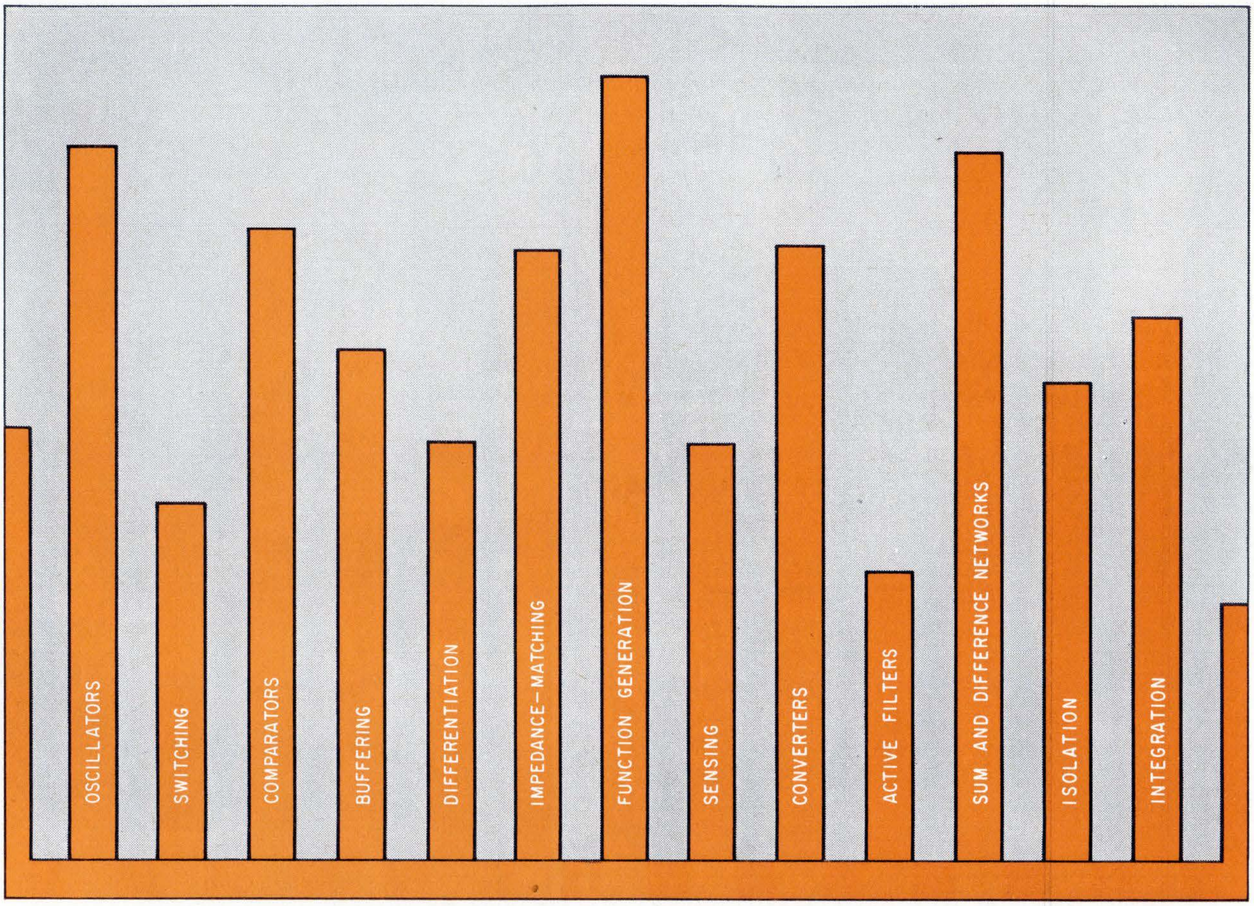


MOS analog array. Chip containing 230 MOS-transistor elements, General Instrument Corp.'s digital differential analyzer, performs such linear jobs as function generation and analog computing.

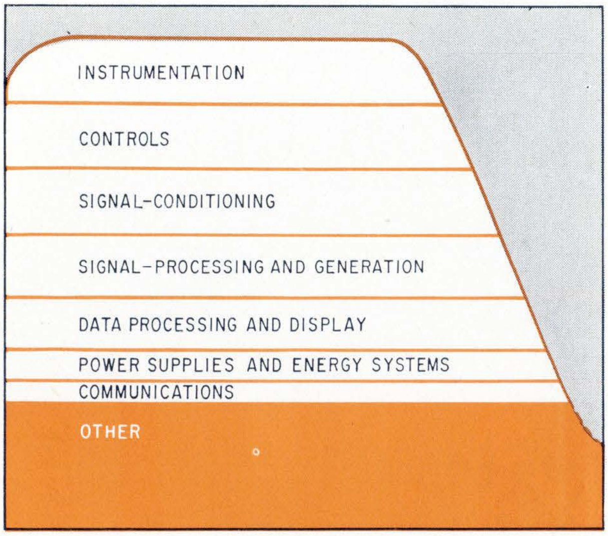


Ultracomplex array. More than 600 elements are crammed into the Plessey Co's linear array, including a 10-by-10 matrix of photodiodes and scores of MOS-transistor amplifiers. MOS input impedance levels approximate those of optoelectronic units, whereas bipolar impedances are orders of magnitude lower.

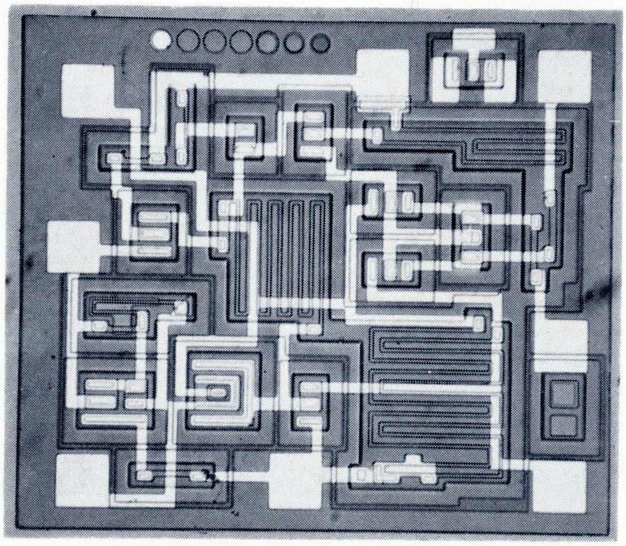
The operational amplifier: jack of all trades



Versatility. More than a dozen major classes of applications are satisfied by operational amplifiers; users merely alter external feedback and coupling components for amplifying, switching, detecting, and other signal-processing needs.



Broad band. Operational amplifiers are used in many different types of major electronic equipment. Circuit applications include comparators, amplifiers, detectors, modulators, demodulators, multipliers and oscillators. The wide usage is possible because the high-gain, wideband amplifier is configured to perform virtually any electronic function that can be expressed mathematically as an impedance ratio.



Kingpin. The most popular linear IC is the 709, a premium operational amplifier invented by Fairchild Semiconductor. Containing 14 transistors and 14 resistors, it has a gain of 45,000, an output swing of 14 volts, and accepts input signals as large as 10 volts. More 709's have been designed into linear systems than any other linear IC product—one reason why at least 12 IC makers manufacture it. This is Amelco's version.

market additional operational and differential amplifiers, comparators, and then dual versions of these items.

The Sprague Electric Co., which has just opened additional manufacturing facilities in Worcester, Mass., sees more room for invention with linear IC's than digital circuits. Devices like its integrated automatic gain control blocks and, perhaps, standard frequency (455 khz) i-f amplifiers will help move the company into the linear market. Hybrid circuits, made by a combination of film and monolithic techniques, will be used for peripheral IC's like sense amplifiers and d-a converters.

By next year the Sylvania Electric Products Inc., a major supplier of digital IC's, expects to be in the field. Toughest markets to conquer, Sylvania believes, will be the automotive and appliance industries, primarily because of the problems in dissipating heat and because a lower-cost package, yet undeveloped, is vital.

Technology abroad abounds

In Great Britain and Europe, technological achievement in linears isn't far behind that of the U.S. Firms such as the Plessey Co. and Mullard Ltd. have concentrated on linear IC's, instead of digital units. Spokesmen at each company indicate that at least 60% of the IC effort has been devoted to linears to date.

Plessey has developed analog and communications type linear products—operational amplifiers, wideband amplifiers, logarithmic amplifiers, and audio units—aimed at the entertainment equipment market and for process control and instrumentation. The firm often prefers to tailor-make products, using compatible IC's and special monolithics. Work is under way on triple operational amplifiers, active filters, and optoelectronic arrays.

Mullard has concentrated on IC's for instrumentation—operational, differential, and video amplifiers—and will encourage circuit development for radio, television, and telecommunications.

Elsewhere abroad, electronics firms have largely relied on U.S. imports for their linear IC needs. In West Germany at least 80% of the linears used are made in America. The Germans, in particular Valvo GmbH and Siemens AG, have been gearing up to manufacture linear IC's for consumer products. They hope to dominate that part of the European market by late next year or early 1969.

In Japan, linear IC activity has flourished. One firm, the Nippon Electric Co., had 1966 sales of some 57,000 monolithic IC's and 90,000 hybrids; most were used in communications equipment. Others, such as Hitachi Ltd. and the Mitsubishi Electric Corp., report more moderate achievements.

Now that volume outlets have been established, the percent of monolithics produced in Japan will be increased. Industrial and consumer markets are expected to absorb large quantities. Among the circuits on drawing boards are compatible operational amplifiers, drivers for power devices, high-frequency amplifiers, servoresolvers, active filters, signal-generators, and instrumentation networks.

Users think twice

Equipment manufacturers switch to linear IC's from discrete circuits because of the promise of continuous availability—at lower and lower prices—of standard circuits that can be used in many ways. Yet the transition is often accompanied by many complaints, and the need to review design methods.

Among the users' concerns are:

- Prices are still too high. Many makers say stock lines are limited and specials are overpriced. Some observers insist military grade linear prices must be slashed to a third of their present level.
- Heat dissipation is a problem. In particular, if linear IC's are to make serious inroads into the appliance and automotive markets, packages and packaging techniques must be refined to get rid of the heat. And the packages must be inexpensive. While plastic packaged IC's are expected to help cut costs, their ability to operate in environments where temperature swings are broad remains in doubt. One large user has set up a 15-week test for plastic-packaged devices during which they are cycled from −35°C to 75°C at 24 cycles per day, with power applied intermittently. IC's tested have exhibited lead failures of 50% and more.

Equipment makers who buy uncased chips—both IC's and discrete components—for use in hybrid circuits have these comments:

- Better chip protection is needed. A high quality passivation layer such as silicon nitride is sought. In addition, chips must be mounted readily and reliably by techniques such as face bonding or beam leads.
- Testing is inadequate. IC chips supplied to users, for example, are not tested sufficiently at temperature extremes. One equipment maker suggests that it would be a simple matter for the vendor to elevate the temperature of the chips in an inert atmosphere and test them before shipping.
- Greater ingenuity in device design is needed. Users want universal arrays of components that can be connected in many ways—like thin-film resistors on a ceramic substrate with guaranteed resistor ratios and temperature coefficients, or multiple transistor arrays.

Linear IC makers have been guilty of a few dark deeds that proved costly to customers. One changed sizes and metalization patterns of an IC amplifier chip without notifying the user who intended to mount it in a ceramic substrate hybrid circuit designed to accommodate only the original version. In another case a user switched to an alternate supplier for an operational amplifier and had to modify the compensation networks to prevent oscillation.

Some users are finding it necessary to revamp their own circuit design organizations. Where individual circuit groups once serviced each design engineering department in a company, one consolidated group may now service several. Such users reason as follows: the best way to drive linear IC prices down is to get volume up. A central group can help by encouraging engineers to base equipment designs on a few standard integrated circuits.

Design ingenuity is the key to success

Clever and resourceful engineering of linear IC's overcomes technological barriers once considered insurmountable

Resourceful design engineers can take the bows for much of the success of linear integrated circuits. They evolved the various elements, configurations, circuits, and unusual designs to meet the dictates of many analog applications.

Not too long ago the linear integrated circuit appeared to be too limited in technical capabilities in several areas: active devices, passive components, and the ensuing power levels, and a-c signal-processing requirements.

The npn transistor elements didn't have terribly high gains; a d-c beta of 40 was considered outstanding. Cutoff frequencies were barely into the megahertz region, too low for many applications, particularly in the communications area. Pnp devices with gains above 1 or 2 could not be economically fabricated. It was felt that the poor quality pnp's and the predominance of npn transistor elements would make it difficult for the IC to meet common linear needs such as complementary design, large output swings, level shifting, etc. Also, the transistors handled only a few milliamperes of current, and had low breakdown limits.

Resistors were imprecise and large-valued types (for example 47 kilohms) consumed most of the chip. Workable inductors, of even of a few microhenrys, were impossible to attain. Capacitors were small-valued, usually a few picofarads, and they had large tolerances.

Output capabilities were typically 5-10 volts or less; breakdown restrictions of the elements projected the use of only low-level power supplies and even smaller subcircuit biasing levels. Parasitic capacitances were present all over the chip, restricting and interfering with its functioning. Such a-c methods as interstage coupling, frequency-selective filtering, and other dynamic functions seemed beyond the capability of the linear chip, restricted by its d-c operating modes and lack of sizable capacitive elements.

Faced with these restrictions, designers realized that processing improvements wouldn't overcome many of the limitations. So they literally evolved entirely new design techniques, largely of a simulative rather than duplicative nature. They put active devices to work like passive components, used special configurations to make a low-beta pnp device behave like a high-beta unit, and created constant-current source replacements for the large resistors. Hybrid assembly and other technologies were chosen to overcome the lack of workable inductors, large capacitors and precision resistors.

Need for simulation

Designers used clever direct-current coupling techniques in place of a-c methods and devised various device configurations to accommodate high power and high frequency needs. These developments, coupled with processing improvements and the experience gained in designing and fabricating digital IC's have brought the linear IC state-of-the-art to a finely honed point. The all-diffused silicon monolithic technology can compete successfully with discrete semiconductor circuits on almost all levels. The tables on page 101, which reflect this parity, were generated by J.E. Solomon and T.N. Fredericksen of Motorola's integrated circuit research and development department. The data refers to junction-isolated devices made by standard monolithic fabrication.

Improved processing has helped to overcome frequency limitations due to parasitic capacitance in the conventional junction-isolated monolithic circuit. A typical high-frequency transistor using a thin high-resistivity collector has a substrate-collector capacitance of less than 1 pf, which compares with the unavoidable strays of discrete circuits. Other techniques such as dielectric isolation and beam lead methods [Electronics, March 20, p. 91], more costly than junction isolation, improve performance in vhf and higher frequency applications.

Buried layer uncovers power path

The use of a buried layer has substantially reduced the problem of high collector saturation resistance, r_{sat}, that resulted from the top-collector contact. Values of r_{sat} from 20 to 40 ohms are now common for small-signal transistor elements, and

Characteristics of npn transistor elements

Parameter	Type: High frequency	Type: High current
f_T	1 Ghz	250 Mhz
r_{sat}	20 ohm	1 ohm
$C_{(col.-sub.)}$	0.8 pf	8 pf
$C_{(col.-base)}$	0.4 pf	6 pf
LV_{CEO}	20 volts	30 volts
I_{max}	10 mA	750 mA
Area	2.5 x 3.5 mils	18 x 20 mils

values less than 1 ohm can be achieved in large geometry devices capable of handling 1 ampere.

The problem of d-c coupling in analog circuits is simplified by combining pnp and npn transistors. Three types of pnp's are compatible with the npn process: the vertical-isolated pnp, the lateral pnp, and the substrate pnp. Of these, the lateral pnp is most used because, unlike the others, it does not require additional processing steps. Despite its lower beta (1 to 10) and a lower gain-bandwidth product, (1 to 10 Mhz), the lateral pnp is quite useful for d-c and medium frequency applications.

The makers have evolved various geometries for realizing the lateral pnp structure; no one geometry has received universal recommendation yet, but showing promise is the closed-circular structure. According to Motorola's Solomon, "The optimum geometry for the lateral pnp appears to be the closed-circular structure. Typical mask spacing between the emitter and collector is 0.4 mil for base depths of 2 microns. Wider spacing leads to lower betas, while closer spacing produces low breakdowns (via the punch-through effect) and other detrimental characteristics. Use of the conventional n+ buried layer significantly improves the performance of the lateral pnp; current collected in the substrate, which is as much as 50% of the emitted current in a nonburied-layer device, is nearly eliminated, yet base recombination current is essentially unchanged. A separate p+ emitter diffusion is also desirable if high beta is needed; d-c beta's of 20 to 40 are possible."

Pnp currents are low

In addition, the lateral pnp has a restricted current-carrying capability; usually just a few milliamperes. This is due to the relatively high resistivities of the emitter and base regions.

Thus far, substrate pnp's can be used in emitter-follower circuits; they have limited current capabilities due to the lightly-doped substrate. A potential use for a medium-current substrate pnp is in the complementary emitter-follower quad. Such a circuit may find wide application as a broadband, class-B, output stage.

The compatible, isolated, vertical pnp is the most desirable device of the three because it offers the highest beta. However, two steps in the manufacture of this device have proven difficult: simultaneous formation of isolated collector regions for the npn and the pnp devices and simultaneous drive-in of the pnp and the npn emitters to obtain good betas. Processes with reasonable yield are still relatively costly and the resulting pnp's have high collector saturation resistances and modest frequency responses. Therefore, equivalent circuit performance and lower cost are more often obtained from designs using lateral pnp's, substrate pnp's, or no pnp's at all.

Inductance out of reach

Inductors have remained the most difficult passive component to make. At frequencies below a few hundred megahertz inductors of sufficient value (more than a few microhenrys) just haven't been obtained; makers concede the inductor element is likely to remain out of reach for some time—possibly five years or more.

Various schemes have emerged to provide inductive effects: layout[1] (using special geometries, such as the plated spiral resistor, circular-configured diodes, retrograded-base transistor elements); hybrid (the use of small discrete inductors); and simulation (configurations of active and passive elements arranged to provide a small inductance-like, or phase-shifting behavior). The last technique is easier and more widely used than the others.

For example, inductance is often simulated by the output impedance of an emitter follower with a large base resistor, R_b. To the first order, and where

$$\frac{\omega_T}{\beta_o} < \omega < \omega_T,$$

this inductance, L_{eq} is:

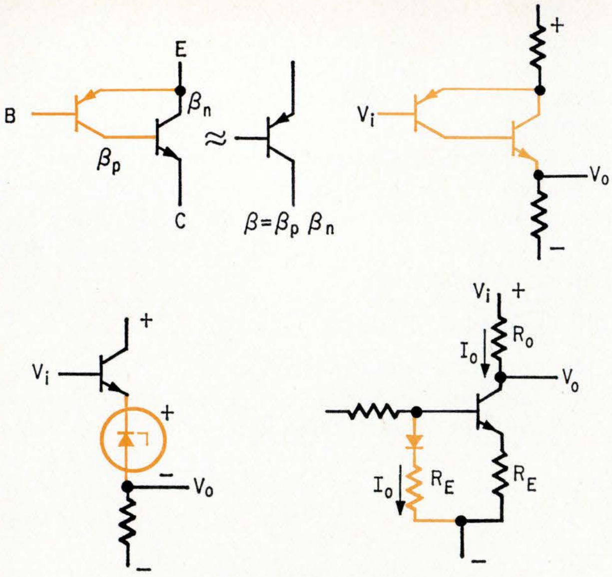
$$L_{eq} \approx (R_b + r_b')/\omega_T$$

Here, β_o is the d-c gain, ω_T the gain-bandwidth frequency in rad/sec, and r_b' the base-spreading resistance.

Equivalent inductors of a few microhenrys have been realized in this fashion. Packing more induct-

Typical IC costs relative to discrete networks

Circuit type	Performance	IC cost relative to discrete
Operational amplifier	100,000 gain 20 V p-p out	20%
Wideband amplifier	100 Mhz bandwidth 100 db gain	30%
Voltage regulator	1 amp 18 volts	60%
I-f amplifier	45 db gain 60 Mhz, agc	45%
Power amplifier	3 watts 0.4% distortion	50%
Consumer entertainment equipment circuits	3–6 functions/chip comparable performance	100–150%



Level shifters. Three techniques for shifting d-c levels in IC's are the lateral pnp-npn composite (top), the zener-diode (lower left), and the resistor-constant-current source (lower right).

ance into monolithics may bring about another breed of IC's—combination linear-digital circuits, wherein shift registers will store the energy. Such a marriage isn't yet economical, but RCA's Jacoby, among others, thinks integrated circuits of that type may be two years or less away.

Other passive components present less difficulty. Motorola's J. Robertson, head of IC applications feels that the total resistance and capacitance allowed on a die, limited by the available area, is now approximately 200 kilohms and 100 pf, respectively[2]; these typify industry opinion. Minimum resistor widths have been reduced to a fraction of a mil by improved masking and etching techniques, permitting higher total resistance and reduced distributed capacitance in the elements.

Resistors in a pinch

A higher total resistance, to 4 megohms, is possible by using the pinch resistor which consists of a conventional p-base diffusion with an n+ emitter used to pinch off the base channel. This channel has a sheet resistance of 5 kilohms to 15 kilohms/square. The control of absolute resistance value is poor but resistor ratios of $\pm3\%$ or better are attained. These resistors are not necessarily restricted to circuits having supply voltages under their low (6 volts to 9 volts) breakdown values. They can be built on separate, floating n-isolation islands; it is only necessary to hold the resistor end-to-end voltage below the breakdown limit.

Capacitors still being used on the die are usually small feedback types, constructed from the reverse-biased emitter-base junction. A polarized capacitor of about 0.5 pf/mil^2 with a maximum breakdown of 6 v to 9 v typifies this element. Higher values, to 2.5 pf/mil^2, are obtained by diffusing the p+ channel into the n+ buried layer and then diffusing the n+ emitter into the surface of the p+ channel. A lighter-than-normal p-isolation diffusion must be used to prevent the junction from leaking heavily above 2 v or 3 v. Typically, 5-v to 6-v breakdowns can be reliably achieved.

The case is not so clear when comparing thin-film capacitors with junction capacitors. Because of limited breakdown voltages, high leakages, polarization, and parasitic capacitance to ground, the junction capacitor often cannot be used, even where small values of capacitance are sufficient.

Demand for thin-film

There are good reasons for using high performance thin-film capacitors. Thin-film capacitive elements are innately superior to junction types, but the manufacturing costs are high. Virtually every major IC maker is striving to produce a low cost thin-film capacitive element. One promising effort is a vapor-plated, tantalum oxide-alumina dielectric which has yielded a capacitance of 1 pf/mil^2 with nondestructive breakdowns greater than 25 v. Estimated manufacturing costs aren't prohibitive. The capacitors were made at Motorola for the Navy.

About 1,000 pf is the practical limit set by General Electric's Aerospace electronics department for thin-film capacitors in its hybrid circuits. Above that it resorts to some form of discrete capacitors, such as barium titanate chips.

It is evident that npn transistors and resistors account for the bulk of elements in monolithic IC's. In practice, the special design techniques work easily within these restrictions and many high performance circuits are being produced.

Bob Grimes of TI points out that because of the lack of large-valued capacitors on the die there is a continuing drive to develop circuits which minimize or eliminate the need for capacitors. Direct coupling is almost always used, whether the IC is intended for d-c, high-frequency or power service.

Bias considerations, d-c paths, current-source needs, and power requirements per stage strongly influence the choice of circuit topology and are often dominant in the design of linear circuits.

D-c amplifier the mainstay

At present the d-c amplifier is used more widely than any other monolithic analog circuit. There are two reasons: low offsets and low temperature drift are easily obtained, and external feedback can be applied to a high gain amplifier type, enabling the circuit to perform a wide variety of linear functions.

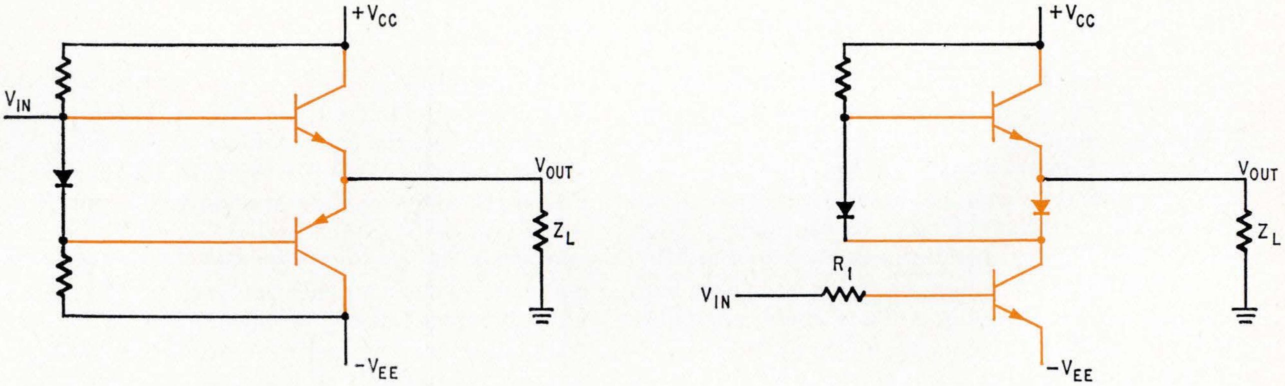
The design of an integrated d-c amplifier differs from its conventional discrete counterpart primarily because of d-c level shifting problems. In the discrete circuit, pnp and npn transistors maintain d-c levels. In the npn-dominated integrated circuit, the d-c voltage builds up toward the positive supply and must be shifted negatively if the output is to have large signal swing. There are three ways to achieve this: the lateral pnp-npn composite, the zener diode level shift, and the resistance level shift [Electronics, June 26, p. 116].

Of the three level shifting methods currently employed, the pnp-npn composite appears most favorable, probably because of the trend to minimize the incorporation of passive elements, and because the manufacturing tolerances for the composite are not too severe. With the resistive method, in addition to its passive status and more demanding tolerances, the area needed is relatively large and power is wasted. Zener diodes present more severe tolerance problems, particularly the low voltage types. Their zener ratings, related to the impurity profiles used, limit the working voltages. The fabrication of the transistor composite is more involved than for the diode and resistor, although the area consumed is less; in terms of extending linear IC capabilities the effort is considered worthwhile.

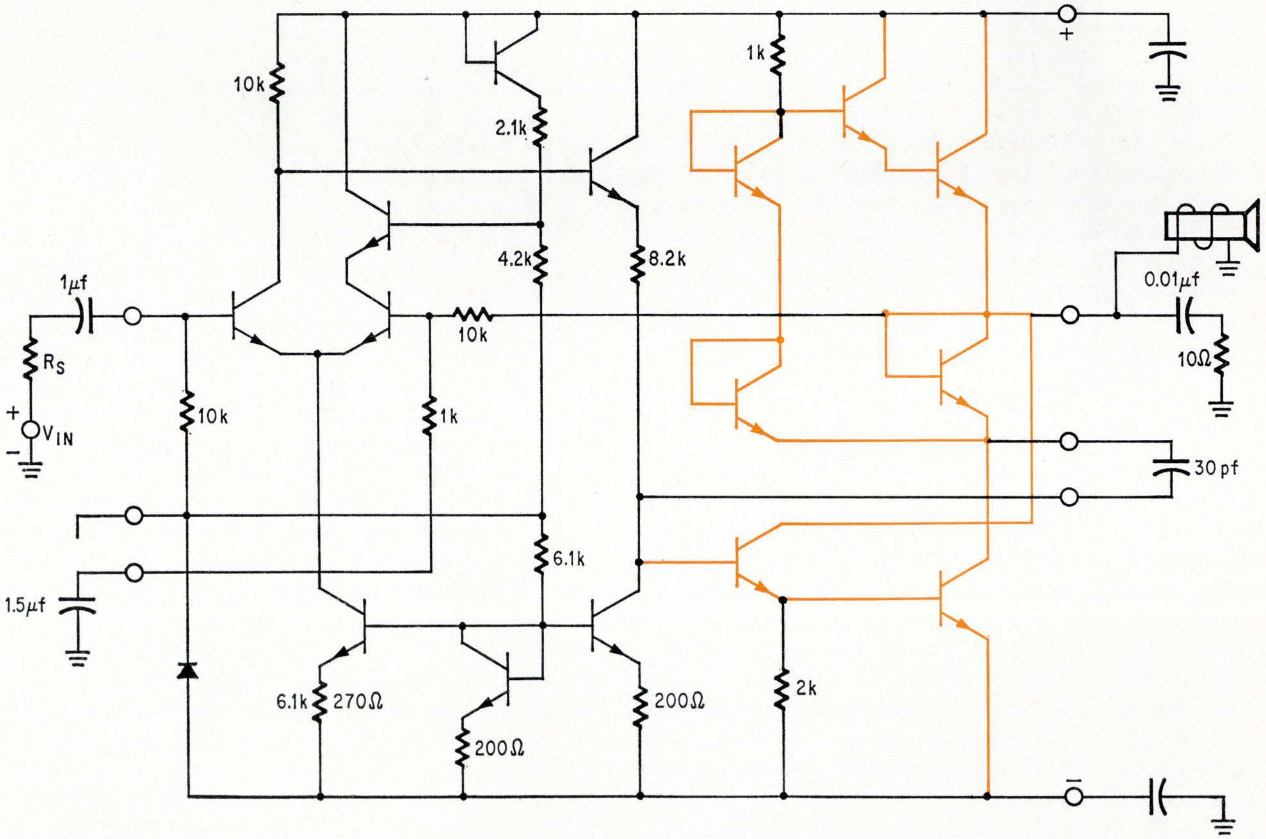
Monolithic operational amplifiers are now available which achieve voltage gains of 100,000, input impedances of 500 kilohms, and unity gain-bandwidth products greater than 1 Mhz. Fairchild's Gifford says, "Most incorporate a lateral pnp technique, and perform as well or better than their discrete counterparts."

Wideband amplifiers are popular

A second linear circuit that has achieved wide acceptance is the wideband amplifier; excellent high-frequency characteristics of monolithic transistor elements are largely reponsible. Most conventional transistor broadbanding techniques are



Comparing techniques. IC power circuit design differs from discrete semiconductor versions. Classic class B output stage (left) requires complementary npn and pnp transistors. IC makers use design tricks—such as diode-coupled npn cascodes (right that avoid need for high-quality pnp's that are costly and difficult to fabricate.



Monolithic power. Totem pole output stages boost power-handling capabilities of IC's. This circuit, Motorola's MC1554, produces 3-watt output as a class B amplifier.

used in integrated amplifiers, but only those reasonably insensitive to component tolerances provide high yield and low cost. The common-emitter amplifier with resistive broadbanding, or local feedback, is one of the most useful basic stages. Performance of a cascade of such stages is improved by adding emitter-follower interstages for additional mismatch, thereby reducing sensitivity to device variations.

Single-ended amplifiers employing over-all feedback to produce high linearity and wide bandwidths are also common. Bandwidths of 40 Mhz, voltage gains of 200, and a total harmonic distortion at 1 Mhz of less than 0.5% have been realized by the monolithic feedback triple. Another type useful for tuned applications is the internally wideband amplifier. All interstages are broadbanded except the input and output ports, which are designed for tuning. Typical characteristics are 45-decibels power gain, 100-Mhz internal bandwidth, 50-db agc range, and very low reverse transmission Motorola's Fredericksen suggests that "two circuits of this type can be used with three tuned circuits (or multipole filters) to fabricate a high gain i-f amplifier at any frequency up to 100 Mhz. The advantages are minimum inductor usage, high stability, simple assembly and alignment, negligible passband shift with agc, and low cost."

Operational amplifiers are not the only linear IC's which can serve a large variety of applications. Some of the makers, RCA and Norden in particular, have already evolved near-universal medium-frequency linear amplifiers. For example, RCA's CA3020 device is suitable for power-supply regulation, in motor-speed control subsystems, for power control in light, relay-switching and pulse applications, in inverter circuits, and as a cable driver and pulser of power semiconductors. In communications service, the 3020 performs as an audio amplifier, part of an a-m broadcast receiver, a front-end amplifier, as well as in i-f strips and frequency multiplying networks. In the instrumentation area the unit is a quasi-operational amplifier and can be a bridge-unbalance amplifier. Norden's "breadboard IC", the NM3025, offers similar applications versatility.

IC's for power

Power circuits represent one of the areas in which integrated devices are now competitive. Several types including power supply regulators, industrial and consumer controls [Electronics, May 15, p. 26], and power amplifiers are finding volume usage.

Because only npn power device are available, design approaches for power integrated circuits often differ greatly from those of discrete circuits. For example, consider a linear transformerless class-B power amplifier. In discretes the output stage uses complementary devices. High current npn and pnp devices are not available on a single die, so an all-npn output stage, such as the diode-coupled totem pole is employed. Using modifications, amplifiers have been built that achieve less than 0.4% distortion at outputs of 3 watts; they are fabricated on single chips, each less than 60 mils square.

Another example is the monolithic series voltage regulator. This circuit would typically include a high-current series pass device on the die, along with a high-gain-control amplifier, a variable zener level shifting network, a short-circuit limiter, a regulated pnp bias supply, and a self-start network. Good transient response is achieved by connecting the regulator amplifier directly to the output sense point and level shifting the zener reference rather than using a conventional resistive divider. Auxiliary power supplies are eliminated by deriving a regulated current from the unregulated input with a multiple-collector, lateral pnp.

Testing gap

One aspect of the technology that has lagged is testing and instrumentation. Very little information is available on the reliability of linear integrated circuits and other high-priority tests; there remains a need for industry-wide standards on circuit descriptions, performance indexes, and the salient parameters for circuit evaluation. Moreover, users and some makers are waiting for low-cost instrumentation gear tailored to linear IC's.

Manufacturers do perform extensive testing in terms of reliability. Most makers assume that linear IC reliability is as good as that of logic units, since the processes are nearly identical. Much has been published on digital IC reliability—the results were assumed to fit linears as well. But the one great difference between logic and analog IC's is in betas of the transistor elements.

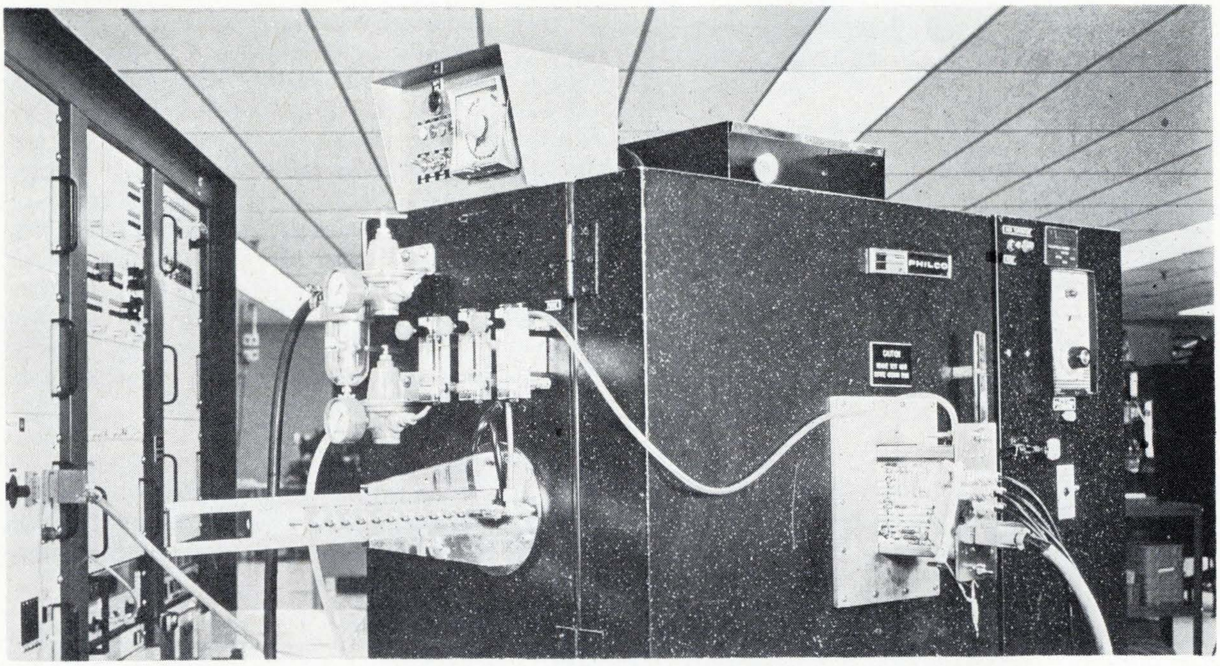
With digitals, wide variances in beta are tolerable because speed is far more important than gain. But in linears, beta is often paramount; too low a value may mean the difference between successful functioning and misoperation or even IC damage.

Texas Instruments recently conducted an extensive reliability test program—reportedly the first of its kind to be made public—on some of its basic linear IC's, series 52 devices. The program was as detailed and comprehensive as that used on digital IC's. After millions of device hours recorded TI concluded that linear IC's are just as reliable as digital IC's; the very low failure rates matched those that arise in logic units and the causes were identical. The program included operating conditions as well as storage, mechanical, and thermal shock; not a single operating failure occurred.

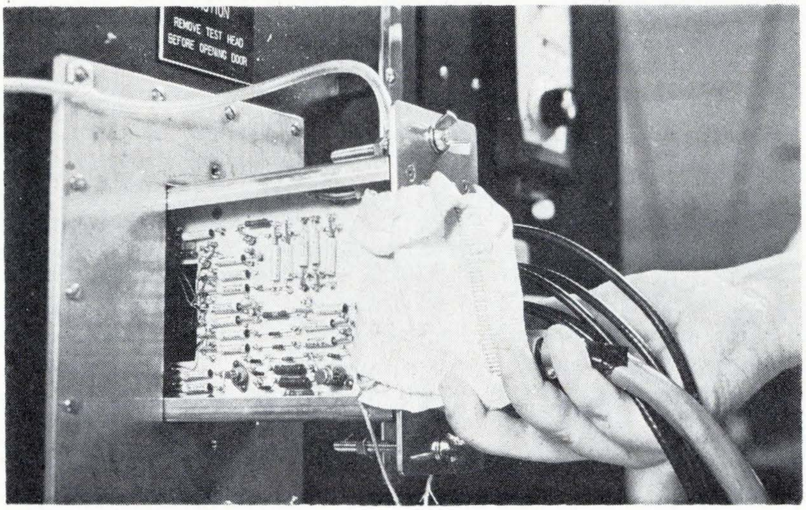
Some critics may scoff at TI spending time and money to end up proving an industry-wide, and thus far valid, assumption—one considered almost axiomatic. But users will probably deem this reliability effort and similar ones in the works reassuring, and will certainly press for further testing.

The over-all problem of standards is being studied. A group under the auspices of the Electronics Industries Association, the active analog circuits committee (MED 3.3), has been working to establish linear integrated circuit standards for the

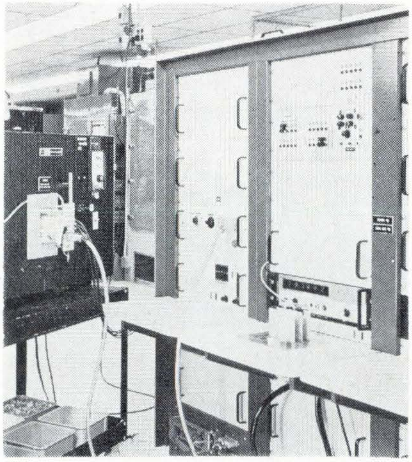
Instrumentation measures up



Environmental chamber blows IC's hot and cold.



Plug-in test modules make a-c, d-c testing a snap.

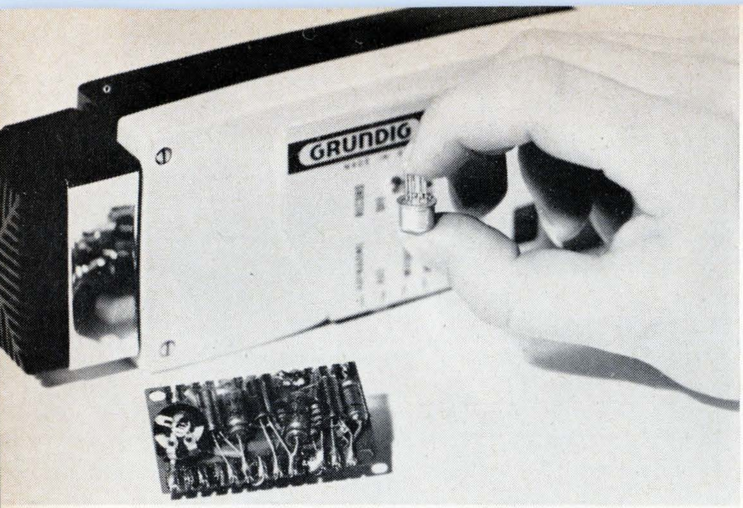


A-to-d interfacers tie the unit to computerized test system.

IC test system. The Microelectronics division of Philco-Ford developed test instrumentation for linear IC's to mate directly with the digital IC tester already in operation. The new unit accommodates both TO-5 and flatpack linear IC's, ranging from established products such as standard operational amplifiers, to recently introduced IC's such as complex communications networks.

IC engineers started out with a single-track automatic environmental test chamber (top) developed by the company's Lansdale division. The unit makes d-c and transient measurements between —55 and +125°C, at the rate of 180 IC's per hour. Linear test leads, tailored to the characteristics of the various IC's, are merely plugged in (center) and pulled out each time a particular product type is to be tested.

The facility is completed by the addition of interface circuitry which converts the analog data into digital form suitable for feeding into the digital IC test station (bottom). The interfacers include control networks, signal-conditioning and generating circuits, computing networks, and converters, all linked together to permit computerized operation of the entire facility.



Monolithic audio amplifier. Hand-carried dictating machine uses IC amplifier. A three-stage audio circuit, Siemens AG's TAA311, replaces discrete components on printed circuit card in the Grundig Model EN-3 tape recorder.

past few years. The committee, headed by H.F. Sawyer, head of microelectronics specialties at General Dynamics' Pomona division, is describing circuit types, establishing applications formats and parameter guidelines, evolving registration testing and methods, and considering numbering systems.

The committee is composed of representatives from nearly all the makers and from a number of medium and large-scale users. A committee member indicated that a report on their completed efforts would be presented to industry later this year. He added, "Aside from our concern with linear IC's in general, the tremendous recent growth and rising importance of analog circuits in electronics, and the sharp criticism of feet-dragging applied to digital IC's over the years has spurred our efforts."

Modify the digital gear

On the matter of instrumentation, makers and users have modified the apparatus used for digital IC testing to fit linears. The IC's, with their different circuit makeup and functioning, require appropriate input signal generation and biasing voltages, compensation networks, and the like; similarly, output loading and metering are modified to fit the analog performance. Some test units employ computers and complete d-c gear introduced during the wave of the logic IC; some set-ups consist of oscilloscopes, power supplies, and signal generators in a hodgepodge that somehow does the job.

Fairchild Semiconductor recently introduced an analog plug-in module which mates with its 4000 IC tester. Linear IC's are directly tested, albeit the tests are d-c, not a-c. The Industrial Products Group of Texas Instruments' Apparatus division has developed a linear test instrument, and will display it at Wescon [Electronics, July 24, p. 25]. It's an a-c module with oscillator and converter circuitry and an adaptive switching network; the unit plugs into TI's model-553 IC tester—claimed to be the only off-the-shelf dynamic semiconductor test system. With the module, the 553 performs complete a-c and d-c testing of linears, including bandwidth measurements to 50 Mhz. Input from 10 hz to 100 Khz are applied; outputs are true rms values.

The Philco-Ford Corp.'s Microelectronics division has an automatic test system for TO-5's and flatpacks. Although developed for linears, the unit was converted to handle digital IC's as well. Philco-Ford, a late starter in linear IC's, made rapid testing a key element in the equipment design. Since they were about to second-source basic operational amplifiers as part of their initial thrust, they wanted to know quickly how good the products were and what failures were occurring during the initial production period. Because new linears, particularly communications types, are on the way, a replaceable test header was developed to handle linear IC's easily and rapidly without resorting to new apparatus. The gear is described in detail on page 105. A Philco-Ford spokesman credits the test apparatus with "being a contributing factor to our improved yields, which have doubled since we installed the system." He adds, "It was also a major influence on our rapidly gaining expertise in the production of operational amplifiers and other basic IC's."

What's ahead

It is very likely that other firms—users and makers as well as companies that specialize in instrumentation products—will market linear IC test systems in the months and years ahead. Similarly, efforts in other regions of the technology aimed at advancing the entire state-of-the-art will be accelerated. Improved yields, more complex chips, and new production means incorporating more automation devoted to further reducing the cost per chip are but a few of the major targets.

Typical of what's in the wings in the way of device improvements is described by Motorola's Solomon: "The monolithic technology will be advanced on many fronts; voltage and current limits will be extended to 300 volts and 5 amperes, respectively. The quality of compatible pnp's will be improved an order of magnitude. Ranges and tolerances of passive elements will similarly improve. Novel circuit techniques, rather than a brand new technology, will be the means for these advances. Increasing efforts will go into the other current technologies —thick- and thin-films—to provide improved tolerances as well as large capacitors and better inductive effects."

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Hybrid technology wins a foothold

Hybrid techniques have become essential to linear IC's, advancing the state-of-the-art beyond monolithic achievement

The hybrid technology is now of intrinsic value to linear IC's because it extends their capabilities and often makes them more economically feasible; it also promises to endure. Generally the hybrid method is employed when the application or the market is beyond the technology or cost limits of the monolithic approach. An Electronic magazine survey shows that hybrids have thus far accounted for between 10% and 20% of the dollar volume of linear IC's sold, with the major portion going for custom IC's. Furthermore, most makers and users feel that hybrid will remain the interim technology between discretes and full monolithics well into the early 1970's, accounting for 25% of sales.

Hybrid activity—meaning any microcircuit technology that is not purely monolithic—is far more widespread than monolithic. Interested parties range from the semiconductor giants, through the ranks of medium and small IC makers and include virtually every type of present IC user. Among users, efforts are being made by instrument houses, original-equipment manufacturers of military and aerospace systems, power supply manufacturers, the telephone industry, makers of data-processing equipment, auto makers, manufacturers of traditional components (capacitors, resistors), and makers and processors of raw materials (such as glass). Hybrid is preferred to monolithic for acquiring some IC competence because it requires less investment (tooling costs are only a fraction of those for monolithics); yet, some hybrid IC's cost more because of greater technical sophistication.

Fairchild's Gifford offers some examples: high voltage, usually 60 or more volts, high frequency, typically a few hundred megahertz and up; low noise, below 4 db; and high power, where 50 watts or more is being handled. Also providing inductance, for high-quality pnp elements, for higher-valued and better toleranced resistors, and for various complex and/or exceptionally accurate custom IC's. Motorola's Jerry Robertson lists another role for hybrid's—the incorporation of MOS-FET's, particularly for the front end of amplifier circuits.

The prototype role

Aside from a method by which certain semiconductors, passive components, and other devices not directly amenable to monolithic fabrication are put on a chip, hybrid serves other purposes, including its use as an engineering prototype microcircuit form. Hybrids can also be a transitional IC form between a discrete system and its eventual monolithic version. Hybrids ease the conversion process by influencing the makeup of the monolithics that evolve and show which sections can become entirely monolithic, and which cannot.

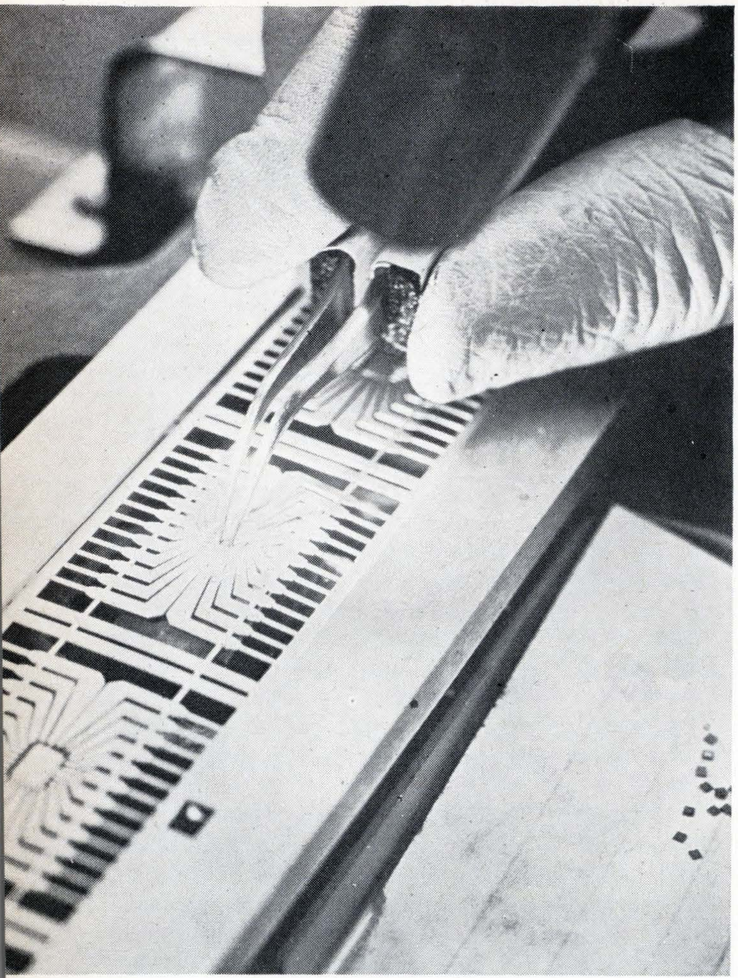
The benefits of the hybrid prototype step are summarized by H.F. Sawyer, head of microelectronic design at General Dynamics Corp.'s Pomona division. GD used hybrids in its Redeye program [Electronics, Oct. 17, p. 77] and in a number of other systems. According to Sawyer, hybrids provide "a short turnaround time, enough design flexibility to preclude major errors in the monolithic design makeup, and a means for protecting proprietary circuit designs. They also sharpen our knowledge of IC's and microcircuit techniques, particularly in evaluation, improve the ultimate production control, and make us less dependent upon development efforts and plans of the IC makers."

Sawyer points out that GD doesn't interpose a hybrid step all the time, but restricts its applications to those areas where monolithic means won't produce circuits of sufficient capability at a reasonable price and in a relatively short time. For GD, with its history of large IC purchases and its plans to buy about $3 million worth of linears in 1968, the hybrid concept continues to have value.

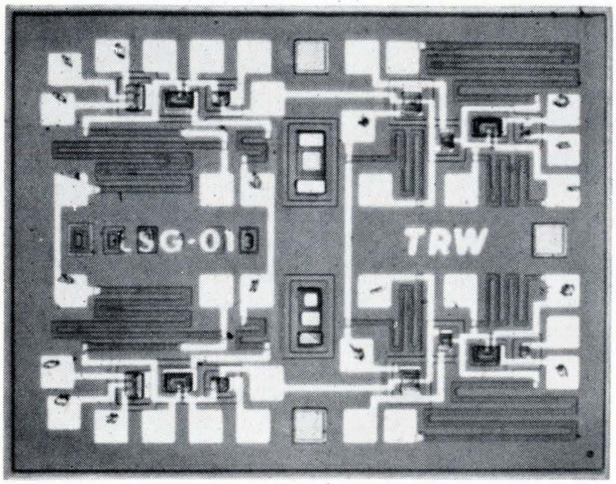
A spokesman for Japan's Nippon Electric Co. indicates hybrids are being used to develop pulse-code modulation networks and other gear for the telephone industry. The Mitsubishi Electric Corp.'s IC effort thus far has been almost entirely hybrid; and in developing its monolithic product lines the experience is invaluable because only hybrids which help define the circuit needs for high-volume outlets are being converted to monolithic designs.

Paving the way

Another example of the interim role of hybrids is TI's thrust at two markets—the automotive [Electronics, May 1, p. 26] and the consumer entertain-



Cost-squeezing. Packaging of linear IC's into low-cost, nonhermetic-sealed, dual-in-line packages (DIP) is a primary means of bringing device costs down. At TI's Dallas facilities four of every 10 IC's made this year will be plastic-encapsulated types. The same monolithic chip used in metal cans and flatpacks (such as this SN52709 amplifier) is placed onto DIP carriers; subsequently, each molded package is cut into a separate unit.



Compatible. Combination of monolithic active elements and thin-film resistors on a common substrate forms compatible IC's. This unit, developed by TRW Sytems, is a precision multichannel level shift gate comparable to a dual three-input NAND gate.

ment equipment industries—[Electronics, June 12, p. 38]—which promise to provide product volume demands paralleling the computer industry's needs for digital units. The company developed a voltage regulator, an f-m sound system and four audio circuits; rather than entail substantial system redesign, the hybrid units were tailored to existing requirements to minimize changeover during evaluation. The chips combine equal grade npn and pnp transistors, field effect devices, zener diodes, scr's and other semiconductors, and thick-film resistors. Present pricing is competitive with the vacuum tube and transistor networks that perform the same functions.

TI anticipates a gradual lowering of the hybrid costs as IC's acquire acceptance and the concurrent elevation of their monolithic content. When it appears likely that the IC's will reach saturation levels in these applications, TI plans to offer full monolithics, for within two years the monolithic capability will meet the technical requirements and the volume needs will justify production. Generally speaking, hybrid is more economic than monolithic when 50,000 or less IC's are involved.

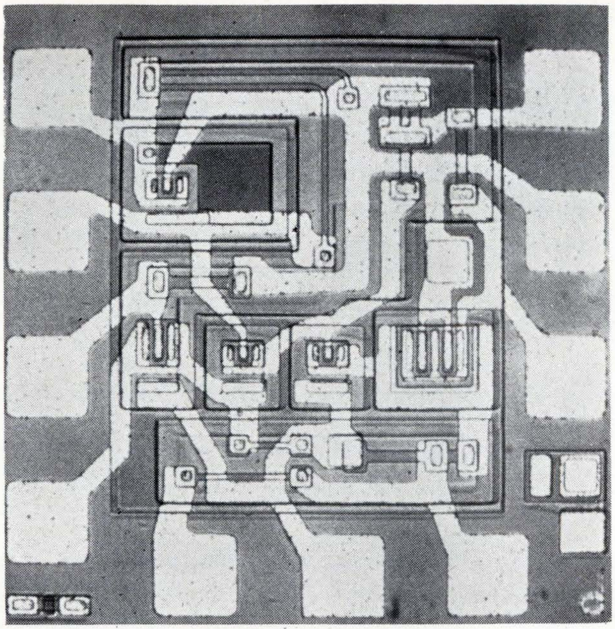
Hybrids possess other features not found in monolithics. Packaging of individual chips is typically larger; heat-sinking is therefore less of a problem. Diverse elements not mutually amenable to monolithic fabrication are easily combined, providing broader technical capabilities (such as a-c line operation, higher noise immunity, etc.). Thus, the hybrids can better withstand those environmental stresses that may impair circuit functioning such as thermal shock, electromagnetic radiation and noise in the automobile.

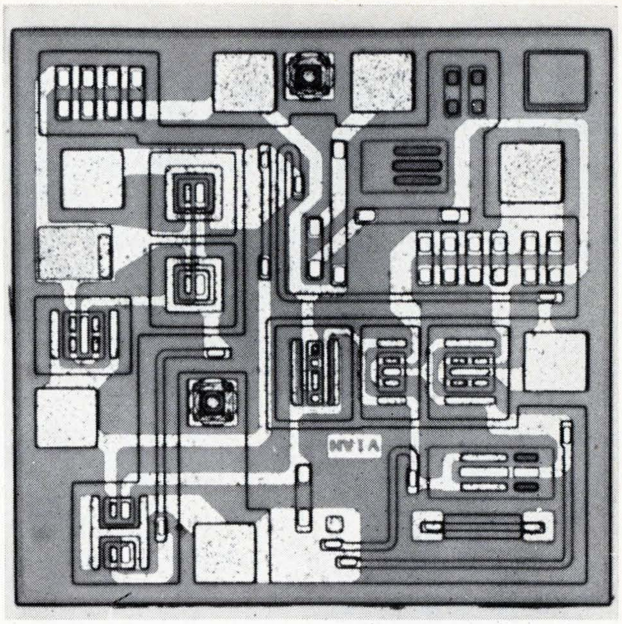
Licking the problem of passives

Another form of hybrid, dubbed compatible, which combines monolithic active elements with thin-film passive components, is also taking hold. A spokesman for the Marconi Co.'s Microelectronics division considers thin-film "the full complement of the monolithic technology." He contends that their marriage will permit the microcircuit state-of-the-art to advance more rapidly than by any other means.

Compatible IC work is going on in many quarters—by the giants and among medium-sized makers such as Norden, Signetics, and Union Carbide. A number of users—such as General Dynamics, Autonetics, TRW Inc.—are also engaged in similar efforts. Most attempts are aimed at premium applications with characteristics exceeding those of the monolithic art. Many experts view thin-films as the answer to interconnection problems in monolithics and as a precursor to large-scale integration (LSI) products.

In compatibles the monolithic chip offers the most advanced active-device capabilities, and the thin-film is used to provide premium passive elements. TRW Systems Group's [Electronics, June 26, p. 111] compatible IC program, already implemented in a number of custom circuits, is success-





High-gain amplifiers. Extensive internal feedback staging in newer wideband amplifiers results in higher and higher open-loop gain-bandwidth products. Philco-Ford's PA7600 (left) has 9-Ghz product; Motorola's MC1553 (right) has a 7-Ghz gain-bandwidth product. Under closed-loop operation the 7600 develops 28 db of gain over a 130-Mhz bandwidth; 1553 in closed-loop mode maintains 46 db of gain over 35-Mhz bandwidth.

fully procuring new business. TRW's LeRoy A. Darling, IC program director, outlines the compatible IC fabrication process: active devices (bipolar transistors and diodes) are constructed in monolithic silicon blocks by oxide masking, diffusion, and epitaxial growth techniques. Thin-film resistors are formed by depositing cermet (chromium, silicon monoxide) over the silicon dioxide layer and etching to the desired geometries.

Next, MOS-type capacitors are added by coupling the dielectric isolation process with aluminum deposition; the capacitors are in monolithic silicon block form. The aluminum is deposited over the surface and etched to desired geometries to serve as circuit interconnections and MOS capacitors. Finally, the monolithic blocks are mounted in the package; metal wires are bonded block-to-block and block-to-package to form the remaining connections. The package is hermetically sealed by a compatible glass-to-metal coating.

Characteristic of compatible IC's

C.P. Johnson, manager of IC applications at TRW, lists these resulting characteristics: sheet resistances of 1,000 ohms per square, with temperature coefficients of 150 parts per million, resistance tolerances adjustable to 1% and stray capacitances of less than 0.02 picofarad per square mil. He adds that "we've obtained amplifiers with drifts of a fraction of a microvolt per degree centigrade."

TRW has concentrated on amplifiers operating at vhf or higher frequencies, prototype custom circuits for microwave applications, level shifters, complex current-sources, and switching regulators. Johnson reports that some of the needs for these high-performance linears came from users turned away by the big IC houses—usually because the volume was too small. TRW has thus carved out a useful niche in the competitive IC industry; a spokesman hinted that the systems group's efforts may help the semiconductor division reenter the IC picture.

RCA recently established a high-performance custom circuits group at its Somerville, N.J. facility. Part of the defense microelectronics operation, the new group will develop hybrid custom IC's, using the thin- and thick-film, and compatible technologies, for various departments. A spokesman indicated that the unit will strive to build a high-volume production capability, possibly to service IC product needs outside the company.

Thin-film vs. thick-film

The major passive-element fabrication technologies, thin-film and thick-film, have each contributed to the linear IC state-of-the-art. Most hybrids make use of one or the other; the compatible IC's developed thus far use thin-films exclusively. Yet, that old controversy, "thick-film vs. thin-film," persists.

A consensus of IC makers suggests that thick-film will eventually win, although most agree that matters probably won't be settled until the 1970's. Thin-film's strength is largely based upon what monolithics cannot achieve—more precise passive elements, for example. The technique offers higher packaging density than thick-film does, and is more workable in providing premium elements; it also is more expensive.

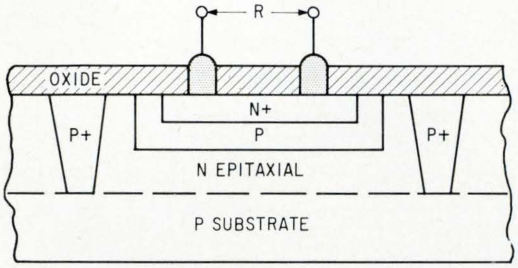
Thick-film techniques entail simpler production methods (no vacuum); they have higher power capabilities and cost less. Hybrid interim linear IC's, a means of penetrating new markets, usually rely on the incorporation of thick-film techniques,

(Continued on page 112)

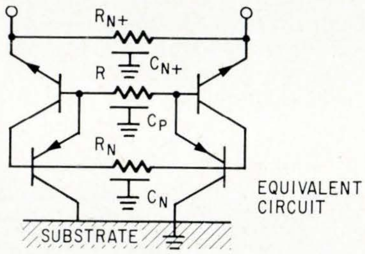
Passive elements: a contrast of IC structures

Monolithic diffused resistors vs. thin-film resistors

Diffused resistor (emitter sheet)



DIFFUSION CROSS SECTION AND STRUCTURE

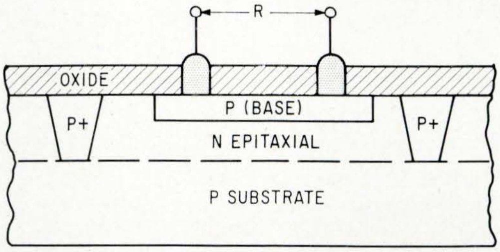


Characteristics

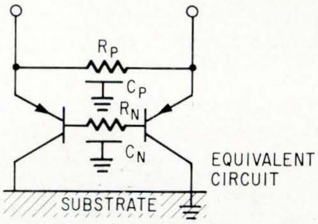
$R_{N+} = 3\ \Omega/\square$
Tolerance $= \pm 10\%$; $\pm 5\%$ matching
Temp. coeff. $= \pm 0.1\%/°C$
$C_{N+} = 1.5$ pf/mil^2

$BV_{ebo} \approx BV_{eco}$ (npn) $= 9$v
$BV_{ebo} \approx BV_{ceo}$ (pnp) $= 80$v
$R_P = 1{,}600$ ohms/sq.
$R_N = 50$ ohms/sq.
$C_P = 0.7$ pf/mil^2
$C_N = 0.5$ pf/mil^2
$\alpha_{npn} = 0.98$
$\alpha_{pnp} = 0.01$

Diffused resistor (base sheet)



DIFFUSION CROSS SECTION AND STRUCTURE

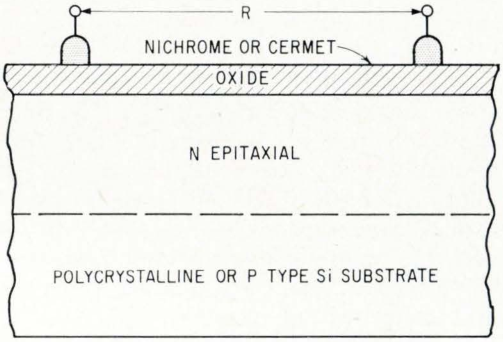


Characteristics

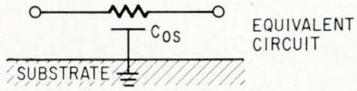
$R_P = 180\ \Omega/\square$
Tolerance $= \pm 20\%$; $\pm 5\%$ matching
Temp. coeff. $= \pm 0.16\%/°C$
$C_P = 0.7$ pf/mil^2

$BV_{ebo} = BV_{eco} = 40$v
$BV_{cbo} = BV_{ceo} = 80$v
$R_N = 50\ \Omega/\square$
$C_N = 0.4$ pf/mil^2
$\alpha_{pnp} = 0.01$
$I_{cco} = I_{eco} =$ lna

Compatible thin-film resistor



CROSS SECTION AND STRUCTURE

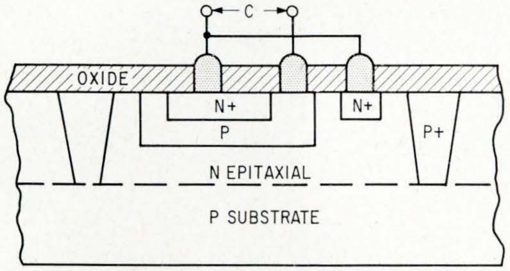


Characteristics

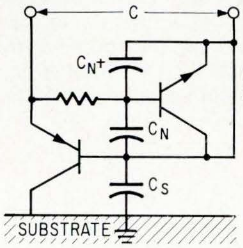
$R = 300\ \Omega/\square$
Tolerance $= \pm 10\%$; $\pm 5\%$ matching
Temp. coeff. $= 100$ ppm;
$= 25$ ppm (tracking)
$C_{OS} \leqq 0.02$ pf/mil^2
$BV_{OXIDE} \geqq 400$ v
$I_{d(OS)} \leqq 10^{-9}$ ma
Dissipation $= 1$ na/mil^2

Diffused junction and MOS capacitors vs. thin-film capacitors

Diffused capacitor



DIFFUSION CROSS SECTION AND STRUCTURE



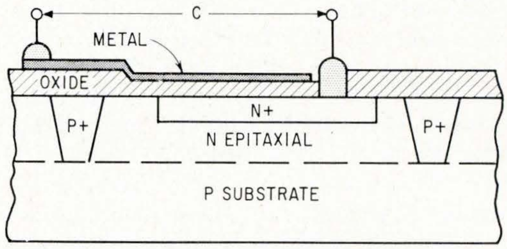
EQUIVALENT CIRCUIT

Characteristics

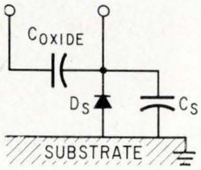
$C_{N+} = 1.5$ pf/mil^2
$C_N = 0.7$ pf/mil^2
$C_S = 0.4$ pf/mil^2
Tolerance $= \pm 10\%; \pm 5\%$ Matching

$BV_{CS} = 100$v
BV_{ebo}(npn) $= 9$v
BV_{ebo}(pnp) $= 80$v
Dissipation factor $= 0.01$–0.1
$\alpha_{npn} = 0.98$
$\alpha_{pnp} = 0.01$

Diffused MOS capacitor



DIFFUSION CROSS SECTION AND STRUCTURE



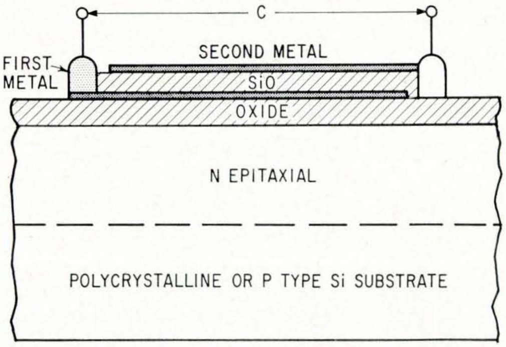
EQUIVALENT CIRCUIT

Characteristics

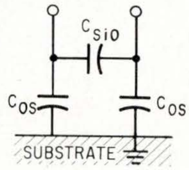
$C_{OXIDE} = 0.25$ pf/mil^2
$C_S = 0.4$ pf/mil^2
Tolerance $= \pm 10\%; \pm 5\%$ matching

$BV_{DS} = 100$v
$I_{dS} = 1$ na
Dissipation factor $= 0.01$–0.1

Compatible thin-film capacitor (SiO)



CROSS SECTION AND STRUCTURE



EQUIVALENT CIRCUIT

Characteristics

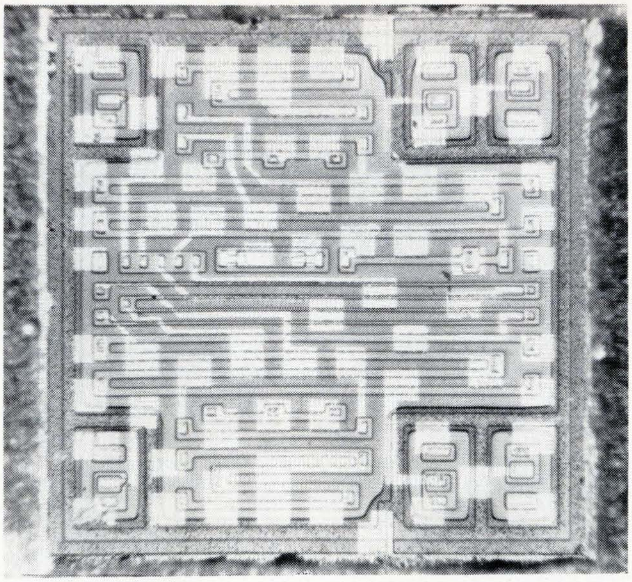
$C_{SiO} = 0.1$ pf/mil^2
$C_{OS} < 0.02$ pf/mil^2
Tolerance $= \pm 5\%; \pm 3\%$ matching
$BV \geqq 50$v
$I_d \leqq 10^{-9}$ ma
Dissipation factor $= 0.01$–0.1

Slice thin. Thin-film passive elements make up the nonactive device portion of the compatible integrated circuit. Although costlier to manufacture than monolithic elements, the thin-film devices offer superior characteristics, such as higher-valued and tighter-toleranced resistors, and, more stable, tighter-toleranced capacitors. Active elements on the compatible chip consist of monolithic chips containing transistors and diodes.

for both cost-savings and boosted technical capability. But by the 1970's, the monolithic art is expected to be far enough along in terms of cheaper, automated production to close the premium gap presently existing between it and thin-film. For that reason, and the innate economy of thick-film, "it is highly unlikely that thin-films will endure," submits Philco-Ford Corp.'s Ekiss, reflecting a fairly widespread industrial sentiment. However, the feeling is not universal.

