Electronics®

Designing filters quickly: page 76

Plated memories that compete with cores: page 101

How to land on the moon gently: page 110

May 15, 1967
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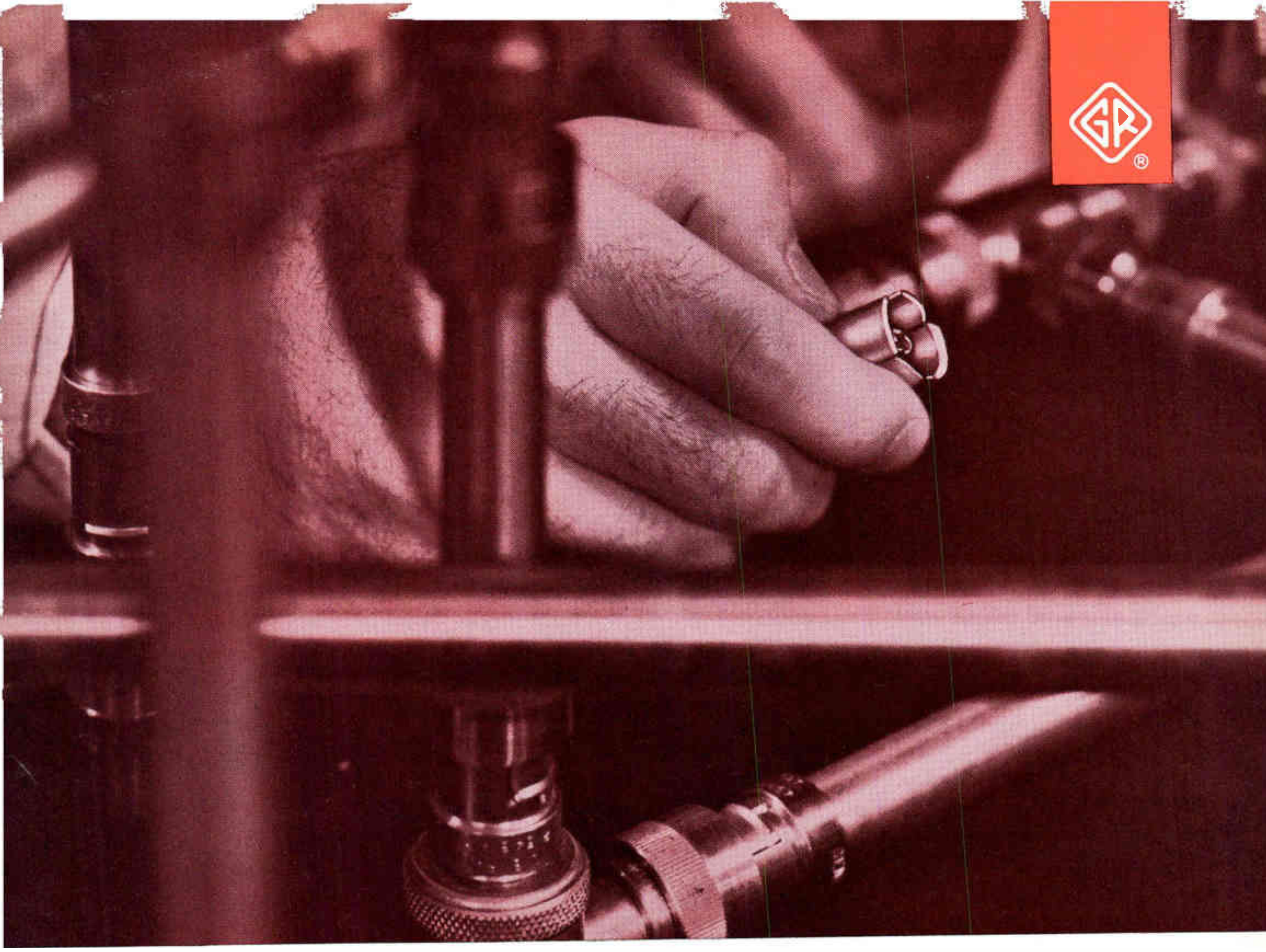
Below: Hologram of shock wave from a capacitor discharge, page 88

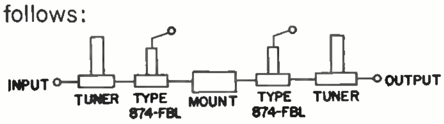


With a little ingenuity...

you can interconnect GR874-equipped coaxial elements to form countless unique "instruments" or special-purpose circuits that are both practical and inexpensive. Experimentation with various setups is greatly simplified by the sexless design of the GR874 connector; any two connectors mate, whether they are locking or non-locking types.

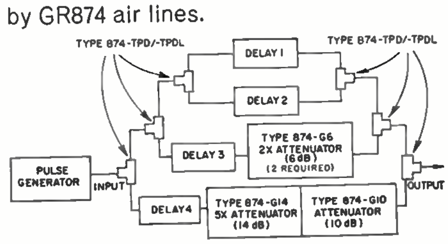
The GR874 connector is the keystone of a versatile coaxial system that includes a wide variety of elements and components . . . power dividers, air lines, trombones, tees, elbows, pads, terminations, adaptors, etc. Typical VSWR of a pair of locking-type, rigid-air-line connectors is less than 1.02 to 6 GHz and about 1.06 at 9 GHz. Pulses are passed faithfully by the connector without ringing or deterioration of rise/fall times.

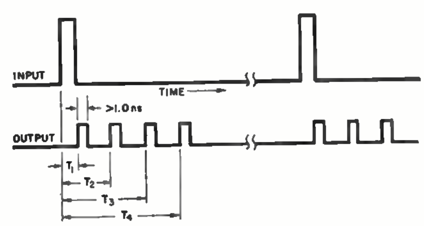
You can build a simple one-transistor amplifier operable to 5 GHz with two tuners (each comprising a GR874 tee and a GR874 adjustable stub), two bias insertion units (Type 874-FBL), and a transistor mount (one of eight types available) arranged as follows:



Type 874-BBL Basic Connector (locking) for use on 9/16-inch-ID, rigid, 50-ohm air lines.

As another example of GR874 versatility, the components shown below can be used to produce bursts of high-rep-rate pulses from the output of a low-frequency, sub-nanosecond-rise-time pulse generator. The delays (up to 1 ns per section) are provided by GR874 air lines.





For complete information on the GR874 line, write General Radio, W. Concord, Massachusetts 01781; telephone (617) 369-4400; TWX 710 347-1051.

GENERAL RADIO

Circle 900 on reader service card

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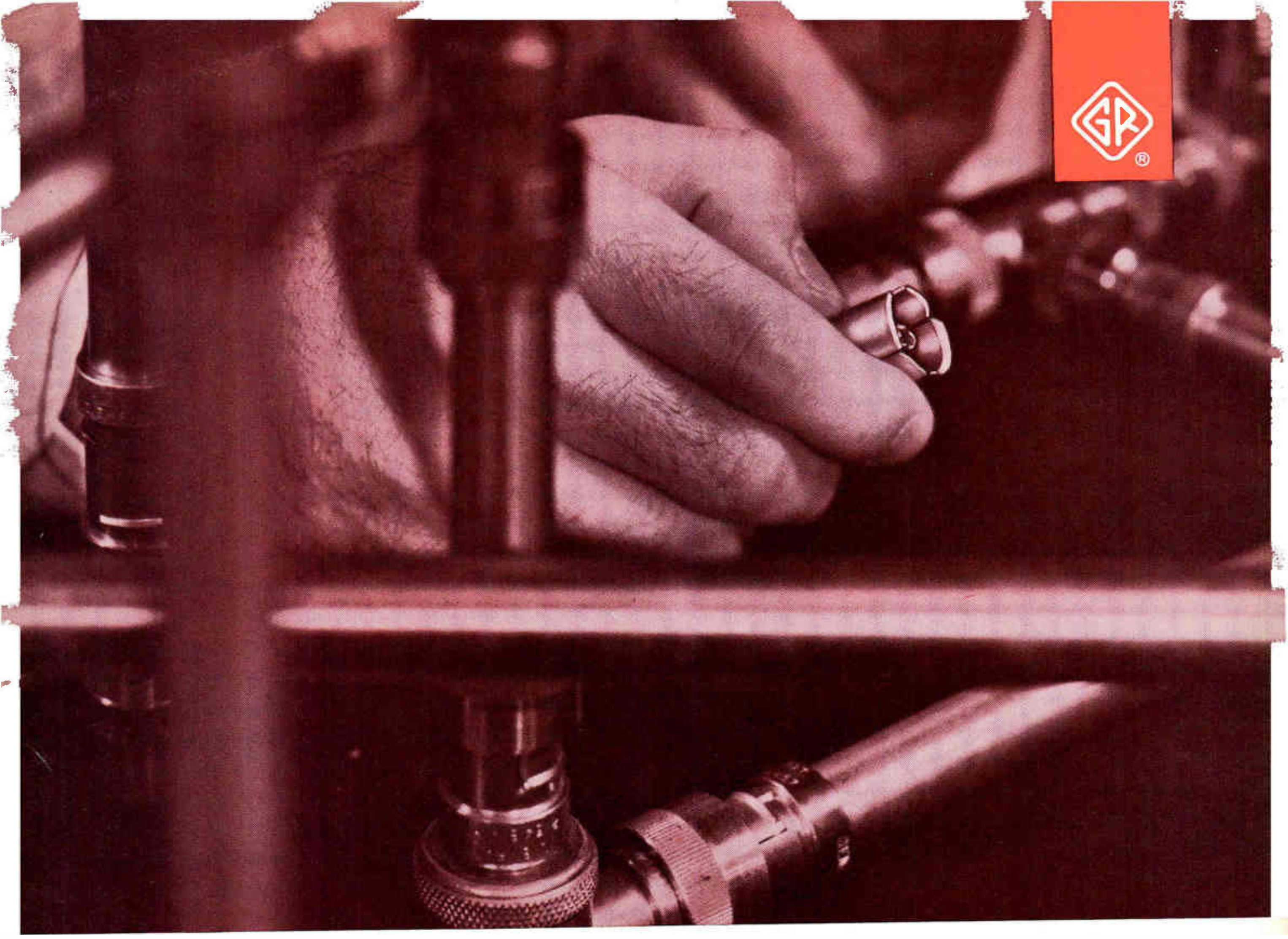

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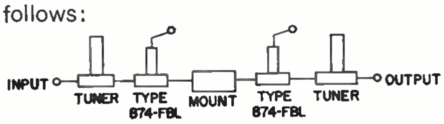

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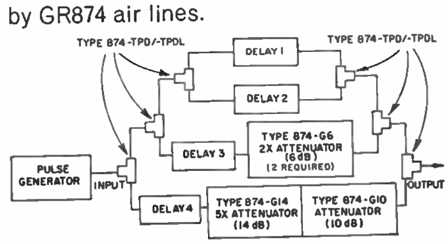

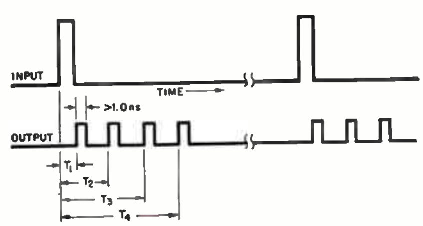

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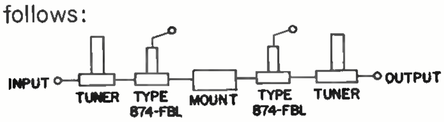

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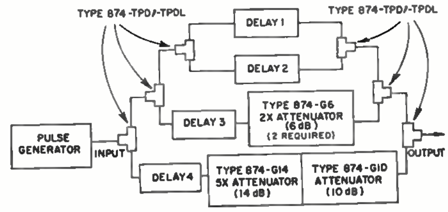

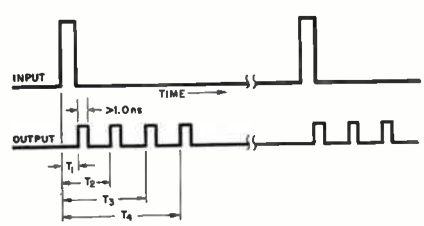

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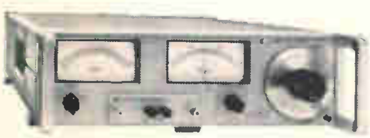
GENERAL RADIO

Circle 900 on reader service card

RF Vector Impedance Meter with direct readout simplifies testing



A COMPANION INSTRUMENT COVERS THE 5 Hz to 500 kHz RANGE

The Hewlett-Packard 4800A Vector Impedance Meter measures impedance in seconds. It does for AC measurement what the ohmmeter does for DC testing. Just plug it in and read it. Price: $1,490.00. Complete specifications are yours on request.

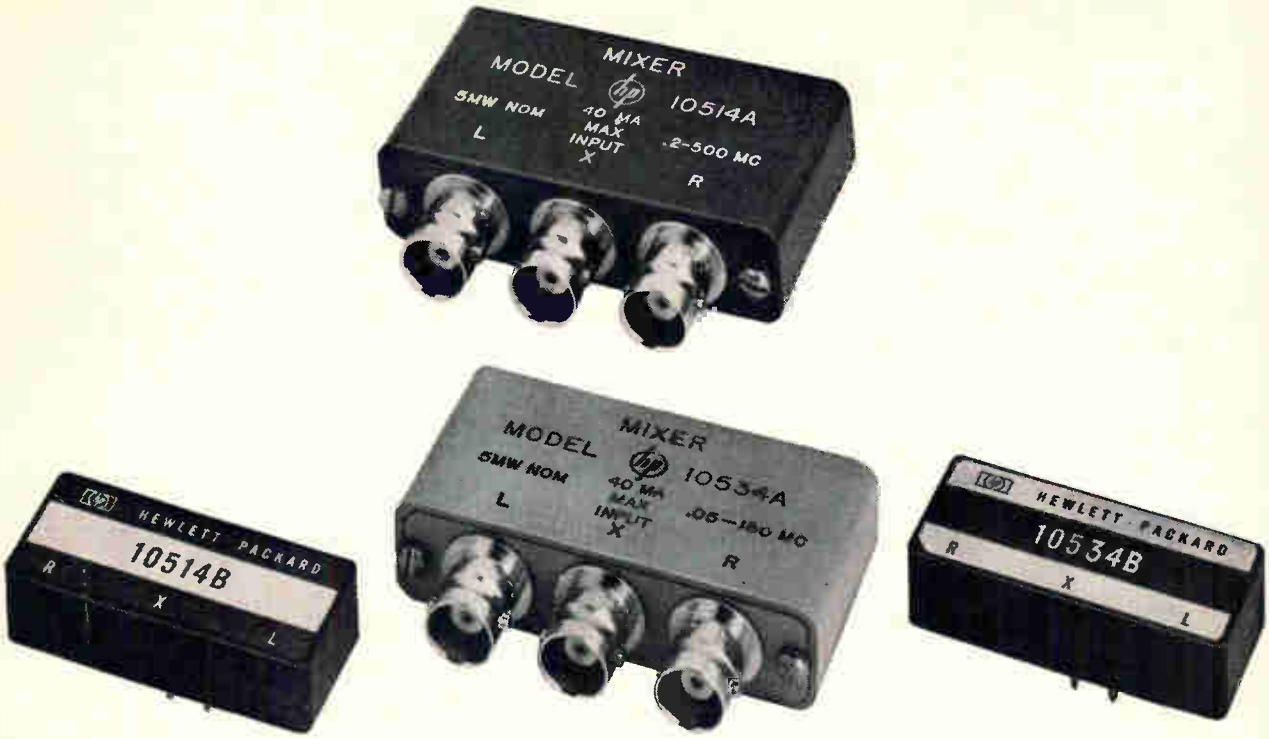
The Hewlett-Packard 4815A RF Vector Impedance Meter provides fast, direct reading measurements of impedance and phase angle over the frequency range from 500 kHz to 108 MHz. The convenience of probe measurement and direct readout make the instrument equally useful for laboratory, receiving inspection or production line measurements. The 4815A reads complex impedance over its full frequency range without charts, data interpretation or a slide rule. As a result, it offers fast, accurate evaluation of the complex impedance of both active circuits and components.

The 4815A is an all solid-state integrated vector impedance *system* that reads out directly in Z and θ. Low-level signal strength minimizes circuit disturbance and prevents overloading the test component. Price: $2,650.00. For complete specifications, contact your local Hewlett-Packard field engineer or write Hewlett-Packard, Green Pond Road, Rockaway, N. J. 07866.

HEWLETT hp PACKARD
measuring instruments for science and industry

Circle 1 on reader service card

The family has grown



and lowered the budget

HP mixers are low in price, low in noise, high in performance. These wideband double-balanced mixers now bring performance extras to your applications—all the way to 500 MHz. New members of the family offer double-balanced performance at single-balanced mixer prices. Each member of the family offers:

- Lowest (and fully specified) l/f noise.
- Complete testing, with all parameters specified in detail.
- Guaranteed performance over a wide environmental range.

These three new models follow the popular 10514A, a 200 kHz to 500 MHz double-balanced mixer with BNC connectors. The new 10514B is similar to its predecessor, but it's packaged for printed circuit mounting; the 10534A/B are optimized from 50 kHz to 150 MHz . . . and priced close to single-balanced mixers.

Low l/f noise characteristics mean high performance in any phase detector application such as phase-locked loops or short-term stability measurements by phase noise methods. Note that single-sided noise is specified all the way down to 50 kHz on the DC-coupled port.

Consistent specs between models in the family mean that an equivalent printed circuit model can replace a BNC model in breadboard . . . with no trouble at all. And our testing and environmental demands save you extra time and concern. This family meets specs and works wherever you need it.

Use these HP mixers for extracting frequency sums or differences, as modulators, spectrum or comb generators, phase detectors, current-controlled attenuators, frequency doublers . . . or to extend spectrum analyzer range.

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

Brief Specifications

Model	Freq. range MHz (2)	Conversion efficiency		Single unit (1) Price
		0.5-50 MHz	0.2-500 MHz	
10514A	0.2-500	7 dB	9 dB	$180
10514B	0.2-500	7 dB	9 dB	$150
		0.2 to 35 MHz	0.05-150 MHz	
10534A	0.05-150	6.5 dB	8 dB	$ 75
10534B	0.05-150	6.5 dB	8 dB	$ 60

(1) Prices are lower in quantity.
(2) "L and R" ports; "X" ports extend to DC for phase detector applications.

The l/f noise is specified on all models as <100 nV per $\sqrt{Hz}$ at 10 Hz, and is typically much better. Single-sided noise figure specification is the same as the conversion efficiency specification shown above, but with the frequency of the X port extending from 50 kHz to the upper limit frequency. The balance specifications are extremely good, 12 to 45 dB (typical performance much better), depending upon frequency and test connections.

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Electronics

May 15, 1967
Volume 40, Number 10

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Probing the News

Electronics Review

Electronics Abroad

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Technical Articles

I. Design

II. Application

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Readers Comment

For example

To the Editor:

I have just read your editorial "IC's change the industry" [April 17, p. 23] and feel called upon to challenge the last paragraph; "Only the instrument makers have been slow to see what's happening. Of hundreds of companies, only Hewlett-Packard has moved to set up its own integrated-circuit facility and to design its own instrumentation computers."

Fairchild Camera & Instrument Corp. is well aware of the expanding test and measurement instrumentation market, has a well-advanced integrated circuit capability, and is making the proper moves to insure a share of this market. As a reader of Electronics, I know from experience that you, also, are aware of Fairchild's integrated circuit capabilities and its position as a leader in this field.

I am quite puzzled, therefore, as to why Hewlett-Packard was singled out as being the only instrument maker with an integrated circuit capability. The facts just do not support your statement.

James B. Moore
Director of Information
Fairchild Camera & Instrument Corp.
New York

■ It's true that Fairchild can and does draw upon the IC expertise of its division, Fairchild Semiconductor. But we cited Hewlett-Packard as an example of the only instrument company, with no previous IC experience, to establish a facility for producing IC's exclusively for its own products.

Credit for IC radios

To the Editor:

In the article on the Japanese radio microcircuit [April 3, p. 177], your writer implies that the Japanese led the march to introduce a microcircuit radio, but General Electric's Radio Receiver Department actually was first with its Model C2450 receiver announcement in June, its test sample shipments in November, and full production shipments in December of

New from Sprague Electric!

bandwidth 50 MHz

voltage gain 40 dB

This is an outstanding performance characteristic of **Sprague UC-1514A Ceracircuit® Amplifiers.** They also feature excellent stability of gain and d-c output operating point, in addition to providing complete short-circuit protection.

The first of a new series of Ceracircuit® amplifier modules, Type UC-1514A is well-suited for video and audio, as well as communications applications.

Manufactured by the hybrid thin-film technique, Ceracircuit® Amplifiers offer substantial size and weight reduction in addition to reliable, stable operation over the entire operating range of —55 C to +100 C. Their precision planar metal-film resistors have an extremely low noise level and excellent load-life stability. Semiconductor devices are mounted on small ceramic wafers which, in turn, are bonded in a leadless configuration to the basic thin-film circuit.

Type UC-1514A Ceracircuit® Amplifiers are encapsulated in low-loss, resilient resin-filled, pre-molded epoxy cases which provide rugged mechanical protection as well as dimensional consistency.

For complete technical data, write for Engineering Bulletin 22111 to Technical Literature Service, Sprague Electric Company, 35 Marshall Street, North Adams, Mass. 01247

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1966. In addition, General Electric has had and will continue to have complete availability nationally.

Furthermore, the General Electric receivers are still the only microcircuit radios which contain no external transistors. We believe our ability to pack the entire power gain of 147 db in a silicon chip about a quarter the size of the one you illustrated demonstrates undisputed leadership.

Some technical discrepancies apparently exist between the published schematic and the microcircuit shown.

The schematic above the photograph of the chip has diode D_4 reversed from the actual chip layout shown.

The schematic at the top of the page has terminal 10 tied directly to B+ while being labeled AGC on the previous schematic. Terminal 10 cannot supply AGC action with this configuration.

H.B. Moore
Manager-Engineering
Consumer Electronics Division
General Electric Co.
Utica, N.Y.

■ Our artist slipped, connecting a diode backwards and shorting two terminals so the circuit is AGC-less.

The right gain

To the Editor:

In the Designer's casebook, "Feedback T yields high input impedance" [April 17, p. 91] the equation for the gain should have been the following:

$$\frac{E_{out}}{E_{in}} = \frac{-R_2}{R_1}\left[\frac{R_3 + R_4}{R_3(1-\alpha)+R_4}\right]$$

in which case, for the values shown, the gain is -1 when $a = 0$ and -101 (not 102) when $a = 1$.

J.D. Crawford
Engineering Department
Sigma Instruments Inc.
Braintree, Mass.

To the Editor:

The gain equation in "Feedback T yields high input impedance" is obviously wrong. Either minus sign must be omitted, the R_2 in the numerator of the third term should be R_3 instead, and the final R_4 should be in the denominator of the third term. The correct version is:

$$\frac{-E_{out}}{E_{in}} = \frac{R_2}{R_1}\left[1+\frac{\alpha R_3}{R_2}+\frac{\alpha R_3}{(1-\alpha)R_3+R_4}\right]$$

E. Krotkoya
Palo Alto Medical Research Foundation
Palo Alto, Calif.

To the Editor:

. . . Although the basic discussion of this article is valid, the equation for the gain of network is incorrect. Specifically the gain is

$$\frac{E_{out}}{E_{in}} = \frac{-R_2}{R_1}\left[1+\frac{\alpha R_3}{R_2}+\frac{\alpha R_3}{R_4+(1-\alpha)R_3}\right]$$

R.D. Horn
Research Engineer
Perspective Incorporated
Seattle, Wash.

■ Readers Horn and Krotkoya caught authors George Cook and William F. Elder Jr. in an error. Reader Crawford's analysis is interesting but incorrect.

People

Keeve M. Siegel's three-month old KMS Industries Inc. must be one of Ann Arbor, Mich.'s fastest growing firms. Siegel has taken only about 90 days to collect some 30 employees, and one military and two civilian contracts. Formerly he was president of the Conductron Corp., a concern 83%-owned by the McDonnell Douglas Corp.

Keeve M. Siegel

The executive, who won't specify what the KMS contracts are for, is slightly more definite about his corporate aims—but only slightly. "We plan to sell educational products and might also take on training contracts. Beyond this, we're thinking about marketing a line of adult games," he says.

Siegel himself has just been elected a director of Microwave Associates Inc. But, he states, "this doesn't mean there will be any direct tie between the two firms."

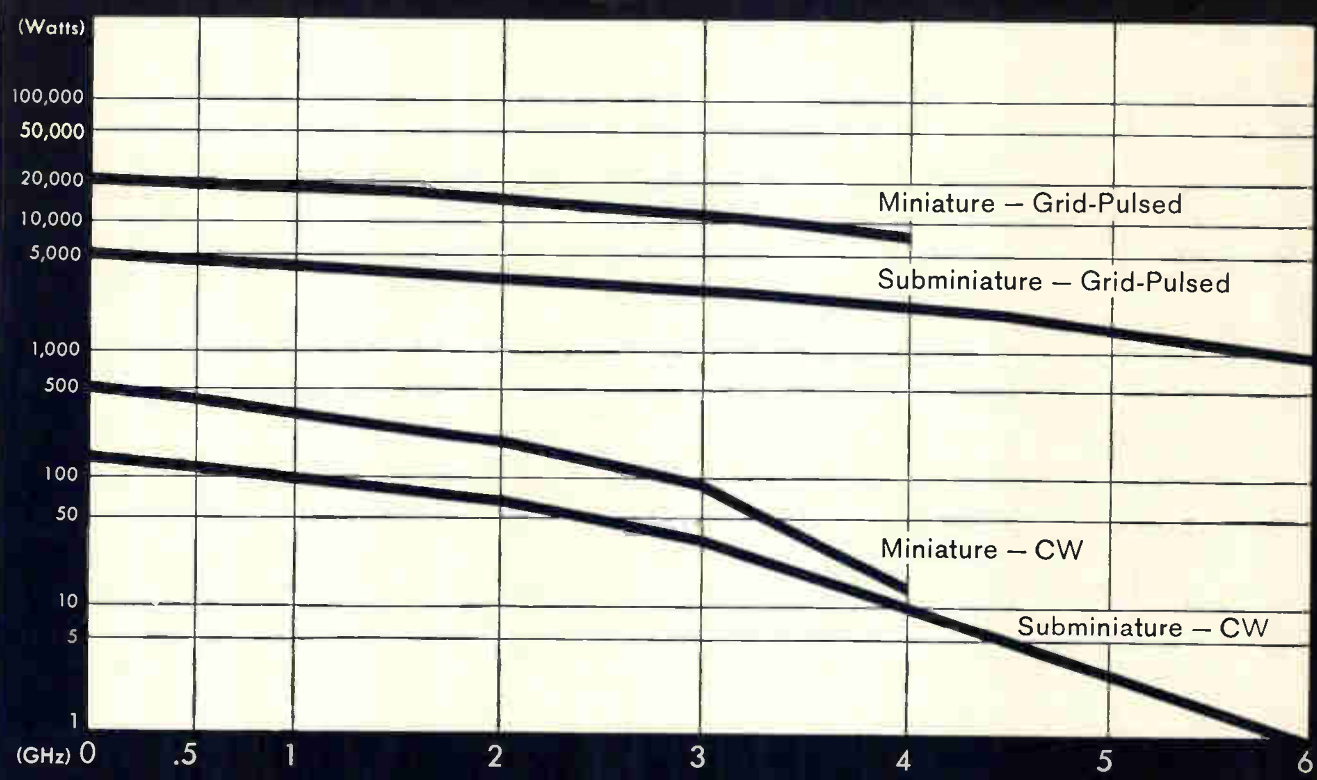
3-D television. An industry insider said he would bet that KMS has holographic television in its future. A disagreement with James S. McDonnell, chairman of McDonnell, led to Siegel's departure from Conductron. One of the major issues was the future role of holographic tv at Conductron [Electronics, Feb. 20, p. 62]. Now Siegel says KMS won't touch holographic tv, formerly one of his pet projects, if Conductron does.

Whatever Siegel's eventual goals, KMS will have an impressive staff to work toward them. The company is planning to retain Emmett Leith of the University of Michigan —one of the developers of the first practical holograms—and Leith's associate, Norman Massey. Other staff members include Chen To Tai, director of the university's electromagnetic research programs, and Murray Miller, whose field is integrated circuits.

Acquisitions. Several of Siegel's former associates at Conductron are also joining KMS. Among them are Gary Cochran, Conductron's head of optics research; Robert Buzzard, holographic manager;

MACHLETT

Check these Machlett planar triode advantages for microwave applications.



Power vs. frequency...some typical curves for grid-pulsed or CW operation

Electrical Advantages

Superior frequency stability

Negligible phasing problems

Comparable or superior efficiency

Low plate voltage

Low noise

Faster warm-up

Mechanical Advantages

Small size

Very low weight

Greater ruggedness

Cost Advantages

Lower initial cost

Lower developmental cost

Lower replacement cost

Write us now for application information on Machlett planar triodes: subminiature, miniature and standard. The Machlett Labs.,Inc., 1063 Hope St., Stamford, Conn. 06907

The Machlett Laboratories, Inc.,welcomes resumes from engineers and scientists.

RAYTHEON

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People

Carlton Thomas, a research engineer, and Wesley Vivian, a radar engineer.

Siegel says KMS will not compete with Conductron. But in view of KMS's staff lineup and its heavy emphasis on holographic and radar expertise, it's hard to see how the company could fail to compete with Conductron, whose chief operations are in radar, optical data processing, and holography.

"We'll be pushing development of solid state microwave signal sources and microwave integrated circuits," says **Wesley G. Matthei,** new manager of research and development at the Micro State Electronics Corp., a subsidiary of the Raytheon Co.

Wesley G. Matthei

Adds Matthei: "We'll also be paying a lot of attention to avalanche diodes and bulk-effect devices," and an important part of this effort will be the expansion of Micro State's in-house gallium arsenide production facility. High-quality GaAs is needed for bulk-effect semiconductors, such as the Gunn-effect signal source and oscillators operating in the limited space charge accumulation mode.

"These oscillators should fit in well with our IC development program," he states. Micro State's goal over the next year is development of the hardware for IC microwave receivers. Switches, phase shifters, limiters, mixers, and local oscillators would all be built in a hybrid IC format.

To streamline product development, Matthei is reorganizing his engineering groups into teams consisting of both systems and device engineers. The idea, says the new manager, is to foster closer cooperation between these two groups.

Before joining Micro State, Matthei was deputy chief of microwave and quantum electronics at the Army Electronics Command.


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Get them by the pound.

There are 712 epoxy TO-5's to a pound; 1,516 epoxy TO-18's. Armed with this basic knowledge you are now ready to assimilate a few more facts about Fairchild epoxy devices.

Full line: We have epoxy PNP's, epoxy NPN's, epoxy FET's, epoxy anythings.

Metal-can performance: Our new EN epoxy transistors are equivalents of their metal-can counterparts, up to 70°C. (For example, an epoxy EN 2369A is the equivalent of a metal-can 2N 2369A.)

Fast delivery: We make more silicon epoxy devices than all the rest of the industry put together. (We can ship 2 to 3 tons per week—5,000,000 devices to be exact.)

Low Prices: Our low epoxy prices are even lower now, while our special one pound discounts are in effect.

Call a Fairchild Distributor: Ask him to deliver a pound of your favorite transistors. And don't forget to redeem your coupon.

25¢ 25¢

This coupon is good for 25¢ at your neighborhood Fairchild Distributor on purchase of one pound of Fairchild epoxy transistors.

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25¢ 25¢

Circle 13 on reader service card

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Appliance Technical Conference, IEEE; Sheraton-Chicago Hotel, Chicago, **May 16-17.**

National Telemetering Conference, American Institute of Aeronautics and Astronautics; San Francisco Tilton Hotel, San Francisco, **May 16-18.**

System Performance Effectiveness Conference, Naval Material Command; State Department Auditorium, Washington, D.C., **May 17-18.**

Midwest Symposium on Circuit Theory, IEEE; Purdue University, West Lafayette, Ind., **May 18-19.**

Paris Trade Fair; Paris, **May 18-20.**

Conference on Nondestructive Testing; Sheraton Mount Royal Hotel, Montreal, Canada, **May 21-26.**

Union Radio Scientific International Meeting, IEEE; Ottawa, Canada, **May 22-25.**

Congress of Canadian Engineers, IEEE; Montreal, **May 29-June 2.**

Conference on Application of Digital Computers for Process Control, International Federation of Automatic Control; Nice, France, **June 5-9.**

Symposium on the Deposition of Thin Films by Sputtering, Consolidated Vacuum Corp.; University of Rochester, Rochester, N.Y., **June 6-7.**

First Conference on Laser Applications and Engineering, IEEE; Hilton Hotel, Washington, D.C. **June 6-8.***

Microwave Exposition '67, Microwave Expositions, Inc.; New York Coliseum, **June 7-9.**

Symposium on Problems of Identification in Automatic Control in Automatic Control Systems, International Federation of Automatic Control; Prague, Czechoslovakia, **June 12-16.**

Aerospace Instrumentation Symposium, Instrument Society of America; Hotel Del Coronado, San Diego, Calif., **June 13-16.** [An earlier item on this meeting was incorrect.]

American Society for Testing and Materials Meeting, American Society for Testing and Materials; Statler-Hilton Hotel, Boston, **June 25-30.**

Automatic Control Conference, Instrument Society of America; University of Pennsylvania, Philadelphia, **June 28-30.**

Short courses

Modern automatic control; Purdue University's Schools of Engineering, Lafayette, Ind.; **June 5-16;** $250 fee.

Semiconductor electronics; University of Wisconsin's College of Engineering, Madison, Wis.; **May 29-June 2;** $150. fee.

Power systems engineering and simulation; University of Wisconsin's College of Engineering, Madison, Wis.; **June 12-16;** $150 fee.

Call for papers

Nuclear Science Symposium, IEEE; Statler Hilton Hotel, Los Angeles, Oct. 31-Nov. 2. **June 15** is deadline for submission of abstracts to R.C. Maninger, L-121, Lawrence Radiation Laboratory, P.O. Box 808, Livermore, Calif. 94551

International Scientific Radio Union Meeting, International Scientific Radio Union; University of Michigan, Ann Arbor, Oct. 16-18. **Aug. 1** is deadline for submission of papers to Thomas Senior, Radiation Laboratory, University of Michigan, 201 Catherine St., Ann Arbor, Mich. 48108

Conference on Circuit and System Theory, IEEE; Allerton House, Monticello, Ill., Oct. 4-6. **Aug. 1** is deadline for submission of abstracts to J.B. Cruz, Department of Electrical Engineering, University of Illinois, Urbana, Ill. 61801

* Meeting preview on page 16.

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Meeting preview

Working with lasers

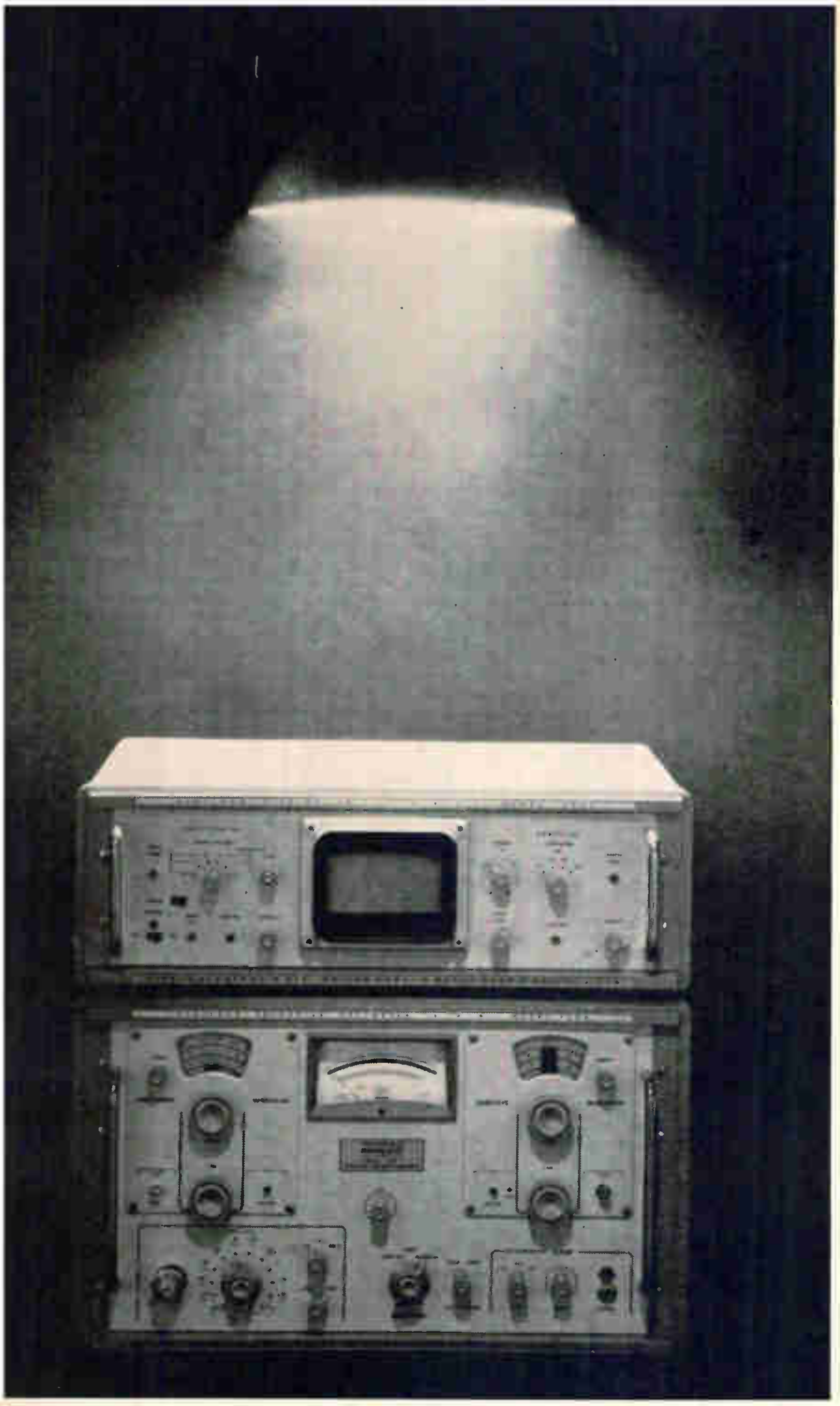
The IEEE is sponsoring the first technical conference on applying lasers, a clear indication that the laser is moving toward commercial maturity. Called the First Conference on Laser Applications and Engineering, it will be held from June 6 to 8 at the Hilton Hotel in Washington, D.C. The meeting's 13 technical sessions and 90 papers will cover such topics as optical ranging, data processing, measuring, communications, and navigation.

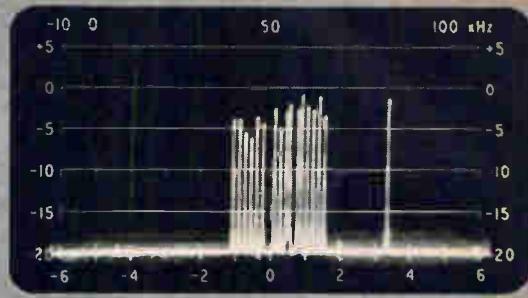
Communications and data processing applications are due for heavy emphasis. About 20 papers will deal with optical delay lines and memories, electro-optic modulators, and deflection systems.

Carbon-dioxide lasers will also be a major topic. After remaining for a year or so at outputs of a kilowatt and maximum efficiencies of about 17%, these lasers are now producing several kilowatts at efficiencies up to 33%. Two papers by researchers from the Army Missile Command's Redstone Arsenal, Ala., will discuss CO_2 lasers that are achieving 25% to 33% efficiencies and outputs of over 3 kilowatts.

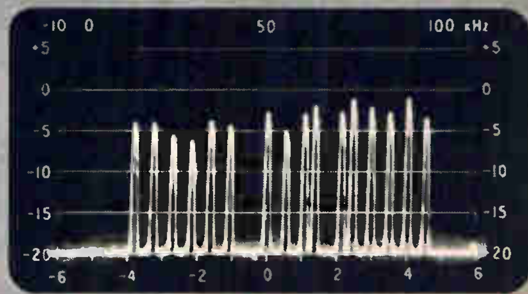
Detecting infrared. Because of its high continuous-wave power, researchers have long wanted to use the CO_2 laser for communications and ranging. But the relative insensitivity of available detectors at infrared wavelengths retarded this application of the lasers. Now, however, engineers can use optical heterodyning instead of relying on diode detectors or phototubes. This method will be outlined in several papers. One, by F. E. Goodwin of the Hughes Aircraft Co., will detail results of experiments with a communications system. Four engineers from the Airborne Instruments Laboratory of Cutler-Hammer Inc. will present a paper on a heterodyne infrared detection system with a 2-gigahertz intermediate-frequency bandwidth.

There will be 25 industry exhibits at the conference, and manufacturers are expected to take advantage of this concentration of laser hardware to run a few experiments on the interaction of laser beams.

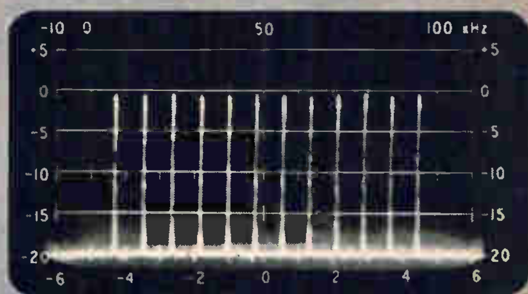




Three L-3 carrier channels shown in 12-kHz sweep width mode: teletype signals on center channel, 2600-Hz "on hook" tone on right channel, left channel idle.



Center channel above expanded to 3.6-kHz sweep width mode: 17 teletype carriers, 1 missing, 2 showing "mark space" information.



Complete N-1 carrier system shown in 120-kHz sweep width mode. Slope is 0 db, all carriers present, channels 2-13, high group.

Sierra brings to light... dark deeds in the underworld of high-density carrier systems

You'll spot them all with lightning speed on Sierra's Model 360A Spectrum Display Unit: Overload, noise, crosstalk, carrier leak. The communications disrupters!

Tracking automatically across the tuning range of a companion frequency selective voltmeter (shown above, Sierra's Model 128A), Model 360A presents an expanded view of selected frequency segments on a high-resolution, swept-band CRT display. Sweepwidths of 120 kHz or 12 kHz display thirty- or three-channel segments of the multiplex baseband. A 3.6-kHz sweep position narrows the view to one voice channel, resolving approximately 30 Hz at 3 db down from a carrier peak and 60 Hz at 40 db down. The voltmeter indicates precisely the frequency and amplitude of any displayed signals.

Price of the Model 360A is $2,450. The bulletin sheds further light on the matter. Write Sierra, 3885 Bohannon Drive, Menlo Park, California 94025.

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Circle 17 on reader service card

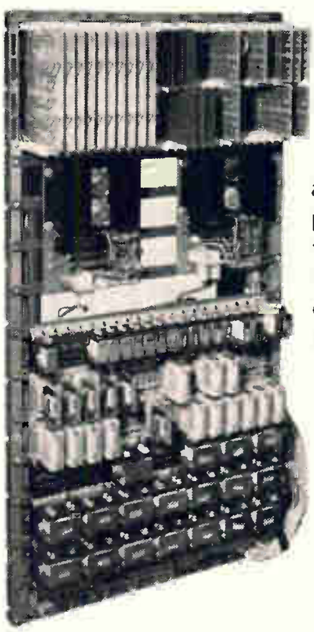
IBM Circuit Design and Packaging Topics

☐ **packaging cost reductions**
☐ **high-speed switching**
☐ **reed switch application data**

☐ packaging cost reductions

Performance Measurements Co., Detroit, Michigan, reports significant savings in packaging their new electronic recording system. The packaging method previously employed required two gates to mount the components in the main console. Now, with IBM's modular packaging as pictured below, only one gate is needed. That's because the IBM technique makes the most efficient use of console space with compactly mounted and connected circuit boards, relays and hardware.

Mounting time has been saved too. Pluggable components, low-cost card receptacles and interlocking card guides have so simplified the packaging job, that Performance Measurements now saves 70% on the cost of mounting hardware. Fewer and shorter wires are needed in the compact console—eliminating three feet of 1½-inch cable and shortening a second cable by eight inches. The modular chassis gave designers freedom to experiment freely with various mounting configurations. It also permits easy access for servicing and diagnostic analysis.



The same design freedom, plus significant hardware and labor savings are available in many applications.

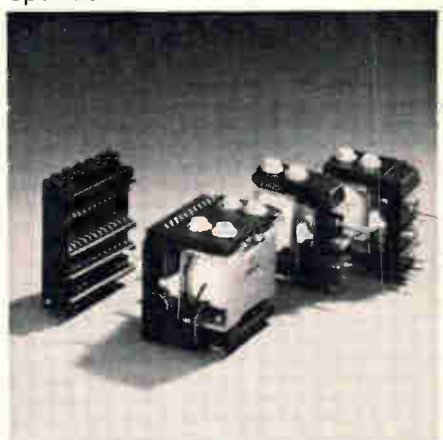
IBM components and packaging can help you in timing control, digital logic testing, telemetering, process or numerical control.

☐ high-speed switching

IBM wire contact relays were originally designed for data processing use. Now they are being used extensively in machine tool and assembly applications. One of these assembly applications is a numerically-controlled component insertion machine. It sequentially inserts random combinations of up to 24 different types of axial lead resistors and diodes into printed circuit boards. Such machines have been widely used, often on a round-the-clock, three-shift basis, in IBM's electronic assembly operations.

Insertion rates range from 3,000 to 4,500 components per hour, depending upon the type of components being inserted.

Instructions from an 8-channel punched paper tape provide the logic input to the relay gate. The gate employs three rows of 6- and 12-pole IBM wire contact relays. These relays control the movement of each printed circuit board through the X and Y axis positioning of the board for each component insertion. They also control the component feed, component insert, and cut-and-clinch cycles for each insertion operation.

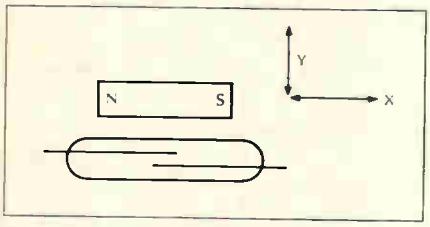


IBM wire contact relays can perform in excess of 200 million operations with an operate speed as fast as 4.5 ms, a release time of 5 ms maximum. The product line includes 4-, 6-, and 12-pole Form C relays, 4- and 6-pole latch models, all with compact, solderless, pluggable mountings—with coil-voltages up to 100 VDC.

☐ reed switch application data

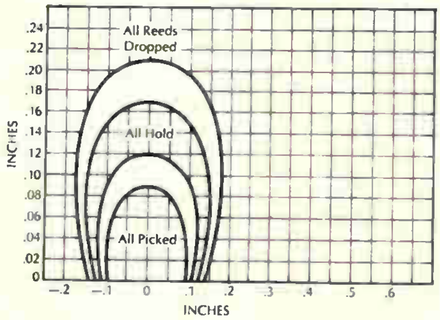
Data on the magnetic switching characteristics of miniature dry reed switches is available to design engineers on request. The data was compiled from extensive tests conducted by IBM to help the design engineer use these switches most effectively. It can also help him determine the motion and position of the magnet required.

Simply described, a miniature dry reed switch operates under the influence of a permanent magnet. When the magnet is adjacent to the reed switch,



the flux of the magnet flows through the cantilever beams, as illustrated. While this magnetic flux is being carried by the beams, a polarity exists across the beams. Look at the overlap area of the beams. The north pole of one beam and south pole of the other beam are in proximity. Since unlike poles of a magnet attract each other, when the magnetic force becomes great enough to overcome the physical mass of the beams, they "snap" together, thus switching.

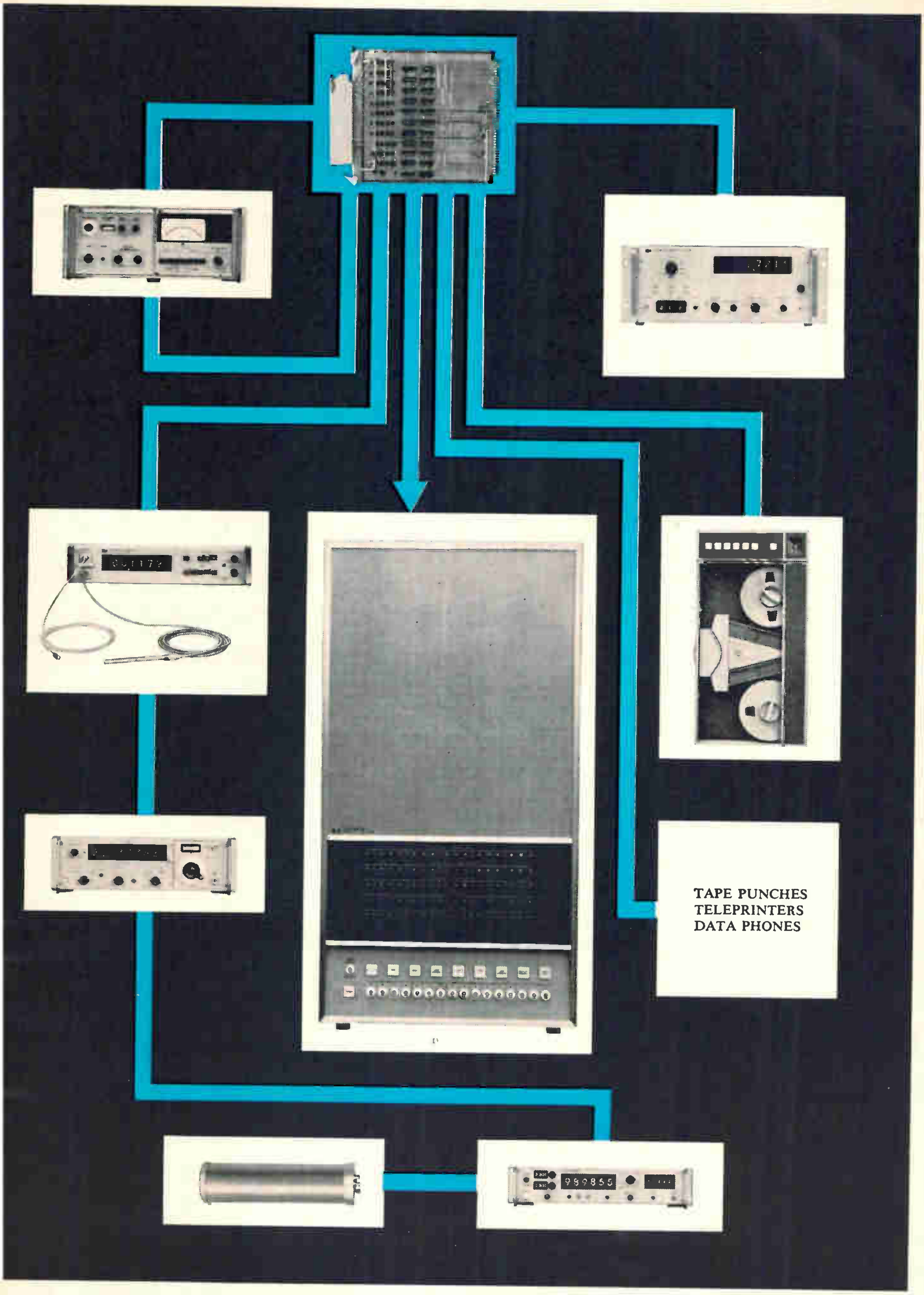
On the graph the X axis represents the displacement (in degrees for rotary motion, inches for lateral motion) of a magnet's center with reference to the center of the reed switch. The Y axis represents displacement (in inches) of the magnet from the outer edge of the



dry reed switch glass envelope. Dimensions shown along both axes represent displacement from the center of the magnet in alignment with the center of the reed switch.

There are some "gray areas" where performance varies due to minor differences in the characteristics of each switch. In these areas the status of each switch is not completely predictable.

Assume the zero point on the X axis is the magnetic center of an IBM reed switch. The magnet is positioned with its center at +.5 on the X axis, and .04 inches above the glass envelope. If the magnet is set in motion along the X axis toward the center of the switch, some reeds will pick when the center of the magnet reaches the point +.12 on the X axis. (The magnet has then reached the "gray area"). If motion is continued toward the center of the switch, *all* reeds will pick when the center of the magnet reaches the point +.09 on the X axis.


TAPE PUNCHES
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CIRCLE 22 ON READER SERVICE CARD

Editorial

In search of a scapegoat

Nothing could have shamed engineers more than the two accidents that cost the lives of four astronauts in 1967. Three American spacemen died on the launch pad during a simulation of take-off procedures; a Russian was killed during a landing when his capsule crashed after the parachute fouled at 23,000 feet, below the altitudes at which most commercial jet aircraft fly every day. These tragedies have reminded the world that the exploration of space is a dangerous business. And they have earned both the Russian and American space programs a heap of unjustified criticism.

In their zeal to understand how such routine accidents could happen and explain them away, many people are looking for a scapegoat. They think only something stupid or careless or criminally negligent could have caused deaths in such routine accidents.

What these critics are forgetting is that in any engineering job—and space technology is 99% engineering and only 1% science—the problems that can't be foreseen cause the most serious trouble. If engineers could have foreseen the accident-causing problems developing, they would have designed around them.

Most of the criticism being piled on the technical effort in space these days is the result of some very obvious hindsight.

The accident at Cape Kennedy, for example—the oxygen atmosphere—identified what is obviously a critical problem, and it will be corrected. Yet the critics who are yelling the loudest about the use of what is a potentially dangerous atmosphere, have forgotten that this same oxygen atmosphere was a part of the half-dozen successful Mercury shots and the eight successful Gemini shots, some of which were letter perfect from launch to splashdown.

Other critics have been lambasting the space agency and its contractors for slovenly work, shoddy components, and careless assembly. Yet the space program has forced electronics suppliers to produce equipment and components whose reliability is the best they have ever attained. In Europe these days, foreign engineers attribute the improvement in reliability of U.S.-made components primarily to the exacting demands of the space agency and lament that there is no equivalent pressure in their countries. And the space program has generated new technology that would have taken far more years for U.S. firms to achieve if there were no space program.

The point has been reached where even the rumor of a frayed wire or a corroded valve in a piece of space equipment is enough to set off a Congressional investigation. In such an atmosphere, technical progress has to suffer. Companies, engineers, and bureaucrats grow gun-shy and they won't try a fresh new approach for fear that a report of trouble from an unseen problem might start the investigators off. Yet without the fresh new approaches, progress slows to a walk.

Nothing will bring back the four astronauts whose deaths everyone mourns. Nobody was smart enough to foresee their deaths and the accidents could not have been prevented, contrary to what many people are saying. These men were test pilots and test pilots do get killed. Yet throughout the history of aviation, development has always continued after fatal accidents and even has accelerated.

Complete technical investigations of the accidents are essential. Nobody would argue otherwise. But breast-beating and excited fingerpointing over frayed wires, loosened components, and stained valves contributes nothing but noise.

Where blame should go

While many people are noisily critical of what they consider insufficient technical foresight which might have prevented the deaths of four astronauts, few seem interested in the lack of technical foresight that is killing a lot of people in airplanes.

Last week two planes landed simultaneously on separate runways at LaGuardia Airport in New York City and crashed into each other at the runways' intersection. Three people died in this monstrous nonsense.

This month's accident at LaGuardia could easily be repeated at any of a dozen major airports in the United States. In fact, while LaGuardia was closed because of the crash, a commercial airliner, Piedmont Airlines flight six from Roanoke, Va., diverted from LaGuardia, narrowly missed repeating the accident with another commercial liner at Kennedy Airport only 20 minutes away. A last minute pullup by the Piedmont plane just before it was to touch down averted a crash.

The blame for this lies squarely at the door of the Federal Aviation Agency which is not only reluctant to poke into anything new technically, but whose enforcement of even routine safety regulations is so slack that flying has become a perilous adventure.

The FAA insists that real-time computing, 3-D radar, and digital communications won't work in air traffic control. After all, the FAA looked at all these things five or six years ago. The agency refuses to recognize that new generations of systems, components, and knowledge are available.

In addition, the FAA keeps repeating that the technology has failed it, that companies haven't come up with equipment that will solve all its problems. The blame for not using technology is placed on industry; ergo, the agency is blamelessly pure.

No one at the FAA is willing to face up to the realization that it is the agency's job to accelerate, persuade, stimulate, encourage, and finance companies to apply new technology to the problems of air traffic control, which is by law the exclusive province of the agency. Until the FAA is willing to accept its responsibility, and stop its nonconstructive role of merely vetoing hardware, flying is going to be a risky business for everyone.

Unlike the space agency, which has made a contribution to reliability and technology, the FAA has contributed nothing but excuses and fatalities.

Electronics Newsletter

May 15, 1967

Plastic IC output outpaces forecasts

Production of plastic-packaged integrated circuits is outpacing the most optimistic 1967 estimates.

In January, IC makers were predicting that up to 30% of 1967's IC's would be plastic encapsulated [Electronics, Jan. 9, p. 130]; latest estimates run from 40% to 50%.

Spokesmen at Motorola and Texas Instruments say that at least 40% of their IC's will wear plastic this year. William Fowler, a TI product engineer, reports that 80% of all new industrial applications specify plastic, primarily to achieve costs typically 40% below the price of equivalent circuits in metal cans.

GE, which already has some of its IC's in epoxy, **is testing an epoxy formulation that's now being used in discrete lines; it's said to outperform the older plastic by lowering leakage current and failure rate while** boosting moisture resistance to military specification levels.

Quick-as-a-wink calibrating

Automated measuring instruments [Electronics, April 17, p. 161] are now headed for in-house calibration laboratories. Electro Scientific Industries will soon market a **meter calibration system capable of calibrating deflection-type multirange, multifunction instruments in as little as five minutes**; manually, such a chore could take three hours.

The Portland, Ore., company's Model 70 system **is controlled by a punched tape or card program.** It provides the currents, voltages, and resistances needed to check the measurement accuracy of such instruments as a-c and d-c voltmeters and ammeters, and ohmmeters. A digital printout gives the deviation from full scale for each measurement.