The General Electric Co., for example, plans to invest $1 million to expand its thin-film IC operation at its aerospace electronics department in Utica, N.Y. this year. The aerospace group achieves high surface resistivities by thin-film vacuum deposition methods—up to 5,000 ohms per square.

Normal tolerances are ±10% (absolute) and ±3% (ratios). If need be, power trimming brings the resistors within ±0.05%. Temperature stabilities and radiation resistance, the department reports, are better than those of thick-films. The practical limit of thin-film capacitors is about 1,000 pf in the GE circuits. Barium titanite chip capacitors are used in the circuits to provide values ranging from 20 pf up to 10,000 pf.



Master circuit. Universal IC breadboard performs various jobs—at user's discretion. Circuit interconnections are made to fit differing requirements; six transistor elements and 33 resistors on Norden's NM3025 chip may be connected to function as amplifiers, power-switch drivers, Schmitt triggers, even RTL digital logic gates.

Around the corner: functional IC's

Linear integrated circuits built as monolithic counterparts of discrete-component circuits are only a few years old but advanced thinkers already see a way to replace them with completely new, simpler devices.

The new technique carries several labels: functional (the circuits perform complete functions, such as amplification and oscillation), bulk-effect (they use a single block of junctionless bulk material), and morphological (designed by controlling shape and composition, or morphology).

Two fundamental bulk effects are under study—one based on electroacoustics, the interaction of electric fields with acoustic stress waves in a piezoelectric material, the other based on a high-field, negative-resistance domain traveling through a semiconductor.

Electroacoustics. Taking the piezoelectric effect a step beyond its use in delay lines and quite a few steps beyond its use in frequency stabilizing elements, researchers have built r-f amplifiers and oscillators based on an electroacoustic effect. The amplifiers can be rated in terms of decibels gain per unit length, so that engineers envision amplifiers being produced simply by cutting off a slice of semiconductor of the proper length.

Electroacoustic amplification was first demonstrated in 1961 by three Bell Telephone researchers —A.R. Hutson, D.L. White, and J.H. McFee. The crystal, commonly zinc oxide or cadmium sulfide, is fitted on each end with a piezoelectric transducer that couples the signal wave into the crystal, launching an acoustic wave of the same frequency. A d-c electric field is placed across the crystal in the same direction as the traveling acoustic wave. The acoustic wave picks up energy from the electric field and is amplified as it travels down the crystal, much the same way that a wave is amplified in a microwave traveling-wave tube. With appropriate feedback, the effect also can be used to produce oscillations.

Traveling domains. In the Gunn effect, microwave oscillations are produced when the electric field across a semiconductor is increased above a certain critical level. Discovered by International Business Machines Corp. researcher J.B. Gunn, the effect was predicted earlier in England by B.K. Ridley and T.B. Watkins and also by Cyril Hilsum. The effect is based on the formation of a narrow, high-field, negative-resistance domain that travels across the crystal, delivering one current pulse to the output for each transit period. Since the domains travel at a fixed velocity, the frequency of the output waveform depends mainly on the length of the crystal.

Besides use in single-frequency microwave oscillators, the effect has been applied at Bell Labs in an ultrahigh frequency oscillator that was tuned by varying the voltage. The bulk material was tapered, and points up the special-purpose potential of controlling the shape of the device. Other engineers at Bell Labs have also used the effect in demonstrating logic operations.

Millimeter-wave power has been generated with a first cousin to the Gunn diode, the limited space-charge accumulation diode, first studied by John Copeland of Bell.

Traveling domain circuits also are being studied in England by Charles Sandbank of Standard Telecommunications Laboratories. He calls the circuits domain-oriented functional integrated circuits—dofic's. Sandbank has already built complex waveform generators, analog-to-digital converters, and believes that optical readouts can be made using the high-field domain to interact with an electroluminescent material.

The place of MOS

The metal oxide semiconductor technology has a reserved place in linear IC's—the question is when it will be compatible with the other semiconductor elements amenable to monolithic fabrication. MOS elements—for example, transistors and capacitors—are used in hybrid and monolithic IC's, but no one has figured out how to consistently combine MOS active elements (transistors) with the bipolars and come up with a high-quality, economically sound chip.

Despite the higher impedance MOS's possess in comparison to bipolars, the use of Darlington-configured bipolar elements and multiple Darlington's appear to suffice in linear IC's.

By itself, MOS has admirable characteristics—it's cheaper and easier to fabricate, has better noise properties and other electrical attributes, consumes less space—but it is difficult to match MOS elements, and MOS transistors are much slower than the bipolars. Moreover, as Norden's Tatom points out, "MOS devices have less immunity to contaminants during the various processing steps—a major cause of intolerable parameter drift."

MOS transistors are wanted for operational amplifier front ends so that a zero input-current condition will exist, and for communications circuits—high and low frequency types—for preamplifiers and high input impedance circuits.

Moreover, the MOS integrated circuit form offers greater compatibility than bipolars when it comes to interfacing with optoelectronic semiconductors largely because the impedance levels of the two are equally extremely high. Thus, off-the-shelf linear arrays combining MOS transistor elements and photo-type devices may well emerge before the 1970's.

M.J. Gay, of the Plessey Co.'s Allan Clark Research Center, sees MOS analog-switching IC's, MOS delay lines, and MOS micropower amplifiers arriving soon. Plessey has developed an optoelectronic array, containing a 10-by-10 matrix of photodiodes, MOS amplifiers, and scanning circuits, that produces a television-type output waveform; the chip contains 620 components.

In terms of what's already available off-the-shelf, there is the General Instrument Corp.'s digital differential analyzer (DDA) [Electronics, Aug. 22, p. 38]. The DDA chip, primarily intended for digital applications, is an MOS-type containing 230 transistors and can be used in linear applications as a function generator and in analog computing applications. However, despite these accomplishments, the MOS-bipolar monolithic chip isn't around the corner.

Expressing an industry opinion, Floyd K. Kvamme, marketing manager of the National Semiconductor Corp.'s Microelectronics division, thinks that the MOS-bipolar combination is a few years away. MOS analog gates are more immediate, he feels. Ekiss of Philco-Ford seconds this view, but another spokesman for the firm expects to see "MOS-bipolar IC's for interfacing with logic circuits within one to one-and-a-half years."

LSI and other matters

Also under consideration are linear's relation to large-scale integration and the question of complexity in general, and the relation of outboard components. "Linears will have a definite place in LSI products but there is considerable doubt that such items as 100-amplifier chips will evolve," claims Lorimer Hill, a TI design engineer. Don Winstead, Signetics' manager of IC development, predicts there will soon be dual and quad versions of existing linear IC's, complete analog subsystems (an all-IC radio receiver) and combination level shifting and interconnection networks to interface with digital units. The interface role is where linears will make their presence felt in LSI arrays as they mate with the large digital sections. Hybrid techniques and MOS elements may be the key means to this.

Another factor on the LSI front will influence the emergence of linear portions on the arrays. If the memory means shifts from core devices to semiconductor memories, the interface between the memories and sense amplifiers is better; present sense amplifiers don't easily mate with core memories because of noise levels, interconnection problems, and magnetic effects. These difficulties are less severe in the all-IC interface.

External components presently coupled to the linear chip—such as compensation capacitors—will be brought inside where possible, either directly or by some design feat that provides the same functioning. The older operational amplifiers typically required compensation networks consisting of one or two capacitors and a resistor or two. In one of the new breed, the LM101 operational amplifier from National Semiconductor, a 30-μf capacitor is all that is needed to compensate down to unity gain. And the Bunker-Ramo Corp. and Radiation Inc. have developed similar amplifiers that contain the compensation network within the chip itself. These improvements are primarily due to the makers putting more and more of the wave-shaping functions inside the chip by employing extra transistor stages as compensating circuits.

One of the largest obstacles to linear IC complexity is the package itself. Most linears have 14 or so leads and more will be required for added complexity. It is necessary for the user to get inside the linear chip more than with digitals—to compensate, to peak, for biasing, to have single and double-ended inputs to key stages, for the application of positive and negative feedback, and so on.

Thus, packages with 28, 32, or more leads are coming; so are new packages with better heat-sinking capabilities to accommodate larger and larger signal and power levels. As Bob Grimes of TI points out, "Small size isn't what distinguishes a chip from a discrete circuit; if the construction is all-monolithic and even hundreds of watts must be handled, a chip as big as a pack of cigarettes can still be considered an integrated circuit."

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.

Wide-range multivibrator doesn't stall at start

By Gilbert Marosi

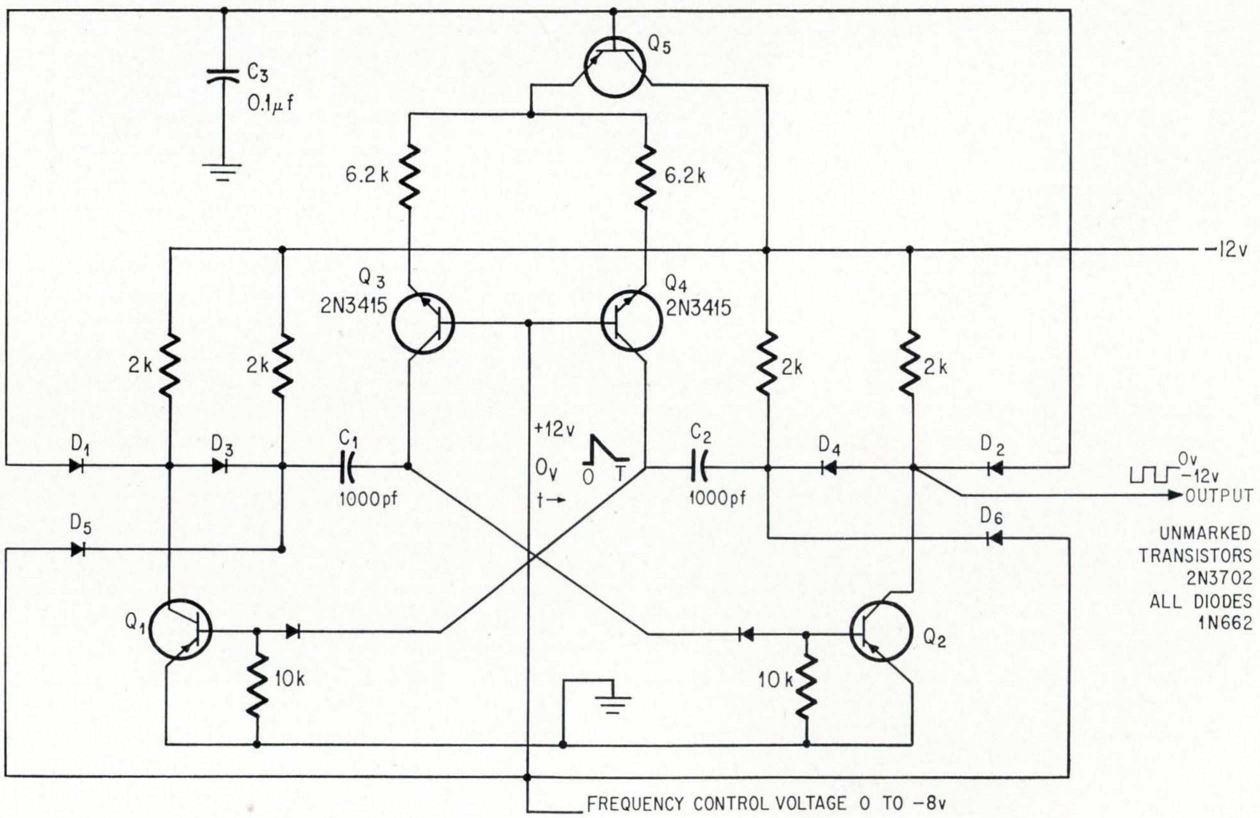
CMC Systems Inc., Sunnyvale, Calif.

A square-wave oscillator becomes a versatile device when its output amplitude is independent of the frequency control voltage, its output asymmetry is variable, it attains a wide frequency range with small control voltage variations, and it doesn't stall when the supply voltage is turned on. The five-transistor multivibrator shown below has all these features.

Without the nonstall feature, switching transistors Q_1 and Q_2 are turned on simultaneously by biasing currents from Q_3 and Q_4 when the supply voltage is first turned on. If Q_1 and Q_2 both conduct, the multivibrator is stalled. In this multivibrator a self-biasing feature prevents stalling.

Assuming transistors Q_1 and Q_2 are both on when the supply voltage is applied, diodes D_1 and D_2 do not conduct and the voltage at the top of capacitor C_3 remains at ground. Thus, the emitter-follower Q_5 is also grounded and it supplies no current to transistors Q_3 and Q_4. With Q_3 and Q_4 off, no current flows to the bases of Q_1 or Q_2 so that one of them turns off first and the multivibrator starts properly.

If Q_1 turns off first and Q_2 remains on, capacitor C_3 charges to −12 volts through diode D_1; it charges through D_2 whenever Q_2 is off. The voltage on C_3, as applied through Q_5, serves as the supply for Q_3 and Q_4—the two transistors that supply base drive and timing current to Q_1-Q_2 and C_1-C_2. Emitter-follower Q_5 provides a separate drive for Q_3 and Q_4, preventing them from loading the collector circuits of Q_1 and Q_2.



Astable multivibrator. Frequency control voltage is applied to the bases of Q_3 and Q_4 and the cathodes of D_3 and D_4 to increase the multivibrator's controllable frequency range by 50%.

The multivibrator's cycle begins with Q_1 just turning off and Q_2 just turning on. If diode D_5 and D_6 are replaced by open circuits, capacitor C_1 will be charged —12 volts. When Q_2 turns on, diode D_4 is forward biased so that the right side of capacitor C_2 is shorted to ground and the output rises from —12 to 0 volts. Since the charge on C_2 cannot change instantaneously, the potential on the left side of capacitor C_2 jumps to +12 volts, keeping Q_1 off. Transistor Q_4 then supplies a constant current that discharges C_2 toward —12 volts. As the voltage on the left side of C_2 reaches ground and goes negative by 1.4 volts, transistor Q_1 turns on, Q_2 turns off, the output drops to —12 volts, and the cycle repeats in the left half of the multivibrator.

A 50% increase in controllable frequency range is achieved by applying the control voltage to the bases of Q_3 and Q_4 as well as to the cathodes of D_3 and D_4. As the frequency control voltage becomes more positive, the bases of npn transistors Q_3 and Q_4 become less negative and conduct more heavily. The larger current through Q_3 and Q_4 discharges the timing capacitors, C_1 and C_2, more quickly; the faster discharge makes the slope of the ramp-shaped discharge curve steeper.

As the frequency control voltage goes more positive, the height of the discharge ramp also decreases. If, for example, the frequency control voltage is —8 volts when the potential at the right side of C_2 equals the control voltage, one potential can go no more than 0.7 volt negative. Thus, C_2 charges to the control voltage.

By reducing the height of the discharge ramp and increasing its steepness, the more positive control voltage cuts the time required to discharge the timing capacitors and thus increases the frequency.

Control voltage determines multivibrator pulse width

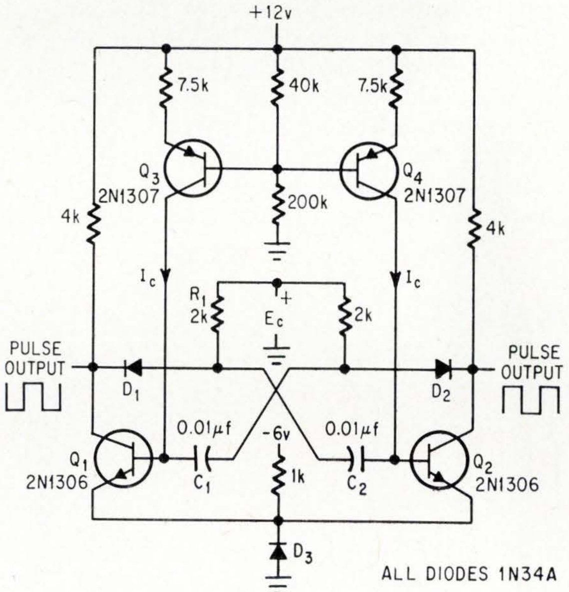
By David J. Comer
University of Calgary, Alberta, Canada

and Donald T. Comer
San Jose State College, San Jose, Calif.

Two transistors added to a conventional astable multivibrator as constant-current sources produce an output pulse whose width is a linear function of a control voltage, rather than an RC time constant. A typical application for this circuit is in modulation systems where pulse-width control is desired.

For the circuit values shown, the pulse width varies linearly from 2 to 10 milliseconds as E_c goes from 2 to 10 volts. The techniques described can be applied to design a one-shot circuit with the same output characteristics as the astable multivibrator.

Transistors Q_1 and Q_2 are driven by the constant current supplied by transistors Q_3 and Q_4. When Q_1 is off, Q_2 is on, and capacitor C_2 charges through resistor R_1 to a voltage equal to the control voltage, E_c. When Q_1 conducts, Q_2 cuts off, and the base of Q_2 drops from 0 volts to approximately $—E_c$. Capacitor C_2 is then charged by the constant current, I_c, from Q_4 until the voltage at Q_2's base returns to 0. At this point, Q_2 conducts. Operation of Q_1 and its associated components is complementary to Q_2.



Variable output. Pulse width is proportional to the control voltage, E_c. Before Q_1 or Q_2 conducts, constant current, I_c, must charge capacitor C_1 or C_2 to E_c.

The charging times of capacitors C_1 and C_2 are given by:

$$T_1 = \frac{C_1}{I_c} E_c \text{ and } T_2 = \frac{C_2}{I_c} E_c$$

Therefore, both portions of the multivibrator's astable period are proportional to E_c.

Diodes D_1 and D_2 isolate the timing capacitors from the output, so that recovery time does not affect the output waveform. Diode D_3 is biased to make its voltage drop equal to the sum of the drop across the saturated transistor and associated isolation diode. Under this condition, the output pulse width is independent of diode drops and transistor saturation voltages, even for small values of E_c. In addition, D_3 compensates for variations in isolation diode voltage drop due to temperature.

Batch testing speeds bolometer curve generation

By Dean Watson

University of California, Berkeley, Calif.

Any one of 10 cryogenic germanium bolometers is quickly selected and its voltage-current curve is generated with this inexpensive field effect transistor circuit. Bolometers are devices that detect infrared radiation by converting the radiation into heat, which, in turn, causes a temperature change in the material used in the detector. This change is then measured to give an indication of the amount of incident radiant energy. The change is plotted as a calibration curve that is useful in determining proper biasing and device response.

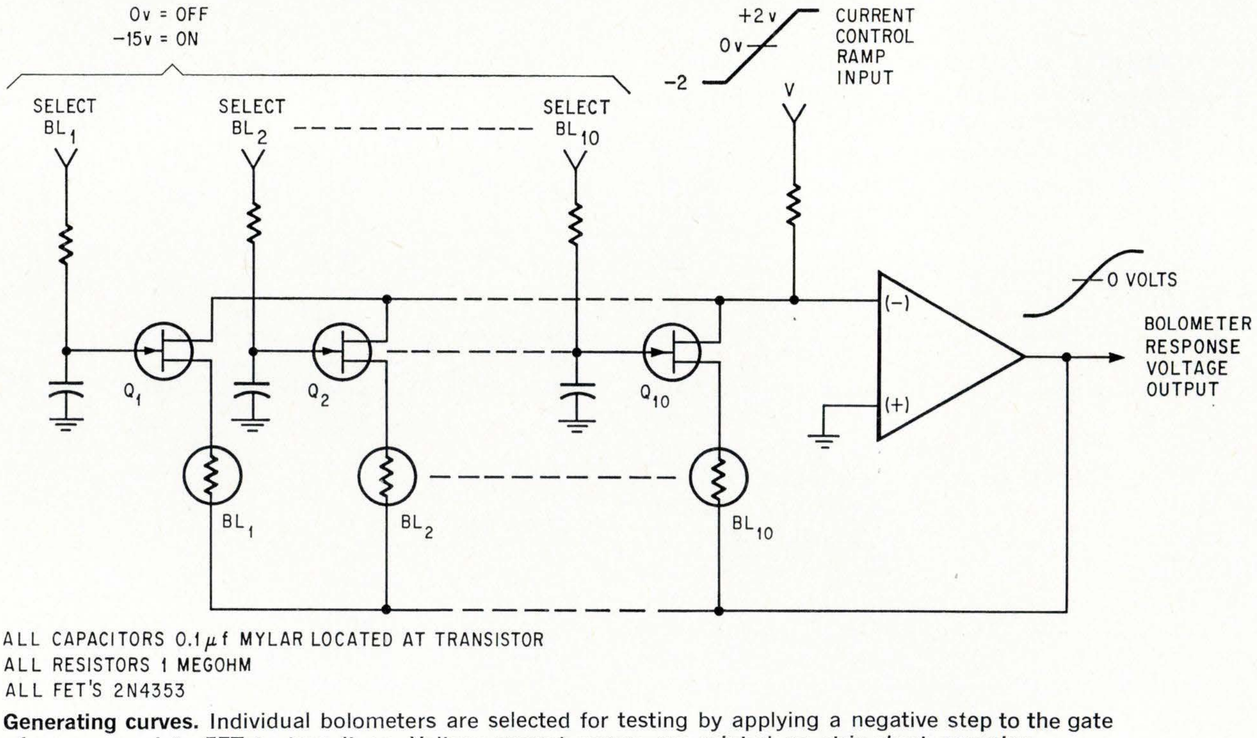
The devices must operate with a cryogenic material such as liquid helium. But the coolant is expensive and is at such a low temperature that it lasts for only a few hours; a batch testing set-up such as this one is therefore essential for economical operation.

Batch testing is feasible as the FET circuit permits efficient switching without relays. Individual bolometers are chosen by applying a voltage to the gate of the corresponding FET switch.

The transistors offer other advantages:

- Their very low gate current enables the designer to use 1-mil stainless steel leads to minimize heat leaks caused by electrical wires entering the Dewar flask.
- They're stable in the low-temperature (100°K) environment.
- With their small size, the engineer can place them inside the vacuum jacket of the Dewar for optimum electrical shielding.
- They provide a high input impedance.

A high-impedance operational amplifier serves as a variable current source for the device under test. The current is controlled by the input voltage, v, and limited by the series scaling resistor, R. A voltage ramp is applied to R, resulting in a cur-



Generating curves. Individual bolometers are selected for testing by applying a negative step to the gate of an appropriate FET to turn it on. Voltage-current curves are printed on strip-chart recorder.

rent ramp whose instantaneous value is v/R. This current ramp and the amplifier output—the voltage developed across the bolometer under test—are simultaneously displayed on a strip recorder.

With the resulting current-voltage characteristic, the designer can calibrate the device to read radiation intensity. Bolometer resistances are in the megohm range, and peak test currents range from 0.1 to 10 microamperes.

RTL slows the response, but boosts IC comparator

By Fred Gruner

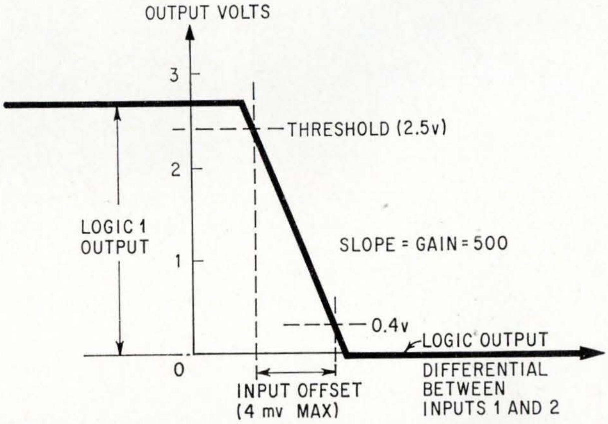
Jordan Controls Inc., Milwaukee, Wis.

A simple, low-cost voltage comparator can be made with a resistor-transistor-logic (RTL) integrated circuit for applications where fast response can be a drawback. For example, this circuit is able to sense overweight or underweight by comparing a signal that represents a measured weight to a standard in a batch-weighing process. Here, the fast response of commercially available IC voltage comparators is a possible source of undesired high-frequency oscillation.

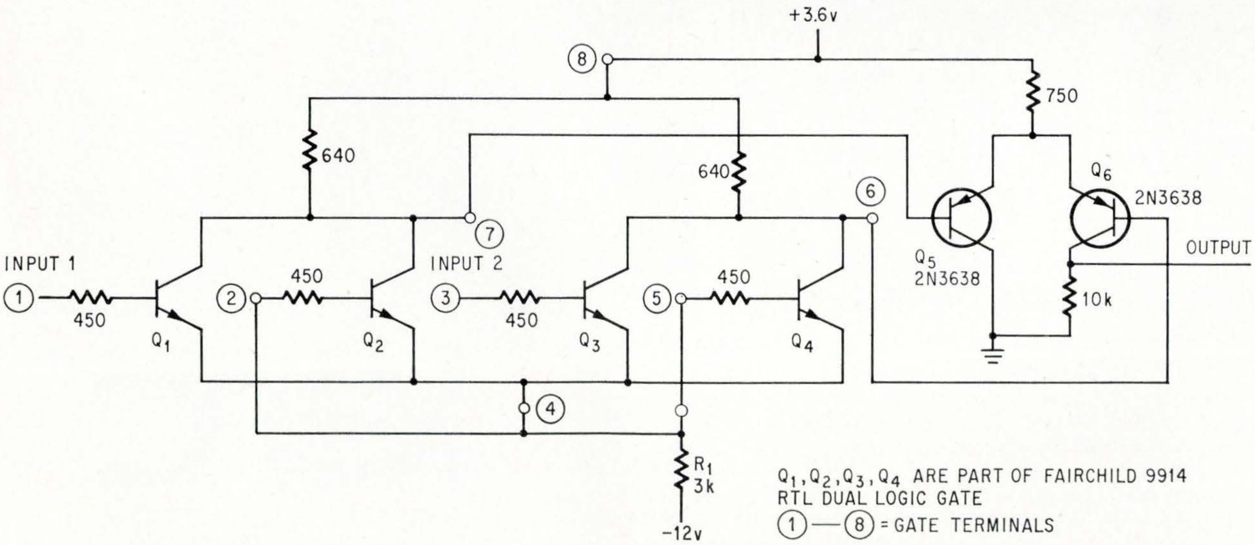
Two of the four transistors of an RTL dual-logic gate (Fairchild 9914), Q_1 and Q_3, are connected as a differential amplifier with an external 3-kilohm emitter resistor, R_1, the base inputs of unused transistors Q_2 and Q_4 are connected to R_1, and the amplifier's input is applied to gate terminals 1 and 3. Output is taken from the 640-ohm collector loads at gate terminals 7 and 6.

By adding two external stages, Q_5 and Q_6, comparator gain is increased. To increase the load-driving capacity an emitter follower can be connected at the output of Q_6, thereby lowering the comparator's output impedance. The output impedance of the collector of Q_6 is 9 kilohms.

The output characteristic of the comparator indicates a maximum offset voltage of 4 millivolts, which may be + or − depending upon the direction of amplifier unbalance. Since transistors Q_1 and Q_3 are on the same monolithic chip, the comparator has good balance and drift characteristics.



Output. Comparator's output characteristic has a maximum offset voltage of 4 millivolts. When the difference between the comparator inputs exceeds this value, the output switches from 1 to 0.

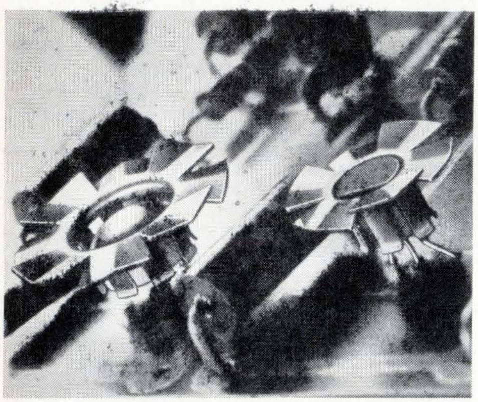


Comparator. Inputs applied to terminals 1 and 3 are compared and amplified, producing a logical 1 or 0 at the output.

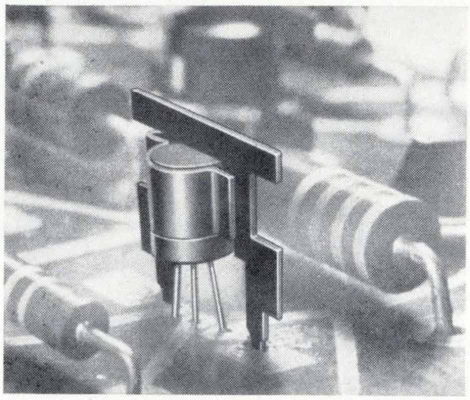
No. 3 of a Series

Tips on cooling off hot "plastic" transistors

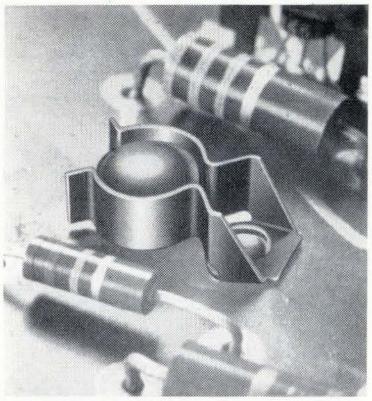
See how circuit and packaging designers use new IERC heat dissipators to increase the efficiency of epoxy and ceramic semiconductors. Models are available for all TO-5, TO-18 and D-case sizes, with and without flanges.



New, press-on "Fan Tops" fit all TO-5, TO-18 and D-case size devices. Need no board area; add virtually nothing to board height. An RO-97 with Fan Top dissipates 400 milliwatts at 65°C. compared to 200 milliwatts with no dissipator.

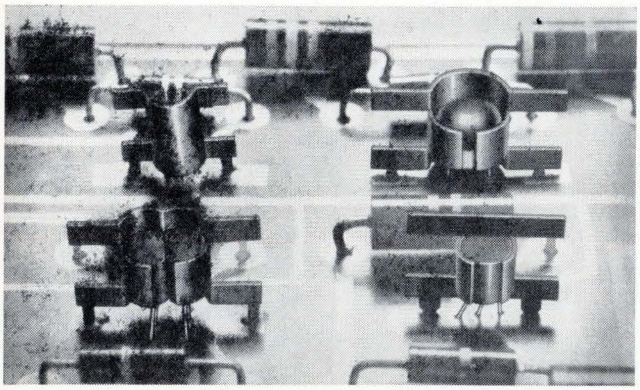


New "Universal" Spade types fit all D-case sizes, including the flanged type. Permit operating power of transistors to be increased 33%. Unique spring-clip retainer accommodates variations in case diameters. Single and dual models.

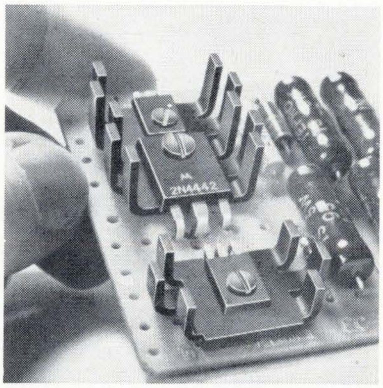


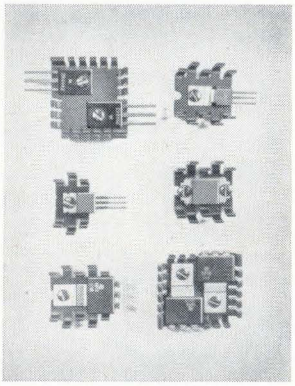
New Clip types are especially effective in high g environments. Hold TO-5 and TO-18 size devices securely; reduce load on leads. Allow 30% more operating power.

Unique new Spade types fit all TO-5, TO-18 and no-flange D-case sizes. Provide excellent retention and dissipation and are also valuable production aids. "Stand-off" legs give a positive 0.1″ grid location for automatic insertion in p-c boards and hold transistors above the solder, preventing possible thermal damage. Single and dual models.



New PA and PB dissipators for medium power plastic devices accommodate the flat, rectangular shaped thyristors, transistors and SCR's. Patented, staggered-finger design and aluminum construction maximize dissipation. In natural convection a PA will permit a single X-58 or M332 case device to be operated with 80% more power. A PB type will allow matched pairs or larger devices to be operated with 200% more power.





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Laser brightens the picture for IC mask-making camera

With position repeatability of 12.5 microinches and resolution of 600 lines per millimeter, a laser interferometer-controlled step-and-repeat camera can boost the yield of integrated circuits

By E. A. Hilton and D. M. Cross

Hewlett-Packard Co., Frequency and Time Division, Palo Alto, Calif.

One of the biggest stumbling blocks in the manufacture of integrated circuits is making photographic masks used in etching and diffusing. Because six or so masks are often needed to make a single circuit, the trick is to achieve precise position and high resolution across an entire wafer. The end result: higher yield.

In hopes of achieving this, several IC makers have focused their attention on optical interferometers to control step-and-repeat cameras for mask making. One of the more promising approaches is a new, automatic system developed by the Hewlett-Packard Co. that uses a helium-neon laser as a single-frequency light source.

Position repeatability of the camera is 12.5 microinches, half the wavelength of the light emitted by the laser. The system is wear-free and frictionless, unlike the most widely used mask-making technique that relies on a mechanical lead screw to control position. Here, position increments are controlled by the wavelength of light, with photoelectric detectors sensing the position of the photographic plate being exposed from the master negative.

The camera projects a single mask image and can repeat it 500 times on a 1.250-inch-square area. The plate is then developed and used to print the masks. Resolution is at least 600 lines per millimeter; focus is 0.1 mil.

The step-and-repeat camera is used at the in-house IC facility that Hewlett-Packard created to meet its instrument needs [Electronics, June 26, p. 155; April 17, p. 47].

Before Hewlett-Packard decided on the step-and-repeat technique, it took a look at other approaches. The company weighed making a large array—all the circuits would be on a glass plate roughly 2-feet square—and then reducing the image optically in a single exposure. But this was rejected because of the difficulty in achieving high resolution across the entire mask area. Also turned down was the so-called fly's-eye technique—the use of multiple lenses to project a single pattern many times. Still largely experimental, this approach is probably best suited for high-volume production of simple masks requiring limited resolution.

If the yield and reliability of IC's are to be high, precise positioning accuracy is essential. The greater the accuracy, the smaller and more complex the circuit can be. The obvious advantage is that more circuits can be crammed onto a single

The authors

E. A. Hilton organized the integrated-circuits department, which he now manages, for Hewlett-Packard's Frequency and Time division in 1965. Before that, he was manager of the photoconductor group at Hewlett-Packard Associates.

D. M. Cross moved over from Hewlett-Packard Associates to design in-plant test equipment for the Frequency and Time division. With the company seven years, he designed the circuitry in the step-and-repeat camera system.

chip. And, as circuit size is reduced, the upper limit of the operating frequency is increased.

Presently, the company is making bipolar IC's for counters using standard silicon processes. Although the circuits' maximum frequency is rated at 12.5 megahertz, much higher frequencies have been achieved experimentally.

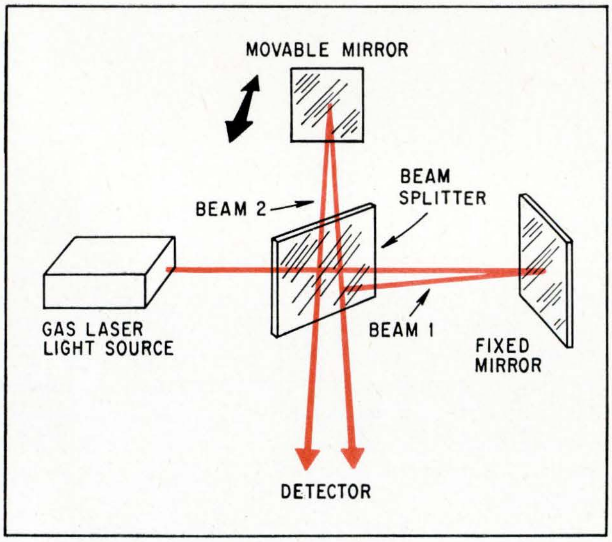
Michelson interferometer

Hewlett-Packard's new control system isn't entirely new at all. In reality, it's an updated version of the interferometer invented more than 50 years ago by American physicist Albert A. Michelson. The system measures position, the distance moved from a reference point, by counting "fringes"—the alternating dark and bright patterns that appear when two beams of coherent light mix. Michelson didn't have a laser; he used multifrequency white light.

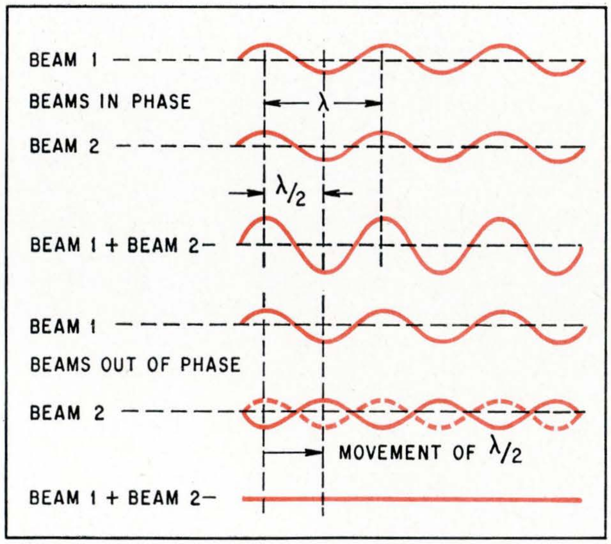
In the Michelson interferometer, a light beam is divided in two by a half-silvered plane mirror, or beam splitter. Beam 1 is reflected back by a fixed mirror to the beam splitter where it is recombined with beam 2, which is reflected back by a movable mirror. If the distance traveled by beam 1 is exactly equal to that traveled by beam 2, the two waves are in phase and recombine constructively. A photodetector senses bright light.

If the mirror that reflects beam 2 moves so the distance the beam travels is changed by half a wavelength, the two recombined waves are out of phase. Destructive interference occurs and no light is sensed by a photodetector.

Moving the mirror that reflects beam 2 either backward or forward causes alternate light and dark fringes to sweep across the photodetector. Whenever light and dark fringes appear, the photodetector produces a sine-wave-shaped pulse. These pulses occur in half- rather than full-wavelength increments of movement because the light beam is reflected on itself by the mirror. Thus, a half-wavelength movement doubles to a full wavelength the distance the light travels. The distance the mirror moves can be determined by counting the pulses generated by the fringe patterns.



Michelson interferometer. Light beam from gas laser is split, reflected from fixed and movable mirrors and then recombined at photo detector.



Interference. In-phase beams produce constructive interference or a bright line at the detector of the interferometer. Out-of-phase beams interfere destructively so there is no light at all when phases are a half wavelength apart.

Between two points

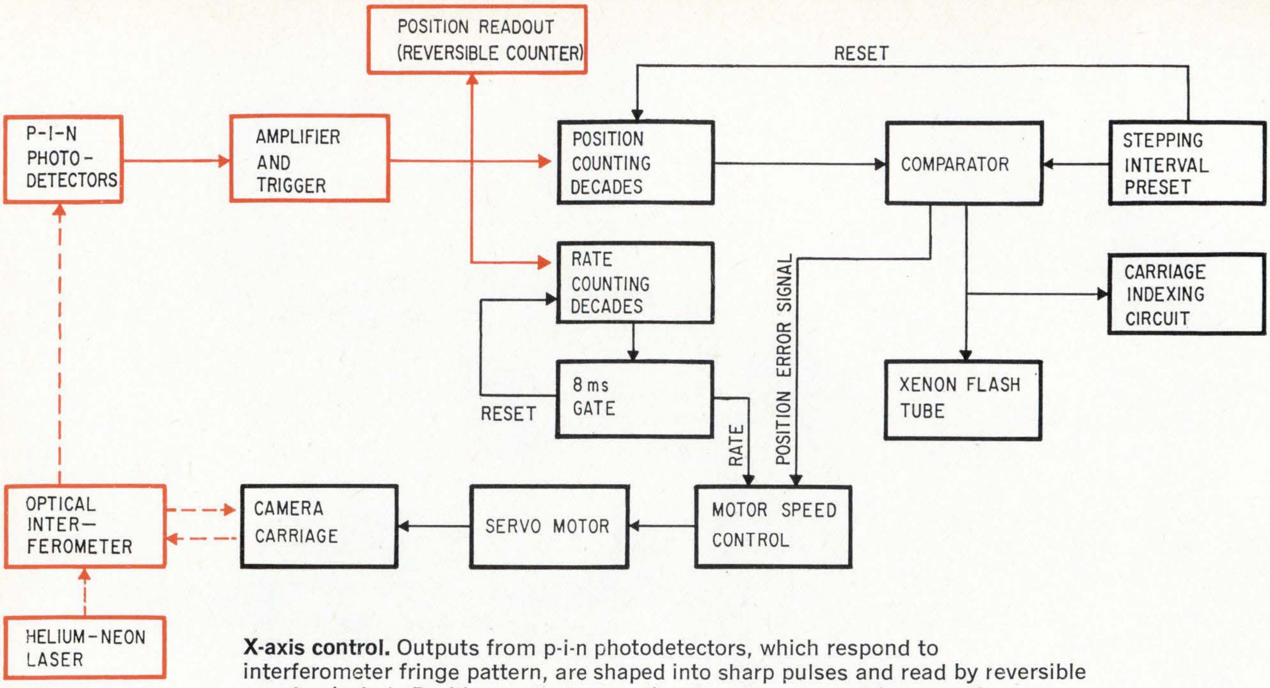
With only a single photodetector, each movement of the mirror generates an identical pulse, making it impossible to distinguish whether the mirror moves towards or away from the photodetector. Such discrimination can be achieved by adding a second detector that receives signals 90° out of phase with the first signal. By coating the fixed mirrors with phase-retarding material, both an in-phase signal and a 90°-shifted signal are reflected. One photodetector receives the in-phase, recombined signals; the other receives the out-of-phase signal combined with the in-phase signal.

The outputs from the detectors are then fed to a reversible counter operating in the A quad B mode. In this mode, only one channel—A—is counted but the direction of count in the plus or minus direction is controlled by the phase relationship between the two inputs.

Thus, when pulses in the B channel lead those in the A channel by 90°, the latter are counted in a positive direction. When the pulses in channel B lag behind those in channel A by 90°, the latter are counted in a negative direction. This means the position of the movable mirror can be determined to an accuracy of one-half the wavelength of the light being used.

With a helium-neon laser emitting radiation at 6,328 angstroms, this distance is 12.5 microinches. Thus, the position accuracy of the control system depends on the light wavelength, and on

Focusing. D. M. Cross focuses the mask master onto the plane of the photographic plate before the xenon flash lamp, to the left of the focusing microscope, is moved into position. Helium-neon laser is in the foreground.



X-axis control. Outputs from p-i-n photodetectors, which respond to interferometer fringe pattern, are shaped into sharp pulses and read by reversible counter (color). Position and rate-counting decades are used for smooth control in d-c motor servoloop.

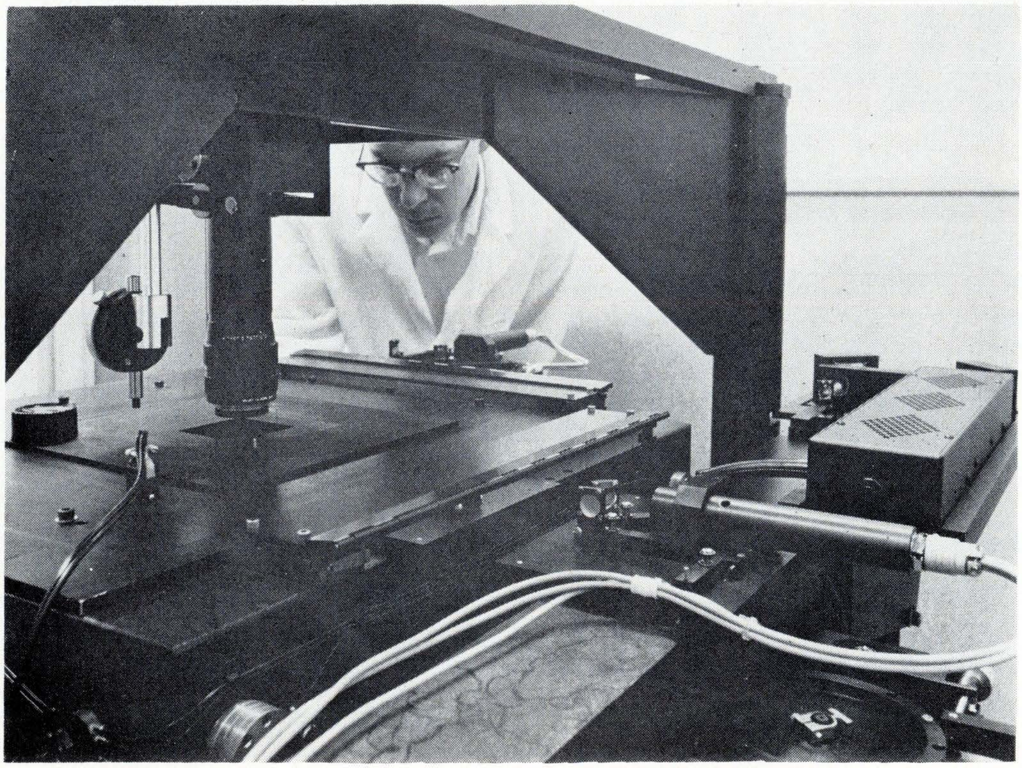
the stability and precision with which the light frequency can be maintained. Accuracy is independent of any mechanical calibration system.

To minimize the effects of air turbulence, the laser beam diameter should be as small as possible. Yet it must be large enough so that diffraction isn't too severe. A telescopic lens system expands and collimates the beam to give it the best diameter.

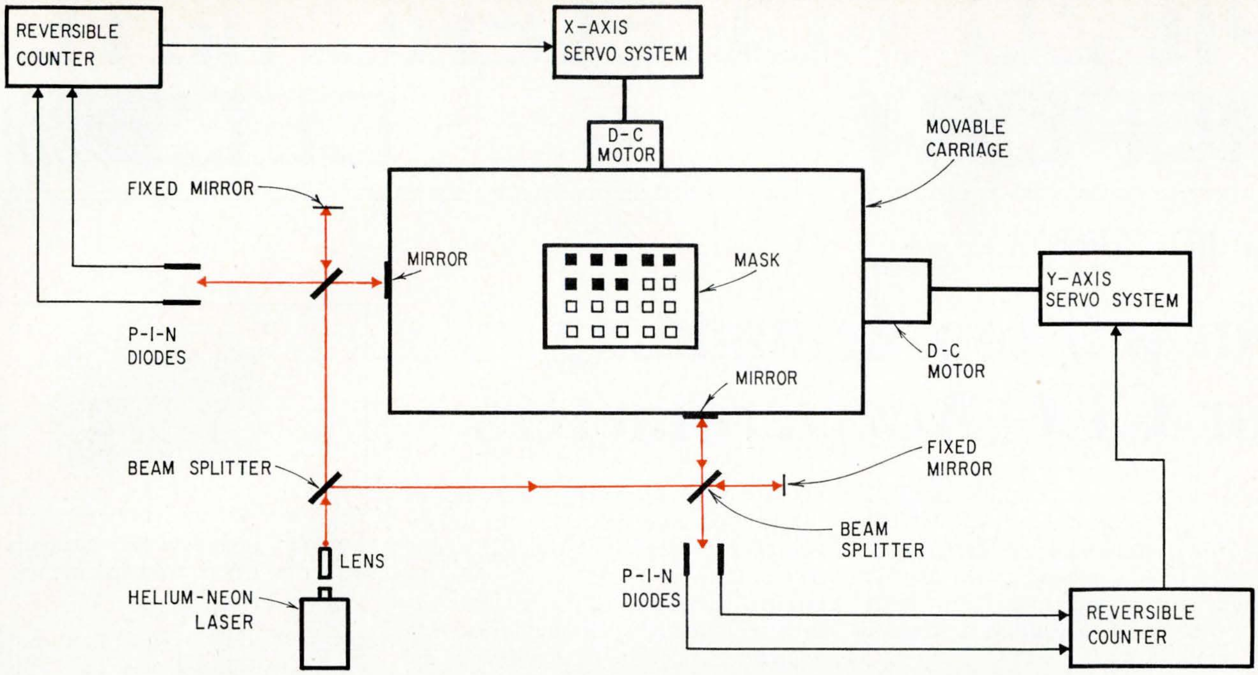
The Hewlett-Packard system uses two interferometers, one to position the x axis, the other for the y axis. Each interferometer has one leg of known length and another that becomes longer or shorter as it is reflected from a mirror on a movable carriage.

Granite beds

The photographic plate to be exposed from the master negative is placed on the carriage, a flat slab of granite, which is supported on cushions of air atop the camera bed—a massive granite



Fringe pickup. Horizontal tube at right contains the photodiodes that sense the fringe pattern of the interferometer. Beam splitter and fixed, reflective mirror are immediately in front of photodiodes.



Reflected light. Interference fringes are created as the laser beam (color) is reflected from quartz mirrors. The absolute value of the carriage's position is displayed on two 2-megahertz reversible counters.

block. Granite ways with air cushions enable the carriage to move horizontally in two orthogonal axes.

The photographic master, which is on a glass plate, is held in a vacuum chuck under a xenon flash tube at the top of the camera. The vacuum chuck is fixed to the camera bed. A lens projects a reduced image of the master onto the 2 x 2-in. photographic plate held in another vacuum chuck on the granite carriage.

The master is produced from the large circuit layout by a photoreduction camera built by Dainippon Screen Manufacturing Co., Kyoto, Japan. This camera reduces the circuit designer's mask layout (generally at a 40:1 reduction in a single step) to the master-mask size required by the step-and-repeat camera. Maximum deviation of the Dainippon camera in master-to-film parallelism is 5 seconds of arc. Positioning repeatability is 0.5 mil when the circuit layout is moved anywhere across the 24-foot length of the camera bed.

Counting fringes

Before the camera exposes the master mask, the stepping interval is set to a numerical value representing the distance the carriage must move. D-c printed-circuit servomotors drive the granite slabs to the preset position. The xenon tube then flashes; a row of equally spaced images is exposed on the plate by a sequence of steps and flashes.

When the end of the row is reached, the carriage is automatically indexed a preset amount to the next row. The carriage stops when the required number of exposures has been made.

The motion of the granite slabs is sensed by a pair of p-i-n photodiodes on each axis. These extremely fast light detectors respond to the light and dark fringes created by the laser beam reflecting from the quartz mirrors of the interferometers. Pulses from the photodiodes are fed to the servoloops controlling the axes motors. An interference fringe produces a pulse output from a diode every time the carriage moves 12.5 microinches.

At first, the light-detecting devices were photosensitive field effect transistors. These were replaced with p-i-n diodes whose response in the blue and violet spectral region is less than a nanosecond, fast enough to count fringes even if the carriage is bumped accidentally. Outputs from the diodes are amplified and shaped into clean square waves by a divide-by-four amplifier and trigger plug-in in a 2-Mhz reversible counter.

Absolute positioning

Two 2-Mhz counters display the absolute position of the carriage. The counters' binary-coded decimal output also provides all the input signals needed to control the carriage automatically. Digital signals are converted to d-c voltage levels in a resistor matrix for mixing with rate signals. The sum of the position and rate signals drives the motors.

Analog motors were used because the smooth table motion they provided was more desirable than that obtained from a stepping motor.

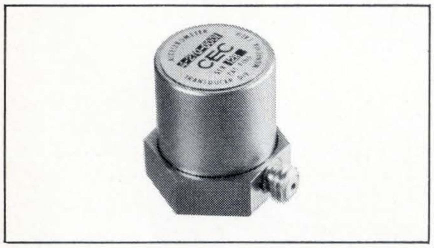
For smoother control, a feedback signal proportional to table rate is obtained by counting the number of interferometer fringes that occur in each 8-millisecond interval, derived from the 60-hertz line frequency. The rate signal is derived by gating the fringe-counting decades. Rate decades are reset in less than 0.3 milliseconds after each sampling interval.

PIEZO ACCELEROMETER REPORT CEC

REPORT NUMBER 3

No job too demanding for CEC Accelerometers

If you can *define* your problem, CEC can *deliver* the solution—because CEC already has accelerometers designed to meet the most demanding and specific requirements. What's more, most units are "on the shelf"—ready NOW to meet your application.



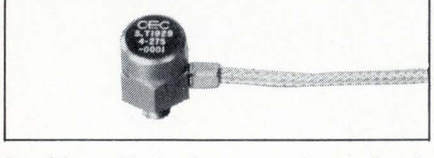
Problem: laboratory measurements—where acceleration measurement over extended frequency range is required.

Solution: Type 4-270

The extreme sensitivity of this unit extends the measurable acceleration range to low levels which are undiscernible by most piezoelectric accelerometers. The 4-270 produces a readable signal at lower than usual g levels.

Specifications:

- *Basic Voltage Sensitivity (Open Circuit):* 72 mv/g nom, 65 mv/g min at 77°F and 100 Hz
- *Charge Sensitivity:* 33 picocoulombs/g nominal
- *Frequency Response:* 2 to 8000 Hz ±5%
- *Temperature Range:* –65°F to +350°F



Problem: limited space where size is critical; small unit required with accurate data capability.

Solution: Type 4-275

First "pea size" accelerometer on the market with a *detachable* cable to eliminate the expense and inconvenience of returning accelerometer to the manufacturer to replace a frayed cable. "Compliant rod" design isolates the sensing element from the housing, virtually eliminating such troubles as cable whip effect, acoustic bombardment, and thermal transients.

Specifications:

- *Basic Voltage Sensitivity:* 5.5 mv/g nom, 4.0 mv/g min (at 77°F and 100 Hz)
- *Charge Sensitivity:* 2.3 pcmb/g nominal
- *Frequency Response:* ±5% from 4 to 15,000 Hz with 300 meg load
- *Temperature Range:* –100°F to +250°F

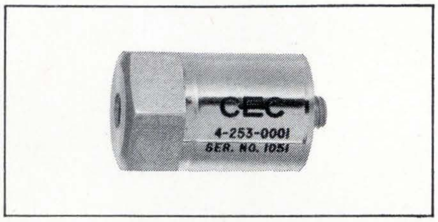
Problem: small, lightweight low-impedance unit needed for direct readout of an output signal.

Solution: Type 4-281

"Compliant rod" construction is combined with an internal source follower, both electrically and mechanically isolated from the housing. Effects of cable whip, acoustic bombardment, ground loops are minimized by this two-fold isolation along with the accelerometer's all-welded housing; with low impedance output the noise susceptibility, contamination, and problems of low-noise coaxial cables are eliminated.

Specifications:

- *Basic Voltage Sensitivity:* 30 ±6 mv/g at 77°F 100 Hz 50,000-ohm load, and 22 v excitation
- *Frequency Response:* 4-10,000 Hz ±5% from 100 Hz reference
- *Output Impedance:* 150 ohms max
- *Harmonic Distortion of Output:* 2% max (at 2.5 v rms and 0.2 ma rms max current)
- *Temperature Range:* –100°F to +300°F



Problem: high accuracy structural testing—free from unwanted inputs.

Solution: Type 4-250

Unwanted inputs from deformation of the accelerometer base are effectively eliminated by CEC's new 4-250 Series Accelerometers—thanks to a unique application for CEC's Ceramicite®. Up to 30 times more resistant to base strain, CEC 4-250 Series Accelerometers feature a compliant rod/mass assembly virtually isolated from distortion of the base. Users are no longer plagued by temperature transients and acoustic loading. As a result, CEC specifies a maximum base strain sensitivity guaranteed to .01 g/10^{-6} in/in. on each accelerometer.

Each of the four accelerometers in this series has unique features to match specific requirements. The 4-250 is designed for high charge output and flat charge vs. temperature sensitivity. The 4-251 provides flat voltage response over a wide temperature range (–320°F to +500°F). The 4-252 gives flat charge response at cryogenic and high temperatures. And the 4-253 delivers flat charge and voltage response at cryogenic and very high temperatures (operating range –320°F to +700°F).

CEC also supplies a line of associated electronics for use with these transducers: source followers, voltage amplifiers, and charge amplifiers.

For complete information on these accelerometers or application problems, call your nearest CEC Field Office. Or write Consolidated Electrodynamics, Pasadena, California 91109. A subsidiary of Bell & Howell. Bulletin Kit #327-X2.

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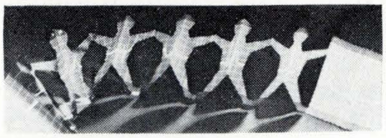


Helping hands

Modern electronic components and signal-processing techniques are the keys to better prosthetic devices for amputees

By Yves Lozac'h, Andrew L. Lippay, E. David Sherman, M.D., and Gustave Gingras, M.D.
Rehabilitation Institute of Montreal, Montreal, Canada

Technology has reached a point where electronics can help restore physically disabled people to a useful life.

With the availability of such components as integrated circuits and miniature actuators and energy supplies, it's technically possible to build powered devices to replace or assist human organs and limbs.

But before these devices are completely acceptable, more must be learned about the interface between man and prostheses. Modern control theory must be brought to bear on that most exquisitely engineered system of all—the human neuromuscular system.

Consider what the system does. Directed by the brain—a device weighing about three pounds and consuming only a few watts—it controls and energizes the physical activities of the body with graceful coordination and useful purpose. It responds to stimuli from the environment, processes this input data, and compares it to past experiences stored in the memory. If physical action is called for, instructions are passed through nerve channels to activate muscles in sequence.

The instructions can be modified or cancelled if obstacles or hostile conditions are encountered. The history of the activity is stored in a short-term memory, and the action can be repeated without further monitoring.

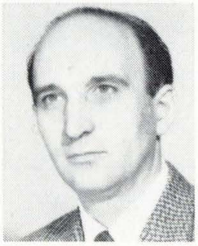
With all this, the system requires relatively low operating costs, and is mass produced by relatively unskilled labor.

The replacement or restoration of any component of this extraordinary complex is a tremendous challenge. Complicating the situation is the fact that each human's problems are unique; this probably precludes the development of any standard device to serve all cases.

Since the Middle Ages, prostheses have been almost exclusively in the form of mechanical devices

The authors

Yves Lozac'h joined the Rehabilitation Institute of Montreal as an engineering assistant after working at Canada's Atomic Energy Research Establishment and Canadian Aviation Electronics Ltd. He served in the French Navy as a telecommunications specialist.



Andrew L. Lippay received his training in physical medicine engineering at Highland View Hospital in Cleveland. He holds an electrical engineering degree from McGill University and worked for Canadair Ltd. and the Northern Electric Co. before coming to the institute.

E. David Sherman, M.D., is the institute's director of research. A Fellow of the American College of Physicians, he is a past president of the American Geriatrics Society and a lecturer in geriatrics at the University of Montreal's school of rehabilitation.

Gustave Gingras, M.D., has been executive director of the institute since its founding in 1949. A professor of physical medicine and rehabilitation at the University of Montreal, he is a Fellow of the Royal College of Physicians of Canada, and of the American Board of Physical Medicine and Rehabilitation.

operated by cables attached to harnesses. The force required to operate the device is derived from the movement of some normal muscle or other part of the body. While this type of prosthetic is surely helpful, it suffers from a number of disadvantages.

In the first place, the number of control sites on the body, especially after extensive amputation, is limited. Secondly, the method affords the patient only a limited degree of functional freedom and clearly presents difficulties in terms of activity, appearance, and mechanical efficiency.

Early in the 1950's, Norbert Wiener suggested that the electrical signals generated by muscles when they contract—the so-called myoelectric potentials—could be used to control externally powered prostheses. Since that time, the myoelectric approach to prosthetics has been the subject of considerable research both here and in Europe[1-3] [Electronics, July 10, p. 105]. Combined with new developments in electrical and gas-operated actuators, it promises to provide the patient with superior control and to minimize adjustments.

Muscle action

The basic module of muscular operation is the motor unit. Small groups of individual cells, or fibers, of skeletal muscles are connected to the terminal branches of a nerve fiber or axon, whose main cell body is in the grey matter in the spine.

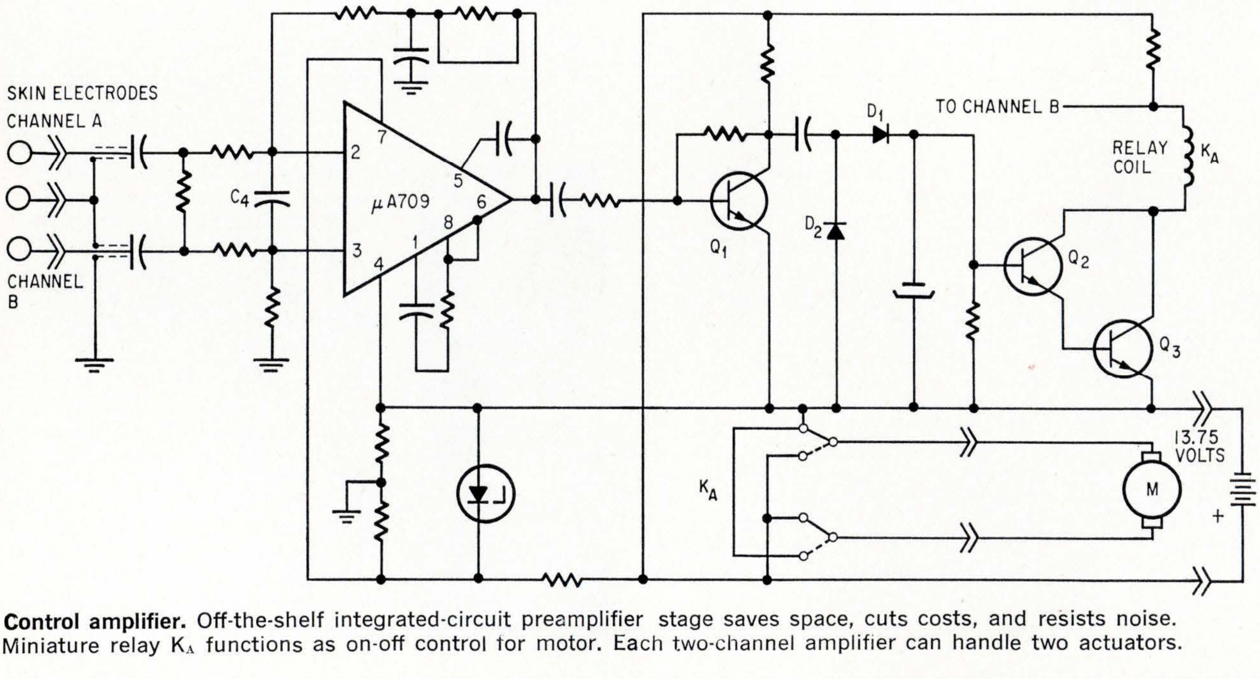
A nerve impulse originating in the central nervous system (brain and spinal cord) travels down the axon at a finite velocity and depolarizes a membrane enveloping the muscle fibers. Ions stored along the membrane by metabolic processes rush in to cancel the opposite-polarity charges produced by the impulse. The fibers connected to the axon contract sharply and almost simultaneously to about 57% of their resting length, then relax completely while other similar units are "fired." As the demand for muscular effort increases, so does the frequency of firing in each motor unit, and additional units are gradually brought into action.

The fibers of a motor unit are distributed randomly across the section of the muscle, which seems to contract smoothly, although even at maximum effort only about one-third of its fibers are contracted at any given instant and a continuous cycling of motor units is taking place. Independent fibers of the motor unit fire at slightly different times, depending on the distance along the terminal nerve branch.

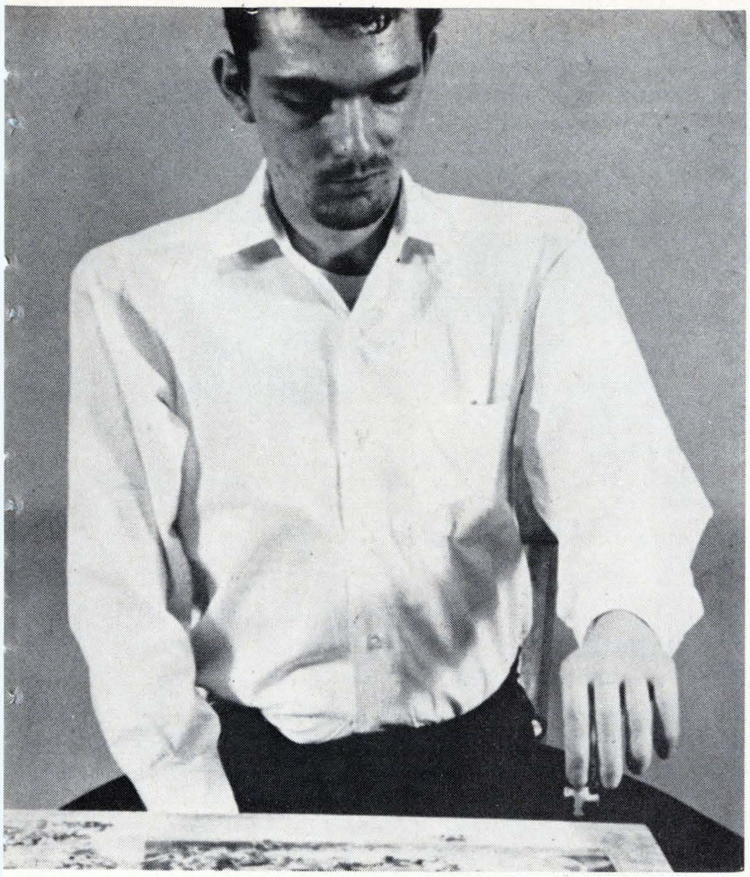
Muscles used for delicate movements require greater precision of control than gross muscles. Accordingly, their motor units are small, with separate nerve ends controlling as few as 10 muscle fibers; other muscles may have motor units containing 2,000 fibers, also controlled by one axon.

In practical applications, the muscle signals must be coupled into the control circuit without penetrating or otherwise damaging the skin. Much effort is now being made to develop components for a miniature radio link that would be implanted in the body to directly connect the signal source to the control unit.[4, 5] At Case Institute of Technology in Cleveland, an operational myoelectric amplifier and transmitter was successfully implanted in the shoulder of a research associate recently. Right now, however, surface electrodes, with all their associated problems, have to be used.

These contacts must be maintained at the appropriate points of the skin, necessarily some distance from the actual control muscle. Motor units' action potentials lose their higher-frequency components in traveling through tissue, and the signal pickup is subject to crosstalk from other muscles operating in the vicinity, including the heart. A poor electrode contact tends to inject noise into the necessarily high-gain amplifier system connected to it. What the control amplifier sees, even



Control amplifier. Off-the-shelf integrated-circuit preamplifier stage saves space, cuts costs, and resists noise. Miniature relay K_A functions as on-off control for motor. Each two-channel amplifier can handle two actuators.



Rehabilitation. Fitted with myoelectrically controlled hand, this amputee demonstrates dexterity.

under the best of conditions, is a distorted form of the electrical sum of the outputs of many motor units. Such gross myoelectric signals must be processed to establish an output approximately proportional to the muscular effort. Control inputs can be derived by comparing two instrumented muscles, or a single input can be used. Short-term integration, measuring the frequency of baseline crossings, or counting the peak reversals occurring in a given time are some signal-processing methods now in general use.

Several important contributions to the development of myoelectrically controlled artificial limbs have been made in the recent past. Russian scientists, for example, have developed an artificial arm for below-the-elbow amputees that uses muscle currents to control the finger movements [Electronics, Dec. 28, 1964, p. 111]. Scientists at the Philco-Ford Corp. initially used myoelectric signals to operate the knee joint of a leg brace on an artificial leg [Electronics, Nov. 30, 1964, p. 74]; later the company went a step further and designed a completely self-powered artificial arm that could bend at the elbow and turn at the wrist [Electronics, Sept. 20, 1965, p. 42]. And a myoelectrically controlled arm aid has been developed at Case Institute of Technology [Electronics, Sept. 20, 1965, p. 110].