High-density magnetic tapes

Newell Associates Inc. of Sunnyvale, Calif., plans to introduce this week a tape transport it says will lead to:

- **A home color television recorder selling for under $500.**
- **A "reelette" of audio tape, costing under 10¢, that plays 44 minutes.**
- **And a half-inch data storage tape with 40 separate tracks,** a recording speed over 1,000 inches a second, **and a bandwidth over 10 megahertz.**

The tape is made with conventional material, iron oxide. The recording is longitudinal, which means, industry sources say, that Newell may have made a couple of breakthroughs. Since the recording heads would move in the same plane as the tape, several recording heads would have to be packed into a half-inch of space, and **the head gaps might have to be etched, rather than made of separate pieces of metal.**

In another tape development, the DuPont Co. is **field testing a chromium dioxide magnetic tape that it says can store twice as much information as conventional iron oxide tape.** DuPont notes that the tape can't be used on existing computers without some adjustment of the computer tape transport.

Printed transistors next in thick films?

A process of screen-printing field effect transistors with metallic and semiconductor inks is being developed by RCA under a NASA research contract. **Researchers hope to make logic and linear circuits almost entirely of thick films.**

The semiconductor portion—cadmium sulfide—of metal oxide semiconductor transistors is already being printed. But the gate insulator and the electrodes are still vacuum deposited. Frequency response ranges from 10 to 50 megahertz.

Franz Huber of RCA says his group hopes to be printing the electrodes by late summer. The oxide can be formed by pyrolytic decomposition of silane. The transistors would not compete with higher-frequency FET's made of thin films, but could be used in low-speed logic and communications circuits.

A new job for linear IC's

General Electric's linear integrated circuits activity is now moving into an untapped market: timing and triggering functional units. The company will introduce this month **a monolithic IC firing unit for power-control** systems. Containing differential amplifier stages and trigger elements, the circuit can be used to gate thyristors and other power semiconductors. **GE also plans to introduce one or two new linear IC's a month** for the rest of 1967 for functions previously unavailable in monolithic form.

TRW expected to reenter custom IC market soon

TRW Semiconductors will probably move back into the custom integrated-circuit business in the near future. Executives at the Lawndale, Calif., division of TRW say the timing and the products to be marketed are still being weighed.

TRW Semiconductor pulled out of the IC field entirely three years ago. One of its main efforts had been in developing transistor-transistor logic circuits including a family for the Phoenix missile program. Many of the engineers working on IC's were moved to TRW Systems Group to augment work under way there aimed at developing IC's for hardware being built by TRW Systems.

Navy scans bids for all-IC radar

The Navy is about to begin development of radar for mid-70's fighter aircraft. Bids came in this month on MAIR, molecular airborne intercept radar. The winning company will receive a contract for a one-year study of an all-integrated circuit, phased-array radar that would perform fire control, terrain avoidance, and other functions.

Although the Navy system appears similar to the Air Force's MERA [Electronics, Feb. 21, 1966, p. 135], **industry sources claim the MAIR study will result in plans for a flyable system.** The Air Force system is a test-bed for microwave integrated circuitry.

Shed more light on low light level systems: Grumman

There has been a duplication of effort in research on low light level attack systems, contends William C. Athas, manager of avionics program, advanced development, at Grumman Aircraft Engineering. Athas, in a paper to be delivered this week at the National Aerospace Electronics Conference in Dayton, Ohio, will call for the Pentagon's Director of Defense Research and Engineering to coordinate an exchange of information on R&D in this area.

LSI array with 2,500 elements

A complementary array of 2,500 active elements on a single chip is being developed by Westinghouse's Aerospace division. First models of the metal oxide semiconductor circuit are expected to be ready by year's end.

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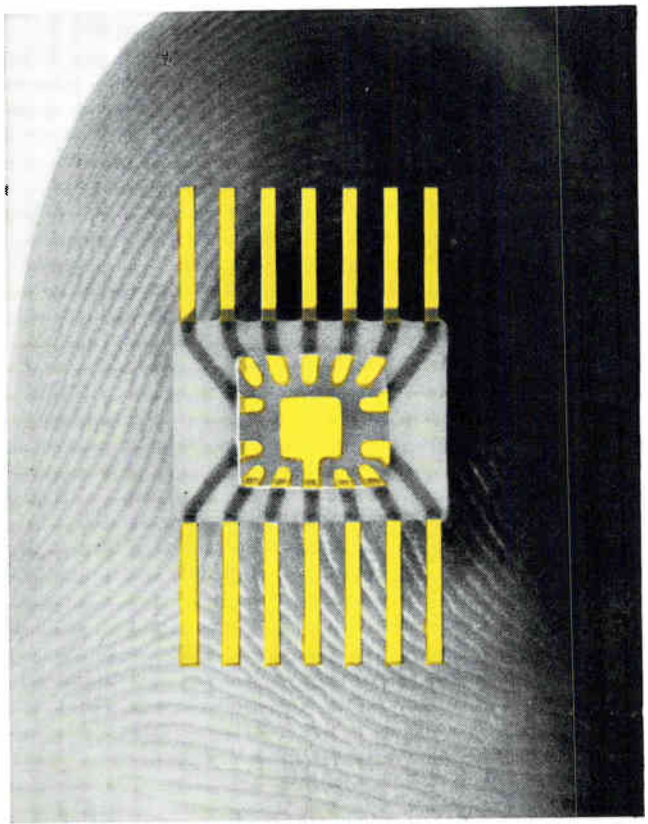

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The JA can be had in any integral or fractional current rating from 0.100 to 30 amperes. Standard maximum voltage ratings are 250vac, 60 or 400 Hz; 65vdc. Our Bulletin 3350 will give you complete specs and catalog data. A copy is yours for the asking, of course. Heinemann Electric Company, 2700 Brunswick Pike, Trenton, New Jersey 08602.

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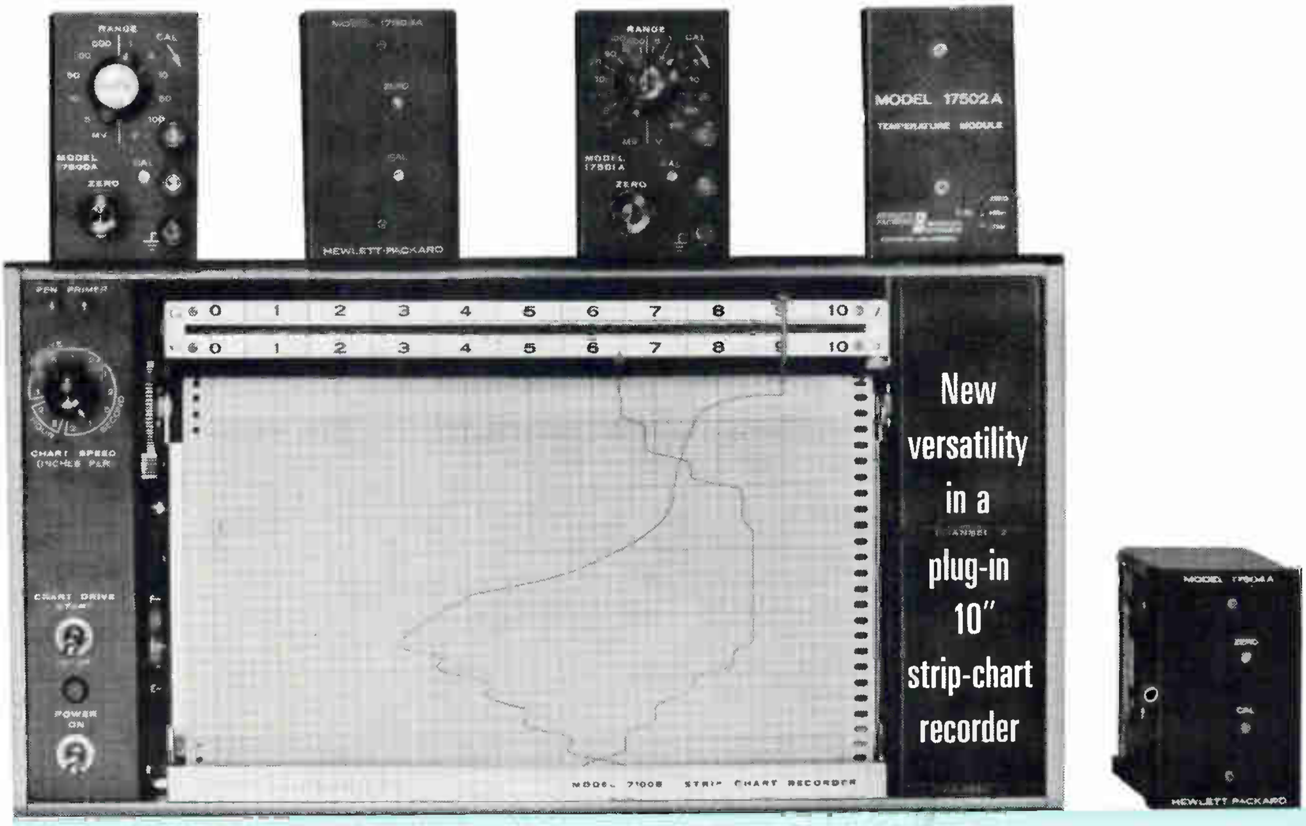
3649

PLUG-IN



- Input modules provide special purpose capabilities
- Mainframe available with one or two pen flexibility
- 12 instantly selected chart speeds, 1 in/hr-2 in/sec
- Half-second response time
- Chart tilts in three positions for easy viewing and notation
- Easy chart loading, tear off or storage, paper supply indicator
- All solid-state circuitry
- Rack-mount, metric models available

The basic mainframe of the 7100B (two pens) and 7101B (one pen) provides 10" strip-chart recording capabilities. Each channel accepts any of the wide variety of input modules which determine the electrical span or special-purpose recording capability.

Features offered, in addition to those above, include event markers, electric pen-lift and chart drive start-stop—all remotely controlled. Retransmitting potentiometers, adjustable high-low limit switches on both channels and remote 10-1 speed changers are also available.

Standard input modules (more to come) offer multiple span ranges, high input resistance (1 meg at null), high cmr and floating inputs to 500 v above ground. Model 17500A has 10 calibrated spans 5 mv-100 v full scale; Model 17501A has 16 calibrated spans 1 mv-100 v full scale. Variable span and full scale zero controls are provided. Model 17502A, a temperature input module with automatically compensated reference junction, linearizes recorder presentation with standard paper. Additional low-cost single range input modules (Model 17503A, 1 mv input with filter; Model 17504A, 5 mv-100 v with plug-in range cards) are also available:

Model 7100B 2-pen Recorder, $1300
Model 7101B 1-pen Recorder, $1000

Model 17500A Input Module, $250
Model 17501A Input Module, $350
Model 17502A Input Module, $250
Model 17503A Input Module, $250
Model 17504A Input Module, $200

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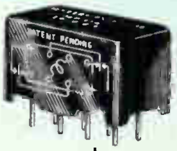
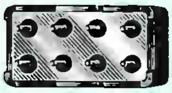
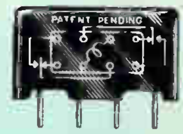
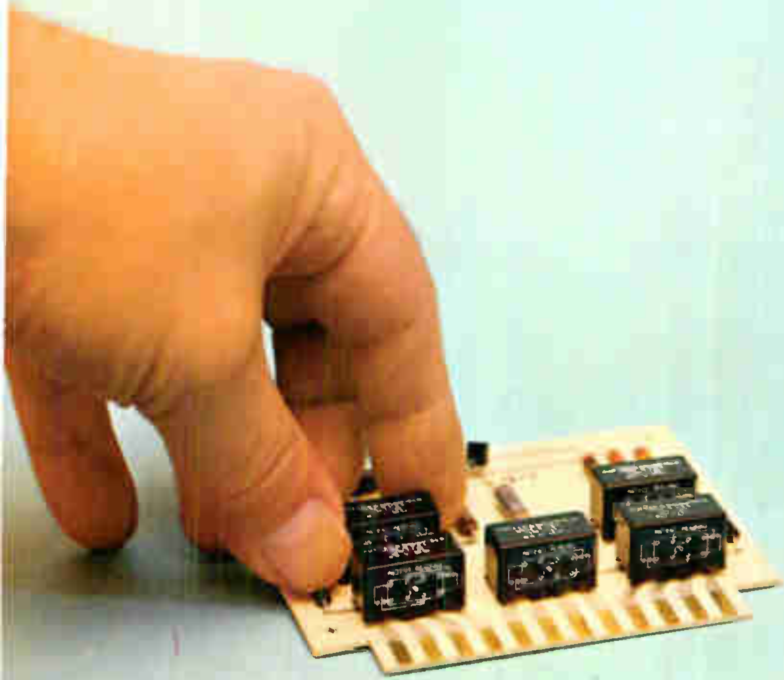
NEW! A commercial relay this  small with 2-ampere dpdt contacts. Printed circuit or socket terminals.  Has Lexan dust cover. This design bonus from our aero/space program is ideal for tape recorders, desk-top computers,  copying machines, television cameras, alarm systems, etc., etc., etc., etc., etc.



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- **Dimensions:** 0.49″ x 0.88″ x 0.48″ max.

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- **Contact Resistance:** 50 milliohms before life measured at maximum rated load.

COILS:
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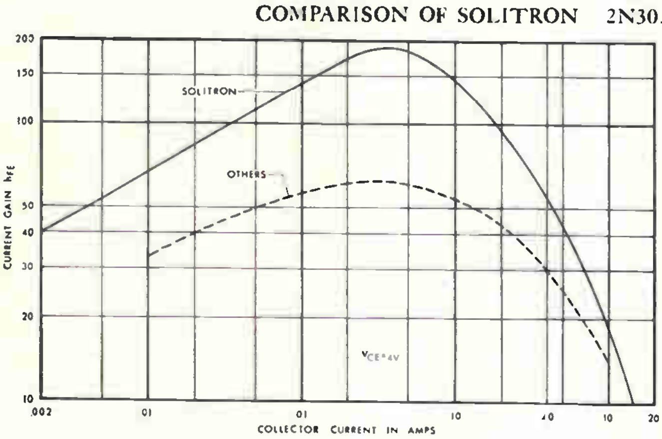

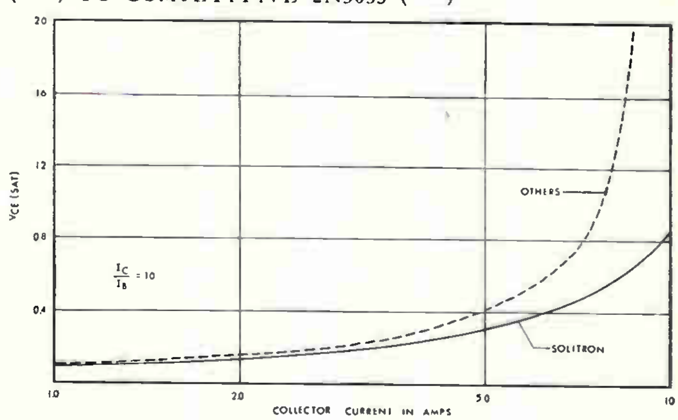

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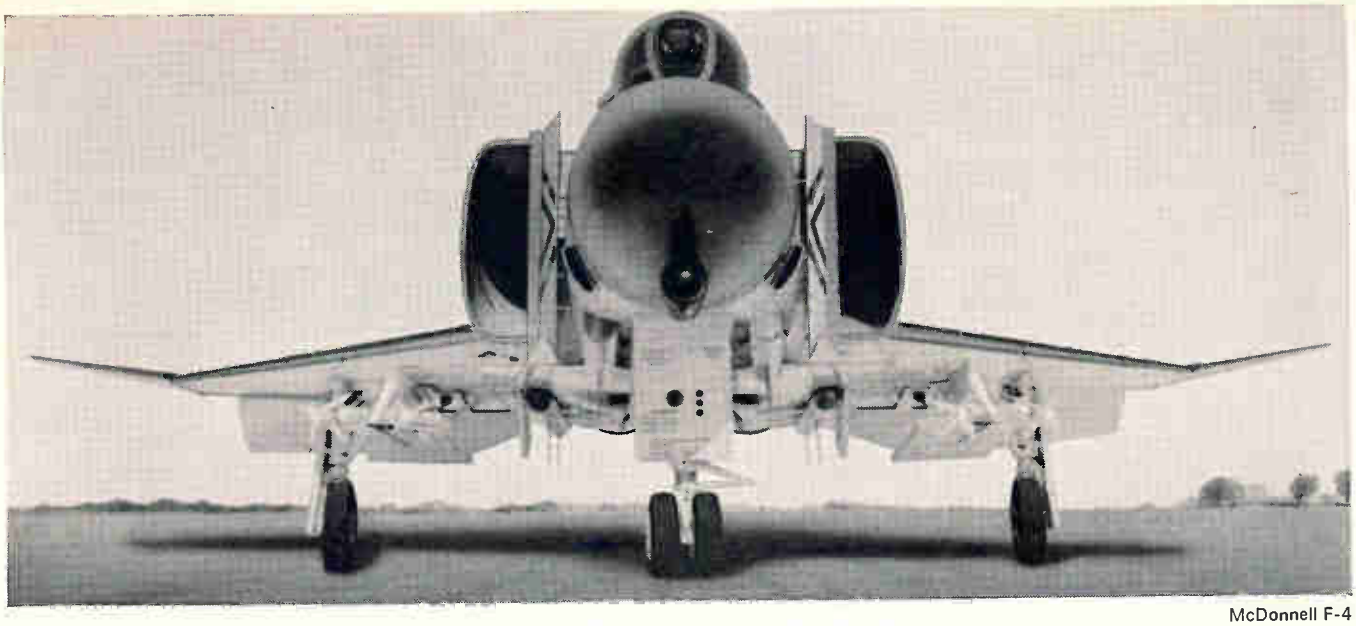

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Bendix Aerospace Products

Electronics Review

Volume 40
Number 10

Consumer electronics

Back talk

What's holding up the introduction of computer-operated teaching machines? In one word, money.

Even the most inexpensive systems in which the student answers the computer's questions by typing the message on a keyboard cost upwards of $350,000. In Norman, Okla., a small electronics firm, Dorsett Industries Inc., has developed a machine that costs $450—and it accepts typewritten, spoken, and handprinted answers, signaling the student when he is wrong.

Short on storage. The Dorsett teaching machine can't provide complex remedial instruction when a student gives an incorrect answer since it lacks the vast storage and display capabilities of computer systems. But Lloyd Dorsett, the company's president, wonders if such flexibility is really worth the high extra costs.

The Dorsett teacher uses the desk-top audio-visual teaching consoles the company has developed over the past few years. This console projects visual material stored on filmstrips or slides onto a viewing screen. A tape, a phonograph record, or a sound film is synchronized to the visual information.

To make the electronics for the three-response systems as compatible as possible, Dorsett chose an eight-bit response code. Dorsett established the eight-letter groups after studying the frequency with which letters are used in the English language. For example, a frequently used letter such as an "e" is grouped with the less frequently used "j" and "z." A typed or printed answer consists at most of eight characters, while a spoken word is sensed by detecting eight aural characteristics that define it.

For the typewriter response system Dorsett has developed a contact strip that fits under most electric typewriters. The strip senses the keys that have been depressed. Because the keys are lumped into eight groups there are eight contacts on the strip.

When a student types an answer to a question, the contacts transfer the response to a shift register within the machine. The correct answer is coded on the film where it is sensed by photocells. If the two eight-bit codes are identical, the student has answered correctly

Audio-visual teaching machine developed by Dorsett Industries costs $450 and permits student to respond in three ways: by typing answers on the keyboard of an electric typewriter (left), speaking into microphone (top), or printing in block letters on pad of paper on electric grid (right).

and the program continues. If the answer is wrong, the machine produces either a sharp tone or a warning light. The student then tries again.

Package deal. For $350 a customer receives a film strip projector, a record player, a pickup strip for the typewriter, or a special alphanumeric keyboard, and transistorized logic and amplification circuitry. The spoken-response circuitry costs an additional $100.

Dorsett's audio discriminating circuitry uses filter circuits to sense the eight different properties of the voice. The filters sense the sibilants, the word length, and plosive sounds such as "p" or "t." Five twin-T reflex audio filters ranging from 800 to 2,500 hertz sense different vowel sounds.

The correct answers are also coded on the film. Sensed by photocells, the coding is compared with the sound characteristics that have been detected and stored in the shift register. Dorsett says that the system can handle an indefinite number of words.

The simplest device is the unit that accepts handwritten responses. Answers are written in block letters on paper placed over a serrated metal template having ¼-inch wide gaps. In the lower right hand corner of the gaps are tiny silver-alloy contact switches which are closed by the pressure of a pencil point. For example, a capital "E" would close the contact, a "W" would not.

Up to eight letters can be used in an answer so that the unit again makes use of the eight-bit shift registers and the comparison circuitry.

Avionics

Beyond the SST

Although President Johnson has just authorized the construction of the first prototypes of the supersonic transport, NASA is already planning the avionics for an advanced version that will fly higher and faster.

Directing this work under a multimillion-dollar, five-year program will be NASA's Electronics Research Center in Cambridge, Mass. This is the center's first major step in aeronautics for the space agency. In charge of the program is Richard M. Head, who once served as a designer of Navy fighter planes.

During the past year the center initiated planning for the avionics of the second-generation SST. The aim is to develop the major electronic elements of a totally integrated avionics system by the 1972 to 1975 period.

One of the first studies planned by the center will be on the feasibility of using a satellite-aided communications system operating at L band, between 1,540 and 1,660 megahertz. A contract will probably be awarded this summer.

For the on-board L-band terminal, several new technologies will be explored, including multiple flush antennas to keep the satellite in sight at all times, and antenna sharing for navigation and collision-avoidance systems.

Laser gyro eyed. In the navigation area, the center will sponsor studies of multimode systems, relying on inertial navigation and updated by a combination of techniques, such as passive navigation satellites. In addition, the laser gryo will be explored as a low-drift-rate inertial component.

Also under consideration is the incorporation of the inertial navigation system into an advanced instrument landing system, the radar altimeter, and an autopilot for an all-weather approach and landing operation.

Flight measurements. The NASA center will seek new gear for the measurement of air temperature, particularly since engine performance will be critically dependent on it. In measuring altitude, Head says, errors must be minimized so that vertical separation of aircraft can be safely reduced to under 3,000 feet.

Techniques will be sought to measure fuel flow accurately at rates up to 100,000 pounds per hour. Instruments will be developed to monitor cumulative fatigue damage, the radiation environment at cruise altitudes of 70,000 feet, the ozone environment in the cabin and at the wheel wells, and the erosive effect of microparticles.

"At these altitudes" Head points out, "it may even be necessary to monitor major solar proton events, particularly the cumulative effects on crews flying polar routes."

Development of automatic and semiautomatic flight modes will be the contribution of advanced electronics technology to the craft, says Head. His group will decide whether to use special-purpose computers for each subsystem or a centralized multipurpose computer. Among the other decisions to be made will be the choice of the functions performed better in flight than on the ground.

Space electronics

'Desperate trouble'

He said not a word about the Apollo tragedy of last January, but it was clear that his remarks were postscripts to the fire that killed three astronauts.

"We are in desperate trouble because of low-grade workmanship," declared Abe Silverstein, director of NASA's Lewis Research Center in Cleveland.

Addressing a group of electronics engineers in Boston, Silverstein said there were 70 failure reports on the Atlas-Centaur booster while it was sitting on the pad at Cape Kennedy awaiting the Surveyor vehicle that is now exploring the moon. The reworking to correct the faults cost $400,000.

"But things are getting better," he added. "We used to have 150 failures in about the same time period."

Cost of success. "Sure we have successes in space," Silverstein said, "but only after a lot of rework right at the pad." He noted that it costs four times as much to rework a part as it does to build it right the first time.

"We aren't putting in the design work that we should," Silverstein asserted. "We don't have enough good designers." The official said most of the design work he looks at "stinks."

"We need components and circuits with the 'Good Housekeeping' label on them," he continued. "the kind that work every time, and are cheap."

Silverstein urged that work on space projects be done in experimental shops, rather than production shops. "There are too many low-grade workmen in the production shops," he explained.

"As it is now," he said, "too many times when we buy an article from a vendor, it's obvious that it was made by someone who didn't know, or care, where it was going."

Defense measure. He also said NASA should find a way to "put a cocoon" around a space vehicle after it's finished "so that they (technicians at Cape Kennedy) will keep their cotton-picking fingers off it."

The first industry "casualty" of the Apollo disaster is Harrison A. Storms Jr.; he was fired as director of the Apollo spacecraft program at North American Aviation Inc. The 51-year-old engineer had been credited with winning the Apollo contract for North American.

His job as president of the company's Space and Information Systems division (the name was changed last week to the Space division) went to William B. Bergen, former president of the Martin Co. Storms remains a North American vice president.

Packaging

Third generation

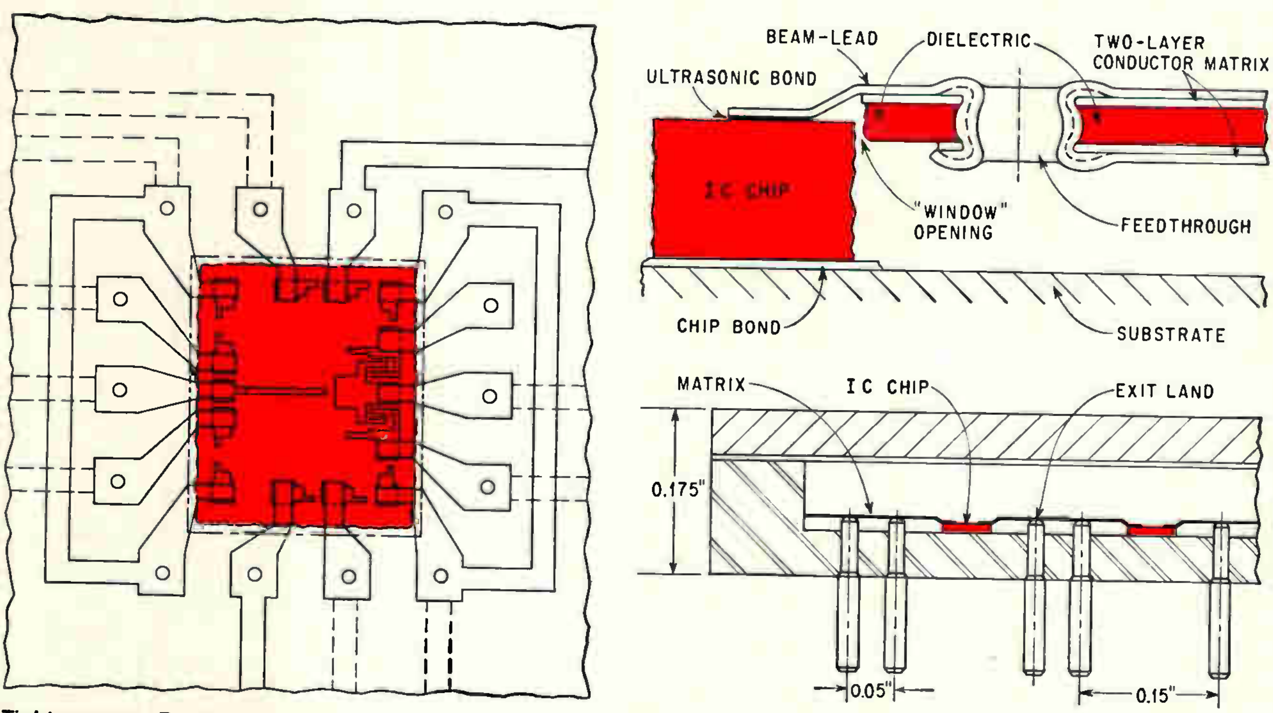
Two integrated-circuit packaging techniques that the International Telephone and Telegraph Corp. has been developing for two years have been synthesized into a third technique that allows 30 IC's to be assembled in a square inch of printed circuitry. What's more, John Marley, an ITT engineer, expects the new assemblies to be far cheaper to make than conventional IC assemblies.

The circuit boards are wispy Mylar films, 5 mils thick. Layers of etched wiring—one on each side—are connected by metal, plated in holes etched in the plastic. The IC chips fit into square holes etched into the plastic under beam-like extensions of nickel plating on the wiring. The tips of the beam leads are ultrasonically bonded to thin-film terminals on the chips.

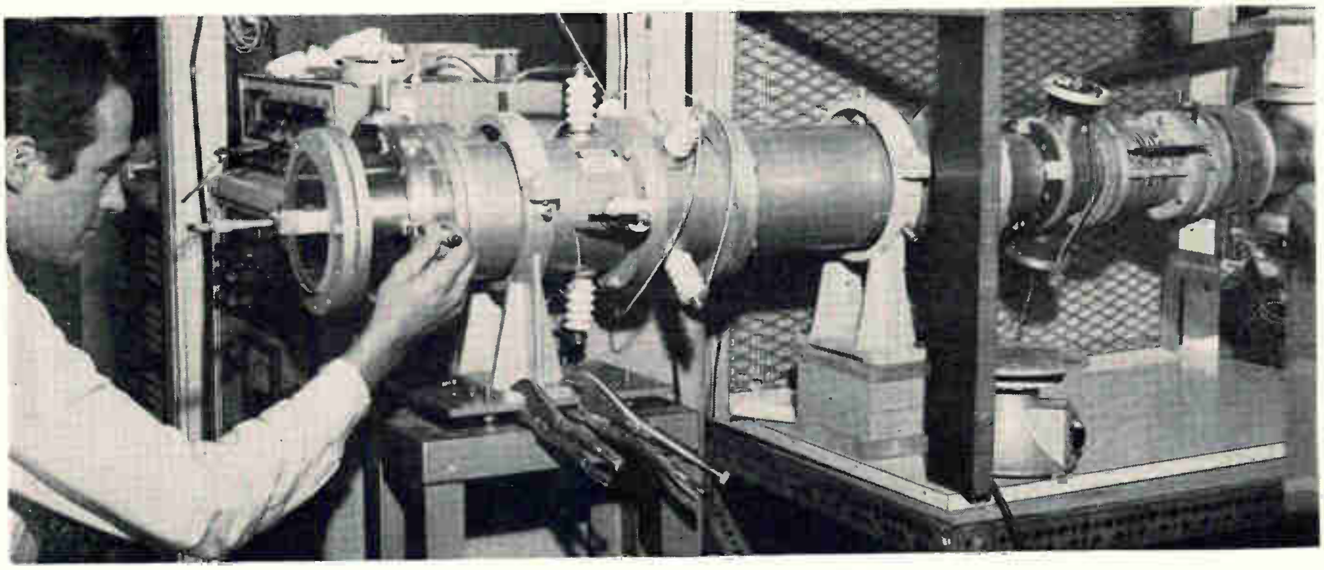
A typical assembly of 42 chips is 1.2 inches square and fits into a 1.4-inch-square package. Up to 196 exit lands can be put into the wiring matrix. These lands can be welded to plug-in pins, as illustrated, or can be connected through wiring on the package substrate to large beam leads along the sides of the package. Such packaging would provide a system density of about 100 IC's per cubic inch.

When large-scale integrated circuits become available, Marley noted, the chip assembly can be converted into a single chip with little redesign.

Progenitors. Forerunner of the printed circuit is the "laminate and cribbage board" assembly that the ITT Federal Laboratories division has been producing for avionics systems [Electronics, Feb. 8, 1965, p. 67]. Each 1¼-inch-square as-



Tight squeeze. Beam-lead bonds and feedthrough eyelets of interconnection matrixes are shown in plan and cross-section in the sketches on the left and at the top. At the bottom is one package design ITT plans to use for chip assemblies.



Zap a circuit. Microbeam of dopant ions bombards host material to form a junction. System designer monitors the process through an electron microscope at the end of the channel.

sembly contains 12 IC's in flatpacks.

The etching and plating techniques have changed little, although the wiring patterns have been made much more compact for the new system. Each square inch now carries the equivalent of 300 discrete point-to-point wires.

The beam-lead bonding method stems from IC packaging methods the ITT Semiconductor division had been working on in a companion project [Electronics, July 12, 1965, p. 98]. The method, however, is not restricted to ITT's circuit design. Marley and a coworker at ITT Federal Laboratories, James H. Morgan, reported at the Electronic Components Conference in Washington that prototype assemblies were built with IC chips made by the Signetics Corp. The beam leads can be aluminum, copper, nickel, and combinations of these metals, and they can be plated with aluminum and gold to accommodate different metals on the chips.

Cheaper joints. A chief attraction of the new technique is low cost. A 42-IC assembly requires only 588 man-made bonds if 14-lead chips are used, while a flatpack assembly would require 1,764 bonds—two wire bonds in the package and one to external wiring. Besides, Marley adds, "chemofacture" of the wiring is cheaper than manufacture of bigger assemblies.

These assemblies are also expected to prove more reliable than conventional assemblies—a point which is being checked out in a reliability study sponsored by the National Aeronautics and Space Administration. Marley and Morgan say the beam-to-chip bonds are stronger than conventional wire-to-chip bonds, while the lesser number of bonds means fewer chances for assemblers and testers to make errors.

If IC's in the assembly are faulty, the beams can be pulled off the chip and a new chip bonded to beams.

Manufacturing

Eye on production

"For five years, we've been finding out 'if.' Now we're ready to start applying the ion-implantation process to production of integrated circuits," says John A. Gale, president of the Ion Physics Corp. of Burlington, Mass.

The "now" is being made possible by the Corning Glass Works, which last month bought from Ion Physics the rights to the implantation process for semiconductors [Electronics, April 3, p. 26].

"Other Corning 'hyphenations' have done quite well. We expect to also," Gale says of the Corning-Ion Physics venture.

Secret of success. Corning brings to the effort money, equipment, and production techniques. It also brings a background in materials technology, plus the circuitry, production, and marketing experience of the Signetics Corp., a Corning subsidiary.

Ion Physics contributes five years of experience with implantation, a process rooted in the Van de Graaff particle accelerator technology of its parent company, the High Voltage Engineering Corp. In the technique developed by Ion Physics, the junctions are fabricated in semiconductor materials by controlled bombardment with dopant ion beams. This process of selectively doping host materials, it is claimed, provides a higher yield, uniformity, and reproducibility than chemical diffusion processes.

"And, in the case of integrated circuits, it gives the circuit designer more freedom," Gale adds.

"Any ion can be implanted in any material," explains William J. King, manager of Ion Physics solid state physics department. "We are not limited by the thermal effects inherent in diffusion processes," he adds.

Leapfrogging over today's silicon technology will be the basic strategy of Corning-Ion Physics. "Why

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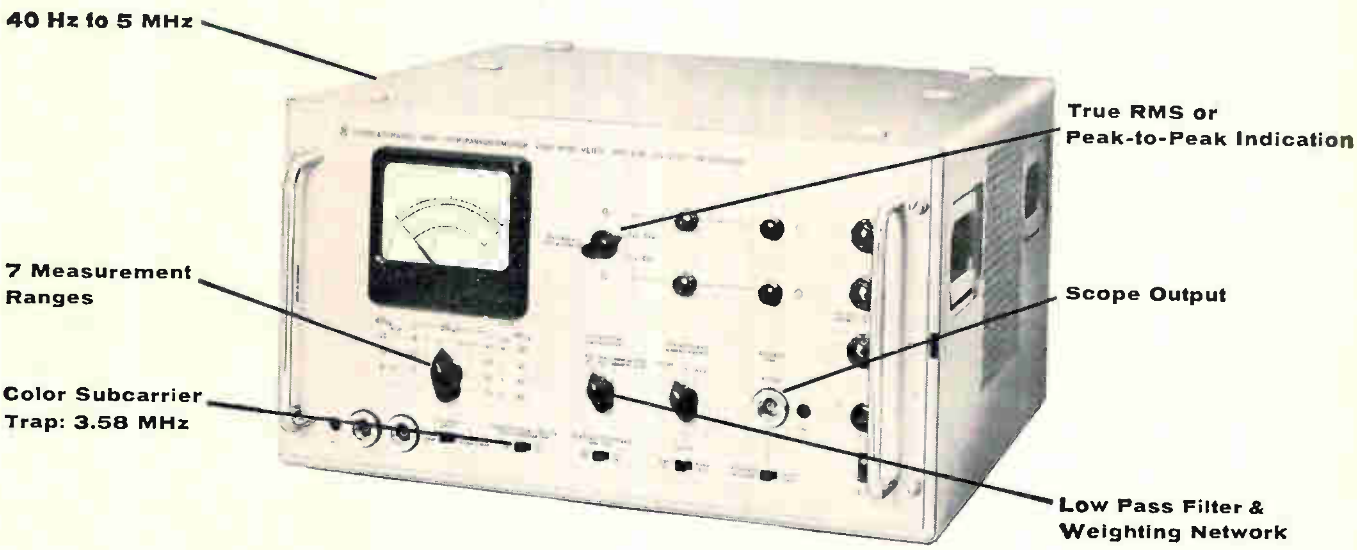

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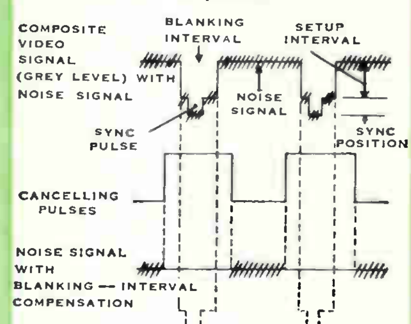

Principle of noise-voltage measurement with H or V internal blanking

Type UPSF Video Noise Meter is designed to measure the unweighted and weighted noise voltages of TV transmission systems. It has the unique advantage of measuring low level components in the presence of high level horizontal or vertical sync and blanking pulses (see line drawing). The UPSF meets the requirements of all U.S.A. black and white and NTS color systems. A bandstop filter adjusted to the color subcarrier frequency (3.58MHz) prevents any residual color subcarrier in the test signal to be picked up. In addition to supplying true RMS value 0.3 mV to 0.3V (full scale deflection) it also can provide peak-to-peak value of 1 mVpp to 1Vpp (full scale deflection). The UPSF can also be used as a conventional broad band VTVM.

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Circle 41 on reader service card

do what is already being done with other integrated-circuit processes?" asks Gale.

"We are aiming at 0.1-micron resolution in line spacing, compared with the 5-micron resolution now available," says King. He adds that ion implantation should provide junction separation of 0.1 micron without masking, plus a cleaner junction profile than is possible with masking techniques.

Diamond circuit? King says he will be exploring particularly the III-V and II-VI compounds of the Periodic Table for new types of IC's with high power and packing density as well as faster switching times. His group has already investigated gallium arsenide, indium arsenide, silicon carbide, and indium antimonide and found that the implanted junctions are electrically satisfactory. The group has implanted boron ions in diamond, but sees no appreciable market for a diamond circuit.

The three-to-five-year goal, King says, is an all-beam process, with the exception of the connection to the outside world. An oxide will be deposited by a beam-type sputtering process developed at Ion Physics, and various controlled beams will write the circuit on the substrate, selectively remove oxide, and deposit thin-film materials for resistor and capacitor paths.

The ion generation system will probably be in the 100- to 500-kilovolt range, followed by equipment to control the size, energy, and direction of a beam or a bundle of beams. A feedback system will operate between the beam at the workpiece and the control equipment. For large-scale integration, a bundle of beams will consist, for example, of 100 phosphorus beams writing simultaneously, under computer control, on a group of substrates.

Solar cells were the first devices fabricated at Ion Physics by implantation techniques [Electronics, April 19, 1963, p. 26]. The company produces solar cells on a pilot production basis but has equipment capable of putting out 2,500 2-by-2 inch silicon solar cells a month. The process has also been applied to fabrication of transistors and diodes.

Ion Physics plans to continue work on high-frequency transistors because it feels that implantation offers advantages in junction resolution and depth.

Advanced technology

Test tube

Reliability and stability problems have long plagued attempts to measure the relative intensities of the different wavelengths of light sources in space. In efforts to measure such things as the faint air glow or aurora phenomena in outer space, scientists have used spectral photometers with rotating filter wheels; but the moving parts often stick after long use aboard satellites. Other experimenters have used several tubes, each with its own filter, to measure a different component of light. Eventually, however, the photomultipliers have drifted, spoiling the measurements.

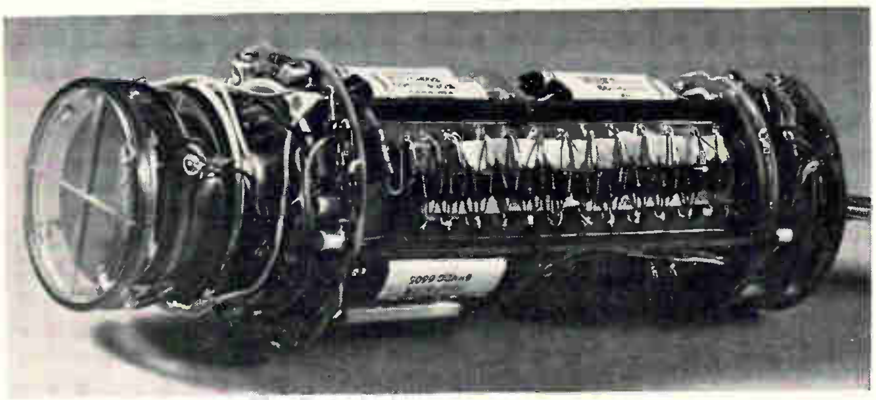
Now, a tube that has no moving parts and provides four light-level readings of different frequencies simultaneously has been developed by Electromechanical Research Inc., Princeton, N.J.

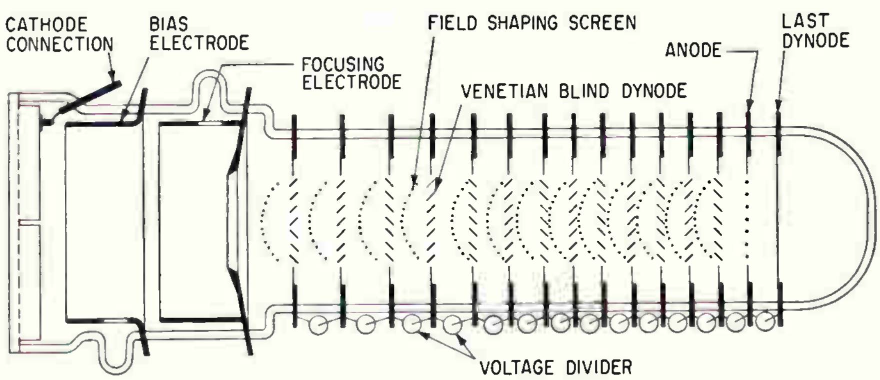
The new tube is a photomultiplier with a cathode divided into four quadrants. Although each quadrant operates separately, the four are fed through a common beam-multiplying structure.

Spectrum. The spectrum range covered is slightly broader than the visible range—3,000 to 8,000 angstroms, according to the developers, Martin Rome and O.H. Sackerlotsky.

In operation, when one quadrant is turned on the other three are reverse biased. Because only 16 to 20 volts is required to turn the quadrants on and off, direct-coupled transistor switching circuitry can be used.

By sequentially switching the





Down the pipe. Photomultiplier tube has 14 venetian-blind dynodes that amplify the electron beam through a series of secondary emission steps. The quadrants can be used with individual filters to sense the intensity of four color components of a light source. The tube is about 6½ inches long and 2 inches in diameter.

cathode on, an output signal on a single channel can be obtained in which the four successive levels correspond to the relative light intensities focused on each of the quadrants.

The tube could also be used in position indicators and aspect sensors. Each quadrant can be related to the x-y coordinates of a light beam, and the position of the light source can be determined by nulling the four signals in a feedback loop. Precise nulling is possible because the tube has a common amplifying structure for all four signals.

Diode boost

An avalanche diode capable of 435-watt pulsed outputs at 400 to 1,010 megahertz has been developed by the Radio Corp. of America. The pnn^+ diodes deliver several hundred 1-microsecond pulses per second with 30% to 40% efficiency. The best previous avalanche transit time diodes yielded only 33- to 37-watt pulses with 3% to 5% efficiency at about 8 gigahertz.

According to C.K.K. Chang, head of the group in Princeton, N.J., that developed the new diodes, the next steps are to find out how the devices achieve their high efficiency and to see if they will deliver continuous output. Higher diode frequencies and consistent performance are still sought. Thus far, output and efficiency vary from device to device.

Up and down. Comparing the performance of avalanche diodes operating at 8 Ghz with the levels reached by the new devices can be misleading, since power falls as frequency increases. If RCA's diodes derate as their predecessors did, they would deliver only about 1 watt at 8 Ghz. However, since efficiency need not drop at higher frequencies, the input power needed to generate that watt could be from 10 to 15 times lower than previously required.

Until now, avalanche devices with good performance at 400 Mhz were rare. The high voltages needed for operation at these frequencies often burned out the diodes. RCA's diode withstands the approximately 200-volt, 2-ampere pulses required by using a circular mesa structure 26 mils in diameter to spread the heat over a relatively large area. A heavy copper mount, which doubles as a heat sink and an ohmic contact, also is used.

Diode fabrication begins with a substrate of n^+ (heavily doped) silicon. An n-type epitaxial layer is then added, followed by a boron-doped p-type layer with an abrupt junction. The sandwich is etched, leaving the circular mesa of p- and n-type silicon. The top of the p layer is aluminized and a thermally bonded gold ribbon lead is used to make a second ohmic contact.

What's the use? The new diodes could find their way into Blue Chip, RCA's project for an all-integrated-circuit radar system, says Harold Sobol, who heads the project. To do so, the diodes would have to operate at about twice the frequencies already reached. Present plans call for Blue Chip to use a master oscillator having a 2-to-2.5 Ghz frequency range. Varactor diode multipliers will boost output to X band (about 8 to 12 Ghz).

Industrial electronics

Automatic draftsman

Instead of relying on a draftsman to convert an engineer's rough jottings of a circuit schematic or logic diagram into a finished drawing, engineering companies will soon be able to turn the work over to a drafting system built around an automatic phototypesetter.

A developmental unit called the Engineering Graphics System has been designed by Photon Inc. of Wilmington, Mass. It reproduces on film or photographic paper more than 750 electronically oriented symbols and alphanumeric characters.

In addition to handling schematic and logic symbols, the system reproduces symbols found in flow charts, plus piping and organization diagrams.

Pick a symbol. A special digitiz-

Polaroid Land film makes you wait 10 seconds for an oscilloscope picture. The suspense can be unbearable.

We're sorry we can't do anything about that 10-second wait.

But if you can bear up under the strain, you'll get a sharply detailed, high-contrast, trace 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 also get a choice of four films for oscilloscope recording in pack, roll, and 4 x 5 formats.

The standard film has an ASA equivalent rating of 3000. And if you think that's fast, you haven't heard of our special film called Polaroid PolaScope Land film.

With an ASA equivalent rating of 10,000, it's the fastest thing in films. It can actually record a trace too fleeting for the human eye [for instance, a scintillation pulse with a rise time of less than 3 nanoseconds].

Of course, Polaroid Land films are as quick to point out a mistake as they are to point out a success.

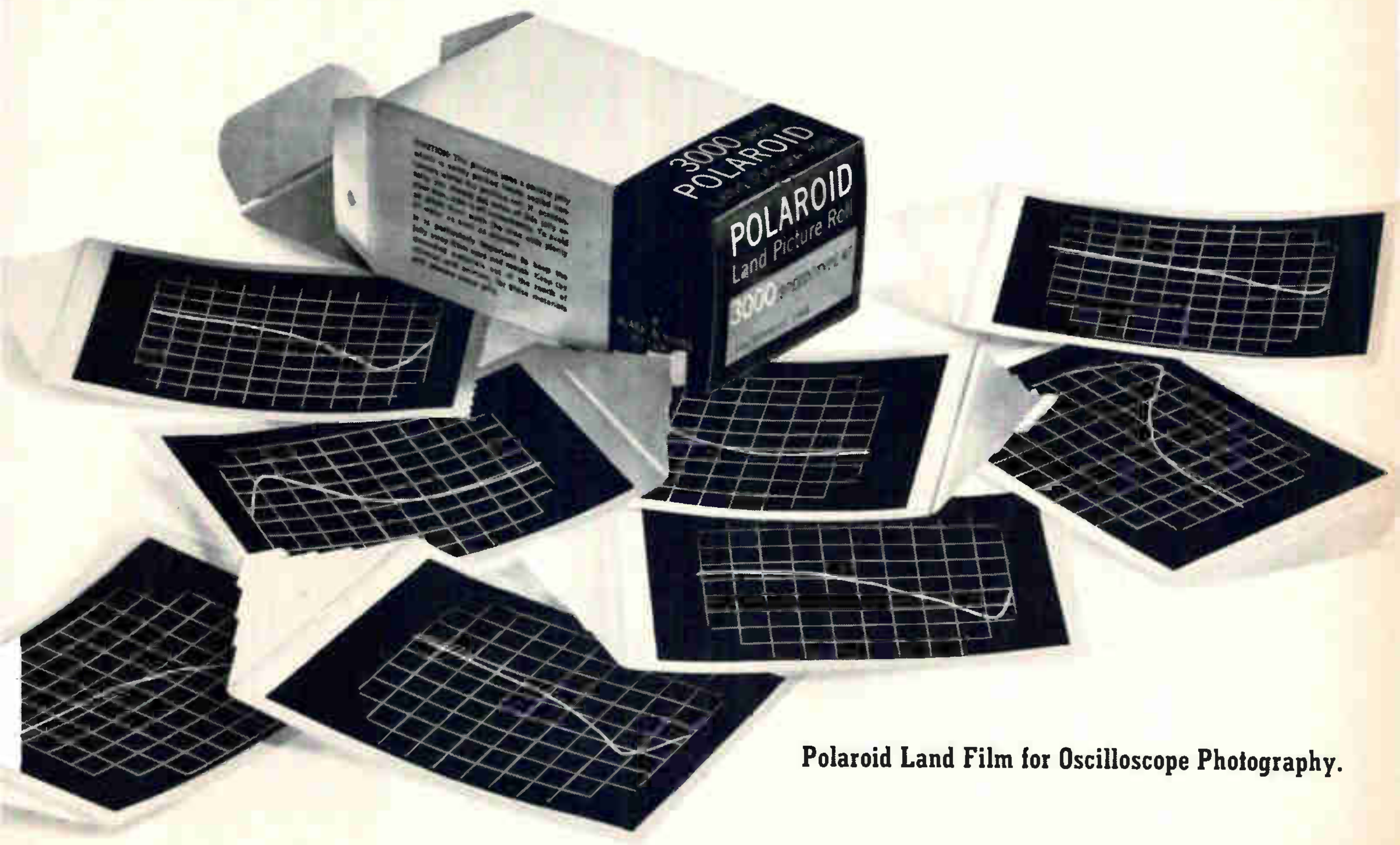
If your trace shows an error, you know it right away. And you never go through the tedium of darkroom procedure only to find out that your blip was a blooper.

To use these films on your scope, you need a camera with a Polaroid Land Camera Back. Most manufacturers have them. Such as: Analab, Beattie-Coleman, BNK Associates, Fairchild, EG&G, General Atronics, Hewlett-Packard, and Tektronix.

You can get complete details by writing to one of these manufacturers or to Polaroid Corporation, Sales Department, Cambridge, Massachusetts 02139.

By the way, if 10 seconds fray your nerves, just imagine what it was like when Polaroid Land film made you wait 60 seconds to see your trace.

"Polaroid" and "PolaScope"®



Polaroid Land Film for Oscilloscope Photography.

ing table is used to select the symbols from a chart. The symbols' location on the diagram is stored on a punched tape; alphanumerics are entered on a Flexowriter.

The tape is then processed in a computer that prepares the information in sequence on either paper or magnetic tape. This processed tape is then fed into a phototypesetter.

The phototypesetter stores the symbols and characters in a film memory and then reproduces them, under tape control, in a finished drawing on film or photographic paper. Lines are drawn by sequentially exposing segments of a straight line stored in the memory.

The system, with two digitizing consoles, a phototypesetter, and programing, will cost $85,500.

Communications

Predicting blackouts

An experimental advance-warning system for proton events on the sun, which disrupt long-range radio communications, has been established at the University of Paris, Meudon, France. It has already successfully predicted radio blackouts on earth caused by solar flares.

Called the proton flare watch, the network was established as a result of the International Years of the Quiet Sun. A satellite, Solrad 8, developed by the U.S. Naval Research Laboratory at Washington, is one of the system's key components. In addition to the satellite, about 20 observatories around the world are feeding information to the French center.

"The flare watch is not a practical warning network for communicators, but we are learning a great deal which will lay the base for engineers to predict these blackout events," says Herbert Friedman, a scientist at the Naval lab. "It hasn't quite reached the stage when all the bugs are ironed out, but the mode of work has already given us knowledge about how an operational network might work."

The project has profound implications in the manned space program, says Friedman. A warning of several hours to several days in advance of a proton event would give astronauts sufficient time to reach the safety of a shelter.

Companies

In the wake

Two high-level operations men have resigned from Texas Instruments Incorporated's Semiconductor-Components division, indicating that the smoke still hasn't cleared from the firm's recent managerial shakeup [Electronics, Feb. 6, p. 33].

Latest to leave are James R. Reese, assistant vice president and the division's operations manager, and A.N. Provost, manager of the division's year-old Sherman, Texas, plant. Both resigned late last month.

Another key figure, Earl Gomersall, who had headed up integrated circuits manufacturing before J. Fred Bucy replaced Cecil Dotson as division manager, is currently on "temporary assignment" to the division's purchasing department.

Reese plans to form his own company.

A source close to him said: "The new regime wanted to rearrange some operations in the division and Reese would have been left with a different type job than he was used to. He has always wanted to operate his own business and he felt this was a good time to step out."

No replacement has been named for Reese, who had all product groups reporting to him.

Provost was succeeded by Edward P. Miles Jr., manager of TI's Nice, France, plant and before that manufacturing manager and controller in Dallas.

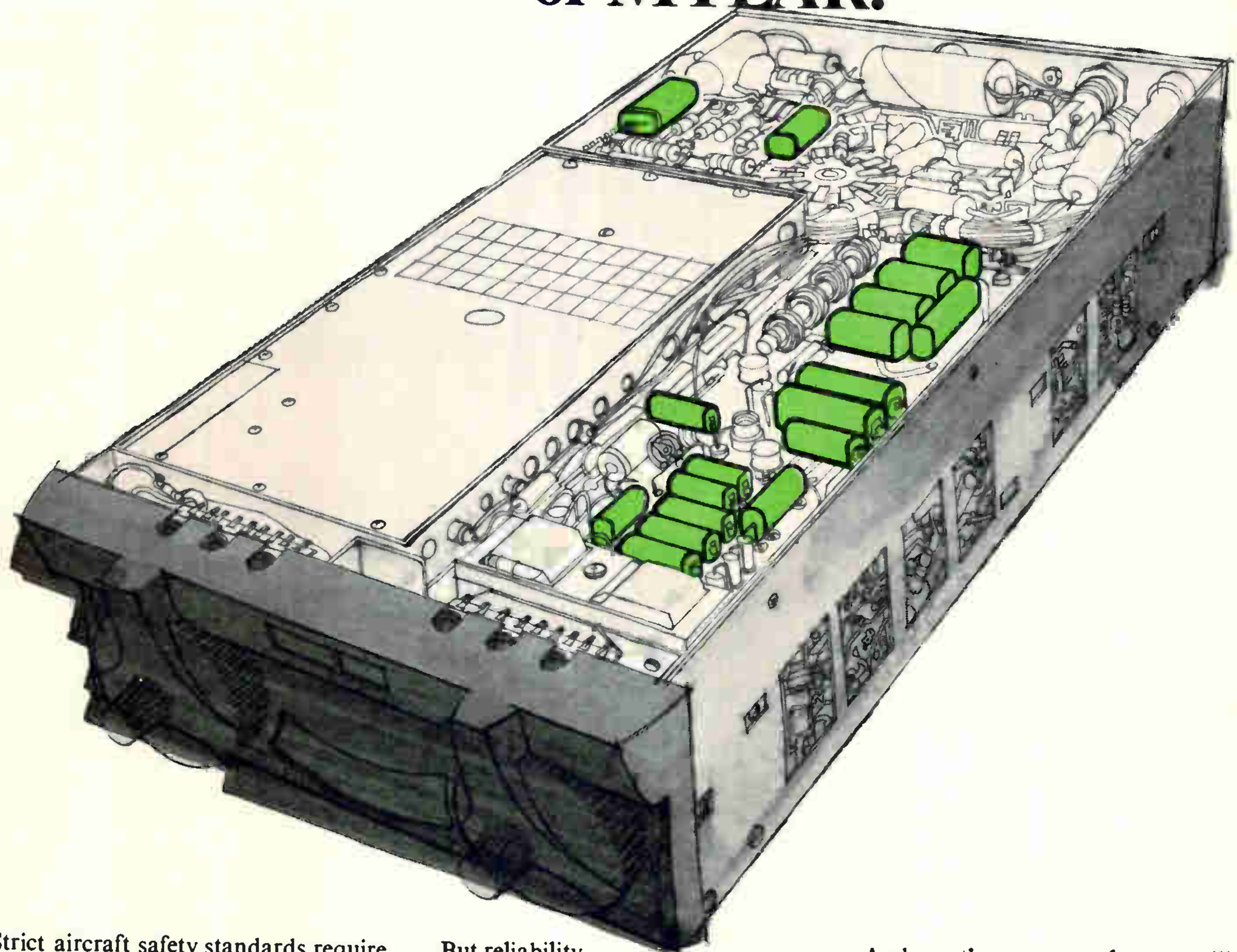
Computers

Think a bit

Everybody talks about how nice it would be to have a remote terminal in a time-sharing system that could

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 Du Pont 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 47 on reader service card

do some of its own low-level computation, but not much has been done about it. Now engineers in a year-old custom design house in Southern California have come up with just such a terminal—really a small computer redesigned for this particular application.

Richard F. Musson, president of the Digital Logic Corp. in Orange, Calif., and his vice president, Jerald C. Murphy, have added some circuitry to the PDP-8/S computer manufactured by the Digital Equipment Corp. The PDP-8/S is the first computer to sell for under $10,000; as such, it is a small, slow cousin of the same company's PDP-8. It comes with a teletypewriter as standard equipment; the teletypewriter is its input-output console. Musson, Murphy, and their colleagues, drawing on Murphy's experience as a former applications engineer at Digital Equipment, added an external data channel, and an autoloader to the PDP-8/S. This gives it the capability to act as a remote terminal as well as compute. The external data channel permits up to four input-output devices, such as card readers or printers, to run at once; the autoloader, or bootstrap loader, simplifies starting up the machine whenever a new program is entered.

For the record

Updraft at Xerox. Abe M. Zarem has been named senior vice president and director of corporate development at the Xerox Corp. [Electronics, May 1, p. 35] Zarem is founder and chairman of Electro-Optical Systems Inc. (EOS), a Xerox subsidiary that is about to be merged with the Xerox's Information Systems division. Sanford C. Sigoloff has been elected president and chief operating officer of EOS, rising from the post of executive president.

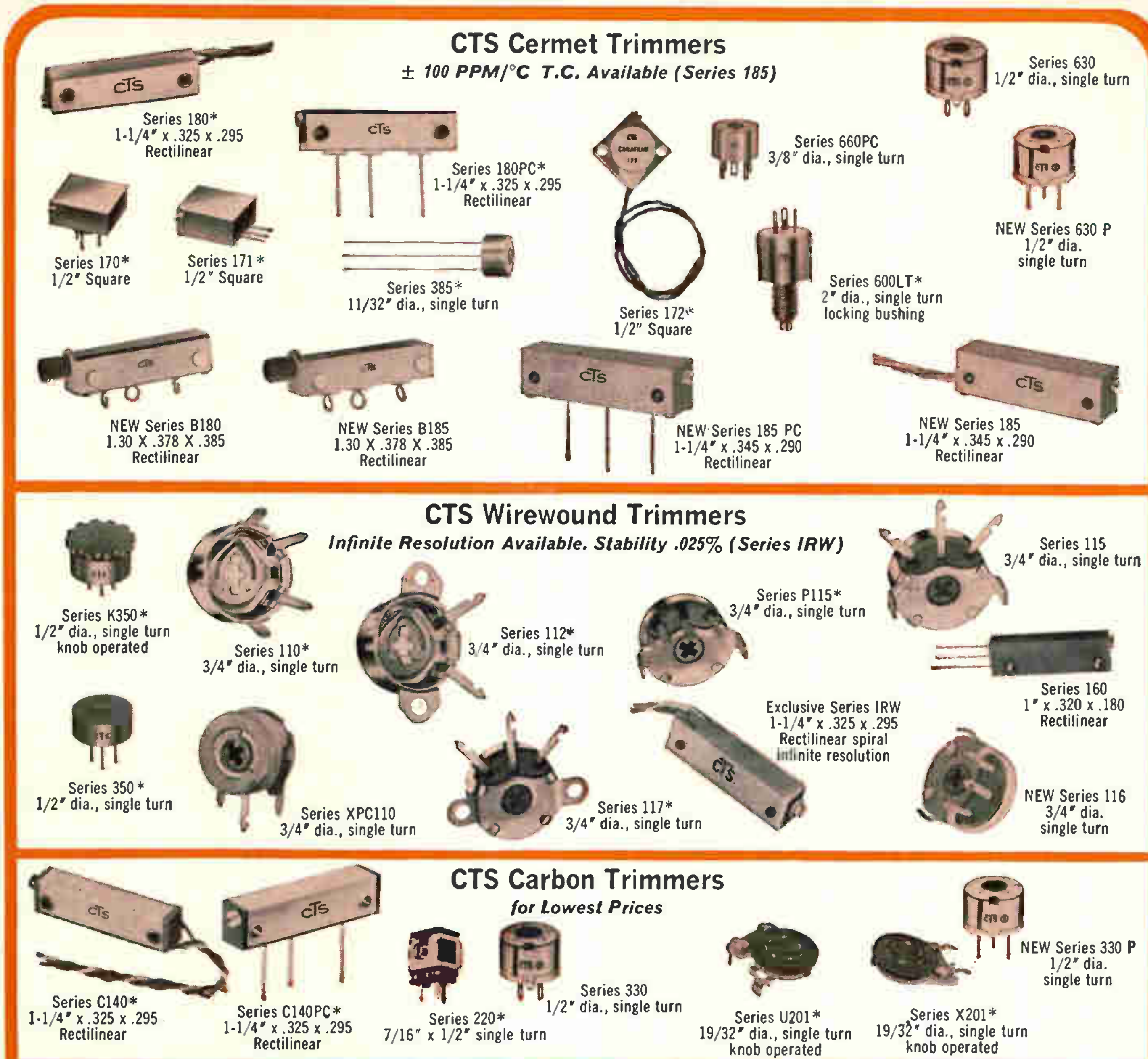
Change of command. Edgar A. Sack has succeeded R.A. Shieber as general manager of the Westinghouse Electric Co.'s Molecular Electronics division. The switch should mean little change in the division's product programs; in his former position as assistant manager, Sack already had been directing the division's product development. Shieber left Westinghouse after 26 years service to take the new position of staff vice president for manufacturing at the Radio Corp. of America's Defense Electronic Products division.

Radar ready. The first modules of Texas Instruments Incorporated's MERA solid state radar are in operation and working well, according to Tom Hyltin, head of the development program. To be delivered to the Air Force in mid-April, 1968, MERA is an all integrated circuit terrain-following radar using 600 identical oscillator-amplifier-receiver modules in a phased array.

Design change. The Port of New York Authority has changed plans for one of its twin, 110-story World Trade Center office buildings so it can carry the weight of television transmitters and antennas. This is another move in the Port Authority's running battle with owners of the Empire State Building over possible television interference and transmitter location.

Easy incision. Bell Telephone Laboratories has developed an articulated arm that makes it easier for surgeons to use a laser beam as a scalpel. The beam is guided through several hollow-tube sections that are connected at right angles by hollow blocks. Prisms within the blocks bend the beam 90°. Previously, spherical mirrors or fiber-optic bundles carried the laser beam.

Built-in mother-in-law. The Ford Motor Co. is experimenting with a driving-pattern monitor that counts the number of times a driver moves his steering wheel to change direction. If the count is too high, the device buzzes, alerting the driver to his erratic steering. The device also buzzes if the count is too low, warning the driver that he may not be paying attention. The company's subsidiary, the Philco-Ford Corp., has set up an automotive electronic development laboratory at Blue Bell, Pa., to develop control, communications, and entertainment gear for autos. Philip H. Cholet will head the lab.



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Washington Newsletter

May 15, 1967

Vietnam priorities slow FAA program

The Vietnam war is slowing implementation of a civilian automatic air traffic control system in the U.S. Two of the first four common digitizers made by Burroughs for the Jacksonville, Fla., traffic control center have been preempted by the military and shipped to Saigon for the busy airport there. **This means that the Jacksonville center—first of 20 across the nation—will be limited in its capability until as late as December 1968.** Full tests were scheduled to begin at Jacksonville next spring by the FAA.

On-again, off-again radio-tv on again

The on-again, off-again FCC tests of transmissions from mobile radio equipment over unused tv channels in the vhf range are now slated to begin about June 1 on Channel 6 in Washington. First scheduled for April [Electronics, March 6, p. 67], the tests were delayed, and apparently doomed, when **three manufacturers who were going to lend equipment and technical support to the test—RCA, GE, and Motorola—suddenly told the FCC they were withdrawing.** But just as suddenly, the companies had a change of heart and agreed to participate.

The FCC is confident the feasibility trials, which will continue for several months, will show that it can assign unused commercial tv frequencies to mobile-radio operators without causing any interference with tv signals. Television broadcasters are opposed to giving up any of their spectrum space.

FAA ruling to open new avionics market

Impending action by the Federal Aviation Administration will open up a new market for advanced avionics equipment. Planned FAA regulations would permit a privately owned aircraft to land at a major airfield during periods of low visibility if the craft were equipped with about $60,000 of additional electronics gear. The Category 2 landings —under conditions of 100-to-150-foot ceiling and 1,200-foot visibility—currently can be made only by military and commercial aircraft. Private aircraft can use these fields only when visibility is at least a half-mile.

The FAA estimates that owners of about 500 private aircraft—mostly corporations—will buy the additional electronics equipment during the next five years.

Another AAFSS?

A proposal is being prepared by a four-company team for a surveillance version of the Advanced Aerial Fire Support System (AAFSS) helicopter. **The proposal is unsolicited and probably won't even be submitted until early this summer, but it already has tacit Army approval.**

The helicopter envisioned would incorporate an integrated avionics system that some Army critics say would correct faults inherent in the Integrated Helicopter Avionics System (IHAS), some portions of which are being designed into the first AAFSS helicopter (AH-56A). These critics contend that IHAS has too many instruments and controls for the pilot to handle efficiently. The new system would have a less complicated instrument panel and simpler controls. Some say that IHAS also has too few communications links with the ground; the new system would add channels to improve tactical air control and navigation.

Under the proposal, Lockheed-California would provide systems integration and build the airframe; Honeywell would study mission needs and develop new infrared sensors; Cutler-Hammer would design new forward- and side-looking radar systems; and Cubic would build navigational subsystems.

Army musters the night watch

The Army has consolidated several night-surveillance programs into a single effort called Sea (for Southeast Asia) Niteops. **The two-year, multimillion-dollar program includes low-light-level television and other image-intensification techniques.** Improved signal processing and better sensor technology are listed as key program needs by the Army's chief scientist, Marvin E. Lasser. Most of the work on the project will be done at Ft. Monmouth, N.J., and Ft. Belvoir, Va.

Warships may get 2 antennas to keep space links intact

The Navy is considering equipping each of its ships with two satellite communication antennas. Because present shipboard satellite antennas are too large for mounting atop masts, line-of-sight links to satellite repeaters would be blocked by a ship's superstructure and masts. The installation of two separate antennas to fix on a spacecraft is one way to get around this obstruction problem, notes Capt. M.D. Van Orden, who runs the Navy's satellite communications development office. Interference from the forest of radiating antennas aboard a modern man-of-war also is a problem, and the Navy is trying to develop ways to reduce spurious harmonic radiations in the crowded ship environment.

Despite these hurdles, the Navy expects to begin to use satellite links for most communications to and from major ships by the early 1970's.

F-111 is best bet for Navy's Phoenix

Although evaluation tests are barely under way, it now appears probable that the Navy will order into production its trouble-plagued version of the General Dynamics F-111 (formerly the TFX). The reason: **however short of specifications the plane may fall, the Navy's top brass has decided that no other aircraft can better serve as a vehicle for Hughes Aircraft's Phoenix missile in the 1970's.**

The Phoenix system, with its long-range multiple tracking and attack capability, has been described as vital by Navy Secretary Paul Nitze and Adm. David McDonald, chief of naval operations, in testimony before Congress. **Though it fell a year behind in development, the Phoenix has now operated more than 8,000 hours on a test basis, including three successful guided firings.**

FDL, in hot water, may be refloated

Scuttled by the Senate, Defense Secretary McNamara's Fast Deployment Logistics Ship project may yet be refloated. Indications are that a compromise is in the offing in which Congress will give the go-ahead for the construction of two prototypes without committing itself to a long-range program. But hopes for an automated shipyard appear to have run aground—at least for now.

McNamara's plan for 30 FDL's was handed a severe jolt when the Senate withdrew authorization for two FDL's already approved for the current fiscal year [Electronics, April 3, p. 65]. The House is expected to okay funds for four prototypes, but wants to take a hard look at the entire program next year. **The outlook: Senate-House conferees will salvage the FDL program by approving the original two prototypes.**

INTERLOCKING CIRCUIT PROTECTION EASY MADE ~~POSSIBLE~~ WITH AIRPAX SERIES 50 APL CIRCUIT PROTECTORS

APL 3
SHUNT TYPE

AN EXAMPLE: In interlocking circuit protection, the problem is to interrupt power to one circuit when the current in another circuit exceeds its rated limit. The solution is easy with Airpax Series 50 APL circuit protectors. These electromagnetic time-delay protectors are assembled in a variety of connections. Several protectors can be ganged mechanically so that when one trips it opens the others. For example, equipments A and B operate jointly; if either fails, the other should be shut down. Each draws a different load; each has different inrush and transient overload characteristics. The solution is easy: select two different Airpax Series 50 APL protectors, each matched to the equipment it protects. If shut-down alarm is needed, choose one protector with separate contacts for remote indication. Mechanically gang the protectors, and there you have it. The table below shows stock combinations ready for your order.

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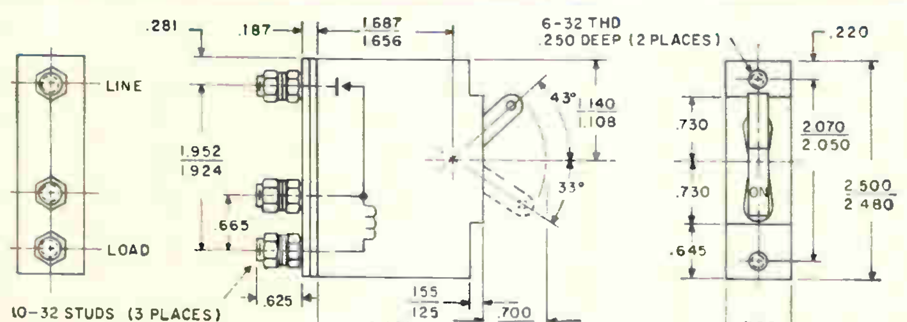
APL 1-RE
SERIES WITH REMOTE

TYPICAL DATA

Power	Delay	Typical Trip Time (Seconds) At 150% of Rated Current
Dc	50	0.02
	51	0.77
	52	12
60 Cps	60	0.04
	61	1.22
	62	14
400 Cps	40	0.03
	41	1.34
	42	19
	43	168

Types	Circuits	Standard Ratings (Amperes)
APL 1	1 Pole, Series	0.050
APL 3	1 Pole, Shunt	0.100
APL 11	2 Poles, Both Series	0.250
APL 13	2 Poles, 1 Series, 1 Shunt	0.50
APL 111	3 Poles, All Series	0.75
APL 113	3 Poles, 2 Series, 1 Shunt	1.00
APL 4	1 Pole, Relay	2.5
APL 1-R	1 Pole, Series, with Remote	5.0
APL 14	2 Poles, 1 Series, 1 Relay	7.5
APL 11-R	2 Poles, Both Series, 1 Remote	10.0
APL 114	3 Poles, 2 Series, 1 Relay	15
APL 111-R	3 Poles, All Series, with 1 Relay	20
		25
		30
		50



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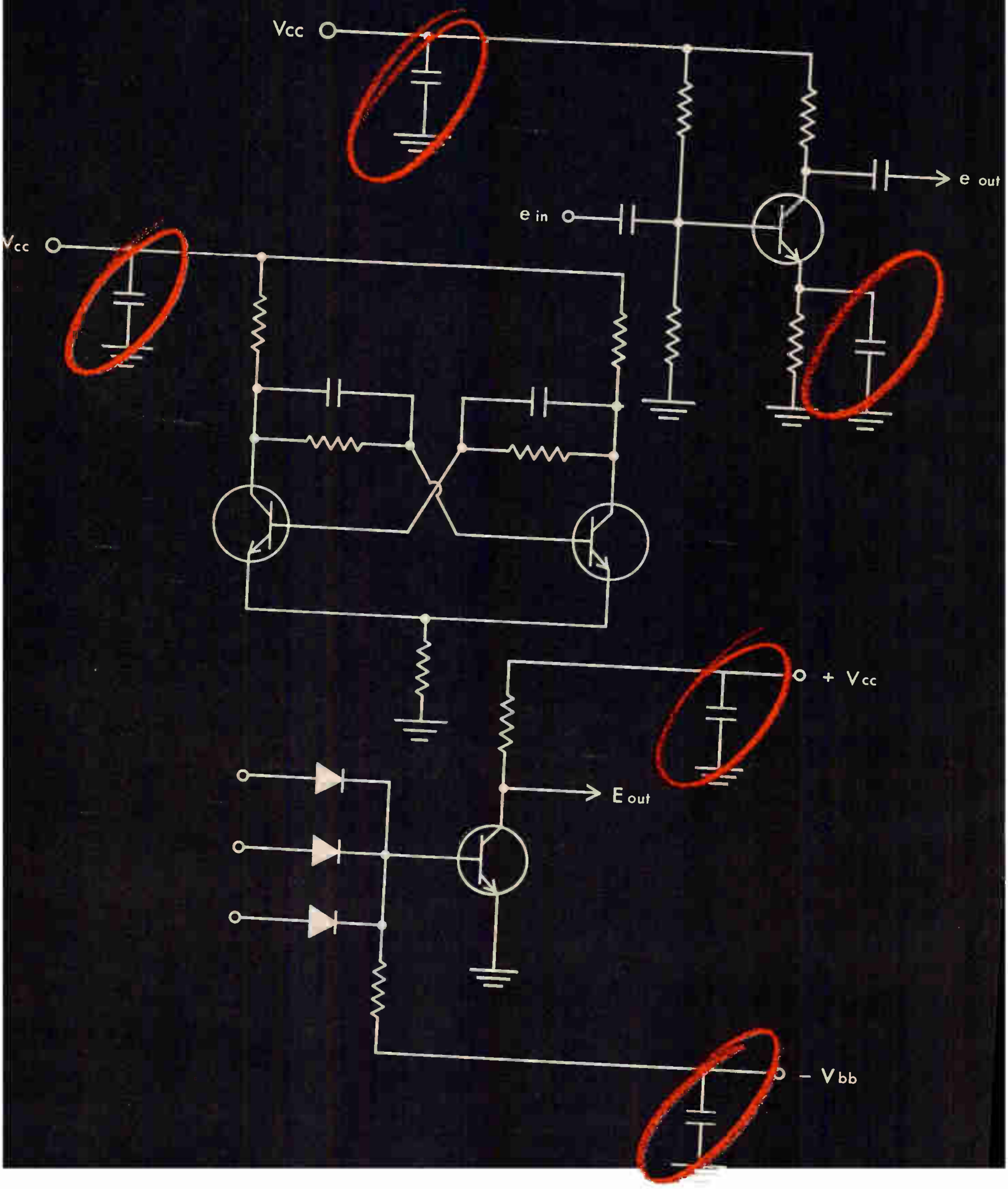

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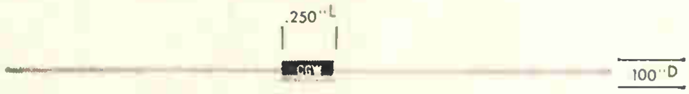

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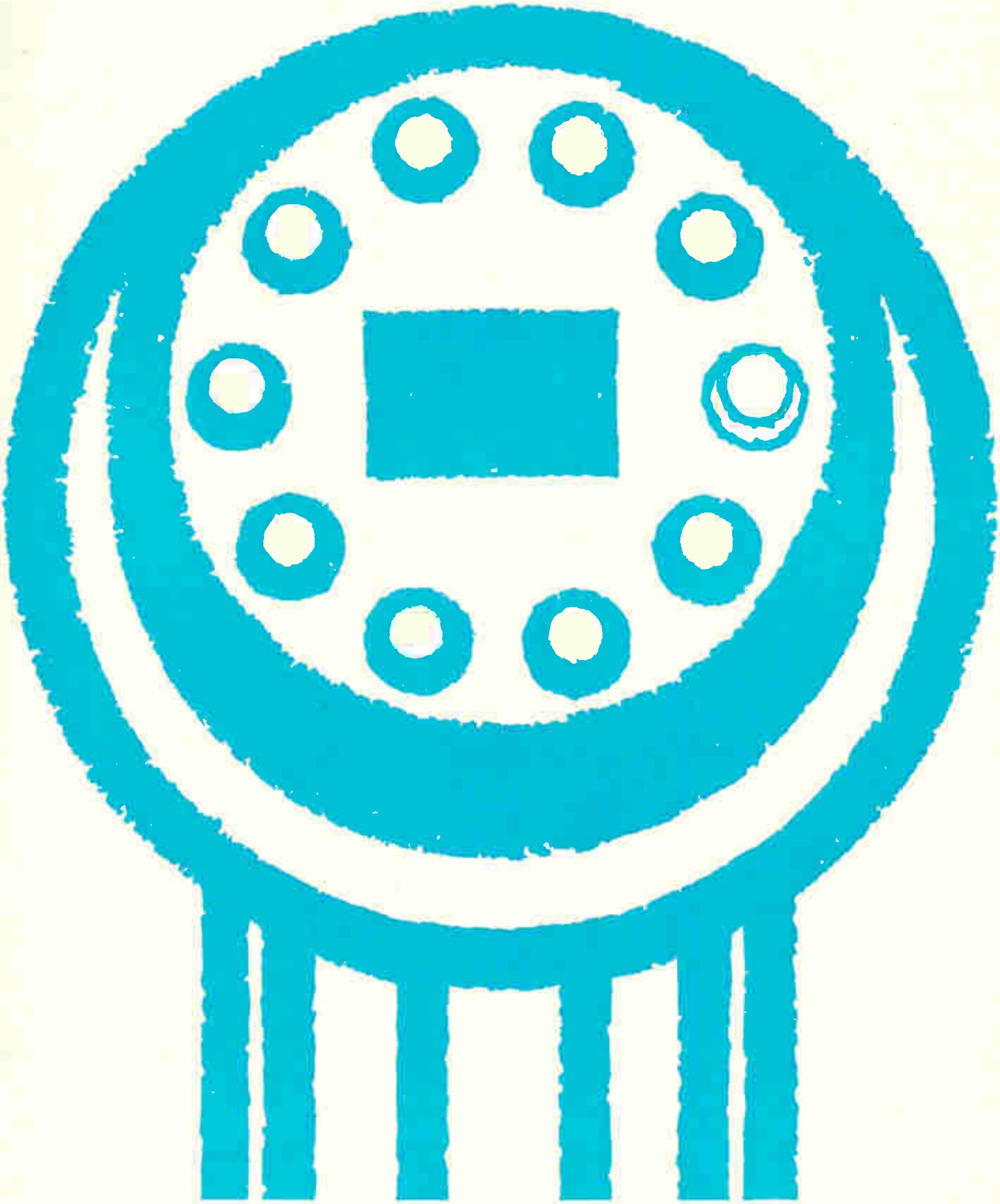

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	GENERAL PURPOSE	HIGH VOLTAGE	MERCURY-WETTED	MICROCLAREED
Contact Arrangements	Forms	Forms	Forms	
Enclosed Modules (up to 3 spaces)	A, B, C	A, B, C	A, B	Up to 5 form A
Open Coil Modules (up to 12 spaces)	A, B, C	A, B, C	A, B	Up to 5 form A
Round Cans (up to 12 spaces)	A, B, C	A, B, C	A, B	
Contact Rating Switched Load	15 va max., non-inductive 1 amp max., 250 v max.	15 va max., non-inductive 1 amp max., 250 v max.	50 va max., non-inductive 3 amps max., 500 v max.	10 va max., non-inductive .750 amp max., 200 v max.
Carry Load	5 amps max., not switched	5 amps max., not switched	5 amps max., not switched	2 amps max., not switched
Life Expectancy High Level Load	20×10^6 operations .500 amp, 28 v	20×10^6 operations .500 amp, 28 v	100×10^6 operations 3 amps, 16.5 v	10×10^6 operations .125 amp, 28 v
Low Level	100×10^6 operations	100×10^6 operations	1×10^9 operations	100×10^6 operations
Stand-Off Voltage	500 v rms	1500 v rms, Standard 5000 v peak, Special*	1000 v rms, Standard 3000 v peak, Special*	250 v rms
Operate Time** (nominal coil power, including bounce)	As low as .6 ms			As low as .5 ms
Must Operate Sensitivity	As low as 80 mw			As low as 60 mw

*AVAILABLE WITH SPECIAL ASSEMBLIES **DEPENDING ON NUMBER OF CONTACTS

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The MTOS process—second generation MOS

In the MTOS process a thick oxide is grown over the entire silicon chip except for the gate regions. The thin oxide over the gate regions is retained to keep the threshold voltages low. The thick-oxide layer produced by the MTOS process is ten times as thick over the P-regions as any other known process employed in the manufacture of MOS devices. This strengthened thick-oxide layer over the P-regions, and the sequence of steps used in the MTOS process, which limits the etching time before metallization, eliminate the problems caused by pinholes that could occur at crossover points, a major cause of failure in integrated circuits. Further, the thick oxide over the P-regions also minimizes the possibility of electrical short-circuits caused by the breakdown of the oxide resulting either from a flaw in the oxide layer or an accidental overvoltage.

Speed and MTOS

Because crossovers occur over the thick oxide, stray capacitance is reduced, thereby increasing frequency and switching speeds by a factor approaching 10 for the more complex circuits. The MTOS process, in providing higher yields, permits the production of larger, more complex chips. This increased complexity makes possible the utilization of highly sophisticated circuitry to further improve speed capabilities. One example of such a circuit now in use is a multi-phase dynamic system which not only enhances operating speeds, but reduces still further the low power dissipation inherent in MTOS circuits. MTOS arrays are now being delivered with rated operating frequencies of 5MHz. (Pilot production devices are operating at still higher frequencies.)

LSI means Large Scale Benefits, too...

The unprecedented packaging density and high yields made possible with the MTOS process provide cost and reliability advantages never before attainable in integrated circuits. In addition to the resulting lower initial costs per function, costs are further reduced by the elimination of most external wiring, printed circuit boards and assembly labor. Moreover, by minimizing the need for external interconnections, a higher order of reliability, improved performance and product yield are obtained, making available the most complex functions so far achievable on a single monolithic chip.

What MTOS can do for you

- It can lower the cost of your equipment
- It can shrink the size of your equipment
- It can upgrade the reliability of your equipment
- It can improve the performance of your equipment
- It can put you ahead of your less innovative competitors...and at least abreast of your more aware ones!

General Instrument's exclusive MTOS has made Large Scale Integration a practical reality. There is no longer any need to await the possible future developments of LSI...It is ready now for utilization in your equipment designs — whether you want to choose from the only broad line available, or in order to meet your special requirements—at General Instrument.

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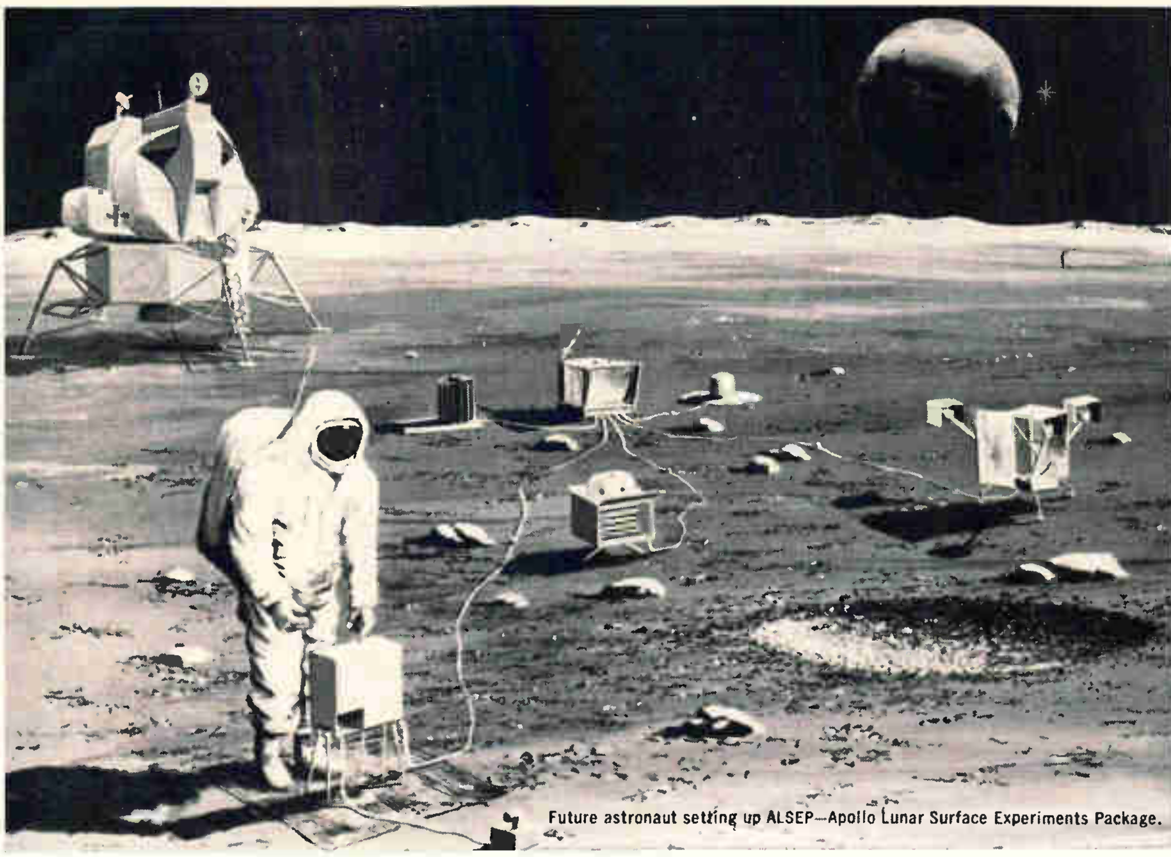

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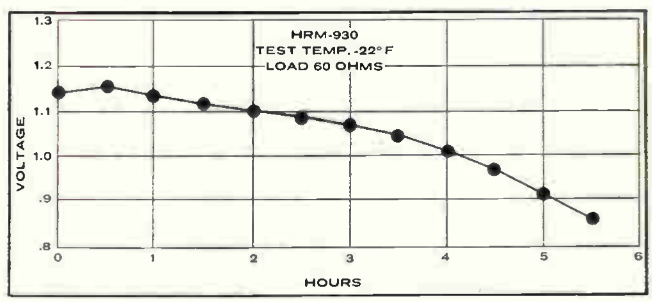

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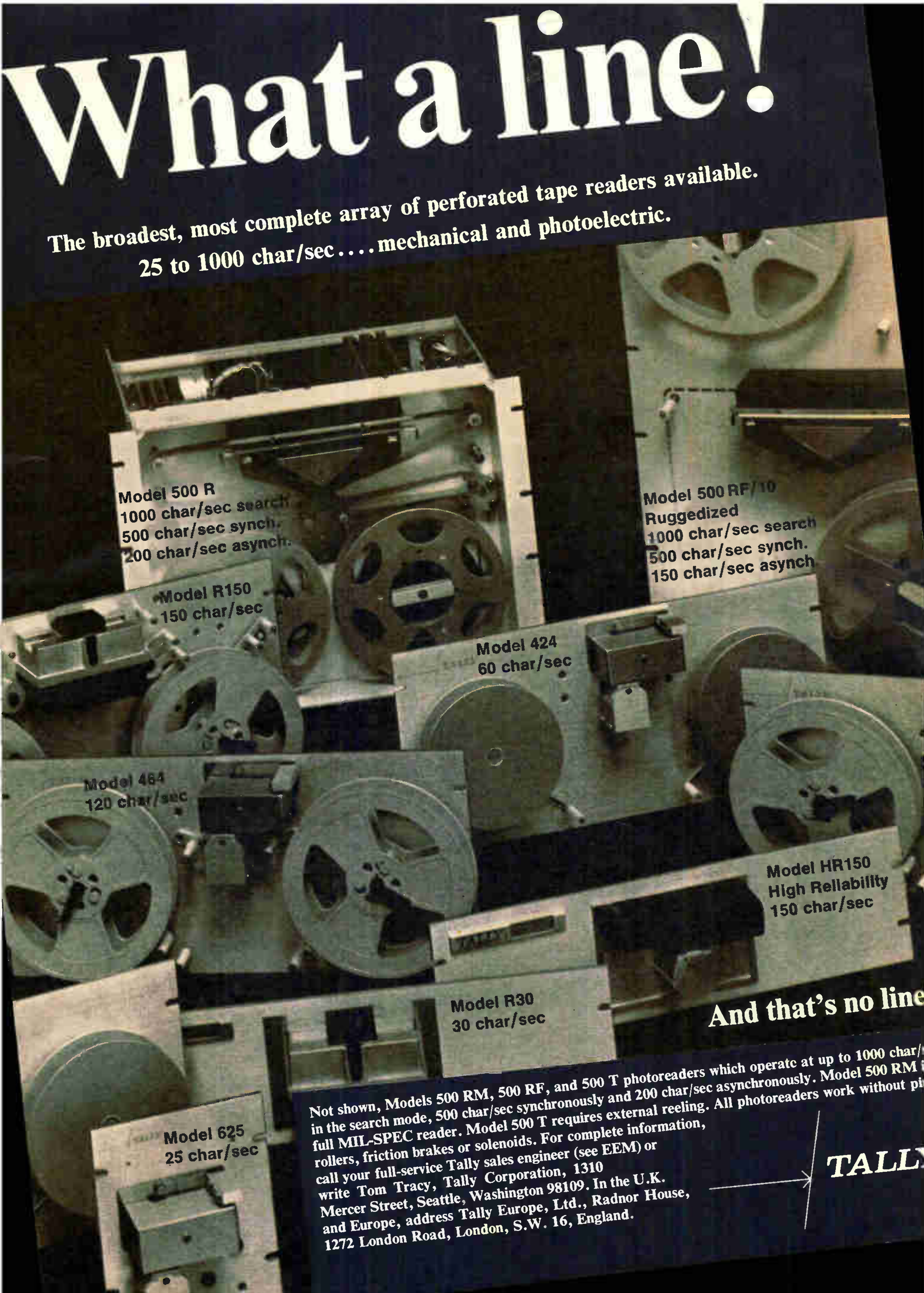

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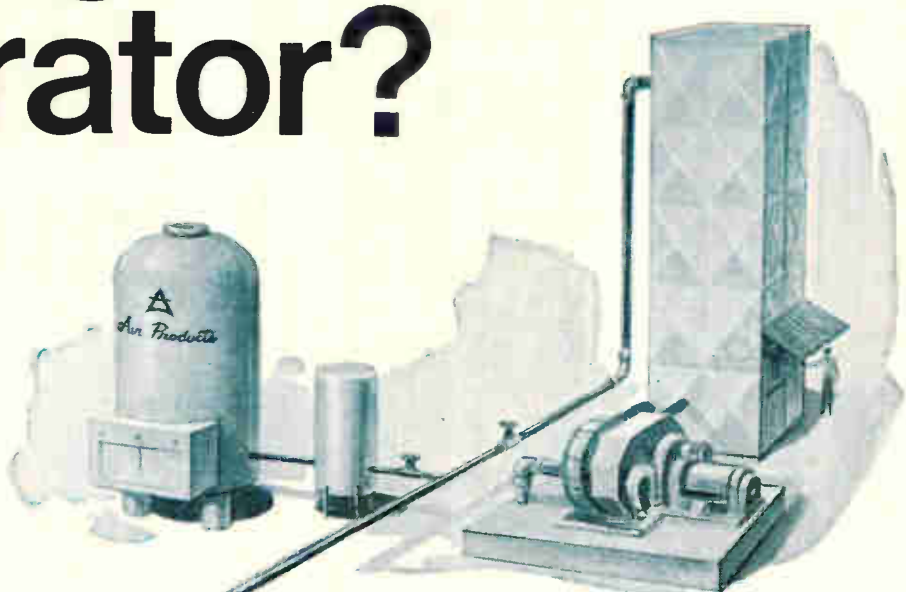

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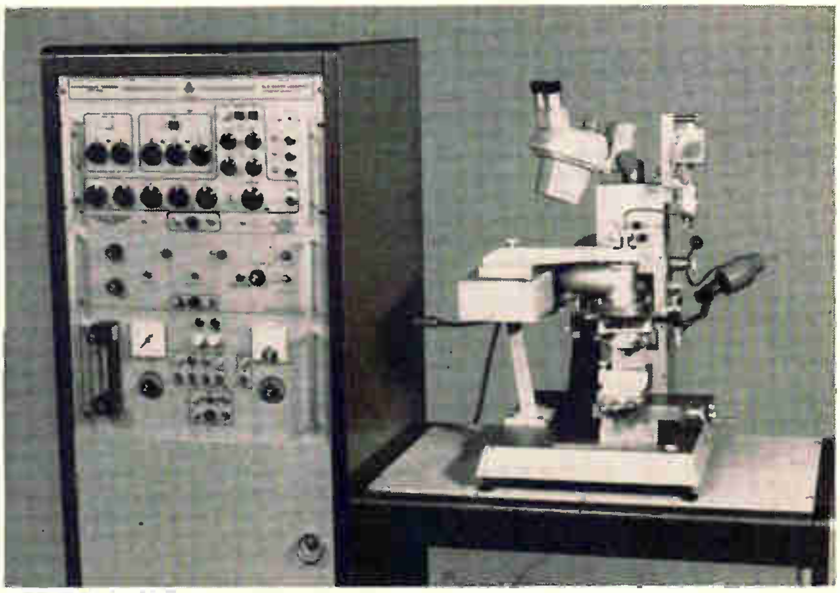

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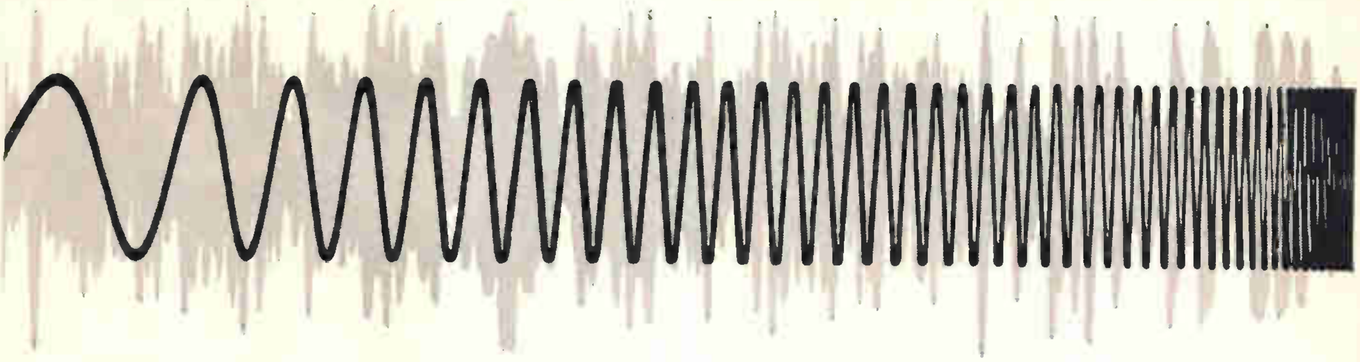

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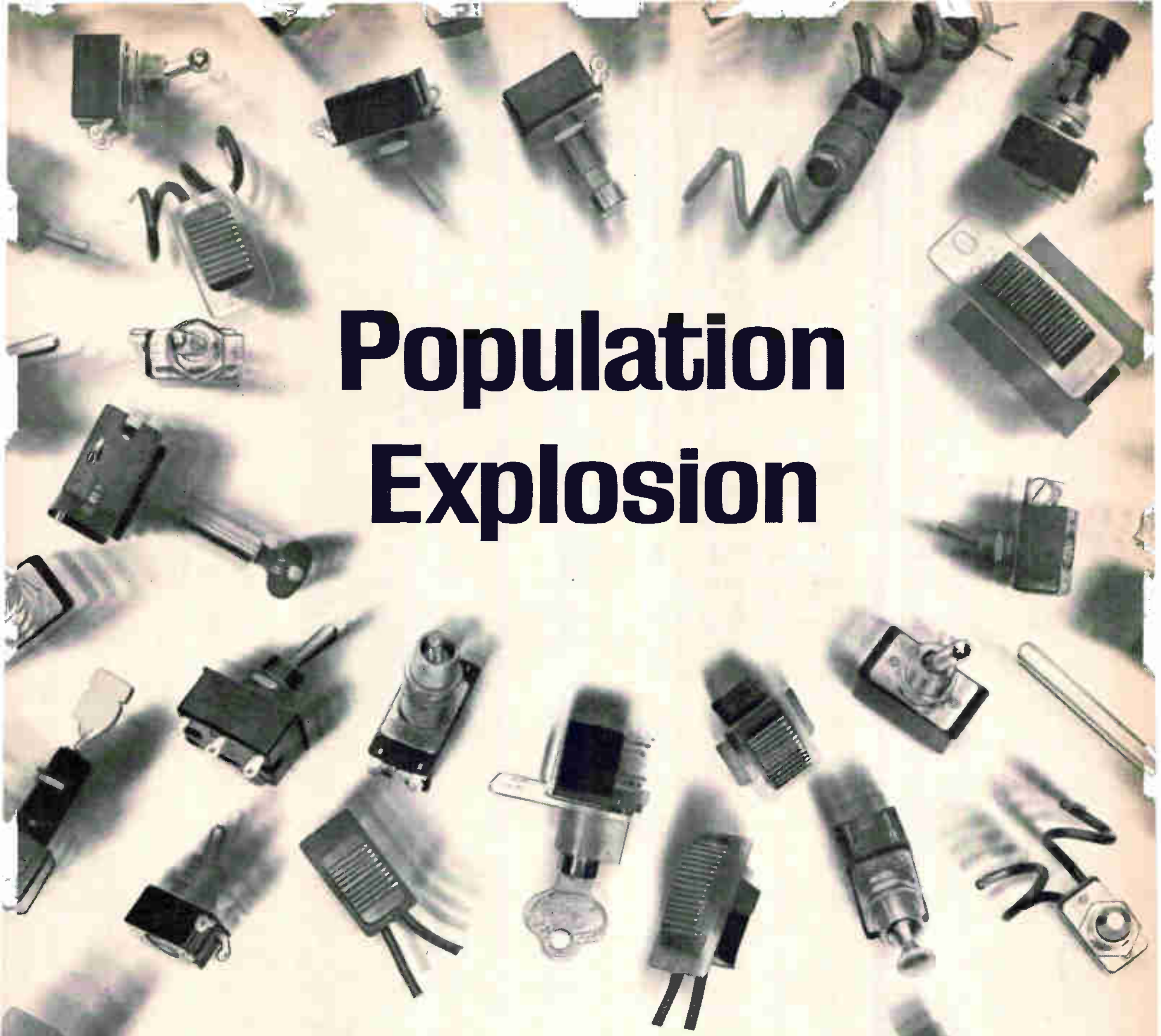
Circle 71 on reader service card



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May 15, 1967 | **Highlights of this issue**

Technical Articles

Charting a speedy path to active filters
page 76

Designing an active filter was a tedious and costly job until the Minactor was developed. A hybrid integrated circuit, the Minactor comes with a characteristic chart that contains 75% of the synthesis an engineer would expect to do. With the device and the chart, an engineer can design any filter configuration in the low and audio frequency range by adding a few external resistors and capacitors as instructed.

New dimension for interferometry
page 88

The hologram's ability to store an optical wave adds to interferometry the capacity to produce interference between two light waves that exist at different times. As a result, interferometry techniques can do a lot more measuring jobs than they can with ordinary light. For example, on the cover is shown the interference fringes set up by the shock wave generated when a 20-joule, 10 microfarad capacitor is discharged. The fringes are produced by using a hologram with a double exposure, once with a reference beam, and once with the subject.

Plated-wire memories: Univac's bet to replace toroidal ferrite cores
page 101

Thin-film memories have finally caught up with ferrite-core memories in cost, size and speed, after years of almost making it but never quite succeeding. As fast as the advocates of thin-film memories improved their products, the makers of cores produced smaller and faster devices that were still cheaper and better than the thin-film innovations. Now using plated wires, a computer maker can produce thin-film memories at a penny a bit and with capacities upward of 100 million bits.

Settling on the moon:
page 110

Last month Surveyor approached the moon carefully then landed and dug out samples of surface for the first time. The radar system responsible for that safe landing will also be on board the Apollo spacecraft which will take men to the moon. It has a three-beam doppler system to measure velocity and a single-beam altimeter. The requirements the moonship's altimeter have to meet are so stringent new test equipment had to be developed to check it out. An interesting digital system will put the altimeter through its paces before the space ship leaves the earth.

Coming May 29

- **IC calculator helps intercept enemy aircraft**
- **Tactical air reconnaissance**
- **The Rotator—a versatile new circuit element**

Design theory

Charting a speedy path to active filters

What was once a tedious design problem is now a snap with a chart, a few components, and a new eight-pin device called the Minactor

By Fred H. Irons
EG&G Inc., Boston

Designing an active filter, once a tedious and costly process, has become a simpler matter—because of a new eight-pin miniature component, the Minactor. Any desired filter configuration in the low and audio frequency range can now be built quickly and economically. A few external resistors and capacitors, determined from a data curve supplied by the manufacturer, are the only additions.

Previously, an engineer requiring an active filter was confronted with two equally unattractive choices: design it from scratch or have it done by an outside firm that specializes in such work. The first choice was time consuming; the second, expensive. In either case, the job often produced unsatisfactory results.

The Minactor (for miniature active resonator) was developed by EG&G Inc. of Boston [Electronics, Feb. 20, p. 221]. Measuring only 0.8 by 0.6 by 0.2 inch, it is a completely encapsulated hybrid integrated circuit consisting of a thick-film resistor substrate, discrete capacitors for fixed frequency operation, and an amplifier with eight transistors. Seventy-five percent of the synthesis, in the form of a characteristic chart shipped with each unit, is already performed by the manufacturer. Each device provides an independent pair of complex conjugate poles and a tunable Q in its voltage transfer function. The resonant frequency can be tuned externally with optimum results from 0.7 to 1.4 times the nominal resonant frequency. Some typical operating parameters are listed in table 1.

With 10 nominal units available, spanning the range of 100 hertz to 18 kilohertz, temperature-stabilized filters can be designed for operation at any frequency between 70 hz and 25 khz. The engineer merely selects the Minactor that comes closest to the desired operating frequency. With appropriate external circuitry added, the component can provide a completely tunable low-pass, bandpass, or high-pass filter.

The Minactor shown on page 83 is handled much the same as a crystal. It must be placed in an acceptable impedance and signal environment, and it must be tuned. Undesirable responses for a given application must be either shifted or cancelled by the addition of an input network. But unlike crystals, the Minactor's resonant mode and spurious responses may easily be changed by external adjustments. Spurious responses of conventional resonant devices are extremely rigid.

Exact frequencies not needed

Rapid filter synthesis is accomplished by setting the unit to the required frequencies as determind by analysis; however, cut-and-try filter design may also be accomplished where exact frequencies are either unknown (due to incomplete system specifications) or when an optimized response is desired.

In a cut-and-try design, the engineer in effect uses the Minactor as an analog computer to simulate a filter solution. Since the critical frequencies may be tuned independently, a simple adjustment enables the designer to go from a Butterworth, to Chebyschev, to Gaussian, or to any nontabulated response that meets his specific requirements. The results enable him to design a production package based on a small number of resonant components.

In its most common configuration, top page 77,

The author

Fred H. Irons is responsible for new product development at EG&G Inc.'s magnetic/networks department and specializes in basic network analysis and synthesis. His primary design experience is with active filter devices in the frequency range of 1 hertz to 1 megahertz.

the Minactor can be used to design all-pole bandpass filter approximations, discriminators, simple free-running oscillators, and various forms of frequency modulators.

A model relating Minactor output to the voltages at either control pin 4 or source pin 5 is at the right. The normalized expression, $M(\lambda)$, in the model is called the Minactor function and is defined by:

$$M(\lambda) = -\frac{16.4}{\left(\frac{C_o}{C_{0nom}}\right)} \frac{(\lambda+0.949)(\lambda+0.316)}{(\lambda^2+2\alpha\lambda+\omega_o^2)(\lambda+\beta)} = \frac{e_o}{e_A} \quad (1)$$

In equation 1, β represents the location of the Minactor pole on the real axis, and α is the distance from the $j\Omega$ axis to the complex pole pair. Normalization is taken with respect to the nominal frequency, f_{0nom}; the nominal resistance, R_{0nom}, that makes $2\alpha = 0$ at the nominal frequency; the nominal capacitance, C_{0nom}, that makes the angular frequency of oscillation $\omega_o = 1$. The normalized frequency variable, λ, is obtained from

$$\lambda = \Sigma + j\Omega = \frac{(\sigma+j\omega)}{|2\pi f_{0nom}|} \quad (2)$$

= normalized frequency related to Minactor used

where

$s = \sigma + j\omega$ = actual complex frequency in radians per second.

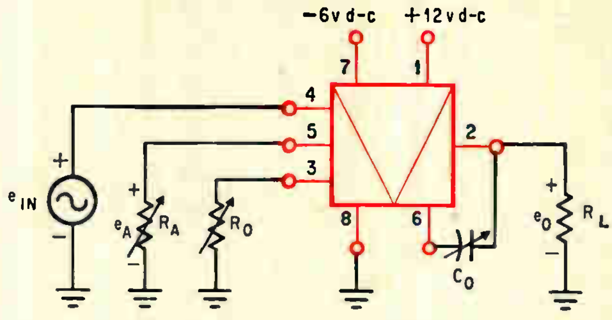
The pole-zero pattern for $M(\lambda)$ is at the right. Note that the plot deviates from ideal RLC resonance only in its real axis behavior. This is by design. Normally, the only critical frequency on the real axis would occur at $\lambda = 0$; however, since the Minactor may be used as a basic low-pass, all-pass, or notch filter, it is undesirable to have a zero at $\lambda = 0$.

Since the pole-zero values shown represent a good approximation of ideal behavior in the vicinity of $\lambda = j$, the component is acceptable for most bandpass filter and oscillator applications.

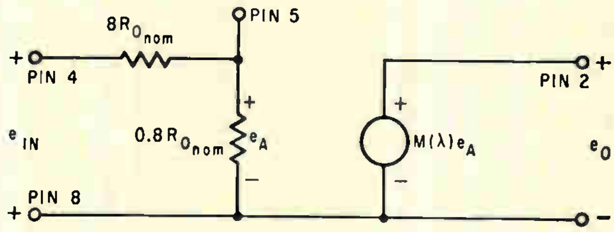
Adjusting resistor R_o and capacitor C_o moves the poles of $M(\lambda)$ about the λ-plane. Essentially, R_o shifts α horizontally in the complex plane with little or no effect on β. This adjustment sets the Q of the filter. Changes in C_o affect both β and ω_o with only a second order affect on 2α. The adjustment also sets the magnitude of the resonant frequency. The nominal relationships for tuning are as follows:

$$\left(\frac{C_{0nom}}{C_o}\right) \approx \frac{1}{16.4}\left[12.64\,\omega_o^2 - 6\alpha + \frac{10(\omega_o^2-0.3)^2}{(1.264-2\alpha)}\right] \quad (3)$$

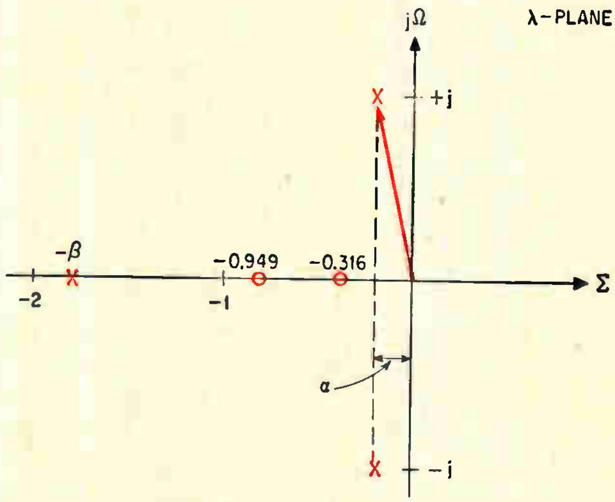
$$\beta \approx \left[1.264 + \frac{(\omega_o^2-0.3)}{(1.264-2\alpha)}\right] \quad (4)$$



Connection diagram for normal operation of the Minactor shows pin 8 as the reference, and pin 4 as the input control. Elements R_A, R_o, and C_o tune the filter.



Output voltage, e_o, shown in the equivalent model of the component as a controlled source, is equal to the product of the transfer function of the device, M (λ) and the voltage e_A developed across pin 5.



Normalized Minactor function, M (λ), is plotted in the complex λ-plane. Crosses represent the poles of the function, circles represent the zeros. The angular frequency ω_o is a vector drawn from the origin to the pole. By adjusting R_o the designer can shift the poles horizontally. Varying C_o shifts the poles vertically. Shifting the zeros doesn't affect resonance.

Table I: Typical operating parameters

Bias voltage	+12, −6 v d-c at 5 ma each
Maximum output signal	2.5 v rms to a 10 kilohm load
Maximum resonant gain available	60 db (in high Q applications only)
Maximum short circuit output noise	1 mv rms

$$K \approx \frac{16.4\left(\frac{C_{0nom}}{C_o}\right)}{\left[2\alpha + \frac{(\omega_o^2 - 0.3)}{(1.264 - 2\alpha)}\right]} \qquad (5)$$

where K is a term introduced to simplify the mathematics.

$$\left(\frac{R_o}{R_{0nom}}\right) \approx \frac{20}{(K - 10)} \quad \text{for } 10 < K \leq \infty \qquad (6)$$

The relations given by equations 3 through 6 are plotted on Minactor data sheets. Thus, the designer is relieved of the tedious calculations. In particular, design chart 1 enables the user to determine R_o and C_o. The values for β as a function of 2α and ω_o, equation 4, are plotted on design chart 2.

Extremely low-Q, complex pole-pairs necessary for low-pass filter synthesis require the Q-adjust resistor to be placed elsewhere. This resistor, called R_o^*, is placed in parallel with C_o; then, R_o becomes an open circuit, and no connection is made to pin 3. When R_o^* is connected, its relationship to R_{0nom} is given by

$$\left(\frac{R_o^*}{R_{0nom}}\right) \approx \frac{8K}{(10 - K)} \quad \text{for } 0 \leq K \leq 10 \qquad (7)$$

When C_o varies between

$$2.5\, C_{0nom} > C_o > 0.33\, C_{0nom} \qquad (8)$$

the magnitude of the resonant frequency, ω_o, correspondingly varies between

$$0.7 < \omega_o < 1.45 \qquad (9)$$

Thus, each Minactor may be adjusted over 1 octave of frequency. The ratio of adjacent nominal center frequencies of the 10 Minactor types, table 2, is approximately 1.8:1 to provide an overlap.

Designing a local oscillator

As an example of how the Minactor simplifies design procedure, consider the case of a local oscillator required to operate at 400 hz.

Step 1. Select the nearest nominal Minactor frequency from the available 10 listed in table 2 and determine ω_o. Thus, Model 331 is chosen with a f_{0nom} of 330 hz, a C_{0nom} = 900 picofarads, and a

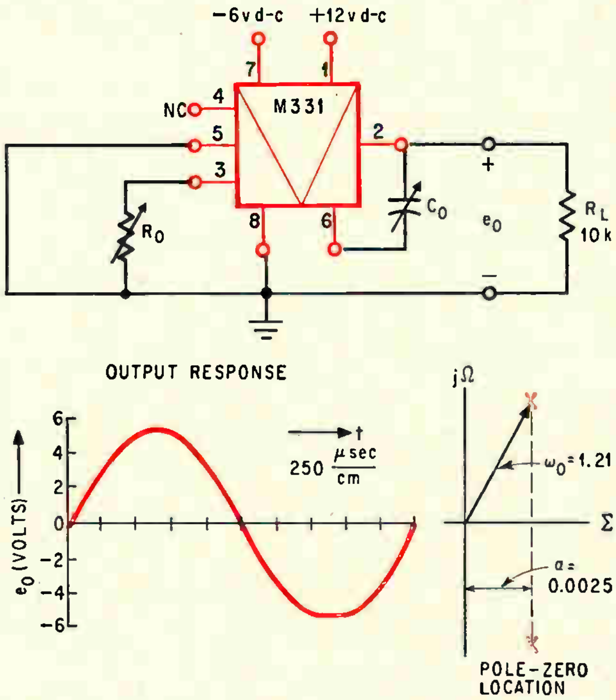
Table 2: Nominal component values

Type	f_{0nom}(hertz)	R_{0nom}(kilohms)	C_{0nom}(pf)
M101	100	46.25	2880
M181	180	46.25	1570
M331	330	46.25	900
M561	560	46.25	520
M102	1,000	46.25	288
M182	1,800	46.25	157
M332	3,300	46.25	90
MH562	5,600	7.60	288
MH103	10,000	7.60	157
MH183	18,000	7.60	90

R_{0nom} = 46.25 kilohms.

$$\omega_o = \frac{\text{desired operating frequency}}{\text{nominal frequency}} = 400/330 = 1.21 \qquad (10)$$

Step 2. Select a value of 2α. Hence, to obtain oscillation, the complex pole should be on the j axis ($2\alpha = 0$) or slightly in the right half of the λ-plane ($2\alpha < 0$). The case of the pole on the j axis is referred to as marginally stable (or unstable) since it makes an initial disturbance to start oscillation. With the pole slightly to the right of the jΩ axis, unconditional oscillation exists at all times and the amplitude is determined by the saturation or cutoff characteristics of the amplifier. An arbitrary value



Design of this local oscillator requires a Model M331 unit connected as shown. Poles of the assembly are in the right half of the λ-plane. Negative portion of the output waveshape is slightly clipped due to the cutoff in the output stage of the Minactor amplifier.

of $2\alpha = -0.005$ is chosen (this corresponds to a pole Q of 200 in the right half plane).