The Rehabilitation Institute of Montreal has been fitting amputees with externally powered prosthetic devices for about four years. Gas-operated devices were initially used, mainly to equip young children born with deformities that were caused by the drug thalidomide. Two years ago, electric devices were introduced, primarily electric hands designed and built in the Soviet Union.[6] Experience with these turned up serious maintenance problems. Designed with marginally rated components, the units failed whenever noise at the amplifier input became excessive.

The institute staff decided to design and build a similar control system using available U.S. and Canadian hardware. Performance specifications and size requirements practically dictated the use of monolithic integrated circuits in the preamplifier.

Design considerations

The institute's experience with myoelectric controls defined some of the requirements for the system, while prosthetic considerations, costs, and a pressing need for operational equipment dictated others. The principal objective was to produce a practical, reliable, reasonably inexpensive control system for two existing electrically powered devices—an artificial hand and a prosthetic hook—that both perform the function of simple prehension (pinch) when energized.

An on-off mode of control is initially being used, but proportional control is projected as the next step. The equipment has to be used by nontechnical people, of course, and operation has to be simple, and servicing and maintenance minimal.

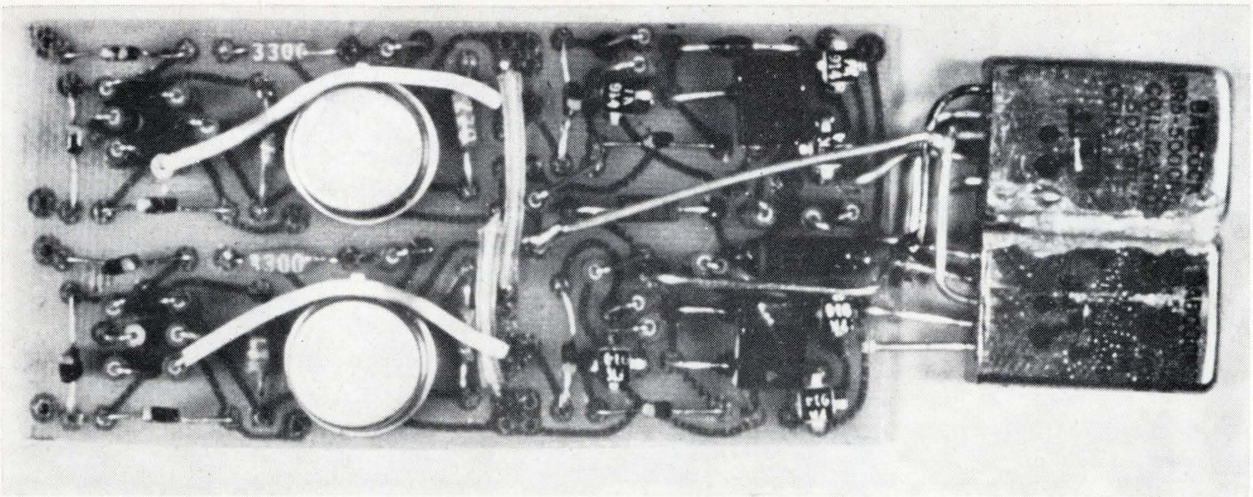
Independent muscle signal inputs for each channel were preferred by designers to techniques that use a balancing of opposing muscles or compare the output of several muscles. The devices, it was reasoned, would often have to be fitted in cases where control muscles could only be found on the trunk, perhaps in the abdomen.

Because of low signal levels and high ambient noise, a low input impedance in the range of several thousand ohms is desirable for the preamplifier. On the other hand, the amplifier sees a high and variable source impedance because of changing physical conditions at the electrodes. The amplifier may be looking into several tens of kilohms or more, which must be matched to the input circuit. An equivalent input impedance in the order of 50 kilohms in therefore a reasonable compromise.

Because shielding is difficult, high levels of electromagnetic interference make high common-mode rejection essential to prevent operation of the prosthetic device except on command. Thermal stability is also an important factor, and silicon devices are used exclusively.

A relatively narrow frequency-response band of 80-1,000 hertz was specified to increase the signal-to-noise ratio while reducing sensitivity to high-frequency ambient noise and power-line frequencies. Capacitive coupling of the input eliminates the effects of variations of d-c levels occurring in the tissue and at the electrode-skin interface.

A maximum over-all time delay of 100 millisec-



Prototype. Assembled two-channel control unit incorporates IC preamplifiers and miniature relays.

onds between a command and actuator movement was specified. Any greater lag would require conscious concentration on the part of the operator, and delays of more than 200 msec could cause serious frustration in his part.

Selecting the preamplifier

In the first design attempt, it was intended to install the IC input stages directly over the pickup electrodes. This would eliminate much of the ambient interference and permit the locating of the rest of the amplifier at any convenient point independent of lead length. However, for production reasons this scheme was abandoned in favor of a single control unit, separated from the structure holding the electrodes in place but installed in reasonably close proximity. The IC preamplifiers provide, in a very small package, a balanced and matched differential input, high stability and input impedance, and an open-loop gain of about 50,000.

Two flatpack IC amplifiers were used in the first experimental installation, which has now been in service on a female patient for more than nine months. Flatpacks ideally meet the space requirements, but they are expensive, involve long delivery times, and require that the control circuit be adjusted each time a new preamplifier is wired into the unit.

The design was therefore changed to accommodate a Fairchild μA709C amplifier packaged in a TO-5 case. It is available off the shelf and costs less than $10 each in 100-unit lots. More than 30 of these devices were interchanged in the breadboard, and only one—which later proved to be defective—caused appreciable changes in the operating characteristics of the prosthetic arm.

In keeping with space requirements, discrete microminiature components were selected for the rest of the control circuit. Capacitors must have a comfortable margin of voltage ratings because the system is frequently exposed to high noise levels at the input.

Babcock miniature relays in a flat can energize high-speed permanent magnet motors to drive the prosthetic devices. The motors draw approximately 150 milliamperes at full load and 700-800 ma when stalled. No relay failures have yet occurred, although some motors have been exposed to continuous operation on the breadboard and to vicious chattering during adjustments and electrode trials. Since the motors have to operate in either direction with dynamic braking, the usual methods of protecting contact aren't practical. However, shunting the contacts with back-to-back zener diodes can divert high voltage surges if the relays are affected by the inductive loading.

Control unit

The input circuit couples the signal from the muscle to the preamplifier. A single-transistor

The human factor

Replacing a missing human limb isn't just a matter of hooking up the man to an artificial device. The design of a prosthetic device is naturally affected by a great number of psychological and physiological factors. Here are just a few, as described by the authors:

The designer must never forget that he is dealing with human functions. The most sophisticated preprogramed crane attached to a wheelchair won't serve the purposes of rehabilitation as well as a simple splint the patient can use to hold a hook by bringing thumb and fingers together.

The patient must be able to adapt to the machine's idiosyncracies.

If the patient has to accept discomfort and limitations, the device must significantly improve his functional freedom. Conversely, if operation is smooth and sustained, the efforts demanded of the patient mustn't be fatiguing.

Cosmetic aspects can't be ignored. The prosthetic device shouldn't embarrass the patient by being noisy, jerky, or noticeably slow or fast. It should be light and strong, easy to operate and clean, and not irritating.

amplifier stage follows the preamplifier, whose output is an a-c analog of the input. The input, in turn, is approximately proportional to the muscular effort. After half-wave rectification, the signal is filtered by an RC circuit that performs, in effect, iterative integration. The d-c output is amplified in a Darlington power amplifier that drives the relay on or off when the coil current reaches a predetermined level.

The muscular command signal input is capacitively coupled to the input network, which matches the source impedances to the preamplifier.

The Fairchild μA709C is essentially a dual operational amplifier with an inverting and non inverting input channel, and is designed for comparator and low-signal applications. Input impedance is specified at 400 kilohms and the open-loop gain is 45,000 when operated with a supply voltage of ± 18 volts. In the prosthetic control, the supply voltage is zener-regulated to ± 4.5 volts, reducing the open-loop gain to approximately 80 decibels.

Frequency response

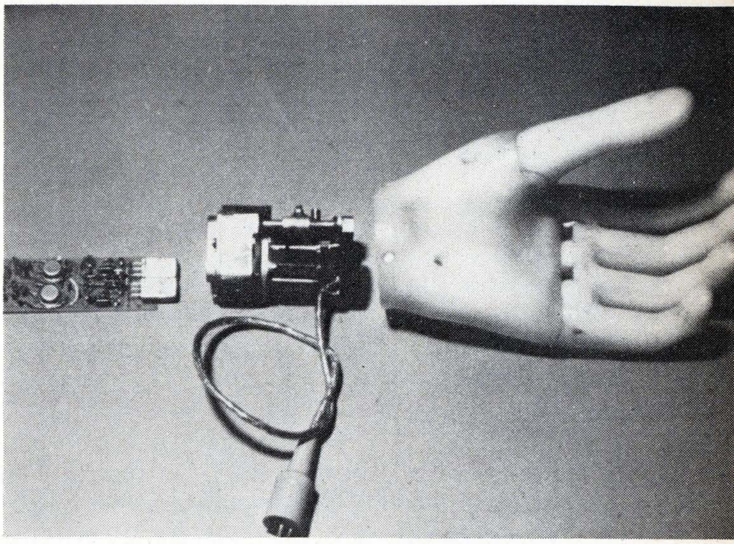
To achieve d-c stability, the loop is closed around the amplifier, establishing very low d-c gain, minimizing the effects of drift, and eliminating the need for offset adjustment. The gain characteristic rises smoothly from unity at d-c to a maximum approaching the open-loop gain at 120 hz. The curve is flat within 3 db of this level up to 200 hz, then rolls off to unity gain at approximately 2 kilohertz. At 60 hz the gain is 15 db down. The area under this characteristic curve coincides with the frequency limits representing the maximum information content of the myoelectric spectrum. The amplifier thus combines high sensitivity to the most important segment of its signal input with relatively narrow frequency response for a high signal-to-noise ratio.

The measured output impedance of the amplifier is 150 ohms. The root-mean-square noise amplitude is on the order of one microvolt, referred to the input, using the maximum gain figure of 80 db. At the standard frequency of 200 hz, the common-mode attenuation is approximately 90 db. The input impedance was determined under simulated input conditions to be 45 kilohms.

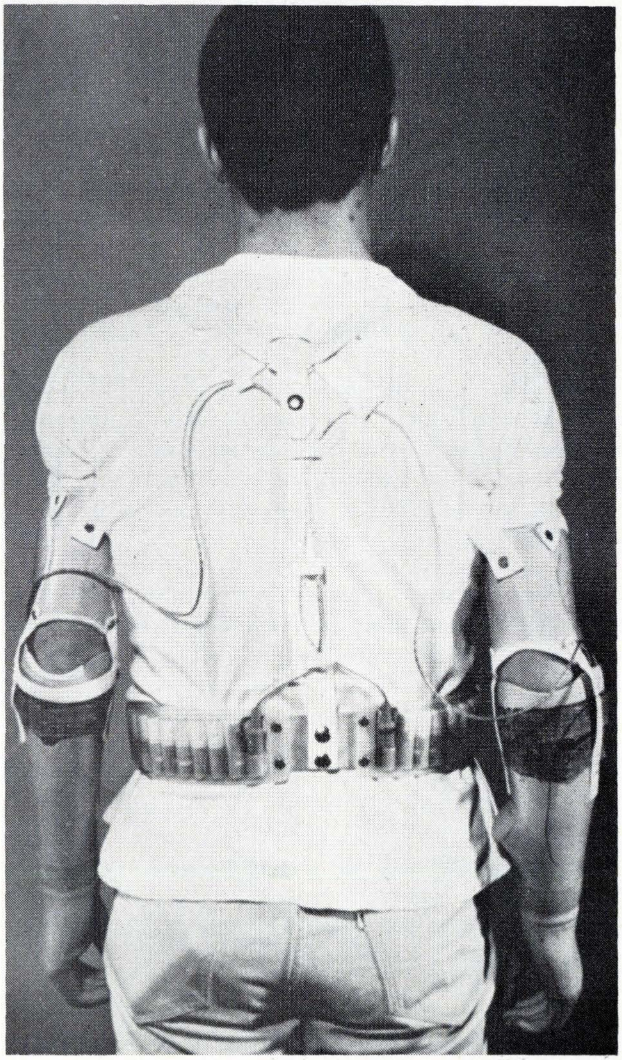
The single transistor, Q_2, and its base resistor serve to decrease the effects of capacitive loading on the output [figure on page 126]. The stage produces a voltage gain of 25, increasing the signal enough to overcome the forward threshold of integrating diode D_1.

Signal processing in the form of short-term integration is accomplished with half-wave rectification and RC filtering. Diode D_2 provides a reference voltage for the coupling capacitor. The response of the integrating circuit, approximately 100 msec under operating conditions, is less than the RC product since the circuit is never completely quiescent when connected to the electrodes.

Because there is no bias in the first stage of the Darlington amplifier, the circuit triggers when



Improvement. Closeup of prosthetic hand and drive motor with IC control unit. Design successfully overcame shortcomings of Russian prosthetic hand, which suffered frequent breakdowns because of poor-quality components.



Fitted out. Patient with double amputation below the elbow wears myoelectric hands. Battery pack is installed on belt.

the integrator output exceeds the base threshold, and turns off when the voltage falls. This action provides a positive triggering, completely cutting off the relay coil current when not energized and thus reducing the standby drain on the battery.

In a two-channel control, a common resistor is added between the relays and battery neutral to ensure selective operation of the desired channel and to counteract simultaneous activity due to muscular crosstalk. The difference between pickup and dropout voltages in the relay provides an inherent hysteresis characteristic, which helps absorb fluctuations in muscle signals occurring even under steady contraction.

Energy source

A single battery power supply is desirable to minimize the amount of equipment carried by the patient. A nickel-cadmium battery pack consisting of 11 Eveready C45T cells in a Vitrathene envelope has been used on institute patients with electric prostheses for some time. Rated at 450 ma-hours at a nominal 13.75 volts, some of these batteries have operated satisfactorily for more than 18 months, representing at least 300-400 cycles of discharge.

They seem to be indestructible unless grossly mishandled; a simple charger with a series resistor to limit initial current and final voltage takes care of recharging without a timer or charge-level indicator. Because of the motor load current, voltage regulation has to be provided in the preamplifier stages. In previous installations, especially with a patient who had lost limbs on both sides of the body, the drop in battery voltage caused serious problems and individual batteries had to be used for each side.

Even such a bilateral amputee needs simple surface electrodes to operate the equipment throughout the day without adjustment or assistance. Solid stainless-steel buttons of approximately an 8-millimeter diameter and spaced 25 mm apart are used.

A water-soluble electrode jelly is rubbed over the skin surface in the electrode area. Natural skin salinity and moisture, in combination with a light salty residue from the jelly, maintain the electrode resistance at a reasonably low value indefinitely.

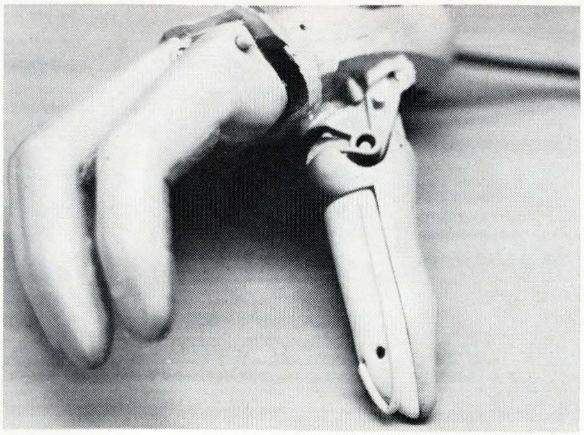
Mechanical design

The space available in the prosthetic structure limits the physical size of the control unit. To make the location of the electronic package independent of the level of amputation, the unit was designed to fit between the walls of the laminated socket structure common to all prosthetic devices; this is necessarily custom-tailored to each individual patient. On this basis, the maximum dimensions for a two-channel unit were set at 7 mm thick by 25 mm wide by approximately 60 mm long. Various curved shapes were considered for the printed circuit board at first, but a straight narrow shape was finally adopted because it's most easily adaptable to individual variations in prosthetic design.

Exhaustive testing in an environment of intense high-frequency fields showed the system to be unaffected. When operated near airborne vhf and radar equipment, no false operation was observed, and no interference or objectionable reflections were caused by the prosthetic system. In fact, the system has been cleared by Canadian Pacific Airlines for use aboard its planes.

With a single battery supplying both the control unit and the drive motor, armature noise is continuously reflected into the supply voltage. Furthermore, the battery inevitably picks up ambient electronic noise.

Electromagnetic induction in the metallic structural parts of the prostheses has created problems in previous systems, but the present IC amplifier is much less sensitive to such disturbances. Preparation of the control sites appears to be far less



On the other hand

The simple on-off type of control used by the Rehabilitation Institute is relatively demanding when compared with the complexities and versatility of an actual human limb and the neuromuscular system that drives it. With an on-off system, the patient must actuate his prosthetic device with a delicate application of force.

An approach that more closely approximates the action of a human limb incorporates feedback in a proportional control circuit. An electromechanical hand based on this principle was developed recently by the medical biomechanical research laboratory at the U.S. Army's Walter Reed Medical Center [Electronics, May 1, p. 38].

Unlike the institute device, this hand isn't under myoelectric control. It is instead powered by a nickel-cadmium battery that operates a motor directly through an amplifier. The wire on the hand's thumb in the photo above is connected to a piezoelectric crystal that acts as a sensor. The sensor automatically detects the pressure required to hold an object; the sensor's output is coupled to the motor through the amplifier for the needed torque. If power is cut off, the hand retains the object without further effort by the patient.

critical than before, and the required muscular effort is appreciably less; fast response and good control are reported by users.

Since the introduction of this control system at the institute two years ago, 23 electric hands have been fitted to patients with widely different medical histories. All the devices were controlled myoelectrically, and a few were combined with pneumatically driven systems.

With a few exceptions, the control of the electric hands became subconscious in a short time, even in cases where the control muscles were anatomically disassociated with hand functions. For example, after only three days of training, a bilateral shoulder amputee operated a pair of electric hands through four muscles of his back with apparently less concentration than he would need to select the control valves for a pneumatic elbow and wrist actuator.

Most patients with below-elbow amputations report that their electric hand becomes closely identified with the phantom image of the missing hand; this identification increases in intensity with continued use of the residual muscles as myoelectric signal sources. Even with amputations where functional loss is minimal, some patients insist on constant use of the externally powered devices, although such applications might be considered economically extravagant.

Brief and informal experiments with children as young as four years of age showed that they can master myoelectric control quickly. With surface electrodes applied to control sites on the limbs, trunk, and abdomen, the children operated appropriate muscles with few errors.

The future

Electronic prosthetic control will come into its own when more sophisticated powered functional devices and systems are available. Whatever form of energy is used, the performance of available devices is still far from the efficiency and versatility of the human limbs the equipment replaces. Mechanical developments are urgent.

Portable energy sources developed for commercial and military purposes more or less satisfy the immediate needs of powered limbs. However, more efficient batteries and energy conversion would reduce the weight and bulk the patient has to carry, and would permit the design of more extensive and powerful systems. For example, lithium batteries are reported to have a four-fold advantage over nickel-cadmium cells in storage capacity.

Hydraulic actuators and devices are excellent for energy conversion in high-gain mechanical systems, but their application to prosthetics lags because of the difficulty of pressurizing a small portable system. Researchers at the Northern Electric Co. are currently developing a very small, electrically driven pump and a four-function hydraulic-arm complex suitable for very young amputees. An earlier electric-arm system is now undergoing clinical and home evaluation. Also under development is a multifunction artificial hand adaptable to electric, pneumatic, or hydraulic drive. All these devices will be fitted to children at the Rehabilitation Institute.

The ideal type of bioelectric prosthetic device would operate under the control of actual nerve or brain signals sensed by a direct connection to the central nervous system. But this type of man-machine connection isn't immediately feasible.

Even the simple myoelectric devices available now are useful clinical and rehabilitative tools; most installations offer significant improvements in functional freedom. The cost is still high, but volume buying and new commercial developments will reduce unit costs from the prototypes' price of several hundred dollars.

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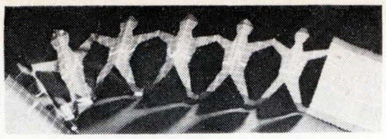


Vigilant machines

Electronic monitoring systems are improving patient care while considerably reducing the workload on hospital staffs

By Morris White

Hewlett-Packard Co., Waltham, Mass.

The heart patient's chances of survival have been dramatically improved by the use of electronic monitoring equipment in hospitals. Already the mortality rate among patients admitted after heart attacks has been halved—to 20%—since monitoring equipment first appeared in hospitals about seven years ago.

Continuous, automatic monitoring in intensive care wards is a boon to doctors and nurses, reducing their workload and enhancing their vigilance. Audible or visible alarms immediately alert the staff to changes in a patient's condition, and sometimes even provide corrective measures via feedback. An example here would be the cardiac monitor that incorporates a demand-type pacemaker.

Dynamic data is displayed visually on oscilloscopes; slowly changing physiological data is shown with meters and numerical readouts. Important information and signs are recorded and stored at central stations.

What the systems monitor are the electrical signals (called biopotentials) generated by the human body [Electronics, July 10, p. 103], and such biophysical phenomena as liquid pressure, flow, displacement, temperature, sound, and force. The equipment can handle the biopotentials directly, but nonelectrical data has to be converted into electrical signals.

In either case, the job isn't easy. Patients can't be designed or modified to accommodate the electronic system. Sensors are usually applied externally, but not always. Surface electrodes are safer and easier to use than internal sensors, but their performance can be degraded by muscle-generated noise and the outer layer of skin resistance.

Shock hazard

Connecting a patient to electronic equipment poses the threat of electrical shock. The danger is most serious when currents have to be passed directly through the heart, since the lethal current level in the heart may be as low as 100 microamperes root-mean-square.

This hazard, though, is significantly reduced in a series of electrocardiographic machines recently developed by engineers at the Hewlett-Packard Co.'s Sanborn division. Instead of using a direct wire connection or reference electrode, these machines connect the patient to ground potential through an amplifier with a current-limited output. Essentially, this active circuit operates like a fuse but is capable of reacting to the very low current values considered lethal.

Should a patient accidentally contact a voltage source, such as the power line, through the electrocardiograph's ground circuit, the amplifier circuit's impedance increases to block any current flow. This technique reduces the leakage current from any 120-volt a-c source to 4 μa or less, and simultaneously produces a grounding impedance lower than an electrode's contact impedance.

Besides its bedside role, monitoring gear has a place in the operating room when major surgery is performed. Among the parameters monitored are blood pressure, heart potentials (electrocardiographic tracings), heart rate, body temperature, and brain waves (electroencephalographic tracings). The anesthesiologist uses the EEG, for example, to gauge the level of unconsciousness.

The author

Morris White has been with the Sanborn division of Hewlett-Packard for 20 years. He has been involved in both the engineering and marketing of medical electronic instruments, and is currently a product manager for the division.

Operating-room displays range from small scopes showing only EKG and EEG to multichannel systems with big scopes for real-time data, meter or numerical readouts, and magnetic-tape recorder.

A large monitoring installation like that at George Washington University Hospital in Washington, D.C., usually has the bulk of the electronic equipment in a room apart, with only oscilloscope and numerical-readout displays inside the operating areas. From the central control room, the monitoring equipment at the university hospital serves a cardiovascular and several general operating rooms, a recovery room, and a special-care unit.

The signals monitored are transmitted through cables to the control room for signal conditioning, recording, and routing. The system's operator is in two-way voice communication with the surgical teams, and duplicate visual monitors are mounted on the walls or ceiling of operating rooms. Such an installation eliminates the clutter of instrumentation in the operating room and reduces the hazards associated with electronic gear. The recordings can be played back during surgery.

The control-room operator at George Washington monitors signals displayed on an eight-channel, 17-inch scope, and a consulting anesthesiologist can keep track of the patient's EKG on a five-inch oscilloscope in his office.

Each bed in the hospital's recovery room has an oscilloscope for continuous display of the patient's EKG, a heart-rate meter with adjustable high and low thresholds, and associated alarm indicators.

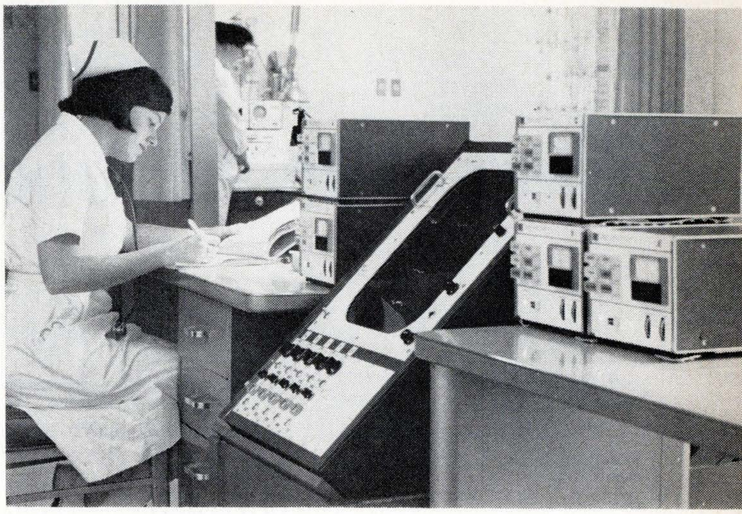
Postoperative

After leaving the recovery room, the patient is placed in an intensive care unit where EKG, heart rate, peripheral pulse, and central venous pressure are monitored. Peripheral pulse—detected at a fingertip or ear with a photoelectric-type pickup—serves as an index of the heart's pumping power.

For continuous and accurate measurements of blood pressure, a small, hollow catheter tube is inserted directly into a vein. In the Sanborn monitoring system, these transducers work into a carrier amplifier to yield an output voltage calibrated in pressure. The output waveform can be recorded on an oscillograph, displayed on a scope, or processed by circuits that detect and hold the highs and lows for digital display.

Continuous-loop magnetic tape recorders provide EKG information on the heart signals just prior to an emergency situation. Each loop can hold about 15 minutes of data, although a 40-second loop is typical. Recording erases previous information. When an alarm is triggered, however, the erase mechanism is inhibited and the EKG for up to 15 minutes prior to the alarm is available for study.

The Washoe Medical Center in Reno, Nev., has an intensive care unit for heart patients that provides graduated levels of care. Some patients are kept under direct observation by nurses viewing monitors at a central station; others get this kind of attention only in case of alarms.



Central monitoring station. Five-bed cardiac care unit is watched over by one nurse. Multichannel scope simultaneously displays each patient's EKG. Individual units display patient's heart rate on a meter, and lighted indicators warn of significant changes.

The bedside installations include meters for displaying heart rate as an average value; flashing lights to indicate each heart beat; visual alarms to signal irregular heart rate, peripheral pulse loss, or cardiac arrest; a strip-chart recorder to take a 10-second EKG sample every 15 minutes; and facilities for internal or external heart pacing in the case of heart failure.

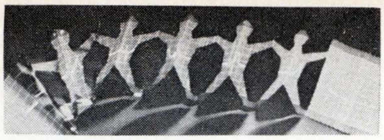
The central station at Washoe has individual oscilloscopes to observe each patient's electrocardiographic waveforms, an alarm system, and a numerical readout of blood-pressure and temperature measurements.

Emergency measures

In systems that feature data logging, impulses from the monitors are fed into a central data-gathering unit that periodically prints out such measurements as temperature, respiration rate, and blood pressure. If the readings fall outside preset limits, though, the alarm is given and the system speeds its printout of the salient parameters. At the same time, a tape memory unit automatically prints out the patient's EKG for the 40 seconds prior to the emergency, and a pacing device begins automatic heart stimulation.

In cases where patients have faulty heart rhythms or a complete block, an electronic stimulator can save their lives. This pacemaker can be built into the monitoring system to operate automatically in response to distress signs or on command from the central station. In temporary situations, the pacing pulses can be transmitted by surface or intracardiac catheter electrodes; the pulse's duration is about 2 milliseconds.

Hewlett-Packard pacemakers deliver a constant-current pulse whose amplitude can be adjusted from several milliamperes for internal electrodes to over 100 ma for external electrodes. The impulse rate is adjustable from 50 to 150 pulses per minute.



More than an ounce of prevention

Comparison of the results of multiphasic screening tests can draw a picture of a patient's health status. The technique comes under the heading of predictive medicine, and the goal is health itself

Arvo Schoen and Joseph J. Poyer
Beckman Instruments Inc., Fullerton, Calif.

The prime goal of future medical efforts will be the prevention of chronic and degenerative diseases. Advances in diagnostic techniques and therapeutic agents have given doctors the weapons to contain, and in some cases eradicate, their traditional enemies—acute and communicable diseases. With these gains, the pursuit of cures is becoming secondary; health itself is the main objective.

The trend is producing a new field of endeavor —periodic multiphasic screening—and a new technique—predictive medicine. Here, physicians, scientists, and engineers have to work in concert; the anticipation or early detection of illness requires the extensive use of monitoring instruments and data systems.

In this approach, health and illness are viewed as opposite ends of a scale, not as discontinuous conditions. A person doesn't suffer a heart attack because a healthy heart suddenly loses its blood supply. Strokes don't occur because healthy arteries suddenly rupture or occlude. The overt problems are the result of subtle biochemical changes that persist and grow over a period of time. If spotted early in the degenerative process, these changes might be arrested or even reversed.

The important concern in predictive medicine is to pinpoint the individual's level of tolerance to various stresses, and to thereby gauge his predisposition to disease. In monitoring a patient's adaptability to stress, rate of response and rate of changes of response are more significant than the result of any physiological measurement by itself. Measurements of the overcorrective feedback of the adaptive mechanisms, and of the time lag following the stimulus, can be taken as indicators of potential reactions to future stress.

In glucose tolerance tests, for example, a sugar load is administered and adaptive reactions are measured as the body tries to cope with the metabolic overload. Any deviations in the mechanisms that regulate this capacity to maintain the body system's functional integrity suggest a potentially diseased state. The use of a treadmill in cardiovascular tests also stems from this principle.

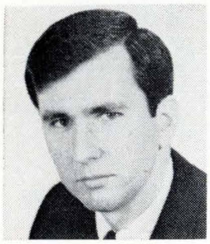
Killing pace

Ample evidence exists that chronic diseases, which seem endemic to modern civilization, represent inadequate adaptations by individuals to the environment. Heart disease, cancer, and diabetes are examples of these so-called maladaptive diseases.

Some assert that these metabolic illnesses are only now becoming prominent because of the containment of infectious diseases. They argue that the shorter life spans of earlier times masked the degenerative processes we have to deal with now. Certainly aging is a factor here, but much experi-

The authors

As a project engineer in Beckman's predictive health program, Arvo Schoen is responsible for the development of new medical systems and techniques. He has helped design systems for the biochemical monitoring of astronauts.



Joseph J. Poyer is a communications specialist for medical and health programs at Beckman's Advanced Research department. He is currently heading a team studying the technological and socio-economic aspects of multiphasic screening.

mental data on proneness to diabetes and high blood pressure, for example, hint at a considerable toll exacted by the environment alone.

A distinction should be made between predictive medicine per se and preventive medicine. The latter aims at maintaining health by dealing with problems before they become debilitating. The special job of predictive medicine is to establish the status of a person's health and to determine the degree of his susceptibility to disease. Treatment of the injured and sick, of course, falls in the realm of clinical medicine.

Picture of health

Predictability is established from a reproducible sequence of events. These sequences can take the form of individual or general profiles composed of historical, physiological, biochemical, and psychological data points. The results of periodic tests produce a picture describing the proneness of an individual or a population group to certain diseases. Such profiles have already been used to forecast susceptibility to cardiovascular disease.

General profiles are suspect; setting them up involves the apparently impossible task of compensating for individual hereditary, biochemical, and physiological differences. Most experts hold that the statistical approach will never be as useful as continual follow-up testing on an individual basis —periodic multiphasic screening.

In this screening procedure, individuals are given a battery of tests and are re-tested periodically for signs of change. There is growing enthusiasm for industrial and community programs along these lines; at least 55 organizations in this country started multiphasic screening plans in the past decade, and Senate hearings last September on the approach attest to this interest.

Medical men generally agree on the value of multiphasic screening, but there's considerable disagreement on the format to be followed. For one thing, many aren't convinced of the validity of some biochemical tests currently used to diagnose overt disease, and would be even more dubious if the tests were given to detect problems in the subclinical stage.

New tests must be developed to measure the effect of various kinds of stress on outwardly healthy persons. As body functions are dynamic, the stress tests should be dynamic and should measure the total response. It just isn't feasible to selectively alter the physical system parameter by parameter to determine the effect of the alteration. The system's responses must be taken as a whole, lesser reactions must be viewed in context with major ones, and enormous amounts of data must be amassed.

Much of the monitoring equipment needed for this kind of analysis exists today, either as commercial or laboratory instruments. The scientist has the tools to identify and measure all the biochemical substances known to be metabolically active. He can measure metabolic changes occurring at the cel-

Second generation

Future multiphasic screening programs may follow a format as broad and comprehensive as this range of tests proposed by the authors:

1. Historical data
- a) Cornell Medical Health Index or a Tape Medical Inventory
- b) Medical status profile

2. Behavorial data
- a) Minnesota Multiphasic Personality Inventory
- b) Cognitive tests

3. Physiological data
- a) Opthalmic
  Tonometry, retinal photography, visual acuity.
- b) Hearing
  Full-spectrum audiometry
- c) Musculoskeletal
  Movement and flexibility analysis
- d) Neurological
  Reflexes
- e) Body Build
  Full body photograph
- f) Cardiovascular
  Exercise tolerance with treadmill electrocardiographic analysis by computer, heart sounds, blood pressure, infrared scan for peripheral vascular disease
- g) Pulmonary-respiratory
  Function tests under stress, respiratory volumes, chest X ray

4. Biochemical data
- a) Hematologic
  White blood cell count—differential; Hemoglobin—bleeding time
- b) Electrophoretic
  Serum proteins, enzymes and isoenzymes
- c) Serologic
  VDRL, rheumatoid factor, immunological indices
- d) Serum chemistries
  Liver function tests, lipids, cholesterol, lipoproteins, glucose tolerance test, uric acid, triglycerides, creatinine, trace minerals, hormones, amylase
- e) Urine chemistries
  Renal clearance tests, glucose, protein, microscopic analysis, specific gravity
- f) Histochemical
  Pap smear, colposcopy

After these tests are given, and the results are processed and stored by a computer, a doctor (either a program staff member or the subject's private physician) should review the test data with the patient, discuss and amplify on the medical history, and perform a physical examination emphasizing those organs or functions shown to deviate from clinical norms.

The whole battery of tests should be repeated periodically to establish a profile of the subject's health status.

lular and molecular level, and detect substances in nanogram and picogram amounts.

Established instruments for the multiphasic screening lab include spectrophotometers, fluorometers, atomic-absorption and flame photometers, automated chemical systems, gas chromatographs, and isotope tracers. Refinements in infrared and ultraviolet spectroscopy permit us to measure carbohydrates and protein fractions. With infrared spectroscopy and gas chromatography we can define fatty acids, adrenal and gonadotrophic hormones, cholesterol and its derivatives, and various glycerides. Reaction kinetics and interactions are now monitorable with ratio spectrophotometers.

The fluorometer has been adapted to analyze catecholamines, adrenalin, and noradrenalin—the primary biochemical indicators of stress. Electrophoresis—an old technique involving the movement of molecules or particles through fluids by a force supplied via electrodes—is being applied to protein fractions and other serum components.

Detectors such as these can be mated to the chromatograph, which can not only analyze complex mixtures of blood or urine or breath, but can separate them and identify their components.

As noted before, the dynamic testing of many response parameters generates an enormous amount of data. Systems to store and process this information, therefore, will be the hub of health maintenance programs. Also, more extensive laboratory automation is needed for increasingly complex biochemical, cytologic, and physiologic studies.

Future systems

Monitoring instrumentation will have to keep pace with changes in test procedures. In the future, temperature measurements may well be replaced by measurements of pulse wave velocity, for example, and vectorcardiograms may be preferred to the standard 12-lead electrocardiogram.

Further, machine interrogation of patients will rid the doctor of one of his most irksome, routine, but important chores. Most of a doctor's time with patients is now devoted to history-taking rather than to examination, diagnosis, or consultation. Many in the medical profession claim that automation diminishes the doctor-patient relationship, but actually the machine will give the physician more time to do the jobs he was trained for.

With a questionnaire based on the Cornell Medical Health Index plus an IBM Votomatic machine, a person coming in for tests can tap out his own punched-card health history. In the Tape Medical Index developed by Dr. Webster Marxer, director of the Beverly Hills Clinic in California, a tape recorder asks the questions, explains medical terms, and spells out symptoms.

A psychological profile is becoming an important part of any evaluation of health status; the Minnesota Multiphasic Personality Inventory is one extensively used test that is applicable to computer processing.

There are currently about 45 multiphasic screening programs operating in the U.S. Information assembled for last year's Senate hearings indicates that they have a lot in common, despite different circumstances, objectives, and approaches.

The survey showed that there is only limited communication among the programs and their personnel. Staffs are unaware of many of the other programs, except for the well-publicized Kaiser-Permanente Health Plan Clinic in Oakland, Calif.

The present programs emphasize screening for cardiovascular and respiratory diseases, glaucoma, diabetes, cancer, and certain blood disorders. The tests commonly given at the clinics include: electrocardiogram, chest X ray, audiometric measurement, vision chart, tonometric eye measurement, Pap smear, and glucose determination for diabetes.

All these examinations are generally performed on resting subjects. Static testing can detect most chronic diseases, but studies indicate that it can't spot cardiovascular and respiratory problems in their early stages.

Future screening programs will surely employ more dynamic loading of body systems, more function testing, and more electronic history-taking [see panel on page 135].

Payoffs

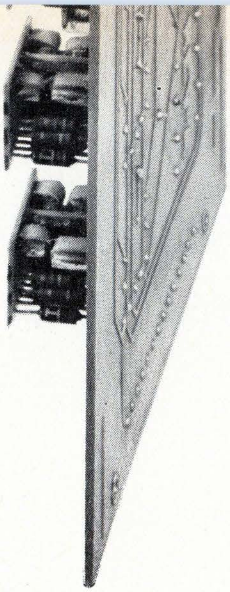
Three chronic diseases—heart disease, cancer, and stroke—account for more than 70% of the deaths in this country. And the vast majority of the 1.5 million people now in U.S. medical institutions have been put there by some chronic illness.

By any standard—humanistic, dollars-and-cents, or productive man-years lost or retained—the expansion and upgrading of multiphasic screening programs promises tremendous rewards. A preliminary Government study of a cervical cancer screening plan showed that 7 million women were examined over a five-year period, more than 80,000 cancer cases were isolated, and about 34,000 deaths from cancer were averted. On the basis simply of potential treatment costs, the study estimated that the program returned $9 for every $1 invested.

A number of industrial companies concerned about the high cost of their employees' medical and insurance benefits have experimented with preventive medicine projects. One Midwestern firm started such a program at one of its plants seven years ago, and recently found that its cost per employee there for sickness and disability payments—including insurance premiums—was $61 a year. By contrast, payments averaged $372 a year at another of the company's plants that has no health program.

But beyond these dollar figures, the establishment of more comprehensive and better-equipped screening programs can bring us all closer to the World Health Organization's ideal of health—"optimal physical, mental, and social efficiency and well-being."

Reprints of this eight-part report are available at $1.25 each.



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But only one way, vapor deposition, gives you a *perfect* conformal coating all over in one shot, every time. No matter how dense the circuitry or how complex the component, a uniform and continuous coating is deposited. (Vapor deposition of BAKELITE parylene is an exclusive process from Union Carbide.)

Here's why. With parylene, you're not coating with a liquid. You're vapor-depositing a polymer. There are no solvents to evaporate, no opacifying fillers, no additives, no baking, no drying. And no multiple coatings are needed to make sure it's pin-hole free. (This means that you can save as much as 10 hours in coating time.)

Parylene conformal coatings can be as thin as 0.002 mil or as thick as 3 mils or more. And they won't, they can't run, sag, bloom, blister, wrinkle or blush.

What else? As a conformal coating, parylene is a primary dielectric, an unsurpassed moisture barrier, resists softening at high temperatures, and its chemical resistance is outstanding.

If you have a circuit or component that you think might benefit from this new plastic why not let our development custom coating service make a trial run for you. Why take our word for it?

(If you haven't heard, parylene production units for your own use are available, with a license, from Union Carbide.)

For additional information about our BAKELITE parylene, please write to Union Carbide Corporation, Dept. EM-8, 270 Park Avenue, New York, New York 10017.

UNION CARBIDE
PLASTICS

BAKELITE is a registered trademark of Union Carbide Corporation.

Circle 137 on reader service card

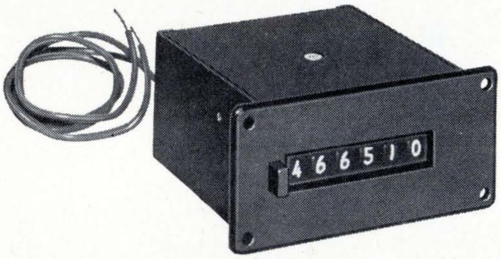
DURANT'S NEWEST!

Preview the latest in count/control advancements at Wescon, Booth 2124-2125

49600 UNISYSTEM®

New, single-level predetermining count/control system developed to meet the need for a small, inexpensive digital counter or timer. It provides direct digital reading, eliminating dial interpolation. Ideal for installation on control panels for machine tools, textile machinery, wire, machinery, metering and scaling equipment. This exceptionally compact unit is available as a standard unit equipped with 2, 3 or 4 Unipulser decades. Design permits it to be used equally well as a desk or panel mount without change. Important advantages include ease of presetting and resetting (panel or remote) . . . set-up and wiring simplicity . . . pre-determined visual setting is always retained. Count life and reset life proven for over 100 million counts. Count speed up to 30 cps. 115V — 230V, 50-60 cycles.

For more information circle No. 491 on Reader Service Card



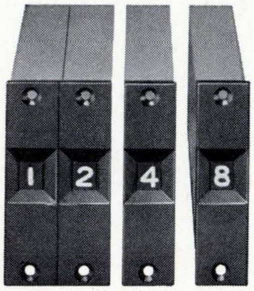
6 YE SERIES ELECTRIC COUNTERS

These new 6 figure electric units have been developed for instrument or control systems, office machinery, data processing equipment where long life and high count speeds are required. Reset is optional, manual push-button or electric, with entire mechanism housed within the case. The 6 YE Series is available for base or panel mounting, providing permanent tamper-proof installation without extraneous hardware.

High accuracy and reliability are assured by an exclusive Durant drive feature: the power impulse cocks, power release counts, resulting in a uniform indexing force and smooth counting action.

Count speed is 2400 cpm DC — 1800 cpm AC (rectified). Models available for 120V, 240V AC or 120V, 28V DC — other voltages on request.

For more information circle No. 493 on Reader Service Card



BCD UNIPULSER®

Durant Unipulsers are now compatible with count/control equipment using binary coded decimal systems. They are especially suited for use in data processing equipment, medical instrumentation, business machinery and more.

BCD Unipulsers use the 0-1-2-4-8 code and hook up easily with only 5 wires using standard connectors. Drive and visual readout is digital. Electrical readout is automatically encoded from digital to binary, eliminating the need and expense of code converters.

Important advantages include high count speed (40 cps), large readable figures, high current carrying capacity, and long life (proven for over 100 million counts). The BCD Unipulsers are the latest addition to the growing line of Durant decade modules, permitting you to count or control practically anything; hours, minutes, units, ounces, pounds, etc.

They are available in three models — 400 BCD non-polarized, 401 BCD with a common negative, 402 BCD with a common positive.

For more information circle No. 492 on Reader Service Card

DIGITAL CLOCK – ELECTRICAL READOUT

Hours, minutes, seconds or decimal combinations of any time period can be readout visually and electrically by this highly dependable unit. It can be used in data reduction systems . . . for controlling batching where timed mixing is important . . . to aid in computing piece rate in all production processes . . . for use in all types of data or material handling where a time base is required.

Three, four, five and six digit models are available as shown or without cabinet for 9½" panel or 19" relay rack mounting. 115V or 230V AC, 50 or 60 cycle. Prices start at $280.00.

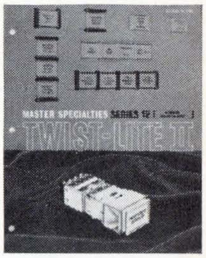
For more information circle No. 494 on Reader Service Card

DURANT®
MANUFACTURING COMPANY
MILWAUKEE, WISCONSIN
In Europe: Durant (Europa) N.V. Barneveld, Netherlands

This is the lighted pushbutton switch with aerospace quality at commercial prices!

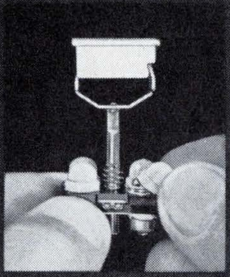
The MSC Series 12 Lighted Pushbutton Switch embodies aerospace quality and engineering features that reduce installation costs, increase performance and simplify maintenance . . . yet it is priced to compete with commercial grade units. Compare the features listed below. From the exclusive Twist/Lock front end removal that permits easy lamp, legend or color filter change without tools (and without the hazard of accidental switching during replacement), to the internally bussed common ground lamp circuits that cut installation time and costs by reducing solder connections, you'll find better features for better performance. You'll discover why the Series 12 has been specified for computers, data processing equipment, industrial controls and commercial equipment where dependable, long-term performance is the prime consideration. You'll pay no more. Why settle for less?

GET THE 20-PAGE CATALOG 2001
It details all of the many options offered by the versatile MSC Series 12 to solve any switching problem. Use the reader service card or write on your letterhead for an operating demonstration by your regional MSC specialist... in your office!



Series 12

TWIST-LITE® II
LIGHTED PUSHBUTTON SWITCH



4-LAMP VERSATILITY

INDIVIDUAL COLOR CONTROL

SILICONE RUBBER COLOR FILTERS
for uniform light intensity and disbursion

COMPLETELY REMOVABLE FRONT-END ASSEMBLY
Will not actuate switch when replaced.

SNAPS INTO PANEL CUTOUT
No tools or hardware required

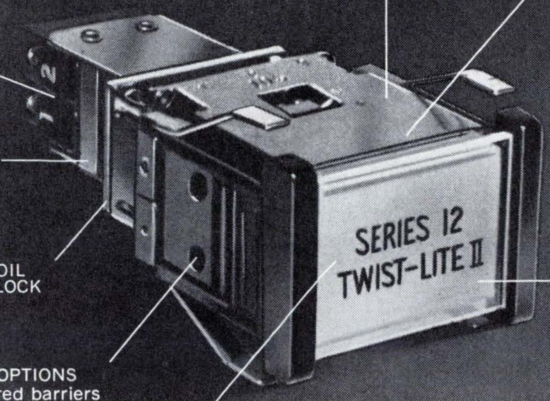
SNAP-ON SWITCH MODULES RATED AT 5 AMPS/125 OR 250 VAC

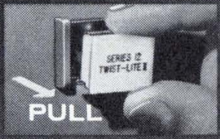
INTERNALLY BUSSED COMMON GROUND LAMP CIRCUITS
Requires fewer solder connections

OPTIONAL HOLDING COIL FOR ELECTRICAL INTERLOCK

12 MOUNTING OPTIONS
Spring clip or colored barriers for styling versatility

FULL DISPLAY TO 4-WAY SPLIT
Legends supplied with order





EXCLUSIVE FRONT RELAMPING
with Twist/Lock safety
No tools required.

Master Specialties Company

25 YEARS IN INFORMATION DISPLAY (25) AND CONTROL DEVICES

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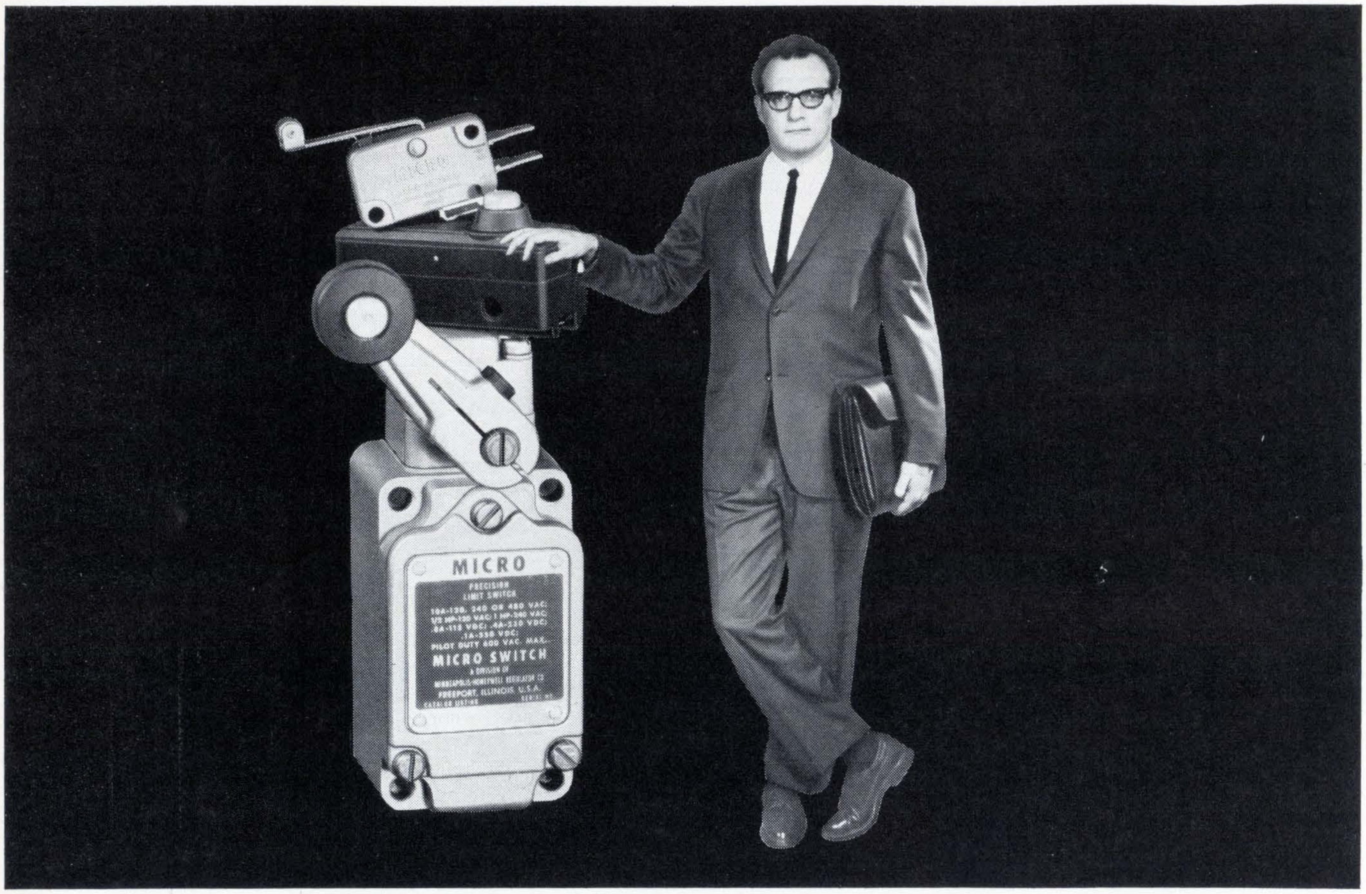
World's largest selection of switches gives you a little extra design freedom.



Not just a switch...

A MICRO SWITCH Field Engineer joins your team the instant you blow the whistle on a switching problem. He's especially trained to help you take full advantage of the complete capability offered by MICRO SWITCH.

He offers you not just a switch, but a complete service capability, including (1) the largest group of switch engineering specialists—meaning we can put the best brains in the business to work on your switching problem, (2) the industry's largest R&D facilities—meaning the switch design you need may be already on file waiting for a problem like yours to come along, (3) the largest switch manufacturing facilities, with computerized inventory control—meaning on-time delivery.

Call a Branch Office (Yellow Pages, "Switches, Electric"). Or write . . .

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 Circle 140 on reader service card

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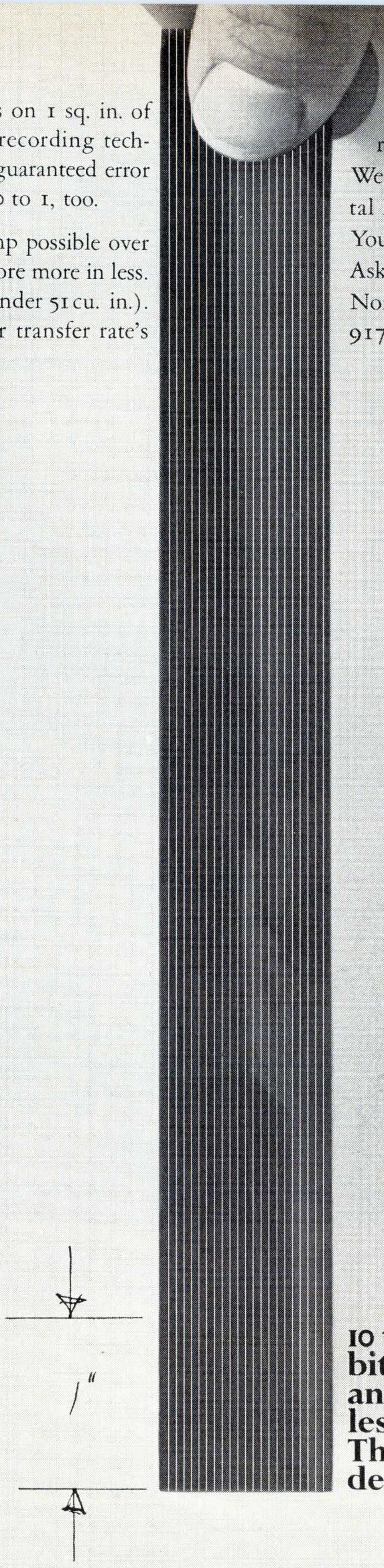
1"

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INTO 300 EQUAL PARTS?

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OVER 1500° PHASE SHIFT?

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Options in electrical components, particularly the McCoy tight parameter-controlled quartz crystals, permit wide choice of narrow, intermediate and wide-band filter types for every circuit need.

McCoy filters have low insertion loss, minimum ripple, and excellent passband characteristics over temperature ranges of −55 to +105°C.

Such filter precision is made possible by the use of McCoy-made quartz crystals having the proper combination of inductance, capacitance, Q and frequency stability. When you specify McCoy crystal filters, you are going to get the highest quality available.

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Take two electronics companies, each producing quality products for its own customers. Put them together, combining their experience and research, and you've got one whale of a source for electrolytic capacitors, potentiometers, resistors and other components.

Tennessee Electronics, Inc., and Nashville Electronics, Inc. have merged for greater production capacity and better quality control. We call the new company Whale Electronics, Inc.

What's more, we now have an agreement with SIC-SAFCO of Paris for the production of highest quality, even more sophisticated components manufactured in the four production plants of this noted French firm. We also have access to and regular use of SIC-SAFCO's environmental test laboratories in Paris.

We also have a subsidiary in Hong Kong, producing components primarily for the home entertainment field.

Whatever your needs — whether you manufacture TV sets, computers or sophisticated guidance systems for space, you'll find the quality you want at the price you want at Whale Electronics. Let us hear from you.

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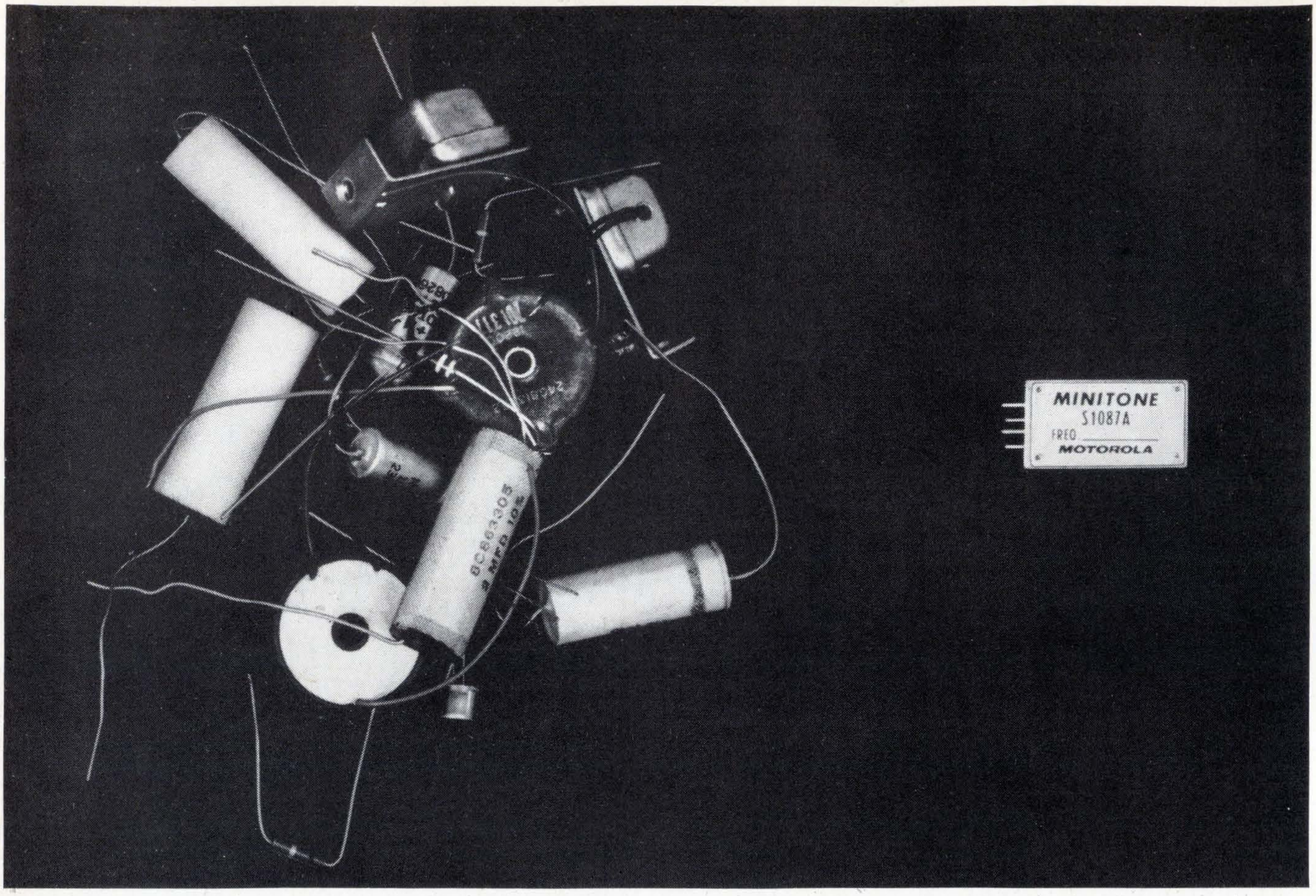

Two ways to achieve selective signaling

The MINITONE reed on the right does it better

Motorola's new miniaturized resonant reed either generates a highly stable audio tone, or provides very selective decoding. It does the job better because it's small, has excellent stability, and contains no contacts to wear out. And the MINITONE resonant reed is more economical; it eliminates the expense of extra components and design time needed to build highly selective tone oscillators and associated compensating circuits. Take a look at these facts:

See it at Booths 3116 & 7 at WESCON

SMALL SIZE: About ¼ of a cubic inch in volume. Measures only 1.11″ x 0.619″ x 0.393″.

LONG LIFE: No contacts to wear out or cause malfunctions; life comparable to solid-state devices. Plus 3-year warranty.

HIGH STABILITY: Frequency tolerance ±0.1%. Temperature stability better than ±0.001% per °C between −30°C and +100°C (25°C reference).

WIDE FREQUENCY RANGE: From 67 Hz up to 3150 Hz.

QUICK DELIVERY: Over 200 standard frequencies available from stock.

RUGGED CONSTRUCTION: Exceeds E.I.A. standards for shock and vibration.

PROVEN PERFORMANCE: Reeds have been proven in thousands of demanding situations, such as in aviation, control systems and radio communications applications.

FOR MORE INFORMATION contact your Motorola representative. Or write for bulletin TIC-3214.

MOTOROLA COMMUNICATIONS AND ELECTRONICS INC.
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MOTOROLA
PRECISION INSTRUMENT PRODUCTS

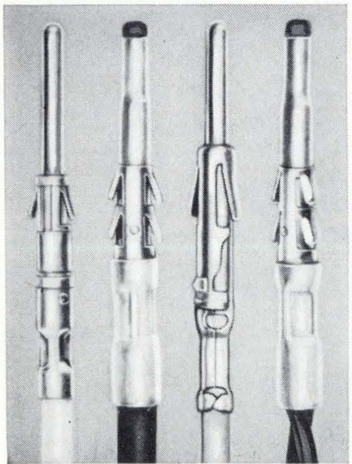
1.34 X 10^5 COMBINATIONS

(ONE OF THEM HAS GOT TO WORK FOR YOU.)

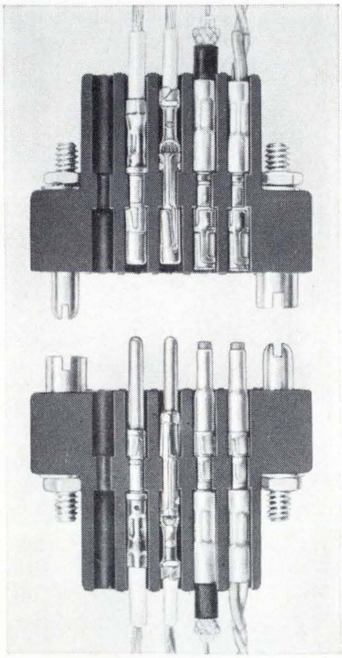
When we say our Trim Trio has enormous application potential, we're not kidding. The combination of numbers surprised us too. For any of our three types of contacts—sub-min coax, machined or continuous formed strip—will work in any of nine connector blocks (14 to 152 positions). In any combination.

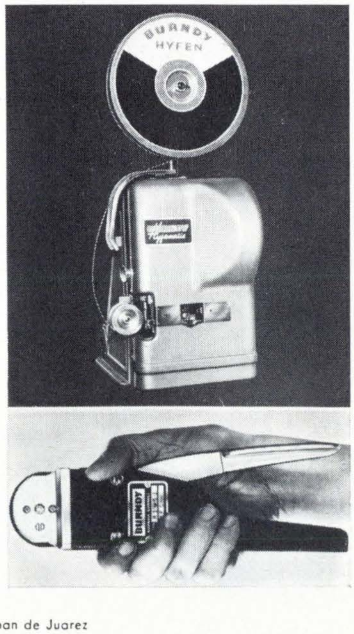
And if you wanted to count wire sizes, or figure the twisted pairs our sub-min coax can accommodate, or leave some contact holes open, the possibilities would truly be endless. Probably most of them haven't been used yet. Surely some of them will solve your problems.

And Burndy can make your installation problems easier, too. Whether you crimp one at a time on a hand tool or 3,000 per hour with a Hyfematic™ you can count on built-in quality control, save time and money. For the full story and details on the combination that will work for you—from breadboard to production—write for our Bulletin MS67.



Machined Sub-min Coax Strip Hyfen Twisted Pair





See more at WESCON Booths 5344-6

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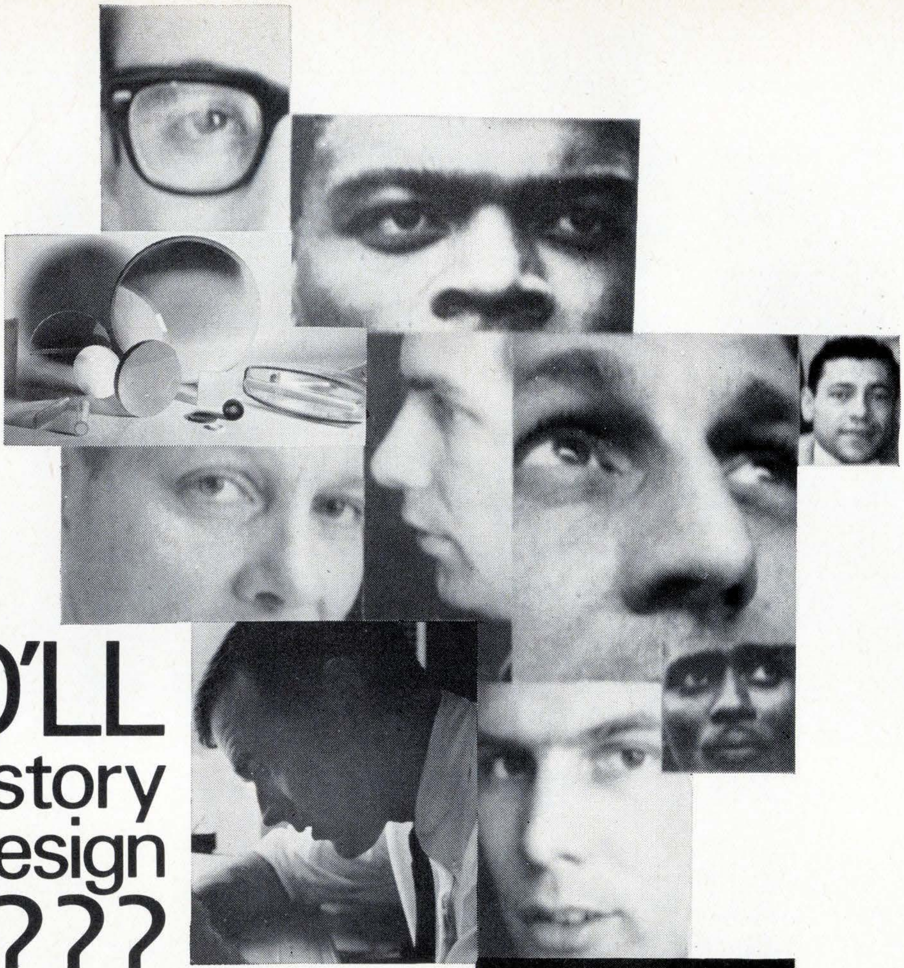
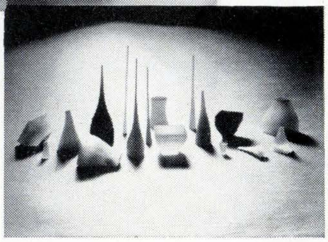
Circle 145 on reader service card



WHO'LL make history in EDP design ?????

Could be YOU: and Mosaic's Fiber Optics!



Fiber optics is not a "someday" technology. It's here *now* . . . and EDP systems design engineers are already making history with it. Creating new EDP systems with superior talents. Advances like greater speeds. New capabilities. Design freedom. Greater reliability and lower costs.

Do you know what happens when you use Mosaic's fiber optic faceplate on a CRT, vidicon, or orthicon tube? Your recording sensitivity is greatly increased (in some cases, as much as 40X) enabling you to compromise on the tube design. With the effect of a zero thickness window, you get improved contrast and resolution, and can take *direct* accurate measurements on the image.

Have you heard about Mosaic's Fiber Optic systems? On new EDP printers, readers, punched tape and card verifiers, keypunch and teletype equipment, they beat heat, wear and friction-prone mechanical systems hands-down: with increased reliability, greater efficiency, speeds over 4 times faster and lower cost!

Mosaic's fiber optics can help *you* make history in EDP design, *now* . . . a field that leaves you no time for old design notions. Give those specific design problems of yours a hard look, today. Then contact Mosaic Fabrications. We know fiber optics inside-out. We're the largest single source of fiber optics technology, capability, and productivity in the world!

Mosaic will work with you to solve your EDP design problems *now* . . . will help you design and develop, from prototype to production, the specific EDP fiber optic hardware to put you far ahead!

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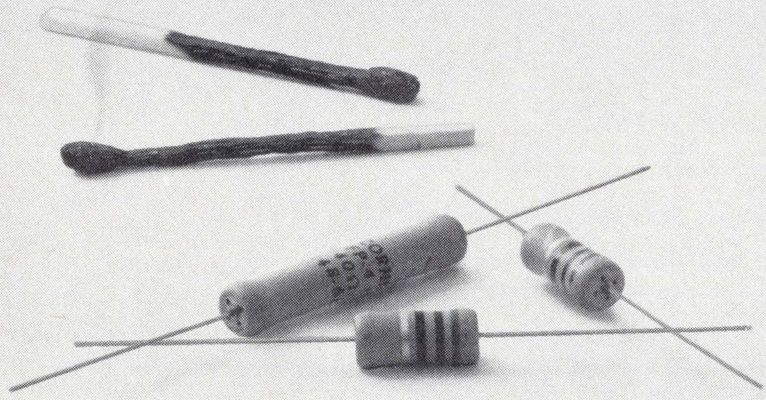
347-9191 for descriptive literature today!

Bendix Electronics

Flaming resistor failure used to be a catastrophic danger.

So Corning changed resistor failure.