Step 3. Determine C_o/C_{0nom} and R_o/R_{0nom}. Substituting the values $\omega_o = 1.21$ and $2\alpha = -0.005$ in equations 3 through 6, or directly in chart 1, yields:

$$(C_o/C_{0nom}) \simeq 0.56$$
$$K \simeq 32.8 > 10 \qquad (11)$$
$$(R_o/R_{0nom}) \simeq 0.89$$

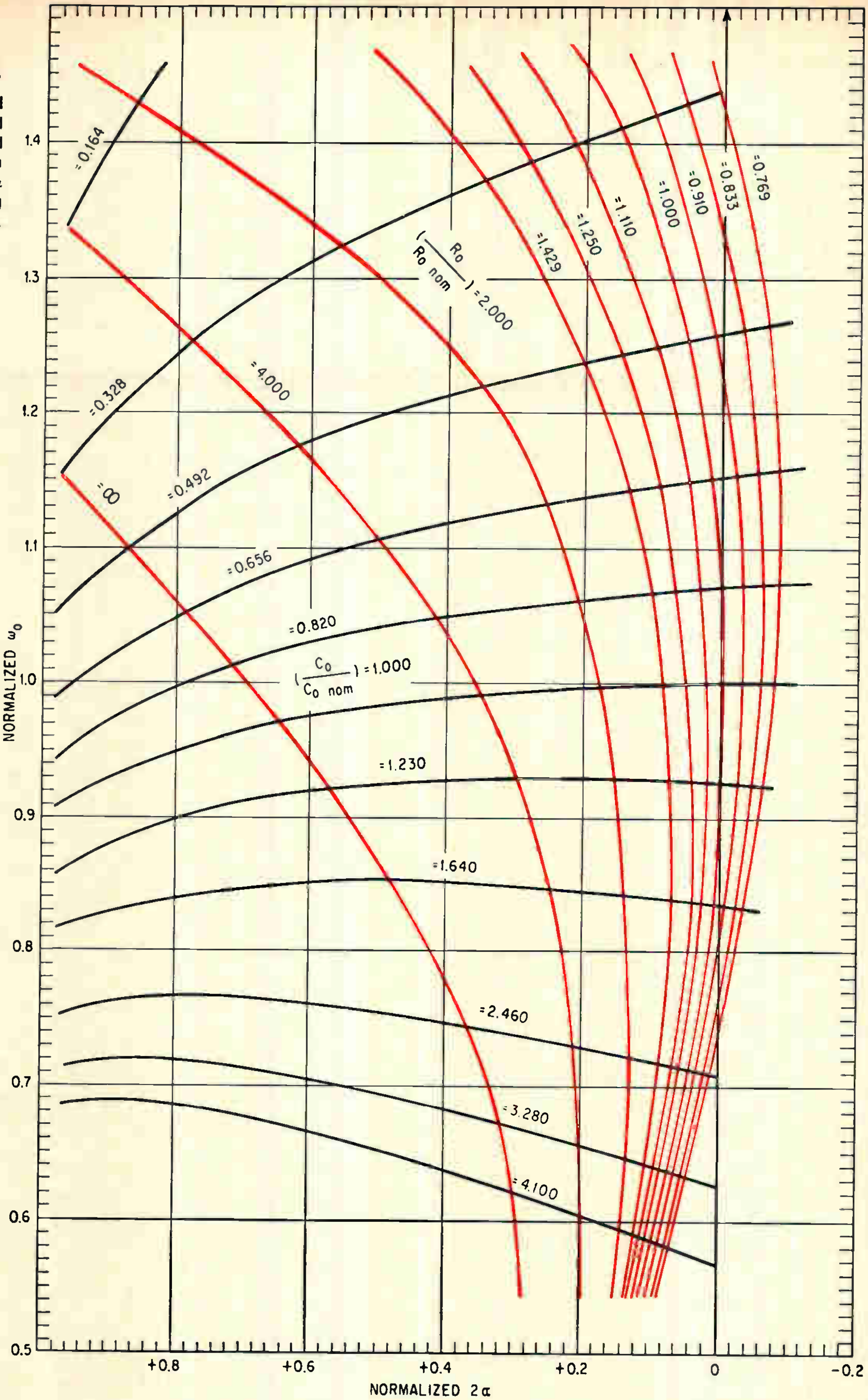
Step 4. Determine the values for R_o and C_o.

$$R_o = 0.89\, R_{0nom} = (0.89)\,(46.25 \times 10^3) = 41.16 \text{ k}$$
$$C_o = 0.56\, C_{0nom} = (0.56)\,(900 \times 10^{-12}) = 504 \text{ pf}$$

The complete oscillator circuit, pole diagram, and typical waveform are shown above. The small clipping on the negative portion of the signal is due to cutoff in the output stage of the Minactor amplifier. This is expected since the pole lies in the right-

Design chart 1

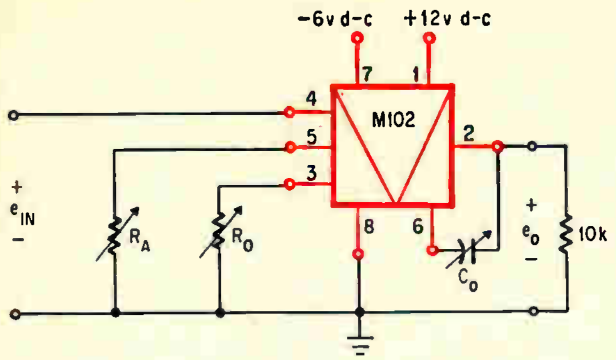
Values for R_0 and C_0 are determined from this normalized plot from known values of α and the operating frequency, ω_0.

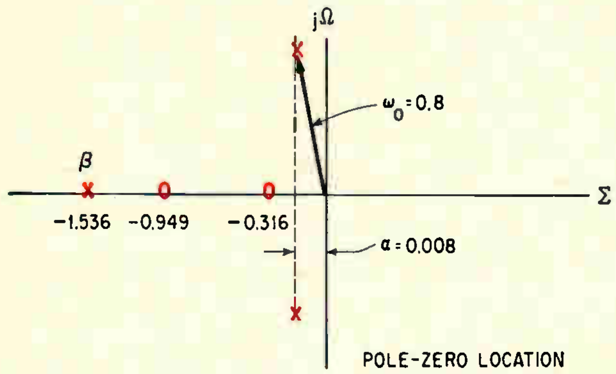


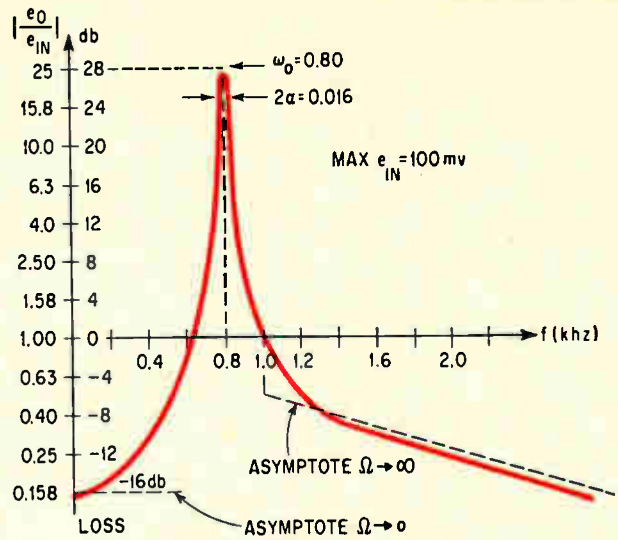
half side of the λ-plane. Capacitor C_0 may be adjusted to tune and stabilize the frequency to within desired tolerances. The practical stability limit obtainable is about 1 part in 1,000.

Note that when R_0 is very large (open circuit), the unit has a very low Q pole in the left half plane. With the input shorted, as shown, the unit would not have an output since it is in a stable state without a driving signal. Thus, the oscillator may be tuned on and off by a switch (transistor) placed in series or parallel with R_0.

This type of local oscillator could be applied to generate tones under digital control for data encoding. Other possibilities include using capacitance







Selective amplifier at the top left is tuned in this example to 800 hz with Q equal to 50. All poles in the diagram at the lower left are in the left side of the complex plane together with two zeros on the sigma axis. Frequency response plotted above reaches a resonance at 0.8 khz.

control, in this case C_o, to convert a mechanical displacement to a variable-frequency signal, or generating various forms of low-frequency f-m signal.

Designing a selective amplifier

The Minactor can also be used in filters that are commonly referred to as selective amplifiers. These include comb filters, stagger-tuned amplifiers, and several kinds of bandpass filters, depending on how many units are cascaded or connected in parallel. Their time- and frequency-domain responses are equivalent to that of a simple-tuned RLC network.

In designing such filters, three factors should be considered: the resonant frequency, ω_o; the filter Q, given by $\omega_o/2\alpha$; and the filter gain, A_p. With the Minactor configuration shown above, the designer can adjust each of these three factors independently. The components required are C_o, R_o, and R_A.

A selective amplifier tuned to 800 hz with a Q = 50 and operating with a maximum input signal of 100 millivolts root mean square is required. Design for maximum gain is the problem.

Step 1. Select the nearest nominal Minactor and determine ω_o. From table 2 a Model 102 Minactor is chosen with a $f_{0_{nom}}$ of 1,000 hz. Therefore,

$$\omega_o = 800/1{,}000 = 0.80 \qquad (12)$$

Step 2. Determine the value of 2α. Thus,

$$2\alpha = \omega_o/Q = 0.80/50 = 0.016 \qquad (13)$$

Step 3. Determine the maximum gain. Since the maximum output signal of the Minactor for linear operation is 2.5 volts rms, the maximum gain between the input and the output is found from

$$\text{Maximum } A_p = \text{maximum output/maximum input} = 2.5/0.1 = 25 \qquad (14)$$

Step 4. Determine $C_o/C_{0_{nom}}$, $R_o/R_{0_{nom}}$ and β. Substituting ω_o and 2α in equations 3 and 6 or locating them directly in charts 1 and 2 yield:

$$(C_o/C_{0_{nom}}) = 1.8$$
$$(R_o/R_{0_{nom}}) = 0.94 \qquad (15)$$
$$\beta = 1.5$$

These results completely define the Minactor function, $M(\lambda)$, that results when the filter is tuned to the desired Q and resonant frequency. Substituting the results of equations 12, 13, and 14 into equation 1 and letting $\lambda = j\Omega$ to evaluate the sinusoidal response, results in the following:

$$\frac{e_o}{e_A} = M(j\Omega) = -8.975 \frac{(0.949+j\Omega)\,(0.316+j\Omega)}{(0.64-\Omega^2+0.016\,j\Omega)\,(1.5+j\Omega)} \qquad (16)$$

The magnitude and phase relationships between the output signal e_o and the control voltage e_A can be found from equation 16 for all sinusoidal excitation frequencies over the interval:

$$0 \leq \Omega < \infty \qquad (17)$$

The peak output is obtained when $\Omega = \omega_o$, thus

$$\text{Max}\left(\frac{e_o}{e_A}\right) = M(j0.8) = \frac{(8.975\ \angle 180^\circ)\,(1.24\ \angle 40.2^\circ)\,(0.858\ \angle 68.4^\circ)}{(0.0128\ \angle 90^\circ)\,(1.73\ \angle 27.5^\circ)} = 431\ \angle 171.1^\circ \qquad (18)$$

This result shows that there will be a gain of 431 between e_o and e_A when the filter is operated at the resonant frequency. To maintain linear operation e_A must not exceed 5.8 mv rms as determined from

$$\max e_A = 2500/431 = 5.8 \text{ mv rms} \qquad (19)$$

Connecting a resistor, R_A, from pin 5 to ground attenuates e_A with respect to the input voltage e_{in}. The relationship is given by

$$\frac{e_A}{e_{in}} = \frac{R_A}{(11\ R_A + 8\ R_{0nom})} = \frac{1}{A} \qquad (20)$$

Substituting the maximum values of e_A and e_{in} into equation 20 yields

$$R_A \cong 1.28\ R_{0nom} \qquad (21)$$

The results of equations 15 and 21 and the pole-zero diagram of the amplifier circuit is shown in the diagrams on page 80. For this circuit:

$$\frac{e_o}{e_{in}} = - 0.52 \frac{(0.949+j\Omega)\ (0.316+j\Omega)}{(0.64-\Omega^2+j\ 0.016\Omega)\ (1.536+j\Omega)} \qquad (22)$$

The direct current gain is found by letting $\Omega = 0$ in equation 22.
Thus

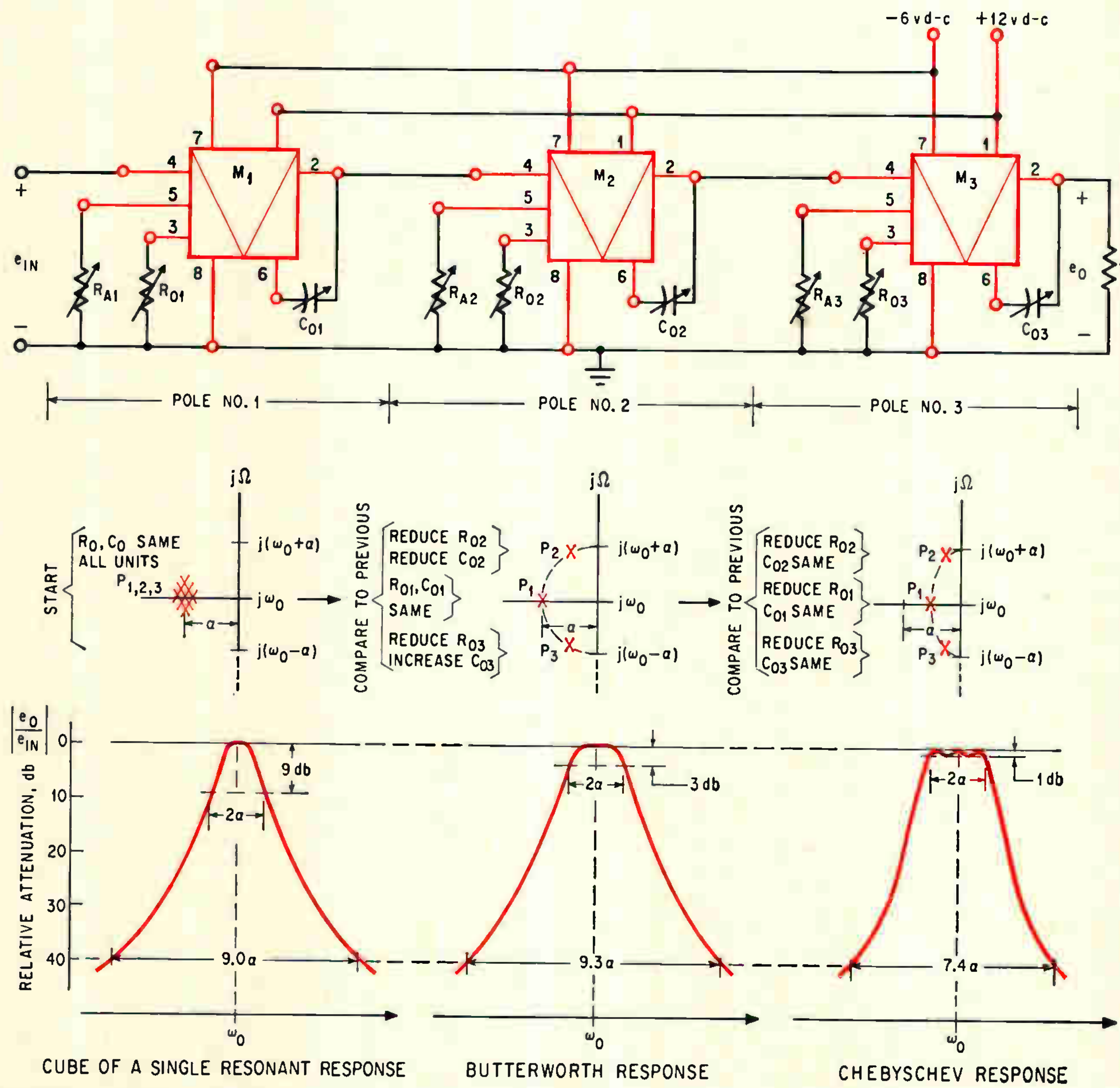
$$\frac{e_o}{e_{in}} = -\frac{0.52\ (0.949)\ (0.316)}{(0.64)\ (1.536)}$$
$$= -0.159,\ [-16\ db] \qquad (23)$$

The high frequency behavior is found by letting Ω approach infinity in equation 23. Thus,

$$e_o/e_{in} = +0.52j/\Omega \qquad (24)$$

Stagger tuning

By interconnecting several units almost any type of response is available from the Minactor. For example, with three units initially tuned to identical Q's and resonant frequencies, the user can go from a single resonant response to a Butterworth response, and finally to an equal-ripple



Cascaded Minactors produce a variety of responses ranging from a single resonance to a Butterworth response, or to an equal-ripple Chebyschev pattern. All the Minactor units are nominally the same, but M_1 is tuned to the desired center frequency and adjusted for maximum gain.
Other units are adjusted to provide unity gain at their respective resonances.

Chebyschev pattern. Typical pole patterns are on page 81 for each of these responses. They are shown to scale and thus may be used for design purposes. Note that in the Chebyschev response the maximum pole Q is four times the resulting filter Q.

Direct synthesis

The most direct way to design filters is to work from specified pole-zero patterns. Usually these come from system requirements that are carefully analyzed and defined. For purposes of illustration, suppose that the function required, when normalized to a nominal Minactor frequency, is:

$$T(\lambda) = \frac{0.01\,\lambda^2}{[(\lambda^2+0.054\lambda+1.09)\,(\lambda^2+0.050\lambda+0.915)]} \qquad (25)$$

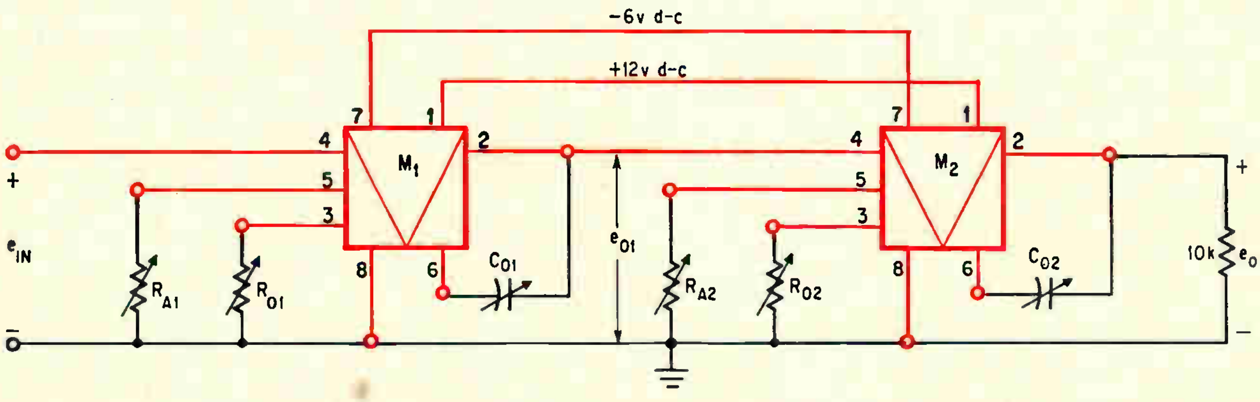
This function represents a bandpass type filter having two zeros at $\lambda = 0$ and two pairs of complex poles. It requires two identical Minactors to achieve this function. For the first pair of poles, Minactor M_1 shown below is applied. The required values for ω_{01}^2 and $2\alpha_1$ from equation 25 are: $\omega_{01}^2 = 1.090$; $2\alpha_1 = 0.0540$. Hence,

$$\left(\frac{C_o}{C_{0nom}}\right) \simeq 0.87$$

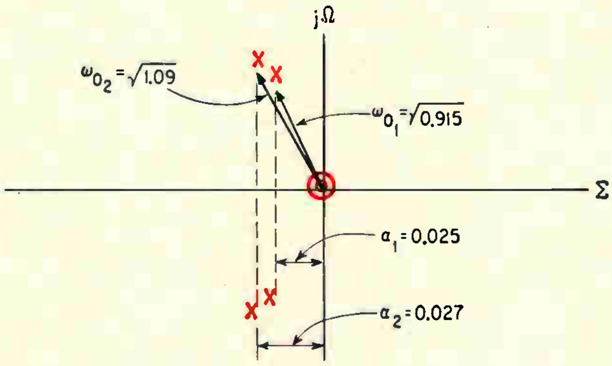
$$\left(\frac{R_o}{R_{0nom}}\right) \simeq 1.21 \qquad (26)$$

$$\beta_1 \simeq 1.916$$

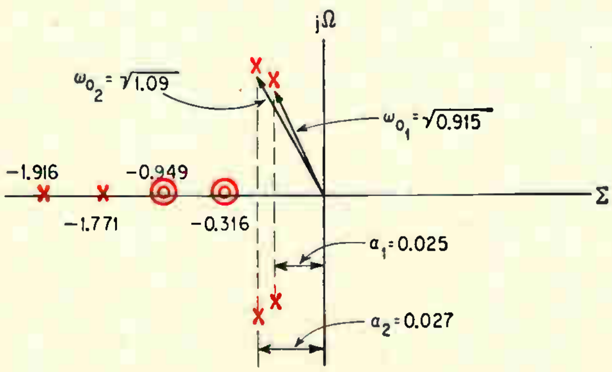
For the second pair of poles, the Minactor M_2 is applied. The required values for ω_{02}^2 and $2\alpha_2$: $\omega_{02}^2 = 0.915$; $2\alpha_2 = 0.05$. Hence,



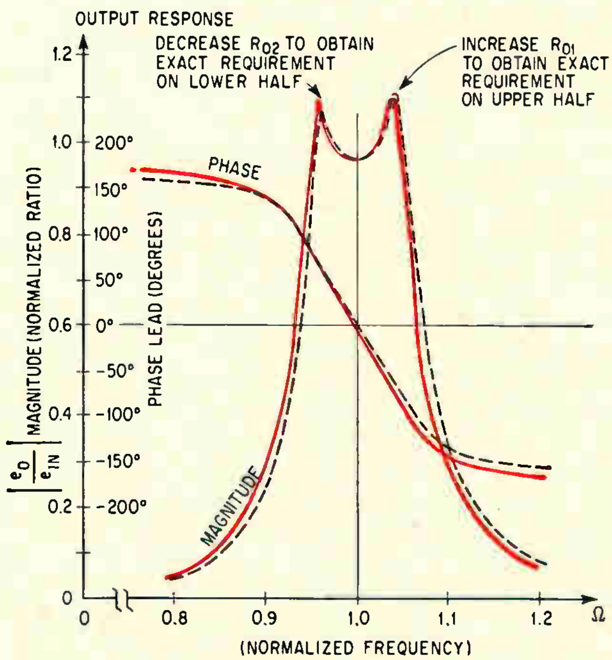
Cascade arrangement of two Minactors are used to reproduce the transfer function of equation 25.



Location of the poles and zeros for unit M_1 indicates both pole pairs are to the left of the jΩ-axis.

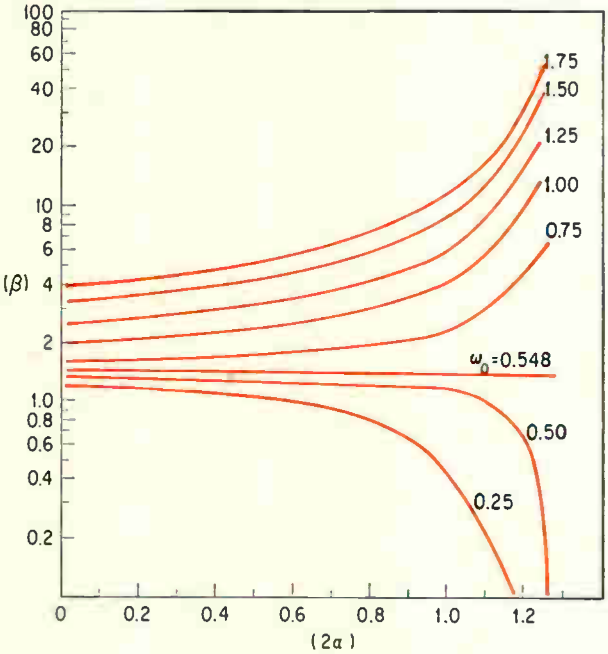


Location of the poles and zeros for the cascaded M_1 and M_2 arrangement. All are to the left of the jΩ-axis.

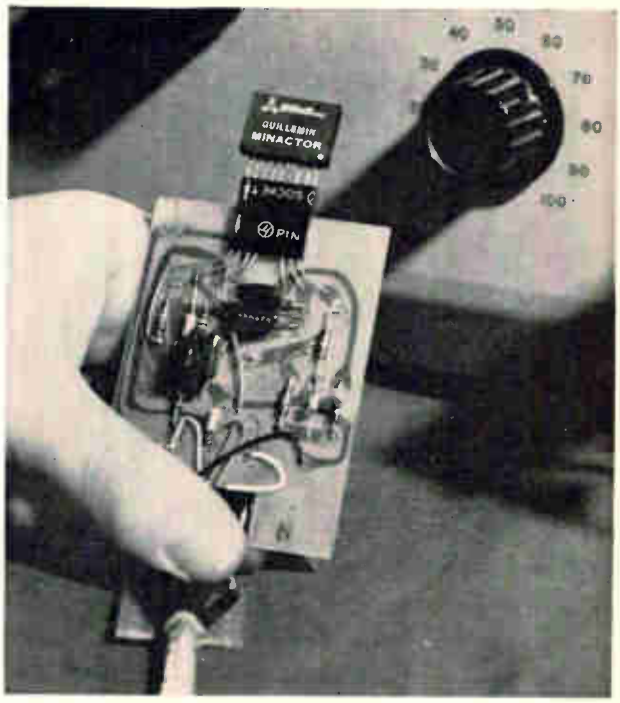


Filters can be synthesized directly from a given transfer function. Here the theoretical (color lines) and actual (dashed lines) curves are the output plots. Adjustments of the components can easily correct the small error caused by approximation of λ^2. Adjustments between the two curves can be made by tuning the Q of each pole.

Design chart 2



Values for β are determined from this plot when the designer inserts ω_o and α. The β value is used to locate the filter's pole along the real axis.



Eight-pin component, the Minactor, is connected to a printed circuit board containing resistors and capacitors. Pin separation is 0.1 inch.

$$\left(\frac{C_o}{C_{0nom2}}\right) \simeq 1.13$$

$$\frac{R_o}{R_{0nom2}} \simeq 1.24 \qquad (27)$$

$$\beta_2 \simeq 1.771$$

With the units in cascade, the normalized response is then given by:

$$\frac{e_o}{e_{in}} = \frac{e_{o1}}{e_{in}} \times \frac{e_o}{e_{o1}} = \frac{M_1(\lambda)}{A_1} \times \frac{M_2(\lambda)}{A_2}$$

$$= \frac{-16.4\,(\lambda+0.949)\,(\lambda+0.316)}{0.87\,A_1\,(\lambda^2+0.054\,\lambda+1.09)\,(\lambda+1.92)}$$

$$\times \frac{-16.4\,(\lambda+0.949)\,(\lambda+0.316)}{1.13\,A_2(\lambda^2+0.050\lambda+0.915)(\lambda+1.77)} \qquad (28)$$

$$\frac{e_o}{e_{in}}(\lambda) = \frac{273}{A_1\,A_2}$$

$$= \frac{(\lambda+0.316)^2\,(\lambda+0.949)^2}{(\lambda^2+0.054\lambda+1.09)(\lambda^2+0.050\lambda+0.915)\,(\lambda+1.916)\,(\lambda+1.771)}$$

where A_1 and A_2 are the required gain adjustments for each Minactor. Equation 28 differs from equation 25 in that it has zeros and poles along the real axis instead of the double order zero at $\lambda = 0$. For most practical bandpass filters, this discrepancy is not a serious error. To determine the A_1, A_2 constants, and thus resistors, R_{A1} and R_{A2}, the error terms in equation 28 should be set equal to $0.01\,\lambda^2$, the numerator of equation 25, for $\lambda = j$.

Thus,

$$\frac{273}{A_1\,A_2}\,(0.473) = 0.01 \qquad (29)$$

when the magnitude of equation 28, is divided by the magnitude of equation 25 for λ equal j. Thus,

$$A_1\,A_2 = 1.29 \times 10^4 = A^2 \qquad (30)$$

In this example, the attenuation has been split equally between R_{A1} and R_{A2}. Thus, $A_1 = A_2 = 113.6$; which yields

$$R_{A1} = R_{A2} = 0.078\,R_{0nom} \qquad (31)$$

from equation 20. The actual function realized by the circuit becomes:

$$\frac{e_o}{e_{in}}(\lambda) = \frac{0.0212\,(\lambda+0.316)^2\,(\lambda+0.949)^2}{[(\lambda^2+0.054\,\lambda+1.09)\,(\lambda^2+0.050\,\lambda+0.915)]\,(\lambda+1.916)\,(\lambda+1.771)} \qquad (32)$$

This function is plotted on page 82 and compared to the given transfer function, equation 25. The largest error is about 4% over the band plotted, and would be much less for higher-Q filter approximations.

The error present is due to Minactor approximation of λ^2. However, this error is designed into the unit to provide d-c stabilization. Also, there is very little power supply dependence or intercoupling when the units are cascaded, and motorboating instabilities don't occur. Although some discrepancy between practice and theory occurs, it can be tuned away by making slight changes in the Q's of each pole, as suggested by the plot.

Drawing a line between laser signal power and noise

A nomogram can be used to quickly estimate this ratio—a key to performance—in a common optical communications system

By John Ward

ITT Federal Laboratories, San Fernando, Calif.

Laser telemetry systems are like radio communications links in that their usefulness is largely determined by the ratio of signal power to noise power at the output of the receiver's detector. In laser systems, this ratio is usually difficult to estimate because it is affected by some 15 factors, including most of those listed on the opposite page.

However, a nomogram has been constructed that can be used to quickly predict this signal-to-noise ratio for one common type of laser setup—a system with an amplitude-modulated helium-neon laser for a transmitter and a photomultiplier tube for a receiver. Since phase-modulated beams have to be converted to amplitude modulation to be detected, the nomogram is also useful for analyzing angle-modulated systems; the phase-to-amplitude conversion efficiency would be included as part of the receiver's efficiency.

The basis of the nomogram is an equation that accounts for all important noise sources. These include shot noise produced in the optical detector. by both background (sunlight) radiation and the signal beam, as well as by interactions caused by the detector's square law response. The equation is derived from a general expression for the power-density spectrum at the output of a photodetector.[1]

Calculations of signal to noise in optical communications systems usually ignore the additional noise produced by interaction between the signal and noise. But this added noise can exceed the shot noise due to background radiation alone when the system is operating at signal powers greater than 10^{-7} watts at the photodetector, or when using narrowband optical filters that increase the noise spectral density in background-limited operation.

The laser system analyzed by the nomogram is one that could be used in a satellite communications system, as in the diagram on page 87. The amplitude-modulated helium-neon laser operates at 6,328 angstroms and transmits a narrow beam, θ_T, to the receiver. At the receiver, the signal beam plus background radiation is collected by an aperture of diameter D_R and passes through a narrowband optical filter that reduces background radiation. The signal and filtered background is then detected by a photomultiplier tube that has a post-detection filter at its output.

Equation for ratio

Assuming that the photomultiplier's frequency response is constant over the bandwidth of the modulated laser beam, the ratio of signal to noise power, (S/N), at the detector's output is given by the equation

$$\left(\frac{S}{N}\right)_P = \frac{\left(\frac{\eta}{\Delta E}\right)^2 (P_S)^2 \left(\frac{k}{1+\frac{k^2}{2}}\right)^2}{\Delta f\left\{\left(\frac{\eta}{\Delta E}\right)^2 (2\pi)\left(\frac{1}{\Delta\nu}\right)\left[P_B^2 + \frac{1}{2} P_S P_B \left(\frac{k^2}{1+\frac{k^2}{2}}\right)\right] + \left(\frac{\eta}{\Delta E}\right)\left[P_S + P_B\right] + N_0\right\}}$$

The terms in this equation and those following are defined in the box on page 85, along with the values that are constant in the nomogram.

There are three distinct noise terms in the equation's denominator. The terms in the first set of brackets—so-called quadratic terms—were previously referred to as interaction terms; they include the square of the background noise (sunlight), P_B, and the product of the background noise and signal power, P_S. These quadratic terms are higher-order correlation terms produced by driving one probabilistic process—detector shot noise—by another probabilistic process—background radiation plus signal. First-order shot noise due to the power,

$P_S + P_B$, that impinges on the detector is represented by the term in the second set of brackets. The third term, N_O, is the dark-current parameter.

Shot noise is caused by the random emission of electrons from the photodetector's cathode surfaces. In deriving the equation, the shot noise is represented by a Poisson distribution, while the input background is described by a Gaussian distribution. The average current at the photomultiplier's output is proportional to the square of the amplitude of the input beam, which in turn is proportional to the intensity of the beam.

Evaluating powers

To determine the values of P_B and P_S, it's necessary to consider the system geometry, the beamwidth of the optical transmitter, and the efficiencies of the transmission medium and the transmitter and receiver components.

For P_S, one should first compute the irradiance, H_R—the power per square centimeter at the input to the receiver. The irradiance is given by

$$H_R = \frac{4}{\pi}\left(\frac{P_O}{(\theta_T)^2 (R \times 10^5)^2}\right)\tau_T\,\tau_A$$

When multiplied by the area of the receiver's collecting aperture and the efficiency of the receiver's optics, the signal power at the detector is

$$P_S = H_R\left(\frac{\pi}{4}\right)(D_R)^2\,\tau_R$$

The background noise that impinges on the photodetector is given by

$$P_B = N_B\left(\frac{\pi}{4}\right)^2 (D_R)^2\,(\theta_R)^2\,(\Delta\lambda)\,\tau_R$$

It is assumed that the background radiation fills the receiver's entire field of view. In addition, the equations are only valid when distance R is large enough so that

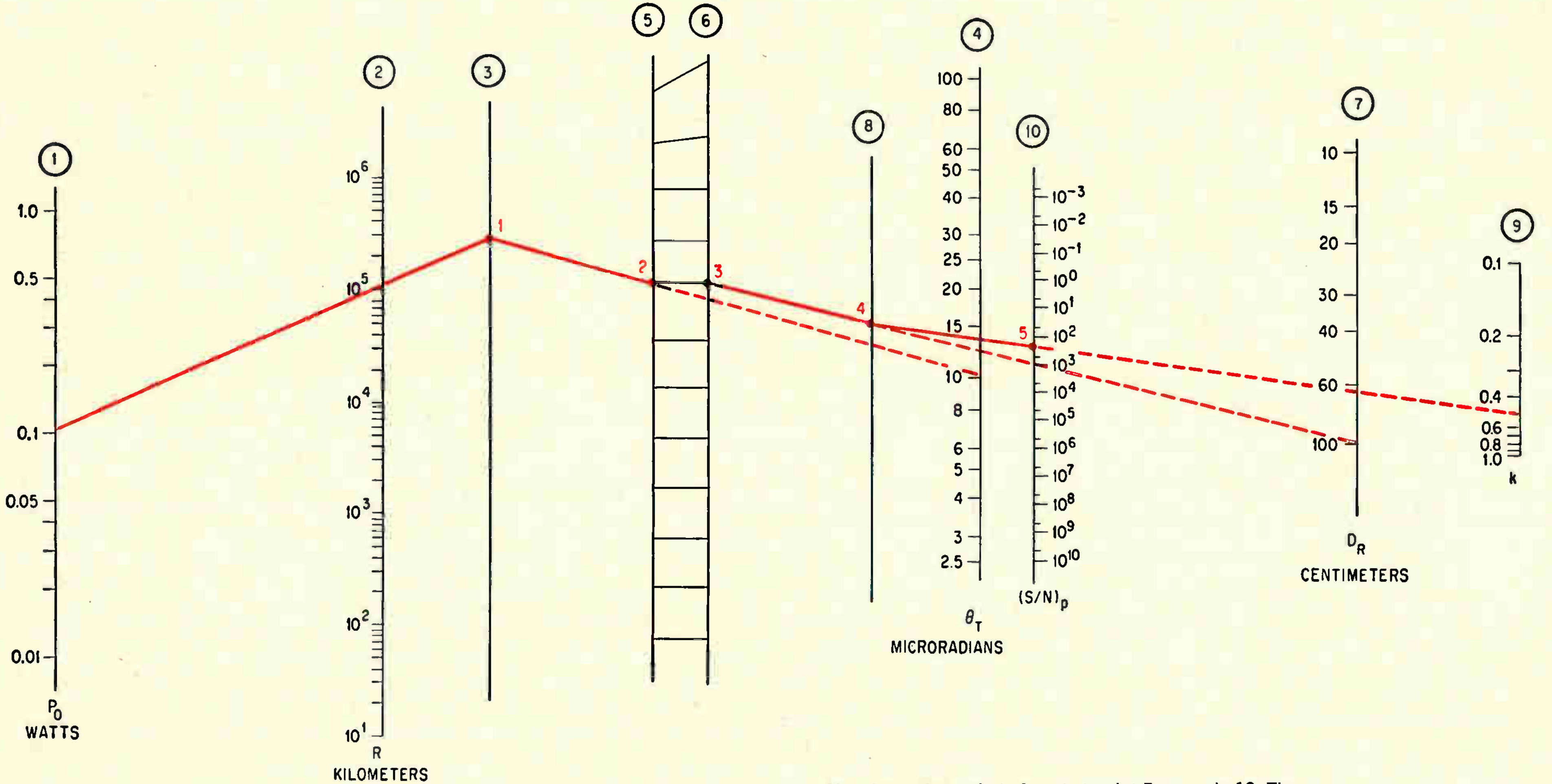
$$D_R \leqq \theta_T\,(R \times 10^5)$$

This means that the beam's diameter must be greater than the receiver's optical aperture.

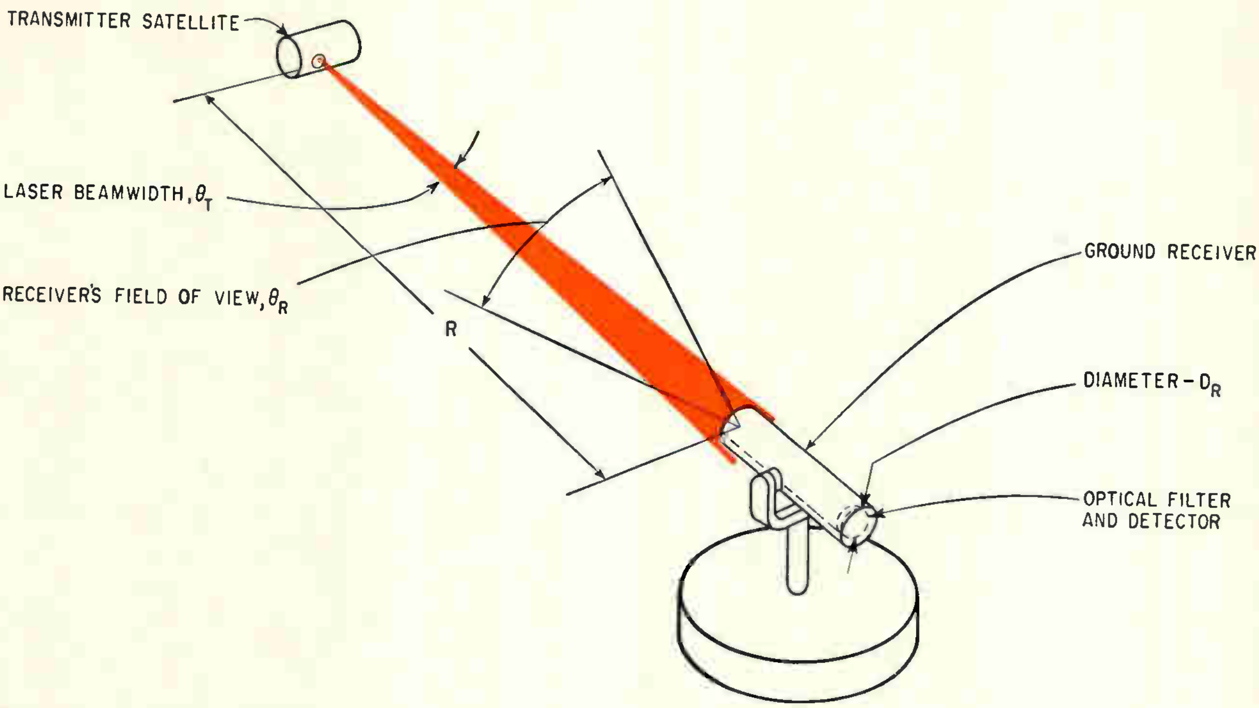
These equations have been used to develop the nomogram on page 86; certain variables have been assigned typical fixed values as tabulated. Further, the signal-to-noise ratio is normalized to a post-detection bandwidth, Δf_n, of 1 megahertz; for other bandwidths, the ratio is multiplied by $(1 \times 10^6)/$

Terms and fixed values used in nomogram

Term	Definition	Constants, fixed values, and units	Term	Definition	Constants, fixed values, and units
c	Velocity of light	3×10^{18} angstroms per second	P_S	Power in the portion of the laser beam that impinges on the detector	watts
D_R	Diameter of the receiver's collecting aperture	centimeters	R	Distance between the optical transmitter and receiver	kilometers
ΔE	Energy per photon in the frequency band passed by the optical filter = h(c/λ)	2.97×10^{-19} watt-seconds	$\left(\frac{S}{N}\right)_P$	Ratio of signal power to noise power at the output of the receiver's detector	
Δf	Post-detection bandwidth. The bandwidth of the filter immediately following the detector	1×10^6 hertz	η	Photomultiplier's quantum efficiency. The average number of electrons emitted per incident photon	4%
h	Planck's constant	$.625 \times 10^{-34}$ watt-second^2	θ_R	The receiver's field of view	50×10^{-6} radians
H_R	Irradiance	watts per square centimeter	θ_T	Laser's transmitted beamwidth	radians
k	Amplitude-modulation index		λ	Laser's wavelength	6,328 angstroms
N_B	Spectral radiance of background corresponding to daylight	2×10^7 watt cm^{-2} steradians^{-1} angstroms^{-1}	$\Delta\lambda$	Optical filter's bandwidth in angstroms	1.0 angstrom
N_O	Dark-current parameter in the photomultiplier. The average number of photoelectrons emitted per unit time	10^4 seconds^{-1}	$\Delta\upsilon$	Optical filter's bandwidth in hertz	74.9 gigahertz
P_B	Power of the background noise that impinges on the detector	watts	τ_A	Transmission efficiency of the air path between the transmitter and receiver	70%
P_O	Laser's output power before passing through transmitter's optical system	watts	τ_R	Transmission efficiency of the optical system at the receiver	40%
			τ_T	Transmission efficiency of the optical system at the output of the laser transmitter	40%



Signal-to-noise ratio is found at point 5 on scale 10. The points in color are determined by the values of the laser power, P_o, the distance between receiver and transmitter, R, the laser's beamwidth, θ_T, the diameter of the receiver's collecting aperture, D_R, and the index of amplitude modulation, k.



Optical communications detector receives not only the laser beam, but any background noise that falls within its field of view, θ_R.

(Δf), where Δf is the actual post-detection bandwidth.

The selected 1-angstrom-bandwidth filter centered at the laser frequency is equivalent to about a 75-gigahertz bandwidth. This is larger than the total bandwidth of any radio system and is also larger than the information bandwidth required for most existing communications systems; smaller optical bandwidths are difficult to achieve. The filter's bandwidth in hertz, $\Delta\nu$, is related to the bandwidth in wavelengths $\Delta\lambda$ by

$$\Delta\nu \cong c\,\frac{\Delta\lambda}{\lambda^2}$$

The nomogram

As an example of calculating signal-to-noise ratio with the nomogram, consider a communications system with the fixed design values given in the table on page 85 and the following additional design values:

$R = 10^5$ kilometers
$P_O = 100$ milliwatts
$k = 0.50$
$\theta_T = 10 \times 10^{-6}$ radians
$D_R = 100$ centimeters
$\theta_R = 50 \times 10^{-6}$ radians

If we want to determine the signal-to-noise-power ratio at the output of the photodetector for an information (post-detection) bandwidth, Δf, of 5 megahertz, we perform the following steps in the nomogram:

- Draw a straight line through the value of the laser power, P_o, on line 1 and R, the distance between the transmitter and receiver, on line 2. Extend the line until it intersects line 3 at point 1 (in color).
- Connect point 1 on line 3 with the value of the transmitted beam width, θ_T, on line 4, and mark the intersection with line 5 as point 2.
- Using the transfer slopes between lines 5 and 6, transfer point 2 to point 3 on line 6.
- Connect point 3 with the value of the receiver collector diameter, D_R, on line 7. The intersection with line 8 is point 4.
- Draw a straight line between point 4 and the modulation index value, k, on line 9. This line intersects line 10 at point 5, where the signal-to-noise power ratio is found to be 2.82×10^2.

This value is for a 1-megahertz bandwidth. To find the signal-to-noise ratio for the specified 5 megahertz, we multiply by $(1 \times 10^6)/(5 \times 10^6)$ and obtain 56.4.

The slopes of the transfer lines between nomogram lines 5 and 6 indicate the predominance of different types of noise. The horizontal transfer slopes indicate a predominance of shot noise, while increasing slope shows the influence of background and dark-current shot noise.

References

1. W.F. Davison, "Shot Noise in Optical-to-Electric Converters," 49th annual meeting of the Optical Society of America, 1964.

The author

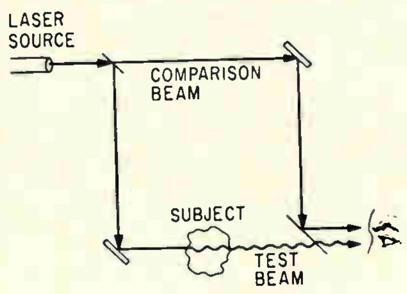
John Ward, a senior member of the ITT Federal Laboratories' technical staff, has developed a number of optical tracking and communication systems in his present job and earlier at Texas Instruments Incorporated. He also served as consultant on the Apollo simulator for North American Aviation Inc.

Interferometry and holography

Interferometry is based on the principle that if two beams of the same monochromatic light are superimposed, the intensity in the region of superimposition depends on the phase difference between the waves. If the two waves are in phase, an intensity maximum is found; if they are out of phase, intensity is a minimum. The variations of intensity form a pattern of alternate dark and bright fringes.

Because the wavelength of light is so short (0.6 microns, or 6000 angstroms, for red light), an extremely small change in the path length of one beam can cause a phase shift of 180°. This will change an intensity maximum to a minimum, or vice versa, and will result in a fringe shift of one-half the distance between fringes. Changes as small as a tenth of this magnitude can be measured. Thus, interferometry finds application in measuring extremely small changes in physical dimensions, or changes in refractive indices that change optical path lengths.

Mach-Zehnder. Although there exists a great variety of interferometers, the Mach-Zehnder arrangement, developed in 1891, is typical and illustrates the basic principles.



It's still commonly used for the study of gas densities and for tests in wind tunnels and shock tubes. Its square configuration allows wide separation of the test and comparison beams; often the comparison beam can be routed around the subject.

With this approach, light from a monochromatic source is divided into two paths by a beam divider. One beam, in the comparison path, passes unperturbed to the output by means of a mirror and a second beam divider. The other beam, in the test path, passes through the object being investigated. The phase of the waves passing through the test object are altered according to the velocity of propagation and the path length. The two beams are recombined at the output where the fringe pattern resulting from the interference of the superimposed beams is viewed.

Beyond the fringe. A hologram is also a pattern resulting from an interference effect between two beams—but not a fringe pattern. The interference fringes are generally too fine to be visible.

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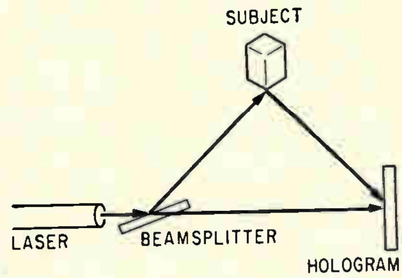
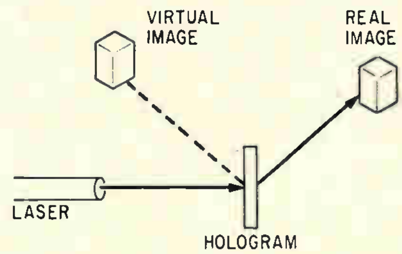


angle between the two beams. For the typical 30-degree beam angle, the spacing is twice the wavelength. The hologram's interference pattern shouldn't be confused with the pattern in the interferometer. In an interferometer, the beams are nearly parallel ($\alpha = 0°$), so that fringe spacing is much greater and can be analyzed with the unaided eye.

To reconstruct the image, the developed photographic plate is illuminated by only the reference beam. This beam is diffracted by



the hologram, and the exact wavefronts of the test beam are reproduced. A virtual image can be observed through the hologram in the position formerly occupied by the actual object. A second real image, not used, is also produced.

pattern produced by the changes.

Common-path interferometers also permit three-dimensional observations beyond the capacity of conventional equipment. By inserting a diffuser between the test beam and the test object, the object is illuminated by diffuse light. Because the diffuser is fixed, it doesn't introduce fringes in the interference pattern. But because light passes through the test object over a wide range of angles, the interference pattern corresponding to any viewing direction can be examined by changing one's viewing perspective. To get the same effect with a conventional inferometer, a diffusing screen would have to be introduced before the beams are split, and the path lengths would have to be matched in all directions.

Double-exposures

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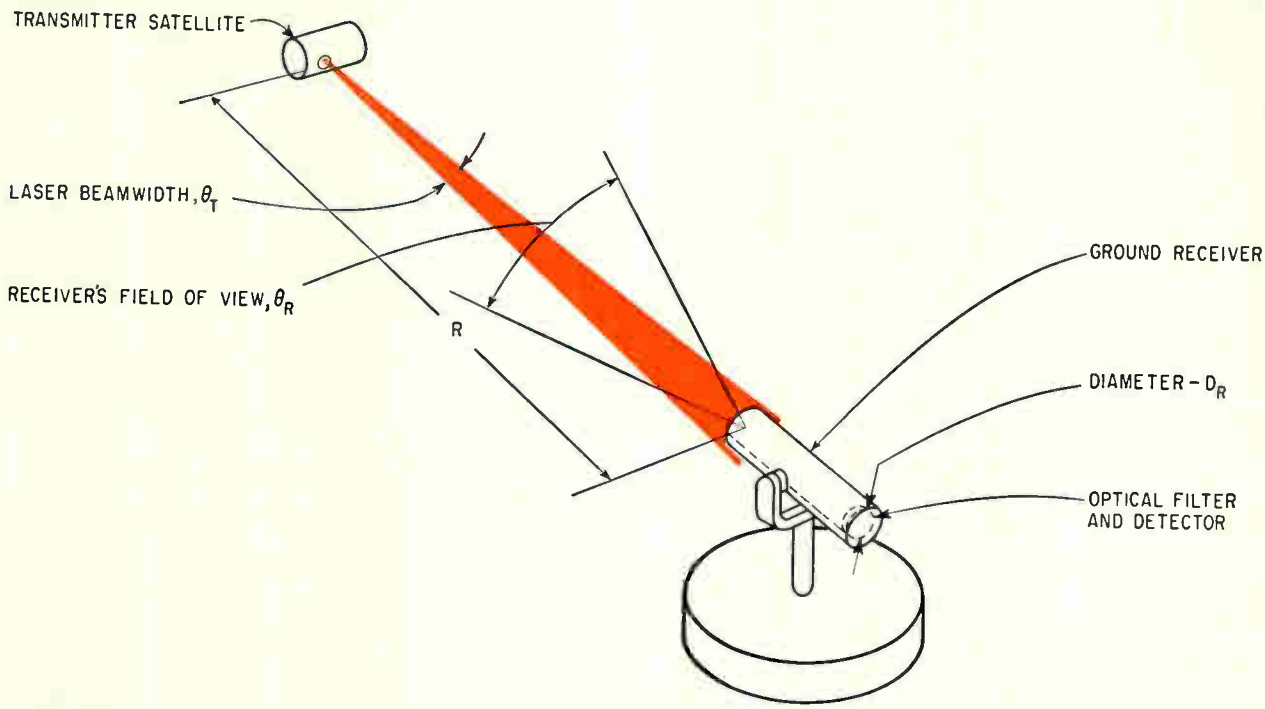

Optical communications detector receives not only the laser beam, but any background noise that falls within its field of view, θ_R.

(Δf), where Δf is the actual post-detection bandwidth.

The selected 1-angstrom-bandwidth filter centered at the laser frequency is equivalent to about a 75-gigahertz bandwidth. This is larger than the total bandwidth of any radio system and is also larger than the information bandwidth required for most existing communications systems; smaller optical bandwidths are difficult to achieve. The filter's bandwidth in hertz, $\Delta\nu$, is related to the bandwidth in wavelengths $\Delta\lambda$ by

$$\Delta\nu \cong c\,\frac{\Delta\lambda}{\lambda^2}$$

The nomogram

As an example of calculating signal-to-noise ratio with the nomogram, consider a communications system with the fixed design values given in the table on page 85 and the following additional design values:

$R = 10^5$ kilometers
$P_O = 100$ milliwatts
$k = 0.50$
$\theta_T = 10 \times 10^{-6}$ radians
$D_R = 100$ centimeters
$\theta_R = 50 \times 10^{-6}$ radians

If we want to determine the signal-to-noise-power ratio at the output of the photodetector for an information (post-detection) bandwidth, Δf, of 5 megahertz, we perform the following steps in the nomogram:

- Draw a straight line through the value of the laser power, P_o, on line 1 and R, the distance between the transmitter and receiver, on line 2. Extend the line until it intersects line 3 at point 1 (in color).
- Connect point 1 on line 3 with the value of the transmitted beam width, θ_T, on line 4, and mark the intersection with line 5 as point 2.
- Using the transfer slopes between lines 5 and 6, transfer point 2 to point 3 on line 6.
- Connect point 3 with the value of the receiver collector diameter, D_R, on line 7. The intersection with line 8 is point 4.
- Draw a straight line between point 4 and the modulation index value, k, on line 9. This line intersects line 10 at point 5, where the signal-to-noise power ratio is found to be 2.82×10^2.

This value is for a 1-megahertz bandwidth. To find the signal-to-noise ratio for the specified 5 megahertz, we multiply by $(1 \times 10^6)/(5 \times 10^6)$ and obtain 56.4.

The slopes of the transfer lines between nomogram lines 5 and 6 indicate the predominance of different types of noise. The horizontal transfer slopes indicate a predominance of shot noise, while increasing slope shows the influence of background and dark-current shot noise.

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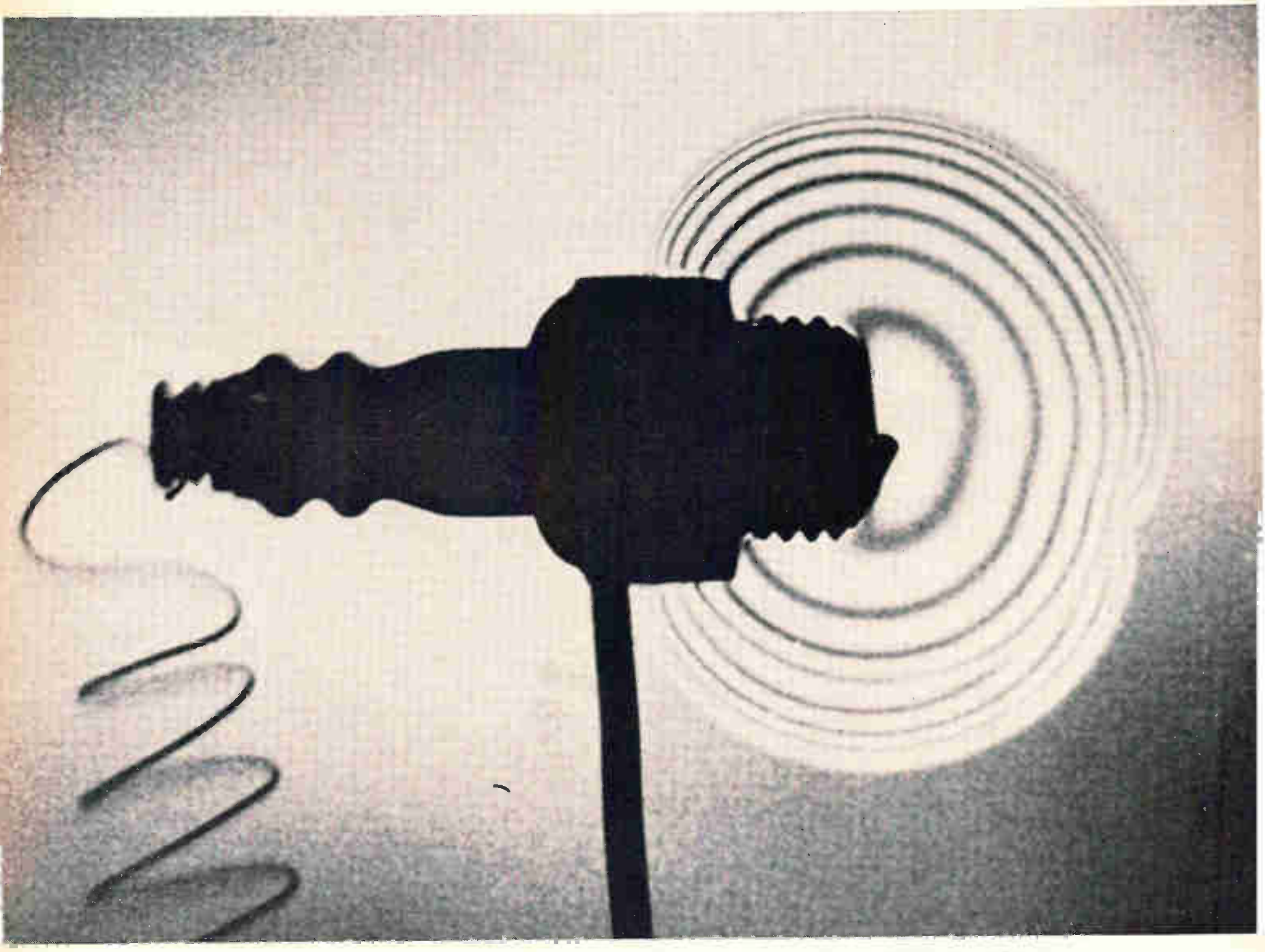
The author

John Ward, a senior member of the ITT Federal Laboratories' technical staff, has developed a number of optical tracking and communication systems in his present job and earlier at Texas Instruments Incorporated. He also served as consultant on the Apollo simulator for North American Aviation Inc.



Holographic interferogram shows moving combustion front after spark plug ignites acetylene-air mixture.

Advanced technology

New dimension for interferometry

Interference patterns between light waves occurring at different times can be analyzed from holographic records of the beams. Holograms can also do the work of conventional interferometers, and at a lower cost

By Robert E. Brooks
TRW Systems Group, Redondo Beach, Calif.

The hologram's ability to store an optical wave adds to interferometry the capacity to produce interference between two light waves that exist at different times.

Besides opening the way to new interferometric techniques, the hologram can do the jobs of conventional interferometers in measuring small displacements and refractive indices, and with lower-quality, lower-cost optical components. The savings are especially important when the subject of an interferometric study is large.

Holograms make feasible the following types of interferometers:

- Differential. The unchanging aspects of a complex object can be canceled in an investigation of subtle changes.
- Three-dimensional. The object can be studied from any angle.
- Time-average. Vibration modes can be observed.

The use of a hologram in such applications is best demonstrated with a basic interferometer setup such as the Mach-Zehnder. This approach uses only two beam dividers and two mirrors, but a hologram can be used in more complex systems since it offers considerable savings. [For a basic discussion of the technology, see "Interferometry and holography," page 90.]

Two beams are needed to obtain the interference pattern—a test beam that passes through the object under study, and a comparison beam that passes directly to the output.