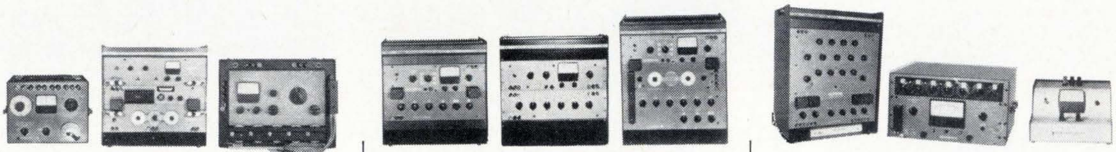
The fact is, new CORNING® FP Resistors just won't burn.
Even if a circuit smacks one with an overload of a hundred times or more, it won't burn.
It knows how to fail gracefully. It will open up,
but no flame and no short. But don't just take our word. Test this new resistor yourself.

FP resistors come in 2, 3, 4, 5, 7 and 10 watt sizes, from 9 ohms to 90K.

Just write for free samples and complete data.
Meanwhile, we're looking for more changes that will improve resistors. That's how our line of glass tin oxide film resistors has grown to be one of the most extensive and useful. That's how we've earned our qualifications for exceptional stability and reliability.
Corning Glass Works, 3904 Electronics Drive, Raleigh, N.C.

CORNING
ELECTRONICS

Support your local Resistance.



	Multi-purpose instruments			Resistance Bridges			Ratio/Deviation Bridges		
Model	250 DE	292	300	231	232	242	122	500	261
Range	.1Ω-12MΩ	.1Ω-1.2MΩ	.01Ω-500MΩ	.01Ω-12GΩ	.1Ω-500MΩ	.001Ω-120MΩ	.001Ω-100MΩ	.1Ω-111MΩ	10Ω-2MΩ
Accuracy	.1%	.05%	.02%	.01%	.01%	50ppm	0.2ppm	.01%	.1%
Price	$475	1380	875	2050	1075	3500	4000	2595	Appr. 250
Comments	R, C and L	R, C, L and G	R, E, I and Ratio			Ratio and deviation ranges	1:1, 10:1 ratios	Deviation ranges ±10% to ±.01%	1:1 ratio ±1%, 5%, 20% ranges

Resistance measurement is very much a local matter, requiring resistance measuring instruments designed to match your local needs. Whether the job is production testing, on-line inspection, or laboratory calibration and certification—you want an instrument specifically tailored to the task.

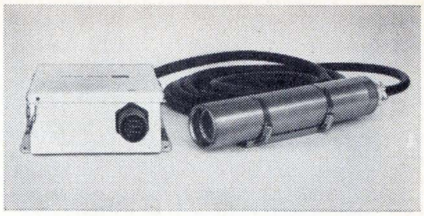
The chart illustrates the wide range of approaches ESI can offer to meet your resistance measuring needs. Among them, you're sure to find the ranges, accuracies and special features that suit your particular application. In many cases, you may be able to answer a number of different electronic measurement requirements in a single multi-purpose instrument.

It's not by chance that every major manufacturer of precision resistors uses an ESI measuring instrument. You'll find, as they have, that ESI instruments are fast and easy to use. And they give you the greatest reliability and accuracy for your dollar. That's a good local cause to be supporting, ESI, 13900 NW Science Park Drive, Portland, Oregon 97229.

Electro Scientific Industries Inc. esi®

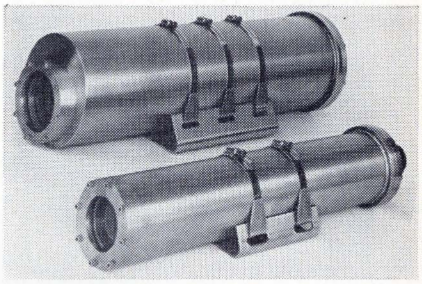
WESCON Booths 2717-18

Solve any CCTV problem with one of these seven basic systems from Cohu.



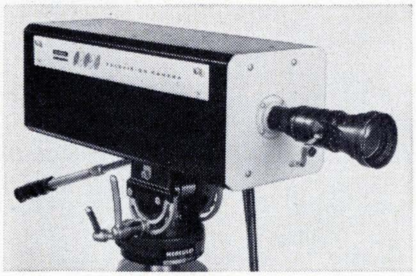
Radiation-tolerant

Get top quality TV pictures from radiation environments up to a cumulative dosage of 10^8 roentgens and/or 10^{12} neutrons/cm^2 with 3-inch diameter 2500 Series cameras. Readily de-contaminated.



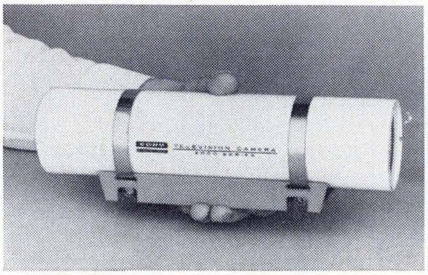
Underwater

Tested to 10,000 PSI and up to 20,000 foot depth. Neutral buoyant. 70° view lens. Camera and cable independent.



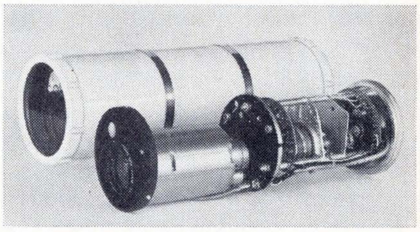
High-fidelity color

1000 Series system includes the first CCTV camera with built-in references for correct registration and color balance. Compact, light, low-priced and easy-to-operate.



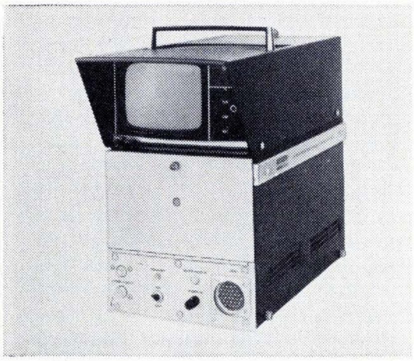
Miniaturized

Series 2000 cameras feature 3″ outside diameter cylindrical housings that will accommodate remote-controlled 4:1 zoom lens. Many lens options available, including 10:1 zoom. Operate on 10 or 20 megahertz bandwidths.



Environment-resistant

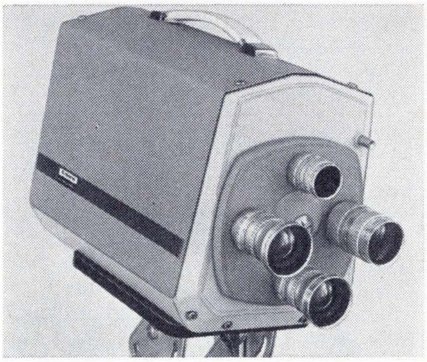
3000 Series cameras provide continuous-duty operation in up to 100% humidity, at temperatures from –20°C. to +60°C., ocean depths to 250 feet and altitudes out to deep space. Meet military explosion-proof specifications. Operate on 10 or 20 megahertz bandwidths.



High-resolution self-contained

Modular-designed 3200 Series offers choice of plug-in sync generators for EIA 525 or 729, 873 or 945-line scan rates. Compensates for light level variations to 10,000:1. Optional viewfinder.

Cohu is looking for Design Engineers (in this area) with a degree. If interested, write to Chief Engineer J. L. Kimball . . .



Industrial self-contained

Complete with all camera control circuits, Model 20/20 cameras need only video cabling and any standard TV monitor to make a complete CCTV system. Highly versatile.

See us at WESCON, Booth 3001

Which one solves yours?

For details on the industry's most complete CCTV line – including monitors, accessories and video switching systems – contact your nearest Cohu representative or call Bob Boulio direct at 714-277-6700 in San Diego.

COHU ELECTRONICS, INC
SAN DIEGO DIVISION

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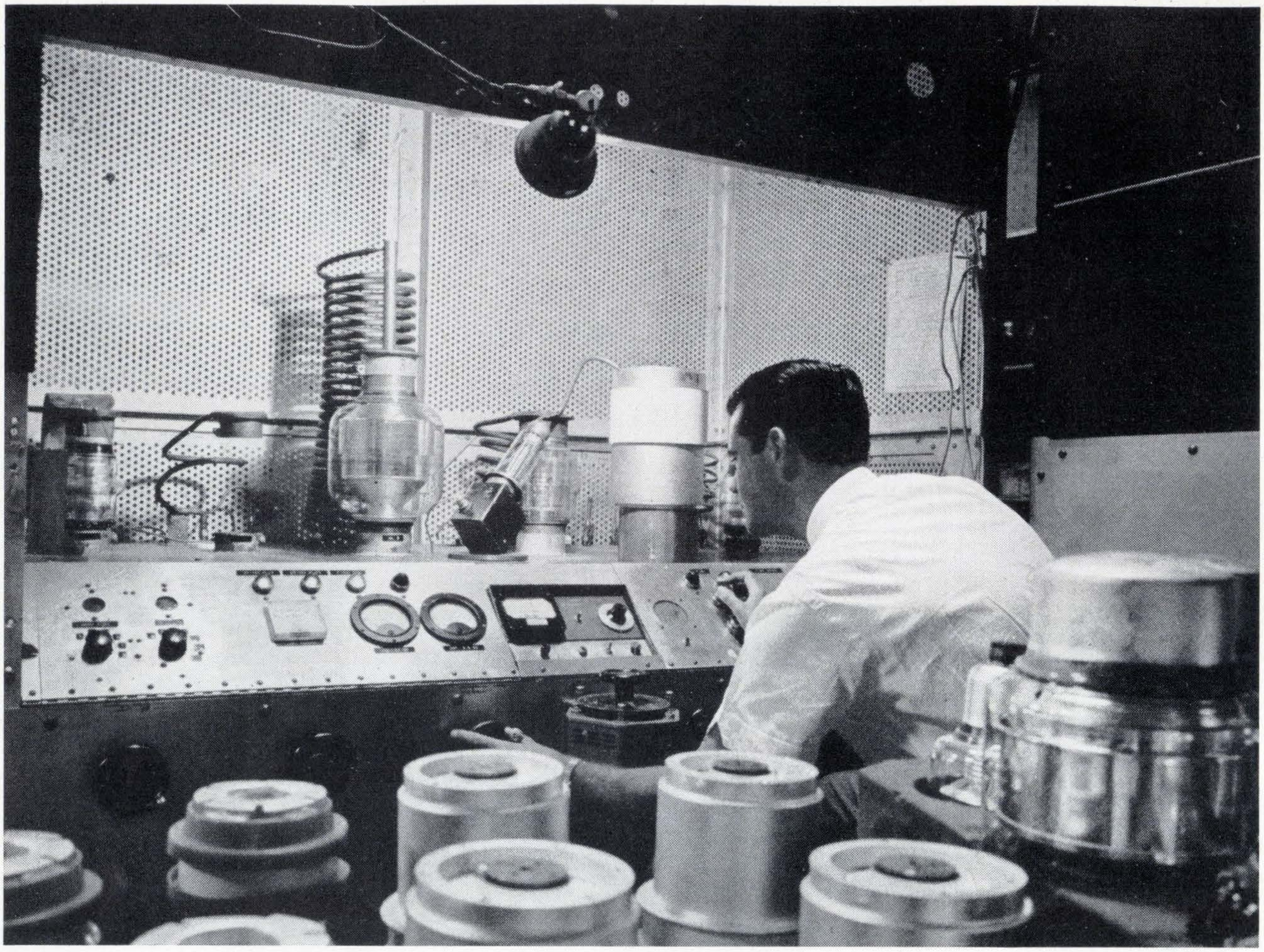

Our vacuum capacitor testing is the next best thing to the worst field conditions.

Only ITT Jennings maintains the facilities to test vacuum capacitors in an environment that exactly duplicates actual operating conditions—and then some. In fact, as a government-approved facility equipped to perform capacitor qualification testing under MIL-C-23183A, we carry our testing to extremes far beyond the worst possible field conditions.

Our vacuum capacitors are rf tested at rated voltage and current or to customer specifications on transmitters ranging in frequency from 17 kc to 600 mc and up to 100 kw cw power.

ITT Jennings environmental testing includes capacitance shift versus temperature from −65°C. to +125°C.; dynamic vibration; static vibration; shock; salt spray; humidity; and bellows life testing.

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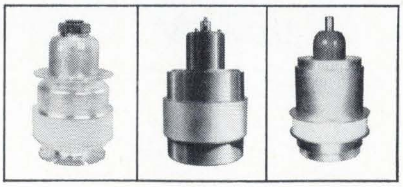
Amps rms (16MHz)	65	600	125
Overall Length	5.8 in.	23 in.	8 in.



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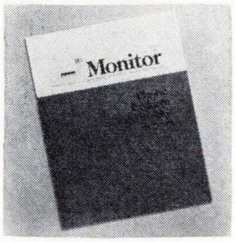

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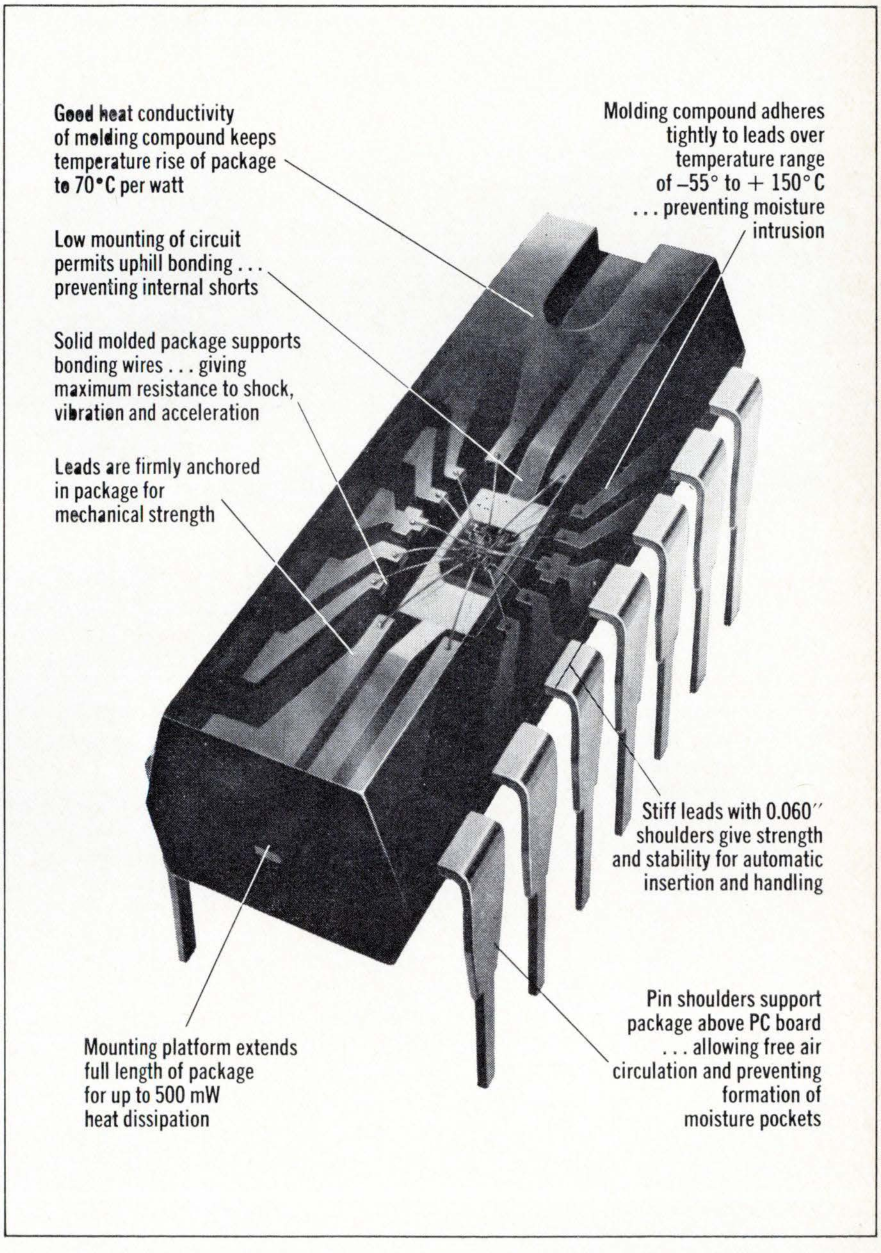

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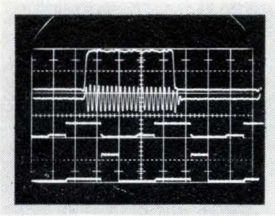

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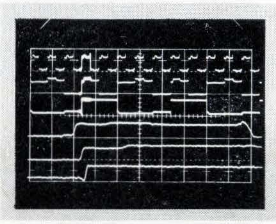

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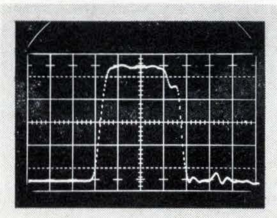

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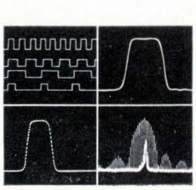

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Integrated electronics

Western firms banking on IC's

Swelling volume is picking up much of the slack caused by the slump in discrete devices; some IC producers even expect to turn a profit

Integrated-circuit manufacturers have long been accustomed to a looking-glass world where, like Alice, they had to run faster and faster just to stay in the same place. The more they cut costs, the more prices dropped. Western semiconductor companies, however, have put on an extra burst of speed this year and may have gained a little ground. They are reporting shipments three and four times as great as in 1966; and with yields showing dramatic increases and prices declining only slightly, many makers are talking about a profit in IC's in 1967.

That turnaround may have come just in time. Discrete components, which have carried their glamorous cousins through several unprofitable years, have gone through severe price declines since late last year; and while discrete unit sales are up, dollar volume during the first half of 1967 remained about level with that of the last half of 1966. Discretes account for such a large percentage of sales that the price cuts are holding over-all semiconductor sales to 1966 levels.

No one is particularly happy about the trend in discretes, but the swelling demand for IC's has done a lot to assuage the pain. The Semiconductor division of the Fairchild Camera & Instrument Corp., of course, has been a consistent moneymaker in IC's since it cut prices in 1964; and the Signetics Corp., a Corning Glass Works subsidiary that makes only silicon monolithic IC's, has also been profitable. But this year the IC operations of both Texas Instruments Incorporated and the Semiconductor Products division of Motorola Inc. are expected to be in the black, as are those of a number of smaller companies.

Semiconductors at a glance

Balancing act

Semiconductor dollar volume has made no headway of late

Price cuts and a sales slump in discrete devices are primarily responsible

Market, about $1.05 billion last year, may reach only $1.1 billion in 1967

But integrated circuits have come on strong

Sales are up more than 50% so far this year

Follow the leaders in monolithic IC's

	1966	1967
Fairchild	$38-41	$60-75
Texas Instruments	31-35	45-55
Motorola	18	25-38
Signetics	11-14	21-23

U.S. factory sales in millions. Electronics' estimate.

Total semiconductor IC volume will be between $225 million and $250 million during 1967

One good order could put an outfit like Westinghouse, Sylvania, Philco-Ford, or General Instrument firmly in fifth place

What's ahead

A 50% increase in facilities manufacturing IC's will lead to overcapacity in some lines by yearend

Prices will weaken, further trimming profit margins

I. Explosion in IC's

Making a forecast of industry-wide IC sales is a little like handicapping a horse race for two-year-olds: even the experts are frankly guessing. Motorola, for instance, has been advertising itself as second only to Fairchild Semiconductor in IC shipments, a claim ac-

. . . large-scale integration is both the hope and despair of IC makers . . .

cepted by none of its competitors —particularly since the company has yet to move production into its huge Mesa, Ariz., facility, dedicated with such fanfare last fall. Yet one industry observer, Glen Madland of the Integrated Circuit Engineering Corp., a Los Angeles-based consulting firm, does believe that Motorola was number two in IC shipments last year, and may even become second to TI in semiconductor dollar volume in 1967.

Output spurt. Part of the confusion stems from the fact that production is expanding so rapidly. Jerry Sanders, marketing manager at Fairchild Semiconductor, says the division will be delivering 4 million to 5 million circuits a month by the end of the year, and total shipments this year may reach 25 million—nearly three times the 1966 level. Signetics, according to marketing manager George Didinger, expects to ship up to four times as many IC's this year as last; the best industry estimate is that this surge would put Signetics' sales at 7 million to 8 million units.

Over-all monolithic IC shipments last year totaled just under 30 million units; that figure may triple this year, with dollar volume rising from 1966's $148 million to $250 million. Madland attributes the boost to a doubling of yield and a 50% increase in the floor space devoted to IC manufacture. He predicts an overcapacity in certain areas by the end of the year, with a weakening of prices.

Sanders disagrees. "I don't expect overcapacity this year, and in fact, some major equipment manufacturers had better start ordering soon or they'll have trouble getting delivery," he says. Thomas J. Connors, a Motorola vice president who directs semiconductor marketing activities, says, "I don't think the industry can keep pace with demand this year."

Question of logic. With sales expanding so rapidly, the giants can afford to be detached in their discussion of the merits of the several IC logic families. Donald T. Valentine, Sander's predecessor at Fairchild, who resigned in a dispute over the company's manufacturing/marketing reorganization [Electronics, July 24, p. 44], points out that the Fairchild 930 diode-transistor-logic line has been thoroughly designed into government contracts that are just getting into production stages. "As that happens," he says, "eight companies participate in the volume."

Valentine believes resistor-transistor logic is reaching the stage of substantial, 100,000-unit orders, in the industrial area outside data processing, and is sharing the test and measuring equipment market with TI's transistor-transistor-logic family. In data processing, DTL and TTL will move from the stage of million-unit orders to 2- and 3-million-unit orders; "Here," Valentine says, "the real participants are Fairchild, Motorola, TI, and Signetics." Smaller manufacturers are waiting to see which way the cat will jump before committing themselves to any one logic family.

Over the horizon. Large-scale integration, which is both the hope and despair of IC makers since it promises both great cost reductions and greater price reductions, plays almost no role in their short-term planning. Most companies feel that the technique won't be an economic factor before 1970. In the meantime, IC packages like the microelectronics modular assembly (MEMA) made by Amelco Semiconductor, a division of Teledyne Inc., may serve as transitional products. Amelco is integrating chunks of its MEMA assemblies; and it has reduced one from 25 chips to six.

Linear IC's, however, are rapidly becoming a significant factor. [For more on linear IC's, see page 88.] Fairchild claims half of this market, which may reach $40 million to $50 million this year. Since linear IC's are higher priced than digital circuits, the leap will tend to slow the decline in the average price of IC packages. In 1966, that average was about $4.90; this year marketing men expect it to slide to $3.25 to $3.50.

"At this price," says Signetics' Didinger, "profits will be up because increasing yields have kept costs down." Didinger expects some commercial and industrial lines to go below $2, or even under $1 for plastic-packaged RTL units. But in high-reliability military circuitry, a dual gate will still cost $16 to $20.

II. Slump in discretes

After all of the glowing words about integrated circuits, it comes as something of a shock to hear Motorola's Connors predict that the semiconductor industry will at best match 1966 sales this year.

At TI, Richard Hanschen, marketing manager for the Semiconductor-Components division, puts last year's over-all semiconductor market at about $1.05 billion, and adds that the company looks for a small gain this year, probably to around $1.1 billion. The integrated circuit market should come close to the $240 million to $250 million forecast earlier, the TI official says. Hanschen notes that the semiconductor sales slump has paralleled that in durable goods.

Hard figures. Last month, TI announced that sales for the second quarter of 1967 slipped to $142.9 million from $149.3 million in the like 1966 period. Though six-months sales climbed to $288.1 million from the year-earlier $285.4 million, earnings fell to $26.8 million from $31.8 million.

At the same time, Fairchild reported a first half sales increase to $120.7 million from $109.7 million a year before, but an earnings decline to $5.5 million from $7 million. Both sets of figures include all corporate activities, but TI's announcement tied the profit drop directly to semiconductors.

Diode dive. Motorola's main discrete lines are silicon and germanium transistors, zener diodes, and silicon controlled rectifiers. Connors says SCR's are the worst performers this year and zeners relatively the best. Sales of both types of transistor are trailing 1966.

But while Motorola can live with the diode slump, others can't. "People are selling germanium diodes for less than cost in volume," says Edson B. Gould, who heads the Microelectronics division at the Hughes Aircraft Co. "Silicon diode prices are also way down." He attributes the drop to higher yields and automation—factors that have cut costs—and to the inroads made by IC's in diode markets. Another manufacturer says, "One customer who doesn't blink at a $20,000 tooling charge on an IC order won't pay the extra $2,500 if I'm a penny too high on an order for 250,000 10-cent diodes." He ascribes the oversupply in discretes to a military request for three-month inventories in 1966. "Everybody expanded, and then the demand dried up last November," he explains.

Connors figures the industry was fooled into overexpanding in 1966. Certainly, this was true at Motorola; the company underwent large-scale layoffs last fall. The overexpansion, plus better yields, led to the disastrous price cuts.

Foresight. Fairchild blames consumer products for the decline in demand; radio and television sales were below the 1966 level during this year's first half. But the company claims to have come out of the slump in a better competitive position. "We saw it coming," says Valentine. "Knowing that the IC demand would tax our output, we concentrated our advertising on discretes and gave some discrete production space, at Portland, Maine, to IC's." The result, Valentine says, is that Fairchild maintained its sales pace and increased its share of the market.

The Continental Device Corp. figures that the softness in consumer demand is about over. With military demand steady, the company reasons, discrete-component sales should increase later this year. Continental also looks for sales gains in the computer market; Delbert Van Winkle, executive vice president, expects high-current, fast-switching diodes to remain in heavy demand.

Exception. While the big suppliers have been agonizing over price cuts, a small maker of field effect transistors, Siliconix, Inc., says it hasn't made a reduction in nine months. "Some companies have whipsawed their suppliers to buy on price, and have been burned six months downstream on quality or delivery,' says Richard E. Lee, president. He blames the manufacturer for knuckling under, and adds, "There are some situations where you have to let the contract go." Slowly expanding, Siliconix is picking its spots in the IC market as well; "We have been making deep inroads in areas that combine FET and IC technology—the multiplexer and analog-switch world," says Lee.

III. Ready or not

When the Microelectronics division of the Philco-Ford Corp. cut prices on its metal oxide semiconductor line by 50% last month, and the General Instrument Corp. followed suit within two days, the question was again raised: is MOS finally close to a production breakthrough? And once again the answer—even from MOS makers—was "not yet."

To be sure, Philco says that with yields up by as much as an order of magnitude, and with improvements in production techniques, it is now ready to produce in volume. But Don Richard, product marketing manager, concedes that Philco must get MOS designed into systems before the devices become high-volume products. Richard estimates the MOS market at $6 million last year, $10 million to $11 million this year, and $20 million to $30 million next year.

"Prices are still outrageous," snaps Fairchild's Sanders. "Who will pay $13 for a J-K flip-flop when we can sell him one for $3?" To which Richard replies, "We're not going after the bipolar market, and the J-K won't sell on its own merit but as part of a system. Try to build a 100-bit shift register in bipolar."

Howard Bobb, who left Philco in 1966 to form his own MOS company, American Microsystems Inc., holds that "price lists don't mean anything anyway to someone who is serious about MOS." Bobb, who didn't cut prices, says that the few high-volume buyers are already enjoying low unit prices.

Backup. Richard and Bobb agree that the best thing that could happen to their business would be for Fairchild to come into the market. "I expect Fairchild to be in MOS with both feet, but when?" Richard asks. He figures, and Bobb agrees, that systems designers would be more likely to choose MOS if they were assured of a major supplier. But they think that it will be 1970 or 1971 before MOS accounts for as much as 25% of the IC market.

A surprise new starter in the MOS field last month was the National

Semiconductor Corp., the home of Charles E. Sporck and the topflight management crew that left Fairchild with him last February [Electronics, March 7, p. 45]. National, says marketing boss Floyd Kvamme, will be a linear and MOS house. The company is introducing four MOS circuits—all of which are shift registers—it says are available off the shelf.

But if the smaller companies are banking on help from Fairchild, they will have to wait. Fairchild has had an MOS manufacturing arm since last September, but production in this area has been trivial.

One problem that plagues the MOS companies is the difficulty of developing a standard line. "There's nothing standard except shift registers, and even there you run into special orders," Bobb says. Both AMI and Philco have put considerable effort into programs to get the buyer to participate in circuit design.

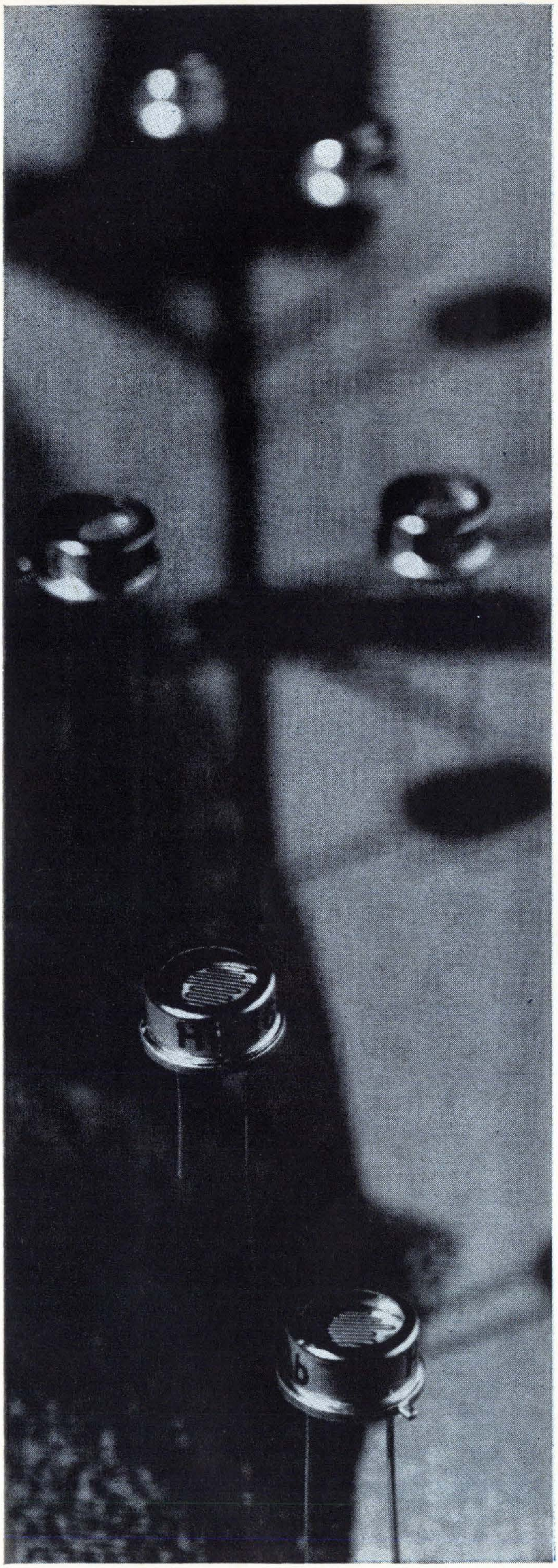
IV. Hope springs eternal

An indication of confidence in IC sales is the position of the semiconductor operation of the Raytheon Co., which second-sources just about every line made. Raytheon obviously believes that demand will continue to grow, and it intends to establish itself in the IC field by delivering when the prime sources are overtaxed. Last winter, the company cut into Fairchild's 709 operational-amplifier sales in such a situation.

With IC's moving into the black, and the slump in discrete sales just about over, most companies see 1968 as a good year. Motorola's Connors predicts a 20% industry-wide sales increase from 1967. If he's right, IC manufacturers will have to make money.

Sanders offers an even more optimistic view of the future. "I feel I will have failed in my job if by 1969 we are still shipping more discrete dollars than IC dollars," he says flatly. And, he indicates, the crossover may well come in 1968.

The reporting for this article was done by Lawrence Curran and Gerald Parkinson in Los Angeles, Marvin Reid in Dallas, and Walter Barney and William Arnold in San Francisco. Walter Barney wrote the story.



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*4604	5	3.05	2.60
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Advanced technology

Ion implantation gets a shot in the arm

Though precious few devices have been produced and more basic research is needed, implantation's potential as a useful adjunct of diffusion has researchers beaming

By Stephen E. Scrupski

Senior associate editor

Ion implantation, long an overpublicized laboratory curiosity, is making a serious run at the real world of semiconductor devices. As yet, only one device is commercially available and there is little likelihood of others coming to market anytime soon. But such is the potential to produce some devices better than can be made by conventional diffusion furnace techniques, as well as some that can't be made at all, that both Government and private interest in the field is quickening. Federal agencies are putting cash on the line to finance more basic studies and industry is underwriting a growing number of in-house projects.

The key to making a practical transistor or diode is placing the impurity dopant atoms—p-type acceptors or n-type donors—in such a way that they form a junction in silicon, germanium, or other semiconductor material. Presently, most manufacturers insert dopants by vaporizing the impurities and diffusing them over a semiconductor substrate in a furnace heated to 1,000° C or higher. This standard approach has its limitations. High temperatures, for example, adversely affect carrier mobility and longevity. As a result, researchers have been striking out in a new direction. Instead of allowing the impurities to migrate slowly from the vapor to the semiconductor, they reason, why not drive the dopant atoms directly into the material?

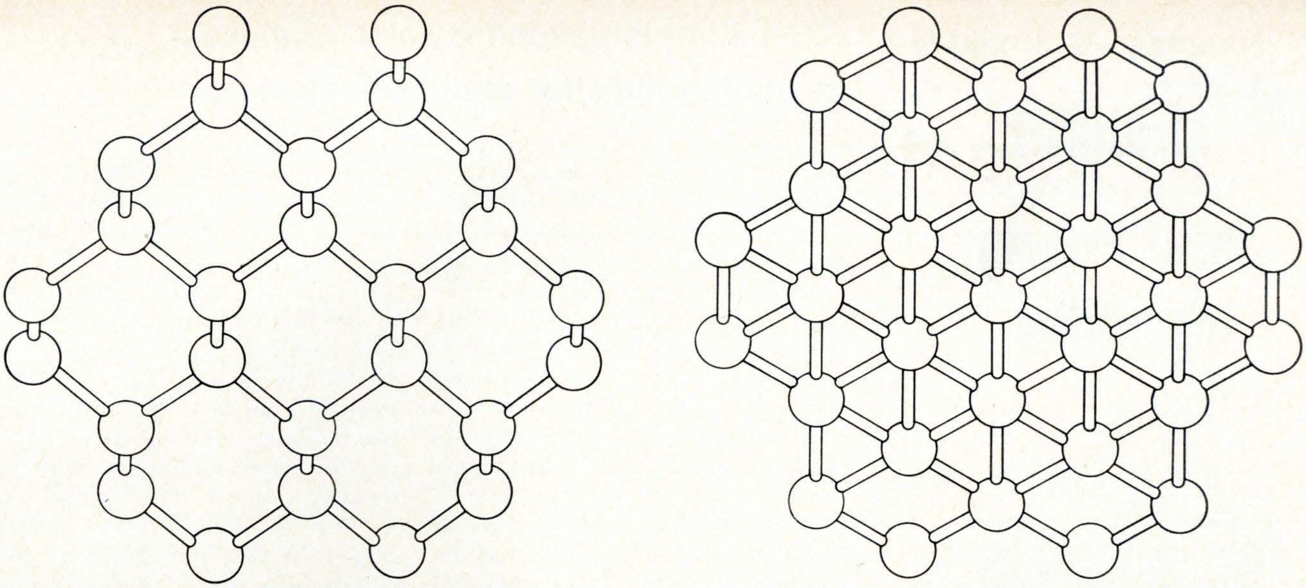
Shooting gallery. An electric field acting on ionized impurities, pointed at a semiconductor substrate, can supply the push. When the ionized impurities hit the semiconductor, they burrow a short distance—typically 1 or 2 microns—into the crystal lattice and take up positions where they can act as dopants.

Down the pipe. North American's James O. McCaldin shows how an ion moves through a semiconductor crystal to act as a donor or acceptor impurity.

I. Circumspection

Most researchers are, however, still cautious in assessing implantation's prospects. Ogden Marsh, who heads the Hughes Aircraft Co.'s Research Laboratories in Malibu, Calif., says, "A lot of physics study has to be done before ion implantation can be used to its fullest potential." Among the questions yet to be satisfactorily answered, Marsh points out, are: "What is the range of an ion as a function of its energy? What factors play a role in annealing damage? What defects are left after annealing? How do such defects influence junction behavior?"

Possibilities. But Marsh isn't unmindful of the attractive features of ion implantation. Hughes has been working in the field for two years, both on its own and with Government support. "Instead of doping a device and then putting on the contacts, you might reverse this process," Marsh says. "And with certain devices, you might



Two way. Along a 110 plane of the diamond structure at left, several atoms superimpose, leaving channels wide open for deep penetration by implanted ions. Along a 111 axis, at right, there are fewer atoms and channels are narrower.

be able to make the emitter first and then the base. Improved characteristics are generally obtainable any time you can tailor the cross section of the device."

Bobby L. Buchanan, a research physicist at the Air Force Cambridge, Mass., Research Laboratories, says, "Every time you bring the heat up to the diffusion level, you move junctions and other areas. And, with diffusion, you need multiple masking." Buchanan is working with high-energy ion beams in the hope of making transistors in a single implantation step—without masks.

Radiation damage resulting from bombardment is, according to a Bell Labs scientist, the great skeleton in the ion implantation closet. But, he adds, "there are now indications that it may be less of a problem than many experimenters previously believed."

Despite some researchers' reservations, ion implantation has an impressive list of potential advantages:

▪ Extreme heat isn't required; processing frequently occurs at room temperature. While annealing is usually necessary to repair radiation damage in the semiconductor host crystal, annealing temperatures are only in the 600° C range.

▪ The doping profile—the way in which impurities distribute themselves beneath the surface of the semiconductor—can be more precisely controlled.

▪ Almost any dopant can be used; ionization sidesteps many of the chemistry problems involved in combining dopants with the proper vehicle gases. Moreover, ionization eliminates the chance of dopant vapors attacking the semiconductor surface.

▪ Masking is simpler, and by electronically deflecting the beam, circuits can be written directly on the substrate with better resolution than is possible with diffusion.

▪ Complex internal junction structures can be formed inside the semiconductor—an accomplishment beyond the reach of diffusion techniques.

▪ Higher yields and improved device uniformity can be expected because control is electronic rather than chemical.

▪ Ion implantation can be applied to a selected part of a device and other areas will not be substantially affected.

II. Meager results

So far ion implantation has been used to turn out only one commercial device: the solar cells produced by the Ion Physics Corp., Burlington, Mass. [Electronics, May 15, p. 40]. The company claims the cells are more efficient and radiation-resistant than those produced by diffusion techniques. One knowledgeable observer believes the firm, which is a subsidiary of the High Voltage Engineering Corp., is getting close to 100% yields.

Most companies investigating the field have fabricated diodes. "A diode is simply a pn junction, and results in this area are pretty reliable indicators of the efficiency of the processing used," says Ralph P. Ruth, a scientist with the semiconductor materials group at North American Aviation Inc.'s Autonetics division. A division of the Columbia Broadcasting System Inc., CBS Laboratories in Stamford, Conn., is making photodiodes that are the equivalent of their diffusion-produced counterparts.

But, on the other hand, only a few concerns have tackled transistors. Russell P. Dolan, a research engineer at Cambridge Labs says, "We haven't seen a bipolar transistor as good as those produced by diffusion. Eventually, we hope, ours will be."

However, replacing diffusion with ion implantation in transistor fabrication isn't necessarily the primary objective. At this point, most researchers consider implantation a complementary technique for special-purpose applications. "There is no point in spending $10 for an implanted device you can produce conventionally for $1," says one researcher. "However, there apparently are devices, or classes of devices, that cannot be produced by diffusion."

Dolan, whose efforts have largely been devoted to the mega-electron-volt energy range, points out, "The goal is to put dopants in deeply, causing virtually no change in elec-

. . . ion implantation may also produce insulating films for semiconductors . . .

trical properties near the surface." Working with Buchanan, Dolan has driven p-type impurities into n-type silicon in such a way that the silicon remains n-type near the surface—creating an npn configuration with a single implantation.

Bonanza. Using a gold mask, researchers at Cambridge have also built buried-grid structures inside the silicon, creating vertical-junction field effect transistors. In such a device, the top of the slice might serve as the drain, and the bottom as the source. The buried-grid structure serves as the gate.

Both Dolan and Buchanan agree that gold is the best masking material for high-energy implantations. Silicon dioxide may be used at lower energies, they say. But to stop incoming ions in the Mev range, silicon dioxide would have to be made thicker than is ordinarily convenient. Gold has about three times the stopping power of silicon dioxide.

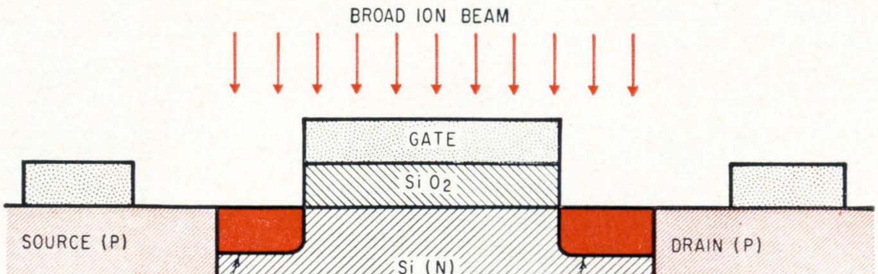
Sharpshooting. When transistors are made by implantation, says James O. McCaldin, of North American's science center, Malibu, Calif., frequencies and switching speeds two to four times those of diffusion-produced devices will be achieved because base thickness can be reduced. Depth profile figures are typically in tenths of microns. Moreover, lateral resolution—the faithful following of the mask's outline—is enhanced. In diffusion processing, the mask is generally undercut.

Leapfrog. Implanted integrated circuits are probably five years away at best, according to most researchers. But Ion Physics disagrees. In a joint venture with the Corning Glass Works, Ion Physics, although it has fabricated some diodes and transistors, plans to skip discrete devices and start work immediately on IC's. The company's designers believe that equipment can be developed for economic production rates running to millions of devices a month. The biggest plus, as far as Ion Physics is concerned, is that implantation promises to give the IC designer more freedom than he now enjoys with conventional diffusion techniques. The company contends the designer will be able to use any dopant in any host material with any desired profile.

However, some experimenters dismiss Ion Physics' IC plans as more pretentious than practical. One source, who questions anyone's right to comment on ion implantation because of the paucity of basic knowledge, goes so far as to call the company's progress reports "comic books."

Coverup. In addition to forming junctions, implantation may have a role in producing insulating films on semiconductor devices. James F. Gibbons, of Stanford University, one of the acknowledged leaders in the field, recently reported implanting nitrogen in silicon to form layers of silicon nitride.

Silicon nitride is a more attractive protectant than silicon dioxide because of its stability. The oxygen in SiO_2 causes undesirable surface states, particularly in metal



Implanted FET. The source and drain regions of this Hughes device were diffused and ions implanted to bring both just up to the edge of the gate. This technique avoids the necessity of diffusing under the gate lead and reduces feedback capacitance by 40 times.

Researchers doing applied and basic ion-implantation work:

Aarhus Institute (Denmark)
Atomic Weapons Research Establishment (England)
Autonetics
Bell Telephone Labs
Chalk River Nuclear Labs (Canada)
Electro-Optical Systems
Fairchild Semiconductor
General Electric
Hughes Aircraft
IBM
Ion Physics
Lawrence Radiation Lab
Services Electronics Research Lab (England)
Sprague Electric
Stanford University
Texas Instruments
Wright-Patterson Avionics Lab
Westinghouse Electric

oxide semiconductor field effect transistors.

III. As time goes by

Ion implantation techniques are as old as the basic nuclear physics studies on the effects of bombarding solids with high-energy particles.

Implants were first made around 1956. But it wasn't until 1961 that Ion Physics produced the first commercial device. There was a good deal of excitement at the time, but as a result of the technology's failure to live up to its press clippings, the Government agencies that had been underwriting the basic research became disenchanted. In recent years interest in ion implantation has been on the upswing; the Air Force and the National Aeronautics and Space Administration are sponsoring the program at Hughes' Research Labs to thoroughly study the process.

Hughes' effort is aimed at pilot-line production of semiconductor devices. The Hughes team has produced metal oxide semiconductor field effect transistors in silicon, light-emitting junctions in silicon carbide as well as rectifying pn junctions in silicon, gallium arsenide, indium antimonide, and germanium. Marsh says the voltage characteristics of these devices compare favorably with those of devices produced by diffusion. But he quickly adds that the work has been done in a research lab, not a production environment. Marsh is reluctant to predict how device characteristics would measure up in a production environment, but feels there are indications that the lower temperatures involved in ion implantation may lead to higher carrier lifetimes in bulk materials.

Although researchers are still using jury-rigged equipment and complaining that the lack of adequate process machinery has been a drag on progress, manufacturers in the radiation-damage and particle-acceleration business say they can build hardware for ion implanters. Several vendors, seeing an emergent market, are reported to be scaling down their high-temperture, high-voltage wares to serve the more modest needs of ion implanters.

Most ion work is being done with energies between 10 and 300 Kev. However, effects can be observed as low as 50 electron-volts and some researchers, notably at Cambridge, are working at energies in the 1 to 3 Mev range.

Freeways. The lower energy work capitalizes on a channeling effect, in which the ions penetrate deeply by moving down the empty passage between lattice atoms. To accomplish this, however, the host crystal must be aligned to within 0.1° of the ion beam to achieve repeatable results.

In the diamond-crystal structure of silicon and germanium, an axis perpendicular to 110-oriented internal planes has particularly wide channels because of the many superimposed lattice atoms. Along other axes, there are fewer superimposed atoms and the channels are smaller. Little damage is done to the crystal as the ions move down the channels, making the technique attractive.

When higher energy is used, the crystal is often purposely oriented off a major channeling axis. Some researchers believe they can better control the implantation depth in this way. This technique is being used at Cambridge to build buried-grid structures.

Energies in the Mev range are, however, accompanied by radiation-type damage since the ions crash into the crystals, disrupting bonds. Researchers have found that if the crystal is heated to about 400° C while being implanted, the ions tend to immediately take up substitutional positions where they can act as donors or acceptors. When implanted at lower temperatures, an annealing step at around 600° C creates vacancies; the ions move from their interstitial sites into substitutional positions.

Checkups. Another problem area to be dealt with is calculating how far the ions penetrate the host crystal. Researchers now rely on the theoretical work done by physicist Jens Lindhard of Denmark's Aarhus Institute of Physics.

But measuring how far the ions penetrate to form a junction is often as much a problem as the computations. For deep penetrations, the angle lap-and-stain method can be used: the surface is lapped 1° to 5° to expose a junction. The exposed surface is then etched with hydrofluoric acid, which causes the p-type areas to darken; n-type areas remain light. Distances on the lapped edge then can be translated into the distances below the surface.

Another method for finding the junction is to use successive stripping processes, taking away a small layer of the surface in each step and then using a four-point probe on the exposed surface to determine the polarity and concentration of the impurities. This approach is useful for shallow junctions, but it is tedious.

Still another check is to measure the junction capacitance and its variation with applied voltage. Depth can be estimated from the break points in the resulting characteristic.

A way to determine whether implanted ions have taken up substitutional positions was developed at the Atomic Energy of Canada Ltd.'s Chalk River Nuclear Laboratories, Ontario, by physicist John A. Davies. Five years ago, Davies, now a consultant to Hughes, discovered—in work unrelated to semiconductor devices—that if protons are aimed down the channels in a crystal, they produce little scattering. The ions are gently steered away from lattice atoms.

James Mayer, who heads Hughes' ion implantation work, heard about Davies' method two years ago and recognized its usefulness. He is spending the summer working with Davies at Chalk River.

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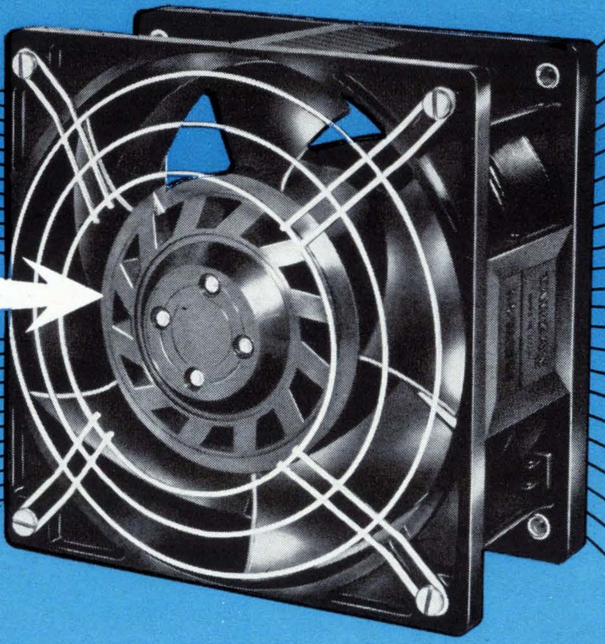

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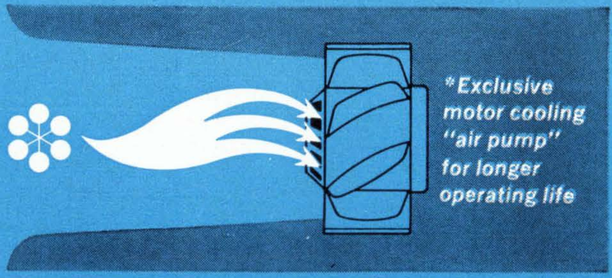

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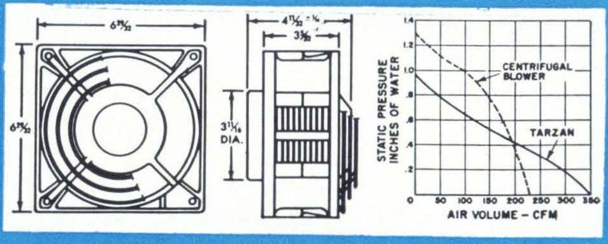

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What's up in San Francisco

Technical sessions at Wescon and concurrent meetings spotlight data compression, electronic tuning, and CAD thermal analysis

Designing a tuner, finding a hot spot on a circuit, and telemetering data are all workaday engineering chores that have been around for awhile. Normally, such subjects wouldn't be considered particularly exciting grist for the convention mill. But such is not the case at the Western Electronic Show and Convention meetings opening Aug. 21 in San Francisco, where new slants will be presented.

Industry bywords like linear integrated circuits, lasers, and large-scale integration will, of course, get a big play. But the technical sessions that stand out during Wescon week are those on electronic tuning, data compression, and computer-aided design for thermal analysis of circuits.

I. Less is enough

The increasing amount of scientific and engineering data being telemetered and processed has become one of the big problems facing engineers in the field of information technology. Telemetry transmission from missiles and satellites, for example, is a wasteful user of the radio-frequency spectrum. More and more data must be sent back from spacecraft as the missions become more complex. Complicating the picture is the fact that ground networks are saturated and storage space is overflowing. The answer is data compression: elimination of redundancy. The concept, a decade old, is just becoming practical. Wescon will cover the subject with a five-paper session.

To demonstrate and promote acceptance of data-compression techniques—many users don't want to compress data because they fear they will lose some—Lockheed Missiles & Space Co., Sunnyvale, Calif., has built a special-purpose computer. The $250,000 system, which isn't for sale, will be described by three Lockheed engineers—J.J. Downing, W.E. Smith, and J.E. Stubbles.

They put five algorithms in the computer so a potential user could match the results from one against the others. "You still can't say that all temperature data, for example, should use one particular algorithm," says C.M. Kortman, manager of advanced techniques at Lockheed's Space Systems.

Another paper from Lockheed, by G.M. Loh, describes the use of a similar machine, except that the system—Simulation Control and Data System—is more highly integrated; the multiplexing gates are addressed by the same random-access system that addresses the memory. Multiplexing and compressing are integrated. It was designed and built for Lockheed's biotechnology program.

At Wescon, Lockheed will demonstrate its special-purpose computer by simulating a pulse-coded modulation telemetry system. It has built a Zero Order Predictor (an algorithm which converts the data curve to horizontal lines on a graph) computer for use with Saturn telemetry. But this machine has yet to be scheduled for flight. The company has also built two ground systems being used to remove redundancy from test data on the Agena rocket— to simplify data analysis, not transmission.

II. Soft touch

Mechanical tuning has proved a stumbling block for engineers trying to design compact, lightweight tactical communications equipment. Air-variable capacitors, spiral inductors, and slug-tunable coils are bulky and require precision gears. Attempts to cut size and weight hurt performance and reliability.

For the past seven or eight years, however, engineers have been investigating what may be the answer

Wescon highlights

Varactor tuning of receivers	Tuesday afternoon	DuBridge Hall
Data compression	Wednesday morning	DuBridge Hall
Designing radio-frequency circuits using FET's	Wednesday morning	DeForest Hall
Large-scale integration of computer design system	Wednesday afternoon*	Edison Hall
Digital approach to analog functions	Thursday morning	DuBridge Hall
High-density recording techniques	Thursday morning	DeForest Hall
Solid-state imaging, an evolving technology	Friday morning	Edison Hall
The future of solid-state phased arrays	Friday morning	DuBridge Hall
Static power systems: controls, inverters, rectifiers, systems	Friday morning	Terman Hall

All Wescon technical sessions are at the San Francisco Cow Palace beginning Tuesday, Aug. 22, and running through Friday, Aug. 25. Morning sessions are 10 a.m.-12:30 p.m.; afternoon sessions are 2:30-5 p.m.

*Special session, 2-4:30 p.m.

to their problems—electronic tuning made possible by the voltage-variable capacitor, or varactor. Until recently, designers have been hampered by difficulties in developing practical varactor circuits and by the performance limitations of commercially available devices.

A Wescon session will hear a description of how engineers have been able to design equipment with electronic tuning, as well as a report on new varactor types.

Electronic tuning not only permits significant reductions in size and weight, but also provides more immunity to shock and vibration. In addition, high-precision tuning is possible, as are remote operation and fast scanning.

One designer, E.A. Janning of the Avco Corp.'s Electronics division, Cincinnati, tells how his firm has been able to design such equipment as the AN/PRC-70 backpack transceiver. It was obvious from the start at Avco that the use of electronic tuning would be limited primarily by the availability of suitable varactors. Large junction capacitance and high breakdown voltage was needed for a large capacitance change ratio.

Janning compares PRC-70 with the recently designed mechanically tuned PRC-77 solid state packset. While the units are of comparable size and weight, Avco was able to extend the frequency range of the PRC-70 (30-76 megahertz to 2-76 Mhz) and increase the number of channels (920 to 74,000). As a result of the weight-saving electronic-tuning approach, the company was also able to increase power output to 40 watts against the PRC-77's 2 watts, and provide automatic antenna matching. Janning asserts that tuner performance is better in the electronically tuned receiver, indicating that nonlinearities of varactors are no problem.

Transceiver designers still want varactors with higher voltages. Currently, 200 volts seems to be the limit, says Jorge E. Roza of the General Dynamics Corp.'s Electronics division, Rochester, N.Y.

In his paper, Roza will detail the design of his firm's remote-operation Southern Cross receiver, which covers 2 to 30 Mhz in eight bands. The receiver operates with a phase servoloop; a variable-frequency oscillator (vfo) uses the same varactors as the r-f tuned circuits. Cross-modulation distortion was minimized by using the varactors back to back, Roza says. He also was able to overcome large signal distortion.

High-priced spread. Solid state tuning costs more than mechanical tuning. Although some designers don't think electronic tuning will be used in home receivers anytime soon, a paper from the Motorola Inc.'s Semiconductor Products division will discuss a new varactor said to be applicable to a-m radio. The authors—Peter M. Norris and Paul Heidenreich—say that electronic tuning in the a-m band has not been extensively applied because the tuning ratios of available elements were too low. The r-f section of a typical mechanical tuning capacitor in a standard a-m radio may vary capacitance by 12:1 to cover the band and to overcome the effect of stray and circuit capacitance. They say the situation has changed, however, with a new tuning diode series called Epicap that has a tuning ratio exceeding 20:1.

The authors will report on a test to evaluate performance of the junction tuning diodes. They took a pair of devices, matched to within 2%, and replaced a two-section ganged, mechanical variable capacitor in a line-operated, transistorized a-m radio. Although some degradation in the signal-to-noise ratio and selectivity was noted with the tuning diodes, the Motorola engineers considered performance satisfactory. They note that performance could be improved by redesigning the oscillator-tank and antenna circuits. Thus, it is now possible to design practical, solid state tuning for a-m receivers with the new tuning diodes.

III. Hot topic

Thermal management—finding potential hot spots—is a key problem in circuit design. Heat caused by high component densities can cause parts failure, followed by the possible loss of the entire circuit.

Common engineering practice has been to build the circuits and then test to detect overheating or poor component placement. But Bruce Hyman and M.J. Merges, engineers at the Bell Telephone Laboratories, Holmdel, N.J., now are using computer-aided design to do the job analytically rather than empirically.

At the eighth International Electronic Circuit Packaging Symposium running concurrently with Wescon at the San Francisco Hilton, the Bell engineers will describe a computer program that applies the classical equations to plot—in a few seconds—the heat distribution across the face of a printed-circuit board or integrated-circuit chip.

The technique is about to become an everyday design tool at Bell Labs, according to Hyman. He says it is part of a company plan to use computers in as many aspects of circuit development as possible.

IV. Two steps

The approach is a two-step procedure. First, the most efficient electronic and geometrical placement of circuit components on the board or chip is defined, then the operating temperature of specific areas—spotting heat that could cause failure—is determined.

The computer plots an optimum component arrangement. The location and operating temperature of each part along with the heat-transfer and heat-sinking characteristics of the board or substrate is fed back to the computer.

To calculate temperature distribution, the computer is programed to divide the circuit's area into arbitrary squares, treating the components in each square as a single heat-generating element. The thermal mass of each square is considered to be at its center, or node. Each node is connected to the nodes of adjoining squares by a thermal resistance. The resistance varies with square size, and board or substrate thermal conductivity and thickness. The computer solves the heat-transfer equations for each node, plotting lines of equal temperature across the face of the hypothetical circuit.

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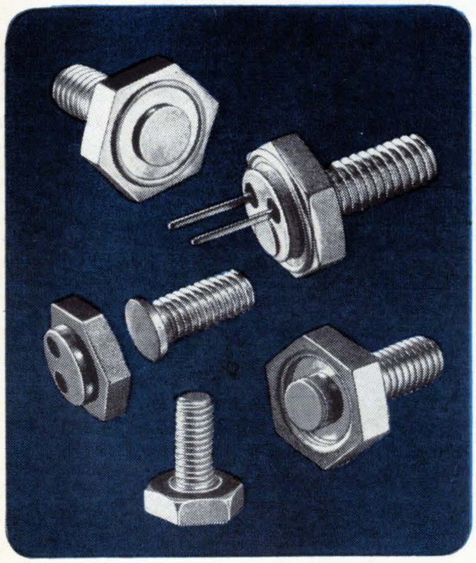

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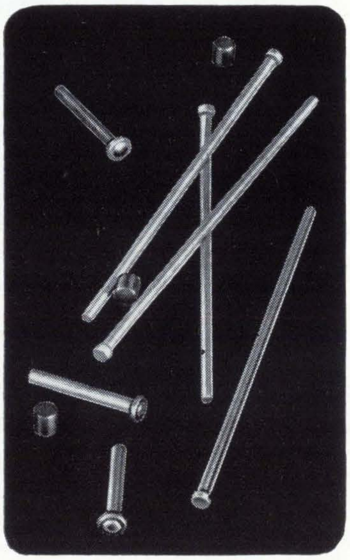

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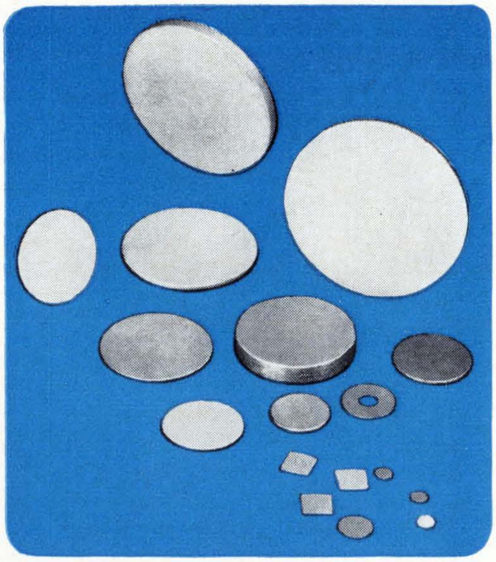

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The direct broadcast picture

Satellite tv system will need large antennas, high-power amplifier tubes, and a big power supply to assure economical hardware for home receivers

By James Brinton
Staff writer

A single satellite could beam television programs directly into homes throughout most of the U.S. by the late 1970's. And the cost of modifying sets to receive these signals could be as low as $20 each. While the fate of an operational system may well be decided by the maneuvering of opposing special-interest groups, the necessary technology is being developed now—slowly but steadily.

Second-generation communications satellites that come closer than ever to providing the large amounts of power necessary for direct broadcasting are in the works: the Hughes Aircraft Co.'s tactical communications satellite under construction and Communications Satellite Corp.'s domestic service satellite now being designed. In addition, the National Aeronautics and Space Administration is funding an increasing number of studies to determine design tradeoffs and to lay the groundwork for a prototype system.

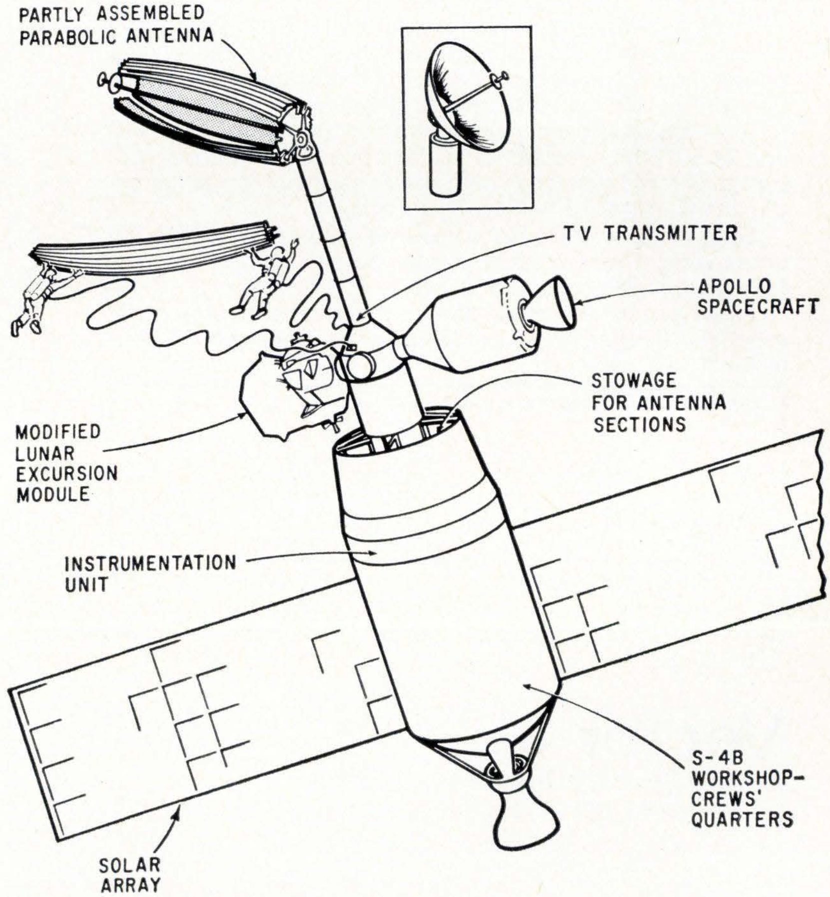
Industry, of course, is pushing hard for the development of a direct-broadcast system and several companies, including Hughes, the General Electric Co., and the Radio Corp. of America, have done a lot of work on their own. "We could deliver a direct-broadcast tv satellite in as little as three years if we got a contract tomorrow," says an optimistic GE engineer.

But many influential people think there's no need for direct broadcast tv. Robert E. Lee, a member of the Federal Communications Commission, believes local station services are adequate and that direct broadcasting would siphon off their audiences. "We won't see direct-broadcast tv in our lifetime," he predicts. Moreover, it's unlikely that the FCC would allow television networks to bypass, and perhaps bankrupt local stations.

Certainly, local stations and community antenna television (CATV) operators would fight the establishment of direct broadcast. Such a system would also reduce the revenue that the American Telephone & Telegraph Corp. now pulls in for distributing network television over landlines. However, an AT&T spokesman points out that this activity accounts for only about 1% of the company's income. Bell, in fact, is fighting for a share of any satellite communications system built in this country.

Next step. A distribution satellite, one that relays tv signals to the medium-sized antennas of local stations or schools for transmission to individual receivers, is probably the next step toward direct broadcasting. Some observers, including the Philco-Ford Corp., maintain it will be the final step.

Comsat's domestic satellite is in this category. Due for launching in 1969, the craft will transmit on eight tv channels to some 30 antennas—each 25 to 32 feet in diameter—spotted throughout the western U.S. It is likely to be a modified Applications Technology



Way out. Orbiting tv station, envisioned by the Radio Corp. of America, would include paraboloid antenna dish that would be assembled in space.

Satellite developed by Hughes for NASA [Electronics, July 24, p. 50].

Coming even closer to the power levels required for direct broadcasting is the tactical communications satellite, which must relay voice transmissions to antennas as small as manpack units. Based on Hughes' HS307 design, the satellite will weigh an estimated 2,000 pounds and cover a relatively large area of the earth with an estimated effective radiated power of at least 30 decibel watts.

I. Check list

Modifications to tv receivers must cost as little as possible if a direct broadcast system is to be practical. What's needed, therefore, is a satellite with enough power to transmit a signal home sets can pick up with small antennas and simple front-ends.

The satellite would have to carry antennas larger than any now operating in space or even planned—probably a parabolic or array antenna 50 feet in diameter. The largest space antenna now in development is the 30-foot parabola being designed by the Goodyear Aerospace Corp., Akron, Ohio; it's scheduled to fly aboard the space agency's ATS-F and ATS-G satellites in the 1971-1972 period.

Direct broadcasting will also require higher powered amplifier tubes than any currently qualified for space. Some firms favor triodes but no high-powered versions are space proven. Even the traveling-wave tube amplifiers used by Hughes on its operational satellites lack sufficient output.

The third big technical problem facing direct-broadcast designers is that of generating sufficient electrical power. Although some companies have drawn plans using nuclear power units, most engineers say such schemes are a decade away. The alternative—and way most engineers are going—is large, lightweight solar cell arrays.

The Atlantic Research Corp., Alexandria, Va., made the first extensive study of the technical tradeoffs involved in direct broadcasting. Under a contract from NASA's Office of Space Science and Applications, the firm's Jansky & Bailey Systems Engineering department used computers to simulate direct broadcasts from synchronous orbits [Electronics, Sept. 19, 1966,

p. 52]. Engineers studied frequencies from 200 megahertz to 12 gigahertz and ERP's of 20 to 90 decibel watts. They investigated both frequency modulation and the U.S. tv standard—vestigial sideband-amplitude modulation (VSB-AM).

Basing their cost and performance predictions on components that could be mass produced by 1970, the probers found that the cheapest receivers would operate at from 600 to 1,000 Mhz.

Outlays would be sharply higher at frequencies below 600 Mhz since more antenna gain and directivity is needed to compensate for cosmic and man-made noise. Above 1 Ghz, equipment costs would rise as tighter tolerances played a bigger part in manufacturing costs. Between 600 and 1,000 Mhz, conventional ultrahigh-frequency tv tuner techniques and VSB-AM could be used.

Tradeoffs. Frequency modulation was found to be more costly for uhf tv than VSB-AM. Above 1 Ghz, however, the inherently higher efficiency of f-m would allow lower effective radiated powers than VSB-AM. Although this could mean a cheaper satellite, a down-converter and a modulation converter would have to be added to home systems raising viewers' costs.

Adapters for receivers in electronically noisy urban centers could retail for as little as $20 if the satellite had an ERP of 80 dbw; this price would include both antenna and preamplifier. Cutting back the satellite's ERP to 70 dbw would boost the price of a receiver adapter by only about $5.

II. Opposition camp

Opponents of direct broadcasting are supported by a study made by the Philco-Ford Corp.'s Western Development Laboratories, Palo Alto, Calif. The report states bluntly that satellites with sufficient power for U.S. coverage will always be at an economic disadvantage vis-a-vis distribution systems.

As an alternative, Philco suggests satellite distribution at microwave frequencies for both educational and commercial tv. Less costly, low-powered—40 to 50 dbw—spacecraft could reach 90% of the country's population through receive-only ground stations installed near 200 cities; local stations or community antenna television systems would relay the signals into the home—either by coaxial cable or a rebroadcasting network.