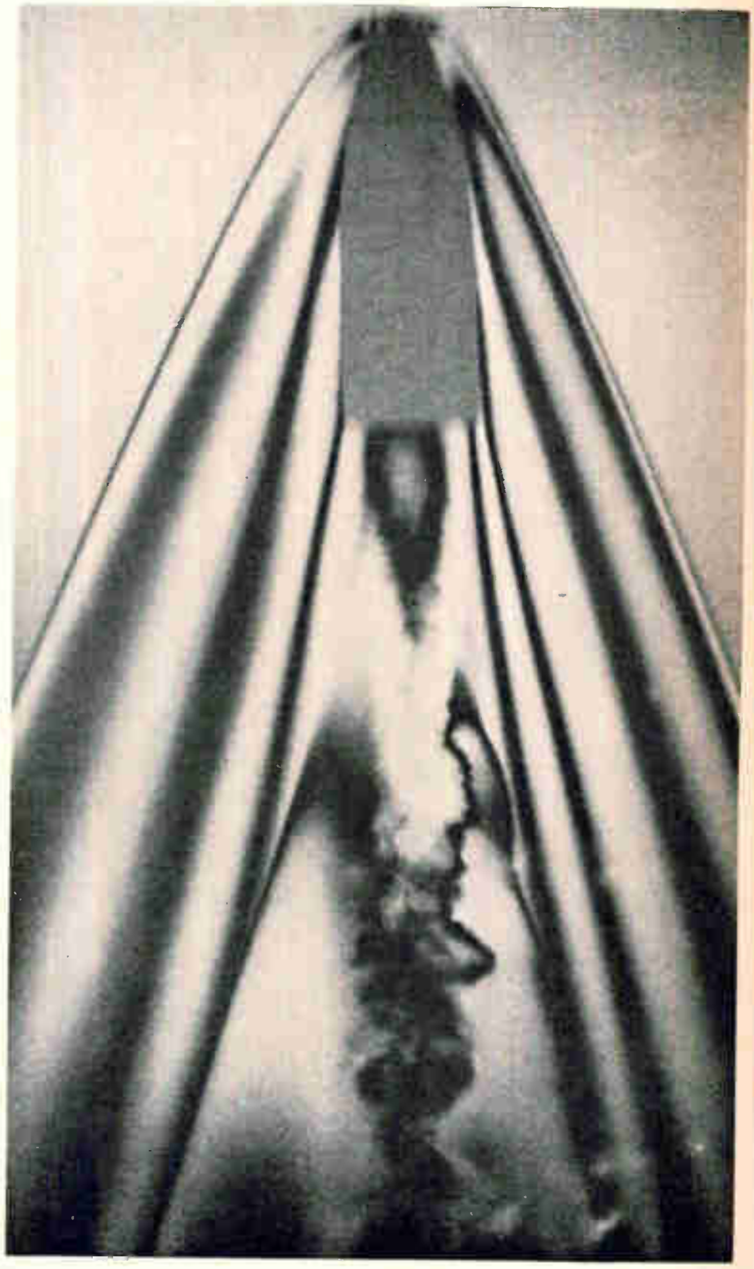
If it's convenient to make tests "on location"—for example, when turbulence is being studied in a wind tunnel or shock tube—a hologram can be made of the test beam and inserted in the Mach-Zehnder arrangement.[1] Measurements then can be made at the experimenter's leisure in a laboratory environment.

The experimenter can even go a step further and use a second hologram to synthetically generate the comparison beam. He can then dispense with the split beam, generating both holograms in the same beam. The result, a common-path interferometer, is an arrangement that offers many advantages.

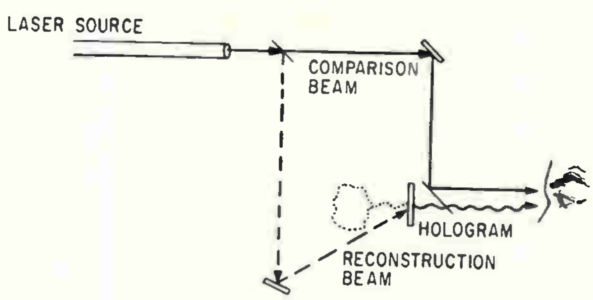
With the common-path technique, both test and comparison beams traverse the same optical path. Because the interference pattern results only from changes in the test object, imperfect optical components can be used without affecting the fringe pattern.

Differential and 3-D

A photograph of the interferometric pattern caused by heating the gases in a common electric lamp was made using holograms for the test and comparison beams. It couldn't have been made with a conventional interferometer; the lamp's envelope would produce fringes that would obscure the desired pattern. With a common-path interferometer, however, those aspects of the subject that don't change don't affect the interference



Shock layer surrounding a .22 caliber bullet traveling at 3,500 feet per second is shown in double-exposure holographic interferogram. The relatively long exposure time, 0.25 microseconds, causes a slight blurring of the bullet image.



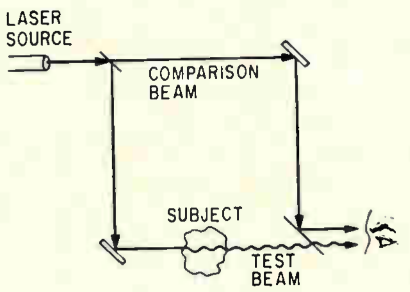
Test beam in the Mach-Zehnder interferometer can by synthetically generated with a hologram. The viewer then sees the interference pattern between the comparison beam and the test beam, released from the hologram with an auxiliary beam.

Interferometry and holography

Interferometry is based on the principle that if two beams of the same monochromatic light are superimposed, the intensity in the region of superimposition depends on the phase difference between the waves. If the two waves are in phase, an intensity maximum is found; if they are out of phase, intensity is a minimum. The variations of intensity form a pattern of alternate dark and bright fringes.

Because the wavelength of light is so short (0.6 microns, or 6000 angstroms, for red light), an extremely small change in the path length of one beam can cause a phase shift of 180°. This will change an intensity maximum to a minimum, or vice versa, and will result in a fringe shift of one-half the distance between fringes. Changes as small as a tenth of this magnitude can be measured. Thus, interferometry finds application in measuring extremely small changes in physical dimensions, or changes in refractive indices that change optical path lengths.

Mach-Zehnder. Although there exists a great variety of interferometers, the Mach-Zehnder arrangement, developed in 1891, is typical and illustrates the basic principles.



It's still commonly used for the study of gas densities and for tests in wind tunnels and shock tubes. Its square configuration allows wide separation of the test and comparison beams; often the comparison beam can be routed around the subject.

With this approach, light from a monochromatic source is divided into two paths by a beam divider. One beam, in the comparison path, passes unperturbed to the output by means of a mirror and a second beam divider. The other beam, in the test path, passes through the object being investigated. The phase of the waves passing through the test object are altered according to the velocity of propagation and the path length. The two beams are recombined at the output where the fringe pattern resulting from the interference of the superimposed beams is viewed.

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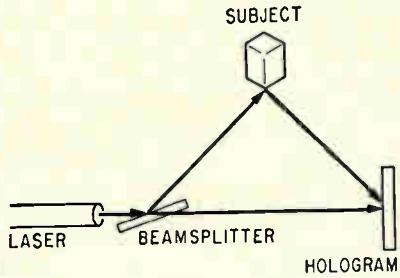

angle between the two beams. For the typical 30-degree beam angle, the spacing is twice the wavelength. The hologram's interference pattern shouldn't be confused with the pattern in the interferometer. In an interferometer, the beams are nearly parallel ($\alpha = 0°$), so that fringe spacing is much greater and can be analyzed with the unaided eye.

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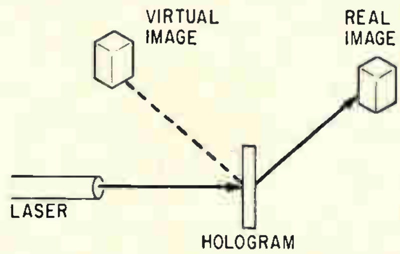

the hologram, and the exact wavefronts of the test beam are reproduced. A virtual image can be observed through the hologram in the position formerly occupied by the actual object. A second real image, not used, is also produced.

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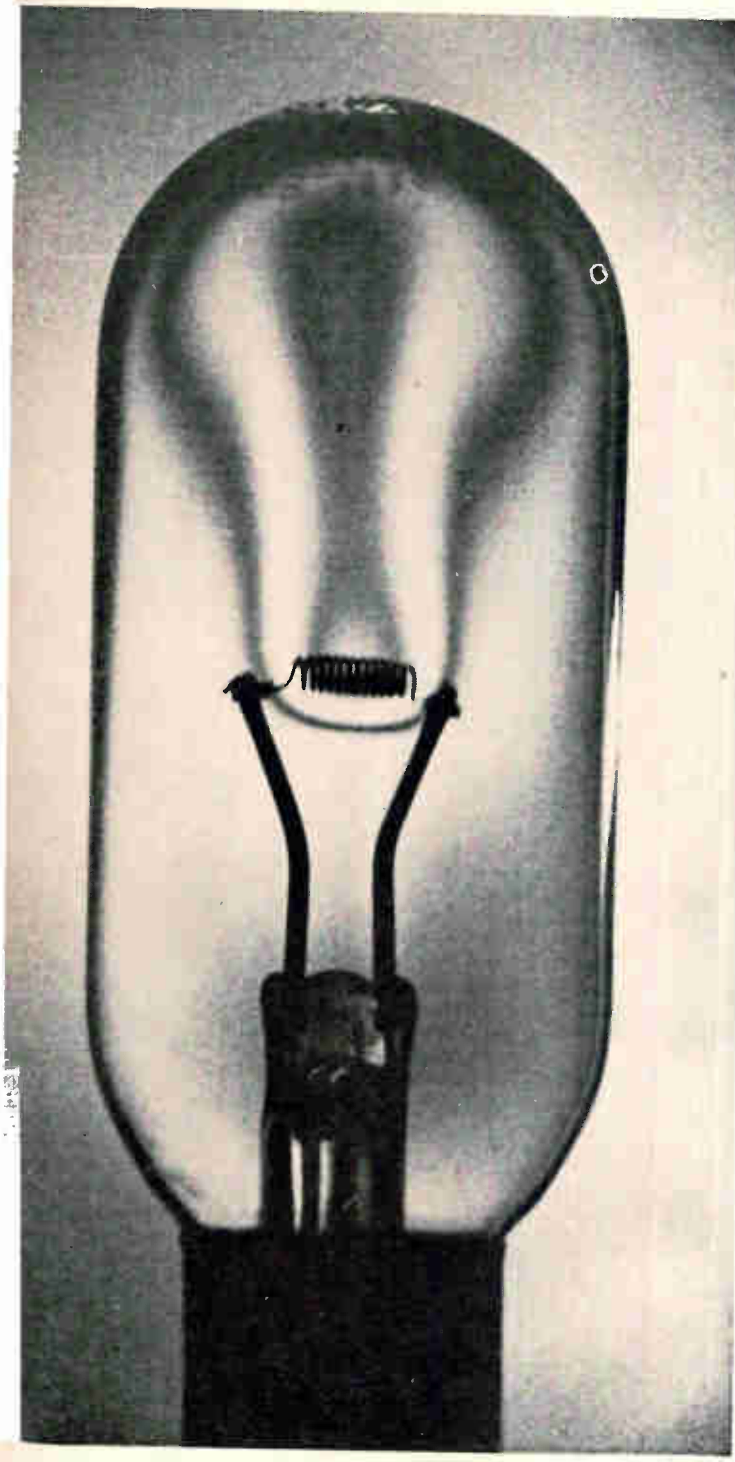
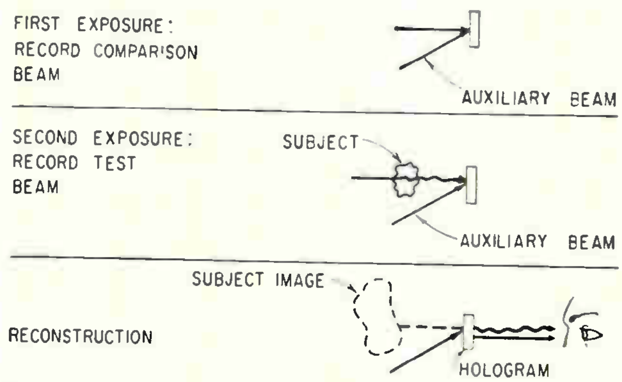


Differential interferometric measurements using double-exposure hologram of a light bulb. One exposure is made with the filament cold, the second with the filament heated. The difference between the two exposures is due only to the density changes in the gas inside the envelope. The interferogram is clear despite the poor optical quality of the glass bulb.



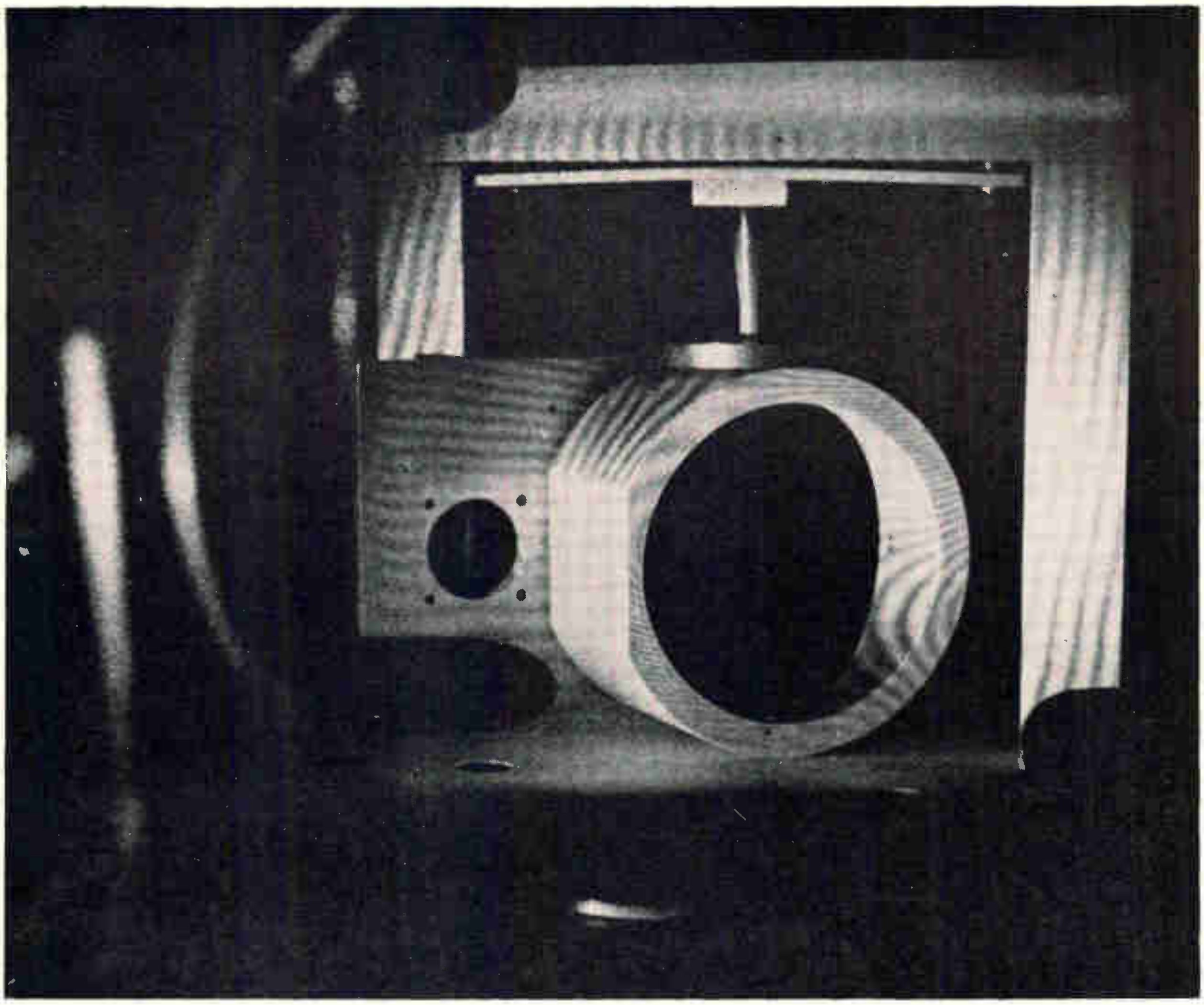
Double-exposure hologram can be used to store both test and comparison beams, eliminating the interferometer arrangement. An auxiliary laser beam is needed to form the holograms and reconstruct the wave patterns.

care must be exercised to minimize distortion of the plate and its emulsion; such distortions will appear as phase shifts in the observed interference pattern. However, a double-exposure holographic approach overcomes these problems—with a small loss in flexibility—by putting the two holograms on the same plate.[2, 3]

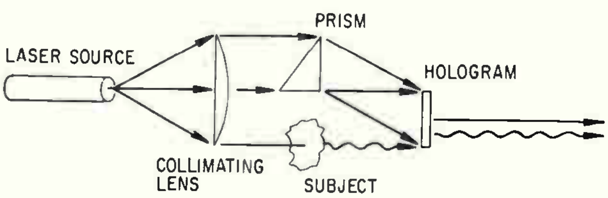
With the holograms of the test and comparison beams locked together on the same plate, shrinkage or distortion of the photographic emulsion or changes in the reconstruction geometry have no effect on the accuracy of the observed interference pattern. Thus the double-exposed hologram can be recorded at one wavelength (with a pulsed solid state laser, for example) and reconstructed at another (perhaps with a continuous-wave gas laser). In addition, precise alignment of the apparatus isn't necessary.

Real-time studies

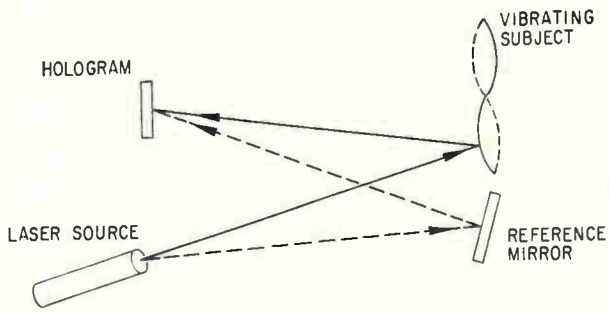
If a test beam is recorded on a hologram, as in the double-exposure method, it's impossible to examine a new subject or view changes without making a new hologram. However, if only the comparison beam is holographically recorded, and this reconstructed beam is compared with any



Real-time interferometry technique in which the comparison beam is stored on a hologram and the test beam is actual. In this arrangement, developed by K.A. Haines and B.P. Hildebrand of the University of Michigan, deformations caused by the applied load set up an interference pattern.



Simple implementation used for real-time interferometry. The prism provides the proper angle for the reconstruction of the comparison beam already recorded. Changes in the subject thus can be studied.



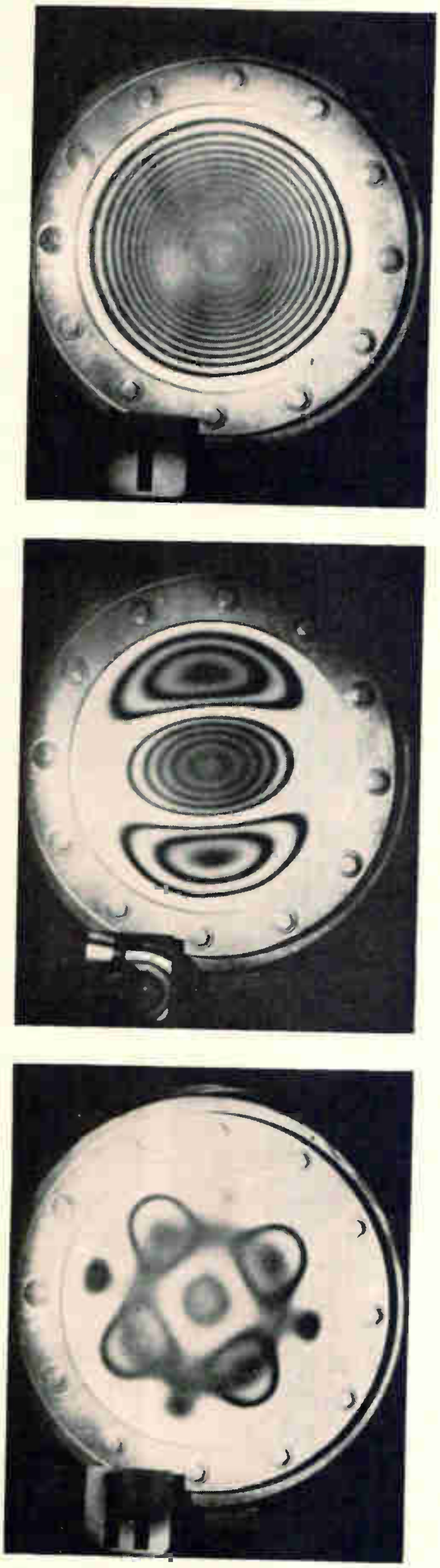
A vibrating subject can be studied with a time-average hologram, which records the subject's vibration modes.

object's actual test beam, the real-time behavior of the subject can be displayed interferometrically.[4-7] Since the same beam is used for test and comparison, the result is a common-path interferometer.

If a hologram of the comparison beam is replaced in the apparatus and reilluminated, one observes simultaneously the actual beam and the reconstructed comparison beam. If a subject is then introduced into the actual beam, it becomes a test beam and can be directly compared with the reconstructed comparison beam.

A simple system for transparent subjects uses only a lens and prism.[4] The lens collimates the laser beam, the prism diffracts half the beam onto the hologram, and the subject is placed in the path of the other half of the beam. This implementation was developed with L.O. Heflinger and R.F. Wuerker of the TRW Systems group.

Although these methods don't require high-



Mode pattern of a vibrating membrane of a sonar transducer. The vibration frequency increases from top to bottom in the experiment performed by R.L. Powell of the University of Michigan.

quality optical elements for good results, precision is necessary in the positioning and holding of the hologram plate. To eliminate the chance of bending or distortion, thick photographic plates—of quarter-inch glass, for example—must be used and carefully processed.

To equalize the two beams' intensities, the test beam should be attenuated during reconstruction. Placing the attenuating filter near the laser point minimizes any phase distortions the filter might cause.

Real-time interferometry can be used to measure differential changes in an otherwise complex subject by holographically recording the unperturbed subject and then viewing changes that are introduced in it. This method is useful for observing strain patterns in objects under various mechanical loads.

Time-averaging

Periodically vibrating objects such as acoustic-wave transducers can be studied with time-average interferometry.[8] The subject is illuminated with a continuous-wave laser and the scatter waves from the vibrating surface are holographically recorded, producing, in effect, a multiple-exposure hologram.

Those rays scattered from nodes on the vibrating surface are reflected undisturbed and appear as bright as the normal surface illumination in the reconstruction. The vibrating parts of the surface, however, show up darker due to a washout of that component of the hologram's fringes.

For a typical case—sinusoidal vibrations—the intensity on the hologram varies with the vibration amplitude as a zero-order Bessel function. As a result, the reconstructed image will appear to be covered with a fringe pattern representing the loci of equal amplitudes of vibration.

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The author

After receiving his Ph.D. from the University of California, Berkeley, in 1962, R.E. Brooks joined the TRW Systems Group, where he is now engaged in research in optics and electro-optics.

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.

Cathode voltage boosts amplifier gain tenfold

By Y.L. Li
University of Malaya
Kuala Lumpur, Malaysia

Increasing a tube amplifier's gain tenfold is accomplished by making its cathode bias the supply voltage for a preceding single-transistor circuit. The transistor preamplifier converted an audio amplifier, designed to pick up a high output crystal signal, to a magnetic cartridge amplifier without a step-up transformer or extra tube stage separately powered.

Assume the cathode bias of tube V_1 is 2 volts produced by an anode current of approximately 2 milliamperes. Thus transistor Q_1 must operate with a maximum collector current less than 2 ma. Assuming $I_c = 1$ ma, the size of collector resistor R_c is determined by

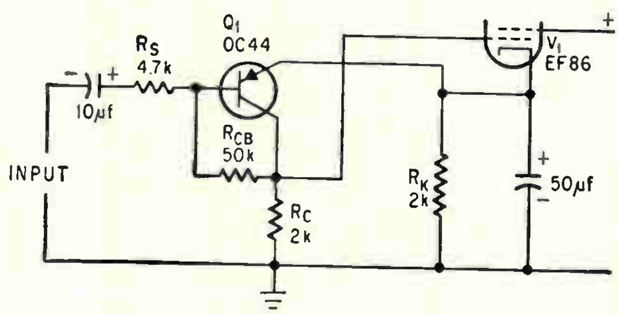
$$R_C = \frac{2 \text{ volts}}{1 \text{ ma}} = 2 \text{ kilohms}$$

Choose $R_k = R_c = 2$ kilohms

Resistor R_{CB} must maintain the proper bias on Q_1 even though the tube's grid-to-cathode voltage is continually changing. A satisfactory relationship for determining R_{CB} is $R_{CB} = \frac{1}{2} \beta R_c$. Since transistor Q_1 has a current gain (β) of 50,

$$R_{CB} = \frac{1}{2} \beta R_c = 50 \text{ kilohms.}$$

When the input source impedance is low and β is high, transistor Q_1's stage gain is given by R_{CB}/R_S; thus, R_S is chosen to be 4.7 kilohms for a stage gain = 10. The frequency response of the amplifier may be adjusted by connecting an appropriate capacitor across R_S or R_{CB}.



Cathode bias from tube V_1 is the supply voltage for transistor Q_1. This preamplifier boosts the gain by 10.

Automatic scale changer shifts recorder range

By B.E. Bourne and R.L. Gattinger
National Research Council, Ottawa, Canada

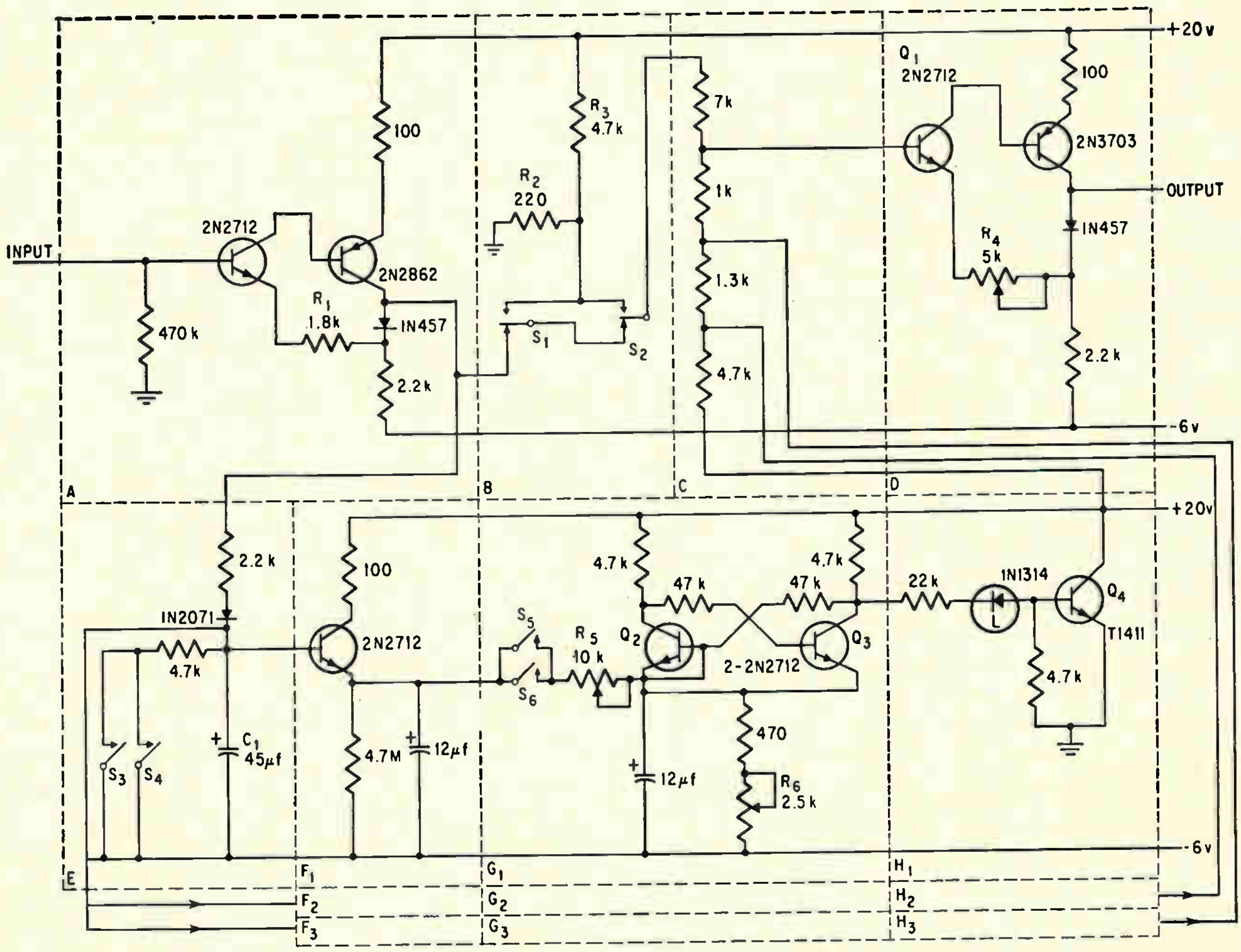
Transistors in place of the reed relays usually found in commercial instruments make it possible to build a low-cost automatic scale changer for meters and recorders. The circuit was designed to operate with a spectrometer that repetitively scans a frequency band of light emissions in the upper atmosphere. As the values of light emissions change, the input voltage to a pen recorder varies. These variations cause the circuit to adjust the multiplying factor of the recorder scale, keeping the results in a useful range. The scale changer reads the recorder peak-input voltage during each scan of the spectrometer.

If an off-scale or low-scale trace is obtained, a voltage divider in the scale changer adjusts the recorder's input to produce a maximum on-scale trace during the next scan.

For simplicity the circuit is partitioned into eight stages, A through H.

Stage A provides a 400-kilohm input impedance and a low output impedance for driving the succeeding stages. The stage output voltage level is maintained approximately equal to the input by selection of resistor R_1.

Stage B enables the operator to determine the scale factor at any given time. The reference voltage at the junction of R_2 and R_3 is routed by switch S_1 or S_2 through the voltage divider in stage C to the base of Q_1. Varying the effective grounding position along the divider changes the scale factor. In passing through stage C, the reference voltage



Scale factors are established when the outputs from H automatically change grounding points on the divider in stage C. Stage E detects the peak input voltage and controls the outputs from the H stages.

is multiplied by a ratio equal to the scale factor at that time. Microswitch S_1, operated periodically by the spectrometer, automatically displays the scale factor on the recorder trace. Switch S_2 is operated manually to determine the scale factor at any instant of time.

Stage D is a driver similar to stage A. Resistor R_4 is selected so that the output voltage follows the voltage at the base of Q_1.

Stage E is a peak-level detector. The spectrometer momentarily closes microswitch S_3 at the start of each scan to discharge C_1. During adjustment of the scale changer, S_4 operates as S_3.

Three identical chains of F, G and H stages, one for each of the three scale factors desired, are fed in parallel from E.

The F stages provide impedance matching between the E and G stages.

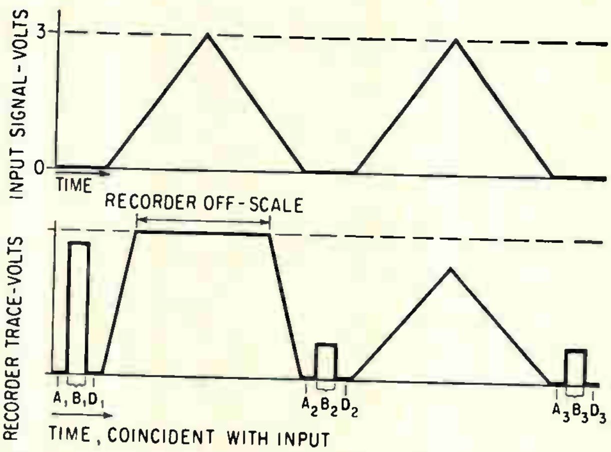
The G stages are flip-flops which can be turned on (Q_2 conducting) or off (Q_3 conducting) at various levels established by the values of R_5 and R_6. Stages G_2 and G_3 are the same as G_1, but are adjusted to switch states at different input voltage levels. The spectrometer momentarily closes microswitch S_6 at the end of each scan to set the G stages for the next scan, determined by the peak voltage measured by E during the previous scan. Switch S_5 is used manually when the scale changer is adjusted.

The H stages operate as grounding switches. In H_1, when Q_4 is conducting, the saturation voltage from collector to emitter is about 50 millivolts and provides an effective grounding point at the end of the voltage divider in stage C. Transistor Q_4 conducts only when stage G_1 conducts. The effective grounding point shifts towards the center of the divider when emitter H_2 or H_3 conducts because of G_2 or G_3 conducting.

The scale changer switches to a lower-sensitivity scale at the end of a scan when the input during the scan rises to 1 volt (G_1 turns on), 2 volts (G_2 turns on), or 4 volts (G_3 turns on). G stages can change state simultaneously. Sensitivity increases at the end of a scan if the peak voltage has fallen to 3 volts (G_3 turns off), 1.5 volts (G_2 turns off), or 0.75 volt (G_1 turns off). With all G stages turned off, the output voltage is approximately equal to the input voltage.

The waveforms illustrate a typical cycle of scale changing. It is assumed that the G stages are off and that the peak-level detector indicates less than one volt before any signal is applied to the input. The height of the calibration pulse at B_1 shows that the scale changer is in the most sensitive range. At D_1, S_3 is closed momentarily to discharge C_1. In the first scan, the recorder pen goes off-scale since the full-scale sensitivity is one volt and the peak input voltage is three volts. At A_2, S_6 is closed momentarily; this causes G_1 and G_2 to turn on since the peak-detector reached three volts during the previous scan. The height of the pulse at B_2 indicates that the input voltage is divided by four in the next scan. Switch S_3 is again closed momentarily at D_2 to discharge capacitor C_1. The sampling at A_3 shows that no scale-factor change is required for the next scan.

Satisfactory operation was obtained with repetition rates from one scan every five minutes to four scans per minute. However, operation is possible with repetition rates higher than 300 milliseconds if the time constants in the E and F stages are decreased. The scale changer can be easily adapted to any instrument having outputs similar to the spectrometer.



An off-scale trace is obtained on the recorder when the peak input exceeds 1 volt. The smaller calibration pulse at B_2 indicates that the recorder scale is increased by a factor of 4, yielding a subsequent on-scale trace for the same peak input.

Decade counter's feedback adds up to reliability

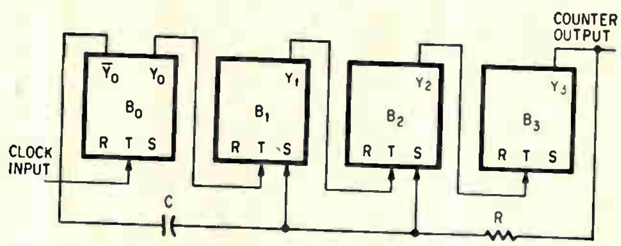
By C.J. Ulrick

Collins Radio Co., Cedar Rapids, Iowa

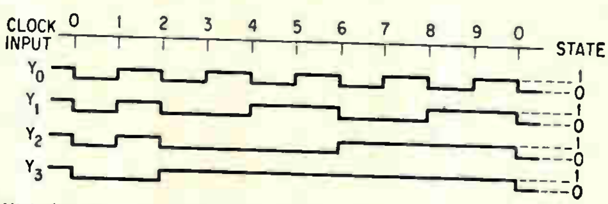
Four flip-flops and a simple RC feedback gate form a reliable decade counter in which feedback effectiveness is independent of flip-flop resolution time.

In feedback counters, the stages receiving the returned signal are often required to change states twice in a short time—once from the trigger input, and again from the feedback signal. If the time between the two signals is shorter than the resolution time of the flip-flops, proper feedback response isn't obtained. The result: inaccurate counting. Often, additional buffering circuitry is required to establish the proper time delay.

With the connection shown, the stages receiving feedback aren't changed by their input triggers at the same time. Thus, a complete clock period is available for these stages to make the transitions. Feedback occurs as follows: Whenever the Y_3 output is zero, a one-to-zero transition of $\overline{Y}_0$ passes through the RC path to the set inputs, S, of flip-flops B_1 and B_2. On the first input pulse, B_0 changes state, and the one-to-zero transition of $\overline{Y}_0$ is fed to B_1 and B_2, forcing them to change state. The



Feedback signals are present at the set input of B_1 and B_2 when Y_3 is 0 and there is a 1-to-0 transition in Y_0.



With feedback, the first input clock pulse increases the count to binary 7.

zero-to-one transitions at the T inputs have no effect on the B_1 and B_2 states.

The state of the flip-flop chain, after the first pulse, is a binary seven; therefore, six extra counts have been added to the cycle. On the second pulse, Y_3 goes from a zero to a one state, and no feedback is possible for the remainder of the cycle. With the feedback path effectively removed from the circuit, the count for the remainder of the cycle is accomplished in the conventional manner of a ripple counter.

On the second through 10th pulses, the circuit counts from seven to 16 in the conventional manner, producing an output pulse (one-to-zero transition of Y_3) on the 10th input pulse.

The only calculation required to ensure reliable counting is the time constant RC. It must be less than one clock period, preferably one-third.

Light-activated Schmitt triggers control relay

By Robert A. Farrall

Clairex Corp., New York

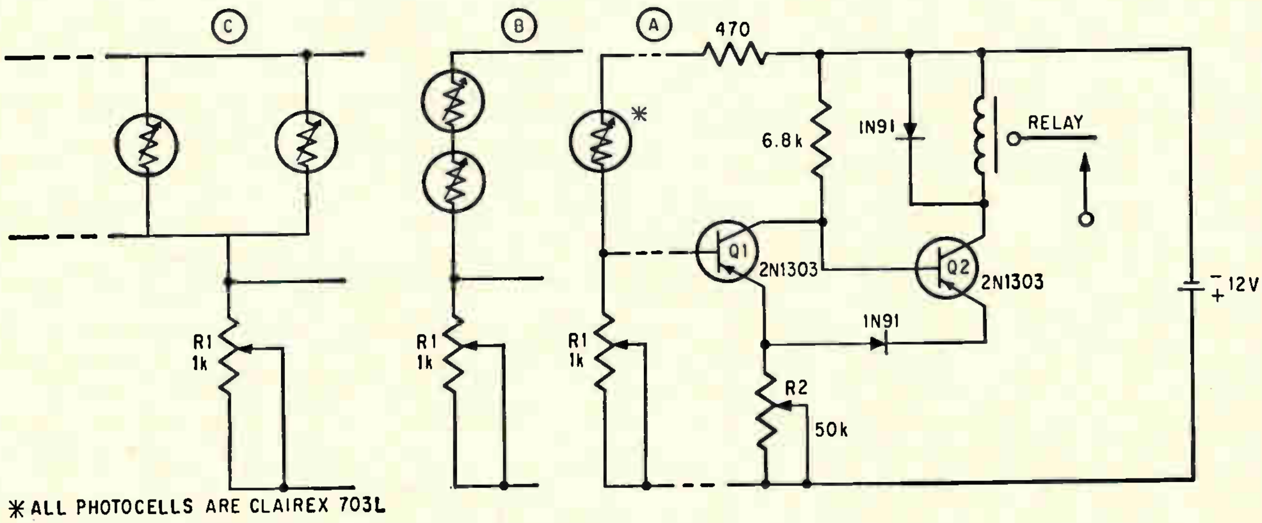
A Schmitt trigger fed by a photoconductive cell trips a relay in response to small changes in light intensity. Fast action and precise control are achieved without sensitive relays.

The basic Schmitt trigger is shown at the extreme right of the schematic. Circuits A, B, and C are several input configurations.

With circuit A, relay pull-in is achieved when the light intensity decreases. At high light levels, transistor Q_1 conducts. When Q_1 is on, Q_2 is off. As the light level decreases, both the base drive and collector current of Q_1 drop until Q_2 conducts. The voltage drop across potentiometer R_2 increases as Q_2 conducts, cutting off Q_1, and causes Q_2 to saturate, pulling in the relay. When the light level increases again, the circuit turns Q_1 on and Q_2 off, causing the relay to drop out.

The operating point of the circuit is set by potentiometer R_1, and R_2 determines the on-off differential of the Schmitt. Since the effects of R_1 and R_2 are interdependent, the two potentiometers are adjusted alternately until the desired operating point and differential are obtained.

The input circuits can be arranged to perform logic functions. For example, with the AND configuration of input circuit B, both cells must be illuminated for the relay to drop out. Input circuit C is an OR configuration; thus, illumination of either cell causes the relay to drop out. If the positions of the cells and potentiometers in each circuit are reversed, relay pull-in with increasing light intensity is obtained. For this type of operation, R_1 is 50 kilohms.



Photoconductive cells supply varying base drive to Q_1 as light intensity changes. When Q_1 cuts off with low base drive, Q_2 conducts, energizing the relay.

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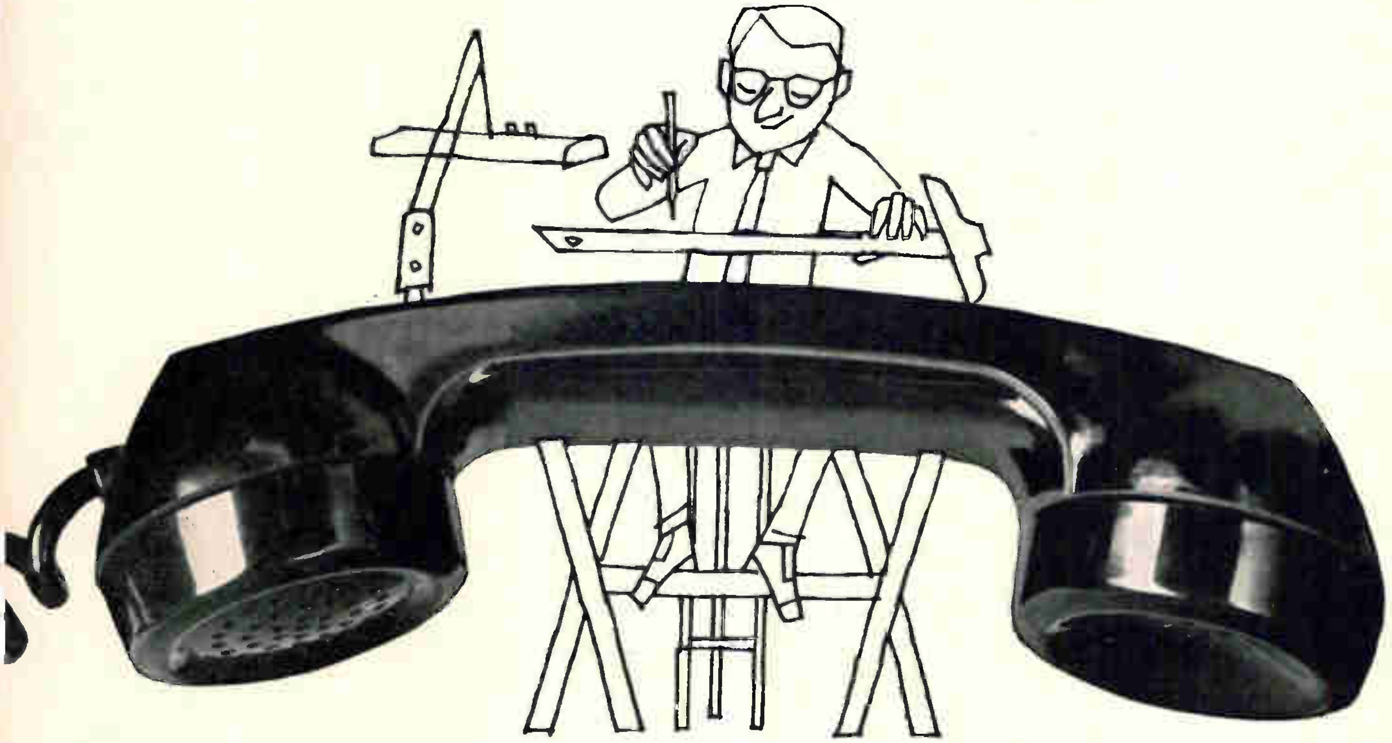

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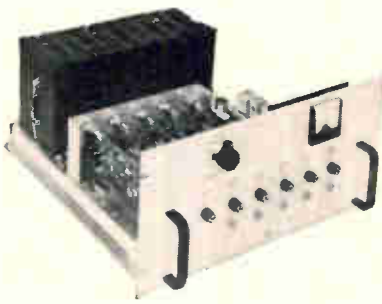

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Circle 99 on reader service card

Plated-wire memories: Univac's bet to replace toroidal ferrite cores

Thin films on wire substrates form stores that are fast, cheap, yet easy to make; memories of 100 million bits are feasible

By George A. Fedde

Univac Division, Sperry Rand Corp., Blue Bell, Pa.

Thin-film memories have finally caught up with ferrite-core memories in cost, size, and speed. It now appears feasible to build—at a cost as little as a penny a bit—film memories with capacities upward of 100 million bits and operating times down to 1 or 2 microseconds.

Random-access, plated-wire memories are already being manufactured for the Univac 9000 computer series. Faster than the proposed mass memories, these stores have a cycle time of 600 nanoseconds. The range in capacity from about 150,000 bits in a module to a million or more bits in multimodule memories.

Up to now, film memories have been feasible only in a few applications. Using plated wires as the main memory in the Univac 9000 represents a breakthrough for film memories in low-cost, high-performance computer systems.[1] Large plated-wire memories have also been built for other applications.

An 8-million-bit feasibility model—resembling a 4-by-8-foot sheet of plywood covered with aluminum foil—has already been built. To form a 100-million-bit memory, a dozen such modules could be stacked. Any of the 64-bit words could be directly accessed in 1 or 2 microseconds. This type of memory could fill the gap between ferrite-core main memories of several million bits and the billion-bit magnetic drum and disk bulk stores which operate in milliseconds.

High speed, low cost, and high capacity are inherent in the design and manufacture of plated-wire memories. Each inch of plated wire can store about 20 bits, with the wiring itself doubling as the sense winding. The volume of film switched is miniscule, as is the switching time. Power consumption is therefore low. Because the readout of data from the film is nondestructive, both the time and the circuitry needed to regenerate the data are eliminated.

By using long lengths of wire, storage construction can be simplified. The magnetic film, a nickel-iron alloy similar to Permalloy, is cylindrically deposited on the wire in a continuous electroplating process. The processing equipment needed to prepare in a year wire with a capacity of 100 million bits costs only one-fourth to one-third as much as the equipment for vacuum depositing an equal number of planar magnetic elements on a substrate.

Shapc of the memory

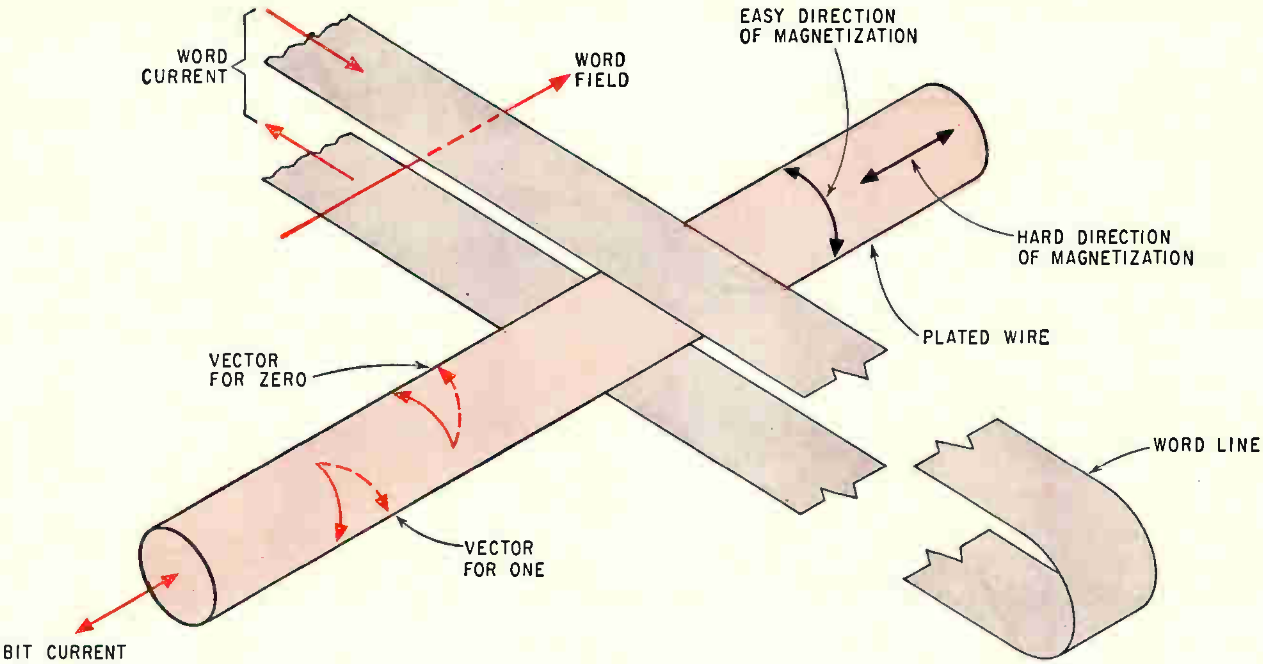
A single memory element, storing one bit, is perhaps 50 mils in length. Several hundred bits can conveniently be stored on each of the many wires making up a memory. Bit positions are determined by the position of word lines, perpendicular to and insulated from the plated wire. Each word line, or strap, forms a one-turn solenoid around all the parallel wires.

In some ways, the plated memory elements are similar to both ferrite cores and planar films.

- Like cores, the plating's cylindrical geometry provides a closed flux path for the magnetization. The path encircles the wire in one direction for a

The author

George Fedde is manager of the advanced electronics research department at the Sperry Rand Corp.'s Univac division. He has been doing research and development work on digital computer memory systems for 11 years.



In a plated-wire memory, the word line forms a one-turn coil around several wires. A current in the word line tilts the vector magnetization from its rest position, shown in solid lines, toward the hard axis of magnetization, generating a pulse in the plated wire.

stored binary 1 and in the opposite direction for a stored binary 0.

▪ Like planar magnetic films, the wire plating is anisotropic—more easily magnetized in certain directions than in others. The closed flux path is parallel to the easy magnetization axis, as shown above. If there is no external magnetic field, there is no longitudinal component of magnetization in the wire.

One way of making a memory plane (sketch, page 103) is to put oversize pilot wires between two sheets of Kapton coated with Teflon (Kapton is a high-temperature cousin of Mylar). Under pressure, the Teflon fuses around the wires. The sandwich is laminated to the remaining components. Freeing the pilot wires by pulling them loose leaves tunnels in the Teflon layer through which plated wires can be inserted. Because the diameter of the pilot wire (0.008 inch) is larger than the plated wire's (0.005 inch), insertion is a simple process.

Many variations of this construction are possible. Each provides a localized magnetic drive field parallel to the wire axis. Bit-storage position is where the wire and the localized drive field cross. This field is called the word drive field, because the current in one word drive line switches all the bits of one or more computer words. Neither the angle nor the position of the wires relative to the word drive straps is critical. The wires need only be nominally perpendicular to the word straps.

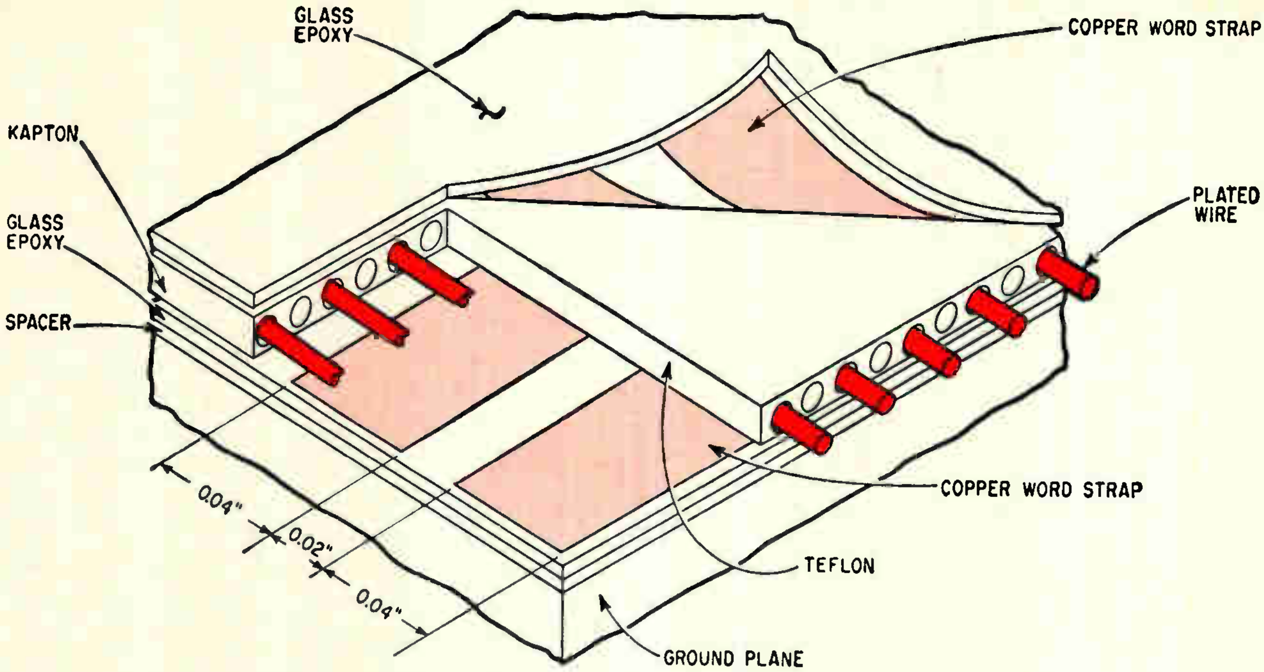
Fast, inexpensive and NDRO

There are numerous similarities and important differences between this newly developed memory element and previous elements. However, it provides a most desirable combination of features not previously available. In operation, the most significant of these is the nondestructive readout (NDRO) of stored data combined with the ability to write new data electronically at high speed. This combination is basic to wide application, high performance, and low cost.

Nondestructive readout provides an effective system speed advantage of 67% over destructive readout (DRO). This advantage arises from the fact that, with NDRO, two independent read instructions can be executed in the time that a ferrite-core or other DRO memory requires for one read instruction. Readout clears, or destroys, data stored in a core, so rewriting the data is necessary following every readout. In a typical computer application, read instructions occur, on the average, four times as often as write instructions. In a DRO memory, every write instruction requires clearing out the old data before writing the new. Thus four reads and one write require 10 operations—five read-write pairs. The same instructions require six operations in this NDRO memory: four reads and one clear-write pair. The ratio of 10 operations to six gives the 67% speed advantage. To make the most of this, the logic designers and system programers must keep this speed advantage in mind when designing their systems.

To write data into the memory, coincident currents are applied to the plated wire and to an etched conductor that forms a one-turn coil around the parallel plated wires. Direction of the current, as is true with other memories, determines whether the bit stored is a 1 or 0.

To read the stored information, a word current pulse tilts the magnetization vector in the plated film momentarily giving it a longitudinal compo-



A sandwich made of plated wires between two layers of plastic insulates the wires from the word straps. The ground plane is a copper-clad glass epoxy board like those used for printed circuits.

nent, as shown in the diagram on page 102. The change in magnetization generates a bipolar voltage pulse in the wire under the plating, the sense wire. At the end of the current pulse, the vector returns to its original position. Hence, the process of reading out doesn't destroy the data.

Latitude in longitude

The closed flux path enables the choice of plated-wire film thickness without regard to bit-packing density (the bit space on the wire) or the coercive force (the reverse magnetization required to remove the residual magnetism from a magnetically saturated material).

Planar thin-film memory elements ordinarily have open flux paths. Thus, the elements resemble bar magnets. Such magnets tend to demagnetize themselves unless their material has high coercive force. The demagnetization field is proportional to the magnet's cross-sectional area, and inversely proportional to its length.

Therefore, if a bar magnet—or memory element—is made smaller, it must also be made thinner, or of a different alloy that has a higher coercive force. Both alternatives have disadvantages. A thinner memory element generates a smaller output signal. The alloy with the higher coercive force requires more drive, and is magnetostrictive—that is, its physical dimensions change when it is magnetized. This affects handling and assembly procedures as well as mounting, packaging, and temperature control requirements that depend upon operating environment.

Demagnetization, weak output signals, and magnetostriction are all neatly sidestepped by using a magnetic memory element with a closed flux path. Such an element in its rest position has no demagnetizing field—practically all the magnetism is contained within the material. In the Univac memory, the size of the element is limited more by spacing of word lines than by considerations of magnetic interference on the wire. The element can be made small enough without either making the film so thin that the signal nearly vanishes or raising the coercive force to the point where magnetostriction becomes a problem. The film can be made thick enough to produce a generous output signal.

Small is swift

Thick films, however, do not mean big elements. The volume of the magnetic material in a typical plated-wire memory element is approximately 2.5×10^{-8} cubic inches—about two orders of magnitude smaller than a ferrite core with an outer diameter of 0.03 inch and an inner diameter of 0.018 inch. The small volume and fast switching speed of the magnetic material reduces the required switching energy to approximately 0.5×10^{-9} joules—only 6% to 7% of that required for the ferrite core.

One of Univac's 100,000-bit memories runs continuously at 100 kilohertz in a serial mode on only 0.3 watt.[2,3] A memory containing 8,192 words of 32 bits each, operating continuously at a 50-khz word rate—32 bits every two microseconds—would dissipate an estimated 4 watts while reading and 10 watts while writing. The magnetic material's speedy switching and small volume reduce the operating power to less than half that required for a ferrite core memory of comparable size. Low power consumption permits substantial economies in the cooling and packaging of the circuits in industrial applications and reduces semiconductor

Plated wires vs. planar thin films

Category	Planar film	Plated wire organized for low cost
Capacity, characters	16,384	16,384
Bits per character	9	9
Bit drivers	9	9
Diodes in selection matrix	16,384	1,024
Transistor switches in selection matrix	512	80
Low-level switches	0	144
Additional gates	640	90

junction temperatures in the memory drive and sense circuits. Many aerospace applications place a premium on low power consumption because available power is severely limited.

Curie temperature is between 500°C and 600°C (the temperature above which the material will not remain magnetized in the absence of an external field). Typical ferrite cores have Curie temperatures of 150°C to 250°C. So the plated wire is much less temperature sensitive than cores.

Time and density

Bit packing density—typically 16 to 22 bits per inch of wire—is affected by magnetic properties and the spread of the word drive field beyond the edges of the word drive strap. Magnetic flux, and hence the amplitude and duration of the output signal pulse, is proportional to the length of the bit, the film thickness, and the magnetization density of the film. Packing the bits more densely reduces the signal output, but by using shorter rise times on the word drive field the signal can be restored to almost any desired peak value. Nondestructive readout signals of 100 millivolts peak and 15 nanoseconds duration have been achieved experimentally.

Element switching time is also directly related to the rise time of the magnetic drive field, as is the case with planar films. Thus, switching time is comparable. In the Univac 9300 computer, the memory cycle is 600 nanoseconds. Of this, element switching takes about 60 nanoseconds. Under different drive conditions, the elements can be made to switch in 15 nanoseconds or less.

Sense line length is determined by output signal delay and attenuation characteristics, and the digital system's cycle time.

The longest sense lines in the high-speed memories of Univac's 9000 series are about 8 feet, including interconnections. Signal delay is approximately 2 nsec per foot. The total sense line consists of several segments of plated wires, connected in series.

The length of the segments is chosen primarily for economy. Wire manufacturing yield is influenced by the length of wire segment and the nature and source of bad spots. Bad spots that occur appear to be primarily related to substrate imperfections. The memories currently in use, as shown on page 108, have four 18-inch segments and three joints in each sense line. Manufacturing yield is high when this length is used.

Plating the wire

The plated-wire elements are well suited to low-cost automated manufacturing. Treated as a continuous substrate, the wire is moved at constant speed through a series of electroplating baths and a testing station (bottom, page 105).

The substrate is a beryllium-copper wire 0.005 inch in diameter (standard 36-gauge). Beryllium copper was chosen because it's stiffer than plain copper and easier to process. Since it serves as the bit-sense winding in the memory stack, the substrate must have relatively good conductivity and be nonmagnetic.

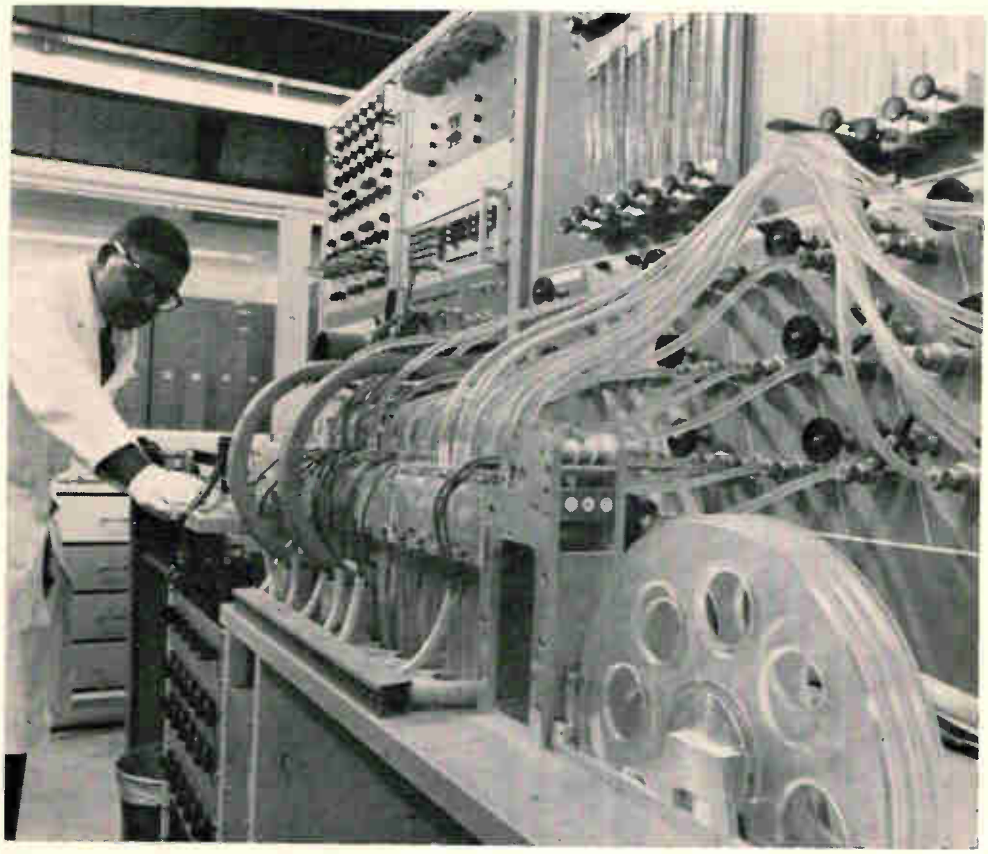
The wire is pushed through the plating and testing apparatus at several inches per minute by pinch rollers at the first processing stage. A pure copper film is first plated on the substrate, and then the nickel-iron magnetic film is deposited on the copper. The molecular properties of the drawn wire's surface would adversely affect the properties of the magnetic film if it were deposited directly on it. Plating the magnetic film on copper film permits better control of the interface than if it were plated directly on the wire.

The nickel-iron plating is done in a circumferential magnetic field of 24 oersteds that establishes the direction of the easy axis. This field is created by an electric current in the wire as it is being

Cores vs. thin films

	Magnesium-manganese-ferrite core (standard)		Lithium-ferrite core (mil-spec)		Univac thin film plated wire	Typical planar thin films
	0.023 in. O.D.	0.030 in. O.D.	.023 in O.D.	0.030 in. O.D.		
Switching time, nsec	240	420	285	580	≤15	≤10
Approximate switching energy, joules	5.7×10^{-9}	7.6×10^{-9}	9.7×10^{-9}	18.1×10^{-9}	0.5×10^{-9}	0.1×10^{-9}
Curie temperature °C.	150° to 200°	150° to 200°	≈400°	≈400°	≈500°	≈500°
Drive current compensation for constant output	−0.36%/°C	−0.48%/°C	−0.16%/°C	−0.11%/°C	−0.07%/°C	−0.07%/°C
Peak output, millivolts	35	38	41	50	10	1–2

O.D.=Outside diameter



Apparatus for plating wire is capable of plating three strands at once —as indicated by the three holes at the entrance to the first cell. The supply reel is in the foreground and the cutting and testing station at the far end.

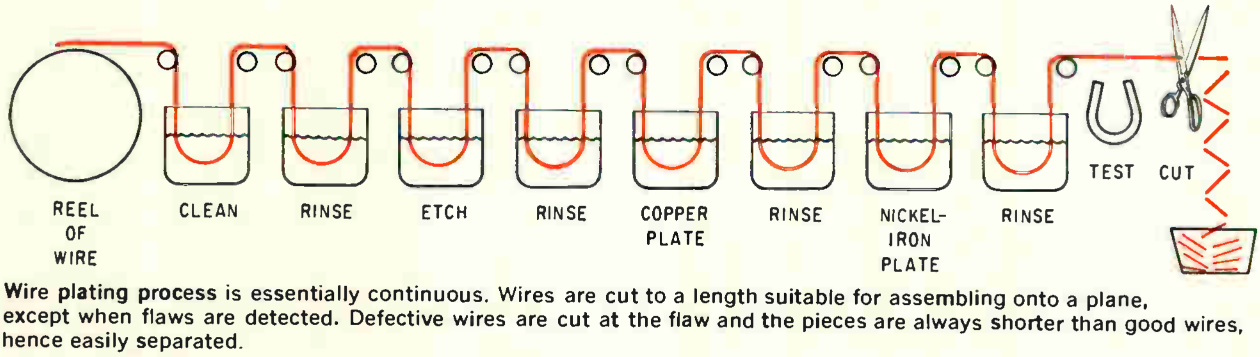
plated. Electrical contact with the wire is made at the supply reel and at mercury contacts following the last rinse. Fluid contacts provide a common ground for the plating cells, and assures that the substrate is not stretched or twisted during the nickel-iron plating. The nickel-iron material, although nominally nonmagnetostrictive, may posses a small residual degree of magnetostriction. If torsion or tension were present during the plating, the film's magnetic properties would be affected.

The plating anodes are platinum; the copper and the nickel-iron are present in the plating solution. This arrangement, together with regulated constant-current power supplies, prevents interaction between the plating cells. Thus, the plating process can be operated continuously 24 hours a day more easily than if the anodes provided the plating material and the solution were passive. The anodes would be used up in the latter case, but the solution can be continually replenished.

Immediate on-line automatic testing of the finished memory element helps in increasing the yield and in keeping the costs down. The plated wire is continuously fed through a test station that measures three major parameters related to coercive force, constant of anisotropy, and saturation ease. The test station also makes a final worst-case test of the wire's ability to store 1's and 0's in adjacent positions and to generate readout pulses from these positions without crosstalk or other disturbances. This testing occurs within one minute of the time the element was plated, thus enabling rapid monitoring and adjustment of the process. In addition to automatically cutting out defective spots, the tester cuts nondefective wire into 18-inch lengths. The distance from the supply reel to the automatic testing and cutting station is 38 inches.

Memory system design

The design of the Univac 9000 memory system is optimized for lowest cost consistent with the performance requirements. Like all magnetic film



Wire plating process is essentially continuous. Wires are cut to a length suitable for assembling onto a plane, except when flaws are detected. Defective wires are cut at the flaw and the pieces are always shorter than good wires, hence easily separated.

memories, it has a linear-select organization—sometimes called two-dimensional. The decoded address selects a single word line in this organization, and one or more words appear on sense lines at right angles to the word line.[4]

But the Univac memory has a 9-by-16 matrix of low-level switches that connect each of nine sense amplifiers to any one of 16 sense-bit lines. The matrix also connects each of nine bit-current drivers to any one of the same 16 lines. Bit-current drivers are used when writing new data in the memory.

The matrix consists of 144 switches between the sense amplifiers and bit drivers on one side and the plated wire on the other. Each switch routes the proper signals from the plated wires to the sense amplifiers, and routes the bit currents from the bit drivers to the proper wires.

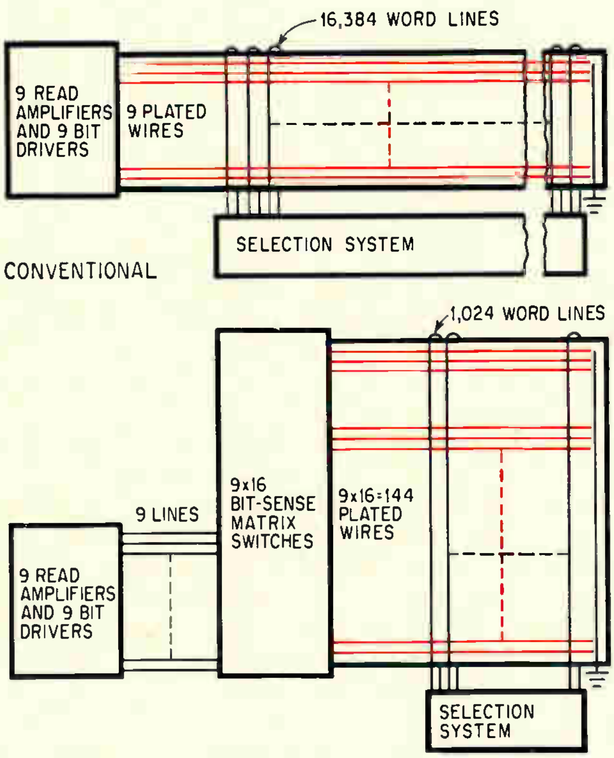
When a word is to be read from the store, several words—in the Univac memory, 16 words of nine bits each—generate sense signals. Each sense amplifier—for each bit of the word—is connected to one of the 16 possible bits by the matrix of low-level switches. The connections are determined by the decoded address. Thus, only sense signals from the desired wire are amplified at the memory-processor interface as data. The other 15 words that generated sense signals are ignored. Since the readout is nondestructive, ignoring these signals does not affect the stored data.

Similarly, when new information is to be written into a single word, the word drive line, or strap, selects 16 words, in any of which the bit-write current could change the stored information. But the matrix connects each bit driver to a sense-bit line. Thus only one word is written with new information.

This operation is possible only if the word-current amplitude required for writing is no larger than the word current used for nondestructive readout. Sixteen word positions are prepared for writing by energizing one word strap but only one word is written. The current amplitude in the word drive strap is the same as that used in nondestructive readout so that the information stored in the 15 unwritten positions is not affected in any way.

This organization has a much higher address decoding efficiency than most other magnetic film memories; it approaches that of three-dimensional or coincident-current ferrite-core memories. Ferrite-core memories that approach the 600 nsec cycle time of the Univac memory use 2-D or 2½-D memory stacks, and sometimes store data with two cores per bit. But the NDRO plated-wire memory offers higher speed at lower cost than ferrite cores.

Future versions of the memory can be expected to have cycle times from two to five times faster. Speed can be increased by designing the computer system to use a read cycle shorter than the write cycle. These very-high-speed main memories will have capacities of up to a million bits.



Switching matrix permits any nine of 144 wires to be connected either to sense amplifiers or to bit drivers. The arrangement is much more economical than the conventional method of using only as many bit lines as there are bits to be read at once. The saving in the selection system more than compensates for the cost of the switching matrix.

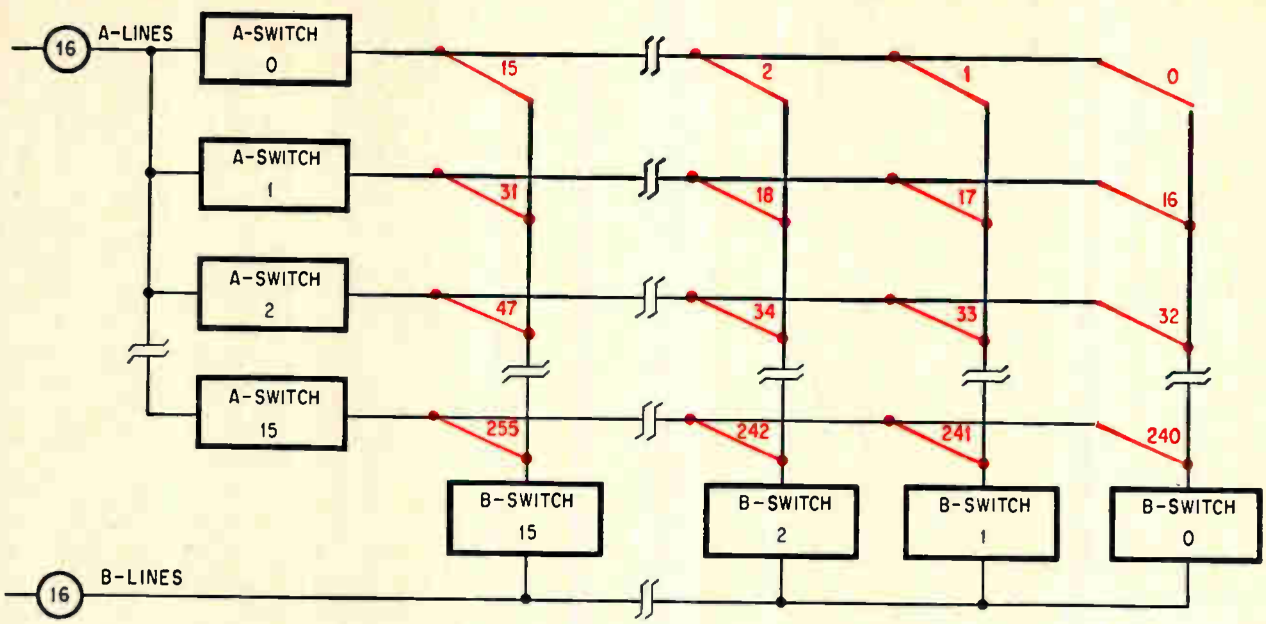
Minimizing the wiring

The bit-sense switch matrix makes possible a highly efficient and economical method for reducing the number of word lines. The diagram at the left compares a conventional 2-D design with the modified word-selection system of the same capacity which uses the bit-sense matrix.

Each sense-amplifier, bit-driver combination is associated with 16 plated wires, one of which is selected by the matrix. The switches reduce the length of the bit-sense line in the array by a factor of 16, thus making large arrays practical. The switch accommodates a bipolar bit current of approximately 40 milliamperes and sense signals of a few millivolts without contributing significant noise.

This memory organization is possible only with an element having NDRO characteristics for both reading and writing. Its economy lies in the fact that a single switch element controls selection for both sense- and bit-drive functions, thereby requiring an array with a common wire for both functions.

The complete memory array is arranged on four planes as in the diagram on page 108. Each plane contains 144 plated wires which intersect 256 one-turn word straps, numbered 0 through 255; the 144 bits under each word strap make up 16 words. Each plane stores 144 × 256 = 36,864 bits or 16 × 256 = 4,096 words. Each word line is in series



Sixteen A-switches and 16 B-switches provide a matrix that selects one of 256 word lines, shown in color. Each word line forms a one-turn solenoid around a group of 144 plated wires containing 16 nine-bit words. Four planes with four sets of B-switches and a common set of A-switches make up the complete plated-wire memory.

with a diode, and all the word lines are arranged electrically into a matrix, as in most 2-D memories. Each plane has 16 A-selection lines and 16 B-selection lines. As shown in the diagram above, a proper choice of one A-line and one B-line permits the selection of any one word line out of the set of 256. Currents in the word lines are unidirectional.

Back-to-back planes

Physically, two planes are mounted onto a single base plate, one on each side. On each two-plane assembly, one set of 16 A-lines serves both sides; but each side has its own set of 16 B-lines.

In the complete array of four planes, the two sets of 16 A-lines are driven by separate sets of switches having identical inputs. That is, the corresponding A-line is selected on all four planes simultaneously.

To select an individual word line in the plated-wire memory, four of 14 bits in the address are decoded to select one of 16 A-switches, and six more bits select one of 64 B-switches. Every A-switch is connected to all 64 B-switches through the word lines. Since only one of each type of switch is turned on, only one of 1,024 word lines is selected. The word line loops around 144 plated wires in the memory plane. The remaining four bits in the address select one of 16 groups of wires, with nine wires in each group, connecting them to nine sense amplifiers and nine bit drivers.

Really big memories

The potential for very low cost makes the plated wire appear attractive for modular random-access memory stacks ranging upwards of 2 million characters. A memory system of eight to 16 of these modular memory stacks could provide simultaneous access to eight or more characters in 1 to 2 microseconds. Such capability appears feasible in the near future at a very attractive cost.

An 8-million-bit module has been built in essentially the same way as two of the 36,864-bit planes. Each word line selects 32 words of 64 bits each. Each of the 32 sense-digit lines served by one sense amplifier and bit driver link each of the 4,096 word lines, as diagramed on page 109.

A different arrangement of the switch matrix would permit readout of words of variable lengths, from one to 2,048 bits. In the Univac 9000 series, the memories always read or store nine bits out of a possible 144 in any cycle, and the only choice is which nine. In the large module every cycle transfers 64 bits out of a possible 2,048, the choice being which 64. A sufficiently complex addressing and decoding scheme would make it possible to read or store any number of bits, from one to 2,048.

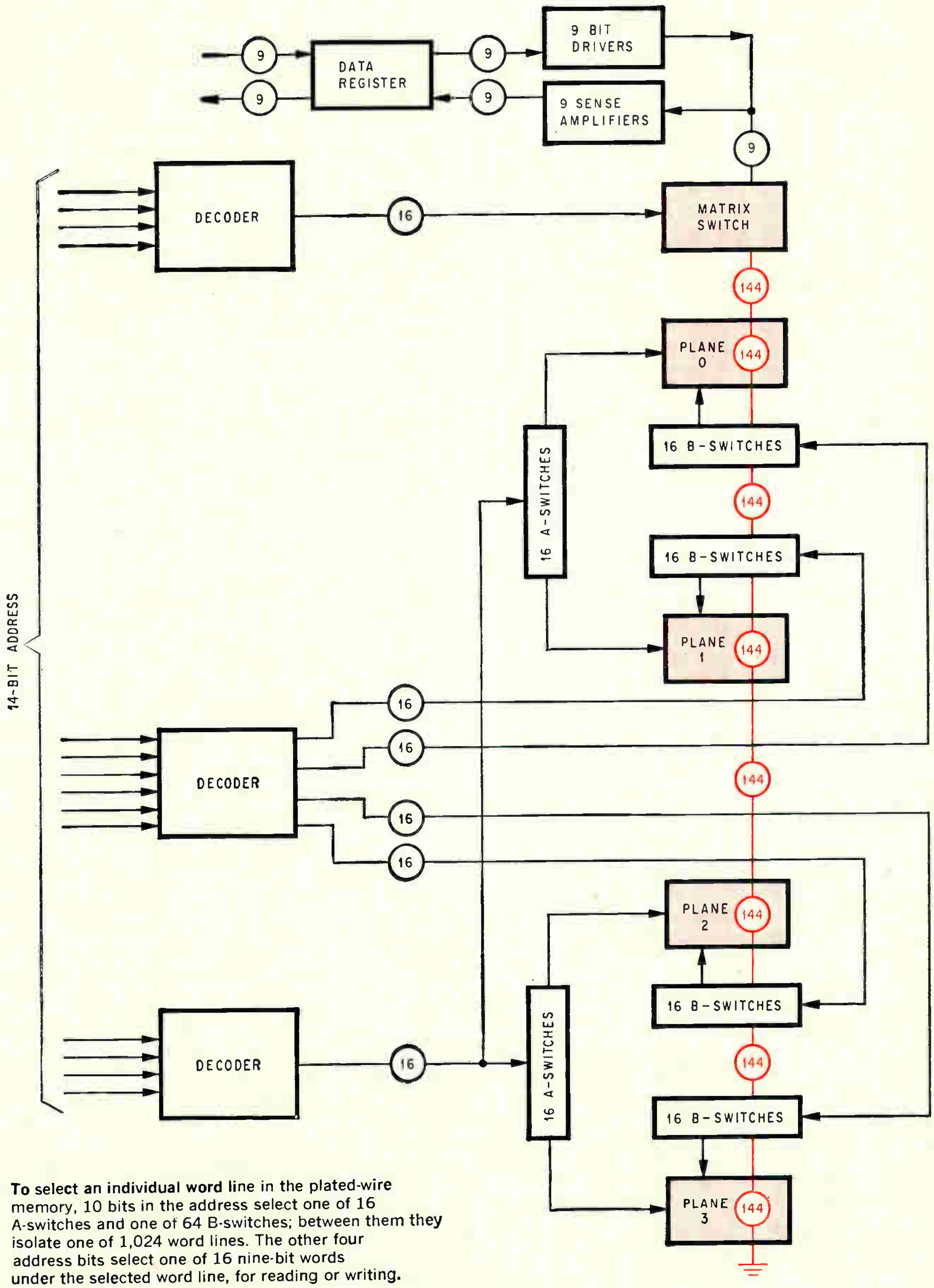
Twelve of the 8-megabit modules could store 100 million bits of data and share input and output circuits, power supplies, and part of the address decoding. Such a memory system could be packaged in an estimated 40 cubic feet for commercial applications; or it could be squeezed into considerably less space if necessary. It would dissipate about 400 watts of power in most cases, but this, too, could be reduced.

Buffers and converters

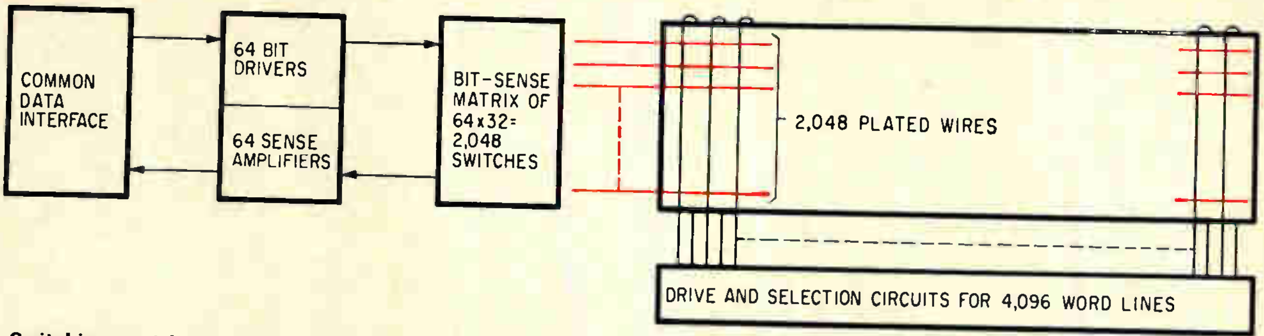
The low level of switching energy required by the plated-wire memory element makes it attractive for applications—in satellites, for instance—where electrical power is limited. The plated-wire memory organization can readily be adapted for buffer memories or serial-to-parallel conversion of data.

As a buffer memory, even simultaneous writing

A low-cost memory organization



To select an individual word line in the plated-wire memory, 10 bits in the address select one of 16 A-switches and one of 64 B-switches; between them they isolate one of 1,024 word lines. The other four address bits select one of 16 nine-bit words under the selected word line, for reading or writing.



Switching matrix can select economically any 64 bits in a module of 8,388,608 bits. Twelve such modules would make up a fast, economical 100-million-bit memory.

and reading is feasible if restricted to two of the words on a single word line. Otherwise the word line selection and driving circuits would have to be duplicated, giving two nearly independent memories.

Parallel-to-serial conversion could be neatly performed by a memory that has one sense amplifier, several bit drivers, and the associated switch matrix. This would provide parallel writing and serial reading. One bit driver and several sense amplifiers would enable serial-to-parallel conversion. An arrangement with equal numbers of sense amplifiers and bit drivers would allow conversion in either direction. A serial input-output memory has been designed[2] in which the data is converted to parallel form before writing into the memory and converted to serial form after readout from the memory to minimize power consumption. The conversion takes place in a flip-flop register and not in the memory.

Read-only memories

Another potential application is read-only memories where content must be altered occasionally. Plated-wire read-only memories should be economical for storage capacities of more than 50,000 bits. Integrated semiconductor memories of this size are not likely to be cost competitive. Read-only memories are used in applications for which the permanence of data is very important.

Neither intentional nor accidental power shutdown affects information stored in a plated-wire memory. Restarting a data handling system following accidental power interruption is far simpler if data in the read-only memory is known to be intact. The plated-wire memory can be made card changeable in several ways. These use the plated wire to detect the presence or absence of an element.[5] In another method, the contents of such a memory may be changed electronically. An example would be the use of one machine to emulate several others—that is, to run programs written specifically for other machines—where programs or data might be interchanged. Electronic alteration is possible by writing in the normal mode when the plated wire is used as a random-access main memory. Special precautions could be taken to prevent accidental altering of stored information due to system malfunction or simple operator error.

Other attractive applications for both NDRO and DRO plated-wire memories are in aerospace guidance, control, and data processing. The NDRO mode stores programs and constants while the DRO mode is used in registers and scratchpads—small, fast memories for temporary storage. A single NDRO plated-wire memory can efficiently perform all these functions. It has a further advantage in that within the total capacity of the memory the portions allocated to the various tasks can be changed as the mission changes. This capability allows a single design to serve many purposes.

Other wires in the plating bath

Univac is not alone in believing plated-wire memories to be a significant new memory technology. Honeywell Inc. is also investigating the technique. France's Compagnie Bull-General Electric used a plated-wire memory bought from Japan's Toko Inc. in the recently discontinued Gamma 140 and 141 computers. National Cash Register Co. has what it calls a rod memory in its NCR 315 machine and claims the technology is the same as for the plated wire. However, NCR's approach is significantly different from Univac's, principally in that the easy axis of magnetization is parallel to the axis of the rod, so that the flux path is open.

General Precision Inc.'s Librascope Group manufactures a plated-wire memory for specialized military applications. Basically, it operates the same as Univac's, but the word lines are insulated copper wires into which the plated wires are woven on a loom in such a way that the finished product resembles a piece of window screen.

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Settling on the moon

Four-beam radar system that guided Surveyor 3 to the moon will also furnish the velocity and range data to land the Apollo lunar module

By Charles J. Badewitz
Ryan Aeronautical Co., San Diego, Calif.

A landing radar that proved its capability by guiding Surveyor 3 to its landing on the moon last month also will provide the data needed to land the first manned Apollo lunar module (LM) on the surface of the moon.

As the two-man LM descends toward the moon's surface at about 60 miles per hour, its landing radar will be switched on at an altitude of 50,000 feet. About three minutes later and 10,000 feet nearer, the radar will begin to make continuous range measurements, and at 25,000 feet it will begin computing the velocity of the module. The range and velocity data will be processed along with auxiliary data from other sensors and the results fed to the landing control system to insure a soft and safe landing. Once the spacecraft lands, the radar's work is completed and it remains on the surface of the moon as part of the lunar module's descent stage.

The landing radar uses a three-beam doppler velocity sensor and a single-beam alitmeter to measure the spacecraft's velocity and range relative to the lunar surface.

The radar return signal in each of the velocity sensor's receiver beams is mixed with a portion of the transmitted signal. The output of the mixers are audio doppler frequencies that are proportional to the spacecraft's velocity components along the respective beams. Frequency data converters break down the doppler frequencies into velocity components in vertical, lateral, and longitudinal antenna directions and relate them to the spacecraft's coordinate system.

The radar altimeter's return signal is also mixed with a portion of the altimeter's transmitted pulse. This produces a frequency proportional to the spacecraft's height above the moon plus a frequency corresponding to the vehicle velocity along the altimeter beam. The latter is removed in the range data converters by utilizing the doppler signals in velocity beams 1 and 2.

After processing by the radar, the velocity and range data is sent to the lunar module's guidance computer in a serial binary form, and as pulse trains and d-c analog voltages to the astronauts' visual displays.

The landing radar's data will be combined with altitude and velocity signals from the space vehicle's inertial measuring unit. These data inputs are weighted by the spacecraft's height above the moon's surface, and programed to assure the guidance computer receives the most accurate input. Errors in the inertial system tend to increase with time. Landing radar errors, on the other hand, are determined primarily by velocity and altitude, therefore they decrease as the velocity and altitude decreases.

The initial effect of the radar data on the spacecraft's guidance system is small, and increases as the descent progresses. However, as the data from the landing radar is factored into the guidance computer, it reduces the effects of accumulated errors in the inertial unit; thus the landing radar updates the inertial measuring unit.

Integrated Antenna

The four radar beams are generated by two planar arrays on the single integrated antenna assembly pictured on page 113. The groups of alternate slotted waveguides in the large center section

The author

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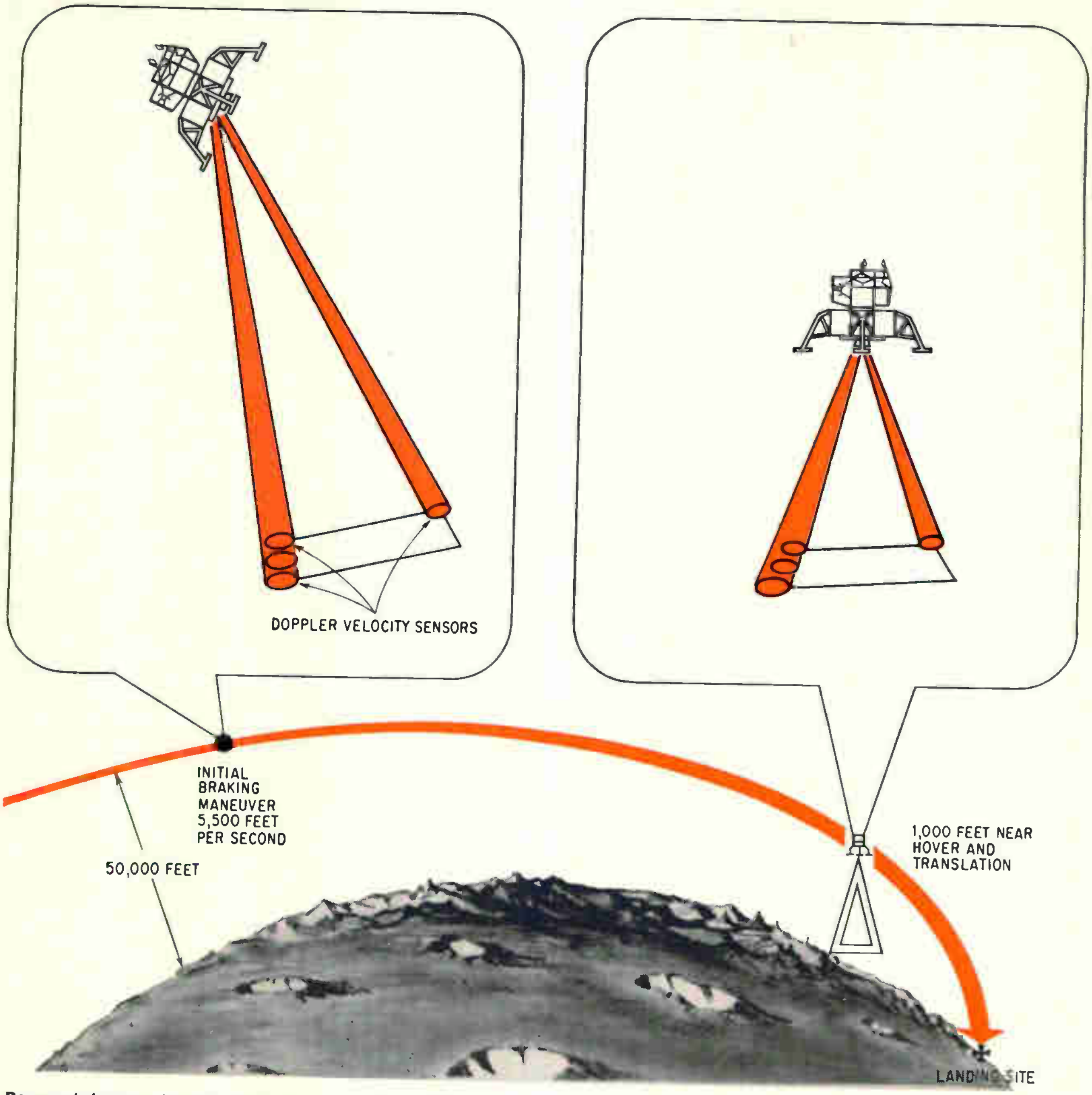


Powered descent begins when lunar module's altitude is about 50,000 feet. Throughout the tilt maneuver, the four radar beams are kept pointing at the lunar surface automatically by the guidance computer. The repositioning is accomplished by rotating the antenna of the landing radar around the Y axis into either of two positions.

are the transmitting antennas; the receiver antennas are the outrigger sections around it. The E-plane slotted guides in the center section transmit the altimeter frequency-modulated continuous wave; and the alternate H-plane slots transmit a c-w velocity sensing signal.

The three narrow beams from the velocity sensor antenna emanate from the planar array in the same manner as legs are extended to form a tripod.

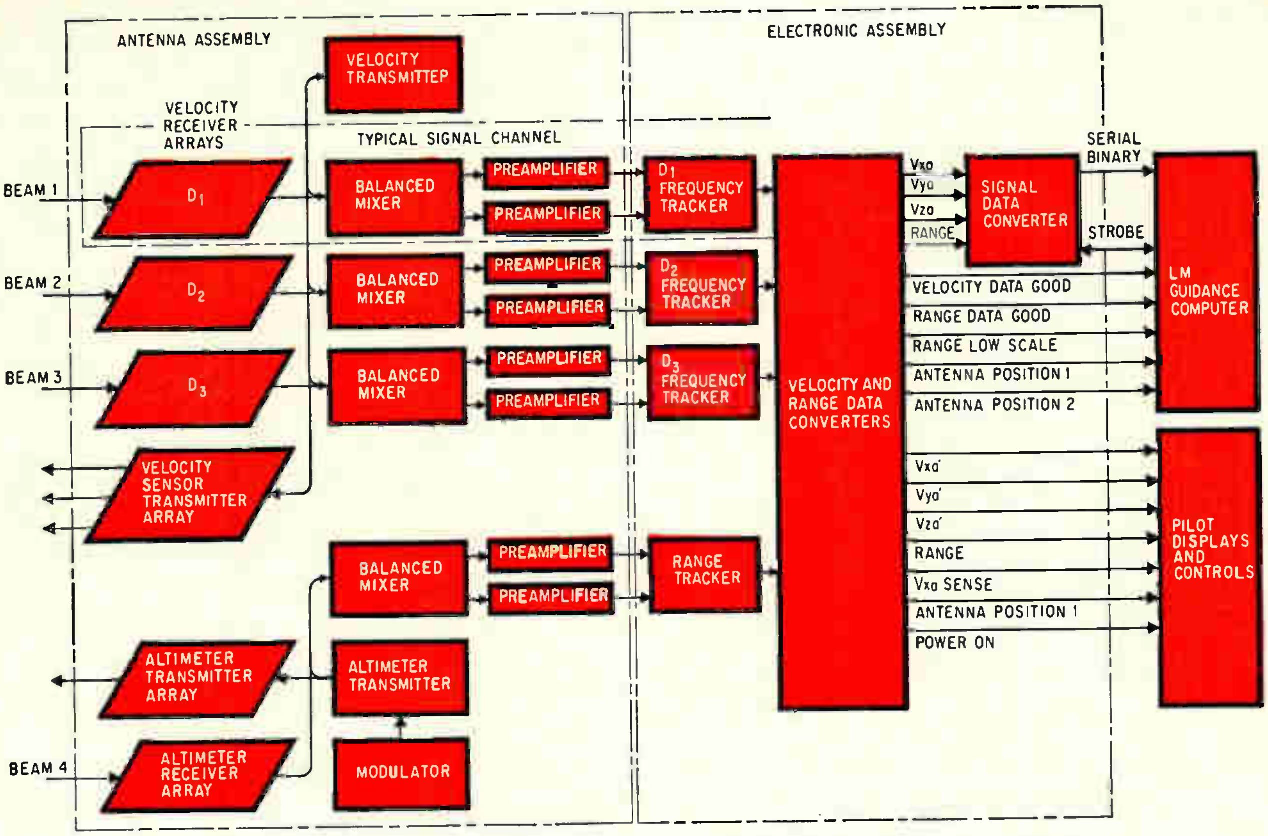
The attitudes of the beams during the initial braking and hover maneuvers are illustrated by the drawing shown above. The multiple beams are generated at fixed angles relative to a line drawn perpendicular to the face of the planar array. The outrigger receiving arrays, which have the same slot orientation as the velocity transmitter array, are the three broadside arrays. Their geometries make each receiving beam axis colinear with the corresponding transmitted beam axis.

The altimeter's receiving array is boresighted so that coincidence of its main lobe with the altimeter transmitter's main lobe is achieved, yielding in turn the desired two-way pattern for the altimeter.

Perpendicular beams

The antenna is mounted on a rotating pedestal on the underside of the spacecraft's descent stage. The antenna can be rotated about the spacecraft's Y axis, into either of two positions, automatically by the guidance computer, or manually by the pilot as the craft's attitude changes. This keeps the radar beams as nearly perpendicular to the lunar surface as possible.

The diagram on page 114 details the basic op-



Lunar module's landing radar combines transmitter velocity and altimeter signals with the signals in return beams to produce doppler frequencies proportional to the spacecraft's velocity and range from the moon. Data converters break down the doppler signals into velocity components in the X, Y, and Z direction. These are input signals for the module's guidance computer.

eration of the radar's velocity sensors. The beam angles and the energy pattern shown are for beam 1, but the patterns and angles for the other two velocity beams are similar.

Two orthogonal sets of velocity components are measured in the coordinate system of the antenna. The V_{xa}, V_{ya}, and V_{za} components are shown on page 114, where V_{xa} coincides with the center line of three velocity sensor beams and V_{ya} lies in the plane of velocity sensor beams 1 and 2. The coordinate system for V_{xa}', V_{ya}' and V_{za}' velocity components is rotated about the V_{ya} axis through an angle, ζ, to cause V_{xa}' to lie in the plane of beams 1 and 2. The primed velocity components are used only for the pilot's visual displays.

To determine velocity, the radar return signal is mixed with a portion of the transmitted signal. This is a process of direct radio-frequency to audio-frequency conversion which produces doppler frequencies proportional to the component of the spacecraft's velocity along the beam of concern. These frequencies, D_1, D_2, and D_3, are combined to produce the orthogonal velocity components such as V_{xa}, V_{ya}, and V_{za}.

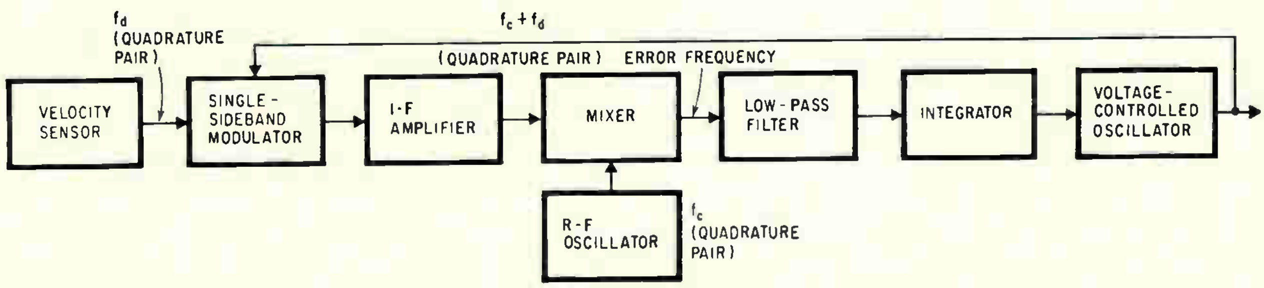
For example, the component of velocity relative to the antenna axis, V_{xa}, is computed as follows:

$$V_{xa} = -\frac{\lambda}{2\cos\Lambda\cos\xi}\,\frac{(D_1 + D_3)}{2} \qquad (1)$$

Where:

λ = electromagnetic radiation wavelength
Λ = beam 1 antenna angle
ξ = beam 3 antenna angle
D_1 = doppler shift along beam 1
D_3 = doppler shift along beam 3

The following equation computes the range to the lunar surface. The $K(D_1 + D_2)$ term is the cor-



LM's frequency tracker is a closed loop servosystem that processes sensor and reference signals.

rection factor which compensates for doppler shift in the range beam.

$$R = \frac{c}{2S} [f_a - K (D_1 + D_2)] \qquad (2)$$

where

R = range to the lunar surface
c = speed of light
S = altimeter's transmitter frequency deviation rate
f_a = altimeter's received frequency, including range and doppler components
K = scaling constant
D_2 = doppler shift along beam 2

The radar antenna assembly divides each doppler signal in quadrature pairs. The beam's quadrature outputs are amplified and used as input signals to the frequency trackers in the electronic assembly. Then recombination of the quadrature pairs and single sideband comparison techniques in the frequency trackers validate the signals and measure magnitude and sense of velocity.

The radar's receiver uses narrow-band filter circuits (labeled frequency trackers in the block diagram) to detect doppler signals, and to separate the true doppler signal from noise background.

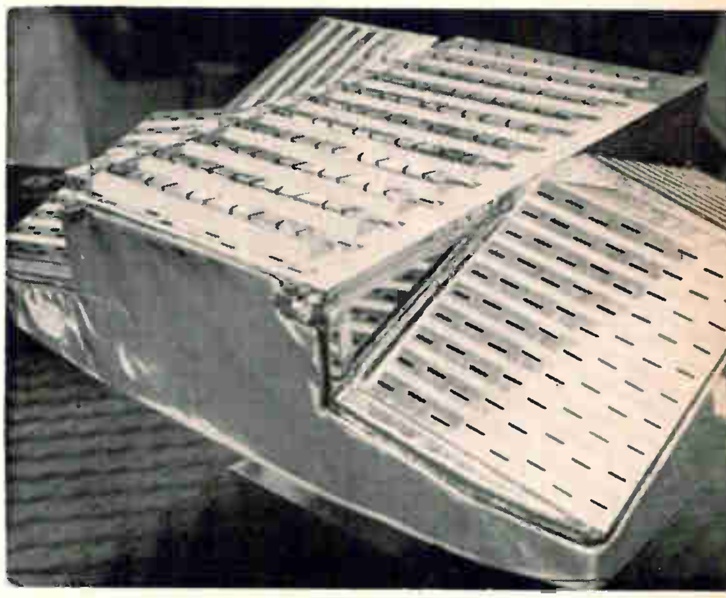
The operation of the frequency trackers is traced by the block diagram below, left. The tracker is basically a closed loop servosystem whose inputs are the doppler quadrature pair, f_d, from the radar velocity sensor, and another pair called the carrier quadrature pair, f_c, from a fixed r-f oscillator.

The input circuit of the frequency tracker is a single sideband modulator which accepts the doppler quadrature pair input and another feedback quadrature pair, approximately equal to $f_c + f_d$, from a voltage-controlled oscillator. The single sideband modulator output is amplified by an intermediate-frequency amplifier and mixed with the f_c quadrature pair in a second mixer.

The output of that mixer is the error frequency of the tracking loop. This signal is filtered, integrated, and used to drive the voltage-controlled oscillator. The oscillator's output is applied to the frequency converters and also fed back and used as a carrier frequency for the single-sideband modulator. Under tracking conditions, the output of the single sideband modulator is very nearly the same as the carrier frequency f_c.

Once the true doppler signal is acquired, it is tracked with a high order of accuracy, about 0.1%, and the tracker output frequency is almost the same as the center frequency in the received doppler signal band.

Each beam's frequency tracker sends a doppler signal to the velocity and range data converters along with a d-c step voltage that indicates acquisition and authentication of a true lunar return signal. The converters then translate the doppler signals into orthogonal velocity sets in the coordinate system of the antenna. The guidance computer uses this data to steer the lunar module. Equation



Landing radar antenna is covered with special thermal finish to protect it against extreme temperatures in space. The center section contains the altimeter and velocity sensor transmitting antennas. The outrigger antennas at either side of the center section are for the receivers.

Radar system characteristics

Type of system	
velocity sensor	c-w, 3-beam
radar altimeter	f-m/c-w
Altitude capability	
velocity	5 to 25,000 feet
altimeter	10 to 40,000 feet
Velocity capability	V_{xa} −2,000 to +500/fps.
	V_{ya} −500 to +500/fps.
	V_{za} −500 to +3,000/fps.
Altimeter antenna	
type	planar array
gain	50.4 db
beamwidth	3.9° E plane
	7.5° H plane
Velocity sensor antenna	
type	planar array
gain	49.2 db
beamwidth	3.7° E plane
	7.3° H plane
Transmitters	
type	solid state
frequency	
velocity sensor	10.51 Ghz
radar altimeter	9.58 Ghz
Output power	
velocity sensor	200 mw min. (50 mw per beam)
altimeter	175 mw min.
Altimeter	
modulation	sawtooth f-m
frequency	130 hz
deviations	208 Mhz and 42 Mhz
Response time	
25,000 feet	0.1 sec

Why did Surveyor 3 bounce?

When Surveyor 3 hopped and skipped on the moon last month, many people were concerned that the same thing could happen to the Apollo lunar module when it reaches the moon's surface. If it does happen, it probably won't be the fault of the landing radar. Apollo will use an updated version of the radar system aboard Surveyor 3. The landing radar will only indicate the range to the lunar surface during the last seconds of flight; the actual landing will be made by the astronauts.

What really happened to Surveyor 3? The scientists at the Jet Propulsion Laboratory at Pasadena, who control the Surveyor program haven't made known the results of their investigation into the cause—but one can speculate.

During a normal Surveyor descent, the spacecraft slows to about five feet per second at 100 miles altitude. At this point, the craft becomes practically weightless because the moon's gravitational pull is 1/6 the force of the earth's, and the Surveyor's retrorockets are thrusting in the opposite direction to the pull. All the while, the spaceship's guidance computer is receiving velocity and range signals from the landing radar. As the craft passes the 14 foot mark, the radar generates a range mark which the Surveyor's control system uses to cut off the engine. Surveyor then falls free the remaining distance to the moon.

A landing with the engines still burning is actually a softer landing than normal — because of the weightlessness. But the spacecraft would come down, touch, bounce, and touch again, and continue to do so until the ship's momentum is dissipated in the bounces.

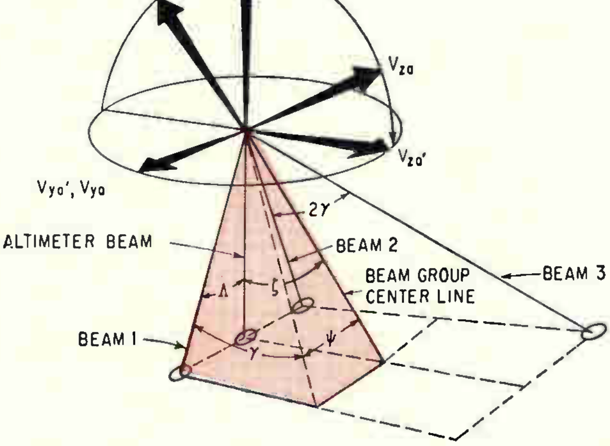
Ryan Aeronautical Co. engineers tend to disclaim early theories that the radar caused the engine cutoff failure by sending confusing signals to the guidance computer. If one of the three velocity sensing beams were pointed down to a hole, it may have generated some contradictory data concerning the Surveyor's velocity across the lunar surface. However, the engine cutoff is made by a signal generated by a fourth beam—the altimeter—and if this beam was pointing down a hole the spaceship would have thought it had farther to go.

Once before at the test station at Holloman Air Force Base, New Mexico, the Surveyor's engines didn't cut off and it bounced. No damage was done to the spacecraft or any of the instruments on board. That time the scientists said it was the fault of the spaceship's instrumentation, not the radar. In the case of Surveyor 3, Ryan engineers think the same thing may have happened.

W.J.E.

1 shows how the sum of the doppler signals from beam 1 and beam 3 are multiplied by a constant coefficient (which is a function of the beam angles) to yield V_{xa}. V_{ya} and V_{za} and the range are obtained in a similar manner.

The measurement of range is accomplished in an analogous manner, the only difference being that some compensation for the doppler shift along the range beam is required. This is provided in the velocity and range data converters by summing the doppler frequencies in beams 1 and 2, scaling the summation, and subtracting the result from the doppler frequency in the altimeter return signal.



Radar velocity sensor's beam 1 geometry is typical of the landing radar's four beam patterns.

The measured range and the velocities are held ready in the radar's signal data converters for readout when requested by the guidance computer. The computer samples the velocity and range data sequentially in a cycle that repeats every 80 milliseconds.

Spurious signal rejection

The basic task of the frequency trackers is to detect relative motion between the vehicle and the lunar surface. However certain physical objects on the lunar module, such as hold-down belts that come loose when the LM and the command and service module separate, may be in the radar beam and moving—thus causing spurious signals. To avoid acquisition and tracking of these signals, unique circuitry has been incorporated into frequency trackers to examine all signals during the search mode and reject all except the true doppler return signal.

The logic used in rejecting spurious signals is based upon recognizing that returns from the vibrating physical elements contain double sidebands. True doppler signals have just one sideband. The technique that is used to discriminate against spurious signals is simply one of examining the signal level in the positions of both sidebands. The tracking filter examines the level in one sideband; and a noise-sampling filter examines the level in the other. A comparison is made and if the signal-to-noise ratio exceeds a prescribed value, the acquisition circuitry allows the frequency tracker to track the signal.

Digital tester okays Apollo's altimeter

Specially designed test set counts frequency and averages it over the pulse period to measure slope and linearity accurately

By V.M. Andreone and J.H. Poirier

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Before it leaves the earth, the radar that will guide the Apollo lunar module to a safe touchdown on the moon's surface will be checked out with equipment that has no precedent or peer.

Like most of the electronic hardware aboard the lunar module, the radar altimeter has some extraordinary test requirements. In almost every subassembly, the Ryan Aeronautical Co. engineers encountered test problems that could not be solved with existing equipment.

For example, the frequency modulator, the heart of the radar altimeter that makes continuous measurements of the spacecraft's distance from the lunar surface, required gear with a measurement accuracy 10 times better than the tightest modulator tolerance. And the equipment must determine inaccuracy in an altimeter that will operate at 25 times the height (50,000 feet) and twice the frequency (X band, 5.2 to 10.9 Ghz) of conventional airborne pulse radar altimeters.

Since no commercial test equipment could meet specifications, Ryan engineers developed their own digital test set. Made with off-the-shelf integrated circuits, it samples the modulator's radio-frequency output and counts the changes in the output frequency as a function of time. By averaging the frequency changes, the r-f wave's sweep rate or slope is determined as well as the r-f pulse's linearity and upsweep and downsweep times.

The digital averaging measurement technique can also be used to plot any periodic frequency-modulated signal as a function of time, provided that the pulse time period is greater than the test equipment's 700-microsecond sampling time.

Glossary of terms

Downsweep average slope, m:

The frequency deviation over the downsweep period divided by the downsweep period, T.

$$m = \frac{1}{T}\int_0^T \frac{df\,(t)\,dt}{dt} = \left(f_H - f_L\right)\frac{1}{T}$$

where f_H and f_L are the high and low limits of the modulated transmitted frequency.

Linearity, l:

The percentage deviation from the downsweep average slope, m, of the measured average slope for any 10% portion of the total downsweep period.

$$l = \left[\left(\frac{df}{dt}\right)^* - m\right]\frac{100}{m}$$

*average value over 10% segment of T

Downsweep/Upsweep ratio, a:

The ratio of the downsweep time period to the upsweep time period.

$$a = \frac{T}{t'}$$

Sweep cycle, t_s:

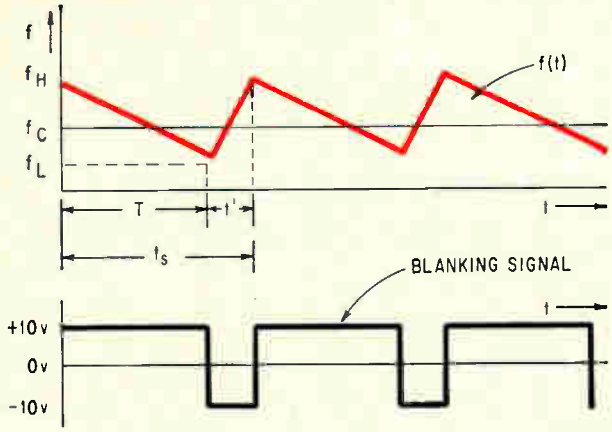
The time required to complete one downsweep and one upsweep cycle.

$$t_s = T + t'$$

Altimeter operation

The output frequency of the radar altimeter's modulator varies as a sawtooth function, shown on page 116, from a center frequency of 99.79 megahertz. Frequency multipliers raise the output to an X-band center frequency, which is transmitted to the lunar landing surface. The radar return signal is received, amplified, and the doppler frequency component extracted.

A portion of the downsweep section of the transmitted and return signal is sampled by the



Frequency of Apollo radar altimeter's modulator varies as a sawtooth function with a center frequency of 99.79 Mhz. A blanking pulse synchronized to the r-f wave is also produced. Frequencies f_H and f_L are the upper and lower band limits of the sawtooth; and T and t' are the downsweep and upsweep pulse periods.

altimeter's range processing circuitry, and the instantaneous frequency difference, Δf, between the two is determined. This frequency difference is related to the range between the spacecraft and the moon's surface by the equation

$$\Delta f = (f_T - f_R) = m\left(\frac{2R}{c}\right) \pm f_d \qquad (1)$$

Where

f_T = transmitted frequency
f_R = received frequency
R = range
f_d = doppler frequency
m = average sweep rate = rate of change of the transmitted frequency as a function of time
c = velocity of light.

The range is proportional to the difference in frequency between f_T and f_R and inversely proportional to m, the average sweep rate or slope. As equation 1 reveals, small variations in sweep rate have a large effect on range measurement. Specifically, a 1% error in average slope is reflected as a 2% error in range.

The altimeter's frequency modulator operates in three modes. In mode 1, there is a high deviation frequency. It is used when the spacecraft descends from an altitude of 2,500 feet to the lunar surface. In this mode, the output frequency varies from 99.998 Mhz to 99.582 Mhz, a deviation of ±208 khz.

A large frequency deviation is required for a more accurate range determination. The second mode is switched in when the spacecraft is at an altitude above 2,500 feet. In this mode, the frequency only deviates 41.6 khz. In both modes 1 and 2 the output waveforms are the same with equal sweep times. The third mode is called the deviation-inhibit mode. As the name implies, the output frequency is a constant, unmodulated 99.79 Mhz. Mode 3 is actually a built-in test mode for center frequency checks and is not utilized during flight.

In addition to the r-f output, the modulator also generates a blanking signal. This signal has the same time period as the downsweep portion of the r-f pulse; and is synchronized with the sweep function. The blanking signal is present only during operation in modes 1 and 2.

Tight test tolerances

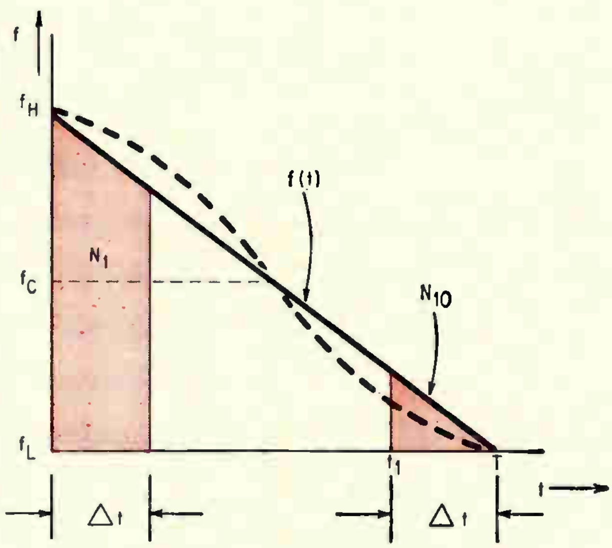
The downsweep average slope proved to be the most difficult modulator parameter to test. It must be measured within an accuracy of 0.05%, 10 times better than the slope tolerance itself. In the low deviation mode, the digital test set had to detect a change of 500 parts-per-million in a slope of approximately 12 megahertz per second. This is equivalent to a change in slope of 6,000 hertz per second. Therefore, over one sweep cycle, the maximum allowable frequency deviation is 42 hz.

Since linearity measurements are qualitively the same as the sweep slope measurement, the 5% linearity specification is easily implemented by whatever technique is chosen to detect changes in slope. Measuring center frequency within 0.05% accuracy is not a major problem since the absolute value of the center frequency is very large.