Country cousin. According to Philco engineers, direct broadcasting could be economical only in areas of very low population density that lack local tv services. But CATV is making steady inroads in those regions [Electronics, June 26, p. 143].

Philco's study also deals with frequency-allocation problems. If direct broadcasting is to be cheap enough to command a large audience, uhf frequencies will have to be used. But in this range, according to the FCC, only channel 71—812 to 818 Mhz—is neither in use now nor applied for.

At least direct broadcasting at uhf frequencies wouldn't run afoul of worldwide interference regulations. The International Radio Consultative Committee (CCIR) has no provisions applying to uhf satellite broadcasts. The organization's regulations would come into play only if broadcast satellites were to use frequencies also allocated to point-to-point microwave systems. If this happened, satellite power would have to be limited to levels that would make either direct broadcasting or satellite distribution impossible.

III. Where the action is

The space agency's programs are centered at its Lewis Research Center in Cleveland, Ohio, and the Marshall Space Flight Center, Huntsville, Ala. General Electric's Missiles and Space division, Valley Forge, Pa., and RCA's Astroelectronics division, Princeton, N.J., completed nine-month studies of voice broadcast satellites just as Lewis awarded two new study contracts—this time for tv systems. One went to TRW Systems, Redondo Beach, Calif., the other to GE.

In the meantime, GE and TRW are pushing ahead on their tv satellite studies for the Lewis Center. Color and black-and-white broadcasting will be investigated, as will f-m and VSB-AM techniques for spacecraft with effective radiated power from 40 to 80 dbw. The booster could be in the Saturn 1-B class.

General Electric is mum about its approach to this contract. But John Jansen, TRW's project manager, agrees with others in the industry that uhf tv bands are the best bet to achieve low-cost home receivers. Jansen figures the effective radiated power for a VSB-AM satellite would have to be 75 dbw —about 34 Mw for a beam of 2° to 3°. But he believes that even with 75 dbw, a dish antenna of six-foot diameter, plus a preamplifier, will be necessary for reception.

Weighty matters. The Marshall Space Flight Center, which is responsible for larger spacecraft than Lewis, is about to let a study contract for a direct-broadcast tv satellite to be launched by the Saturn 5. This booster is designed to put a 62,000-pound payload into synchronous orbit. Three outfits are in the running for the nine-month feasibility award which will be worth about $100,000: RCA's Astro-electronics division, the Convair division of the General Dynamics Corp., San Diego, Calif., and Booz Allen Applied Research Inc., Chicago.

Marshall wants the contractor to investigate tv transmission from synchronous orbit in: the uhf tv band; the 2.5-to-2.69-Ghz international tv band; and the 1.7-to-2.7-Ghz range. Effective radiated power would range from 30 to 80 dbw, with the transmitted beam covering 500,000 to 10,000,000 square miles—almost three times the area of the U.S.

Inside track. Observers give RCA the best chance for the contract; the firm has already come up with preliminary designs for a very heavy satellite. Using the Saturn 5 and an S4B second stage, RCA envisions a tv satellite with a 40-foot parabolic antenna and twin 25-kw roll-out solar-cell arrays, each measuring 2,500 square foot. Radio-frequency power would come from gridded triodes in parallel.

IV. Over the transom

Funded programs were preceded by several private projects underwritten by private enterprise. In early 1966, both GE and RCA presented the space agency with unsolicited proposals for synchronous-orbit, direct broadcast tv satellites. Vista, RCA's contender, weighed in at about 7,000 pounds with a 40-foot parabolic antenna and a 3,000 square-foot, pantograph-deployed solar-cell array. Designed to operate on uhf channel 69—800 to 806

Circle 177 on reader service card

Mhz—the satellite achieved 5 kw transmitter power with a set of four gridded triodes; effective radiated power was about 74 dbw. General Electric's similar but smaller design operated at around 650 Mhz. While RCA had concentrated power in a beam covering only one-sixth of the U.S. But, as if to illustrate the ambiguities facing engineers in this area, GE optimistically figured the same transmitter power could serve the entire country; GE also favored triodes for its transmitter.

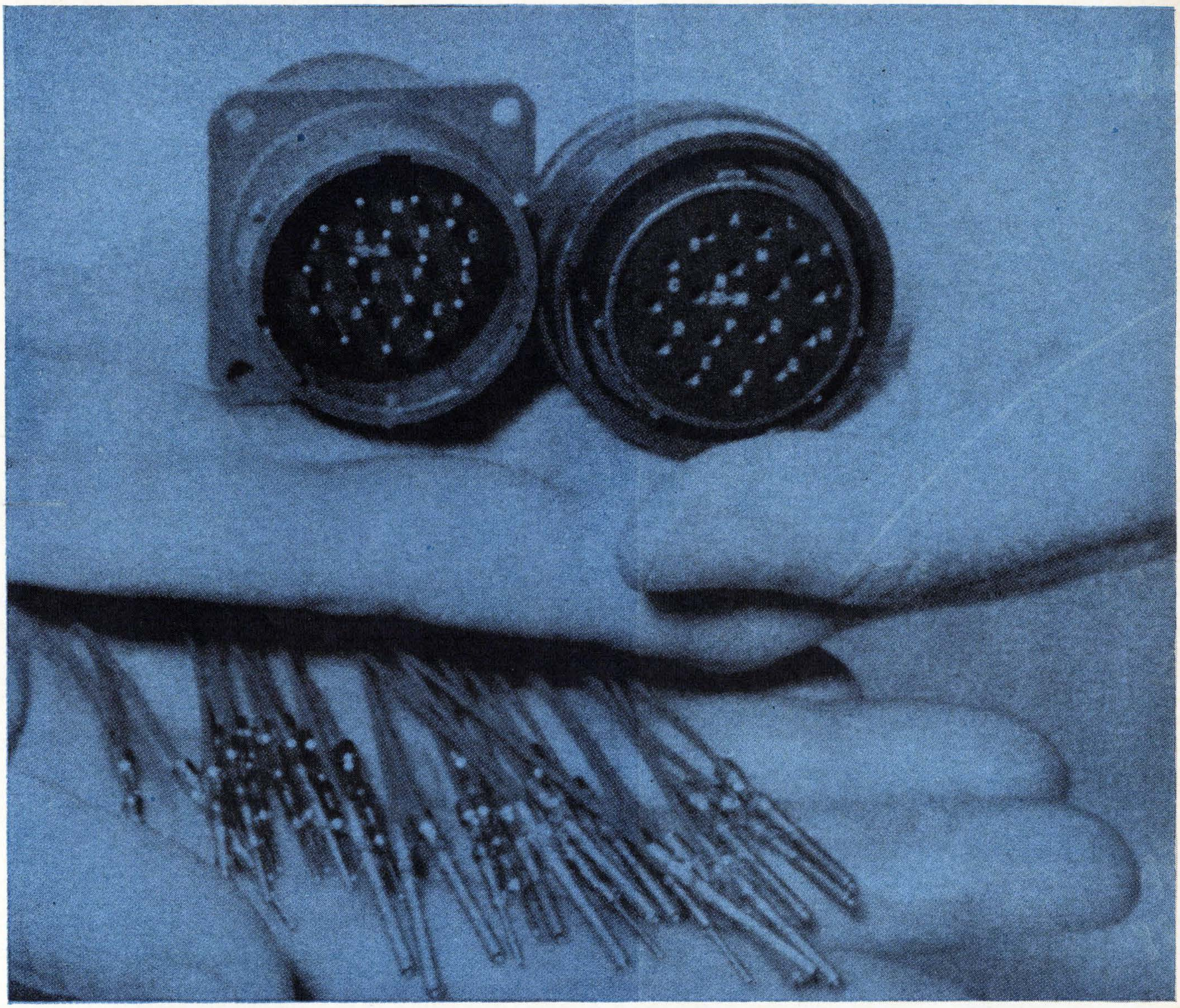
Back to the drawing board. But recently, RCA has designed an advanced spacecraft in which a 49-element, electronically steered phased-array antenna replaces the more common paraboloid. Each element includes a 160-watt transistor transponder. A SNAP-8 nuclear generator system with an output of about 25 kw would furnish power.

The satellite would operate at about 800 Mhz with an ERP of about 70 dbw. Since it would use separate amplifiers for each array element, failure of one amplifier wouldn't knock out the whole system.

By locating the array and nuclear power source at opposite ends of a 100-foot boom, the satellite's designers built in one axis of a gravity-gradient stabilization system. Four other booms up to 200 feet long would stabilize the satellite in remaining axes.

General Electric's latest in-house design uses a 44-foot parabolic antenna. Twin roll-out solar-cell arrays supply 50 kw of d-c power. Transmitter tubes would be four parallel planar triodes or tetrodes; GE is developing tubes for such special applications at Owensboro, Ky.

Sidestep. The Hughes Space Systems division, El Segundo, Calif., has designed spin-stabilized satellites with ERP's as high as one megawatt or 60 dbw. William Bakemeyer, assistant laboratory manager for systems engineering, says these spacecraft would be drum-shaped, measure 10 feet high and 10 feet in diameter, weigh 1,500 to 2,000 pounds, and use solar-cell power. The company is checking a variety of antenna designs, including a 64-element electronically despun phased array backed by multiple output tubes.



Illustrated: MIL-C-26482 and MIL-C-23216 Crimp Contacts

Australian industry says make it at home

Government support for drive to get more military orders spurs expansion by both foreign and local electronic firms

"The longer the Australian electronics industry is deprived of worthwhile military contracts, the more difficult it will be to increase general production," says Sir Lionel Hooke, chairman and managing director of Amalgamated Wireless (Australasia) Ltd. His company—the only 100% Australian-owned concern in the top three of a business dominated by giant American, British, and Continental companies—hasn't received any substantial defense orders in over a year.

But knowledgeable observers believe the government is changing its position. The outbreak of war in the Middle East in June presented electronics industry officials an opportunity to renew their pitch for a larger share of the island continent's defense dollar. The immediate arms embargo slapped on Israel by its friends—the United States, United Kingdom, and France—raised the possibility that Australia might someday have to go it alone in a war. As a result, industry and political leaders have been renewing their pressure on Prime Minister Harold E. Holt.

Keystone. Defense orders are crucial to the expansion designs of the Australian electronics industry. For one thing, domestic markets for industrial and consumer goods are too limited to support sustained growth. For another, there are not enough foreign outlets in which Australian-made electronics are competitive. Since the government orders about 80% of its military hardware, including electronics, from abroad, this area holds the greatest growth potential.

By American standards, the Australian market for military electronics is not particularly prepossessing. Informed sources estimate that electronics represents about 7% of the $865 million worth of defense items that will have been imported by the end of 1967. The total is still enough of a plum to have triggered a flurry of expansion activity. Texas Instruments Incorporated and the Fairchild Camera & Instrument Corp. are among those planning to beef up their Australian subsidiaries and take advantage of the more bullish outlook in military markets.

The buy-at-home campaign seems dictated less by chauvinism than by an interest in having a self-sufficient electronics industry to ensure survival during a war. So long as equipment is built on Australian soil, Aussies are not especially concerned if orders wind up at firms owned or controlled by foreign interests.

Commercial colonialism. Overseas outfits have dominated the Australian electronics scene since the industry opened for business toward the turn of the century. Number one is Philips Electrical Industries Ltd., a subsidiary of the giant Dutch corporation, which manufactures radar, radios, and television sets. It also vends such components as thermionic tubes, yokes, capacitors, resistors, winding wire, and tuners to other Australian-based concerns. Philips also has a majority interest in Mullard-Australia Ltd. and Kriesler-Australia Ltd.; it has bought control of the sometime Australian-owned Electronic Industries Ltd.—reportedly, to move operations to South Africa.

Ranked second is Pye Radio Ltd., which is tied to Philips through the latter's ownership of Pye of England, a U.K. subsidiary. The Australian branch is the island continent's leading producer of tv sets.

Amalgamated, which has a licensing and technical aid agreement with the Radio Corp. of America, is third. It produces radar, tv, radios, thermionic tubes, and related communications gear under the MSP—for Manufacturers Special Products—label.

I. Thinking small

As early as 1965, Australia's political leaders decided that the country must achieve self-sufficiency in integrated circuitry because of defense considerations. Subsequently, the needs of the Post Office, the Department of Civil Aviation, the Council for Scientific and Industrial Research, and other official agencies provided additional impetus to the project.

Manufacturers claimed they couldn't get into production before 1970, but the government came up with three proposals to get the ball rolling sooner. Creation of an official manufacturing facility like the extant Weapons Research Establishment went by the boards. The industry rejected a commercial consortium since manufacturers refused to share their know-how. As a result, a third plan based on competitively bid contracts was adopted; the government is now studying the first tenders from Australian-based producers.

Last year, demand was only about 40,000 devices. By 1970, it will probably be running at an annual rate of 1 million—about the current weekly output in the U.S. But the decision by the government to subsidize a local IC industry has set off a miniboom. No matter who snares the first contract, Philips, Amalgamated, Plessey Pacific Ltd., associated with the U.K.'s Plessey Group, and Fairchild—among others—plan to establish production facilities to supply their own needs as well as the over-all market.

Self-help. Evidence is accumulating that Australian-based systems manufacturers are performing in a way that will further ratify optimism about the government's willingness to give the home front a bigger share of its military orders. On the drawing board, for example, is Project Nangana, an unattended network of submarine detection buoys. Plessey Pacific is set to invest $2.8 million in expanding the

. . . business is better, even for computers . . .

research facilities at three of its Australian units to investigate developments in microelectronics, sonar, defense radio, and airborne and land-based radar. And EMI Australia Ltd. will shortly acquire EMI Electronics of Australia from the British parent, Electrical & Musical Industries of Britain, to go into defense work. The company has been developing the electronic guidance systems for Australia's Ikara antisubmarine missile, which the government has been trying to sell to Japan.

II. Crossroads

On balance, the Australian electronics field is riding a modest upward curve. In June, annual output was estimated at $224 million; 18 months earlier the rate was about $190 million worth of production a year. One reason for this progress is strong tariff protection. A transistor radio selling for $3.50 in Hong Kong would retail for about $10.50 by the time it reached a shop in Alice Springs or Warrnambool. Japan, for one, is less than pleased with such protective barriers and has been unsuccessfully seeking reductions in certain schedules.

Busy signal. While the industry is hopeful about continued progress in the military and consumer sectors, the telecommunications field, a sizable outlet for electronics, has turned in a solid performance and looks forward to further gains. Australia's telephone system, which is under the aegis of the Postmaster General, is being extended into less populous areas in the western portions of the island continent to link them with the commercial centers along the eastern coast. Australian-based concerns now supply 85% of all telephone equipment, a chunk of business that will be worth about $80 million this year. In addition, exports will total close to $6 million. By contrast, local industry filled only 50% of the island nation's telecommunications needs in 1949 when import revenues were virtually nil.

Seismic boom. Stepped-up petroleum and natural gas exploration activities have led to a growing demand for computer processing of seismic data. Two U.S. concerns are vying in this field. Geophysical Service International Inc., a division of Texas Instruments Australia Ltd., is bringing in a TI Model 870 digital processor designed to handle seismic data; IBM Australia Ltd., a subsidiary of the International Business Machines Corp., recently introduced a seismic data-processing service. As a result, the practice of sending data abroad for analysis will probably come to a halt.

Amalgamated Wireless has the only significant equity in an Australian computer firm: a 40% interest in Australian Computers Ltd. Control rests with U.K. interests. Australian Computers is not exactly a goldmine for its proprietors, having lost close to $1 million in fiscal 1966 and 1965. However, with the recent sale of the first of its new System 4 machines, the firm may be headed toward black ink.

III. Right track

American space programs have given Australian electronics a valuable boost. Under the terms of a 1960 agreement, the National Aeronautics and Space Administration will have invested $112 million in six tracking stations by yearend 1967. These facilities—which employ about 700 native scientists, engineers, and technicians—are designed, built, and operated for the space agency by Australian-based companies.

While the watchword in Australia is self-sufficiency, manufacturers still buy most of their components from overseas sources. British, Dutch, and American suppliers fill a substantial portion of the local demand for transistors, power semiconductors, tv tubes, radios, radars, relays, capacitors, and miniature fuses. Japan sells some capacitors in Australia and West Germany merchandises television tubes.

On the plus side of the ledger, the government's willingness to subsidize a native IC capacity may eventually lead to a greater degree of self-sufficiency for Australian electronics. A bigger piece of the military action will also help the industry to chalk up further progress.

INSTRUMENTATION

Swept VSWR is just one of many applications tailor-made for Telonic's new 2003 Sweep Generator. Actually, a sweep "system", the 2003 makes versatility an understatement for it has completely interchangeable frequency oscillators, frequency markers, attenuators, and modulators. You can run a frequency response test in the HF region and two minutes later, check the insertion losses in a microwave circuit.

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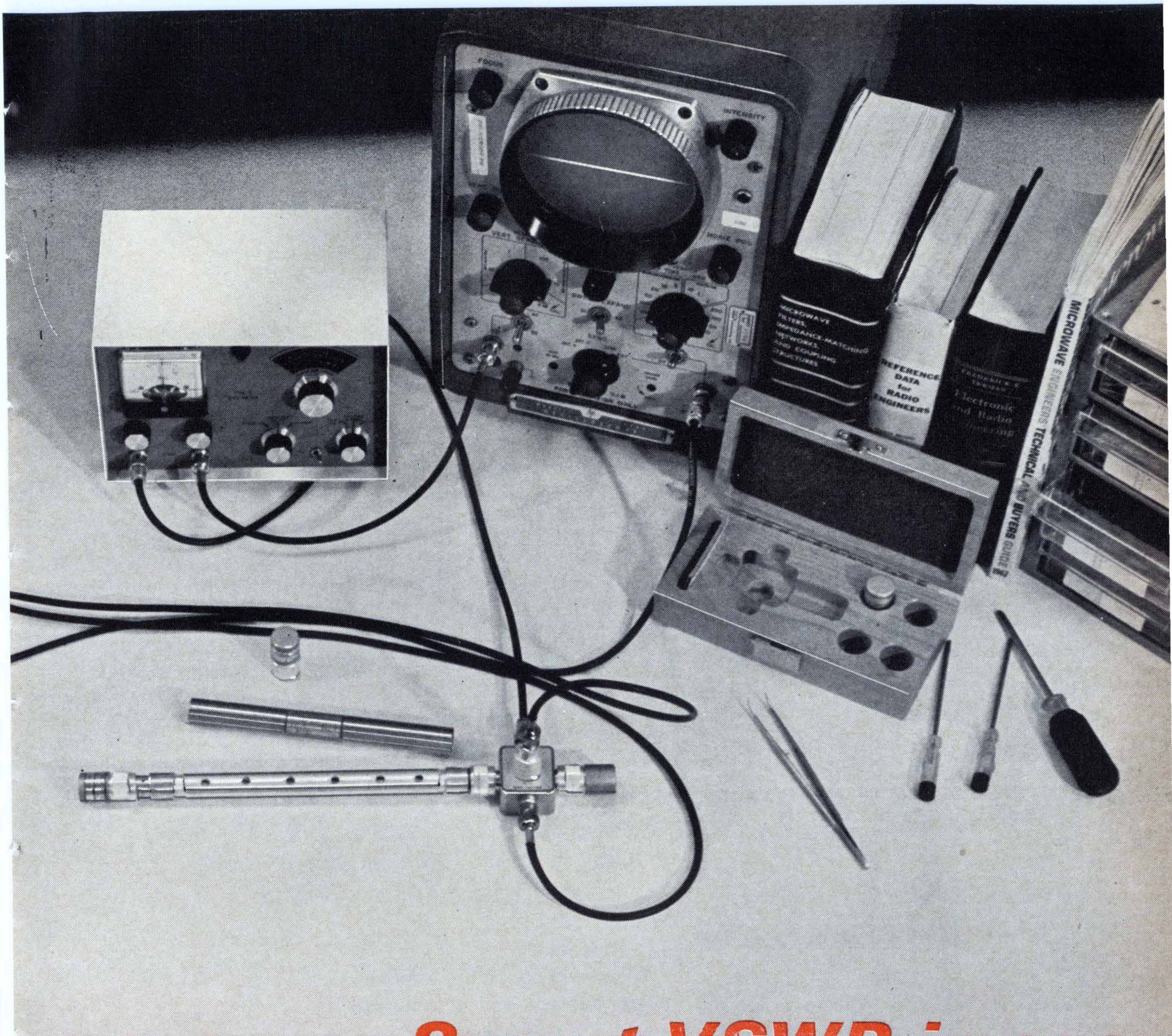

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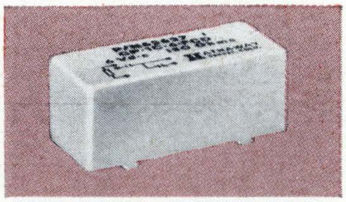

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Sweep generator that is easy to use

Device makes precise frequency measurements, can be operated easily, and requires few accessories

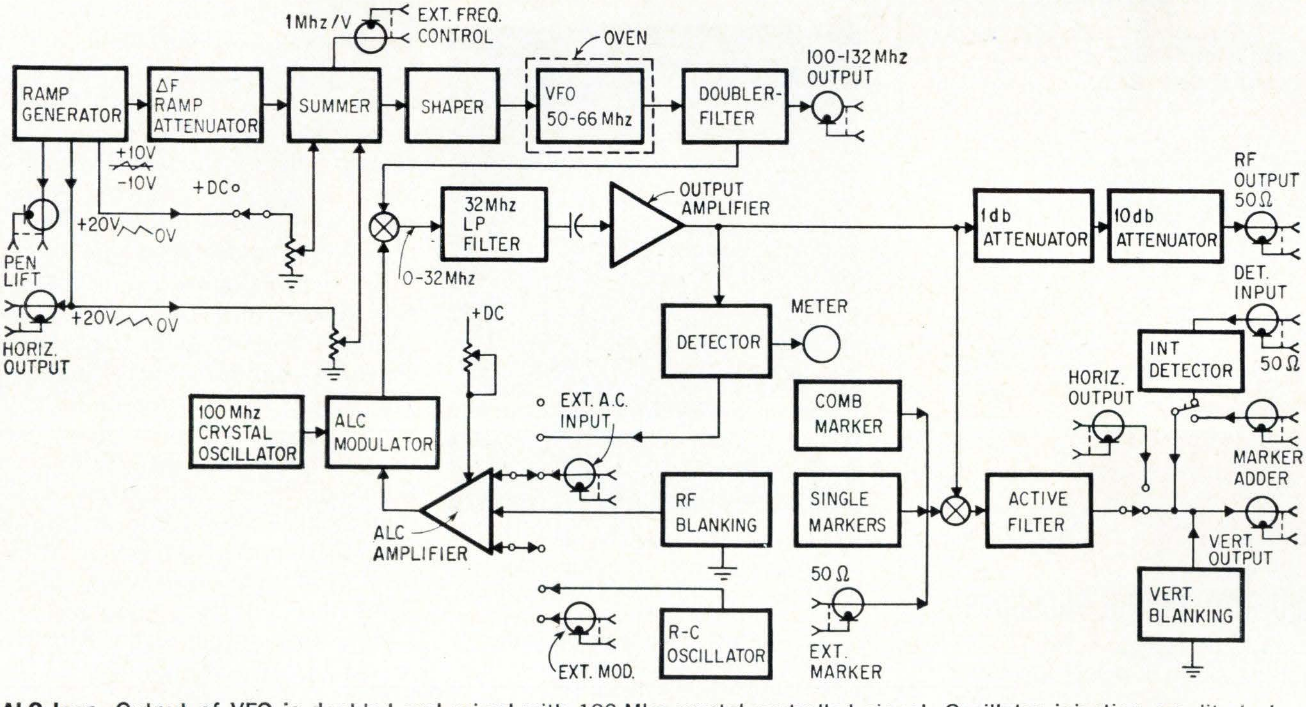
As military and industrial electronics equipment becomes more sophisticated, users' specifications tighten, and designers must make more precise measurements. At the same time, manufacturers don't want to turn their engineering departments into standards laboratories. To meet the needs of both user and producer, the Hewlett-Packard Co. has developed a sweeping signal generator that makes precise frequency measurements and can be operated easily by the average engineer. It also has internal and external modulation capabilities and a built-in detector.

The instrument, designated the 675A, can make either wide or narrow sweeps. With it, an engineer can test such broadband circuits as amplifiers and attenuators over a 3½-decade range in one 10-kilohertz-to-32-megahertz sweep—without changing plug-in units. In addition, because the instrument has exceptional frequency stability and low residual frequency modulation, it can measure the response of narrowband circuits, high-Q filters, and crystals. The generator's start-stop and center frequency sweeps have ±1% end-point accuracy and a temperature drift of less than 3 khz per degree Centigrade. It isn't necessary, therefore, to calibrate each sweep setting individually.

I. Inside the box

Behind these unusual capabilities is a variable-frequency oscillator (VFO) that uses two field effect transistors—one as the driver and the other as a buffer amplifier. The transistors' high input and output impedances minimize loading of the tuned circuits, thus maintaining a high Q and assuring good frequency stability and low residual f-m. A voltage-variable capacitor allows for electronic, rather than mechanical, tuning.

The oscillator has an effective



ALC loop. Output of VFO is doubled and mixed with 100-Mhz crystal-controlled signal. Oscillator injection amplitude is controlled by ALC voltage derived from generator output. Ramp-generating and summing circuits produce signal sweep.

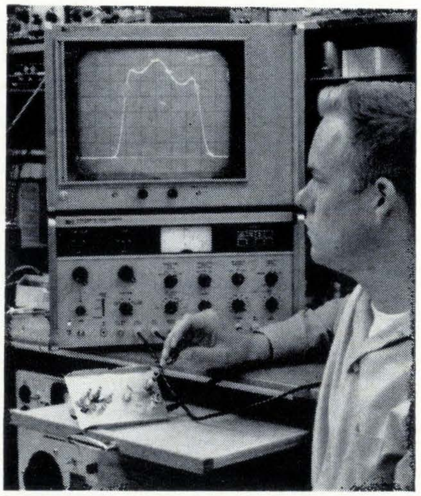
. . . sweeping too fast causes display to shift; sweeping too slow may miss the transients . . .

range of 100 to 132 Mhz, although its frequency varies only from 50 to 66 Mhz, depending on the voltage applied to the capacitor. But by feeding the output into a full-wave rectifier, H-P obtains the second harmonic, doubling the effective frequency range.

A controlled oven helps to minimize frequency variations by keeping the oscillator at a constant temperature.

One disadvantage of the oscillator design is the nonlinearity of the frequency versus voltage curve. To compensate for this, H-P designed a 16-line segment-shaping network to modify the control voltage applied to the variable capacitor. This network makes the oscillator's output frequency directly proportional to the control voltage, resulting in a linear sweep. Depending on the function selected, the control voltage is derived by summing ramps, adjustable d-c voltages, or externally applied signals.

Different sweeps. The generator can handle a wide range of sweep times. Sweeping at too high a rate causes the display to shift amplitude and frequency, while sweeping at too low a rate may not catch the fast transients of interest.



Solid state. Model 675A is both a sweeping and continuous-wave signal generator over a range of 10 khz to 32 Mhz. Completely solid state design incorporates an oven to stabilize the variable frequency oscillator. The display oscilloscope above the generator isn't part of the instrument as it comes from the manufacturer.

In a start-stop sweep, in which the end points are set, a ramp voltage is applied to a 10-turn potentiometer to set the frequency where the sweep begins. Another ramp, the inverse of the first, is fed to a similar potentiometer to set the stopping frequency. The outputs of the potentiometers are then summed to produce a composite control ramp.

If a delta sweep is made, one potentiometer sets a d-c voltage to fix the center frequency. A ramp with no d-c component is then added; the amplitude of the resulting wave form determines the width of the sweep. In continuous-wave operation, the d-c voltage alone sets the output frequency.

II. Generating the output

The generator's output is a difference frequency formed when the output of the variable-frequency oscillator (ranging from 100 to 132 Mhz) is mixed with that of a 100-Mhz crystal oscillator. After mixing, the signal is filtered and amplified.

A critical job of the circuit is to hold the amplitude of the quartz oscillator exactly where it should be. Control is important because the amplitude of the crystal oscillator determines the amplitude of the generator output signal.

A signal proportional to the generator output is derived from a peak-to-peak detector with exceptionally flat frequency response. This voltage is used for output monitoring and also feeds an automatic level control loop.

An ALC modulator using hot carrier diodes directly controls the 100-Mhz output to the mixer and, thus, the amplitude of the final output signal. Hot carrier diodes are used because of their good frequency response. The modulator's functions are leveling and r-f blanking; it also allows for amplitude control from the front panel. Moreover, amplitude modulation can be done through the modulator by adding the output of a 1-khz RC oscillator to the ALC voltage.

Control circuitry. For precise measurements, the oscillator supply

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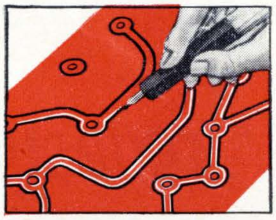

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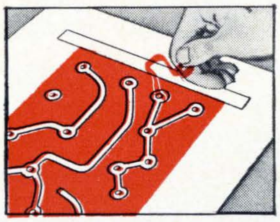

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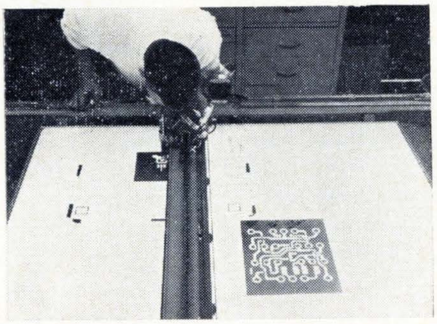

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When the output and marker frequencies are equal, a signal passes through the filter and appears as a marker on the sweep display, identifying the frequency precisely.

III. Using the generator

To examine a narrowband circuit, an engineer first sets a center frequency on a three-place digital dial. He next chooses an independent delta-width control to fix the width of a symmetrical sweep around the center frequency. Delta widths can range from 1 khz to 10 Mhz.

To make a wide sweep, the engineer sets the end points on digital dials, each with a range of 10 khz to 32 Mhz. Since the delta-width and frequency controls are independent of each other, the desired sweep width can be set without many adjustments.

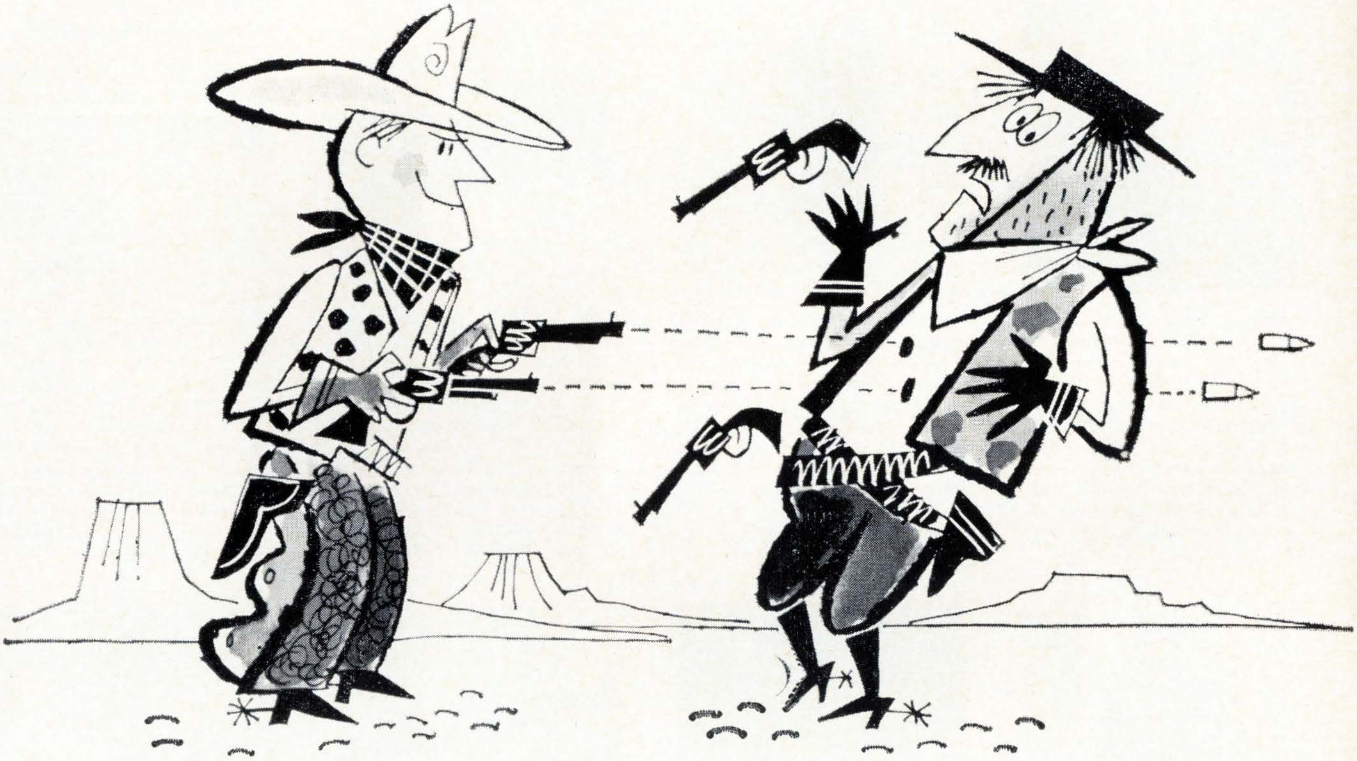
The output of the new generator is uniform over a wide range. Its high linearity enables a user to locate response points and corner frequencies accurately from a cathode-ray-tube graticule. If more precise frequency identification is required, the engineer can buy optional crystal markers.

Minimizing accessories. The model 675A has an internal detector so that some measurements can be made without external equipment. The instrument supplies base-line presentation to represent zero amplitude on the display during retrace.

With vertical blanking, the generator improves the display by grounding the detected signal rather than switching off the r-f. Transients are thus prevented from exciting the device under test.

No other sweeping signal generator can match the flatness of response and wideband linearity of the 675A. Its low residual f-m and dial accuracy are also outstanding.

Hewlett-Packard Co., P.O. Box 301, Loveland, Colo. 80597 **[388]**



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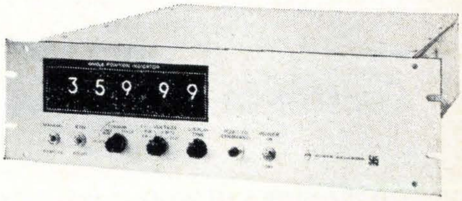

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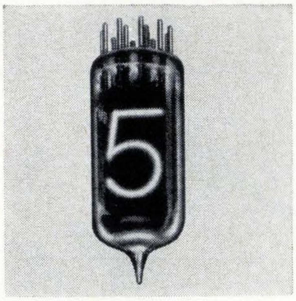
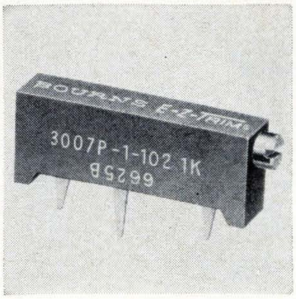
New Components Review

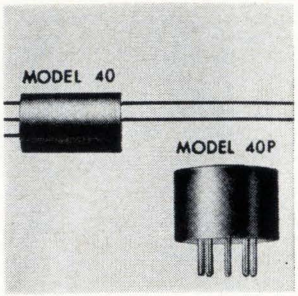
A high-resolution crt features a 4-in. long raised cylindrical faceplate of fiber optics and a yoke-shield assembly for aerial photography, single-line scan display, side-looking radar, and film recording. Type WX-30519 offers a maximum center spot size of 0.0007 in. and an edge spot size of 0.0008 in. Anode voltage is 10kv. Westinghouse Electric Corp., Elmira, N.Y. [341]



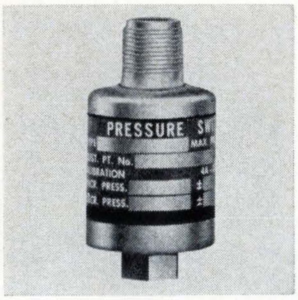
Numerical readout tube NL-874, with an inverted base, is mounted vertically with the base at the top to permit optimum use of panel spacing. It is a side-view display tube with 0.310-in. characters, 0 to 9. It requires a minimum d-c supply of 170 v at maximum cathode current of 3 ma average; minimum, 1.5 ma average. National Electronics Inc., Geneva, Ill. [342]



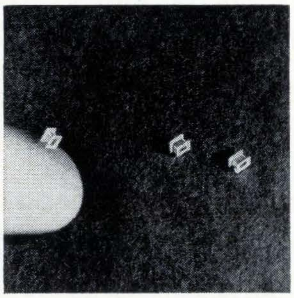
Model 3007P is a wirewound adjustment pot for space-saving commercial uses. It is offered in resistances of 10 ohms to 20,000 ohms. Power rating is 1 w at 40°C, and operating temperature range is −55° to +125°C. Temperature coefficient is 100 ppm/°C maximum. Price is 99 cents each in 1,000-piece quantities. Bourns Inc., 1200 Columbia Ave., Riverside, Calif. [343]



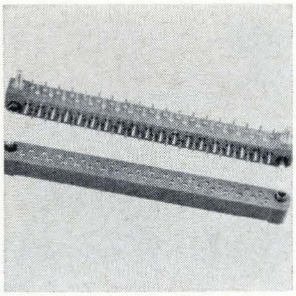
Silicon transistor choppers are encapsulated units for connecting and disconnecting a load from a signal source. Linear switching can be done over a range of less than 1 mv to ±5 v. The devices can be driven from d-c to 50 khz. Model 40 is a miniature solder-in module; the 40P is a plug-in type. Solid State Electronics Co., 15321 Rayen St., Sepulveda, Calif. [344]



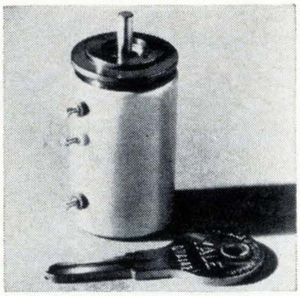
Absolute pressure switch 1857-2261 switches circuits in response to pressure changes in gases and liquids. It has a working range to 350 psi; burst pressure, 250% of proof rating. Electrical rating is 5 amps at 125 v, 60 hz, inductive or resistive; 4 amps at 30 v d-c resistive; 2.5 amps at 30 v d-c inductive. Occo Manufacturing Corp., 8 Romanelli Ave., S. Hackensack, N.J. [345]



Custom-molded bobbins hold coils of fine wire for pots and similar devices. Typical dimensions are: length, 0.073±0.001 in.; flange outside diameter, 0.073±0.001 x 0.106±0.002 in.; core inside diameter, 0.062±0.001 x 0.031±0.001 in. Units offer low moisture absorption and high insulating capacity. Thermotech Industries Inc., 3328 Gorham Ave., St. Louis Park, Minn. [346]



Right-angle pin and socket connectors are used where a soldered joint between connector and p-c board is required. MIG series connectors are available with 11, 15, 23, or 37 contacts, with a contact grid spacing of 0.1 in. They are furnished with standard solder cup terminations as well as in dip-solder contact versions. U.S. Components Inc., 1320 Zerega Ave., Bronx, N.Y. [347]



Ten-turn precision pot 2110 meets MIL-R-12934E, RR1000. It is servomounted, 7/8 in. in diameter, wirewound, and offers ±0.25% independent linearity. Available in resistance values from 100 to 50,000 ohms, the units give more than 20,000 cycles of rotational life. They withstand 15 g shock. Amphenol Controls Div., Amphenol Corp., 120 S. Main St., Janesville, Wis. [348]

New components

Center jack improves small connectors

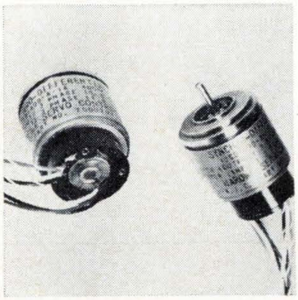
An off-shoot of work for the Apollo project produces connectors with more pins

Overlooking the obvious can be an occupational hazard in highly technical fields. A new line of high-performance subminiature connectors from the Hughes Aircraft Co. attests to this.

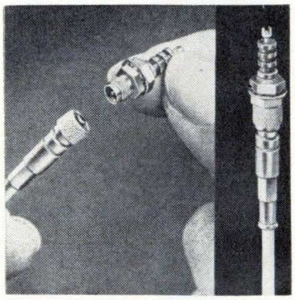
By using a center jack screw, instead of a conventional bayonet locking nut, engineers at the company's connecting devices department in Newport Beach, Calif., have developed commercial assemblies that require less panel space and have more contact pins.

There's nothing new about jack screws; Hughes has long used them in rectangular connectors. But the company believes this to be their first application in circular devices. Queried about this apparent oversight, Dominic DeLorenzis, product marketing manager, says: "We're wondering ourselves why we didn't do it sooner. It's one of those things that's so simple that most of the time it's overlooked."

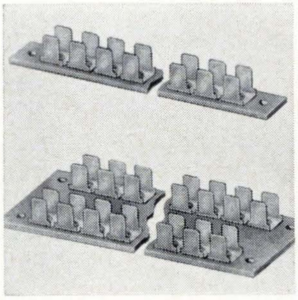
Something borrowed. An offshoot of Hughes' work on the Apollo program, the new connector line has been dubbed Bulls-Eye. Devices are available in American Wire Gauge sizes 8, 10, 12, 14, 16,



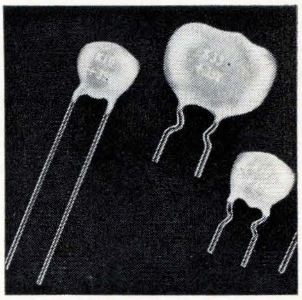
Limited rotation, long-life synchros feature hairspring conductors in place of brushes. They are for use where environmental conditions are detrimental to conventional brushes and rotation does not exceed 330°. The hairsprings pick off rotor winding information and allow a rotation of ±165°. Harowe Servo Controls Inc., Westtown Rd., West Chester, Pa. 19380. [349]



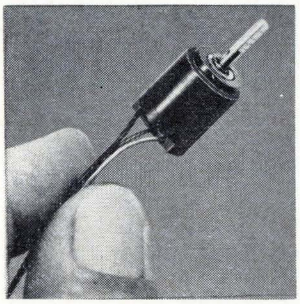
Miniature, coaxial cable connectors are rated at 10 kv d-c for limited pulse applications such as exploding bridge wire firing circuits, photomultiplier tubes, and high-speed cameras. Dielectric seals provide rated voltage standoff when mated. Series 600 connector has a maximum plug diameter of 1/4 in. Reynolds Industries Inc., 2105 Colorado Ave., Santa Monica, Calif. [350]



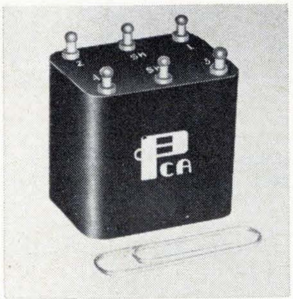
Standardized Kwik disconnect terminal boards permit solderless connections of several circuits to a common feed line. All are rated for continuous operation at 155°C or 300°F. Boards are available in a variety of sizes with brass terminals that are either hot-tin or bright-brass plated. Priced from 13 cents to $1.18. Keystone Electronics Corp., 49 Bleecker St., New York 10012. [351]



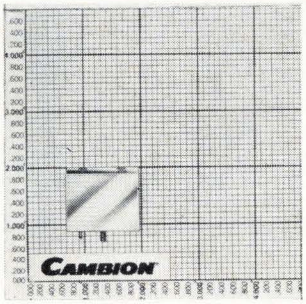
Polar, solid tantalum capacitors in the E series use a dip-coated, hard epoxy encapsulation process. They are suited for decoupling, bypass, filtering, and blocking circuit uses. Units are offered in working voltages of 6 (330 μf max), 10, 15, 20, 25, 35, and 50 (15 μf max.) v. Electronics Division, Union Carbide Corp., 30-20 Thomson Ave., Long Island City, N.Y. [352]



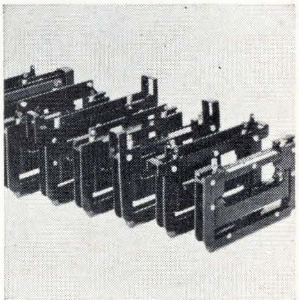
Potentiometer type CP40 was developed for use in precision servo units, or as a feedback device on miniature actuators where only very low torque outputs are available. Resistance values are from 5,000 to 20,000 ohms. Torque is approximately 3 gr-cm, or less if specified. The unit measures 0.5 x 0.68 in. Humphrey Inc., 2805 Canon St., San Diego, Calif. 92106. [353]



An interstage pulse transformer occupying 1 cu in. and weighing 75 grams can operate at altitudes up to 50,000 ft and withstand shock and vibration of 50 g. With a working voltage of 10 kv d-c, the unit has a 1:1 turns ratio, a rise time of 0.5 μsec, and meets applicable MIL-T-27 specs. Price is $32.42 in small quantities. PCA Electronics Inc., 16799 Schoenborn St., Sepulveda, Calif. [354]



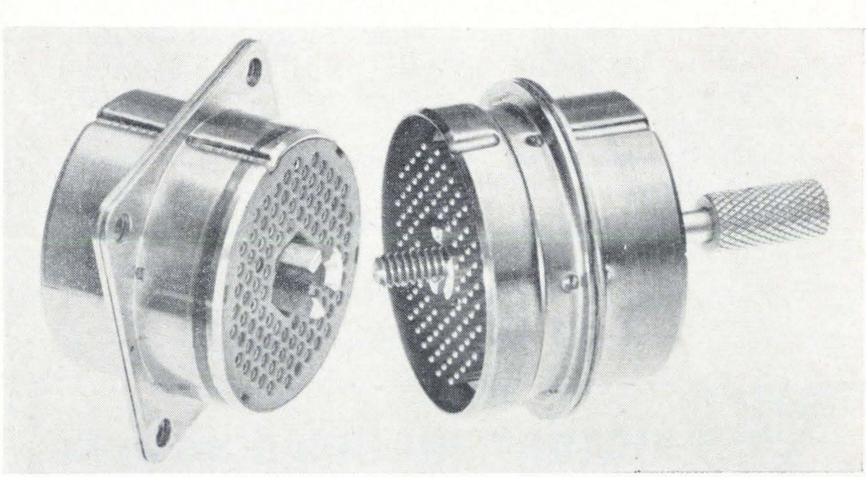
Two **miniature** tuneable filters, types 7022 (bandpass) and 7023 (band rejection), have a center operating frequency of 10 Mhz. Each circuit includes 4 poles and 4 precision tuning elements to fit filter curve characteristics to individual operating requirements. Specified operation conforms to most MIL-specs. Cambridge Thermionic Corp., 445 Concord Ave., Cambridge, Mass. [355]



An extractor-inserter for printed circuit cards, model 30 is a pin-type tool featuring positive retention of the extracted card. It has a maximum extraction force rating of 100 lbs. Pick-up pins engage index holes in the circuit card and the card is extracted or inserted as the spring-loaded trigger is actuated. Flotron Industries Inc., 1201 E. Grand Ave., El Segundo, Calif. 90245. [356]

and 18 in environmental, nonenvironmental, and potting versions for space, airborne, shipboard, and ground applications where size and weight are factors. Or where temperature or humidity changes.

Elimination of the bulky bayonet locking mechanism can put more connectors on a panel. Bayonet locking units are usually spaced a half-inch apart to allow enough room for a worker to get his fingers in to make or break a connection; jack screw devices can be mounted flush with one another. Hughes estimates that nine conventional size-18 connectors take up 25 square inches of panel space; nine Bulls-



Bayonet gone. Center jack screw replaces conventional bayonet whose locking mechanism takes a lot of room. As a result, more connectors can be squeezed onto a panel.

Eyes would need only 16 square inches.

Making room. Removal of the sleeve-like bayonet locking nut also frees space on the face of the connector for more contact pins. The size-18 Bulls-Eye has 122 contacts spaced 0.085 inch apart. On an equivalent assembly, says Hughes officials, the competition can furnish only 85 pins.

A further advantage of the Bulls-Eye line, according to Hughes, is PolarHex hardware, which assures positive alignment and mating. Patented PolarHex techniques have been used for some time on Hughes rectangular connectors.

Bulls-Eye units have nonmagnetic stainless-steel shells and glass-filled diallyl pthalate inserts. The line will make its debut at the Western Electronic Show and Convention in San Francisco, Aug. 22-25.

Hughes Connecting Devices, 500 Superior Ave., Newport Beach, Calif. **[357]**

New components

One power oscillator replaces six

Microdot unit with plug-in heads covers the vhf and uhf frequency spectrum

For years Microdot Inc. of South Pasadena, Calif., has been selling a series of power oscillators to cover the very-high and ultrahigh frequencies. But coverage of the entire range has been expensive for users because each oscillator requires its own power supply. Now, Microdot is offering a single unit, the model 445, with six plug-in heads to cover the vhf-uhf spectrum, from 10 to 2,350 megahertz.

The price of the basic unit without plug-in heads is $2,000; the heads range in cost from $1,375 to $2,250 each. If a customer buys a unit with all six heads he pays about half as much as he would for six individual units, notes Thomas

the course of tomorrow

Tomorrow does not merely happen — it is created. Scientists and engineers, like you, are working now on tomorrow's globe-spanning satellite communications networks . . . on miniature transceivers that are used today by downed airmen in Vietnam, and tomorrow will be pocket-sized communications links for doctors, businessmen . . . on laser systems that offer new possibilities for information handling.

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. . . coaxial cavity lends itself to a plug-in . . .

Eccles, chief engineer at Microdot's microwave products.

I. Applications

The power oscillator can be used to calibrate high-power watt meters or plot antenna-pattern measuring ranges. It also has a place in laboratories developing power amplifiers and varactor multipliers.

The six plug-in heads are: the model 184, covering 10 to 50 Mhz; the 185, 50 to 200 Mhz; the 186, 200-500 Mhz; the 187, 500 to 1,000 Mhz; the 188, 1,000 to 1,800 Mhz; and the 189, 2,150 to 2,350 Mhz.

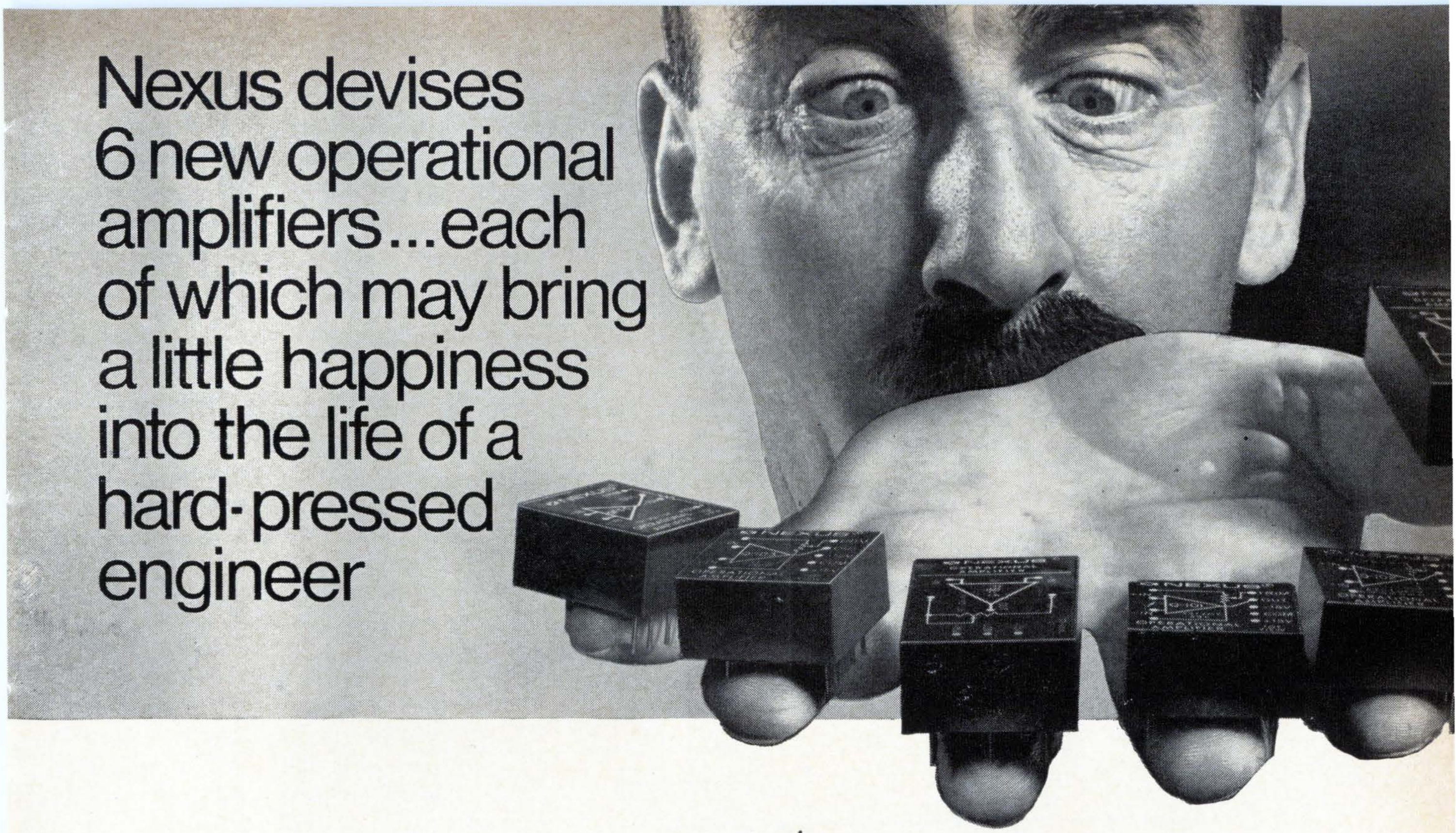
"We try to encompass the major frequency applications for each particular band," says Eccles. "We didn't split any of the common bands."

Microdot was able to design a plug-in unit because all its oscillators, down to the 10-Mhz versions, are specially designed coaxial cavity types that lend themselves to the plug-in system. Larger lump constant circuits, normally used in power oscillators below 200 Mhz, couldn't be adapted to this kind of design.

Accuracy maintained. Since the basic circuitry of both the plug-in heads and the basic housing and power supply is essentially identical to that of the six individual units, the same accuracy and stability is maintained in the 445, according to the company. Direct reading is ±1% of actual frequency at optimum coupling after half-hour operation at maximum rated power. Stability is ±0.002% for 10 minutes after 2 hours stabilization at a constant power and frequency.

Power is variable from 50 milliwatts to 50 watts in all plug-in heads except the model 188 (50 milliwatts to 25 watts) and the 189 (50 mw to 15 w). Both output power and reflected power are indicated on a front panel meter. A switch provides a choice of either 10 or 50 watts full scale for output power measurement. The ability to read reflected power eliminates the need for an external watt meter in the circuit when adjusting for minimum reflection.

The oscillator can be operated in either continuous-wave, 1-kilo-



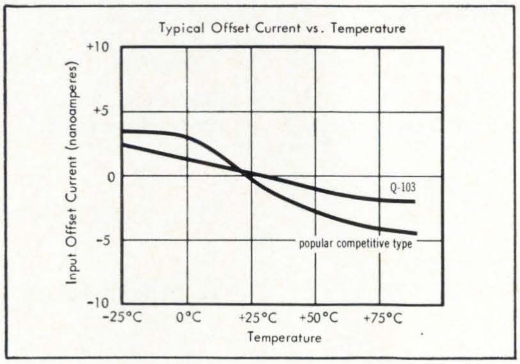
Nexus devises 6 new operational amplifiers...each of which may bring a little happiness into the life of a hard-pressed engineer

3 low-cost, high-performance OP AMPS

These three nifty little modules give better temperature characteristics and lower input bias currents than you would believe possible for the price. Just try to find anything else in the ballpark that comes close to these typical specifications:

TYPICAL PERFORMANCE @ 25°C

	Q-101	Q-102	Q-103
Output	±11V/±5.5mA	±11V/±5.5mA	±11V/±2.5mA
Input Ƶ Diff.	1 Megohm	1 Megohm	5 Megohms
Input Bias Current	±3nA	±3nA	±.5nA
Bias Current Drift	±0.4nA/°C	±0.4nA/°C	±.05nA/°C
Initial Offset Voltage	(Ext Trim)	±0.2mV	(Ext Trim)
Max. Drift vs Temp.	15μV/°C	15μV/°C	15μV/°C
-A Version	5μV/°C	5μV/°C	5μV/°C
List Price	$22	$25	$22
-A Version	$25	$28	$25



1 lowest-cost FET OP AMP

FET prices have gone ffft with the new Nexus QFT-5 which sells for $22 in moderate quantities.

TYPICAL PERFORMANCE @ 25°C

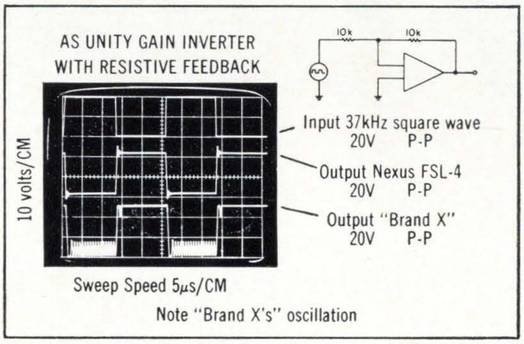
Output	±11V/±5.5mA
Input impedance	10^{10} ohms
Gain	100,000
Drift	50μV/°C
Gain-bandwidth	2MHz
Slewing rate (full output)	5.0V/μs

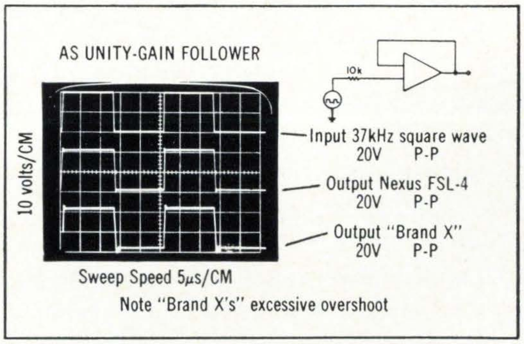
2 ultra-fast differential OP AMPS

Both these new units, the FSL-4 and FSL-5 can handle inverting, non-inverting or differential functions with full output at frequencies up to 1 MHz.

- Smooth Loop Dynamics: 6dB/Octave Rolloff
- 60V/μs Slewing, Either Inverting Or Non-Inverting
- 4μs Settling Time To 0.1% With 20 Volt P-P Square Wave Output
- ±0.2nA/°C Maximum Input Bias Current Drift (FSL-5)
- ±10μV/°C Maximum Offset Voltage Drift (FSL-5)
- ±10 Volt @ ±20mA Output

The following test photos compare FSL-4 performance with a typical competitive (Brand X) unit.





SEE ALL THESE GREAT NEW OP AMPS AT WESCON BOOTH 2420

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Circle 197 on reader service card

. . . protective features are designed into it . . .

hertz-pulse, or external-pulse modes.

II. Protection

The unit also has a number of protective features. For example, a circuit protects individual cavities in the event the unit operated into an open, shorted, or badly mismatched load. A directional coupler in series with the r-f output samples the power reflected from the load. If it exceeds a preset level, the high voltage is switched off; the reflected r-f voltage is rectified and fed to a stable differential d-c amplifier, and the output of this amplifier causes a transistor switch circuit to activate a relay and turn off the high voltage.

The tube is protected from excessive plate current by a fixed cathode bias resistor, and from excessive grid current by an automatic grid current limiter. The limiter employs a transistor and zener diode circuit. The emitter-collector circuit of the transistor is placed in series with the grid-cathode circuit of the oscillator and is biased by the zener diode, which is in series with the cathode supply voltage. The bias is set so that the transistor appears to be a short circuit until 50 milliamps is reached. At this point, the grid current is limited by the sudden high impedance of the transistor, thereby clamping the grid circuit.

Microdot Inc., 220 Pasadena Ave., South Pasadena, Calif. 91030. **[358]**

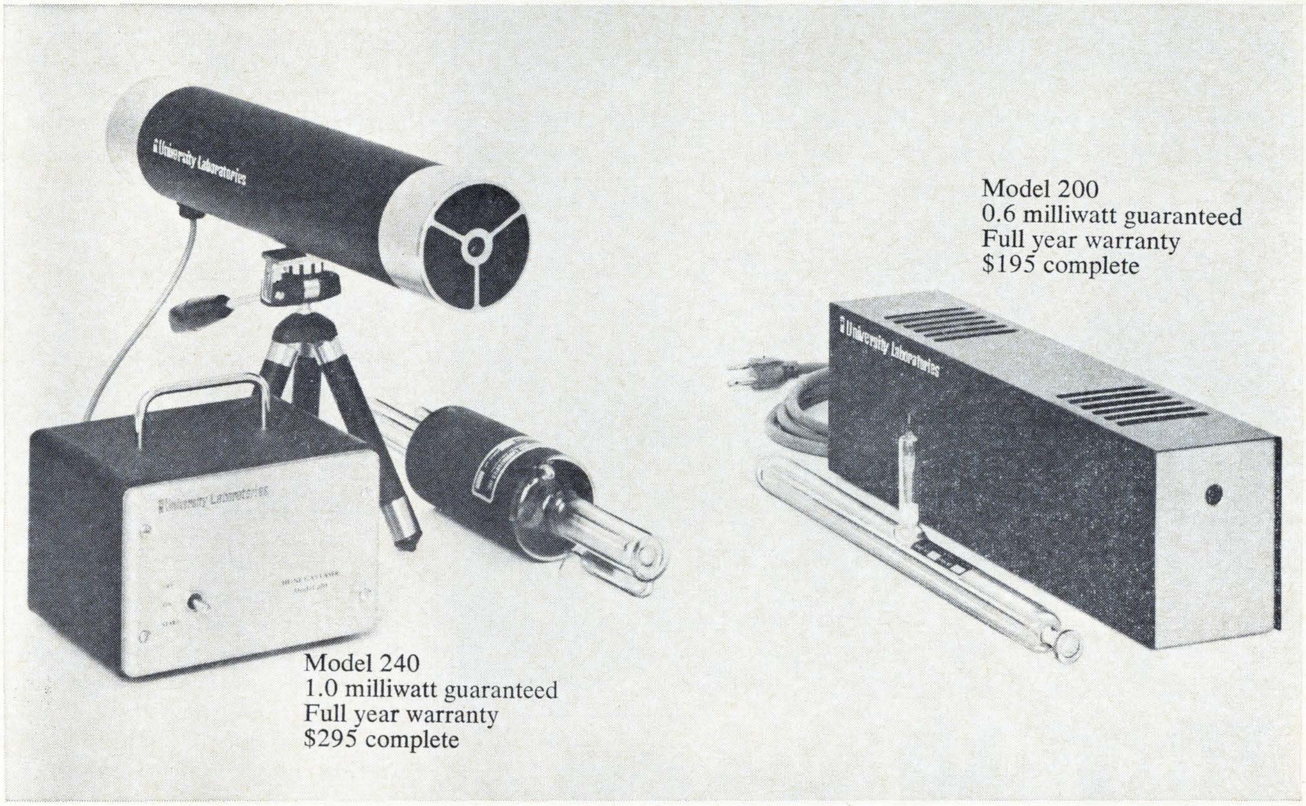
New components

A better mousetrap?

Versatile function generator furnishes precise waveforms at relatively low cost

Despite a continuingly high level of demand, resonant networks that produce a variety of waveforms faithfully have proved a tough development objective. Normally such networks need environmental con-

World's only gas lasers with just 1 control: an on-off switch



Never need adjustment, alignment, or maintenance

As simple to work as a light switch, these new, rugged He-Ne continuous gas lasers are operated by a single on-off control. Nothing more is necessary, because ULI's Lasertron™ plasma tubes have permanently aligned and sealed internal reflectors. Their proprietary design completely eliminates the need for adjusting mechanisms commonly found in other lasers of this type.

The tubes are long-lived and foolproof —will operate even under water! (They are practically complete instruments in themselves and are available separately to OEMs.)

Since they have no mechanisms to get out of order or out of adjustment, these lasers are excellent performers in tough environments. The solid-state power supplies are simple and thoroughly reliable, assuring immediate, continuing output to specification.

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Terms: 2% discount 10 days, net 30 days. ULI products returned for any reason, prepaid and undamaged, within 30 days will receive full credit.

University Laboratories

. . . it outperforms even precision oscillators . . .

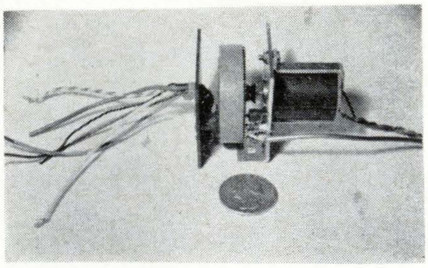
trols as well as special-purpose devices and circuitry, so systems that furnish accurate results in specific applications usually are prohibitively high priced.

Now, however, the Delonics Corp., a six-month-old New York City-based consulting firm, has a versatile and economical device that it believes will meet the requirements of both science and industry. Called Dial-A-Log, it is a variable functional generator about the size of a pack of cigarettes. Delonics is basing its sales pitch largely on the claim that its device will outperform tuning-fork oscillators and other precision systems in Dial-A-Log's price range. The estimated unit cost in large lots is $25. In small quantities, the devices will go for up to $500 apiece.

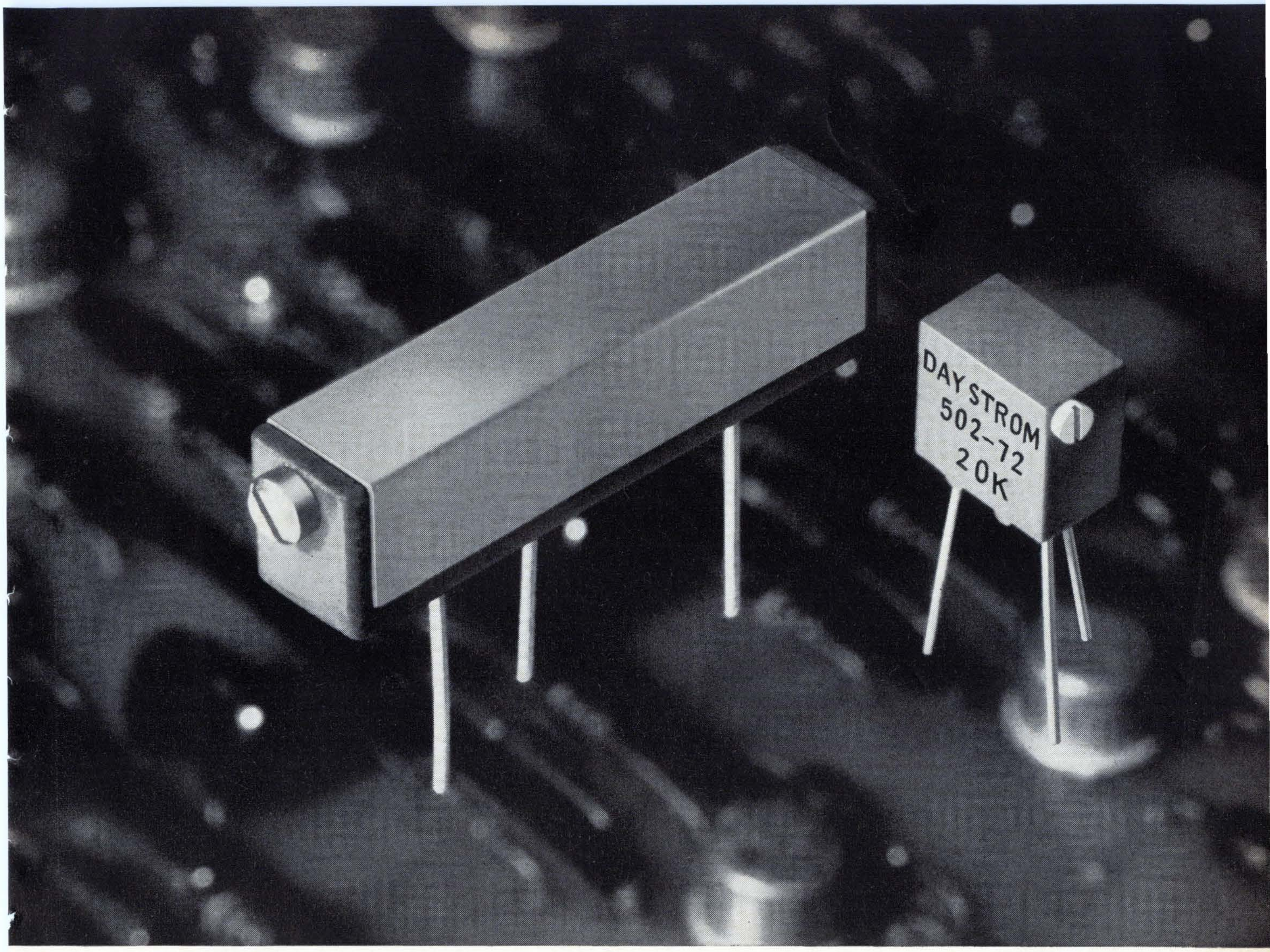
Light touch. Dial-A-Log has a light source in line with one or more photocells. Two or more rotatable, polarized optical filters are placed in the light path. As the polarizers turn, the output of the photocell is a sine wave with a frequency proportional to the angular velocity of the revolving filters. By adding filters and rotating them in opposite directions, frequency can be multiplied to radio-frequency values.