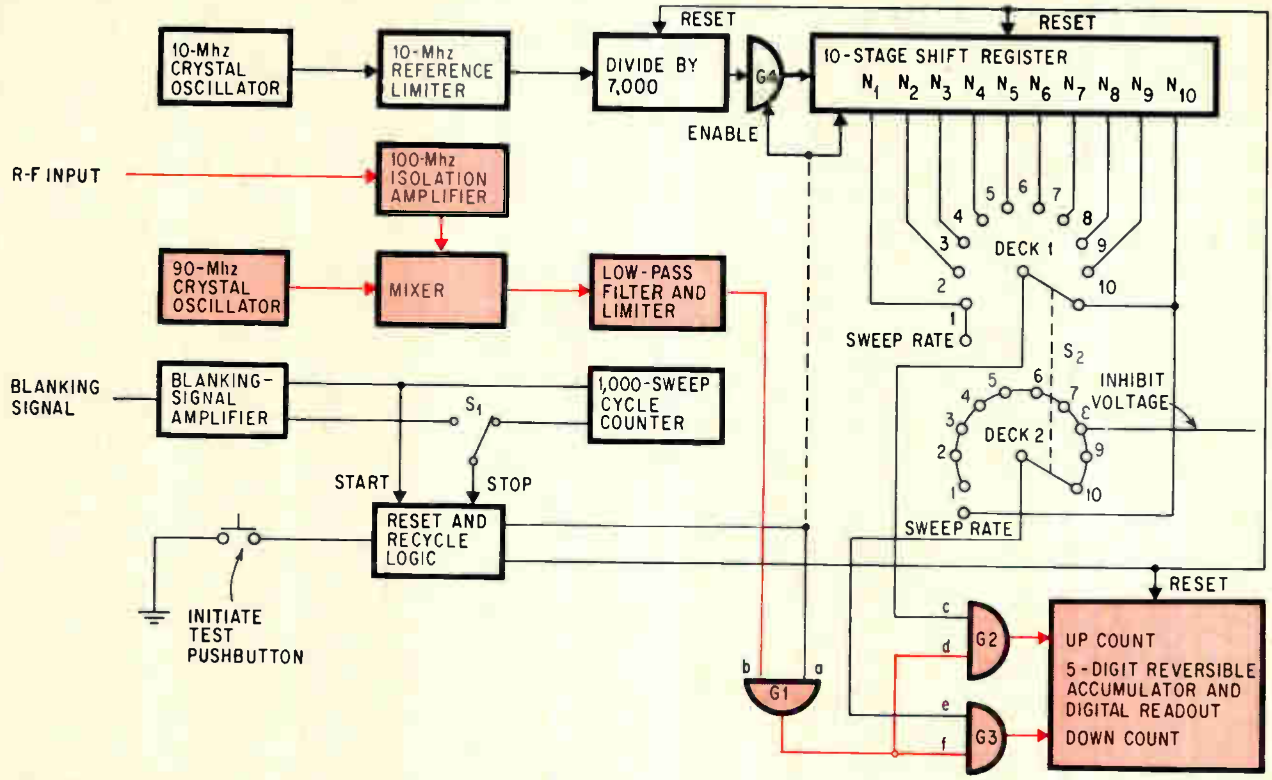
The test set measures the sweep slope by directly sampling the frequency modulators r-f output. The digital averaging technique is unaffected by center frequency fluctuations and more than meets the test's accuracy requirements. Linearity and center frequency error measurements result naturally from the slope measurement.

The quantity $\Delta N = N_1 - N_{10}$ is independent of center frequency. The larger the sampling intervals, the larger the value of ΔN for a given value of m; thus, the resolution improves as the sampling interval increases.

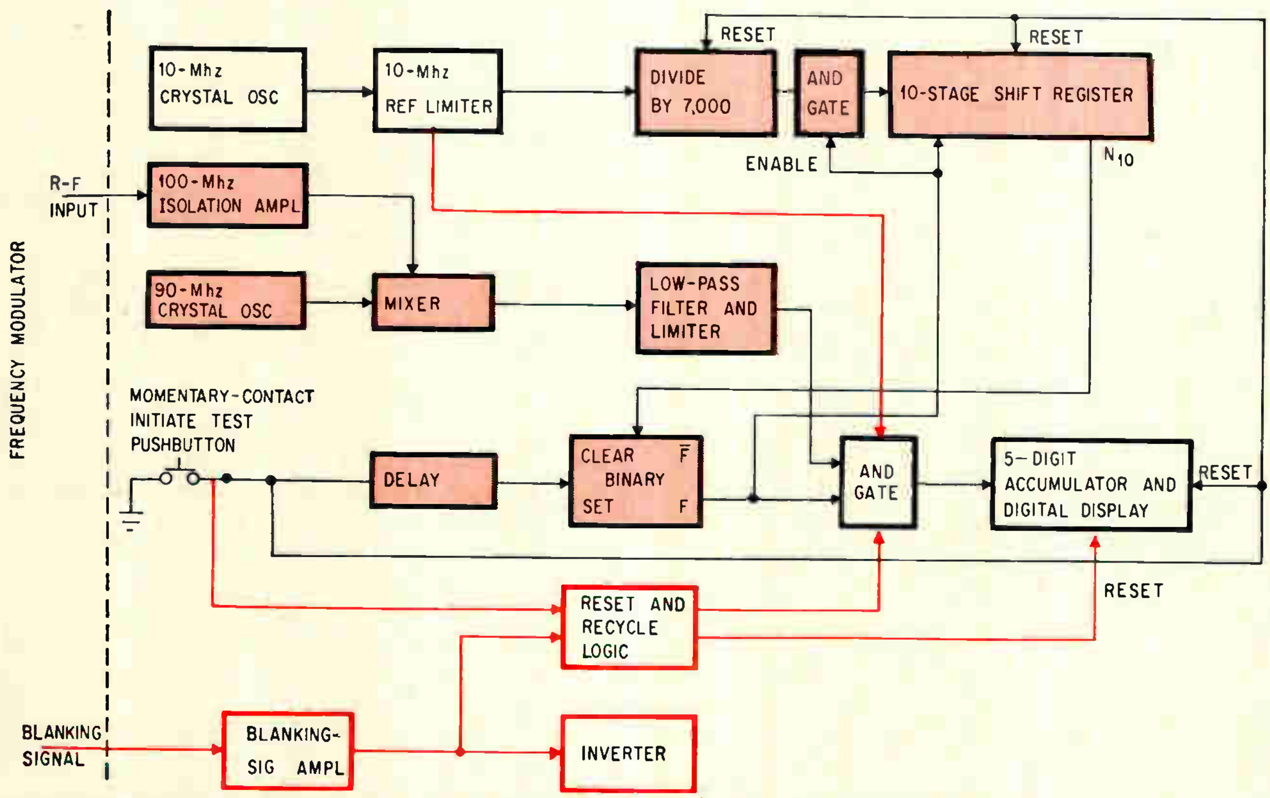
However, there is a tradeoff to be considered. As the sampling interval increases, the slope average is taken over a progressively smaller portion



Frequency modulator's average slope is represented by the solid line between f_H and f_L. Nonlinearities are depicted by the dashed inverted S-curve. The tinted areas are equivalent to the change in transmitter frequency during pulse sample intervals N_1 and N_{10}.



After mixing and filtering, modulator's r-f output passes through AND gates into the digital test set's count accumulator. Sweep rate (average slope) measurements are made by putting S_2 in the sweep rate position and averaging the transmitter frequency over one cycle. This determines the most significant digits. Averaging the frequency over 1,000 cycles determines the least significant digits.



Center frequency measurements are made by the test set's configuration, shown in tint. One microsecond after the test button is pressed, the binary circuit enables the AND gate and the accumulator counts r-f pulses until the end of the shift register's time interval, N_{10}. This count is proportional to the center frequency. To measure upsweep and downsweep time, the test set is switched to the configuration represented by the blocks outlined in solid color. The black-bordered blocks are used during both tests.

of the downsweep cycle. Furthermore, the longer the sampling interval, the greater the effect of nonlinearities on the measurement of average slope.

Linearity measurement

The worst-case nonlinearity in the frequency modulator output is ±5%. For a given nonlinearity, L, the percentage error, p, in the calculated slope for a given T/Δt ratio is:

$$p = L/[T/\Delta t] - 1$$

For these tests, a value of 10 was selected for T/Δt based upon the maximum allowable slope error in the modulator's output, the time allowed for averaging, and cost consideration in implementing the balance.

Digital averaging techniques are accurate if a sufficient number of sweep samples is used.

An error analysis by a Ryan Aeronautical Co. mathematician, Robert Golden, determined that averaging the results of four consecutive sets of 4,500 sweep-rate measurements, each in the low deviation mode, and each set having an inherent accuracy of 0.5%, yields a new accuracy of 0.025%. By averaging an error over a greater number of sweeps, accuracies within 0.01% can be achieved.

The test set also measures the modulator's center frequency drift to an accuracy of 0.0012%.

Pulse counters

The top diagram on page 117 demonstrates the mechanization of the sweep rate and linearity measurement system. The clock is a 10 Mhz oscillator whose output is divided to form a train of pulses, each 700 microseconds in length. The 700-μsec pulse period is the desired sampling interval. The pulse train is a source of shift pulses for a 10-stage shift register wired so that only one stage can contain a logical 1 at any time. A shift pulse advances that 1 from one stage to the next. As a result, lines N_1 through N_{10} will each carry a pulse consecutively, for a period of 700 μsec. With the downsweep portion of the blanking signal initiating this shifting sequence, the net result is to divide the downsweep period into 10 subperiods of 700 μsec.

The r-f input from the modulator is buffered by passing it through an isolation amplifier, and mixed with the output of a 90-Mhz crystal oscillator. The difference frequency is filtered and limited and made available for counting at intervals corresponding to the selected value of Δ N.

By means of switch S_1, the frequency over 1 or 1,000 sweep cycles can be averaged. A test over one sweep cycle determines the most significant digits of the measurement. A second run over 1,000 cycles defines the least significant digits.

The two-deck rotary switch S_2 performs the logic that enables the test set to distinguish between nonlinearity and sweep rate tests.

To measure sweep rate, switch S_2 is placed in the SWEEP RATE position. In this position, the signal on the wiper of the first deck is N_1. Also N_{10} is connected through the wiper on the second deck to input c of gate G_3. This permits the processed r-f signal to pass through to the accumulator during these intervals, for 1- or 1,000-sweep cycles, depending on the setting of S_1.

During the N_1 time interval, the r-f input drives the reversible accumulator in a positive direction; during the N_{10} interval, the accumulator is driven in the opposite direction . The result is Δ N, which is accumulated for 1 or 1,000 sweeps, and read out on the digital display.

When the rotary switch is in positions 1 through 9, the gate G_3 at the DOWN input of the accumulator is inhibited, and a measure of the frequency within the selected interval is obtained. The UP input is enabled during this interval, and as before, either 1 or 1,000 consecutive readings may be stored, and read out at the end of the test.

Finding f_c

In the lower diagram on page 117, the tinted sections show how the test system is configured to make mode 3 center frequency measurements. During this test, the blanking pulses are not used.

To make the test, the operator presses the initiate test pushbutton. This resets the divide-by -7,000 timing circuit, the 10-stage shift register, and the 5-digit accumulator, and after a 1-μsec delay, sets the binary logic circuit which enables the timing generator and the AND gate input to the accumulator. Processed r-f pulses from the mixer are passed by the AND gate into the accumulator. The trailing edge of the N_{10} interval pulse, which occurs 7,000 μsec after the start of delay, clears the binary and terminates the frequency count. The accumulator's digital readout then shows a count which is proportional to the modulator's center frequency.

The blocks outlined in solid color illustrate the test system's configuration when checking sweep times. For this test, the r-f input is removed and the blanking signal used. The clock signal is gated by the upsweep or downsweep portions of the blanking signal into the accumulator for one cycle. The resulting count of the clock frequency is proportional to the up- or downsweep period.

The authors

V.M. Andreone designs computers for data handling. Prior to joining the Ryan Aeronautical Co., he was a systems engineer developing central data processors for Apollo tracking ships. He earned his master's degree at the University of Pennsylvania.

J.H. Poirier is a design specialist at Ryan and assisted in the development of digital test equipment used to measure the accuracy of f-m space altimeters. Prior to joining Ryan, he was an instrumentation engineer at the Naval Electronics Laboratory.

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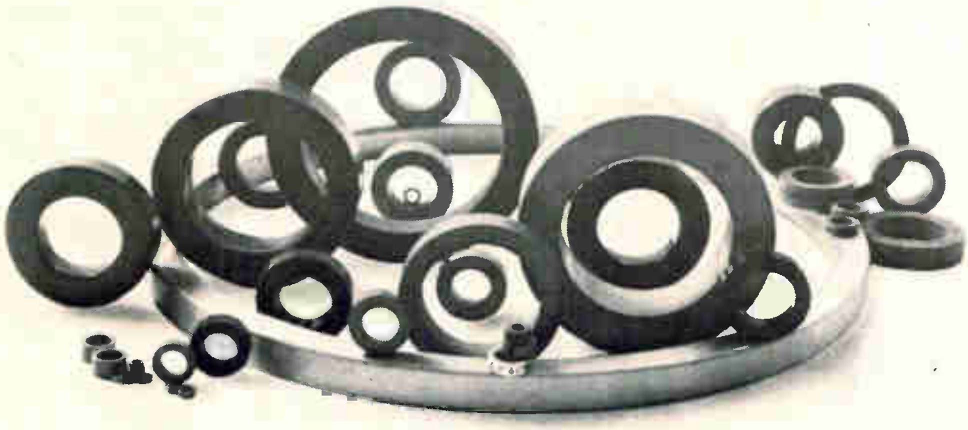

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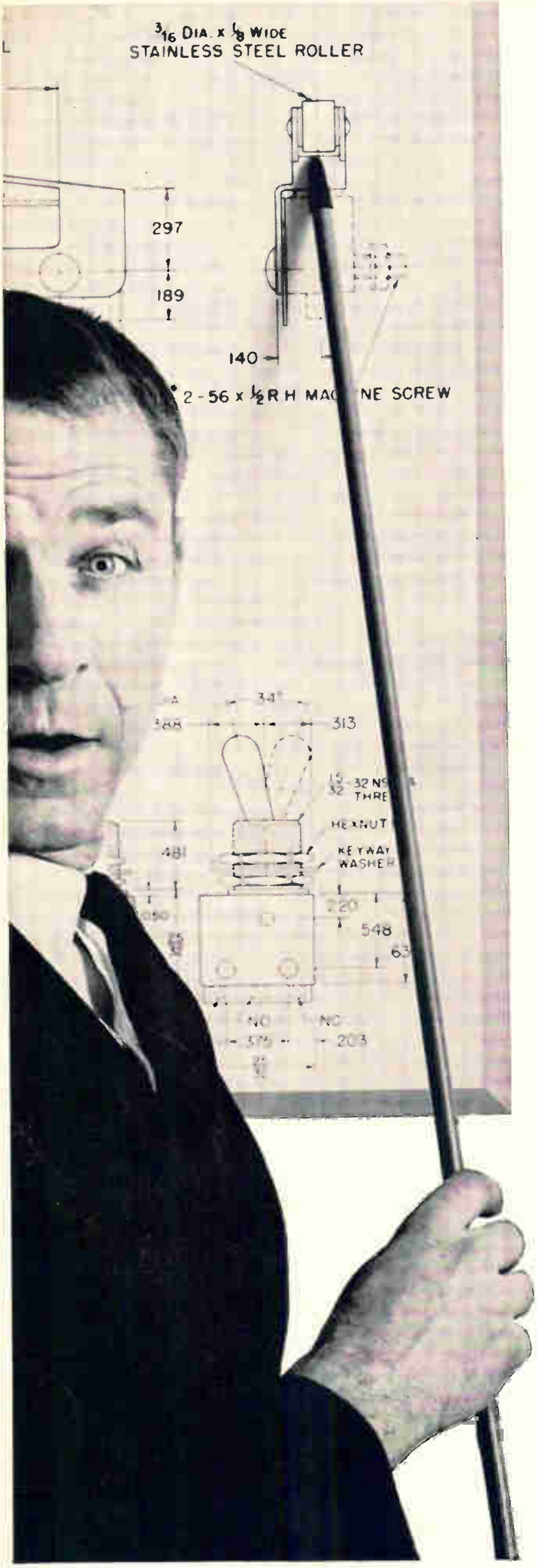

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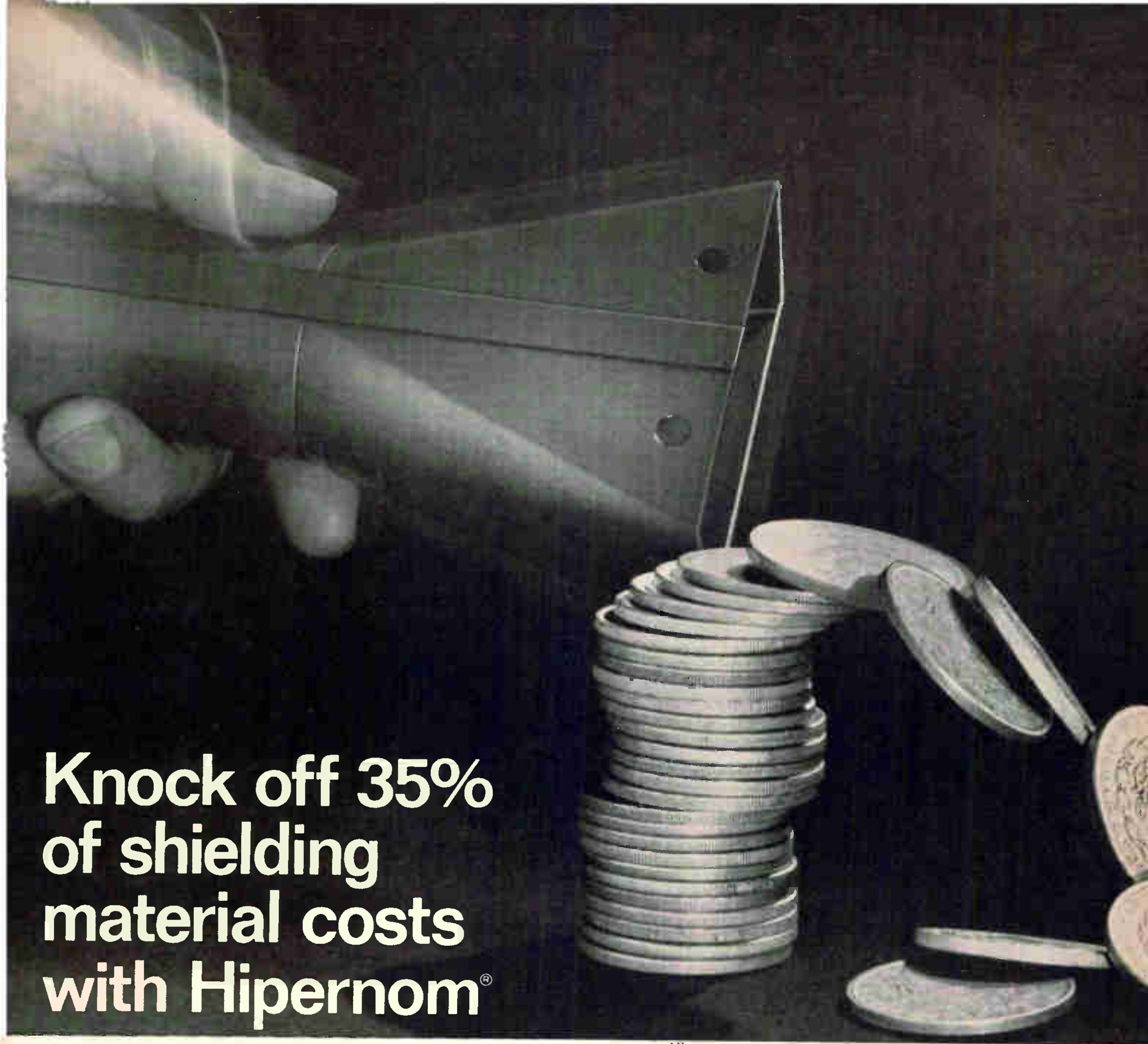

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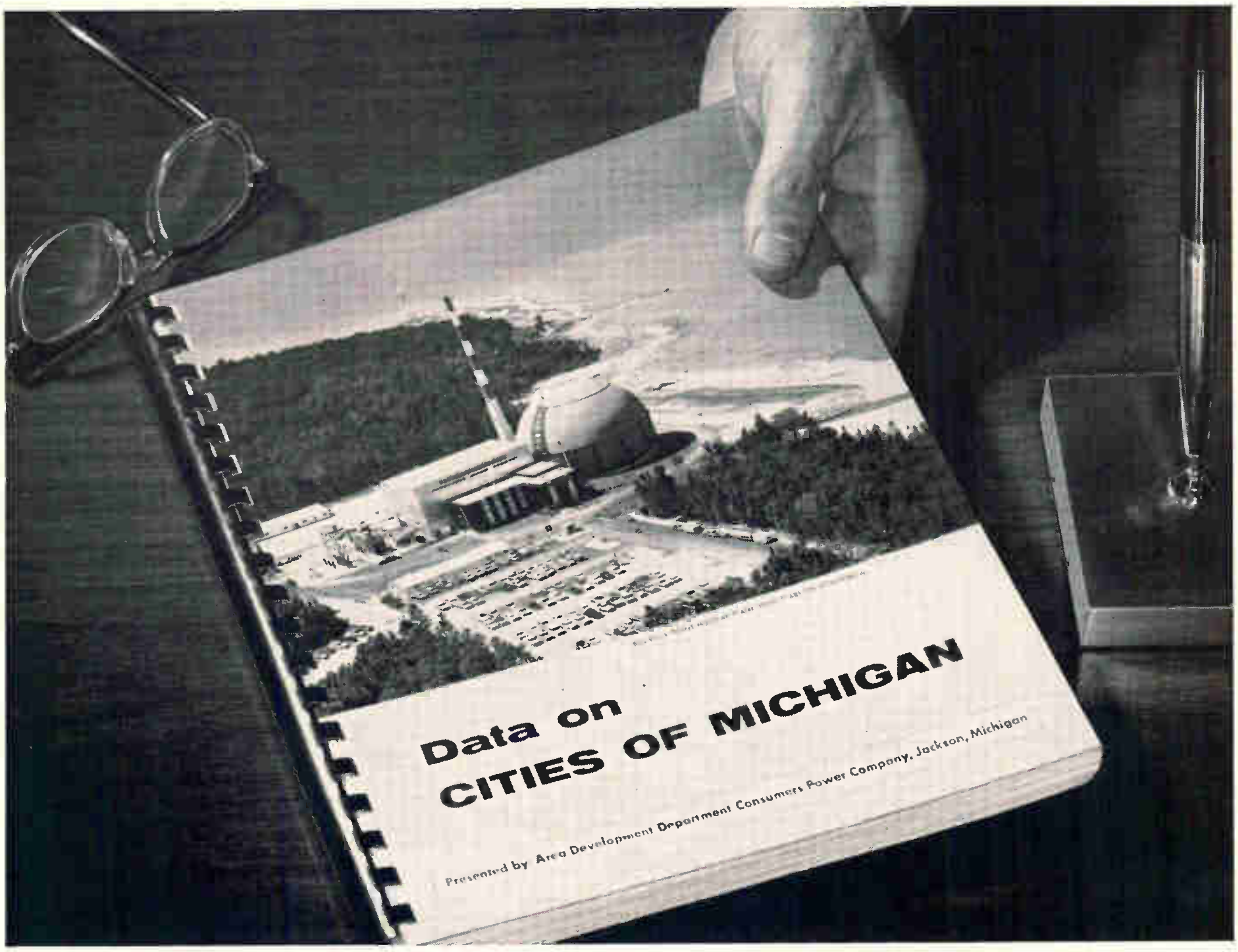

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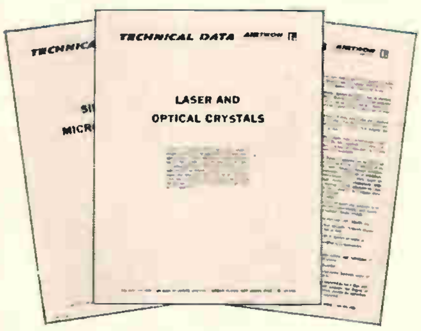

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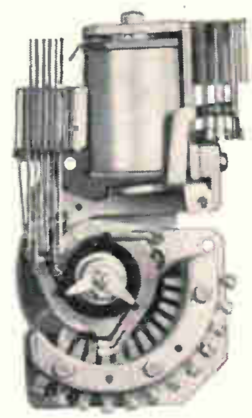

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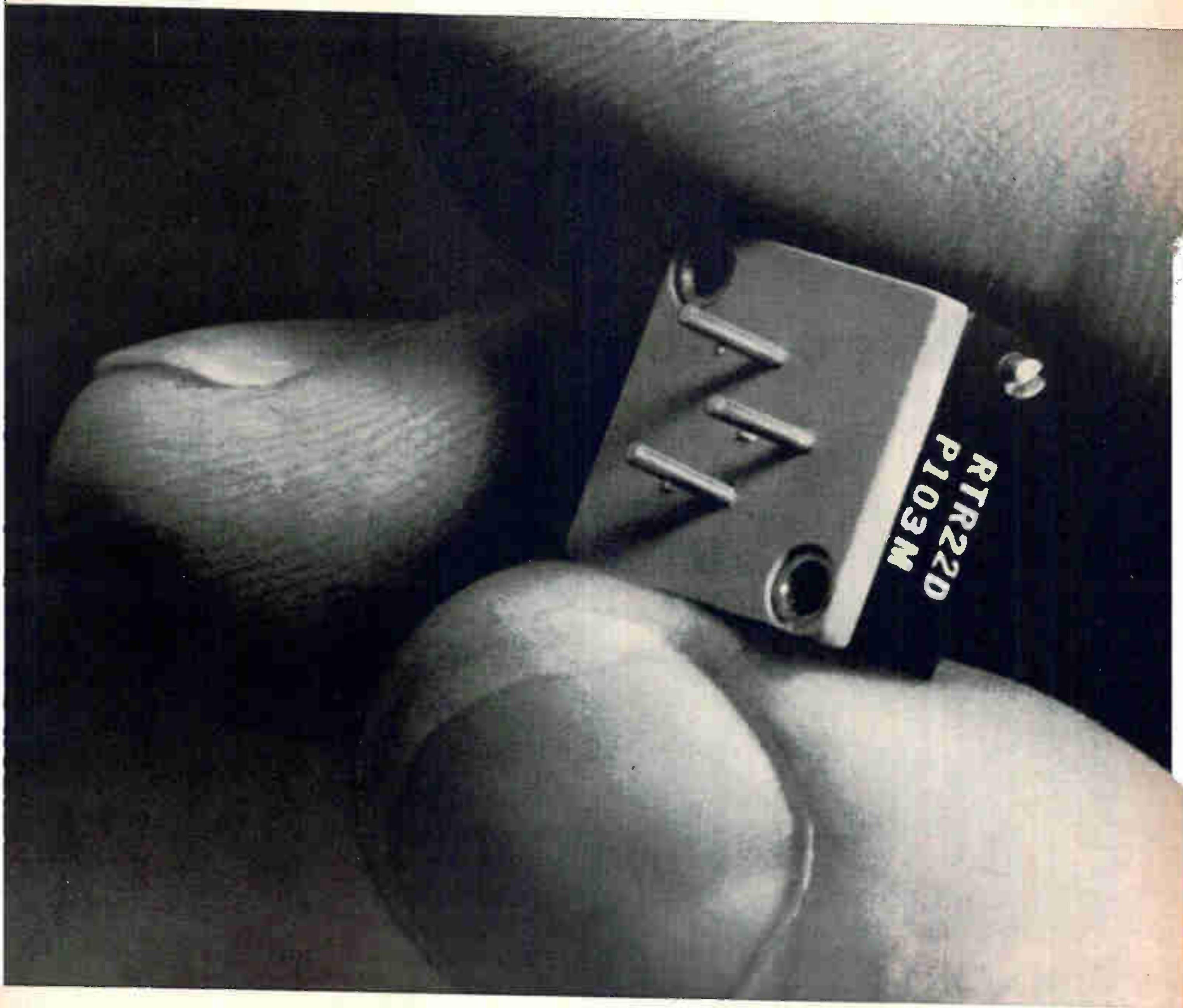

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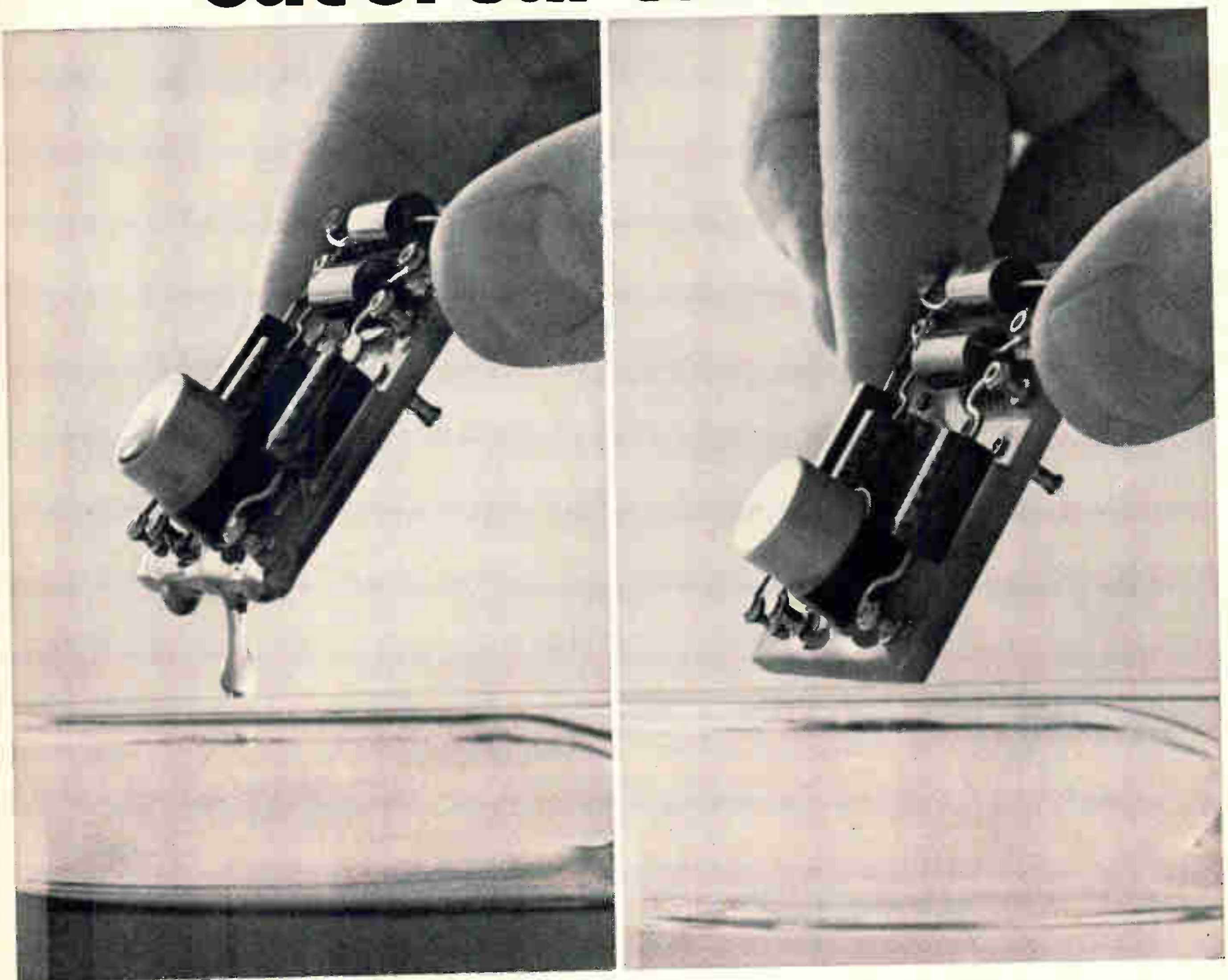

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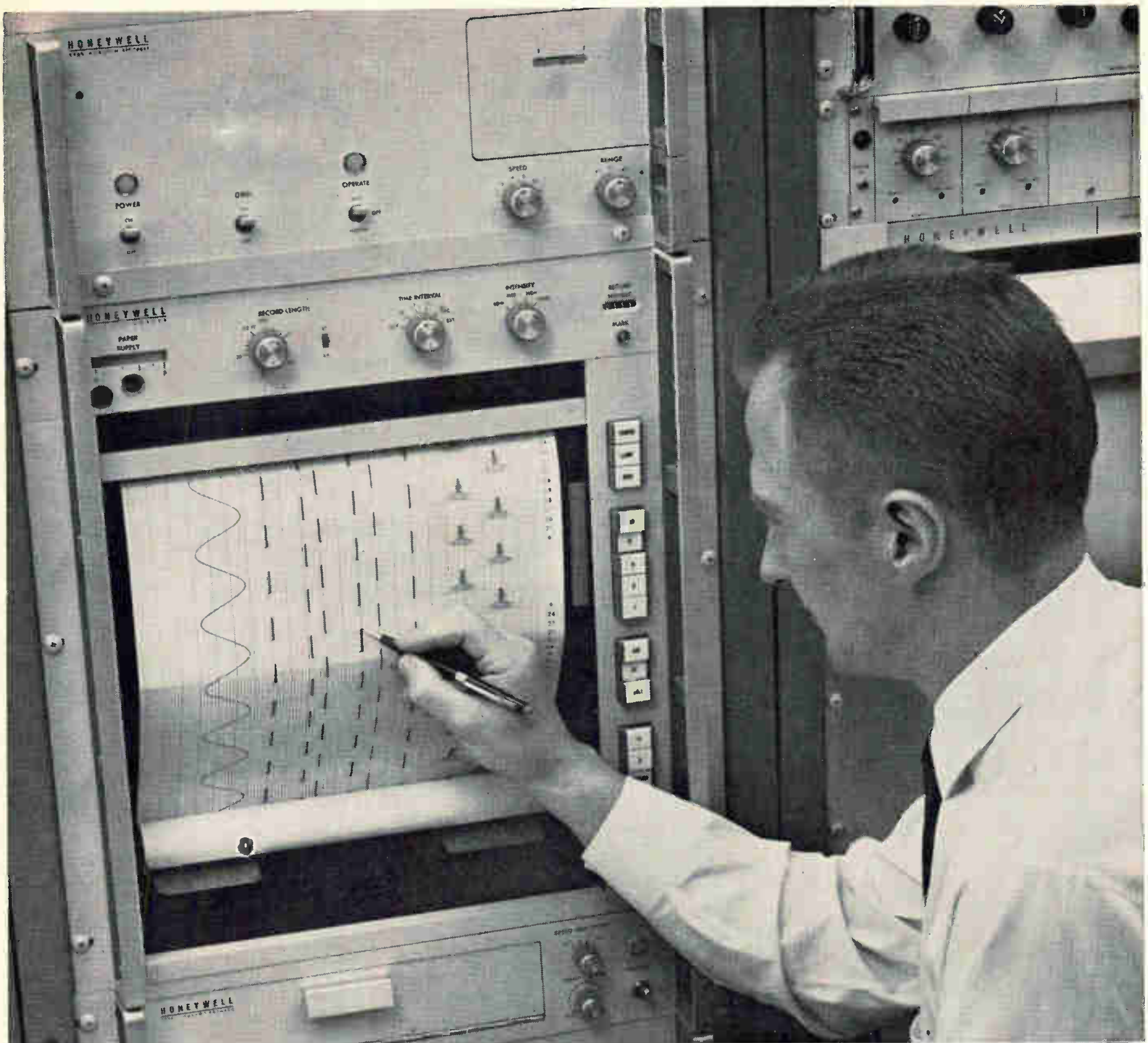

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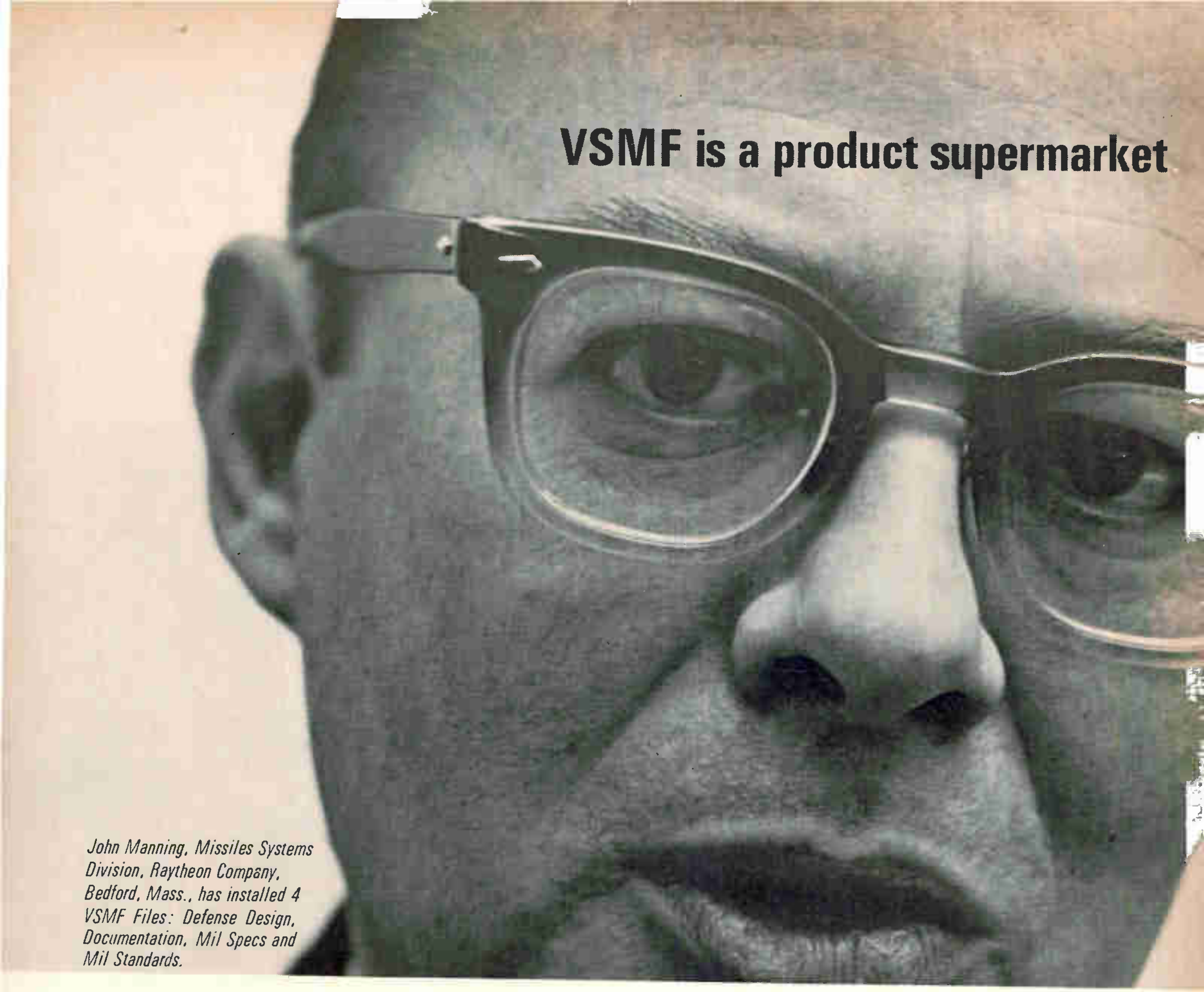

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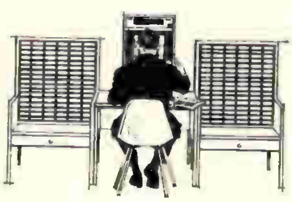

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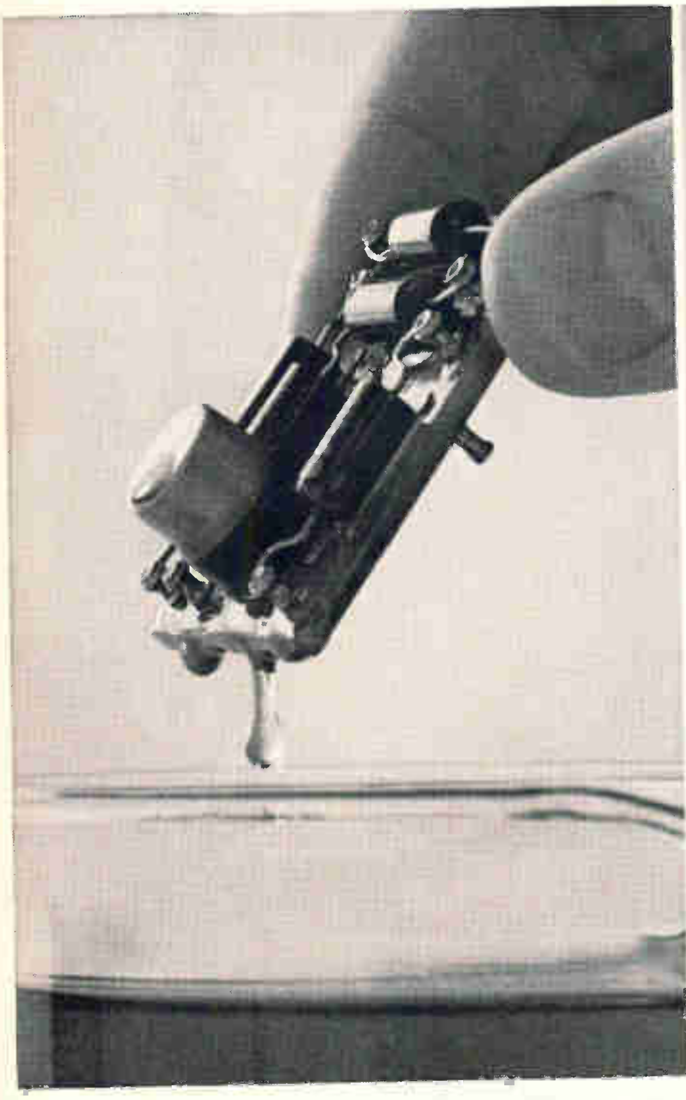

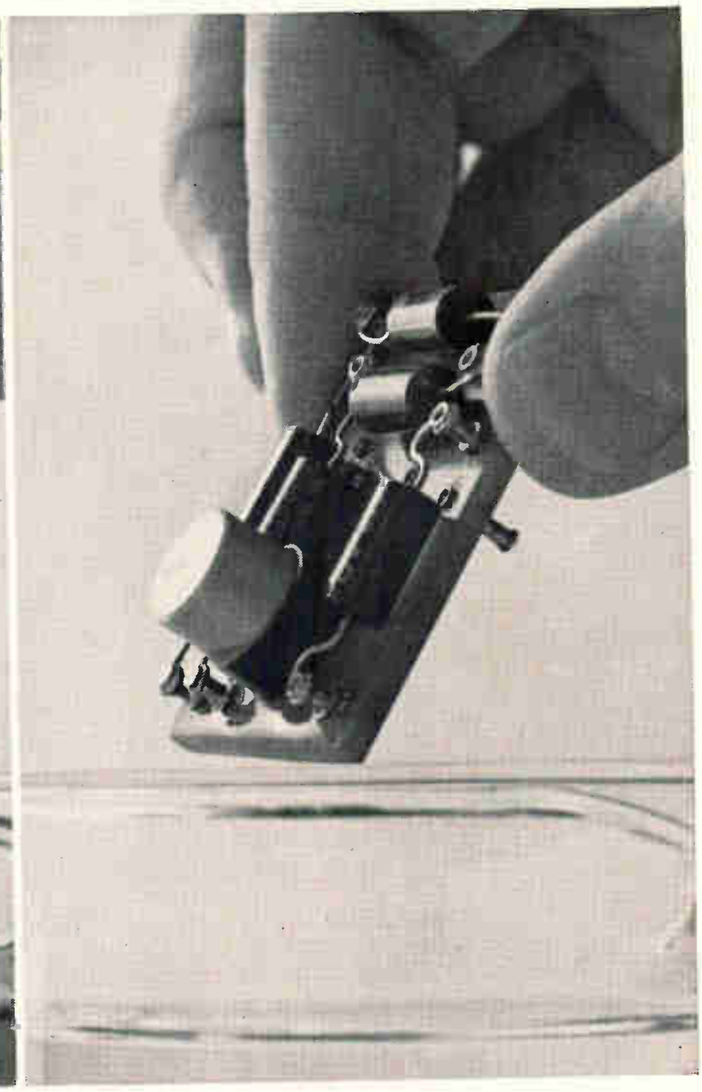

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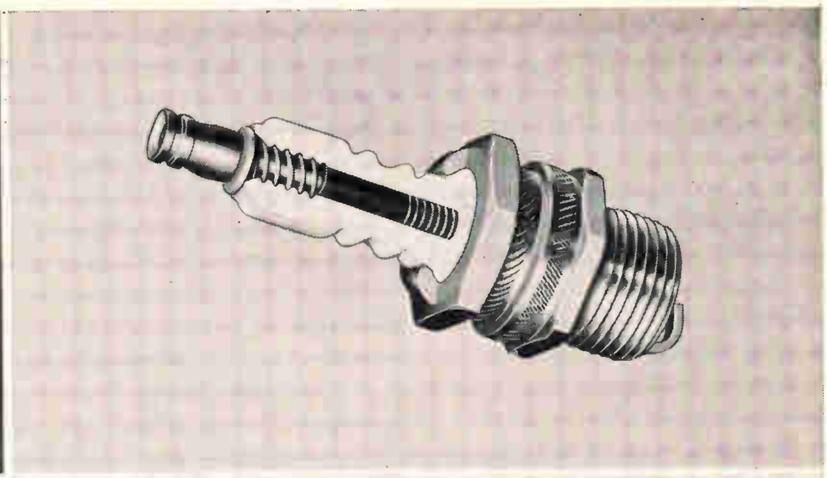

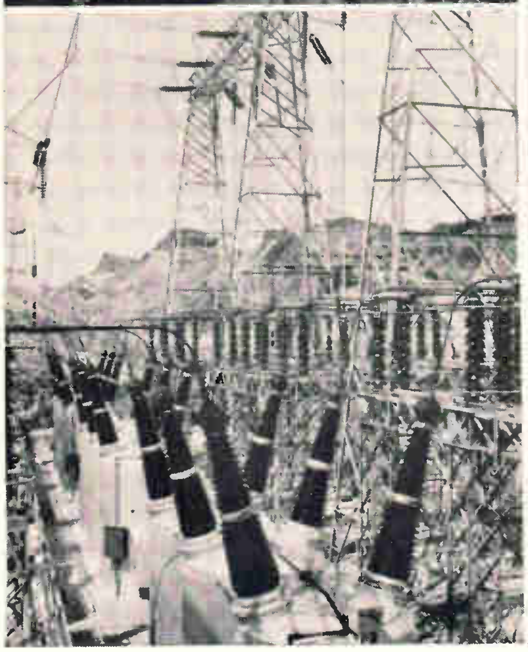

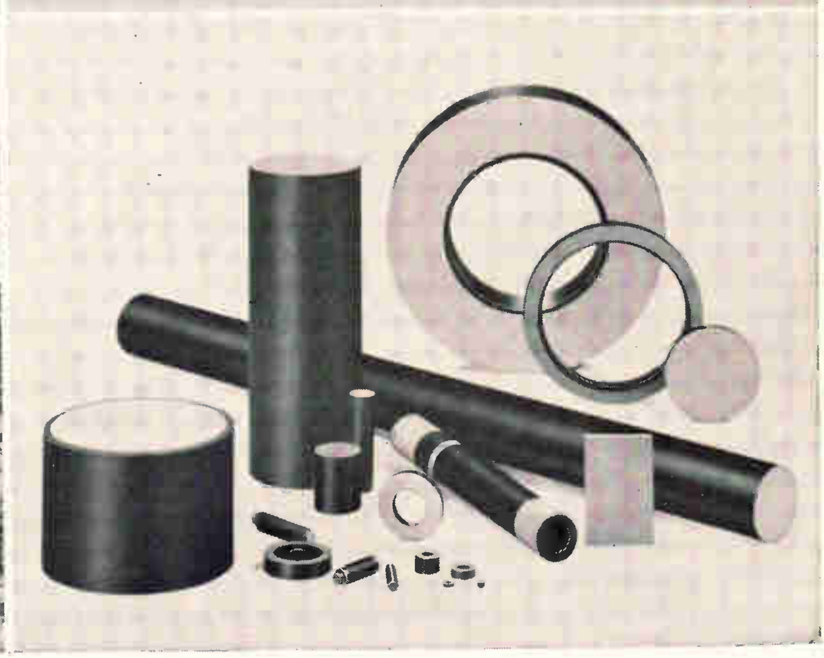

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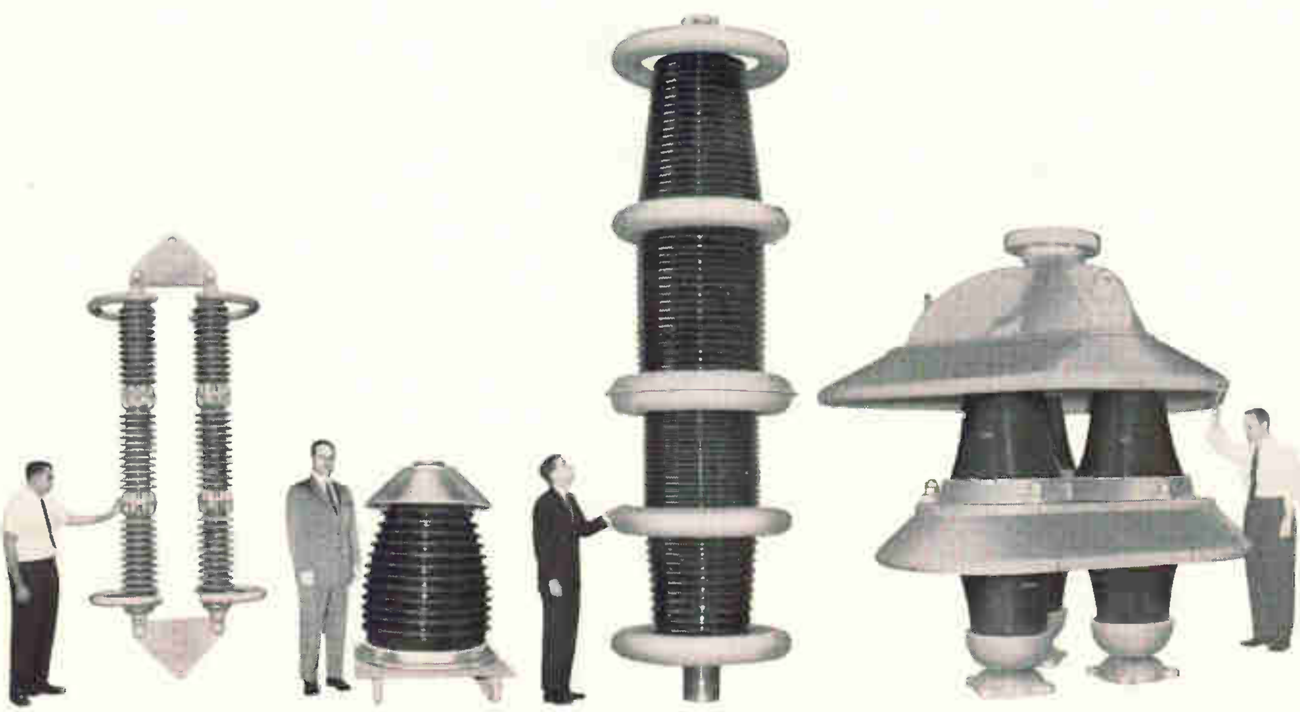

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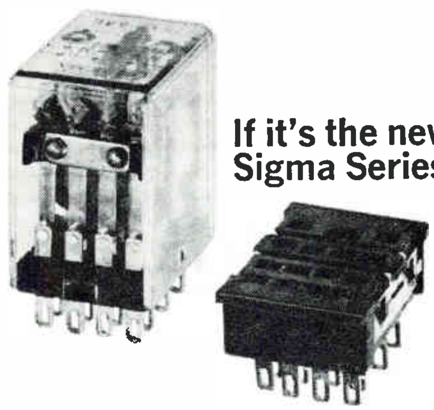

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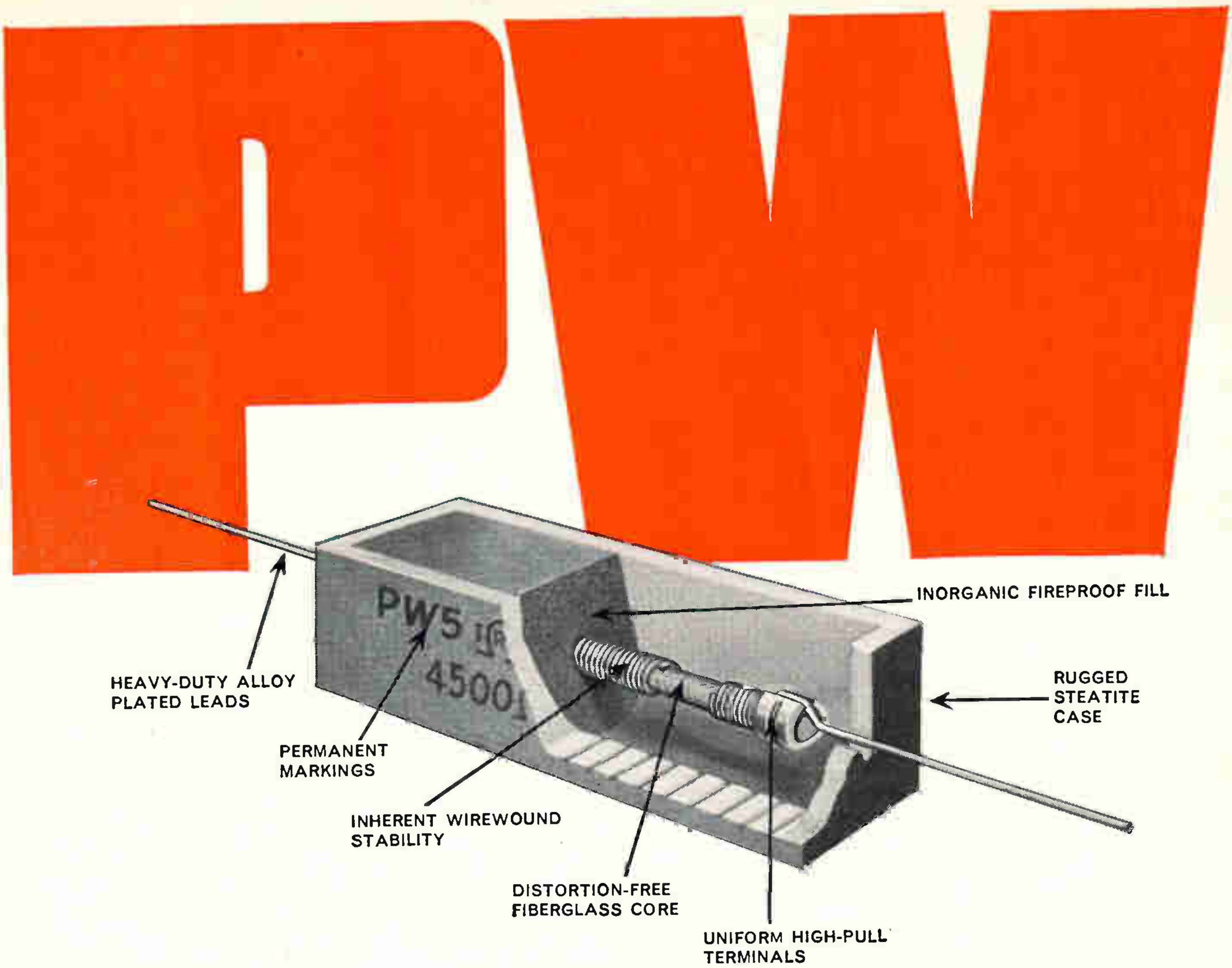

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Computers

Illiac 4, world's fastest computer, won't be slowed by criticism

Design is jelling as Burroughs prepares to build the supercomputer, a research machine capable of making a billion calculations a second

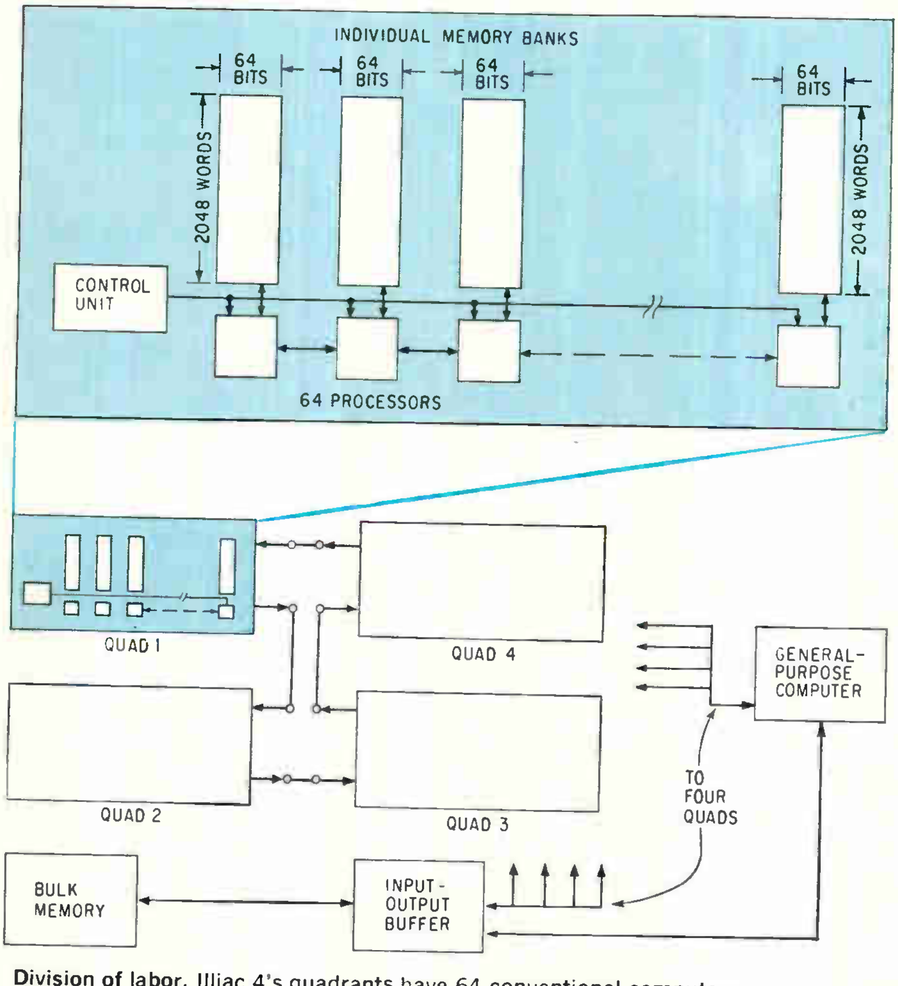
By Wallace B. Riley
Computer editor

Illiac 4—the controversial supercomputer project at the University of Illinois—is beginning to take definite shape now that a contractor has been named. As is so often the case with large systems, the current design approach differs in detail from the original concept [Electronics, April 4, 1966, p. 36].