However, the basic unit is designed to operate at a given frequency, and this may not be changed by the user. Multiple-phase outputs, pulse markers, and a waveshaping vernier are optional features.

When only an arc of a filter is used, the effective light intensity at the photocell is a logarithmic-shaped pulse. Any number of different waveforms can be generated by using specific filters and bias



Photocells in line. Polarized optical filters are in line with photocells, generating a sine wave as they rotate.


DAYSTROM
502-72
20K

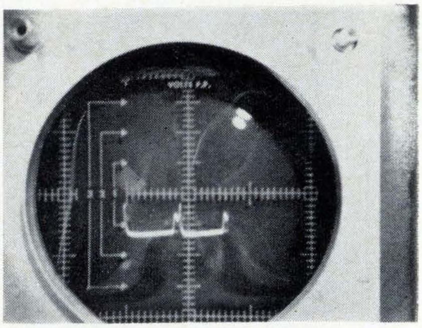
... parameters can be tailored to a user's needs ...

voltage for the photocells.

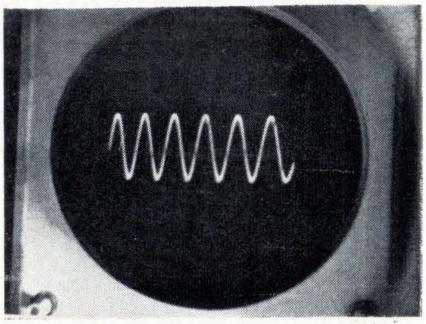
An important feature of the Dial-A-Log design approach is that its circuit parameters are tailored to the needs of the user. For example, the magnitude of the output waveform can be established by using a suitable photocell with the required sensitivity and efficiency. In general, peak-to-peak potentials as high as 100 volts can be achieved by proper photocell selection and appropriate bias potential.

Jack-of-all-trades. Dial-A-Log's

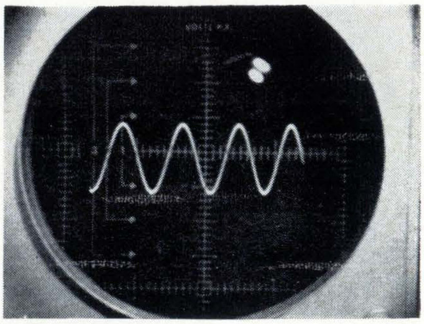
Typical outputs



Marker pulses. Typical fast rise time pulses can be used as frequency markers or as synchronized oscillator triggers.

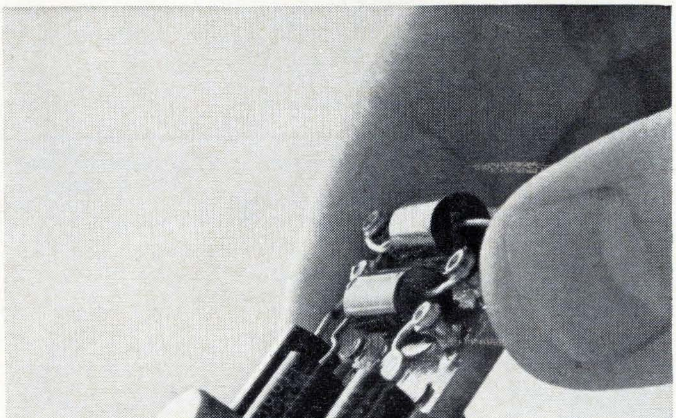


Sine wave. Undistorted sinusoidal waveforms have the accuracy of a tuning fork oscillator.



Frequency division. The frequency of the output sine wave is proportional to the filters angular velocity.

It comes clean out of our test bath



Temperature test your integrated or hybrid circuits in a 3M Brand Inert Fluorochemical Liquid and it'll drain clean, dry immediately and leave no residue.

Unlike conventional test bath fluids, with our Inert Liquids there's no costly cleaning stage to slow down production.

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With those properties and that kind of reliability—plus efficiency at removing heat—it's no wonder our Inert Liquids work equally well as coolants. Test them for either application.

3M Chemical Division
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Send me all the details about 3M Brand Inert Liquids.

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Chemical Division 3M COMPANY

Circle 203 on reader service card

output can range from sawtooth and triangular waves through square and logarithmic waves as well as simple sine waves and pulses. In addition, the device can serve as a direct current-to-alternating current converter, logarithmic amplifier bias supply, or—along with other circuitry—a radio transmitter modulator.

Delonics is currently negotiating with a New York concern to manufacture and distribute various versions of Dial-A-Log in the United States and Europe. In addition, it is talking about a licensing agreement with a Florida-based computer product company.

Specifications

Frequency range	1 hertz to 1 Ghz in discrete bands
Frequency accuracy	7 ± 0.005% per day
Temperature coefficient	0 (from 0° to 100°C)
Outputs	
Sine wave	100 v p-p
Square wave	100 v p-p
Logarithmic or quasi-logarithmic	100 v rms
Output impedance	10 ohms to 10 megohms
Operating voltage	1.5 to 120 v dc; 28 to 240 v ac, 50-400 hz
Dimensions	2.5″ high x 1.5″ wide x 1.5″ deep

Delonics Corp., 32 Union Square East, New York 10003 **[359]**

New Components

Transistors for microwave gear

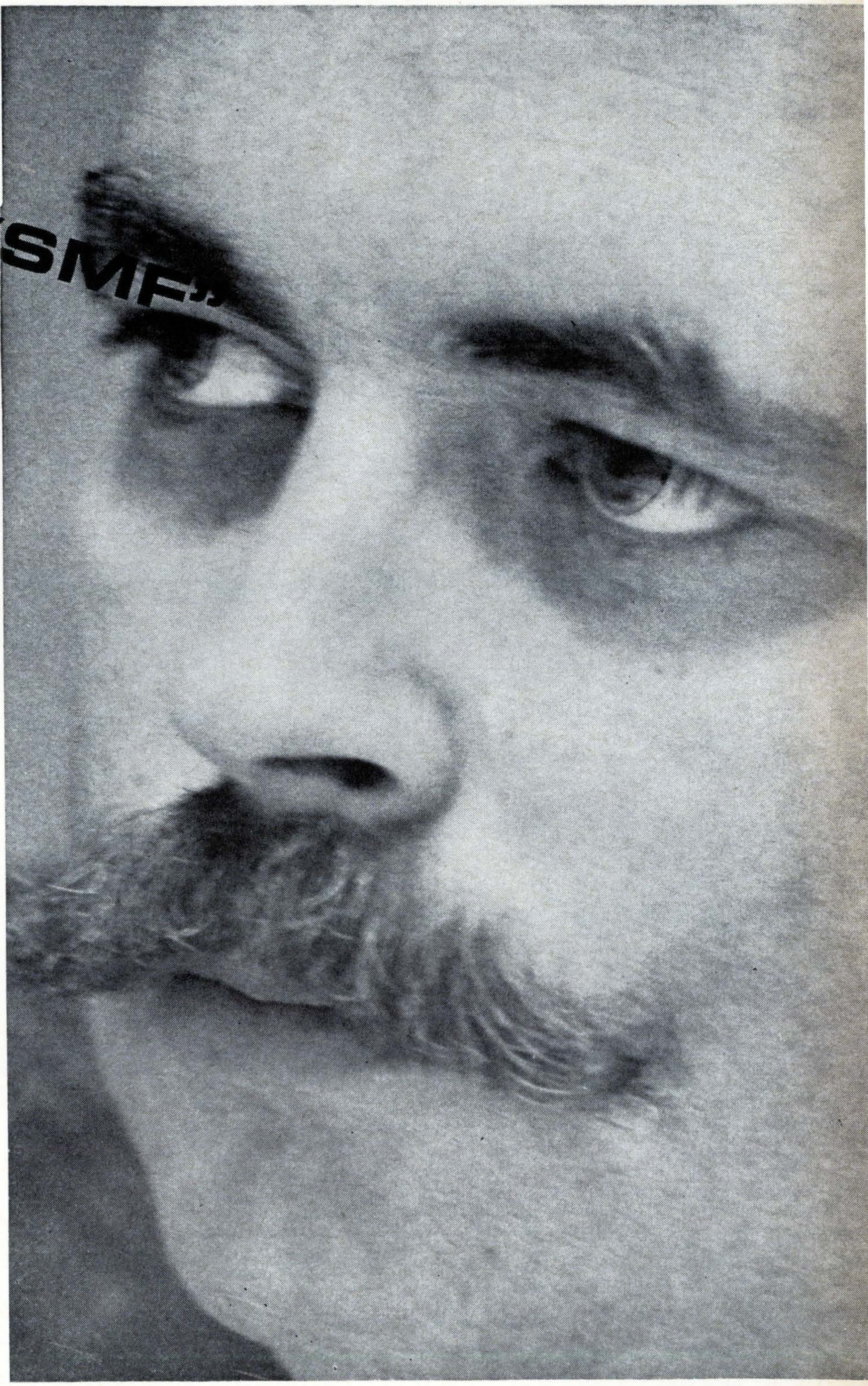
Two new oscillators can handle up to 75 milliwatts at 4 Ghz

Pushing back the power limit on microwave transistors, Texas Instruments Incorporated this month is introducing two new oscillator transistors, one capable of 40 milliwatts power at 4 gigahertz, the other of 75 milliwatts. They are the first devices of this type that can handle more than 10 milliwatts at such high frequencies.

To obtain the high power outputs, TI has rearranged the geometry of the transistors so it's possible to achieve a higher emitter

an invitation from 5,200 Manufacturers:

"look into VSMF"



William H. B. Combs, Manager, Engineering Services, Relay Division, Leach Corporation, Los Angeles, uses the VSMF Defense Design File.

5,200 manufacturers invite your judgment of their products in Visual Search Microfilm Files.

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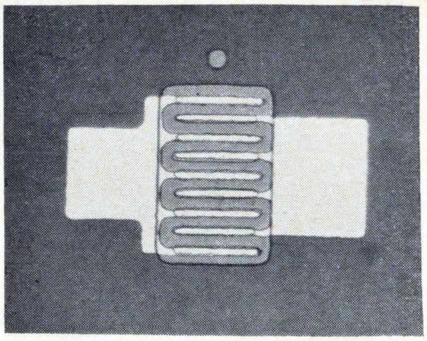
Circle 205 on reader service card



Power pushed. A power gain of 10 db is achieved at 2 Ghz by improved diffusion techniques in the L-186.

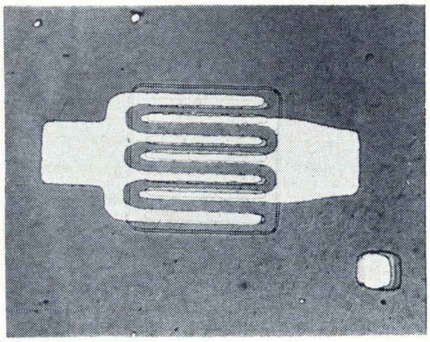
current without ruining emitter efficiency. The new npn devices are made of silicon, and have an epitaxial planar structure built by double diffusion. They have a common base configuration.

The oscillators—the L-187 and the L-187A—will replace low-power backward-wave oscillators and reflex klystron tubes. They can be tuned over octave ranges, attaining a maximum frequency of oscillation of 6 Ghz.

Amplifier too. Along with these devices, TI is introducing another npn transistor, the L-186, for microwave amplifier applications. It has a noise figure of only 5 decibels at 2 Ghz. For single and multistage amplifier circuits, it replaces tunnel diode amplifiers and low-power traveling-wave tubes. Unlike the oscillator transistors, the L-186 has a common emitter configuration.

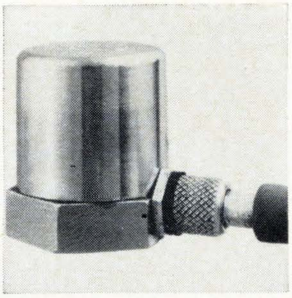
All the new devices are packaged in what the company calls a TI-Line, a unit designed for stripline circuitry. The package has a common-lead inductance of 0.16 nanohenrys and a feedback capacitance of 0.02 picofarads.

Texas Instruments Incorporated, Dallas, Texas **[360]**

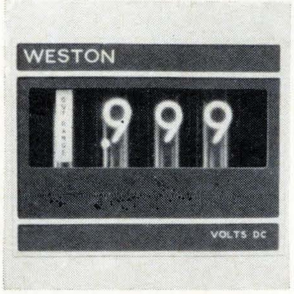


Wave maker. A rearrangement of internal geometries permits the L-187 to put out 100 mw at 2 Ghz.

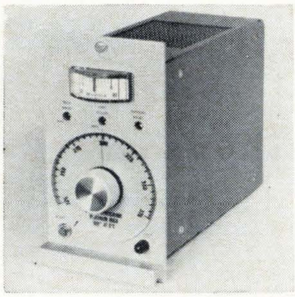
Telephone transmission/noise measuring set model 3555A will bridge or terminate lines of any standard impedances. It will measure frequencies from 30 hz to 3 Mhz. Included in the unit are C-message 3 khz flat and program weighting filters. The instrument can measure to 0 db random noise at 1 khz. Price is $525. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. [361]



Piezoelectric accelerometer model AC-408 is designed for vibration measurements. Voltage sensitivity is 50 mv/g, nominal. Charge sensitivity is 25 picocoulombs/g, nominal. Transverse sensitivity is 1% of axial, nominal; 2% of axial, maximum. The unit weighs 28 grams. Price is $125; delivery, from stock to 2 weeks. Agac-Derritron Inc., 600 N. Henry St., Alexandria, Va. 22314 [362]



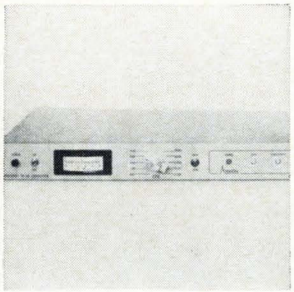
All-electronic digital panel meter 1270 is a 3-digit Nixie tube device suitable for various current and voltage measurements. A dual slope integrating technique assures an accuracy of 0.1% ±1 digit and a stability of 0.05%. Common-mode rejection is 100 db; resolution, 1 part in 10^3. Price is $312 each. Weston Instruments Inc., 614 Frelinghuysen Ave., Newark, N.J. [363]



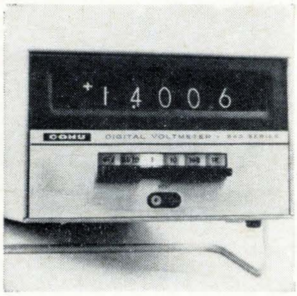
Temperatures can be held within 0.5°F with a solid state process controller. The unit compares the controlled temperature with the set point, automatically modulating electric heating elements to maintain desired heat. It gives virtually straight-line control. The instrument's platinum resistance bulbs operate to 1,400°F. Honeywell Inc., 2727 S. Fourth Ave., Minneapolis 55408. [364]

An integrating photometer digitally totalizes light energy for periods ranging from 0.1 sec to many weeks. The IL600/620 has synchronized and predetermined outputs for delivering preset dosages. It can totalize energy at any wavelength from 200 to 1,200 millimicrons. Price ranges from $1,490 to $2,100. International Light Inc., 12 Unicorn St., Newburyport, Mass. [365]

Pulse generator type 284 produces a pulse output with a rise time of less than 50 picosec and also provides the signals necessary to verify the performance of sampling oscilloscopes. Pulse output has an amplitude of approximately 200 μv into 50 ohms. Repetition rate of the 284 is 50 khz, with a pulse duration of 1 μsec and a flatness of ±3%. Tektronix Inc., Box 500, Beaverton, Ore. [366]



Rack-mounted frequency/d-c converter PI-408R offers high transient response rate, low output ripple, and long-term stability. It features 0- to 5-v d-c floating output with ±0.025% terminal linearity. Dimensions are 1¾x19 x13½ in. The unit is priced from $495. Delivery is 4 weeks. Anadex Instruments Inc., 7833 Haskell Ave., Van Nuys, Calif. 91406. [367]



Integrating digital voltmeter series 540 has an accuracy of 0.01% of reading ±1 digit in 4 ranges from 1.5000 to 1000.0 v d-c. It maintains accuracy specs for 6 months. Unit features 5-digit readout with overranging digit, polarity and decimal; manual and automatic range selection; constant 10-megohm input impedance. Cohu Electronics Inc., Box 623, San Diego, Calif. [368]

New instruments

Borrowing a leaf from broadcasters

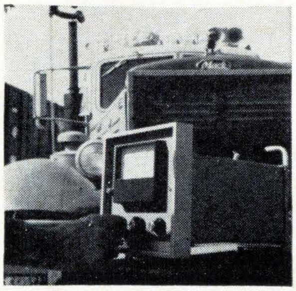
Signal generator for testing f-m and television receivers controls frequency automatically

Engineers who need high carrier stability in an f-m signal generator usually have to make an unsatisfactory compromise: either they buy a high-priced frequency synthesis scheme that isn't really tailored for their requirements, or they settle for less performance. Another alternative is to build a home-designed generator.

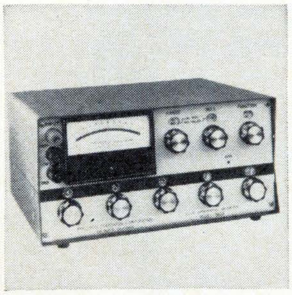
With a new signal generator developed by the Radio Research Co., engineers have still another choice—a commercial instrument. It has long-term stability never before available at such a low price: $850.

Afc loop. Ending the need for compromise is a technique borrowed from commercial f-m broadcasters. In the new instrument, called model 38, there is an automatic frequency control loop, like the one used in broadcast receivers, that locks an LC oscillator to a crystal-controlled reference oscillator. As a result, the LC oscillator supplies pure frequency modulation while retaining the carrier stability characteristics of the crystal reference.

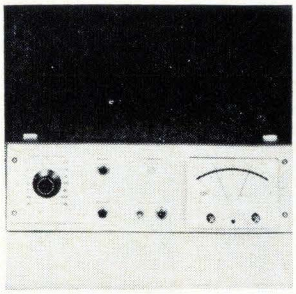
The generator's stability is a hundred times better than that of conventional signal generators: 0.005% or 1 kilohertz (whichever



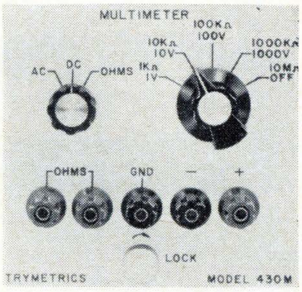
Smoke meter model 912 measures the amount of smoke emitted by diesel trucks. A movable arm positions the sensor above exhaust stacks. Physical connection to the truck is not required. Readout is in both Ringelmann units, the standard smoke-shade unit of measurement, and in % absorbance. Accuracy is ±2%. Beckman Instruments Inc., 2500 Harbor Blvd., Fullerton, Calif. [369]



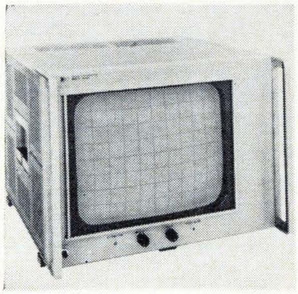
An a-c/d-c voltmeter has high accuracy and stability due to an integral proportional controlled oven for the zener reference. The 365A offers ranges of ±1,100 v, ±110 v, ±11 v, 1,100 mv, and 110 mv. It has a 6-digit readout. High sensitivity and resolution are achieved through a 110-μv full scale null detector. Precision Standards Corp., 911 Westminster Ave., Alhambra, Calif. [370]



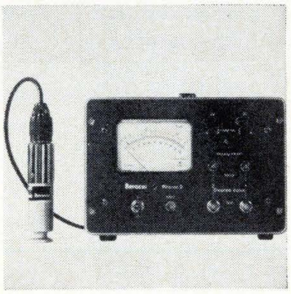
Accept-reject indication for production testing is featured in the model 503CC milliohmmeter. The unit offers sensitivity of 10 microohms; 13 ranges from 1 milliohm to 10 kilohms; 1% of full-scale accuracy; 0.25% repeatability; and less than 10μw dissipation in sample. The instrument measures 5½x17½x13½ in. Keithley Instruments Inc., 28775 Aurora Rd., Cleveland 44139. [371]



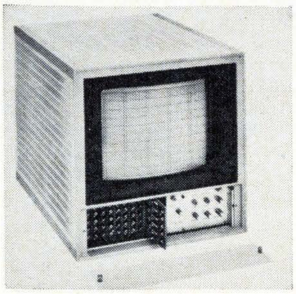
Plug-in module 430 M provides d-c, a-c, and ohms measurement capabilities for the company's 4000 and 4100 series digital voltmeters. It offers 4 d-c ranges from 0.9999 to 999.9 v d-c; 4 a-c ranges of the same voltages; and 5 ohms ranges from 999.9 ohms to 9.999 megohms. The function head costs $295. Trymetrics Corp., 204 Babylon Turnpike, Roosevelt, N.Y. 11575. [372]



Crt monitor model 1300A has an 8 x 10-in. display area. It offers 20-Mhz on horizontal, vertical, and intensity axes, and the crt writing rate is faster than 20 in./μsec. Deflection linearity is better than 1% full screen for accurate presentation of high-frequency x-y plots. The unit requires 175 w. Price is $1,900. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. [373]



Pressure measurement is provided by a Pirani-type gauge, the Piravac S. The unit measures from 100 to 10^{-3} torr, and two independent electronically-controlled relays can be set within the range of 100 torr to 3 x 10^{-2} torr while the instrument is in operation. Output terminals are provided for 10-mv recorders. Heraeus-Engelhard Vacuum Inc., 600 Seco Rd., Monroeville, Pa. 15146. [374]



A profile monitor oscilloscope, with 10-mv full-scale deflection, displays up to 100 channels of information. The PM703 is designed for real-time transducer output displays of temperature, pressure, or other phenomena. Among its applications are the chemical and textile process control fields. Industrial Products Division, ITT Corp., 15191 Bledsoe St., San Fernando, Calif. [375]

A new line of electronic counters and controllers is for nuclear counting, machine-tool control, position indication, and process or manufacturing tabulation. The 6200 series includes 7 instruments. Each has a 4-digit, in-line display, with provisions for an optional 5th digit. Prices range from $495 to $925. Beckman Instruments Inc., 2500 Harbor Blvd., Fullerton, Calif. [376]

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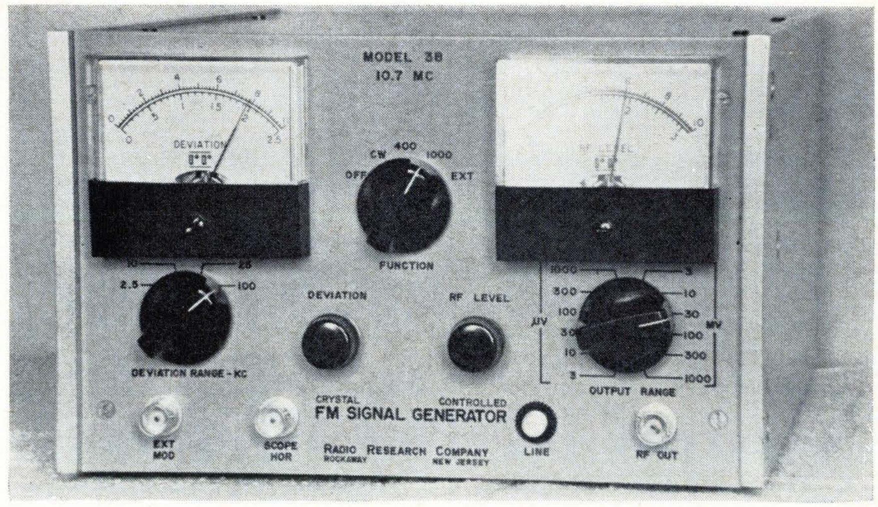
is greater) of any single channel in the available operating range of 3 to 250 megahertz.

The technique is not new. Radio Research first conceived it several years ago when the company was building a stabilized f-m source that had a center alignment frequency of exactly 4.500 megahertz. Now the concept is to be applied to a line of signal generators with different circuitry to handle a wide range of center frequencies. Model 38 is the first in the new line.

All solid state. Since the new signal generator is all solid state and has no blowers or rotating parts, it offers exceptional reliability. In



Fixed frequency. Single channel generator varies voltage continuously.

. . . biggest users will be makers of f-m and tv sets . . .

addition, the transistorized design makes the turn-on drift negligible. Built-in temperature compensation assures stability over the long-term.

With a sinusoidal sweep, the instrument can be used as a restricted range sweep generator for alignment purposes or as a clean signal source for linearity measurements.

Radio Research has built in a provision for disabling the afc loop, so that a slower sweep rate can be obtained. The afc circuit may see a slow sweep as an error signal and continually try to correct the carrier frequency, causing deviation meter inaccuracies. With the afc disabled, however, the sweep rate can be drastically reduced, permitting very narrow sweep widths to be examined.

Because all controls and functions for complete alignment are built-in, model 38 is suited for the test bench, the laboratory, or the production line. The biggest users will be manufacturers of television and f-m receivers.

In laboratory applications, the generator serves as a highly accurate and stable reference frequency easily translated by mixing. It can also be used for f-m dial calibration. On the production line, it aligns and tests f-m and television receivers.

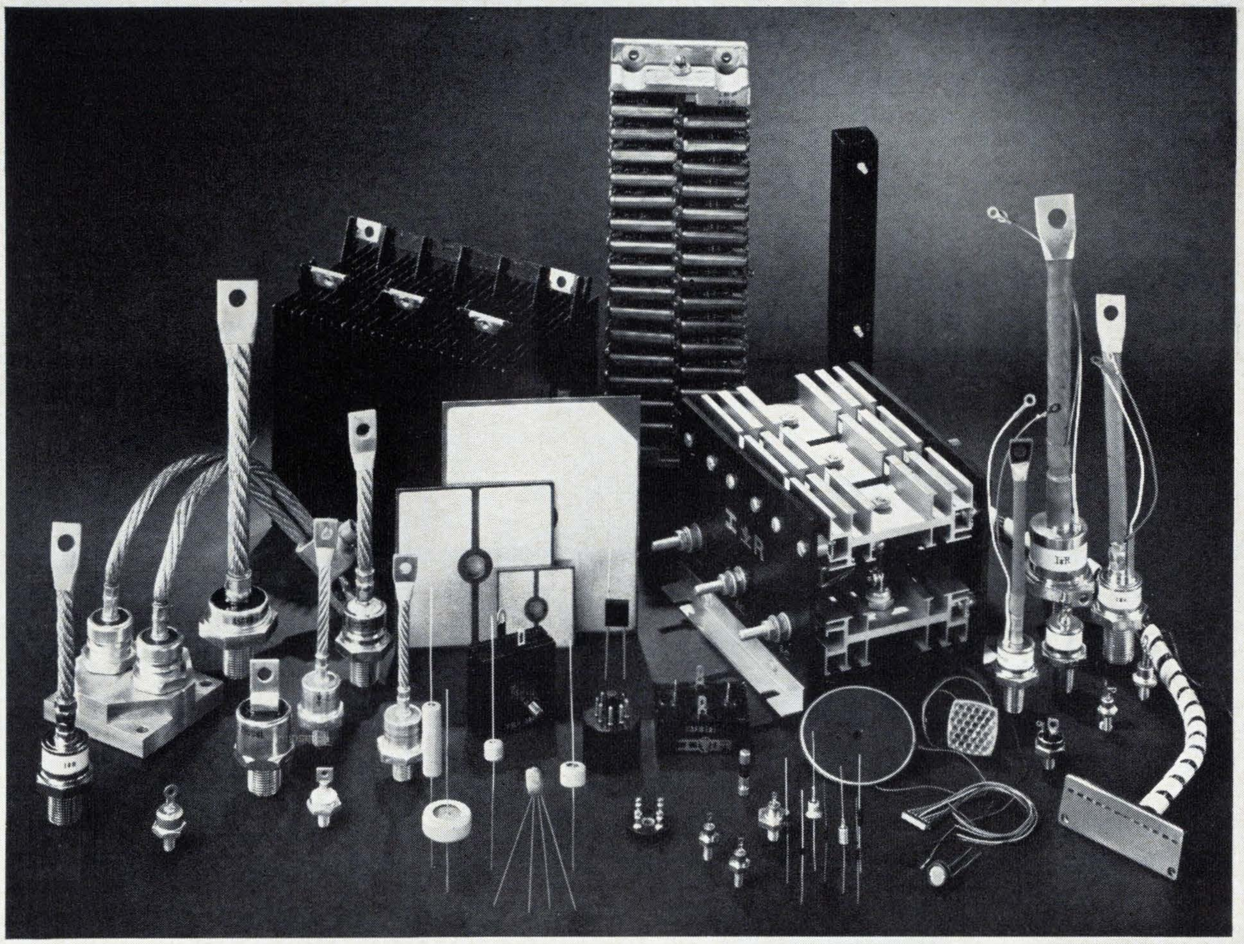
Kinship. A similar instrument, model 39, has been introduced for use only in central distribution systems. The r-f level controls and metering have been eliminated. It supplies a rock-stable 1-volt output into a 50-ohm load.

Specifications

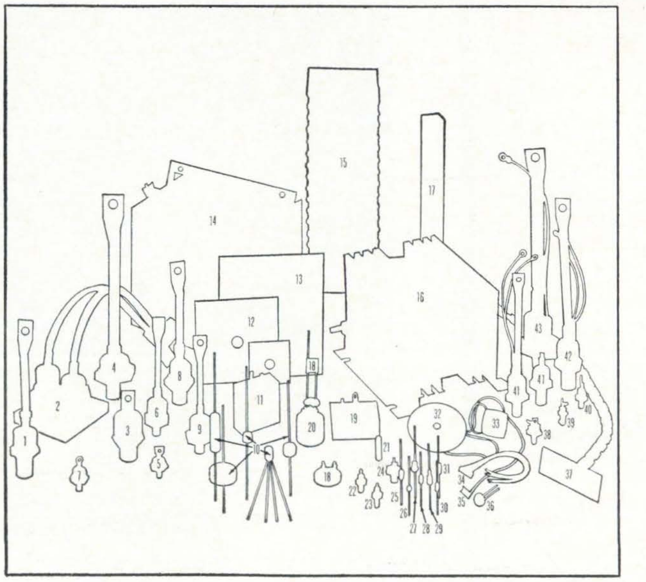
(model 38)

Center frequency	Any single frequency from 3 to 250 Mhz
Frequency accuracy	0.005% or 1 khz, whichever is greater
F-m deviation	0 to ± 100 khz in four continuously variable ranges
Deviation rate	1 khz and 400 hz internal; external from 30 hz to 20 khz below 15 Mhz, 20 hz to 150 khz above 15 Mhz (for multiplex information)
F-m nonlinearity	Less than 2%
Spurious output	Less than 3%
Output voltage	0-1 v rms, continuously variable
Output impedance	50 ohms
Power requirements	115 v ± 20%

Radio Research Co., 189 Mt. Pleasant Ave., Rockaway, N.J. **[377]**



The great IR family portrait



How many do you know? SILICON POWER RECTIFIERS. **1.** High-Voltage 300-Amp Rectifier. **2.** 500-Amp Rectifier. **3.** 200-Amp Economy Rectifier. **4.** 450-Amp Rectifier. **5.** 70-Amp Rectifier. **6.** 150-Amp Rectifier. **7.** 15- to 60-Amp Rectifier. **8.** 250- to 300-Amp Rectifier. **9.** 150-Amp Rectifier. SELENIUM RECTIFIERS AND ASSEMBLIES. **10.** Selenium Cartridges. **11.** Klip-Sel Voltage Transient Suppressor. **12.** Single Selenium Split Cells. **13.** Single Selenium Cells. **14.** Selenium Stack Assembly. SILICON RECTIFIER ASSEMBLIES. **15.** Silicon High-Voltage Column. **16.** Silicon Stack Assembly. **17.** Encapsulated High-Voltage Assembly. **18.** General Purpose Molded Circuits. **19.** Medium Current Molded Circuit. **20.** Silicon Tube Replacement. **21.** Silicon Plug-In Rectifier. ZENER REGULATORS, VOLTAGE REFERENCES, AND LOW POWER RECTIFIERS. **22.** 10-Watt Zener Regulator. **23.** 12-Amp Silicon Rectifier. **24.** 50-Watt Zener Regulator. **25.** 1-Amp Silicon Rectifier. **26.** 1-Amp Silicon Rectifier. **27.** 1.3-Amp Silicon Rectifier. **28.** Low-Power DO-7 Glass Zener Regulator. **29.** 2.0-Amp Silicon Rectifier. **30.** Low-Current DO-7 Glass Zener Regulator. **31.** 1-Watt Zener Regulator. LIGHT SENSITIVE DEVICES. **32.** Selenium Photovoltaic Cell. **33.** Silicon Photovoltaic Cell (mounted). **34.** Silicon Readout Array. **35.** Silicon Photovoltaic Cell (unmounted). **36.** Cadmium Sulfide Photoconductive Cell. **37.** Custom Silicon Readout Array. SILICON CONTROLLED RECTIFIERS. **38.** 63-Amp RMS SCR. **39.** 4.7- to 7.4-Amp RMS SCR. **40.** 16- to 35-Amp RMS SCR. **41.** 55- to 110-Amp RMS SCR. **42.** 160- to 235-Amp RMS SCR. **43.** 400-to 550-Amp RMS SCR. We'll gladly send you information about any of the above. Write.

INTERNATIONAL RECTIFIER

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Circle 211 on reader service card

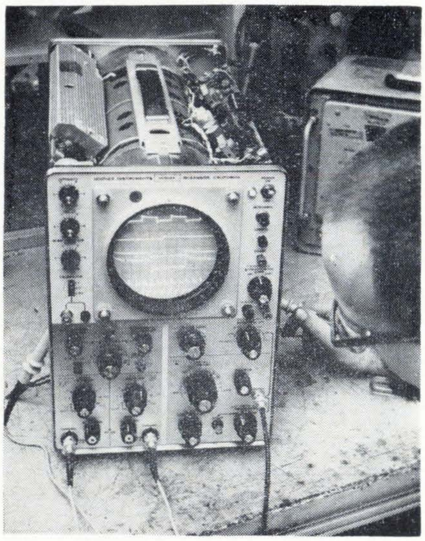
Fast-writing scope broadens a line

Instrument maker buys two designs that use the fast Memotron tube

When Measurement Control Devices Inc. bought the Memo-Scope line of oscilloscopes from a division of the Hughes Aircraft Co. last month, two unmarketed oscilloscope designs were included in the deal. Hughes had planned to introduce both instruments last year at the annual Wescon show, but production plans were shelved when company management started talking acquisition. With the purchase signed and sealed in June, the new owner is rushing the designs into manufacture so it can show them off at Wescon later this month (Aug. 22 to 25).

Fancy tube. Both of the new units, designated the 1502 and 1531, will use Memotron cathode-ray tubes built and still to be supplied by Hughes. It is this tube that MCD feels gives the new instruments a big edge over competition. Its major advantages:

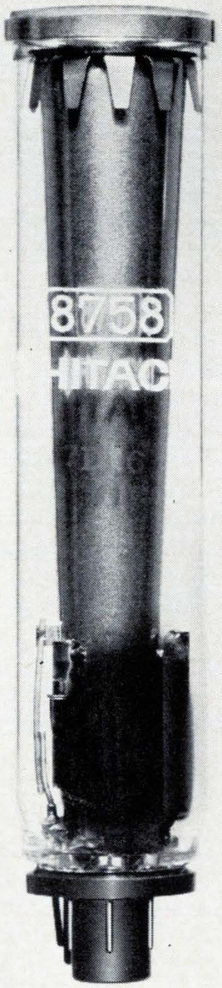
- A maximum writing speed of



Acquired. Rushed to the marketplace after Measurement Control Devices purchased the design, new laboratory oscilloscope still has the Hughes name plate on its face.

THE ECONOMICAL HITACHI VIDICON

The new Hitachi Vidicon 8758 is an improved, low-cost, replacement for the 7735A or 7262A Vidicons:



ACTUAL SIZE

TYPE — 1 inch.

SHORTER LENGTH — for small transistorized cameras.

LOWER HEAT POWER — 6.3 V, 95 mA.

HIGHLY SENSITIVE PHOTOCONDUCTIVE LAYER — clear images even with poor lighting.

HIGH RESOLUTION — over 600 TV lines at the center of the screen.

FOR ECONOMY — THE HITACHI VIDICON 8758

Size	Overall length (mm)	133±3
	Greatest diameter (mm)	28.6φ±0.3
Method	Focusing method	magnetic
	Deflection method	magnetic
Examples of usages	Heater voltage (V)	6.3±10%
	Heater current (mA)	95
	Illumination (lx)	10
	Target Voltage (V)	20~40
	Dark current (μA)	0.02
	Signal output current (μA)	0.2
	Center resolution (TV lines)	600

Additional economies: the Hitachi Vidicon 8758 has the same base connection as the 7 pin-stem of conventional picture tubes, permitting the use of the lower-priced standard sockets. It is suitable for use with industrial television equipment and other closed-circuit television systems.

HITACHI
Hitachi, Ltd. Tokyo Japan

HITACHI SALES CORPORATION: 333 N. Michigan Avenue, Chicago, Ill. 60601, U.S.A. Tel: 726-4572/4 / 48-50 34th ST., L.I.C., N.Y. 11101 U.S.A. Tel: 361-3090/9 / HITACHI, LTD., DUESSELDORF OFFICE: 4 Duesseldorf, Graf Adolf Strasse 37, West Germany Tel: 10846

... Hughes lacked the network to sell scopes ...

5 million centimeters per second is five times faster than any other storage tube.

- Maximum light output is 20 foot-lamberts, four times brighter than conventional cathode-ray tubes.
- Trace retention capacity—as long as several months with undiminished brightness at all writing speeds—far outclasses other storage tubes, most of which have retention times around 15 minutes.

Dynamic duo. The major difference between the two new scopes is that the model 1531 has no storage capacity, an economy that makes it cost only half as much as the 1502. The other unit can store displayed patterns, using repetitive or single sweeps, or it can operate as a high-speed, nonstorage unit.

Because the 1502 scope can freeze and hold a trace on its Memotron tube, it can be used in such applications as viewing transient phenomena associated with nuclear testing, measuring shock and vibration of structures, testing relays for contact bounce—recording voltage waveforms at the instant the contacts close—and studying shock waves from explosions.

Model 1531 is a general-purpose instrument for laboratory use.

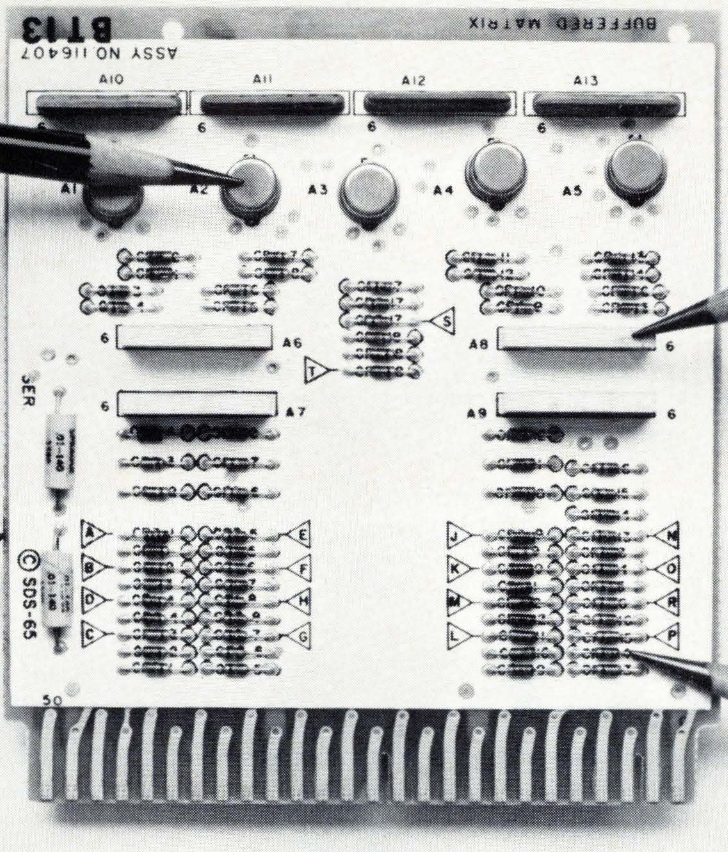
Trouble in the market. Although Hughes' management was convinced that the line of Memo-Scope's were good products, the company never could market them successfully. The chief reason was that the company did not have the proper distribution network to sell instruments because its main business is systems engineering in aerospace. In addition, Hughes had only a few models and a complete line is required to satisfy a large enough demand.

MCD already builds a line of low-priced oscilloscopes. Its newly acquired instruments give it higher-performing, higher-priced devices with which it can invade a new market, the laboratory. Model 1531 costs $995; 1502, $1,850.

Measurement Control Devices Inc., 2445 Emerald St., Philadelphia, Pa. [378]

Our I.C. digital modules reject more noise than anybody's.

Integrated flip-flops, inverters and buffer amplifiers in T Series modules are made to our proprietary design and hermetically sealed in TO-5 cans.

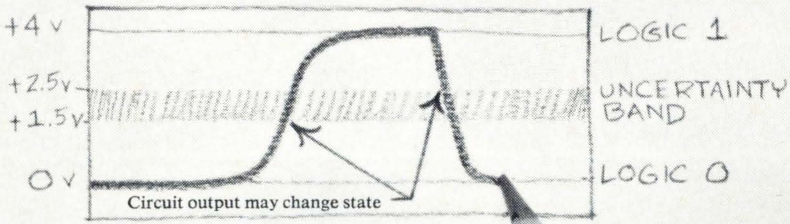


T Series input and load resistors, made to much tighter tolerances than can be attained with integrated components, are mounted outside the integrated circuit containers, eliminating power dissipation problems.

Full-width copper ground plane sandwiched between epoxy-glass boards minimizes circuit inductances and discourages noise spikes. Mounting cases also have full-width shield planes to retard noise coupling between logic wiring.

Discrete input diodes enable us to place the switching threshold right in the middle of the logic swing.

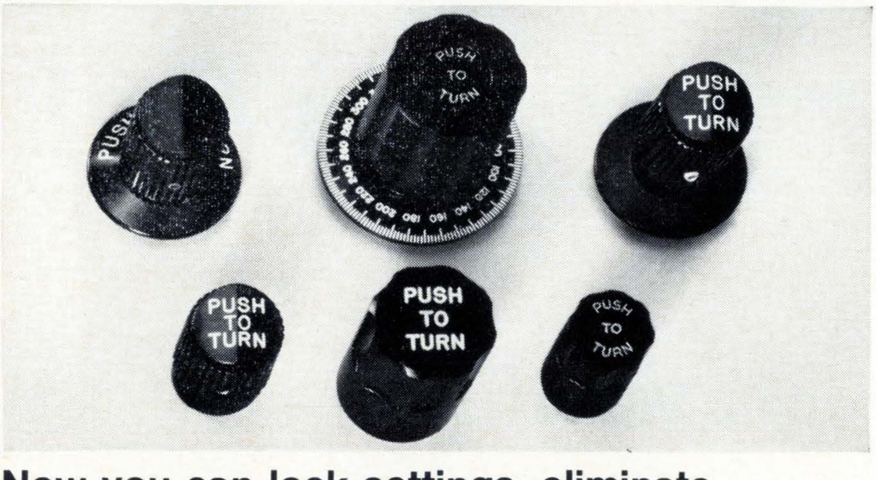
The payoff.



T Series logic levels are 0 and +4 volts, and noise rejection is 1.5 volts minimum, leaving a maximum uncertainty band only one volt wide within which noise can trigger the circuit output. This uncertainty band of 25% is far narrower than those of other I.C. modules on the market.

SDS

Scientific Data Systems, Santa Monica, California



Wedge for a laser

Ceramic detector ends beam splitting in meters

Laser beams can burn through a solid brick wall so they can easily burn through a meter placed in the beam to measure its energy level. To prevent destruction of the sensing element, laser beams are often split before a measurement takes place.

Splitting the beam is no longer necessary with a new laser energy meter built by Barnes Engineering Co. The model 30-410 also measures the energy of either pulse or continuous wave beams. Its measurements are limited to the spectrum from 0.3 to 40 microns.

Wedge-shaped. A wedge-shaped pyroelectric detector, made of a rugged ceramic material, enables the meter to withstand the destructive impact of the laser's beam. The ceramic is shaped as a deep hollow wedge—what physicists call a Mendenhall wedge—to absorb maximum energy by multiple reflection instead of by direct exposure regardless of the angle or point at which the beam hits the instrument. Since the material is pyroelectric, a charge builds up with a change in temperature.

Constant charge. A major advantage of the new device is that the entire receiver is the energy sensor.

Initially the temperature rises only at the point where the beam hits the wedge. As the heat diffuses through the ceramic material, the temperature rises slightly, while it falls at the point of impact net charge remains the same.

The voltage remains constant for 2 seconds. It takes that long for the heat to reach a copper heat sink at the rear. Waiting time between measurements is only 2 seconds.

Measuring c-w. To measure a continuous-wave laser beam, the instrument has a shutter that synthesizes a pulse of 25 milliseconds. Shutter action is produced by a slot in a reflecting disk mounted in front of the meter aperture.

Barnes Engineering Co., 30 Commerce Road, Stamford, Conn. **[379]**

New Tracor instrument measures frequency difference instantly, front-panel meter reads directly to parts per 10^{11}.

See us at
Wescon Booth
2205-2206

Built-in oscilloscope–and time-averaging–yields 1×10^{-12} precision, provides signal-quality assessment. Inputs: 100 kc, 1 mc, 2.5 mc, and 5 mc; reference and signal frequencies need not be the same. Price: $2850

AUSTIN, TEXAS–A new instrument, the Tracor Model 527A, now makes frequency-difference measurements direct-reading without waiting time.

Tracor engineers found the need for such an instrument virtually universal among those concerned with time/frequency measurement. Their new 527A reads on a front-panel meter with precision to 1×10^{-11}.

By using an internal oscilloscope and time-averaging techniques, users can extend precision to 1×10^{-12}. (On the most sensitive scale, one complete rotation of the oscilloscope dot pattern in 100 seconds indicates a frequency offset of 1 part in 10^{12}.)

Inputs signals may be any one of four different frequencies and the compared signals need not be the same nominal frequency. Either may be called "reference."

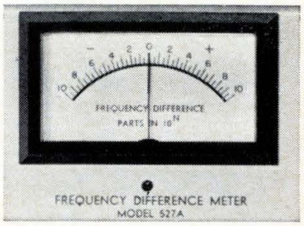
For example, if a signal of 1 mc that is high by 1 part in 10^{11} is used as "reference" and an unknown "signal" of 5 mc that is low by 7 parts in 10^{11} is compared to the "reference," the meter will read minus 8 parts in 10^{11}.

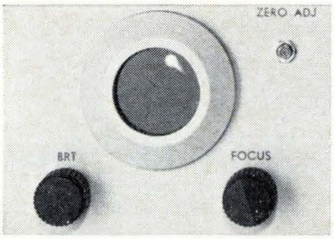
A typical bench setup to measure frequency difference requires, in addition to a complex array of equipment, timing of Lissajou-pattern rotation on a 'scope. At 1 mc with 1×10^{-11} frequency difference between compared signals, the Lissajou pattern will make about *one revolution per day!* The Tracor 527A can do this same job within one minute after turn-on.

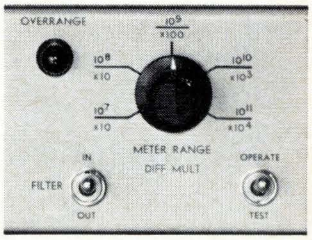
TFA-266-A

Tracor's Model 527A frequency-difference meter allows adjustment of two oscillators to the same frequency, adjustment to a specific offset, determination of offset—all instantly—plus both short-term and long-term stability analysis. No additional equipment is needed.

The zero-center meter reads frequency-difference directly in parts per 10^7, 10^8, 10^9, 10^{10}, or 10^{11}. Full-scale reading is $\pm$ 10 parts per 10^n.





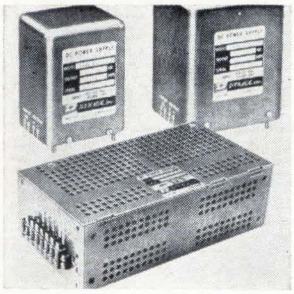


A rotating dot on the front-panel oscilloscope indicates phase relationship between compared frequencies with fractional frequency difference multiplied by 10, 100, 1000, or 10,000 as selected by the range switch.

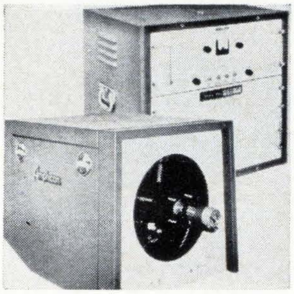
★ ★ ★

Full technical and application information may be had by writing the manufacturer: TRACOR, Inc., 6500 Tracor Lane, Austin, Texas 78721. Phone 512-926-2800.

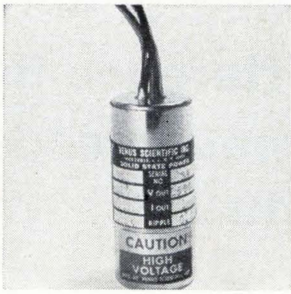
New Subassemblies Review



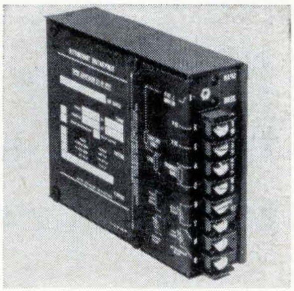
Dual modular and rack power supplies are for use with operational amplifiers. The K and KH series feature slave tracking to $\pm0.005\%/°C$, regulation to $\pm0.05\%$, and a temperature coefficient to $\pm0.015\%$. They are available at ±10 v, ±12 v, and ±15 v d-c with current outputs from 150 ma to 2 amps per output. Dynage Inc., 390 Capitol Ave., Hartford, Conn. [381]



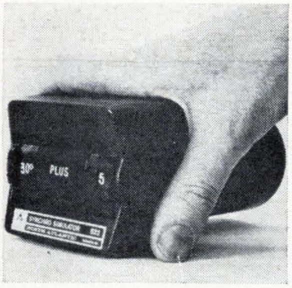
Large-screen television projector model 260 features a resolution of 1,000 lines and adjustable scan rates to as high as 1,203 lines at 60 fields per sec. The system uses a 6-in. crt and a high-powered video amplifier. The projection head measures 27 x 24¾ x 36 in., the control unit measures 19¼ x 21 x 20 in. Price is $11,000. Amphicon Systems Inc., Oak St., Norwood, N.J. [382]



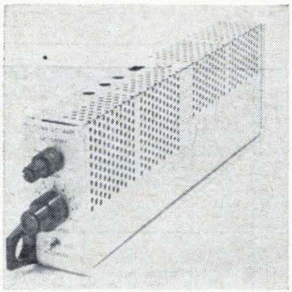
Model K15 photomultiplier power supply is a d-c/d-c converter that delivers up to 1 ma of current with a ripple of 0.1% or less for inputs ranging from ±35 to ±15 v d-c. Output voltage is from ±300 v to $\pm1{,}500$ v. The unit is reverse polarity protected. It measures 1 x 2¼ in. Price is $178 in small quantities. Venus Scientific Inc., 25 Bloomingdale Rd., Hicksville, N.Y. [383]



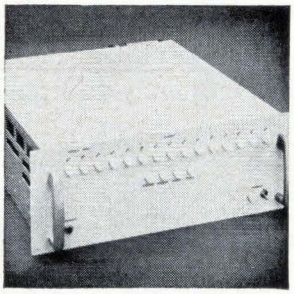
Temperature transmitters 18-111 and 18-112 receive signals from thermocouples and other millivolt sources and provide d-c voltage or current output signals. Accuracy of the output signal is to $\pm0.1\%$ with linearity of $\pm0.05\%$ of a straight line connecting actual end points, suiting the output for computation or control. Bell & Howell Co., 706 Bostwick Ave., Bridgeport, Conn. [384]



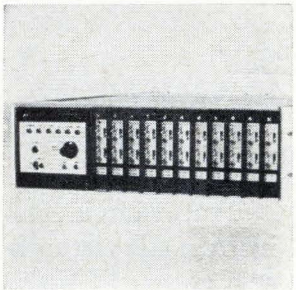
Synchro simulator model 532 develops synchro reference angle data for aircraft and satellite simulators, and production testing consoles. It takes up less panel space than a synchro-plus-vernier dial, furnishes output data angles in 5° steps from 0° through 360°, and provides 30 arc-sec accuracy. Price is $375. North Atlantic Industries Inc., Terminal Drive, Plainview, N.Y. [385]



D-c amplifier 1-168 drives high-frequency, light beam galvanometers. The single plug-in module provides isolation between input and output and between circuitry and ground. Voltage gain ranges from 0.1 to 500. Frequency response is from $\pm1\%$ d-c to 5 khz. Overload recovery time is 100 μsec. Consolidated Electrodynamics Corp., 460 Sierra Madre Villa, Pasadena, Calif. [386]



DADIT is a 15-bit integrating a-d converter with common-mode rejection of 10 million-to-1 at d-c to line frequency. It is for monitoring such low-level transducers as strain gauges in high-level a-c environments, and also works well with multiplexers. No preamplification or individual point filtering is needed. Control Data Corp., 4455 Eastgate Mall, La Jolla, Calif. [387]



Calibration system model 8812 is designed for subcarrier discriminators. It generates all 21 constant-bandwidth channel frequencies and a reference frequency simultaneously and applies the resulting frequency-multiplex group to the discriminator system. Deviation bandwidths for each channel can be set at ±2, ±4, or ±8 khz. Vidar Corp., 77 Ortega Ave., Mountain View, Calif. [388]

New subassemblies

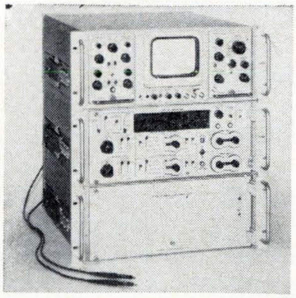
Converter puts tv on telephone lines

Low-cost rotating scanner downgrades tv signals to an audio bandwidth of 8 kilohertz

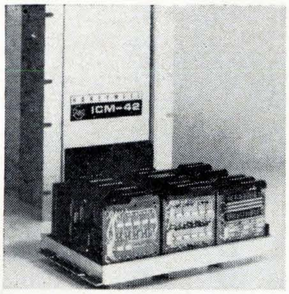
The cost of transmitting closed-circuit television signals more than a mile by coaxial cable or microwave relay are prohibitive. Where slow-scan signals can be used, conventional telephone or radio circuits are the most economical means.

Seeking to capitalize on this situation, Colorado Video Inc. has developed a converter system that enables the transmission of closed-circuit, slow-scan tv signals over telephone lines. Although comparable equipment is available, CVI's

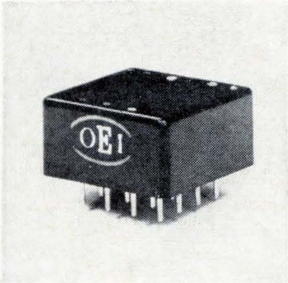
Clear image. Quality of picture after it has passed through the two converters is still good enough so that printing can be easily read. One big application could be in banks where the system would verify signatures and speed check cashing.



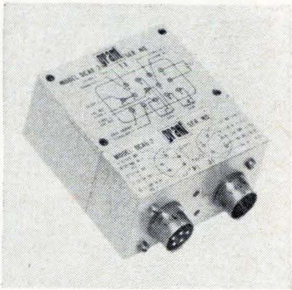
Type S-3100 time measurement system features digital programing, measurement speeds greater than 100/sec, and programable vertical and horizontal sampling units. It consists of a type 568 oscilloscope, type 230 digital unit, an auxiliary unit, and programable time-base and vertical units with a 50-ohm or 100-kilohm, 2-pf input. Tektronix Inc., Box 500, Beaverton, Ore. 97005. [389]



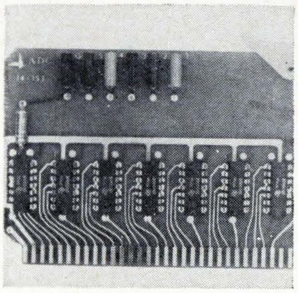
Core memory ICM-42 is for use in communications, telemetry, code conversion, machine tool control and digital buffer applications. Full cycle time is 1.5 μsec and access time is 700 nsec. The IC-designed, self-contained system is available in capacities of 2,048 words and 1,024 words of 12 bits per word. Computer Control Division, Honeywell Inc., Framingham, Mass. [390]



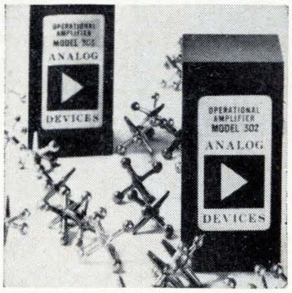
Solid state analog function modules are useful building blocks in measurement, control, and analog computation systems. The 269 is a bipolar logarithmic amplifier; 337, a matching bipolar antilog amplifier; 517/518 a polar analog multiplier; 521/522, a polar square root amplifier; and 523/524, a polar squaring amplifier. Optical Electronics Inc., Box 11140, Tucson, Ariz. [391]



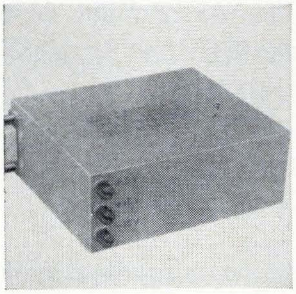
Airborne d-c instrumentation amplifier DCA8-2 offers flexible design, permitting a variety of sensor inputs. It contains an isolated, regulated 5-v transducer excitation supply. The unit withstands high shock. Output operates into a load of 10,000 ohms or greater without degradation. Operating temperature is —65° to +185°F. Grant Electronics, 2017 Glendon Ave., Los Angeles. [392]



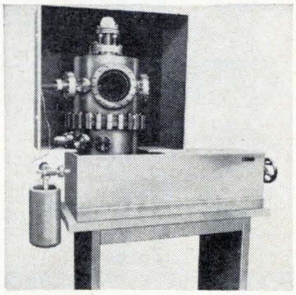
IC logic modules, designated the 14 series, feature dual in-line chips, economy and flexibility. Simplified board layouts permit mixing of chip types on a single board. The DTL integrated circuits work from a 5-v power supply at 5-Mhz operating speeds. Noise rejection is typically 1 volt. Canoga Electronics Corp., 20131 Sunburst St., Chatsworth, Calif. 91311. [393]



Varactor bridge operational amplifiers 302 and 303 are for inverting and noninverting circuitry, respectively. They have ½ picoamp max bias current and 0.05 picoamp/°C max current drift at 25°C. Peak-to-peak noise from d-c to 1 hz is 0.01 picoamp and 2 μv. Differential input impedance is 5 x 10 ohms. Analog Devices Inc., 221 Fifth St., Cambridge, Mass. [394]



Hermetically sealed for aerospace use, the PM1570, a 3-channel d-c/d-c instrumentation power converter, has a temperature coefficient of 5 ppm/°C without ovens. Output voltage regulation for power line excursions of 22 to 36 v d-c after load changes from ¼ load to full load is ±0.1% on all channels. Pioneer Magnetics Inc., 1745 Berkeley St., Santa Monica, Calif. [395]



The 120 LEED (low-energy electron diffraction) system for crystal-surface studies is used primarily for obtaining data regarding atomic geometry. It permits direct study of corrosion, oxidation, epitaxial growth, and catalytic processes. Vacuum chamber pressures down to 3 x 10^{-8} torr are available. Varian Associates, 611 Hansen Way, Palo Alto, Calif. [396]

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apparatus costs less and is smaller in size. It has the capability of holding pictures indefinitely.

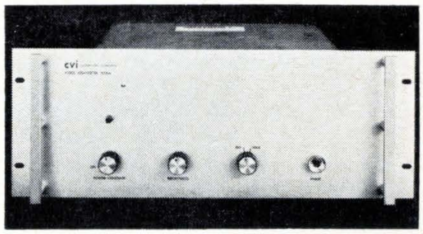
I. Down and up

There are two converters in the system: one, the 201A, downgrades tv signals to an audio bandwidth of 8 kilohertz; the 220-A, a new video disc converter, upgrades the signal to video bandwidths at the terminal.

Glen Southworth, CVI's president, says the company designed the 220-A to use as much standard tv equipment as possible. The unit has a sliding pulse generator, a synchronous generator, a record-erase playback amplifier, and a wideband rotating disc video memory made by Data Disc Inc., Palo Alto, Calif.

The disc permits the operator to use a recirculating video memory and to insert data to reconstruct a picture over periods of time ranging from a third of a second to hours. It's also possible to record a tv timing reference on the disc to get a timing accuracy of 100 nanoseconds.

Foolproof. Incoming pictures can be recorded at a slow scan rate on the disc and simultaneously played back at conventional tv rates with a bright nonfading image that can be erased in 1/30 of a second. The 220-A requires from 4 to 7 seconds to reproduce a single picture. A selected slow-scan signal automatically erases the previous picture and records a new one. However, there is a hold mode to prevent unwanted erasures.



Compact. Each converter is packaged in its own neat rack.

At the transmitting end, the tv camera's image is verified by a

. . . any company with a phone can use the converter . . .

monitor before the 201A is activated. The 201A, a solid state unit, has a sliding pulse generator, a real-time video circuit, a sample-and-hold circuit with a d-c-coupled amplifier, and a simple circuit to signal the 220-A when a picture is being transmitted. It downgrades the signal by high-speed sampling.

At the receiving end, the 220-A takes the signal at a line rate of 60 per second, scanning from top to bottom and left to right. It converts the signal to a standard tv horizontal frequency of 15,750 hertz and a vertical frequency of 60 hz to produce a 525-line picture.

II. Conditioned lines

Competitive systems can use regular voice-rate telephone lines but the CVI system needs conditioned lines, which cost more. However, the company says the conditioned lines give its system a picture transmission capability of 10 seconds, against a minimum of 40 seconds for other gear.

Southworth says, "Any company that uses a phone can use my system." He concedes, however, that his best markets are those where sharp reproduction is needed.

Prospective buyers. Banks could use the system to keep a central depository of records for their branches, and they are the first big marketing target. Southworth says signature-verification could be improved and banks could save the cost of keeping card files. Other potential uses, he says, include security surveillance of remote areas and schoolroom applications in which the system is "the tv equivalent of the slide projector."

The 201A costs \$1,950 and measures 3½ x 19 x 18 inches; the 220-A costs \$5,000.

If radio, narrow-band microwave, or intercity telephone circuits are used, a special modulator-demodulator unit may be required to improve low-frequency characteristics. As a rule, however, the simplest connection between the 201A and the 220-A is an ordinary telephone pair without transformers or loading coils.

Colorado Video Inc., Box 928, Boulder, Colo. 80302 **[397]**

Dial Direct–and Save

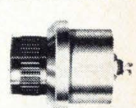
Introducing the direct-dialing Bourns KNOBPOT® Model 3650—a digital dial, knob, and 10-turn precision potentiometer in a single assembly. At $25, this integrated unit costs you less than a precision potentiometer and digital dial bought separately, yet gives you greater accuracy. Correlation between dial and wiper output is guaranteed accurate to 0.1 per cent! There are no phase-it-yourself problems with the Model 3650, either. Each unit is phased at the factory. You save time, trouble and expense!

Settings are fast and easy, thanks to the large, clear numerals that show turns, tenths of turns and hundredths of turns. Calibration marks beside hundredth-turn numerals allow settings as fine as 1/1000 turn or 1/10,000 of the total applied voltage.

Reliability is enhanced by extensive in-process inspection, 100 per cent final inspection, the Bourns Reliability Assurance Program, and by such outstanding construction features as the exclusive SILVERWELD® termination—the strongest in the industry. For value you can count on, specify Model 3650. Write today for complete technical data.

MODEL 3650 1¼″ dia., 10-turn
STANDARD SPECIFICATIONS

Dial accuracy (correlation of dial reading and output, including linearity)	±0.1% (50K and above)
Repeatability of dial reading	±0.05%
Power rating	2.5W at 25°C
Humidity	MIL-STD 202 Method 103
Resistance Range	100Ω-500K



unit shown 1/4 actual size

BOURNS INC.

BOURNS, INC., TRIMPOT DIVISION, 1200 COLUMBIA AVE., RIVERSIDE, CALIF.
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TRIMPOT® AND PRECISION POTENTIOMETERS—RELAYS—MICROCOMPONENTS: TRANSFORMERS, INDUCTORS, RESISTORS AND CAPACITORS

Circle 221 on reader service card

New subassemblies

Interferometry in a suitcase

For machine tool calibration, digital IC's shrink laser interferometer

There's nothing better than a laser interferometer for determining whether a numerically controlled machine tool is stepping through its programed paces accurately. Nothing better if you can pay the price—upwards of $20,000—and can accommodate the bulky console housing the electronics that goes with the laser head.

Now the DoAll Co. has introduced a laser interferometer which is small enough to fit into a women's overnight traveling case. And its price—$10,000—is roughly 25% less than the cost of instruments presently available.

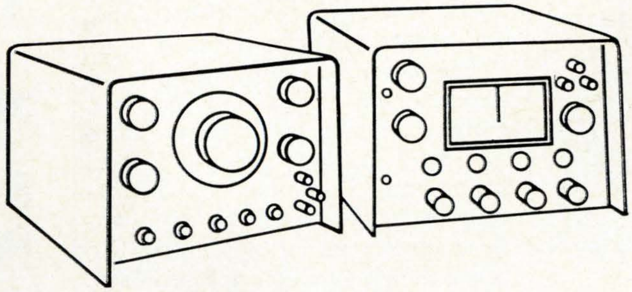
DoAll has been able to shrink its unit down to portable size—it weighs 50 pounds—by using integrated circuits, says Thomas W. Mitchell, manager of quality and technical support. In comparison, the electronics console alone of a competing unit weighs 180 pounds.

In designing its unit, DoAll had to develop a bidirectional counter that operates at 20 megahertz.

"We began by trying to find a counter on the market that would meet our requirements," says

Portable. The bulk is taken out of new laser interferometer.

See the little boxes.



See what they can do.

Measure voltage and frequency. Generate sine, square, triangle, ramp, tone burst, trigger, sweep, sine², phase lock, VCG, plus analog and digital control of frequency and amplitude.

See the little boxes work at Wescon, booth 2417.

WAVETEK®

8159 Engineer Rd., San Diego, Calif., Tel. 279-2200
European Sales: 3000 Bern 9, Seidenweg 17, Switzerland

Circle 223 on reader service card

‘. . . we redesigned our circuits to use cheaper chips . . .’

Mitchell. “But the fastest counter we could find only went to 5 Mhz and it was much too expensive. So we decided to design our own.”

The counter enables the interferometer to operate with machine tools traversing even faster than the usual maximum of 240 inches per minute. Theoretically, a 1-Mhz counter would just keep up with this speed. Using a counter 20 times higher in frequency provides that much more safety.

The design road was not an easy one, however, and it wasn’t DoAll’s fault. “The semiconductor company that was supposed to provide our IC’s stalled around for six months before they told us they couldn’t deliver,” says Mitchell. “We redesigned our circuits and we were not only able to get cheaper chips from competitors but we also wound up with a better design.”

“If you feel you’re getting the business on IC’s, look around,” Mitchell advises. “You may have to change a board, but it could be worth it.”

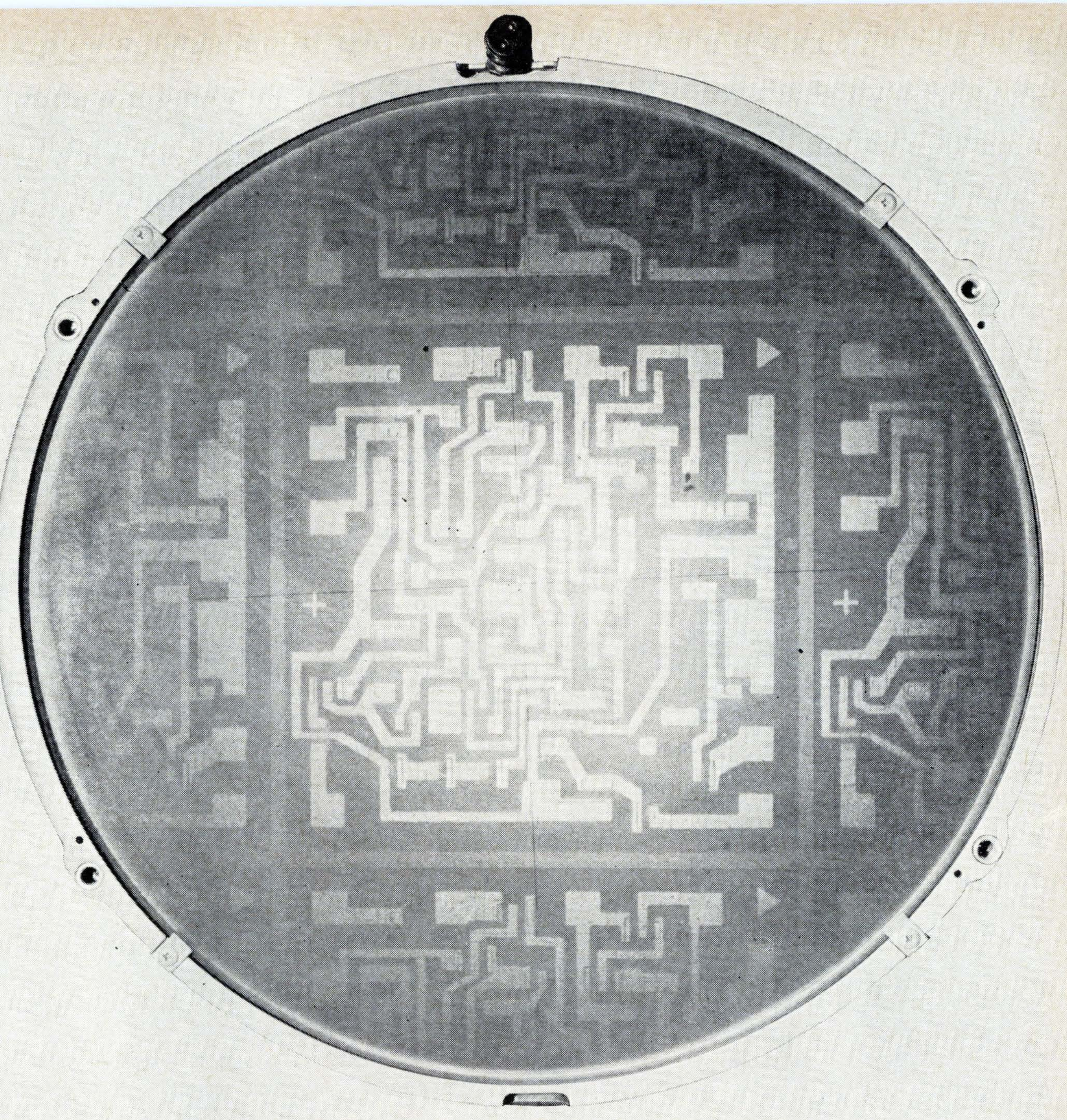
DoAll has designed the interferometer to be as modular as possible. One module contains the single frequency, helium-neon laser and its power supply, another the interferometer optics. A separate electronics package—measuring 3 x 14 x 12 inches—contains the counter, nine-digit tube readouts, and preset and reset decades. In an earlier DoAll unit, the electronics was 30 inches square, 5 feet high.

Positioning accuracy is 6.24 microinches, one-fourth the 6,328-angstrom light emitted by the laser.

Extra modules give the unit more capability. A plug-in computer correction board converts the interferometric fringes counted into either decimal or metric equivalents. Thus the readouts indicate inches or centimeters directly.

There are also modules to compensate for temperature and pressure variations in the operating environment. One compensation method uses a thermistor to sense temperature changes and a second transducer to detect pressure changes. Their outputs are fed into the circuitry to modify the count.

DoAll Co., Des Plaines, Ill. 60016 [398]



Challenge In Microelectronics

You'll find it at Delco Radio in a variety of research/development and manufacturing programs. Rapid expansion of microelectronics and silicon device projects has created new career opportunities for the B.S., M.S., Ph.D. in Chemistry, Electrical Engineering, Mechanical Engineering, Metallurgy, Physics, Physical Chemistry, and related fields.

Research and Development Programs in:

Linear and digital circuitry, embracing monolithic . . . thick film . . . thin film . . . and hybrid microcircuits

Silicon transistors from low power 10 milliampere through 25 ampere; voltages to 1200

High frequency transistors to 1gHz

Thyristors from 50 millampere through 500 ampere, 2000 volts

Silicon rectifiers from milliampere through 250 ampere, 3000 volts

Process Engineering Positions:

Unlimited opportunities in this area to develop and create new processes for manufacturing germanium and silicon semiconductor devices, integrated circuits, and automobile radios. Includes development of automatic and semiautomatic fabrication equipment, pilot line operation and general cost savings investigations pertinent to semiconductor manufacturing.

Call us collect for an interview or more information. Area Code 317/459-2808. Ask for C. D. Longshore. Or send your resume to Mr. Longshore, Supervisor, Salaried Employment, Dept. 105, Delco Radio Division of General Motors, Kokomo, Indiana.

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MARK OF EXCELLENCE

New subassemblies

How bright the laser?

Optical power meter gives precise readings over wide spectrum

As the commercial and laboratory applications of medium-power lasers grow, users increasingly need calibrated meters to precisely measure power and power intensity over a broad range. One problem here is that commercial power meters generally can measure either at one wavelength or only a few. But at this month's Wescon meeting, Coherent Radiation Laboratories of Palo Alto, Calif., will introduce an optical meter that measures light power over the entire visible and near-infrared spectrum with closely calibrated precision and sensitivity.

The battery-powered instrument, the model 202, is essentially a specialized voltmeter that reads out in watts of optical power. It gives one nanowatt resolution in ranges from 100 nanowatts to 300 milliwatts full scale, and a flat response from 4,700 to 8,000 angstroms.

Contributing to the 202's sensitivity and resolution are: a silicon solar cell; a high-gain, low-drift amplifier; and a zero-suppression circuit.

I. In the head

The solar cell is in the separate sensing head, which holds attenuating filters and apertures and can be either hand-held or mounted on a stand. The instrument case contains the solid state operational amplifier, range resistors, a meter, and the zero-suppression controls.

The solar cell converts light energy into electrical energy for the output amplifier, which in turn feeds the range resistors that determine the gain between the solar cell and the indicating meter. The range switch selects feedback resistors that control amplifier gain.

Block out. The zero-suppression circuit controls a current in oppo-

Chapter II. The Word from GENISCO.

LET THERE BE LIGHT
OR
TELL ME ABOUT THE FREE $50 SWITCH

It's yours absolutely, unconditionally free. All we ask is that you give us $50 for it. Why do we call it "free" when we are earnest about getting paid for it? Two reasons:

First of all, when you throw the mechanical switch on, nothing happens until a teeny solid-state device senses that the voltage passes through zero. Then the switch turns the circuit on. When you throw the mechanical switch off and the current passes through zero, the circuit is turned off. That means that the on-off switching is done at the point of minimum energy. And that means no step function voltage to generate high-frequency components. And that means that the switch is *free* from radio frequency interference. *Quad est demonstradum.*

The second reason we call it "free" is we thought that if you thought you could get a $50 switch for nothing you'd probably be greedy enough to read this ad. There appears to be some justification for this assumption.

Circle 495 on reader service card

OUR TELEMETRY GEAR WILL NEVER GET OFF THE GROUND

Because we manufacture only equipment associated with checking out telemetry transmission while the transmitter is still nice and accessible.

For example, our new, compact FM Discriminator for playback in FM/FM telemetry systems. The pulse average design has 0.1% linearity. The Model 71-282 operates on all IRIG channels, 1-21, and A through H, with an input sensitivity of 20 mV. Accommodates any center frequency from 300 Hz to 300 KHz. Each one weighs less than a pound. Disgustingly inexpensive, too.

Circle 496 on reader service card

HOW WE INVENTED THE SANDWICH

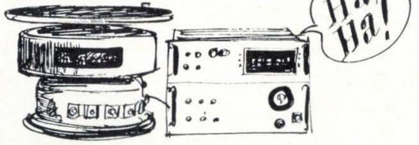
To make the ruggedest possible field portable tape recorder we suspended the entire tape transport mechanism between two parallel flat plates. This gives double support to all members, and as the tape contacts only the primary drive mechanism, reel hubs, two turn rollers and the head surfaces, its oxide coating gets maximum protection.

As you know, the flanges on tape reels are cantilevered members which can be supported against extreme shock and vibration only at the cost of a substantial increase in the rotational inertia of a system. So we got rid of them. The tape can't slip off the reel because hoop tension forces resulting from normal pulling of the tape provide great compressive forces within the reel stack. It would take in excess of 300 g's for slippage to occur.

The result of our Sandwich and Flangeless design approaches (plus a few other neat ideas): a rugged, high performance field portable tape system. Request full information.

Circle 497 on reader service card

OUR RATE-OF-TURN TABLE LAUGHS AT ABUSE



Our new Model 1147 maintains high precision performance regardless of rough handling and transportation. (One reason it's used as the AGE gyro test table for F-111 Aircraft System.) Hydrostatic bearings give precise dimensional stability, excellent alignment, low runout and eccentricity, low mechanical noise and long life. The bearing is capable of smooth rotation at less than siderial rates (.004°/sec.). And up to 1500°/sec.

The Model 1147's compactness makes it ideal for field or bench checking. Its ruggedness makes it ideal in case you just happen to feel like kicking hell out of a fine piece of equipment.

Circle 498 on reader service card

OUR COMPUTER CAN BEAT UP YOUR COMPUTER

Filled with supreme confidence the engineer plugs in his newly designed gem of a system. Then discovers that it's too noisy. So off to the supplier for a custom filter. It's expensive and its weird configuration makes it almost impossible to maintain a hermetic seal under the stresses of high pressures and extreme temperature variations.

We can help you avoid the what-me-need-a-filter syndrome. Give us a work statement. For free, we'll crank the system parameters into our computer and it will design the Perfect Filter. It will do the job right, and cost you about 40% less than one that must be produced downstream.

Out of the hundred or so companies in the industry only two or three use computers. We're better at it than they are, and besides our salesmen know good jokes. Come on, give us a break.

Circle 499 on reader service card

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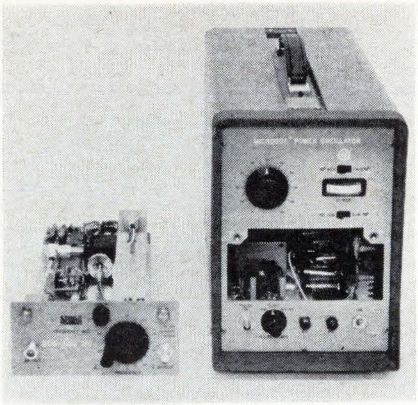

Broad range. Power meter reads over the visible and near-infrared spectrum.

sition to that generated by the photoconductor. By blocking out 90% of the signal, for example, and amplifying the remainder, the meter can measure small differences in large amounts of light.

The 202 should therefore be valuable in many areas of laser research and development. In polarization studies, its sensitivity of 10^{-8} watts (at 10% of full scale) allows measurement of extinction ratios to 10^{-6} with only a 10-milliwatt source. Scattered optical loss in lenses, windows, and mirrors, can be measured directly, according to Coherent Radiation. The company says the 202 is well-suited for use as a scanning head for plotting diffraction patterns and mode structures.

II. In any plane

The extreme thinness of the sensing head—2.25 by 3.125 by 0.75 inches—makes the 202 ideal for detecting light in any plane, an important feature for holographic work.

The head, made of anodyzed aluminum, contains one dielectric filter and three neutral density filters. Further, the head is threaded, so lenses and extension tubes can be added to it. A helium-neon laser producing no more than 50 milliwatts can be measured in direct beam, but a high-power CO_2 laser cannot.

With variable meter illumination, the 202 can be operated in complete darkness. Battery operation with well-shielded components eliminates noise from vibrations induced by power lines.

The unit is priced at $1,250.

Coherent Radiation Laboratories, Palo Alto, Calif. **[399]**

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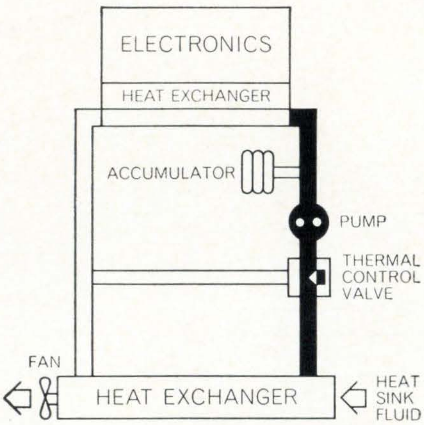

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This AiResearch "ICE" system includes both the heat transport system and electronics enclosure with integrated heat exchanger.

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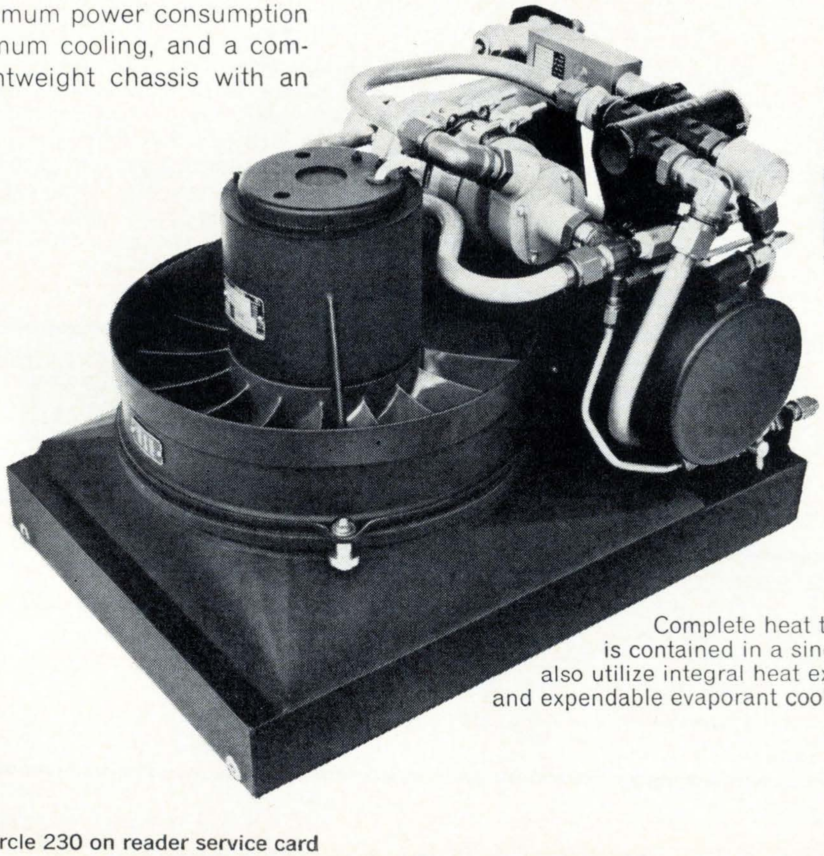
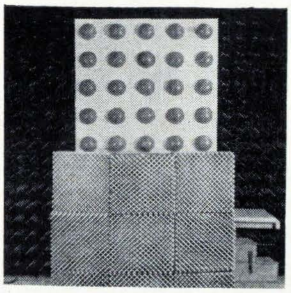
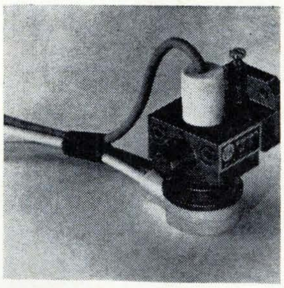


Complete heat transport system (left) is contained in a single, compact unit. We can also utilize integral heat exchangers, heat pumps, and expendable evaporant cooling methods.

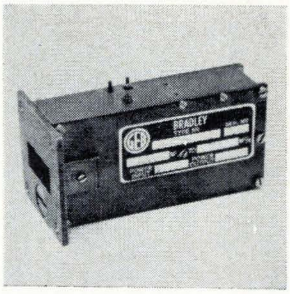
New Microwave Review



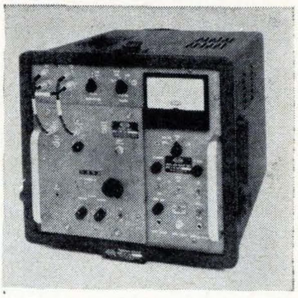
Spherical passive devices called Ecco reflectors increase radar cross section and also produce scintillation patterns useful for simulating natural targets and for identification purposes as radar beacons. Parameters are the number of reflectors, distance between them, radar frequency, and each reflector's radar cross section. Emerson & Cuming Inc., Canton, Mass. [401]



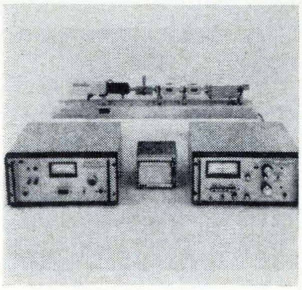
Reflex klystron oscillators covering 26.5 to 35 Ghz serve as pump tubes in parametric amplifiers. Tuning over a 1,000-Mhz range, the VA-312 delivers 150 mw at a beam voltage of 550 v. The VA-313 has a mechanical tuning range of 700 Mhz and delivers a minimum of 500 mw at 26 Ghz. The tubes weigh 4 oz. Varian Associates, 611 Hansen Way, Palo Alto, Calif. 94303. [402]



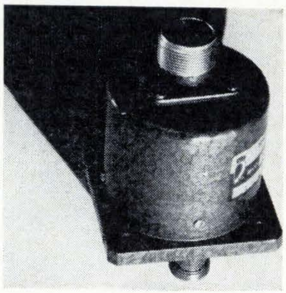
Klystrons can be replaced by an X-band, step recovery local oscillator. Simply connect a 17.5-v to 28-v supply and produce 10-mw output for 1¾-w input. Bandwidth is 400 Mhz tunable with ±10 v d-c. Noise is in the same order as a klystron. Operating range is +80° to —40°C. Price is $650. Edwin Industries Corp., 5858 E. Molloy Rd., Syracuse, N.Y. [403]



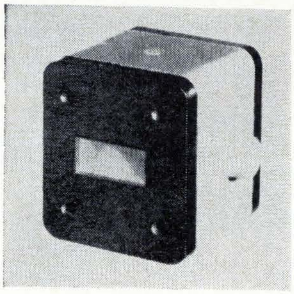
Tuning unit T-RW spans 2 to 75 Ghz and plugs into model TR general-purpose/antenna-pattern receiver. The first mixer is mounted externally for direct connection at the receiving antenna, at distances up to 100 ft from the receiver. Operating modes include a-m, f-m, c-w, and pulse. Price is $2,750. Polarad Electronic Instruments, 34-02 Queens Blvd., Long Island City, N.Y. [404]



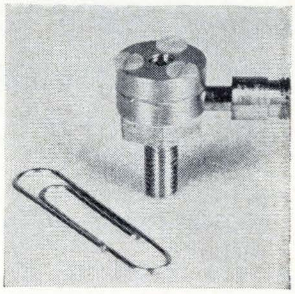
A microwave noise temperature calibrator checks sources utilizing gas-discharge noise lamps. It includes an i-f switched radiometer that compares the output of an unknown noise source to that of a reference standard noise source. Difference is read directly in db from a front panel dial. The standard has ±500°K accuracy. Airborne Instruments Laboratory, Deer Park, N.Y. 11729. [405]



Fail-safe coaxial switches are single pole, triple throw. The SDN3120EFS provides minimum isolation of 60 db, max insertion loss of 0.2 db, and max vswr of 1.2, from d-c to 3 Ghz. Switching time is 10 msec and life expectancy is 1 million operations. Units return to position 1 in event of power failure. Price is $325. Sage Laboratories Inc., 3 Huron Dr., Natick, Mass. [406]



Navigation systems and airborne radar are among the applications for a compact, 21-oz beacon magnetron. The MA-250 operates at a fixed frequency in the 8.5 to 9.6 Ghz range with a 0.5 μsec pulse width and a 0.005 duty ratio. Minimum peak power output is 7 kw. Input connections are made through flexible leads or solder lugs. Microwave Associates Inc., Burlington, Mass. [407]

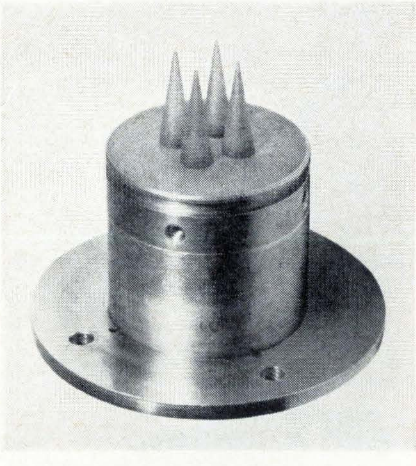


A miniature microwave generator consists of a silicon avalanching diode mounted in a radial mode cavity. The source is tunable over 3% bandwidth in the 5- to 9-Ghz frequency range and can deliver up to 100 mw continous microwave power. The unit weighs less than ½ oz and has a volume of 0.06 cu. in. Sperry Microwave Electronics Co., Box 1828, Clearwater, Fla. [408]

New microwave

Slim antenna makes a point

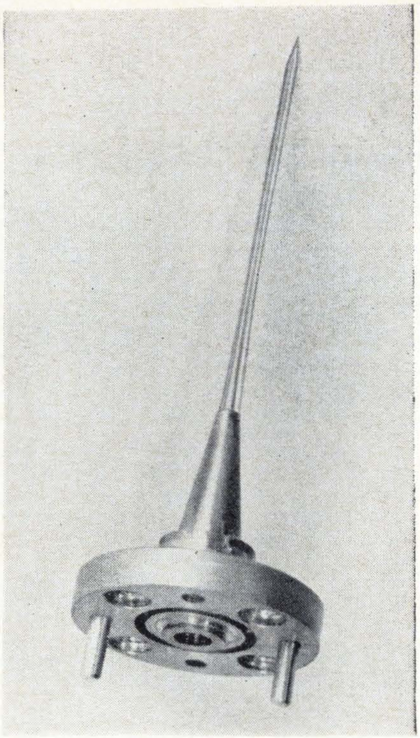
Shaped like a pencil instead of a trumpet horn, it can handle 12 to 140 gigahertz



Spiked. Higher antenna efficiency and lower sidelobes resulted when TRG substituted spikelike polyrod antennas for horns in this 94-ghz scanning feed.

A new antenna is small, light, and shaped like a sharpened pencil instead of having the traditional look of a trumpet horn. Developed by TRG, a division of the Control Data Corp., the antenna is suitable for use at from 12 to 140 gigahertz. The company calls the device a polyrod antenna because of its shape and the plastic material in it.

TRG was trying to scale horn antenna feeds down to millimeter-wave size when its engineers conceived the pointed rod approach. The problem was to design a four-horn antenna feed for a tracking interferometer that worked at 94



Tip of the line. Taper of plastic rod decides beam shape of polyrod antenna.

Ghz. But the traditional shape of a flared horn radiator performed inadequately because the bulging horns couldn't be squeezed together tightly enough. At 94 Ghz, the thickness of the horns' walls was a large fraction of the wavelength so the thickness of the walls forced the axes of the radiators too far apart.

To tighten the radiator cluster the engineers started slimming the horn walls but eventually dropped horns completely for the rod antenna. The slim shape raised feed efficiency and reduced sidelobes.

Plastic pencil. TRG builds the radiators by filling one end of a cylindrical waveguide with polystyrene plastic. Inside the waveguide, the plastic is tapered to provide an impedance match. Beyond the end of the waveguide, the plastic is machined to the taper that achieves desired beamshape.

At the time of the initial development these advantages were byproducts. Now TRG feels the byproducts are good enough to be the basis for a commercial line of antennas. First in the line is model 860 designed to work at 95 Ghz. Its beamwidth is 20°; maximum sidelobe level is —16 db; gain is 18 to 19 db.

TRG Inc., a division of Control-Data Corp., Boston **[409]**

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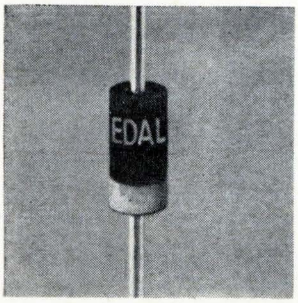
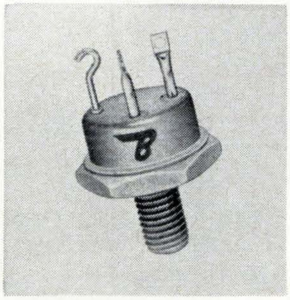
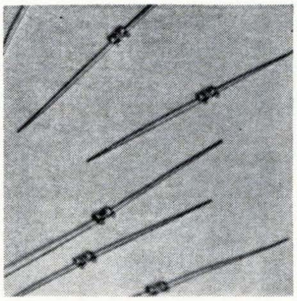
New Semiconductor Review



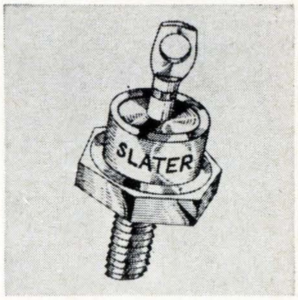
Subminiature silicon rectifiers have compact tubular construction and flexible leads that facilitate circuit mounting and provide high thermal conductivity. Length is 1/4 in. and diameter is 0.115 in. Voltage ratings for the series B223 run from 1,000 to 6,000 v piv; current ranges from 200 to 1,000 ma are standard. Edal Industries Inc., 4 Short Beach Rd., East Haven, Conn. [436]



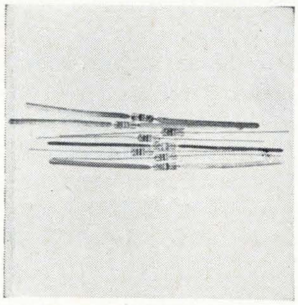
Radiation-resistant silicon power transistors feature a continuous collector current of 20 amps. They withstand exposure levels of 5 x 10^{14} NVT (total integrated neutron flux with energy levels greater than 10 KEV). Power dissipation is 50 w; collector-to-emitter voltage, 40 to 75 v; and gain bandwidth product, 200 Mhz at 28 v and 0.5 amp. Bendix Corp., Holmdel, N.J. [437]



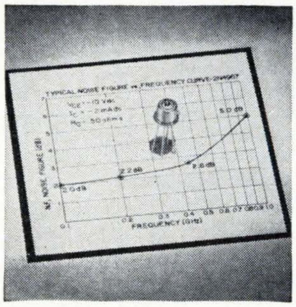
High-isolation switching diodes come in 2 types. MO-2825 is a fast-switching type with a test frequency of 8 Ghz; insertion loss at 10 ma of 0.85 db max; and isolation at −10 v of 15 db minimum. MO-1126 is a p-i-n switching diode with 8-Ghz test frequency and insertion loss at 50 ma, 0.50 db max. Alpha Industries Inc., 381 Elliot St., Newton Upper Falls, Mass. [438]



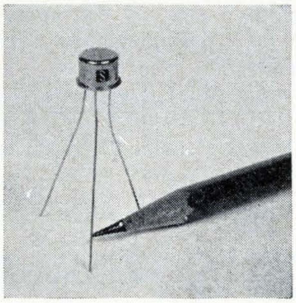
Four series of silicon power rectifiers are for use in power supplies, converters, and motor controls. The controlled-avalanche process eliminates matching while insuring reliability and conformance to MIL specs. Maximum current ratings are from 18 through 60 amps; max prv, 50 through 1,000 v. Prices start at $1.09. Slater Electric Inc., 45 Sea Cliff Ave., Glen Cove, N.Y. [439]



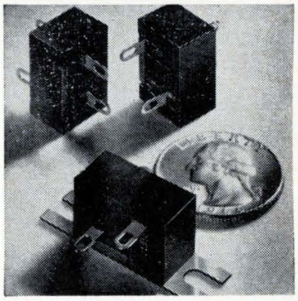
Point-contact diodes called Pico-Min are designed as broadband mixers and detectors for series mounting in stripline and coax circuits. They are housed in a microminiature glass case with axial wire or ribbon leads. Typical is the MA-4811D S-band mixer type with a maximum noise figure of 5.5 db at a test frequency of 3,060 Mhz. Microwave Associates Inc., Burlington, Mass. [440]



Silicon pnp transistors 2N4957-9 feature maximum noise figures of 3 db and minimum power gains of 17 db at 450 Mhz in the common emitter configuration. At 1 Ghz, the 2N4957 delivers a typical common emitter power gain of 13 db at a typical noise figure of 5 db. Prices range from $13.50 each to $4.50 in lots of 100 and up. Motorola Semiconductor Products Inc., Box 955, Phoenix, Ariz. [441]



Silicon chopper transistors in TO-5 cases have voltage capabilities from 100 to 160 v. The pnp devices, series SSS1001-14, offer high reliability and 2-v saturation voltage, and can be bought in matched pairs. Applications include modulators and servos, and telemetry and multiplexing circuits. Solitron Devices Inc., 1177 Blue Heron Blvd., Riviera Beach, Fla. [442]

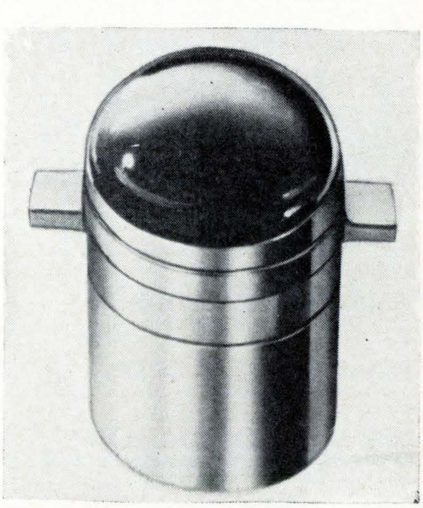


Single-phase bridge rectifier model S-896 is made from a superconductive selenium material. Life expectancy is over 100,000 hours when operated at full load at 35°C. The plastic-cased unit is rated at 60 ma and 230 v rms. It measures 3/8 x 25/32 x 1/2 in. high, exclusive of terminals. Price is 82 cents each in 100-unit lots. Sarkes Tarzian Inc., 415 N. College Ave., Bloomington, Ind. [443]

New semiconductors

Catching up in optoelectronics

Motorola starts a three-phase program to make photosensitive semiconductors



Tiny. Photodetector measures only 0.06 in. in diameter.

In the semiconductor industry, where the technology already encompasses an awesome variety of products, even the biggest companies can't introduce lines of every kind of product as quickly as they would like. Sometimes a producer has to ignore a segment of the market until it becomes too big to pass up any longer.

That's what Motorola Semiconductor Products Inc., which already makes 80% of all kinds of semiconductor products, has done

... Motorola has to play catch up with other makers ...

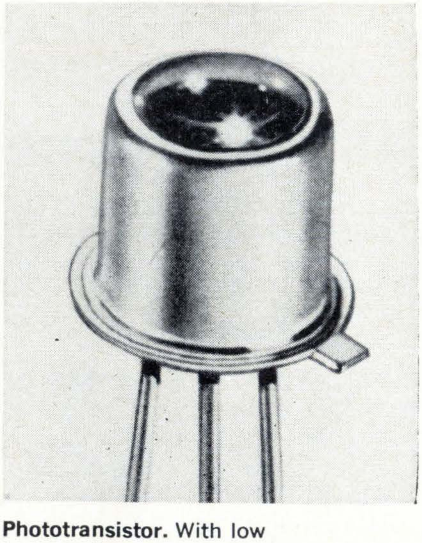
so far about optoelectronics. But this month, the company will widen its field of operation with its first optoelectronic devices: two photosensitive semiconductors. One is a photo detector (type MRD200), the other a phototransistor (type MRD300).

Catching up. Motorola is playing catch up in this area, and just how much catching up Motorola has to do can be seen by the performance of new products being introduced by others who have been in the field longer [see page 238]. The two products are designed primarily for such industrial and commercial applications as punched-card or tape readers, lighting controls, and counters.

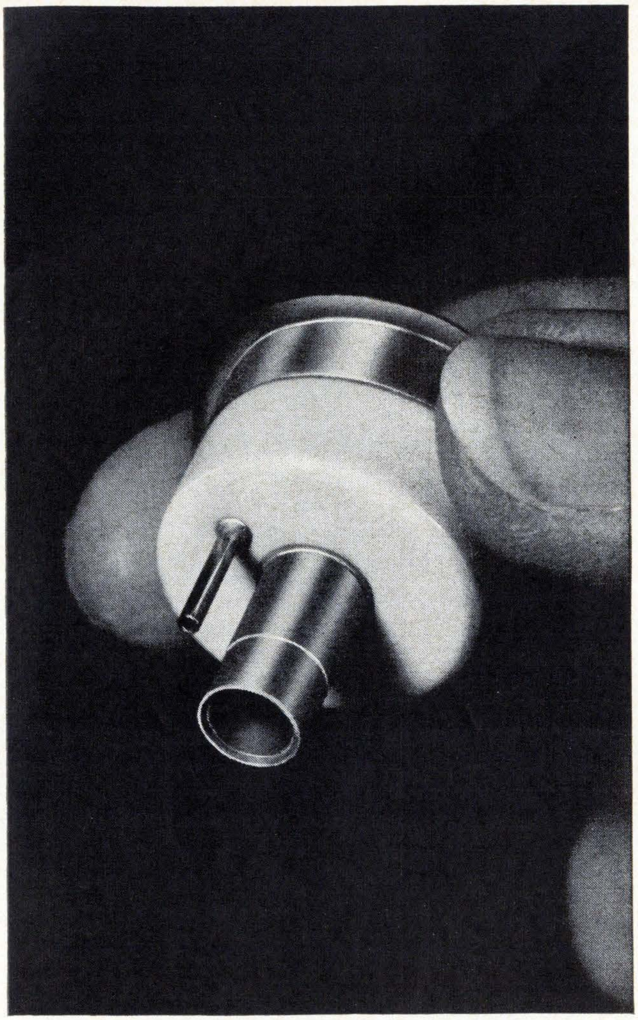
Because the new detector is only 0.06 inch in diameter, it can be mounted in a dense arrangement of devices, the kind of pattern needed in high-speed tape and card readers and rotating shaft encoders. Its output is linear over the dynamic range, so it can be used, for example, to read the sound track of a motion picture. It has a collector-emitter radiation sensitivity of 0.5 milliamperes per milliwatt per square centimeter.

Maximum turn-on/turn-off time is 6.5 microseconds, allowing far faster reading than would be possible with mechanical contacts. Finally, cross-talk is minimized by a 20° field of view.

Higher sensitivity. The new tran-



Phototransistor. With low leakage, it can work with lasers.



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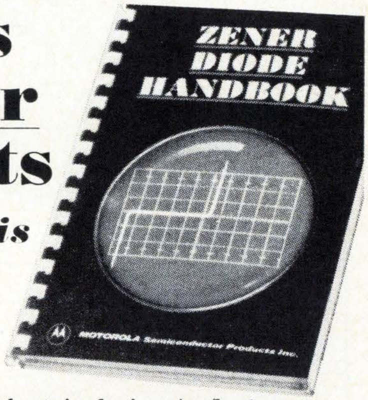

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sistor has a higher sensitivity than the detector: 1.6 ma/mw/sq cm. It responds to modulation well above the audio spectrum, so it could be used to transfer information from laser light sources.

Because its leakage is low, the MRD300 transistor can be used in direct-coupled circuitry at low signal levels. Packaged in a TO-18 can with external connections for additional control, the new unit has rise and fall times as fast as those of the detector's.

Both of the new devices operate from power supplies of 1 to 50 volts. Each costs $6.75 apiece if bought in quantities of 500 units.

Long-range plans. Now that Motorola has broken the ice with its first optoelectronic devices, the company has put together a three-stage plan to broaden its penetration. The total 1967 market for light-sensitive semiconductor devices was estimated at $23.5 million in Electronics' annual market report [Jan. 9, p. 125].

To complete the first phase, the company will add a p-i-n diode, a photosensitive field effect transistor, and a photosensitive switch with characteristics like those of a silicon controlled rectifier.

Main objective of the second phase will be to add light emitters. That means a line of gallium-arsenide phosphide devices radiating from visible to near infrared.

In the final phase, the components developed earlier will be combined into more complex devices, such as photo choppers.

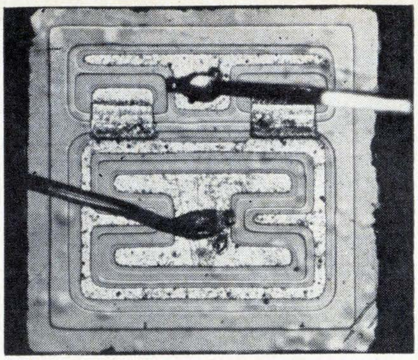
Motorola Semiconductor Products Inc., Box 955, Phoenix, Ariz. [444]

New semiconductors

Package doubles as photo-device lens

Photo detector can pick up as much as 75% of the light 40° from its center line

Many more engineers could use phototransistors if the field of view of most devices wasn't so narrow. A narrow view makes for tight tol-



High gain. Two npn transistors are connected in a Darlington amplifier to increase the gain of the detector. Both are made by planar technology.

erances in other parts of the equipment and raises the cost of manufacturing.

Now from the General Electric Co. comes a new photodetector that has a wide angle of view. As frosting on the cake, the new device costs less than $2 in single quantities and as little as 68 cents a piece in quantities of a thousand or more.

Because the curved side of the plastic package operates as a lens, as much as 75% of the illumination is detected as far as 40 degrees from the center of curvature—against the 10 degrees most phototransistors are limited to [see page 235]. In addition, the new device is relatively nondirectional.

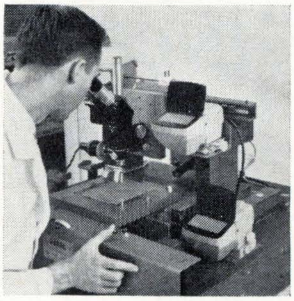
The new detector, labeled the L14B, is really two photo transistors connected in a Darlington amplifier to increase the gain of the detector. Both are npn silicon transistors and are made by planar technology.

Wide spectral range. The detector's sensitivity to varying wavelengths is very broad also. Although the spectral response is centered near 0.9 microns, the device has a relative response of 75% over the range from 0.73 to 0.98 microns, so it can operate in light varying from infrared to unfiltered tungsten illumination.

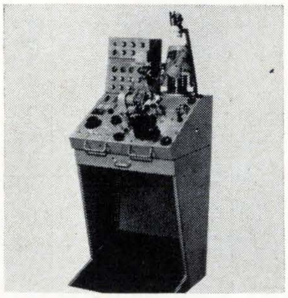
Because it loosens mechanical tolerances on the equipment in which it's used, the wide-view photodetector will open some new applications for optoelectronics, such as replacing tiny switches in vending machines or detecting gas fumes.

General Electric Co., Syracuse, N.Y. [445]

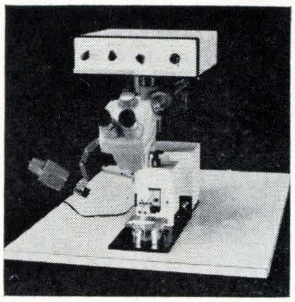
New Production Equipment Review



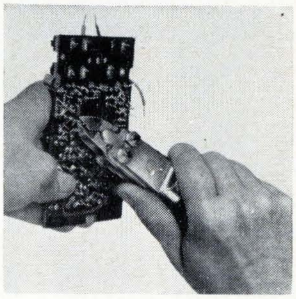
The 6X6M coordinate measuring machine has a 6-in. travel in both X and Y axes. It offers fast, reliable inspection of complex components used in IC's and related assemblies. Base and ways are made of Escondido black granite for stability and the desirable mass. Both coordinate movements are floated on air bearings. DoAll Co., 254 N. Laurel Ave., Des Plaines, Ill. [421]



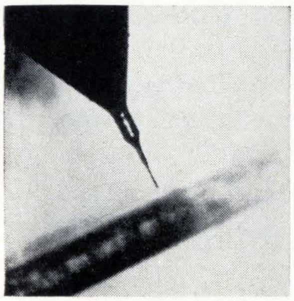
Toroidal coil winder TO-125C accommodates interchangeable shuttle heads and core holding and rotating fixtures, permitting fast changes in set-up. It produces finished coils from 0.028 in. i-d to over 5 in. o-d in wires from No. 16 to 50 Awg. It has variable winding speed controls and a 2-knob core positioning system. Leesona Corp., 131 West St., Danbury, Conn. [422]



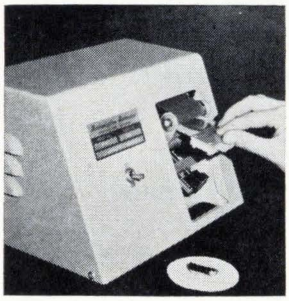
A reflow solder system is offered for attaching flatpacks to p-c boards, thin-film and simple a-c welding. Its solid state-circuit power supply features positive phase firing control, enabling precise selection of amplitude and duration. Bond-to-bond repeatability is featured, regardless of size or composition of pads and leads. Unitek Corp., 950 Royal Oaks Dr., Monrovia, Calif. [423]



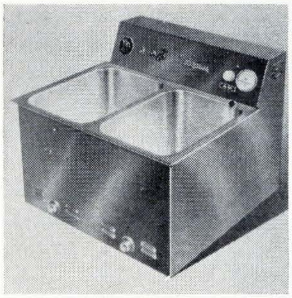
Air-operated pliers model CP-42 can cut cleanly and quickly through soldered, 0.062-in.-diameter copper wire. An adjustable jaw design prolongs jaw life, reduces down-time, and adapts jaw opening for the type of material being cut. The feather-touch throttle permits thousands of cuts with minimum effort. Chicago Pneumatic Tool Co., 6 E. 44th St., New York 10017. [424]



A building-block tooling system is suited for drilling IC's and printed circuits. Metal removal is a mechanical function; however, the system features optional automatic electronic and fluidic controls. Holes less than 0.001-in. diameter can be drilled on a production basis and simultaneous drilling of many holes per sq in. is possible. National Jet Co., 10 Cupler Drive, Cumberland, Md. [425]



Model 1180A is an automatic belt-type fracturer for semiconductor wafers that works equally well on thick-film scribed substrates. In the wafer-fracturing process the wafers are batch spray coated on the reverse side with a quick, air-drying emulsion that holds the die together after fracturing. Price is $390. Mechanization Associates, Mountain View, Calif. [426]



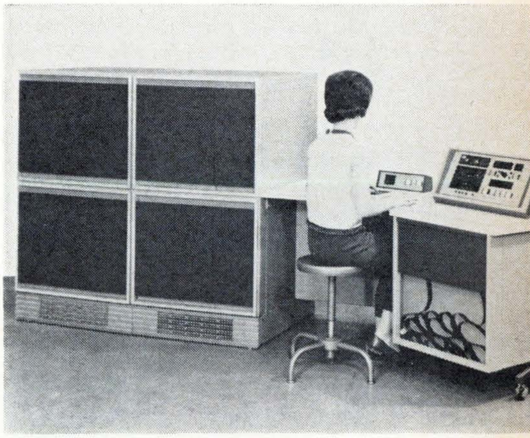
Ultrasonic twins is a dual-tank, stainless-steel consolette that cleans and rinses ultrasonically. It can be flush mounted on benches. A selector switch permits alternate tank operation, saving draining and refilling time. Each tank is powered by 200 or 300 w at 40 khz from self-contained generators and measures 14 x 10 x 9½ in. Dynasonics Corp., Box 672, Pipestone, Minn. [427]

Thickness of evaporated and other thin-film deposits is measured and recorded by the Talystep. Step heights are electronically recorded at 8 magnifications from 5,000 X to 1,000,000 X. A variable stylus pressure of 0 to 30 milligrams prevents damage to soft deposits. Stylus tips are 0.0001, 0.0005, and 0.003 in. Engis Equipment Co., 8035 Austin Ave., Morton Grove, Ill. [428]

New production equipment

Dynamically testing linear IC's

Modular plug-in instrument can also make d-c and digital measurements



Dynamic design. Model 553 operates on punched tape input so it is independent of other program sources.

The swift and sudden growth of the market for linear integrated circuit (LIC's) [Electronics, July 10, p. 125] has left a gap in the instrumentation field. And Texas Instruments Incorporated has moved quickly to fill it. The company's Houston-based Apparatus division, alerted to the deficiency by its sister division in Dallas, which makes linear IC's, is introducing a modular plug-in unit that dynamically tests linear IC's, replacing the hastily modified equipment that

. . . tester is adaptable to digital circuits too . . .

many company's have been forced to throw together to test the new devices.

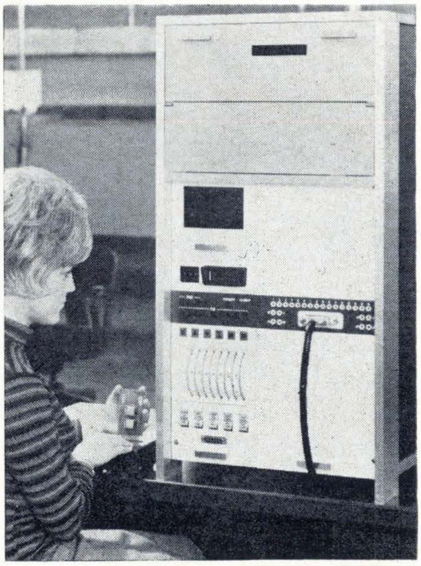
Digital, too. To be sure, the TI unit isn't limited to linear circuits; it's adaptable to digital devices and can take d-c and dynamic measurements at repetition rates of up to 50 megahertz. The unit, the model 553, is digitally programed and can test all multilead devices, be they IC's, discrete component, thin-film modules, or printed circuit boards.

As many as 10 d-c inputs and two pulse inputs can be connected to any point, and measurements can be made to any point.

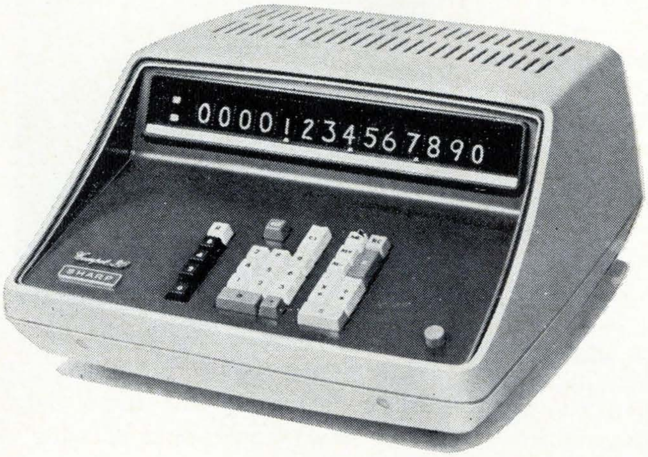
The model 553 has 20 leads: 16 are dynamic and d-c, four are d-c only. Each dynamic lead can function as either an input or an output point. And since each point in the test station has a unique address, more than one condition can be programed to any lead.

The 553 will sell for between $135,000 to $200,000, depending upon optional equipment.

The functional parts of the tester are an adapter board, a switching unit, and a performance board. Test sockets are mounted on the adapter board as connections for the d-c and dynamic leads. The switching units consist of programable coaxial reed relays that connect the inputs, loads, and probes to the test sockets. The device un-



D-c tester. Model 668 administers d-c tests to integrated circuits, can also check out printed circuit cards.



A status symbol?

No! a logical tool used by people who value time, their time. The electronic desk caluculator, Compet-30, was designed to be a work tool—speedy, accurate, efficient, not a show piece. That it is lightweight, easy-to-carry and good design was fall-out. It does add status to a desk, but that's not its prime purpose.

Additional new features (to an otherwise already good looking tool) are two little lights. The **yellow** one is the "memory register"—which stores intermediate answers for continuing calculation and saves a lot of time.

The **red** one prevents (or tries to) human errors such as overflow. It makes real status: a perfect, no mistake human!

For looks and efficiency Compet-30B on your desk frees you for time at the club or long, long lunches.

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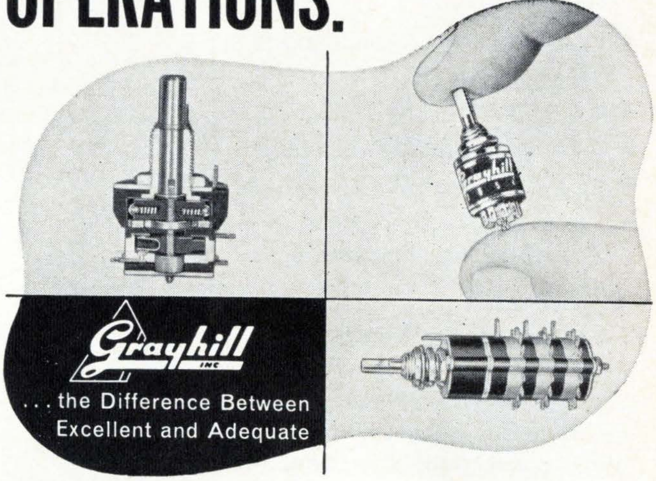

Select Materials:

- Contacts: Silver Alloy, Silver Plated Brass, Gold Plated when needed
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"PIONEERS IN MINIATURIZATION"

. . . desk-top version for go, no-go tests . . .

der test is mounted directly onto the performance board, minimizing the length of the leads between tester and circuit.

I. Stable, adaptable

Since the 553 is digitally controlled, accuracy is inherent. The unit's built-in clocks operate at increments of 10 nanoseconds and have a jitter of ±20 picoseconds. This accuracy makes the instrument ideal for true differential measurements in time.

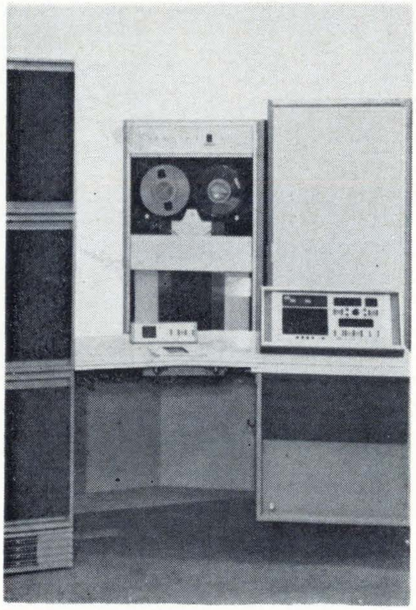
The 553 is an adaptable test station. With little or no modifications, such things as environmental chambers for temperature and humidity tests can be added.

Cousin. For the user who doesn't need the dynamic capabilities featured by the 553, TI is offering a cousin, the 668—a desk-top instrument that offers a go, no-go unit for d-c tests. It can test both chips and encapsulated devices. Priced at $33,000, the 668 offers multiplexing accessories so it can be used with several probe stations.

To achieve test flexibility, TI designed the 668 with five voltage supplies, one current supply, and two load resistors, all of which are directly programable.

II. Modifications

Although the 668 is a go, no-go



Using tape. In this configuration, a magnetic tape unit programs model 553 test station.

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. . . programing is easy, takes less than 5 minutes . . .

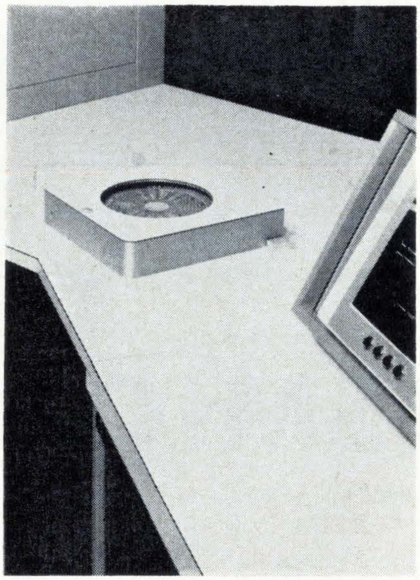
instrument, it is fairly adaptable. For example, the user can select any of nine "fail" categories and any of three "pass" categories; hence, the user can modify this program for military requirements or less stringent industrial requirements.

Like the 553, the 668 can be tape-programed to run a series of tests; either a Friden or a Dura typewriter can be used to prepare the tape. Program words are gated to the addressed functions by flip-flop registers and stored until changed. And for visual verification of the state of each flip-flop register, or memory, a display is provided.

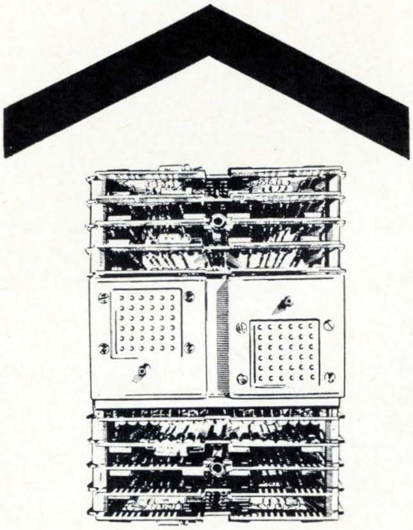
Both the 553 and the 668 were developed originally for in-house use by TI, but are being offered commercially to other producers.

Both testers use a human language program—a variable word-length system with logic designed for unlimited number of words. Each word has an individual address for each instruction. Programming time is less than 5 minutes per test and conversion from written program to perforated tape is done on any typewriter with eight-bit tape punch facilities.

Texas Instruments Incorporated, Apparatus division, Houston. **[429]**



Fixture. Also available as an accessory is a special fixture for integrated circuits that can work with Model 668.



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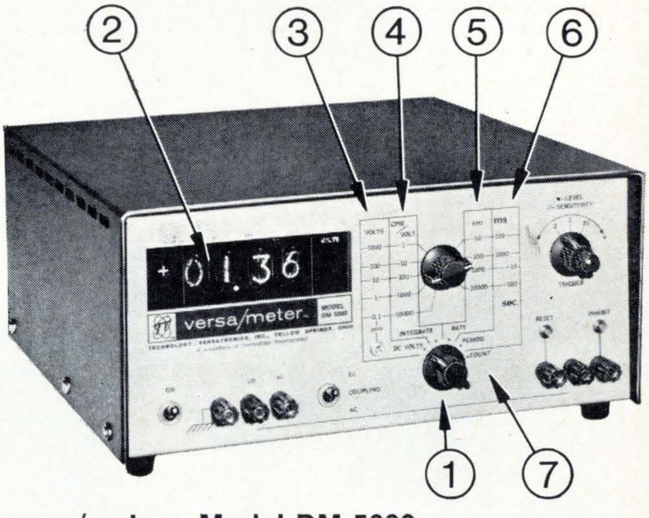

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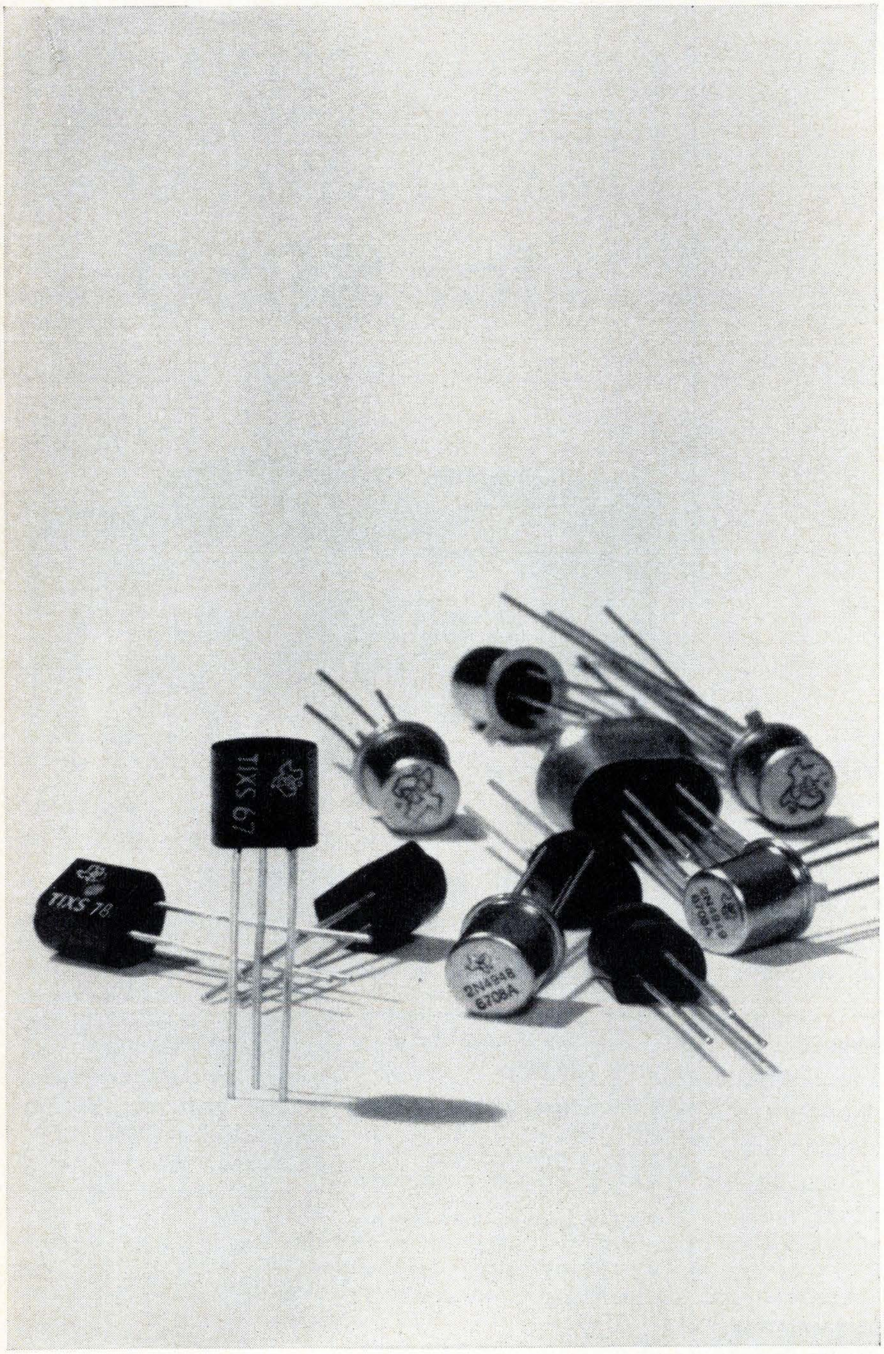
Circle 247 on reader service card

New FETs, UJTs and SCRs from TI to optimize your circuit designs



Improve your products, create new designs with these "firsts" from Texas Instruments: • six new families of FETs • six unijunctions • four low-cost SCRs.

Most of these devices are available in the exclusive SILECT™ package with TO-18 pin-circle lead configuration. SILECT transistors are backed up by more than 10,000,000 hours of testing. A preliminary report concludes that SILECT transistors are capable of meeting military specifications and are as reliable as metal can devices tested under the same conditions.

Circle 281 for Reliability Report.

New low-cost, high-voltage FET replaces vacuum tubes

The new TIXS78 silicon n-channel FET offers a 300-volt minimum breakdown voltage, making it a one-for-one replacement for vacuum tubes in such applications as high-voltage switching and large-signal amplification.

The new FET is priced for computer, industrial, communications and entertainment usage.

Circle 282 for data sheet.

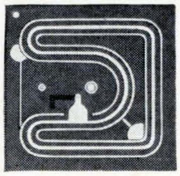
New tetrode FET features industry's highest transconductance to capacitance ratio

The TIXS80 is a high-frequency metal-can tetrode FET that has a minimum transconductance of 5,000 μmhos with a maximum reverse transfer capacitance of 0.8 pF. A second gate simplifies biasing, AGC, and oscillator injection circuitry. The TIXS80 is designed for mixer and automatic gain-control applications.

In rf amplifiers, it provides high, stable gain at frequencies of 30 to 300 MHz without neutralizing.

Circle 283 for data sheet.

Industry's first plastic-encapsulated MOS FET



The TIXS67 is a p-channel silicon enhancement-mode field-effect transistor. It is the first such device to be encapsulated in plastic.

The unit features high transconductance (3500 to 6500 μmhos), low feedback capacitance (4 pF), and the lowest leakage characteristic to be found in a plastic-encapsulated device (50 pA). These characteristics make it suitable for switching and high-input-impedance amplifier applications from dc through medium-frequencies.

Circle 284 for data sheet.

New economy matched-pair FETs

Here is a low-cost matched-pair FET assembly for analog computers, comparators, and differential amplifiers. The n-channel TIS68 pair, similar to the 2N3819, is matched for gate-leakage current and gate-source voltage. I_{DSS} and transconductance are matched within 5%. Minimum transconductance is 1000 μmhos, maximum input capacitance is 8 pF, and reverse-transfer capacitance is 4 pF maximum.

A metal clip is furnished for banding devices together.

Circle 285 for data sheet.

Matched dual FETs have high common-mode rejection capability

This is the first dual FET having matched output admittances as well as matched transconductances for improved common-mode rejection capability. Designated 2N5045, this TO-18 type metal-can dual is ideal for general-purpose differential amplifier applications. Output admittance differential is within 1 μmho; transconductance and I_{DSS} are matched within 5%. The 2N5045 is priced below comparable pairs which are matched to a lesser degree.

Circle 286 for data sheet.

Nine new FET switches feature lowest on-resistance

Here are industry's first low on-resistance switching FETs. The TIS73-75 series is offered in the SILECT package, while a metal-case TO-18 series is designated 2N4856-61.

Low on-resistance (25 to 60 ohms max.) and extremely low leakage (0.25 and 2.0 nA max.), make these devices unusually versatile.

Circle 287 for data sheet.

New planar UJTs offer optimized characteristics for specific applications

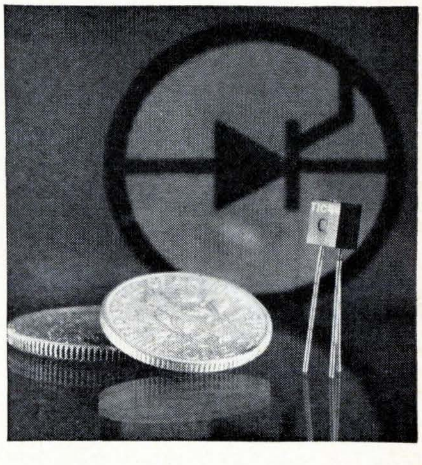
The 2N4892-94 series of planar silicon UJTs in SILECT packages and the 2N4947-49 family of metal-case equivalents are the first such devices on the market which are characterized for specific applications. They are designed for use as long-time-delays, SCR triggers, or high-frequency relaxation oscillators.

Leakage is typically 0.1 nA... one-thousand times lower than comparable alloy types. Other advantages are low base-emitter saturation voltage and high pulse-output voltage.

Circle 288 for data sheet.

Smallest, lowest-cost SCR

TI's new TIC44-47 SCRs are priced only one-third as much as the metal-can equivalents. They are also the smallest SCRs available. The series is rated for 600 mA continuous dc current at 30, 60, 100 and 200 volts. A maximum gate-triggering current of 200 μA provides high turn-on gain.



Applications include motor speed controls, ignition systems, light flashers, light dimmers and a-c phase control systems.

Circle 289 for data sheet.

Call your nearest TI sales representatives or authorized distributor for more information. If you prefer, write us at P. O. Box 5012, Dallas, Texas 75222.

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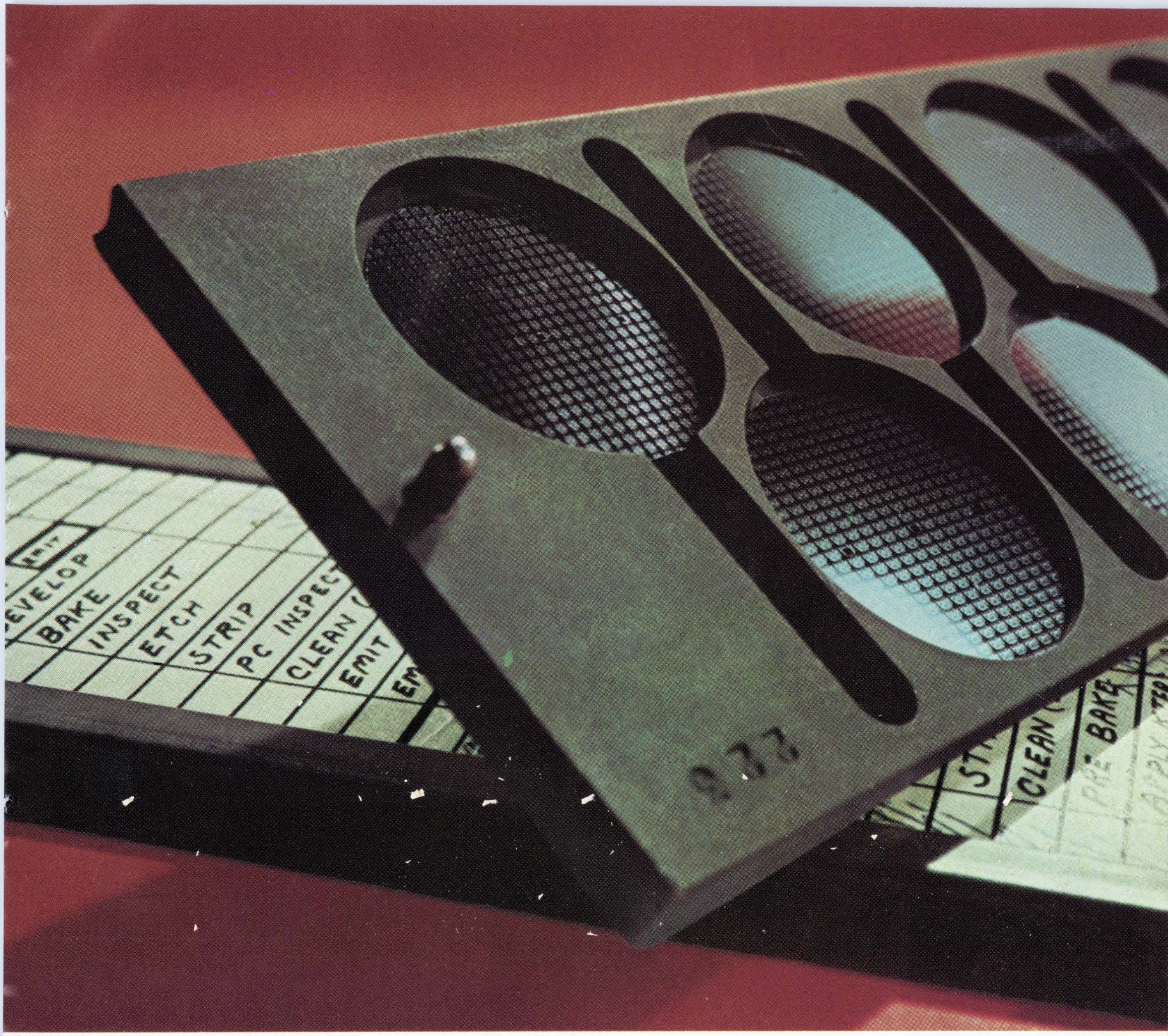

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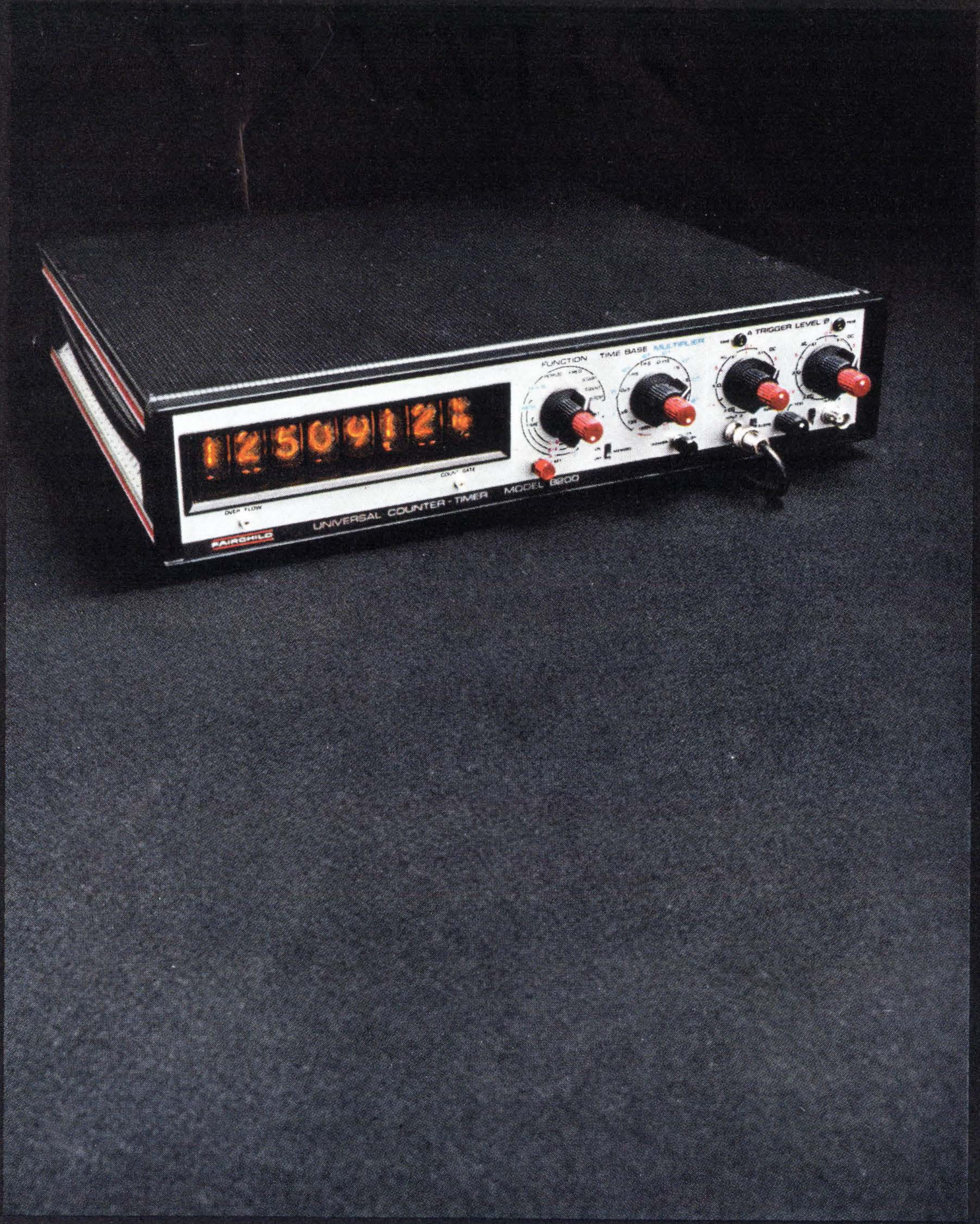
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TIME BASE MULTIPLIER
A TRIGGER LEVEL B
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New Books

Potent blend

Handbook of Engineering Sciences
Edited by James H. Potter,
D. Van Nostrand Inc., 1,347 pp., $37.50

This weighty volume is commendable for its recognition of the broad range of activities of modern engineers and the need for information organized in novel ways for application to interdisciplinary problems.

The book covers mathematics, classical physics, modern physics, chemistry, graphics, statistics, theory of experiments, and mechanics.

A second volume, scheduled to appear later this year, is expected to deal with the applied sciences, and, assuming that the same high quality of presentation is maintained, the set should provide a good working reference for the engineer who needs to know a moderate amount about a lot of things.

As with all anthologies, there are problems. Sixty-eight authors contribute to a wide variation in depth of treatment from one subject to another, and to much duplication in content. But some of the duplication is helpful.

For example, the reader can find at least five different introductions to quantum mechanics, depending on whether he is interested in fundamentals of quantum theory, quantum electronics, quantum mechanics (in the chemistry section), early quantum theory (under structure of matter), or quantum electrodynamics (under optics).

The editor has done an effective job in logically organizing each section. Extensive references are included for each subject. The level of the material is approximately that of first-year graduate students specializing in specific fields, and the book should be useful to the advanced engineer.

While many basic topics are covered, some are slighted. For example, only seven pages are allocated to semiconductors—largely mathematical. On the other hand, sections relating to materials' properties, instrumental analysis, organic and inorganic chemistry, optics, and acoustics are much more comprehensive and styled to provide background for engineers whose main body of experience is not in these fields.

The section on mathematics is reasonably complete in that the basic equations and terms are given for basic calculus, as well as summaries of complex variables, Boolean algebra, vector analysis, matrices, and tensors.

C.G. Thornton
Microelectronics Division
Philco-Ford Corp.
Blue Bell, Pa.

Through the gate

MOS FET in Circuit Design
Robert H. Crawford
McGraw-Hill Book Co., 136 pp., $10.00

A bright future is predicted for the metal oxide semiconductor field effect transistor even though the device now performs far below expectations (present switching speeds are nearly 100 times below theoretical limits). The author, using his experience at Texas Instruments Incorporated, provides valuable practical and theoretical data for the MOS FET circuit designer. He covers the subject comprehensively, using abundant and well-executed illustrations. Unlike other volumes in this series by TI authors, each chapter is supplemented with useful and pertinent references.

At the outset, Crawford gives a concise summary of operation principles and applications, and a prediction of the economic future of the MOS FET. This material is a good introduction for the engineer desiring only a basic knowledge of MOS FET's. The theory in this chapter is elementary, covering only basic definitions and operations of the device; at the end of the section the author recommends how and where the MOS FET can be most effectively used.

The author explains the details of three aspects of the MOS FET: theory of operation in chapter 2, empirical verification of equations in chapter 3; and analysis of transient response of the device in chapter 4.

The chapter on theory of operation covers the subject well, with qualitative and quantitative analyses and a summary of MOS equations. Crawford deserves credit for giving the reader a complete explanation of the notations that he uses throughout the book.

Theoretical equations are empirically verified in the section on MOS FET characteristics. The square-law relationship, transconductance, saturated and triode region operation, and mobility are covered and a device model is developed.

The final chapter discusses analog applications of the MOS FET, various types of MOS circuits, and MOS-bipolar combinations.

Edward Keonjian
Grumman Aircraft Engineering Corp.
Bethpage, N.Y.

Recently published

Medical Electronic Laboratory Equipment (1967-68) Edited by G.W.A. Dummer and J. Mackenzie Robertson, Pergamon Press Inc., 1305 pp., $30

The volume, which incorporates information from Britain, America, Europe, and Japan, provides data sheets on a comprehensive range of electronic and nucleonic equipment for use in laboratories concerned with all branches of medical research.

Elements of Energy Conversion, Charles R. Russell, Pergamon Press Inc., 496 pp., $9

Written at the undergraduate level, the book presents information in terms of fundamental thermodynamics on energy conversion and energy storage. Combustion, electrochemical processes, and direct conversion are discussed.

Theory and Applications of Active Devices, Herbert L. Krauss, Herbert J. Reich, John G. Skalnik, Van Nostrand Co., 739 pp., $12.75

Active circuit elements are treated in a manner that applies to all active devices. The book is intended for an undergraduate, three-semester course in electronics, and, as such, mathematical proofs have been replaced by problem solving.

Methods of Signal and System Analysis, George R. Cooper, and Clare D. McGillem, Holt, Rinehart & Winston Inc., 432 pp., $11.95

The text is a mathematical analysis of systems rather than circuits. After a basic discussion of systems, convolution is introduced. This is followed by a discussion of Fourier and Laplace transforms and random signal probability functions.

Electronic Designer's Handbook, T.K. Hemingway, Business Publications Ltd., Distributed in U.S. by TAB Books, 296 pp., $8.95

Providing a reference on transistor circuit design, the book analyzes specific circuits so that the reader can apply them to his own designs. Chapters on linear-sweep and constant-current circuits provide information not normally found in books of this type.

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Technical Abstracts

Study and Store

Learning control of valve actuators in direct digital control systems
Murray Garden
Leeds and Northrup Co.
North Wales, Pa.

The nonlinear characteristics of electric drive units used as valve actuators make it difficult to apply conventional analog feedback control. A more practical technique is a direct digital control system that learns the actuator's characteristics, stores them, and then sends signals based on this data back to the actuator. This procedure, learning control, allows continuous adaptation to the nonlinear characteristics of the valve actuators.

Learning control offers two major advantages over conventional feedback methods. First, the system costs less because less stable devices can be used since their characteristics are continuously being recorded. Second, the system has better reliability, since automatic adaptation to changing conditions allows for drastic system simplification. Moreover, continuous checking of the actuators can pinpoint deteriorating components earlier.

The valve actuator is an induction motor geared down to operate a valve at low speed. The unit is positioned by applying power for a given amount of time. The travel of the unit, measured in percent of full scale, is a highly nonlinear function of the number of cycles of applied a-c power. The unit's characteristics, however, can be divided into two fairly linear regions, and a separate learning algorithm can be applied to each region.

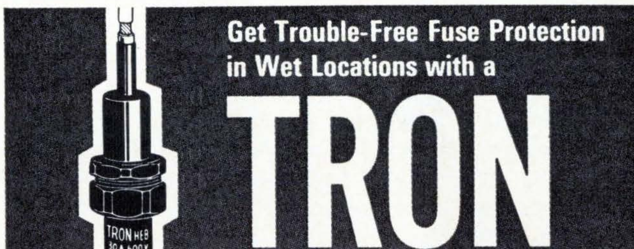
The direct digital control system operates by sequentially scanning the variables—flow rate, pressures—and converting the outputs to digital form for input to the computer. The digital input is processed according to a control algorithm, and the result is a number representing the new valve position or the required position change, depending on the particular algorithm used. These signals are then transmitted sequentially back to the valve actuators.

Presented at the Joint Automatic Control Conference, Philadelphia, June 28-30.

Through thick and thin

Communications via seismic waves employing 80-hz resonant seismic transducers
K. Ikrath and W. Schneider
U.S. Army Electronics Command
Fort Monmouth, N.J.

Narrowband amplitude or phase-modulated seismic signals can be useful in communications where conventional radio and wire transmissions are not feasible, for example, between points far below the earth's surface. Ranges of up to 600 meters have been achieved through soft media like ice and water, and up to 2,000 meters



Technical Abstracts

through hard media—rock formations and the like.

One of the most important limitations on seismic tranmission, however, is signal distortion. In soft media, severe distortion is caused by multipath propagation in the upper, lower-velocity layers of the earth, while in hard media, distortion is produced by acoustical reverberations in mine shafts and weathered rock zones.

The seismic signal carrier frequency was chosen as 80 hertz. Above 100 hz, audio coupling from the transducer to the air becomes intolerable, while below 80 hz electrical interference at power line frequencies precludes readable transmission. Bandwidth is 3 to 5 hz. Design of efficient seismic signal transmitters depends on mechanically matching the signal source to the propagation medium. A slotted steel tube, acting as a mechanical transmission line transformer, was connected at one end to the voice coil of an electrodynamic speaker system. The tube was mounted at the other end on a ground piston that sends the signal into the earth. The transducers designed for transmitting in soft media are limited to a drive power of under 10 watts, and are also used for reception of the 80-hz signals. Transducers designed for transmitting in hard media have a drive power rating of 200 watts.

Presented at the IEEE International Conference on Communication, Minneapolis, June 12-14.

Laser links

Application of lasers to tactical ground communications
D. Smith, M. Lipton, D. Shed, R. Johnson
U.S. Army Electronics Command
Fort Monmouth, N.J.

Lasers, in opening new techniques for military field communications, promise not only to supplement conventional wideband methods but also to replace bulky, unreliable cables in line-of-sight applications. The high data rate abilities of the laser make it an especially useful link for tactical computers. But work is still needed to characterize

the transmission media and fit the laser modulation and detector schemes to the media.

Two experimental links were constructed. The first covered about 300 yards using a helium-neon continuous gas laser with a 3-milliwatt output. An external electro-optic crystal amplitude-modulated the beam, and a collimator reduced its divergence. After passing through the 150-yard one-way path, the light was reflected back to the source and detected by a photodiode. The second link was about 500 yards long. Here a 7-mw He-Ne laser was used and the beam collimated with a Questar field telescope. An optical filter and photomultiplier replaced the diode on the receiving end.

The atmospheric path passed over rolling woods, open fields, suburban homes, and a stream and marsh area. The beam was initially aimed at a reference point and its excursions with time were plotted.

The probability of bit error was also investigated, since it is of paramount importance in the transmission of digital information. The beam was amplitude-modulated at a 250-kilobit rate on the 300-yard link. An electronic comparison was made between the transmitted and received signals, and the errors were counted as a function of percent modulation. For clear weather and light wind, the probability of bit error was less than 10^{-5} at 4.5% modulation, but the modulation level needed to maintain the same probability of error increased as the weather became more inclement.

The probability of bit error was also determined for different atmospheric lengths.

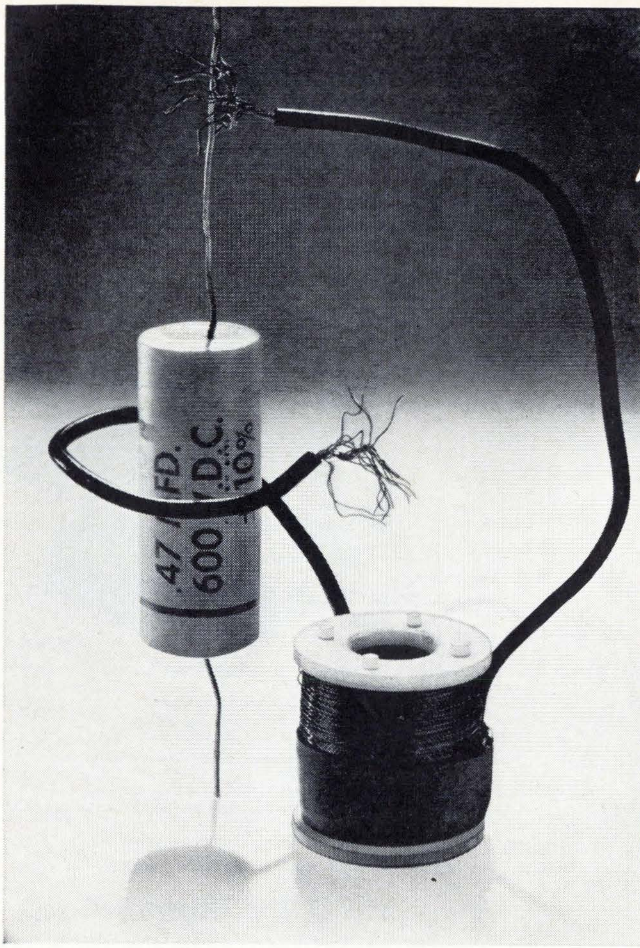
Presented at the IEEE International Conference on Communication, Minneapolis, June 12-14.

Forecasting rfi

A new approach to the prediction of component-generated noise

John R. Gerry
Raytheon Co.
Wayland, Mass.

A graphical technique may be used to accurately predict the levels of radio-frequency interference pro-



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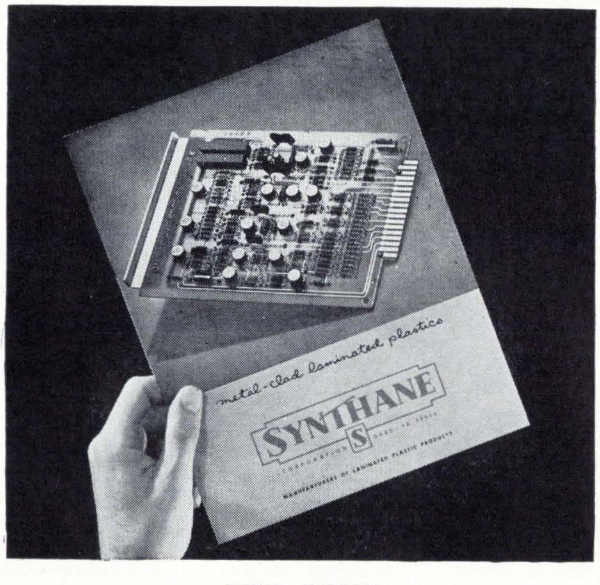

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Technical Abstracts

duced by many noise sources in a large electronic system.

Because rfi is difficult to detect, many equipment designers neglect it when devising complex systems. However, today's integrated circuits permit such high packaging densities that rfi can no longer be ignored.

The new approach consists of four separate steps: a determination of the potential noise sources, a cataloging of the different sources, a graphical prediction of the individual noise source spectrums, and a calculation of the composite effect. The technique is not limited by system complexity —it is equally applicable to one equipment cabinet, a subsystem of cabinets, an entire weapons system, or even a continental defense network. In practice, however, the approach is most effective when predicting the noise produced by a group of equipment cabinets.

In the first step, a cabinet is viewed as an array of elementary dipoles. While an array may appear complex, the cabinet usually contains only a few signal sources that contribute significantly to the noise spectrum being considered. It is even possible to combine many sources using superposition.

The cataloging step groups the various sources into areas such as video, intermediate, or radio frequency, and subdivisions like continuous or time gated.

Once the sources are cataloged, the noise spectrum is predicted by a set of graphs of the radiation spectrum associated with each source. Little analytical effort is required to develop the graphs since they are derived from a set of reference charts for the field around an elementary dipole. These graphs are plotted by reducing the dipole equations to an arrangement of variables that yields the maximum value of the field for all points in space.

The last step is to generate the composite result with a number of methods, ranging from a complete prediction tabulation to a more complex spectral density plot.

Presented at the 1967 Electromagnetic Compatibility Symposium, Washington, July 18-20.

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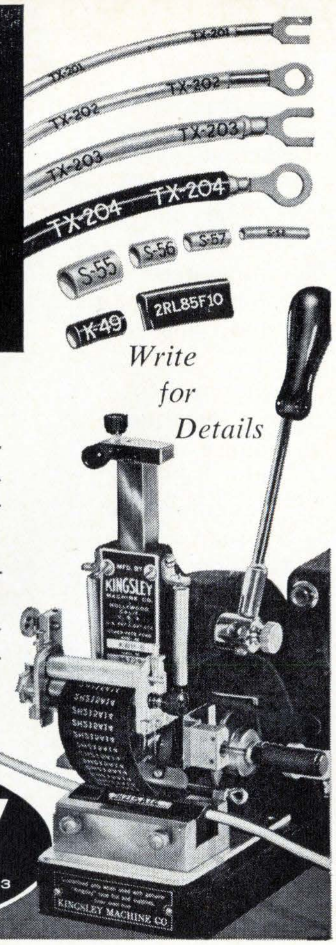

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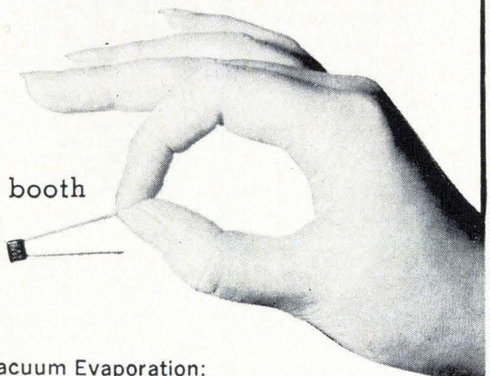

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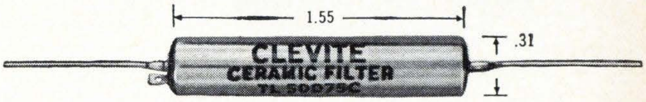

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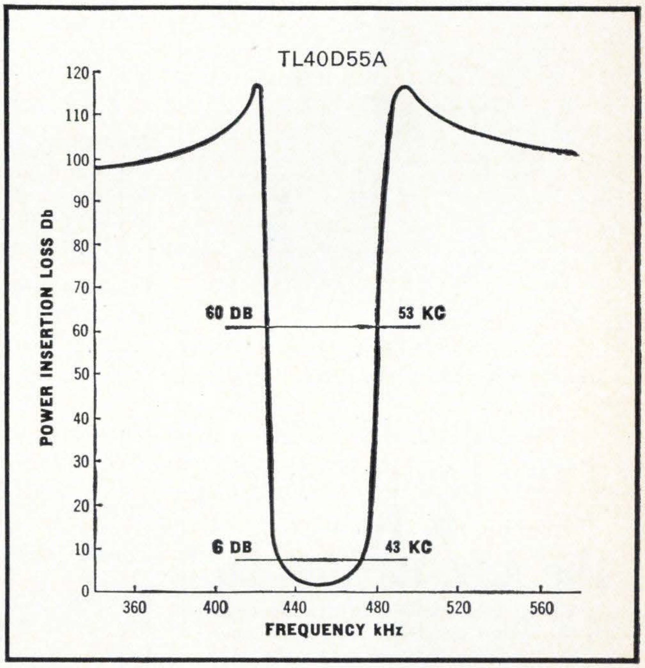

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TL-6D11 (A)	6 kHz	11 kHz	TL-40D55 (A)	40 kHz	55 kHz
TL-8D14 (A)	8 kHz	14 kHz	TL-45D65 (A)	45 kHz	65 kHz
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New Literature

Glass capillaries. Specialty Glass Products Inc., 145 Terwood Rd., Willow Grove, Pa. A technical bulletin describes glass capillaries for thermocompression bonding, flame-off, wire feed, ink marking, and other IC production applications.
Circle **446** on reader service card.

Piezoresistive accelerometer. Endevco Corp., 801 S. Arroyo Parkway, Pasadena, Calif. Characteristics of a miniature piezoresistive accelerometer are detailed in technical bulletin No. 174. [**447**]

Low-pass filter. Dynamics Instrumentation Co., 583 Monterey Pass Road, Monterey Park, Calif. Bulletin PD63-1261 gives complete specifications for the Model 6371 variable low-pass filter that provides both linear phase and Butterworth characteristics. [**448**]

Photochopper modules. Clairex Electronics Inc., 1239 Broadway, New York 10001. Two high-speed cadmium sulfide photochoppers are described in a four-page bulletin. [**449**]

Pressure switches. Sigma-Netics Inc., 100 Route 46, Mountain Lakes, N.J., announces a brochure and technical data folder on series 703 pressure switches. [**450**]

Signal-processing devices. A/R-Anzac Electronics Co., Moody's Lane, Norwalk, Conn. A six-page short-form catalog covers a complete line of devices for processing r-f, i-f, and microwave signals. [**451**]

Dvm techniques. Dana Laboratories Inc., 2401 Campus Drive, Irvine, Calif. 92664, has available a technical paper entitled "Techniques Affecting the Accuracy and Reliability of High-Performance Digital Voltmeter Measurements." [**452**]

Instrumentation catalog. Natel Engineering Co., 7129 Gerald Ave., Van Nuys, Calif. 91406, has a six-page catalog on its complete line of signal-conditioning and transducer instrumentation. [**453**]

Thermocouples. Nanmac Corp., 140 Crescent Rd., Needham Heights, Mass. Catalog TB-167 covers a line of flexible-ribbon and intrinsic thermocouples for surface temperatures. [**454**]

Power supplies. Transformer Electronics Co., Boulder Industrial Park, Boulder, Colo. 80302, offers a catalog on miniature regulated power supplies for aerospace, military, and industrial systems. [**455**]

Millivolt amplifiers. Quindar Electronics Inc., 60 Fadem Road, Springfield, N.J. Bulletin 121 contains photos, description, specifications, and ordering infor-

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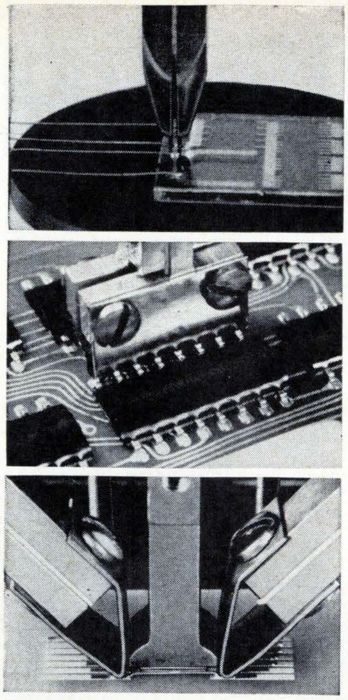

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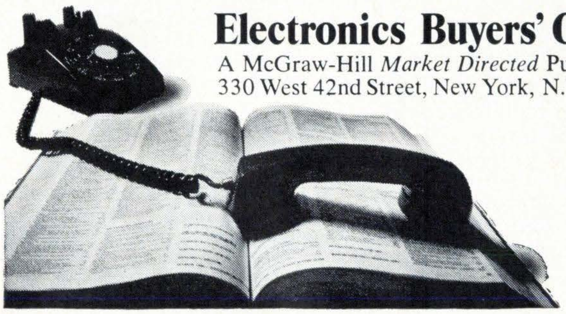

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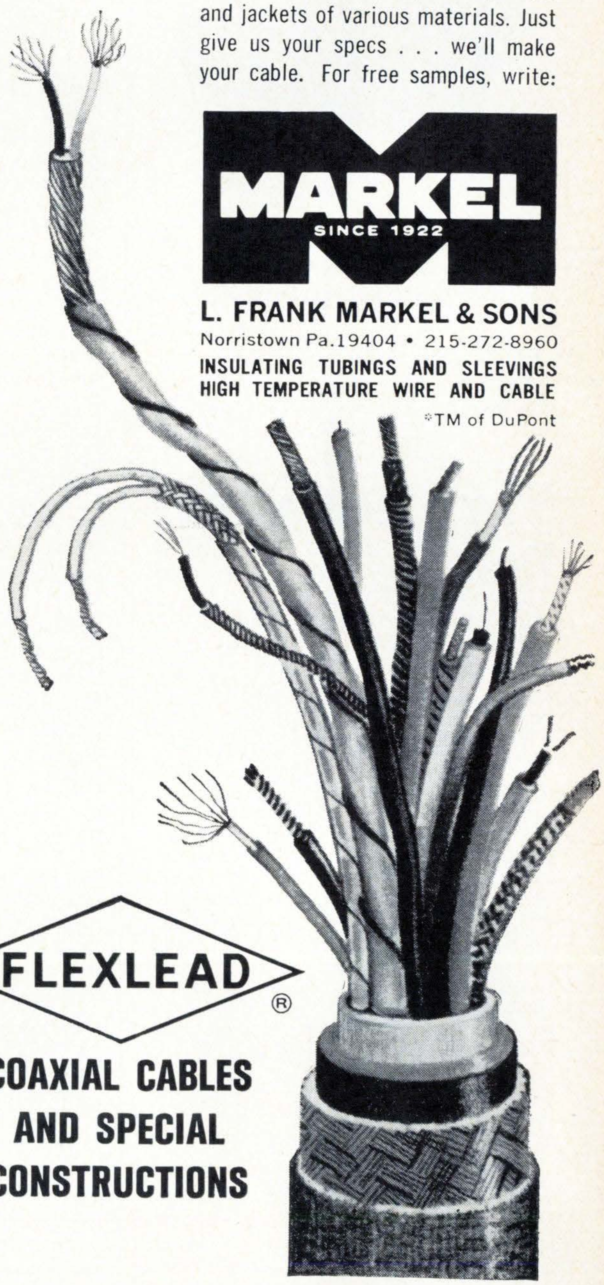

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New Literature

mation on QMVA-10/QMVA-10-1 millivolt amplifiers. **[456]**

Test adapter. McKee Automation Corp., 7315 Greenbush Ave., N. Hollywood, Calif. 91605. Bulletin TA-101R discusses a test adapter that provides low-resistance connections from test points on p-c boards and computer backplanes to circuit analyzers. **[457]**

Transfer molding press. Morris Enterprises Inc., 16799 Schoenborn St., Sepulveda, Calif. A catalog sheet describes a molding press design to replace the potting process in the encapsulation of components. **[458]**

Vacuum products. Vacuum division, Varian Associates, 611 Hansen Way, Palo Alto, Calif. 94303, has published a 24-page condensed catalog outlining its range of high and ultrahigh vacuum products. **[459]**

Traffic control system. Eagle Signal division, E.W. Bliss Co., 736 Federal St., Davenport, Iowa 52808. A four-page, four-color pamphlet covers the integrated-circuit Moduvac system of traffic control. **[460]**

Ferrite components. Western Microwave Laboratories, 1045 Di Giulio Ave., Santa Clara, Calif. 95050, has available a pocket-sized calculator with instruction sheet to assist in specifying ferrite components. **[461]**

Scan/recording system. General Electric Co., Schenectady, N.Y. 12305. Product data sheet A6650G covers the Inframike scan/recording system, a moisture-gauging system for web profile application at the dry end of a paper machine. **[462]**

Electrolytic capacitors. Cornell-Dubilier Electronics division, Federal Pacific Electronic Co., 50 Paris St., Newark, N.J. A 32-page cross reference includes all electrolytic capacitors used in color chassis from 32 set manufacturers. **[463]**

Coaxial latching switches. Microwave Associates Inc., Burlington, Mass., has released a bulletin on the MA-7524 series of compact, coaxial latching switches. **[464]**

R-f circuit design. Motorola Semiconductor Products Inc., P.O. Box 955, Phoenix, Ariz. 85001, has compiled a 150-page booklet containing circuit-design information from its r-f applications engineering staff. **[465]**

Ceramic capacitors. Titania division, American Lava Corp., Manufacturers Rd., Chattanooga, Tenn. 37405, has issued Bulletin 677 giving details on a wide range of mutilayered ceramic capacitors. **[466]**

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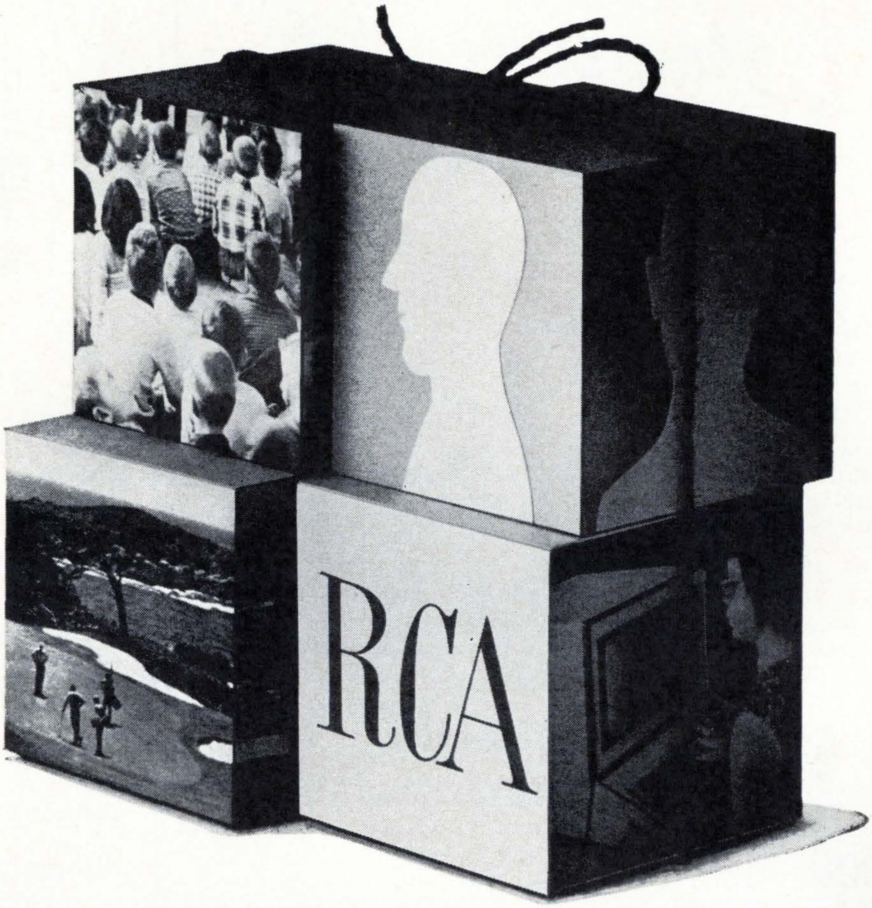

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Newsletter from Abroad

August 7, 1967

France may lift Mideast arms ban

Insiders in the French aerospace industry now say there's a good chance that President de Gaulle will end his embargo on arms shipments to the Middle East early this fall. The reason: **the ban may hurt French exports of military equipment, now running about $500 million yearly, elsewhere in the world.**

Already military officials from South Africa and Australia have asked Defense Minister Pierre Messmer to clarify French armaments policy. Both countries are big buyers of French aerospace and military electronics equipment. But both want assurances that they won't be hampered in the future by a ban on spare parts if they use the equipment for operations that conflict with de Gaulle's policies.

Messmer, whose ministry strongly backs export efforts by French military hardware producers, is urging de Gaulle to lift the ban. Otherwise, he is arguing, France will lose her position as an international arms supplier. Avions Marcel Dassault, the country's leading military aircraft maker, is so convinced Messmer's argument will prevail that it plans to start shipping Mirage fighters to Israel again by October.

Bonn balloons space spending

Despite the Kiesinger government's austerity campaign to wipe out a $2 billion budget deficit, a huge boost in West German space outlays is in the offing.

The Ministry for Scientific Research will get some $457.5 million for space projects over the next five years. And if the economy comes out of the doldrums in time, another $47.5 million will be added to it between 1969 and 1971. **The $505-million total is almost four times more than what was spent in the five years ended in 1966.** About 30% of space spending is for electronic hardware.

Accompanying the stepped-up spending will be a shift in space emphasis. Up to now, the bulk of West German space money was used for international projects, like the European Launcher Development Organization's rocket program. But from now on, the bulk of the expenditures will be for national projects and the Franco-German telecommunications satellite "Symphonie."

Italian tv firms push for color before '70

Public discontent over the color-television policy of Aldo Moro's coalition government is beginning to surface in Italy.

The loudest complaints come from the television industry, which has been hammering at the fact that Italy will be one of the last countries in Western Europe to begin color broadcasting unless the government revises its startup date—1970 at the earliest. Britain, France and West Germany will all start color programs later this year.

Although still far from a clamor, enough public pressure has built up recently to force the Socialist Party to reiterate its opposition to an earlier startup. It was the Socialists who forced the coalition government to stay the start of colorcasts [Electronics, Oct. 3, 1966, p. 25]. They maintain that production of high-priced color sets would endanger both the planned economic growth rate for Italy and—largely because the picture tubes would have to be imported—the balance of payments.

The balance-of-payments argument, however, doesn't stand up any more. Early this summer, RCA announced plans to build a shadow-mask picture tube plant near Rome. Now, a Philips subsidiary says it will

Newsletter from Abroad

build a color-tube plant near Monza in the north. But neither company, apparently, intends to break ground for an Italian picture-tube plant until the Moro government sets a firm date for starting colorcasts.

Computer mishap leaves Zambia minus statistics

Zambian officials no longer have statistical bench marks with which to check out their balance-of-payments position or the effectiveness of sanctions against Rhodesia, their white-supremacy neighbor. **Gross errors have turned up in the program of the kingpin computer for the national accounting system, and their discovery has forced the Zambian government to scrap all its trade figures for 1967.** There's doubt, too, about statistics for the past few years.

Officials say programers from Britain whose contracts ran out earlier this year had the computer adding sets of figures that should have been subtracted. **A new staff of data-processing experts started reprograming import-export statistics this month, but the first figures won't be forthcoming until the end of the year.**

CSF bowing out of U. S. tube plant

France's leading electronics company, CSF-Compagnie Generale de Telegraphie sans Fil, has all but written off its money-losing effort to secure a foothold in the U.S. military market for high-power microwave tubes.

The company has agreed to sell most of its holding in Warnecke Electron Tubes, the manufacturing subsidiary it set up in Illinois for the effort, to the Northrop Corp. The deal gives Northrop about a 90% interest in Warnecke. Previously, Northrop had a minority share acquired when it took over the Hallicrafters Co.

Nippon Electric sells computer to Rumania

The Nippon Electric Co. has made a small beginning in the East European computer market. It has sold to the Rumanian government one of its ultrasmall Model 1240 business computers, which has an 800-word memory and cycle time of 5.3 microseconds.

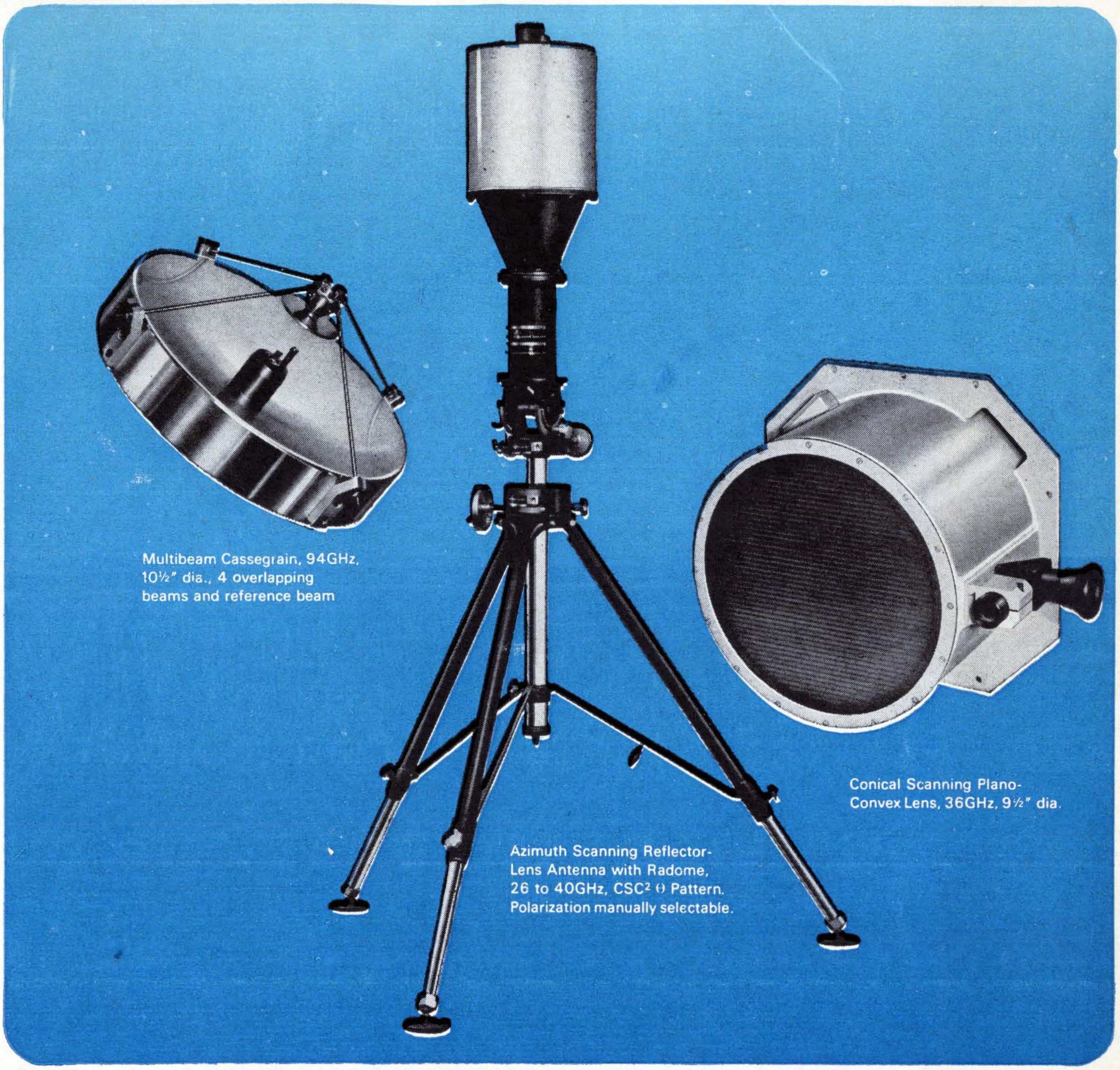
The contract for the $80,000 machine can't be signed until the Japanese government makes sure the export doesn't violate the embargo on shipments of strategic equipment to Communist-bloc countries. **Approval, though, seems to be a formality even though the Model 1240 has integrated circuits.** Larger computers with IC's already have been shipped by Western producers to East Europe.

Boeing 747 to get Elliott system

Elliott-Automation Ltd. has made its first breakthrough into the U.S. commercial aircraft market.

The British company's fuel-flow measurement gear has been picked for the Boeing 747 by the Electro Development Corp., subcontractor for the jet transport's fuel-flow system. Electro Development will produce most of the hardware for Elliott's design, which is basically the same as the Elliott equipment going into the Concorde supersonic transport and the Royal Air Force's Phantom fighters.

Elliott previously had won U.S. contracts for military-aircraft hardware under the offset buying plan that the Pentagon agreed to when Britain bought 50 F-111 fighter-bombers [Electronics, Sept. 5, 1966, p. 199]. **But the deal with Electro Development is the first in which Elliott bested U.S. competitors protected by tariffs.**



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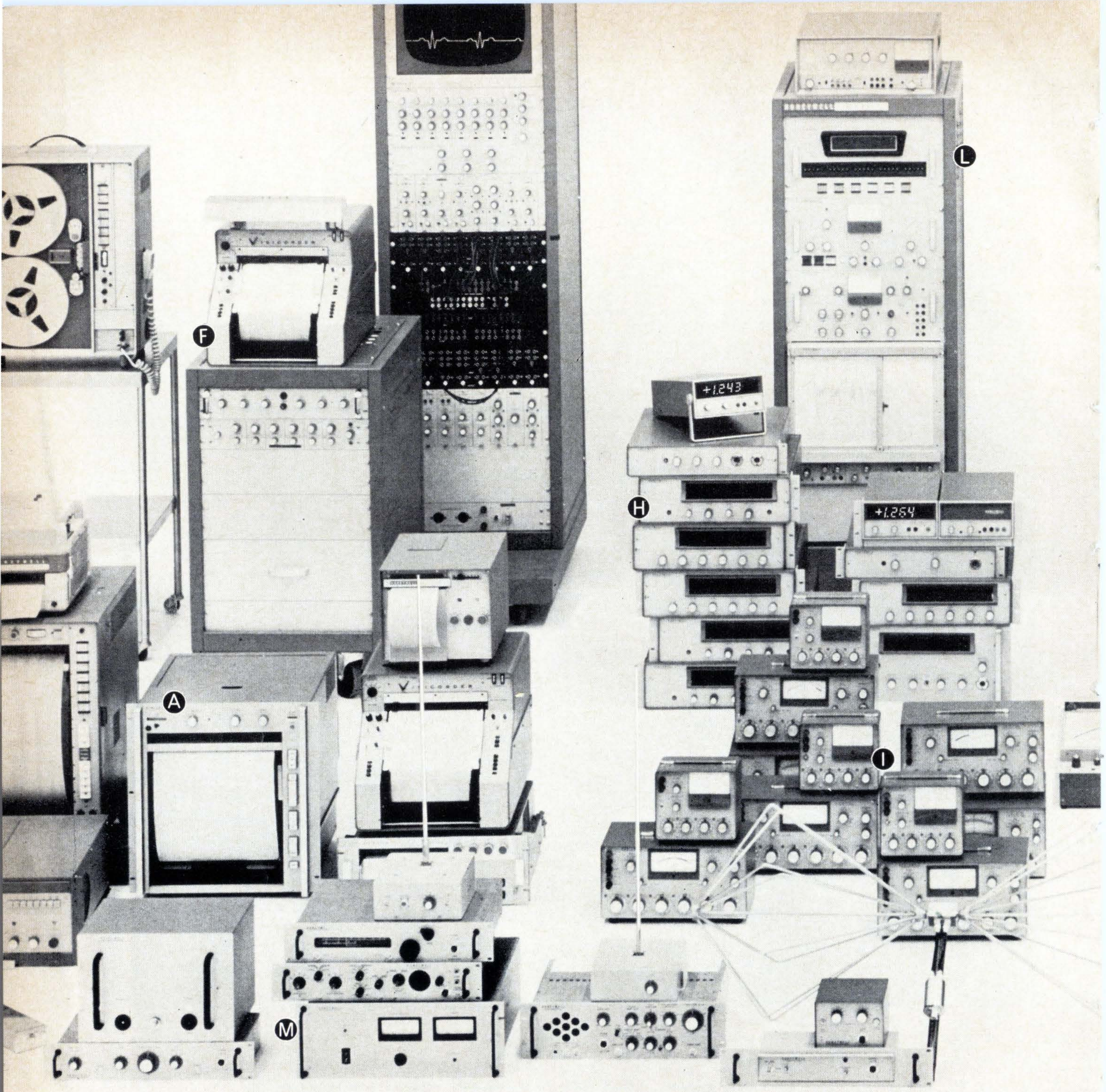

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Electronics Abroad

Volume 40
Number 16

Japan

First reader

Post office officials in Japan now have in sight the critical item of hardware they need to automate mail handling—a letter sorter that can read handwritten zip codes.

After successful tests with an experimental version, the Ministry of Posts and Telecommunications plans to put two or three automatic sorters into post offices for field tests starting next spring. The trials will be part of a $5.5 million effort to install a zip-code system for the country.

The zip codes will consist of five Arabic numerals, and Japanese postal officials figure that about 90% of the time the codes will be handwritten. That rules out sorters that can read only typewritten numerals. Even those are tough to build. The U.S. Post Office Department had considerable teething troubles with its first reader-sorter, a prototype unit made by the Philco-Ford Corp. and first put into service in Detroit 20 months ago. Now, Philco-Ford is installing sorters at post offices in Boston and Houston.

And to make the problem more difficult, the Japanese sorter has to read numerals written with fountain pens, ball-point pens, felt-tip pens, writing brushes, and pencils. The only restriction the ministry plans to place on mail senders is that they write their digits in small frames preprinted on envelopes.

Fast. The prototype sorter, developed under a government contract by the Tokyo Shibaura Electric Co., reads and sorts six letters a second. That compares to one letter a second for manual sorting. In a test on envelopes written by people from all parts of Japan, the Toshiba sorter successfully read about 95%, shunting the balance to a stack for manual sorting. The error rate was about 1%, no better and no worse than with manual handling.

To deal with handwriting, Toshiba's reader-sorter needs about the same logic circuitry and memory capacity as a medium-size computer. The logic circuits, for example, are built around 3,500 integrated circuit packages. The memory has a capacity of 8,000 words of 32 bits and a cycle time of 1.5 microseconds. It includes in its stored program the dictionary through which the reader identifies digits.

Spotted. Basic input for the recognition is a stepped scan by a vidicon camera of the first three digits of the code (the other two digits are used for manual sorting of small post offices). The camera has a scan width 0.2-mm high, and as it sweeps horizontally across the three digits the image picked up is quantized every 0.2 mm to get a binary input for the memory. Thus a complete scan of the 10-mm high frames in which the digits are written puts into the memory a binary readout based on a 0.2 by 0.2 mm matrix.

Next comes a normalization of the stored information, essentially a thinning of characters written in wide brush strokes and a reduction of large numerals. The stored matrixes of normalized characters then are scanned in three-by-three groups to determine stroke directions and the sequence of characteristics along horizontal lines. The sequences are checked against the dictionary to determine which digit has been read. Because extensive branching is needed to account for slight differences in sequences for the same digit caused by variations in handwriting, the dictionary lists about 1 million sequences.

Two-faced

Anyway you look at it, the flat cathode-ray tube figures high in the scheme of things to come at the Hayakawa Electric Co.

Early this summer, Hayakawa showed an 8-inch flat tube it has in the works. Now the company has

Front and back. Conductive-glass deflection electrodes make image visible from either side of flat cathode-ray tube.

built a two-face version with the picture visible from both front and back.

Hayakawa says the tube could find a place in receivers used in room dividers. Those viewing from behind, though, would see a mirror image of the picture in front. A more likely application might be in displays where a second image would be superimposed from the rear.

Material. Essentially, the see-through flat tube is the same as the one-face version. Its distinguishing characteristic is a pair of electrostatic vertical-deflection plates [Electronics, June 12, p. 246]. To make the two-faced tube, Hayakawa simply switched to a transparent — but conductive — glass for the electrodes.

The deflection electrode is a conductive-glass coating on the back panel of the flat tube. The target electrode is the same glass coating on the faceplate—between the phosphors and the glass.

Fine design

As they jockey for better positions in their highly competitive domestic color-television market, Japanese set makers are whittling down their prices—and costs—whenever they can.

Most of the cost-cutting so far can be traced to simpler cabinets and fewer loudspeakers. Now the Matsushita Electric Industrial Co. has come up with some money-saving circuit kinks. As a result, the company's new 19-inch set at $430 lists for less than any other color set its size in Japan.

Shunt out. Over-all, Matsushita engineers have cut the number of tubes in the new set to 20, five or six fewer than found in most sets. But the key characteristic of the new design is a negative feedback circuit that does away with the high-voltage shunt-regulator tube —usually a 6BK4—used in practically all other color sets.

The circuit, Matsushita says, does more than simply make for a cheaper set. It cuts power consumption and, at the same time, eliminates the need for special precautions against X-ray radiation, which in conventional sets comes mainly from the regulator tube. Also, the feedback automatically compensates for deterioration in the horizontal deflection output tube, so it needs replacement less often. And the crucial component in the feedback circuit, its voltage-dependent resistor, lasts much longer than a regulator tube.

Pulse. The input for the feedback circuit is a pulse picked off a winding on the set's flyback transformer. The pulse, proportional to the peak value of the flyback pulse, is rectified by the voltage-dependent resistor and used to control the grid bias of the horizontal output tube. In other words, the output tube supplies only as much power as is needed to obtain the proper brightness level on the screen.

With a shunt-regulator tube, the output tube works at full power always and excess power in the high-voltage circuit is dissipated by the shunt. When the picture-tube darkens, a high current passes through the regulator tube at high voltage and this triggers X-ray emission. The radiation level can be dangerous if the tube's anode and grid cap are misaligned.

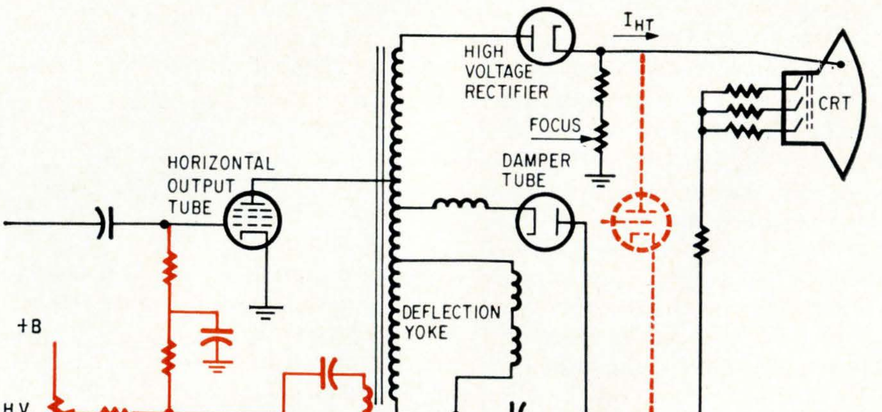
Drawback. Because of the nonlinear characteristics of the voltage-dependent resistor, the feedback circuit also stabilizes the high-voltage output against change in line voltage. However, this leads to a slight problem for the feedback circuit. When the line voltage rises and the power supply follows suit, there is a sharp rise at the plate of the horizontal-deflection output tube. Thus the tube must handle a higher dissipation than it would in sets with a shunt-regulator tube. But Matsushita says the slightly higher cost for the deflection output tube is negligible compared to the over-all savings achieved by replacing the shunt tube with a feedback circuit.

Great Britain

Better memories

As far as Mullard Ltd. is concerned, the ferrite core has just about had it as the mainstay of memories in small computers.

Mullard now expects to slash installed costs of small-computer memories by as much as two-thirds by switching from cores to metal oxide semiconductor integrated-circuit arrays. The expectation is based on the performance of experimental 1,024-bit MOS-transistor arrays being turned out at the company's research laboratories at Redhill. Mullard, a subsidiary of NV Philips' Gloeilampenfabrieken, is a



Banished tube. Negative feedback circuit in Matsushita color set does away with the shunt-regulator tube normally used to stabilize the high-voltage supply. For simplicity, the grid circuit that would be used with the shunt regulator tube (broken lines) is not shown.

major producer of memories.

The company isn't alone in its high hopes for MOS memories. The General Instrument Corp. is producing 128-bit shift registers and Litton Industries Inc. is designing two experimental computers with MOS arrays for both logic circuits and memory [Electronics, March 6, p. 25].

The edge. P.J. Daniel, who heads Mullard's MOST memory-development team at Redhill, England, says the company's IC arrays will be much cheaper for small computers even though the seven-transistor MOST bit circuits have a higher unit cost than ferrite cores themselves. Unlike cores, the MOST memories work at voltage and current levels compatible with IC logic circuits; the arrays thus do away with the line drivers, sense amplifiers, and separate power supplies that account for much of the cost of a core memory in a small computer.

The larger the computer, Daniel notes, the smaller the cost edge of MOST memories over ferrite-core memories. For very large computers, he says, MOST memories might even cost more per bit than core memories but would have an edge in performance. A big advantage is the MOST memory's nondestructive readout, a time-saver in many situations. With ferrite cores, information readout has to be rewritten back into the memory if it is to be used again. Cycle time of Mullard's experimental memories is currently 1 microsecond, and this may be halved eventually.

Discretion. The arrays Daniel's group is building pack 32 words of 32 bits onto a silicon slice about 1 inch in diameter. Along with 7,000-plus transistors for the bit circuits, the slice also carries an address matrix.

The seven-transistor bit circuits are deposited on the slices conventionally. And since yield isn't 100%, Mullard starts with a 40-by-40 array of bit circuits and connects them—bypassing faulty circuits—by discretionary wiring to get a 32-by-32 array.

The mask for the interconnection pattern is produced in about 10 minutes by special optical-mechanical machining equipment, developed by Mullard. The machine is controlled by a magnetic tape prepared for each slice by a computer that is fed punched tape carrying the results of a circuit-by-circuit probe test.

On the program

Help is in sight for British engineers who feel uneasy about using computers.

The Royal Radar Establishment, for one, has worked out an experimental software program that lets a computer understand questions put to it in straightforward English. And Ferranti Ltd., for another, has come to the aid of process-control engineers by setting up basic program sequences that can be put together easily to form control systems.

Questions. In its effort to make computers accessible to anyone who can tap on a typewriter, the Radar Establishment took much the same tack as the General Electric Co. did in its direct English access and control (Deacon) project [Electronics, April 4, 1966 p. 37].

The program developed at the Establishment has three main parts: a dictionary that lists words the computer must recognize, rules of syntax for analyzing sentences, and answer-finding sequences. Questions fed by typewriter into the computer are first scanned for vocabulary and then noun phrases are distinguished from the verb phrases. The relationships between them are established by reference to the syntax rules. When the query has been understood, the computer looks up the answer in its store of facts.

The dictionary, syntax rules, and facts are stored in disk memories. The experimental program has a vocabulary of 120 words and some 60 grammatical rules.

Answers. The Radar Establishment has its basic program working so well that it plans to set up an information retrieval system for the characteristics of integrated circuits by the end of the year. The system will be able to answer questions like: "What are the designations and costs of all circuits that can function as three-input nand gates and are packaged in TO-5 cans?"

At the outset, the system will cover some 40 IC packages and store about 80 characteristics for each. For comparisons among circuits, though, the computer will work with only 17 major characteristics.

On-line. Ferranti's programing scheme permits engineers who can't handle orthodox program routines to change programs on Argus on-line process control computers. What's more, the changes can be checked out, without interrupting the process, before they're put into effect in the control system.

The foundation of the simplified program is a set of 23 routines. Each covers a basic process-control function. In addition, up to nine special routines can be programed for specific applications. Normally, a control loop can be built up by combining about five basic routines. The loops are interconnected to make up a complete control system.

The sequence in each routine is fixed; however, the control engineer can change the values of constants, inputs, and outputs to keep the system optimized when there's a change, say, in raw materials or a slightly different end product is wanted.

The new parameters are simply typed in on a keyboard. Through the keyboard the control engineer can also feed into the computer new combinations of the routines in control loops or even add new loops.

Sweden

Five-finger exercise

In the dozen years since a British research team first hit upon the idea of controlling the movements of artificial hands by the very low voltages generated in muscles, much work has been done around the globe to develop practical prosthetics. Hands that can grasp objects with a claw-like movement have been built in Russia, Western Europe, the U.S., and Japan.

Now that simple artificial hands controlled by myoelectric potentials—as the low-level muscle voltages are known—are fairly commonplace, researchers are turning their attention to more sophisticated aids for amputees. Work on artificial hands that can make wrist movements and finger movements is under way in Japan, Sweden, and Yugoslavia.

The most ambitious effort seems to be in Sweden. There, the National Defense Research Institute is managing a cooperative development program in which several medical-engineering research groups are participating. The goal is an artificial forearm capable of wrist movements and a hand with independent finger movements. Henry Lymark of the Defense Institute will report on the Swedish prosthetic at the Seventh International Conference on Medical and Biological Engineering in Stockholm this month.

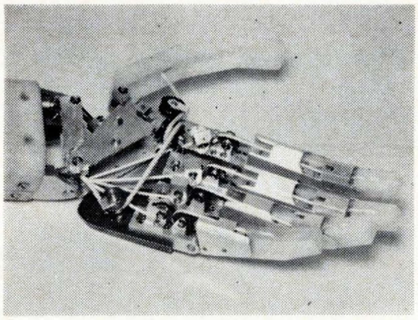
Quartet. The experimental prosthetic the Swedes are developing differs considerably from the open-and-shut-only hands developed elsewhere. Instead of picking up myoelectric potentials from two muscles, the Swedish device works with four muscle pairs. And instead of using skin electrodes, the Swedes will implant eight tiny frequency-modulated transmitters in the muscle pairs to pick up the myoelectric control signals.

The signals control four servomotors mounted in the arm and are linked to the hand through a worm gear, steel wires, and polyester plastic cords.

One servomotor controls finger-flexing movements. It can close the fingers in one second from a fully extended position into a fist. The motor is connected to the fingers through a two-ratio gearbox. Until the fingers contact an object, the gearbox stays in the faster low ratio. When the fingers grasp, it shifts automatically to the more powerful high ratio. Each finger can exert forces up to 20 pounds on a grasped object. The other three motors handle thumb and wrist movements.

Subcutaneous. Because skin electrodes often cause severe irritation, the Swedish hand uses implanted frequency-modulation transmitters to pick up muscle control signals. The transmitters measure 11 by 5 by 4 millimeters and operate at 0.47 volt and 20 microamps. The power comes from a small transmitter on the skin with an output of 20 milliwatts at 3 megahertz.

F-m signals from the implanted transmitters, modulated by muscle-movement voltages, are picked up by a receiver on the skin and fed to transistorized servoamplifiers. Both the servoamplifier circuits and the batteries to power the skin transmitter and receiver are packaged in a small carrying case.



Finger control. Experimental Swedish prosthetic hand is first with five independent fingers.

Worklist. Lymark emphasizes that the Swedish hand is still experimental and that it will take some time to ready prototypes for tests on amputees. One major unresolved problem is deciding which four muscle pairs could best control the prosthetic; muscles must be found that won't trigger unwanted movements in the prosthetic while carrying out their normal functions. Another problem is holding down noise in the drive mechanisms of the hand. This facet of the development has been turned over to a private company.

Although much work remains to be done, several Swedish companies are thinking about producing the artificial hand. The first—and very tentative—cost estimates indicate the eventual price of the prosthetic will be at least $2,000.

West Germany

Sophisticated spots

The small armies of intelligence experts who try to pinpoint enemy targets in long strips of aerial photographs often get the feeling that finding needles in haystacks would be a cinch.

What's needed, military men say, is an electronic photointerpreter that would do the job faster and more accurately. And, for the most part, the bulk of the effort in this direction thus far has been largely based on film scanners that feed data directly into a computer for analysis.

But the trouble is that a typical scanner produces about 6.25 million bits of information from each square inch of film. With films usually 9 inches wide and up to 300 feet long, analyzing the data becomes a formidable task, even for a computer. A huge storage capacity is required and data processing is time consuming.

Trimmed. Researchers at the Technical University at Karlsruhe think they've found a way to ease the problem. They're working on a system that takes much of the load off the computer that analyzes the data. Their system interposes a preprocessing unit and a special coordinate computer between the scanning equipment and the main computer. The interposed equipment relieves the main computer —at Karlsruhe, a Control Data Corp. 3300—of the tasks of pattern definition and coordinate calculations. The main computer, then, gets only the data it needs for analysis and can handle the slimmed-down input much faster.

West Germany's defense ministry is underwriting the work with a $200,000-a-year contract. Helmut Kazmierczak, who heads the research team, says that along with its military applications, the system could be used for photogrammetry, for evaluating photos of bubble chambers, and for counting particles in pictures of blood samples.

Patterns. To help the computer sort out what's significant on an aerial photograph, the preprocessing unit distinguishes among 64 shades of gray. It also calculates the direction and gradients of contrast boundaries and determines the orientation of all thin lines on the film.

Details are picked out by scanning film sections that measure 2 by 2 centimeters. The resolution, programed into both the coordinate computer and the main computer, can range from 32 by 32 binary steps upwards to 256 by 256. In every case, the scan frequency for successive raster points is 125 kilohertz.

To spot and identify the pattern of a tank on a street, say, the coordinates and orientation of the street are determined first by a normal orthogonal scan of the film. Then the coordinate computer reorients the scan along the axis of the street to pin down the object's outline. The pattern thus can be fed into the memory of the main computer without complicated transformation of coordinates. The main computer could be programed to identify the pattern as that of a tank.

Tracked. Contours are pinpointed by rotating a small, round light spot around a circular track near the edge of a contrast boundary. The light transmitted through the film onto a photomultiplier is modulated along the circular track by the opaqueness of the film. The phase of the photomultiplier's output signal indicates the orientation of the boundary.

For thin lines, the system uses a small bar of light rotating about its center. Again, the direction of the line is determined by the phase of the output signal of the photomultiplier. In both scanning modes, the output of the photomultiplier is averaged over 4-microsecond intervals and quantized into one of 64 values by an analog-to-digital converter. The digital values then are fed to the main computer.

Shortcomings. Kazmierczak admits the Karlsruhe system needs considerable refinement. Before photointerpretors can be mustered out, a way must be found to allow the main computer to recognize the objects stored as bits in its memory as planes, tanks, or the like. Kazmierczak's group is considering statistical methods that would piece the stored bits together by trial-and-error, much as a jigsaw-puzzle solver works out his particular problem. But much more research has to be done, he says, before the system can automatically interpret reconnaissance films.

France

In-flight testing

Flight-test engineers in France will be getting much more help from their computers in the future.

Electronique Marcel Dassault has readied two prototypes of an airborne data-recording system that monitors parameters under control of a stored program rather than cabled logic. The company, a division of Avions Marcel Dassault, will install the first system on a Caravelle test plane this year. The prototypes were developed under a $2-million contract from the Bretigny test flight facility of the French air force, but Dassault expects to sell commercial versions for about $160,000.

Handy. Dassault says the system will make life much easier for test engineers. To select the parameters he wants recorded—out of the 200 the system can handle—an engineer simply feeds the desired test sequence into a computer to prepare a punched tape. The information coded on the punched tape is read into the memory of the recorder's programer unit, which controls an acquisition unit that picks up analog and digital data from the plane's test instrumentation. All data is encoded into a digital format and recorded on magnetic tape for on-ground analysis by computer.

Punched in. The stored program can be revised inflight by entering changes on a keyboard. Eight key parameters are displayed in real time on a panel and up to 32 more can be monitored in flight by adding an optional printer.

The recorder system can handle up to 128 analog channels plus 64 digital channels. Maximum sampling rate is 32 hertz and the maximum recording rate 2,000 hz.

Grounded. Although Dassault had airborne use in mind when it designed the recorder, the company says the equipment can be readily adapted for checkouts on submarines and tanks. For less-extensive test programs, the programer unit can be replaced with a simpler one programed by plug-in cards.

Soviet Union

The underground

Among the world's coal producers the Soviet Union ranks first and Soviet mining officials make quite a fuss about their extensive automation of collieries.

At last month's Fifth International Mining Congress in Moscow, Soviet mining specialist L.E. Grafov reported that more than 90 mines now have "complete mechanization and automation." By 1970, he added, the number will be more than doubled.

Grafov also told the congress that the Russians are pushing to get computers into action for regional mine management. An extensive data-processing system will go into service next year at Karaganda, in Soviet Central Asia. Five more systems are scheduled for operation by 1970 in the Donetsk Basin and other rich coal regions.

Belied. At the Intergormash equipment show held along with the mining congress, however, the Russian machines were notable for their size—and their lack of electronic sophistication. If the Russians are as far along in mine automation as they claim, they took great pains to keep their best hardware out of sight at Intergormash. Soviet electronics centered chiefly on gas-analysis instruments and on semiautomatic controls for individual equipment. The Poles, by contrast, offered a variety of solid state equipment and a model of the automatic long-wall system that mines deep seams in their Bielsowice colliery.

Editorial

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well as its developers predict, it will protect only about 3,000 airliners when it starts operating in 1969, while 110,000 small private aircraft will be beyond the pale.

A better answer, Electronics believes, would be to supply controllers with complete information about the location of all aircraft and assurance that orders have been received. Quick improvement could be possible with:

- A small, simple, digital communications system enabling a pilot to acknowledge an order by pushing a button, and to report compliance with the instruction by a second push. The digital code wouldn't interfere with voice traffic.
- Two-D radar at all airports handling fast-moving jet commercial and business traffic. The FAA's current criterion for airport radar —100,000 flights a year to or from different airports—may not be adequate in an era of jet traffic and giant air buses.
- Three-D radar at major airports. Such equipment is already being used by the military, and this technology can be applied to FAA requirements. Companies such as Hughes Aircraft, Avco, and ITT Gilfillan are deeply immersed in this technology. In Japan, Mitsubishi Electric Co. has worked on a low-cost 3-D system.
- Automatic data processing and storage system to keep track of the hundreds of aircraft around major airports. The systems could be programed to display dangerous or potentially dangerous situations.

None of these possibilities are likely to be implemented by the FAA—or even explored—unless Congress prods the agency sharply.

Because it chose an unrealistic approach to data processing in 1959 —one that computer experts considered unfeasible before the project was even started—the FAA is convinced that the concept is useless. Because 3-D radar didn't have adequate accuracy in 1962, it too has been discarded despite obvious improvements since then and such new techniques as phased arrays and electronic scanning.

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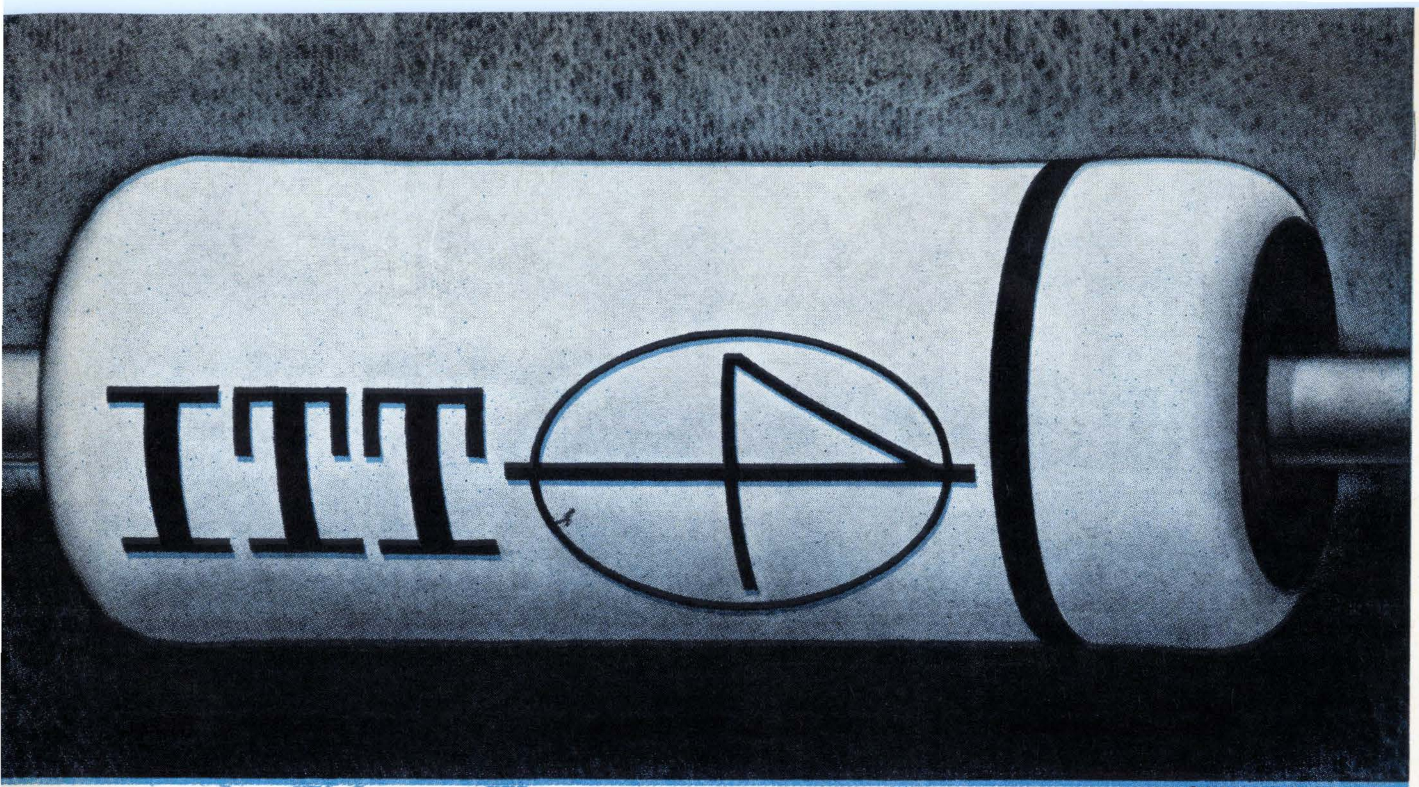

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