However, the goal of the project remains unchanged. Illiac 4's developers are shooting for a computer that can execute up to a billion instructions per second—600 times the speed of the fastest operational high-performance machine. Illiac 4 is being designed to solve problems that give conventional large-scale processors a lot of trouble. It will, for example, be able to make calculations with high-order matrixes, process signals from a phased-array radar, or make long-range weather predictions.

Illiac's speed is to be attained by simultaneously putting as many as 256 conventional computers, or processing elements, to work on different portions of the same problem. For efficient solution of smaller problems, the array can be divided into quadrants, each containing 64 computers and a single control unit. The quadrants will be interconnectible in different ways for problems of different degrees of parallelism. Each processing element will have a 250-nanosecond cycle time, and the timing of all 64 processors in a quadrant will be locked in step. The system will contain more than 2.5 million logic gates.

Illiac 4 will be built by the Burroughs Corp. to the design of Daniel L. Slotnick, project director at the University of Illinois. Burroughs won out in a three-way competition with the Radio Corp. of America and the Univac division of the Sperry Rand Corp. after a six-



Division of labor. Illiac 4's quadrants have 64 conventional computers, or processing elements, each of which has its own relatively small memory.

. . . each processing element will have its own memory of 2,048 64-bit words . . .

month study of the project. Vernon Smith has been put in charge of the program at Burroughs.

The total system is expected to cost from $14 million to $16 million; the money is being provided by the Advanced Research Projects Agency of the Defense Department.

Who needs it? Slotnick views the Illiac 4 as a step toward the development of a network of individual specialized machines that can work independently on small problems and be hooked up to handle problems bigger than any single one could deal with economically. During a debate on approaches to large computing systems at the Spring Joint Computer Conference, Slotnick took pains to point out that the Illiac 4 is a research vehicle.

In some quarters, Illiac 4 is considered little more than a technological white elephant. Gene Amdahl, who headed up a large part of the development work on the International Business Machines Corp.'s System 360 computers, insists that the class of problems to which an Illiac 4 can address itself is practically nonexistent. Not too surprisingly, Amdahl, who is now an IBM Fellow pursuing independent research, opts for big general-purpose units.

But John W. Seward, who managed the applications part of Burroughs' study-contract effort, says: "The more we studied ways of applying the Illiac 4 to large problems, the better the Illiac concept seemed to fit them, and the more reasonable it became to build the machine."

I. To each its own

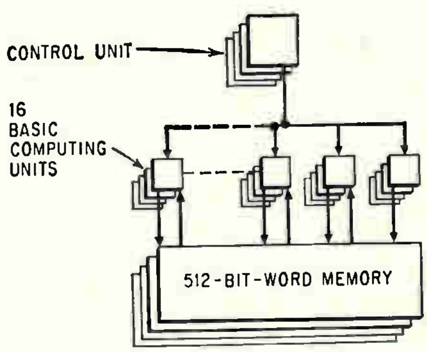
Skepticism in certain quarters notwithstanding, Burroughs and the university are pressing ahead with the Illiac 4, making changes as they go. The most notable departure from the preliminary design is a direct result of Burroughs' study of the project. Instead of one big memory with enormously long words servicing many processing elements simultaneously, each processing element will have its own memory of 2,048 64-bit words. Burroughs uses 500-nsec thin-film memory modules in its B-8500 computer, the largest commercially available processor, and it plans to redesign these modules to run at 250 nsec in the Illiac 4.

Splitting up the memory provides the individual processors with an indexing capability. In conventional machines, indexing allows the execution of the same group of instructions a specific number of times without a rewriting or introduction of an awkward counting instruction. In the Illiac 4, each processor will be able to index a group of instructions separately as its portion of the problem requires. Without individual indexing, some processing elements might be forced to idle temporarily while others caught up with them.

No individual processor would have access to any memory other than its own, but data could be transmitted directly from unit, to unit, using routing instructions included in each processor. If the two units were "neighbors," the transfer would take a maximum of 40 nsec.

Brute memory. Other new features of the Illiac 4 are a bulk memory and an external general-purpose computer to control the four-quadrant system. The bulk memory initially will be a high-speed magnetic disk with a transfer rate of 500 million bits per second —100 times the speed of the fastest commercially available disk units.

Burroughs expects to attain this speed by making detail changes in present designs, rather than designing a complete new unit. For example, Burroughs' present product line includes a head-per-track magnetic disk unit that doesn't require mechanical movement of read-write heads from track to track, and is therefore very fast. By altering the output switching arrangement and adding electronic circuitry that permits all the heads to be active all the time, the 500-megahertz bit rate can be approached. Further increases may be attained by increasing the bit packing density in each track and decreasing the distance between tracks on the disk.



Original. Preliminary Illiac 4 design featured a "layer" of 16 processors connected to a single massive memory; complete system included 8 layers.

Richard A. Stokes, Burroughs' deputy program manager, expects the disk memory to eventually be replaced by a very large core memory containing perhaps half a million words of 4,096 bits each. If such a memory can be built to cycle in 1 microsecond, its transfer rate would be 4 billion bits per second, or 33 million Illiac words per second. Realization of such data rates depends on further design studies of the transmission line driver and receiver circuits. "We may find we have to back off from that a little bit," Stokes admits.

From either type of bulk memory, 4,096 words will be assembled in an input-output buffer, which will then be able to route the data to any one of the quadrants. The destination will be a combination of the 64 local memories in the quadrant.

"The ultimate data rate of the Illiac 4," says Stokes, "will be well beyond the design goal of a billion operations per second. All the registers in the system will hold a total of more than 16,000 bits; at the 250-nanosecond cycle rate, this adds up to a bit rate of 64 gigahertz."

Jack-of-all-trades. The general-purpose computer will set up the bulk memory for data transfers to and from the Illiac 4 through the input-output buffer, and will transfer data to and from the bulk memory and a battery of conventional input-output devices. In addition, this machine will do all assembling and compiling of programs for the Illiac, operate display consoles, and perform other housekeeping chores. The machine will probably be either a standard Burroughs B-6500 or a new computer designed specifically for Illiac 4.

II. Route steps

The 64 processors in each quadrant are not set up, as some might think, in an eight-by-eight checkerboard array, with each square having its own memory. Richard Brown, associate director of the project at Illinois, explains the arrangement this way: The processors are labeled as if they were in one long straight line. The routing instructions permit the nth processor to communicate with four of its neighbors, the (n — 1)th and (n + 1)th on each side, and the (n — 8)th and (n + 8)th eight steps up and down the line. Thus the nearest-neighbor communication scheme of the checkerboard is maintained, but the programer is free to work with any arrangement he pleases, subject to the limitations imposed by the routing instructions.

"Of course, this process of transferring data incrementally from processor to processor takes time," notes Stokes. "During the study project, we considered the idea of a large central exchange for each quadrant, or for the entire system, through which any processor could communicate directly with any other processor. But we found that such an exchange, besides being very expensive, would necessarily introduce such long time delays through the maze of transmission lines that it actually wouldn't be any faster than the incremental transfer."

Housing. Burroughs plans to package eight individual processing elements and eight memories in a single cabinet or frame, and to bolt eight of these frames in a row—together with a ninth frame containing a control unit—to make a quadrant. Four nine-cabinet rows will be distributed about the room in which the system is to be assembled. The bulk memory, its buffer, and the general-purpose computer will be in the same room.

One processing element will be packaged on three multilayer boards about 12 by 14 inches; each board will carry about 50 integrated-circuit packages. Each 64-pin IC, in turn, will contain between 50 and 100 gates on a single substrate. The IC's will be built specifically for the Illiac 4 by Texas Instruments Incorporated.

The logic setup, algorithms, and other aspects of the design will be checked out on prototypes built with conventional 16-pin. IC's, also made by TI; the 64-pin production circuits will be developed in parallel with the prototypes.

III. Manipulator

The Illiac 4 is designed to solve any matrix-oriented problem — a category that covers a lot of territory, including weather-forecasting, hydrodynamics, linear programing, and economic models. Problems in these areas can be solved to a limited extent by large modern computers, but only at the cost of many hours of running time. The Illiac 4 is being designed to run the same solutions in a fraction of a second. Also, since results will be instantly obtainable, more detailed formulation of problems will be feasible.

Basically, a matrix is a rectangular array of numbers that represent the coefficients in a system of simultaneous equations. Solving the equations requires a manipulation of the coefficients, and matrix algebra offers a convenient way to make these manipulations.

One mathematical model developed by the National Center for Atmospheric Research, Boulder, Colo., uses measurements of temperature, humidity, barometric pressure, wind velocity, and other variables. These readings, taken at 5-degree intervals of latitude and longitude and at six levels of altitude over the entire globe, are applied to a set of partial differential equations relating the hydrodynamic and thermodynamic properties of the atmosphere. From the equations, predicted values of the measurements are calculated for a real-time interval of 7½ minutes.

$$\begin{pmatrix} A_{1,1} & A_{1,2} & A_{1,3} & \cdots & A_{1,N-1} & A_{1,N} \\ A_{2,N} & A_{2,1} & A_{2,2} & \cdots & A_{2,N-2} & A_{2,N-1} \\ A_{3,N-1} & A_{3,N} & A_{3,1} & \cdots & A_{3,N-3} & A_{3,N-2} \\ \vdots & \vdots & \vdots & & \vdots & \vdots \\ A_{N-1,3} & A_{N-1,4} & A_{N-1,5} & \cdots & A_{N-1,1} & A_{N-1,2} \\ A_{N,2} & A_{N,3} & A_{N,4} & \cdots & A_{N,N} & A_{N,1} \end{pmatrix}$$

Dealer's choice. Processing a line at a time or a column at a time is made possible by skewing matrix across individual elements' memories.

The calculations are repeated over and over to yield predictions at intervals of 7½ minutes, 15 minutes, 22½ minutes, and so on, at an improvement factor of 20:1. In other words, one hour of computer time yields a prediction of the values 20 hours hence.

The Illiac 4 will be able to make such a calculation thousands of times faster than present equipment—perhaps computing a 20-hour forecast in a few seconds. More accurate forecasts for a longer period of time will also be possible without an unreasonable amount of computation time.

Divide and conquer. The advantage of dividing the Illiac 4 into quadrants becomes evident when weather-forecasting problems are studied in detail. If measurements are made at 5-degree intervals of latitude and longitude near the equator, data points will be 350 miles apart. But in higher and lower latitudes, separations come so close together that they take up valuable space in the memory without contributing significantly to accuracy. Thus, longitudinal spacing can be widened to 10 degrees in midlatitudes and to even more near the poles. On the Illiac 4, two quadrants can be devoted to the equa-

Distinguished forebears

Illiac 4 is the descendant of a distinguished line. The original, made in 1952, was one of the first automatic digital machines. It was built with vacuum tubes and the memory was a bank of 40 cathode-ray tubes, each of which stored an array of 1,024 various-sized dots. Data was read from the memory by a capacitive-coupling technique that sensed the size of the "splash" when the electron beam in the crt crossed each of the dots.

Illiac 2 is still in use. A large solid-state machine, it was built in 1962 to check on design ideas stemming from Illiac 1. Illiac 3, now under construction, is a pattern-recognition computer that incorporates integrated circuits. Patterned after large commercial and military systems, Illiac 3 has a highly parallel organization. It will be completed, as will Illiac 4, some time in 1969.

. . . a machine the size of Illiac 4 cannot be permitted to stand idle . . .

torial zone and one each to the higher and lower latitudes, where fewer data points and hence less calculation is required.

Linear programing, another important outlet for Illiac 4's talents, is a technique to maximize or minimize a linear function of N variables subject to a set of linear constraints. For example, minimizing the cost of a manufacturing process subject to such constraints as the availability of raw materials, market conditions, transportation delays, and the like, would present a problem in linear programing. Such problems break down into systems of simultaneous linear equations that can be readily solved with matrix algebra.

Offbeat. A surprising application of the Illiac 4 could be in Fourier analysis, particularly with the recently developed Cooley-Tukey algorithm [Electronics, Oct. 3, 1966, p. 52]. With Fourier analysis, complex time functions such as voltage waves can be analyzed for frequency components; the Cooley-Tukey algorithm sharply reduces the time required for such an analysis by conventional large-scale computers. A typical problem in Fourier analysis can be solved with the Cooley-Tukey algorithm on the Illiac 4 in less than half a millisecond—an advantage of 6,000:1 over the IBM 7094. This improvement means that the algorithm can be applied to the same problem but with the function sampled at a far greater numbers of points.

Guiding light. Daniel L. Slotnick sees Illiac 4 as a research vehicle.

IV. Skewed matrix

Still another potentially valuable application is in multichannel filtering, a technique to process the data received from large arrays of sensors. The Large-Aperture Seismic Array in Montana [Electronics, July 26, 1965, p. 91], a system that monitors earth movements and could prove useful for detecting clandestine nuclear explosions, is an example of such an array. This installation has 525 pickups that respond to impulses in different ways and at different times; their outputs can be expressed in the form of a matrix with 525 rows and 525 columns. Analyzing this matrix takes several hours on an IBM 7094. The Illiac 4 should be able to accomplish the same thing in less than three seconds.

While detailed examination by Illiac of such events as nuclear blasts is of shorter duration than weather forecasting, the basic equations and method of solution are identical. Similar techniques can be used to process data from phased-array radars.

To streamline the processing of matrix problems on the Illiac 4, the programers, working under the direction of David Kuck at Illinois, developed the skewed matrix. The most straightforward division of the matrix assigns each column to an individual processor, which can then work on it a row at a time. If, however, the nature of the problem is such that the matrix is more efficiently solved a column at a time, the processors must either tackle the columns in sequence, or the matrix elements must be transferred to other processors.

A ground rule in designing the Illiac 4 was to keep almost all the processors going almost all the time to take maximum advantage of the highly parallel organization. A skewed matrix can be evaluated by either rows or columns; no one memory bank contains either an entire row or an entire column. With a skewed format, only operations of a kind hardly ever encountered in matrix analysis could tie up a single processor while the others were idle.

V. Programing

Programing Illiac 4 will be a formidable task, though perhaps not as formidable as it might seem at first glance. The idea isn't to program 256 computers individually, but to program one for a small part of a specific task, and then get all of the others to do the same thing at the same time with other parts of the same problem.

Programs will be written for the Illiac 4 in much the same way that they are written for other large-scale systems. The programers will use conventional languages or variations, and the programs will be translated into machine language by the off-line general-purpose computer. Some kind of operating system will probably be used, because a machine the size of Illiac 4 cannot be permitted to stand idle if it's in working order; the operating system will be installed in the general-purpose computer and be oriented toward keeping the Illiac busy.

Customized software. The software problems that have plagued manufacturers and users of third-generation commercial computers won't be a stumbling block here. For one thing, Illiac 4 is designed for research, not commercial applications. For another, commercial manufacturers have tried to produce universal software that is all things to all machines. Software for Illiac 4 will be strictly custom made.

The reliability goal of the project is a mean time of 10 to 30 hours between failures for all 256 processors. The designers don't consider this a difficult target because the processors will be identical. "Please note," says Slotnick, "that we aren't building a machine with over 2.5 million logic gates, but 256 machines with 10,000 gates apiece. Highly reliable machines of this size are quite common today."

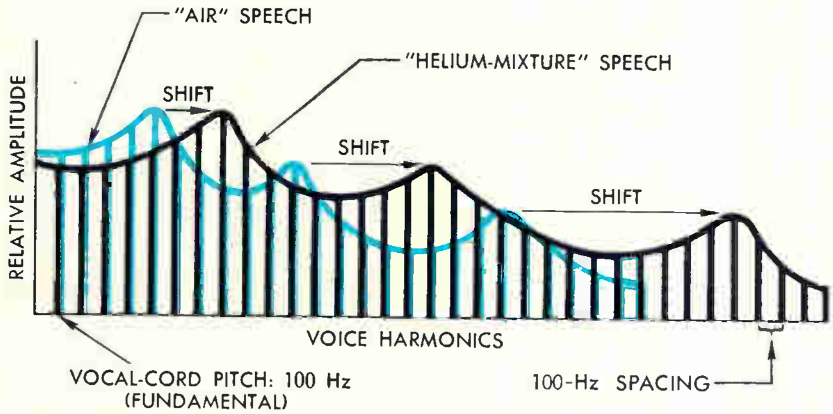
Programs for the Illiac 4 will be independent of the machine configuration, so that if any part of the over-all system should fail the remaining units could continue operating, though at reduced speeds.

Report from

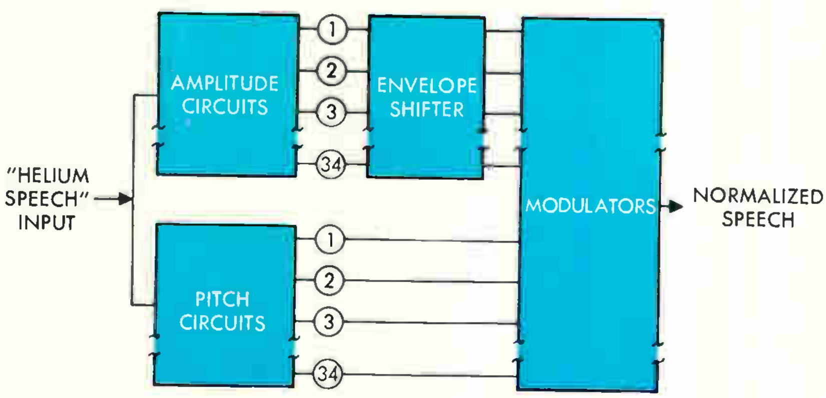
BELL LABORATORIES

Making voices from the depths sound deeper

Bell Telephone Laboratories has had a long-term interest in speech research—tracing back, indeed, to the work of Alexander Graham Bell. It was for this reason that the U. S. Navy asked us to investigate a problem encountered in Sealab II. To prevent "bends" and nitrogen narcosis, the divers breathe a pressurized mixture of oxygen, nitrogen and helium, but the helium gives their voices an unnatural, squeaky, Donald-Duck-like quality. As a result, voice communications between divers and people on the surface are seriously impaired.



Fundamental pitch and harmonics (vertical bars) for normal "air" voice sound (color) and "helium speech" sound (black). Note that the frequencies of the fundamental and harmonics do not change very much, whereas the envelope of the amplitudes shifts toward the right. Note also that the magnitude of the shift increases with increasing frequency.



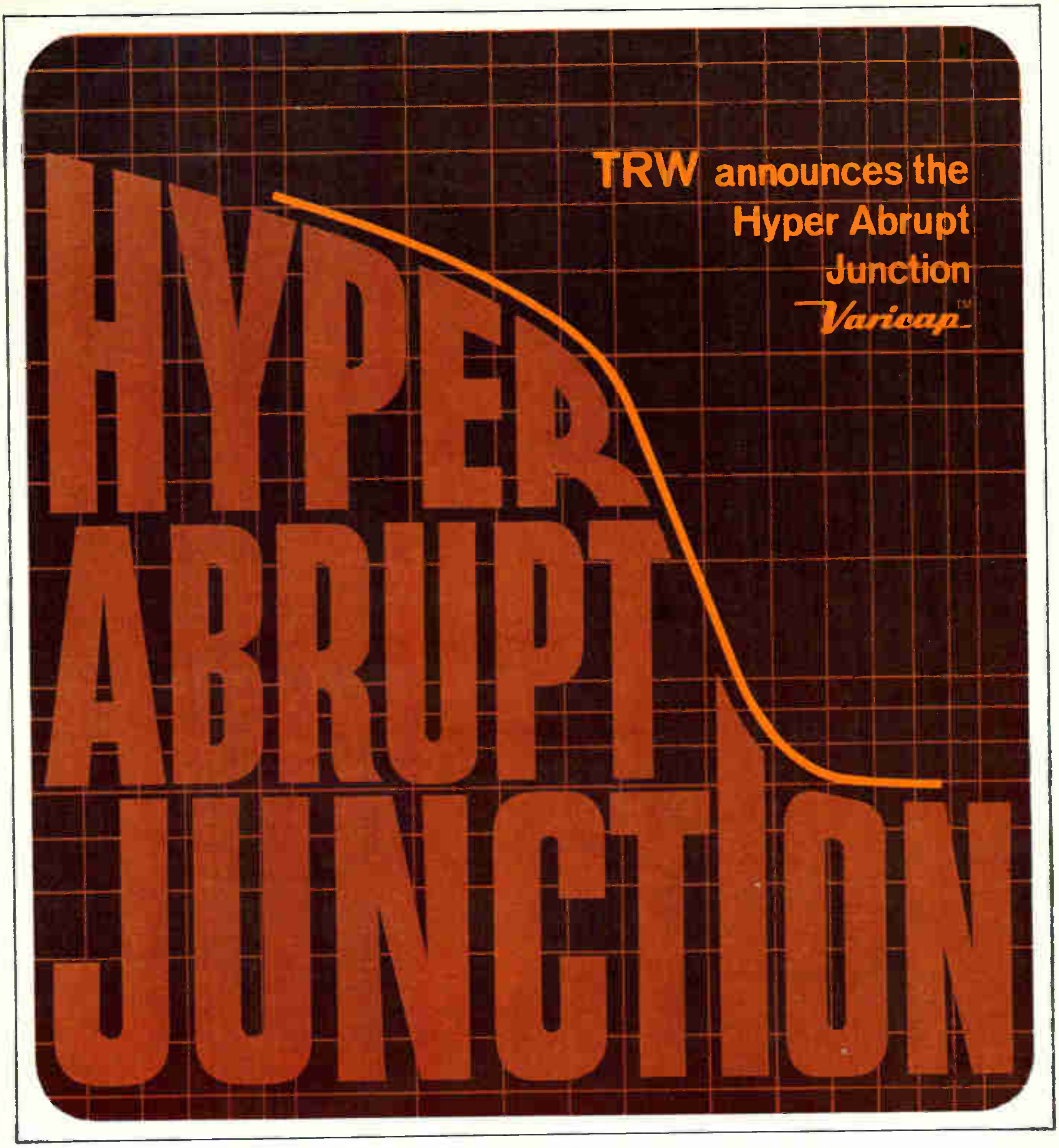
Block diagram of system for restoring helium speech to normal voice quality. Helium speech is fed to amplitude and pitch circuits. In the pitch circuits, the frequencies of the 34 lowest harmonics are determined. In the amplitude circuits, the power levels within each of 34 150-Hz intervals of the speech spectrum are determined. The amplitudes are shifted and applied to harmonics of lower frequency. In the modulators (right), these power levels control the loudness of the 34 harmonic frequencies . . . thus producing a pattern or envelope closely corresponding to the envelope of normal speech.

THE MAJOR PROBLEM is that the velocity of sound in the helium mixture is much higher than in air. This does not appreciably affect vocal-cord frequency, but does strongly affect the acoustic resonances of the vocal tract—which give the voice its characteristic sound quality. So, though fundamental voice pitch remains approximately the same (about 100 Hz in men), the amplitudes or loudness values of the various harmonics change markedly. Specifically, the pattern of these resonances (the envelope) shifts toward the higher frequencies (see graph), and voice timbre is grossly distorted.

THE SOLUTION to this problem was found at Bell Laboratories by research scientists M. R. Schroeder, J. L. Flanagan, and R. M. Golden. The distorted "helium speech" is separated into harmonic frequencies and their amplitudes are measured (see diagram). Then the envelope of the harmonic amplitudes is shifted back toward the more normal or low-frequency condition. In other words, the amplitudes of the harmonics are adjusted to match a more normal envelope.

As a test, the technique has been used on recordings of helium speech made in the U. S. Navy's Sealab II. The processed voices are readily understandable and sound enough like the speaker's "air" voice to be identifiable.

Bell Telephone Laboratories
Research and Development Unit of the Bell System



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Mohawk proves a good scout

Reconnaissance plane sends back instant data on sightings;
Army plans to update current models and order about 100 more

By John F. Mason
Military electronics editor

Its ability to supply instant in-flight intelligence to strike controllers has made the Army's Mohawk surveillance aircraft one of the unsung successes of the Vietnam war.

By contrast, Air Force reconnaissance planes must fly data they've gathered back to base for processing. By the time this information has been evaluated, a target may have moved or gone underground.

But a Mohawk pilot, less than two minutes after his infrared system has detected a suspicious-looking sampan or his radar has looked many miles into enemy territory, can study the picture on his cockpit display. At the same time, the picture is data-linked to identical displays at ground terminals 50 to 100 miles away. Then, while the Mohawk is scouting for new targets, the ground station operator is alerting the nearest strike controller to take out the target with the most appropriate weapon—artillery, armed helicopters, or jet attack planes.

Success story. Army's Mohawk surveillance aircraft can data-link infrared and side-looking radar pictures of targets back to base almost immediately.

I. Four-part program

Proof that the Mohawk is paying its way is the attention again being given the project. The Mohawk program will get a cash transfusion of several hundred million dollars over the next few years. Directed by the prime contractor, the Grumman Aircraft Engineering Corp., the program is divided into four parts:

- Modification. The more than 200 operational planes built with money appropriated in and before 1964 will be upgraded. All three versions of the craft will get new cameras. The OV-1A's only sensor is a camera; the OV-1B, has a camera and side-looking radar, and the OV-1C is designed for infrared equipment. However, most OV-1C's never got infrared sets, and have been operating with just a camera. With the modification plan, this situation will be remedied.
- Production. Approximately 100 new Mohawks will be built between now and 1969, most of them of the OV-1C type.
- Product improvement. A new Mohawk, the OV-1D, will be built with interchangeable sensors. For a modular arrangement, for example, the infrared could be pulled out and a side-looking radar installed in less than 30 minutes. HRB-Singer Inc., a subsidiary of the Singer Co., will make the infrared set, and Motorola Inc. the side-looking radar.
- Research and development. A special program is being funded to develop even more advanced sensors for installation in a limited number of future Mohawks. Motorola is working on a new side-looking radar and Texas Instruments Incorporated is working on an improved infrared system.

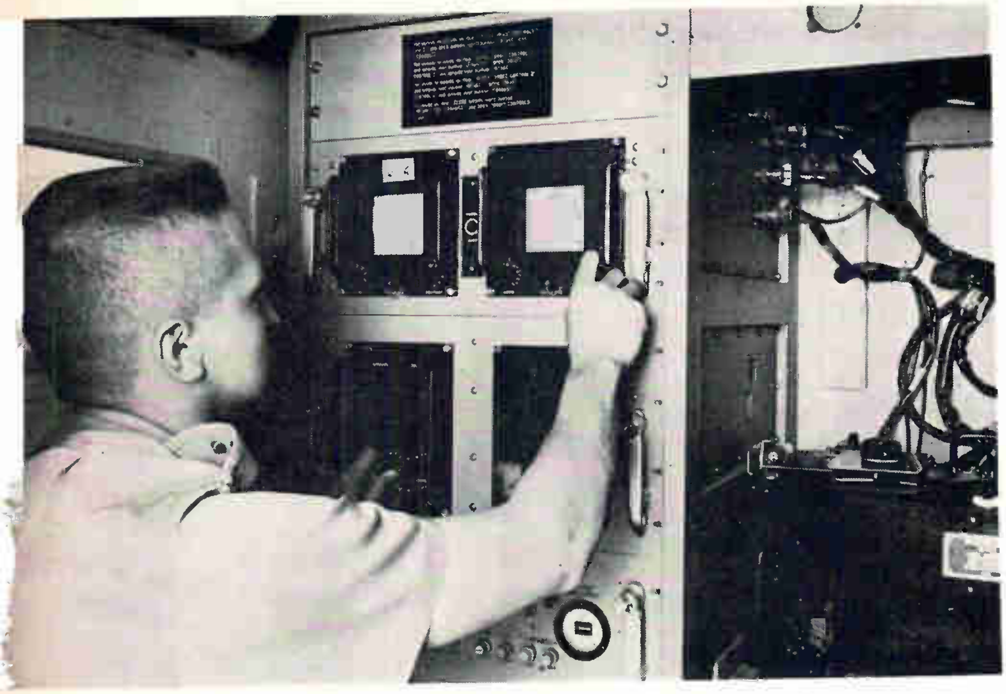
II. Cameras

The planes' current photographic equipment—the remote-controlled KS-61 system—uses a KA-30 framing camera made by Chicago Aerial Industries Inc. In flight, the camera can be pointed straight down or up 15° and 30° from the vertical on either side. Film is stored in 100-foot rolls, each of which will hold 240 pictures.

For night photography, photo-flash cartridge flares are ejected upward from pods mounted on the wings. The camera's shutter automatically opens when the flare leaves the pod, and a photocell on top of the plane closes the shutter when it senses the peak illumination.

The Army plans to mount an electronic strobe light on wing pods on all the new planes. These lights will illuminate the ground enough to ensure good pictures from high altitudes. To assure that the flash won't be missed, the camera shutter will stay open until after the flash.

From a panel in the cockpit of



Twins. Ground terminal for infrared system simultaneously receives the same picture seen by the Mohawk pilot on his cockpit display.

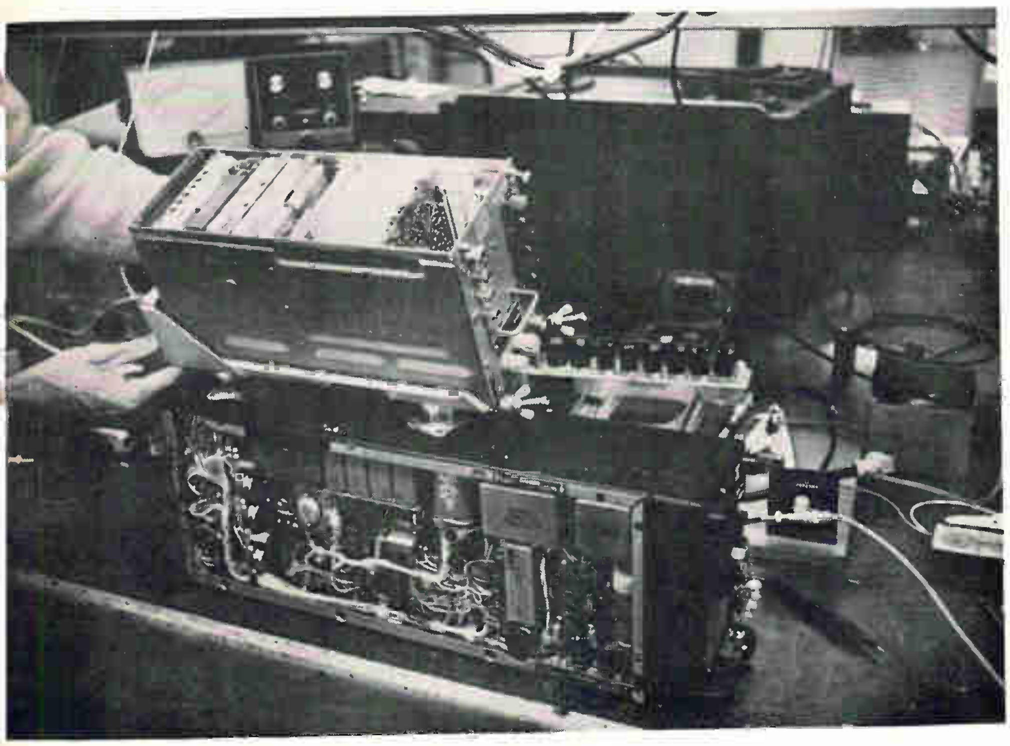
current Mohawks, the pilot or an operator can control the rate at which pictures are taken. By setting the depression angle of the camera for oblique shots, he triggers a computer circuit that compensates for the increased distance between the camera and the target.

Image-motion compensation is provided automatically by an optical v/H (velocity over height) ratio scanner system. Information from the v/H scanner is also fed to a camera control that regulates the overlap of successive pictures. This overlap gives a stereo effect when two photographs are observed through a special viewer.

Panorama. A few Mohawks carry an advanced camera, the KA-60 built by the Fairchild Camera & Instrument Corp. Mounted in the nose of the plane and pointed 20° down from the horizon, the KA-60 scans 180° from side to side. The camera can take 12 pictures a second with exposure speeds from 1/100 of a second to 1/10,000th. The panoramic feature is achieved by a rotating prism in front of the lens that reflects light from the terrain through the lens to put a picture on moving film.

A new framing camera, the KA-76 being built by Chicago Aerial, incorporates an in-flight processing system. Like the KA-30, which it will eventually replace, the KA-76 can shoot straight down or be elevated to 15° and 30° on either side.

The new camera also has automatic exposure control. A photoelectric cell constantly measures light reflected from the terrain and sets the exposure opening accordingly.



Tri-service. Mohawk's AN/APX-44 IFF (identification, friend or foe) system (below) will be replaced by the APX-68 (above) or the APX-72; eventually, all three services will standardize on a single unit.

III. Radar

The AN/APS-94 side-looking airborne radar, built by Motorola, gives the pilot in one minute, a remarkably clear, detailed filmed record of stationary and moving objects on the ground on both sides of the aircraft. As the radar scans the terrain to the side, or sides, of the aircraft, the returns are painted, line by line, across the film. A few millimeters behind the exposed portion of the film, a pencil-like cylinder containing developing fluid processes the film, which then moves slowly over an illuminated glass viewer. Moving objects are shown on one half of the 9-inch wide film and fixed targets on the other.

At the same time the pilot is studying his negative, an operator on the ground, miles away, is looking at an identical picture on a recorder-processor-viewer. There is considerable redundancy in the radar's returns because the aircraft flies at a relatively slow speed and the radar pulse is repeated at a fast rate. A sampling of the returns can be data-linked to the ground terminal without degrading the picture in the aircraft or the one on the ground.

Pertinent information on each picture is automatically printed in its margin by a Motorola annotation system; this data includes the aircraft's position, the date, and the time.

Space saver. To conserve bandwidth, the information is compressed to 1/100th its size for transmission and is then restored on the ground. To extend the data link's line-of-sight range, a relay plane has been used with success.

Data links for the side-looking radar in the OV-1B and for the infrared in the OV-1C are now provided by the manufacturers. In the OV-1D, a tri-service link will be used.

Although final specifications aren't settled, this tri-service data-link system, being developed by the Navy, will probably operate in the microwave range rather than in the ultrahigh-frequency band now used. More bandwidth will be needed to accommodate the growing number of sensors and there just isn't enough available space in the uhf area.

The Army way. The Army's side-looking radar is a noncoherent, pulsed, brute-force system that gives a readable return. The price the Army pays for this readability is the long, awkward antenna that hangs like a giant cigar under the plane.

Although the Army won't say exactly how the new side-looking Motorola radar will differ from existing sets, the trend in such equipment is toward the coverage of smaller areas with greater detail and provision for moving-target indication at slow speeds. In Vietnam it's often important to detect movements as slow as those of a water buffalo.

On its own, Motorola is working on a coherent, nonfocused, synthetic aperture for side-looking radar. With this approach, the company hopes to improve resolution, reduce the size of the antenna, and still have a cockpit readout.

IV. Infrared

The AN/AAS-14 infrared detecting set, built by HRB-Singer, provides the OV-1C pilot with two infrared detectors and two cockpit displays for use at different lengths. The system provides a permanent film record and transmits a data-annotated picture to a ground station via data link. Singer makes the link and the Bowmar Instrument Corp., Fort Wayne, Ind., supplies the annotation system.

The infrared set going into those OV-1C's operating with only a camera will be a slightly improved version of the AAS-14 that Singer built for earlier models of the plane. The delay in outfitting all the OV-1C's with infrared systems was attributed to protracted debugging of the original sets.

The infrared systems in the special R&D project will be built by Texas Instruments. Although the Army won't discuss how TI's equipment will differ from Singer's, a known goal is a forward-looking system; the AAS-14 set looks straight down.

A forward-looking set would give the pilot more time to study the target he's approaching. If an array of detectors were used, it would, of course, cover an area more thoroughly than would a single detector. And, also, if the same spot is scanned more than once, movement can be detected.

V. Avionics

Most of the Mohawks being modified will get the same communications equipment slated for the new planes. The AN/ARC-51BX uhf transceiver will, in most cases, replace the ARC-55. Operating with this amplitude-modulated radio between 225 and 400 megahertz, the Mohawk will be able to report directly to a Tactical Air Control Party (TACP) in Vietnam, which in turn will relay the information to the Direct Air Support Center. The DASC can coordinate a strike with fighters or communicate with other ground stations [Electronics, May 16, 1966, p. 95].

The very-high-frequency, frequency-modulated AN/ARC-54 transceiver will replace the ARC-44. Operating between 30 and 70 Mhz, the ARC-54 will allow the Mohawk to communicate with almost all of the AN/VRC-12 family of vehicular radios, with helicopters, and with the manpack PRC-25.

The vhf a-m AN/ARC-134 transceiver will replace the ARC-74. Operating between 116 and 150 Mhz, the ARC-134 will provide communication with the O1-E Cessna aircraft that operates as a flying forward air controller. The Mohawk can also use this radio to contact the TACP, DASC, or a

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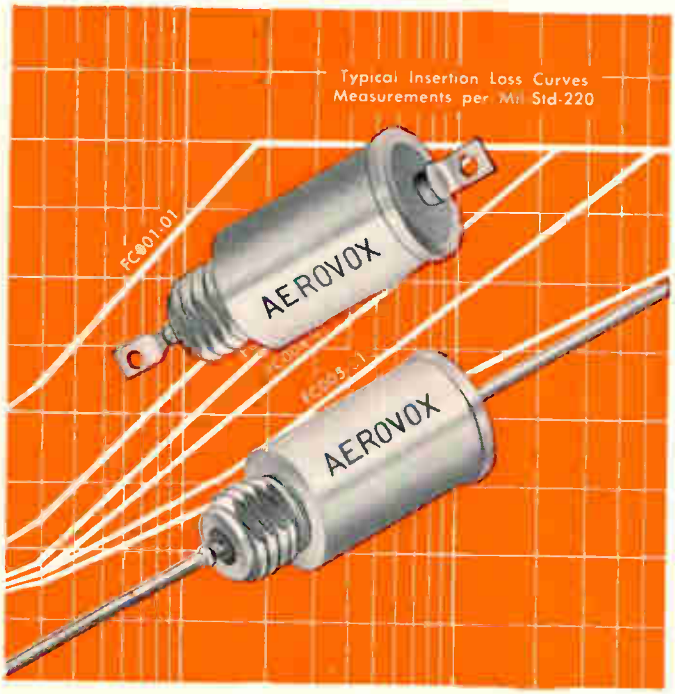

Present military specifications require that electronic equipment be kept free of interference from 150 KHz to 10 GHz. Aerovox type FC low pass, miniature ceramic RFI suppression filters will meet or exceed the applicable requirements of MIL-F-15733. These new units have been life tested for 250 hours at 1½ times the working voltage. After test, insulation resistance of units is greater than 50 megohms.

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by Theodore Levitt, Professor of Business Administration, Harvard Business School

"You can be sure if it's Westinghouski."

Did you know that the practice of using brand names and trademarks on products is under attack in this country?

That certain governmental actions and judicial rulings are moving implacably toward the possible destruction of brand-name marketing?

The great debate that is going on points up the issue of what trademarks and brand names really mean. But, there is, I believe, more instructive value in a look at Soviet experience with branded products than in all the tangled rhetoric expounded by lawyers, economists, professors, businessmen, and politicians in recent years.

A few years ago several Russian factories manufactured identical 17-inch TV sets. On more than one occasion, even though consumers were clamoring for more sets, many simply were not being bought. Inventories piled up. After a good deal of fruitless and wasteful searching for an explanation, the answer came. Because the public could not identify the factory source of any one 17-inch set, and one factory habitually produced "lemons," soon sales of all 17-inch TV sets fell. This refusal to buy was the public's only way to protect itself. But it threw the Soviet central economic plan badly out of kilter. Even worse, it caused a lot of public discontent with Soviet officials.

Factory Marks. It was at this point that Soviet trademarks began to appear. At first, their function was little more than to identify (for the convenience of the authorities) the factory source, but the result was far more than the Russians bargained for. Here is what trademarking did:

(1) It enabled the consumer to choose the output of a plant with a good reputation, and to avoid the plant with a poor one.

(2) Though the sales of the factory with the poor reputation fell, and therefore it failed to meet its economic plan, this caused less economic dislocation than when the entire industry's sales had slumped previously.

(3) It resulted in consumer discontent being shifted from the political (Party) authorities to the trademarked plant with the poor quality.

(4) It created a form of consumer sovereignty—a way of giving the consumer the power to reward quality and punish shoddiness—by enabling him to identify easily the source (trademark) of the output.

In sum, trademarking rewarded quality and efficiency, and punished shoddiness and waste, by making it easy for the quality producer to sell his product because the consumer had developed confidence in his trademark. From experience, the consumer had, in effect, learned that "You can be sure if it's Westinghouski."

Further Developments. The Russians have, since this incident, expanded the practice of trademarking, or branding, the output of different plants. Soviet plant managers now guard the integrity and reputation of their trademarks with the vigor of Cossacks bearing down on revolutionaries. They safeguard the purity of their brands as sedulously as they watch their operating expenses. Their houses depend heavily on what happens to both of these.

The fact that the Russians have adopted brand names and, now, advertising simply reflects the fact that they are more responsive to the dictates of economics, technology, and good sense than to the muddled abstractions of obsolete philosophers. Moreover, the Russians have learned that with brand names, instead of economic planners having to establish arbitrary quality standards and hire engineers to enforce them, the sovereign consumer automatically establishes and enforces the high standards.

The net result has been not only an almost automatic and continuing improvement in Soviet consumer-product quality and design, but also an accelerating tendency to use brand-name advertising as a means of reassuring consumers about the quality and desirability of particular brands and therefore raising their sales and profitabilities.

The Soviet experience clearly demonstrates how the consumer can use the brand as a means of protecting himself and of punishing the producer of trademarked products that do not meet consumer expectations.

From an article by Professor Levitt, "Branding on Trial," in the Harvard Business Review, March-April 1966.

divisional headquarters.

The AN/ARC-102 high-frequency, single-sideband transceiver with a tuning range of 2 to 30 Mhz will provide channels to portable manpack radios carried by ground-based forward air controllers, and Special Forces teams.

The OV-1D Mohawk with interchangeable sensors will get most of the Light Observation Helicopter's (LOH) communications package, which is being built by Sylvania Electric Products Inc., a subsidiary of the General Telephone & Electronics Corp. The uhf ARC-116 will replace the ARC-51; the vhf ARC-115 will replace the ARC-134; the vhf f-m ARC-114 will replace the ARC-54.

Shopping list. The Mohawk's identification friend-or-foe (IFF) system is the AN/APX-44, a pulse-type, fixed-frequency, receiver-transmitter that identifies the aircraft at all of the ground-based radar stations and sites equipped with IFF interrogator-responders. The APX-44, manufactured by Melpar Inc., and the Wilcox Electric Co., may be replaced by one of two newer contenders—the Admiral Corp.'s APX-8, or the Bendix Corp.'s APX-72. The APX-44 is equipped with only 64 codes, whereas the APX-68 and the APX-72 each have 4,096. Also, the newer systems are pressurized; the APX-44 isn't. The APX-68 has still another selling point: it reports the plane's altitude. The eventual contract winner is in for a bonanza since the equipment will be standardized for the three services.

VI. Navigation

The AN/ASN-65 doppler navigator, built by the Canadian Marconi Co., is an all-weather, self-contained system consisting of an f-m continuous-wave doppler radar, a navigation computer, and a true-airspeed indicator. The system displays and feeds into the infrared and side-looking radar the plane's ground speed and track. It will soon be modified to include a new gyro compass being built by the General Electric Co.

The Mohawks also carry: The ARN-59 low-frequency direction finder; the VOR (vhf omnidirectional range) navigation receiver; the ARN-52 Tacan to receive bearing and distance signals from ground beacons; the APN-22 microwave radar altimeter; the ASN-33, which integrates data from the other navigation systems; and the ARN-56 receiver to provide range and glide-slope information in relation to ground beacons.

Ground terminals. Data sent back by the APS-94 side-looking radar goes to the AN/TKQ-2 ground sensor terminal, which displays and records the pictures and annotations. The system is set up in a ¾-ton van. Infrared information is handled by the AN/TAQ-1 terminal, also housed in a ¾-ton van.

Another van contains the AN/TSQ-43, which is used to interpret photographic, radar, and infrared imagery. Finally, there is a portable film-processing darkroom, the ES-38, in a shelter on a 2½-ton truck.

Communications

Mallard's golden eggs

Joint U.S.-Canada-Australia project to develop and build a common tactical communications system for ground forces is arousing the interest of electronics firms everywhere

By William D. Hickman

Washington Regional Editor

Project Mallard—a joint venture by the U.S., Canada, and Australia to develop and build a common tactical field communications system for ground troops—is causing a worldwide stir in the electronics field.

Not only are electronics firms, both here and abroad, anxious to secure a part of the more than $600 million expected to be spent on the system over the next decade, but they are also concerned about the long-term implications of such a massive international undertaking.

For one thing, Mallard designers may decide that all measurements should be on the metric rule—an eventuality that could cost U.S. companies dearly in retooling expense and give the foreign companies a competitive edge.

Although most U.S. firms eager to compete for Mallard business would prefer to avoid adopting metric measurements, the problem is at least timely. Late last month, the Electronic Industries Association issued a statement saying that now is a good time to study the advantages and disadvantages of the metric system.

But, the EIA warns, any change in the national standards for measurement "would have far-reaching effects that can only be cushioned by proper preparation and timing."

Mallard officials freely concede that their program could have sweeping standardization effects on allied military communications equipment. Moreover, a diplomatic agreement was signed specifying that vendors from all participating nations be considered for the contracts.

Bowing out. These rather sticky international problems appear to be the cause of one casualty. Britain, which instigated the project, has dropped out—at least temporarily—apparently because the U.S. refused to guarantee that England's share of the contracts would be proportional to its financial contribution.

But U.S. officials are hopeful of luring Britain back into the fold by agreeing to a subsystem total-package acquisition plan, insuring that research and development contractors on the latter stages of the project will also be hardware suppliers for the first buys.

Indications are that other members of the North Atlantic Treaty

. . . the world's largest tactical military communications effort . . .

Organization are anxious to join Mallard.

I. Entering the lists

Industry has taken to Mallard like ducks to water. So great is the interest that project officials were flooded with requests from companies seeking representation at last month's industry briefing at Fort Monmouth, N.J. More than 400 representatives from 131 U.S. and Canadian firms attended. Australian companies were briefed earlier in Sydney.

Another large gathering is expected at a bidders conference to be held May 20. A request for quotations was issued May 5. Sometime before summer's end, four large systems-oriented companies are expected to be selected to begin defining the system's design. This research work, with companies periodically being weeded out, will continue for about six years and ultimately cost more than $100 million.

Under terms of an earlier agreement of the participating nations, all four of the companies securing definition phase contracts will be American. But the Pentagon is encouraging teaming by the contractors. The likely result: each of the major contract holders will enter into joint-venture agreements with Canadian and Australian companies for part of the work, particularly in technique-support efforts.

Although the financial contribution of each participating nation hasn't been made public, it is understood that the combined Canadian-Australian share will not exceed $50 million for R&D and production. U.S. officials say contributions will be based on the size of a participating nation's army.

If Britain rejoins Mallard, the U.S. share of R&D outlays would be reduced by the amount that London puts up.

II. 'Regional AT&T'

Until the selected companies complete the research work scheduled for 1974, no one is sure exactly what the Mallard system will be like, except that it will be digital. But hardware components are certain to include automatic switches and all kinds of communications links, other than land lines which are being avoided because of the difficulties involved in protecting them. Tactical satellites, transmitting to relatively small vehicular-mounted receivers, will be used where it will be impossible or impractical to employ high-frequency, tropospheric-scatter, or line-of-sight links.

Present Mallard plans don't call for the replacement of existing manpack and vehicle radio sets in the VRC and PRC series. Mallard will only include the tactical trunk lines within a field army down to the brigade level. Deputy project manager John L. Faherty Jr. compares it to a "regional AT&T," stressing, however, that it's not a local system. Long-haul strategic links will still bring communications into the field army's area. The system will offer automatic switching to discrete addresses wherever the addressee happens to be, even when moving across country. Mallard is being designed to be compatible with other communications networks, including long-haul strategic and civilian systems.

Easy does it. Since officials want to be sure that Mallard can simply evolve, without causing undue disruptions to existing systems, it is being designed to be compatible with existing equipment. There has been no decision on which equipment should be replaced first. But a prime consideration of the contractors will be to design toward the modular or building-block concept.

Researchers are also taking great pains to insure that the system is compatible with other tactical communications and electronics programs already on Army's drawing boards. The Tacfire artillery command and control system, for example, is expected to use Mallard circuits to link its forward observers to the firing batteries. Mallard research efforts will also be closely coordinated with the Army's satellite communications terminal program.

The requirements for reliability and ease of transportation are expected to dictate the use of integrated circuits in most hardware components, but IC's are not being specified. To insure that the use of IC's will be considered, project officials are calling for an unusually thorough program definition that will involve learning what technology will be available when it comes time to manufacture the Mallard equipment—expected to start in the mid-1970's.

III. English-speaking union

The Mallard program evolved two years ago during meetings of the army chiefs of staffs from America, Britain, Canada, and Australia (the ABCA countries).

When officials started to discuss the project seriously, the U.S. was in the midst of plans to upgrade its analog communications system for use during the 1970's, planning to work toward a digital system by the early 1980's. Meanwhile, Britain was pressing for a system that would go directly into digital equipment.

After a series of talks, the U.S. agreed to go along with Britain for quicker deployment of the digital system. Canada and Australia joined the fold when they requested participation.

The ABCA countries are expected to be the only full partners in Mallard. Other nations—mainly from NATO—may join, but it appears improbable that the U.S. would share its cryptographic secrets with nations other than Britain, Canada, and Australia. Such sharing would be necessary for full partners.

America's Brig. Gen. Paul A. Feyereisen heads Mallard, which he calls the "world's largest tactical military communications effort." Feyereisen's project office at Fort Monmouth will operate with a management staff of probably under 100. But the organization will draw on the technical resources of the Army Electronics Command which is also located at the northern New Jersey post.

Serving on the staff of the International Joint Agency for Mallard are Australia's Lt. Col. L.G. Moore and Canada's Lt. Col. D.C. Coughtry. Feyereisen heads the program from Fort Monmouth.

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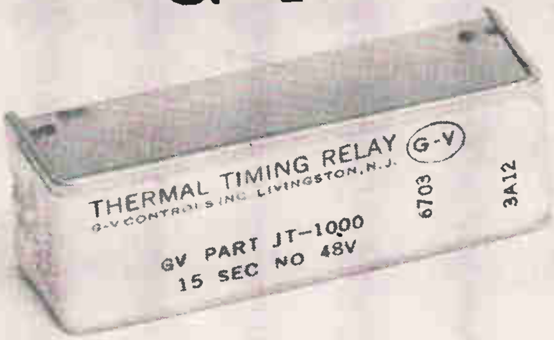

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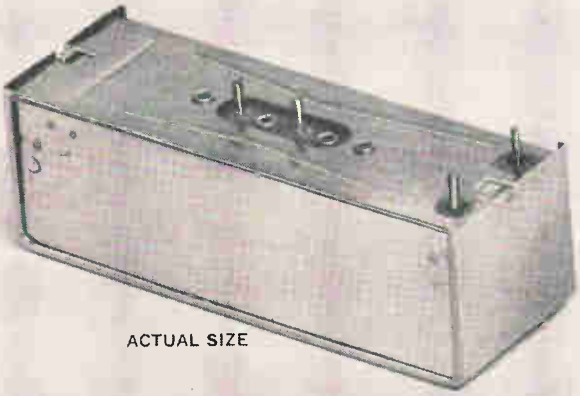

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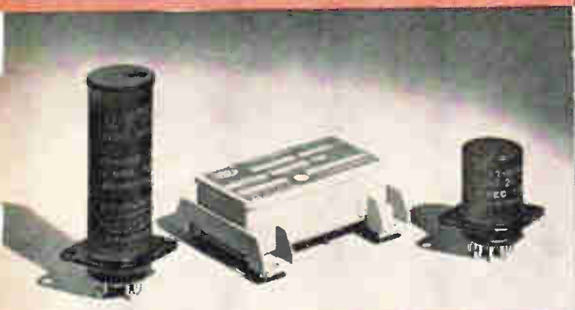

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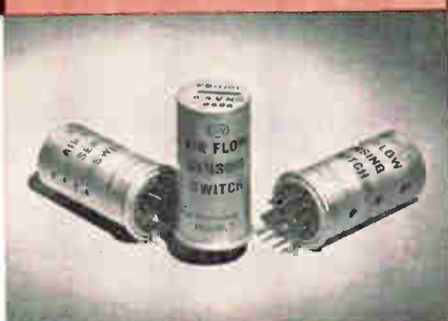

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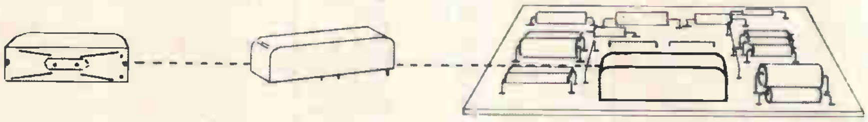

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with solid-state design . . .
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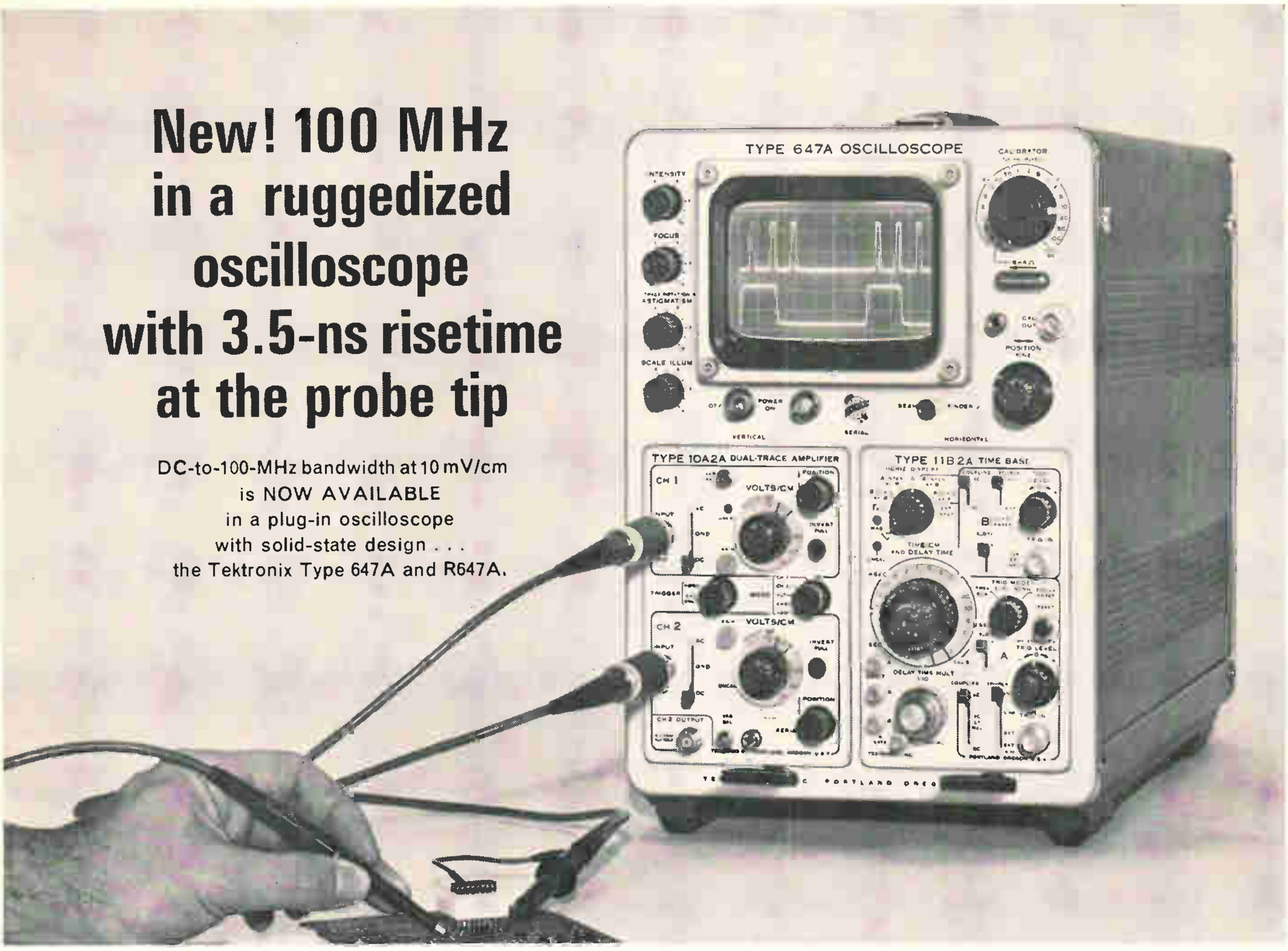

New Type 10A2A Dual Trace Amplifier. The risetime and bandwidth are specified where you use it — at the probe tip. The vertical system performance with or without the new miniature P6047 10X Attenuator Probe is DC-to-100 MHz bandwidth with 3.5-ns risetime at ambient temperatures of 0° C to +40° C (+32° F to +104° F). Bandwidth is DC-to-90 MHz with 4.1-ns risetime over its entire operating range, —30° C to +65° C. The calibrated vertical deflection range (without probe) is from 10 mV/cm to 20 V/cm.

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New Type R647A Rack Mount. The same DC-to-100 MHz performance also is available in a 7-inch-high rack mount oscilloscope, the Type R647A. Additional plug-ins include the Type 10A1 Differential Amplifier and the Type 11B1 Time Base.

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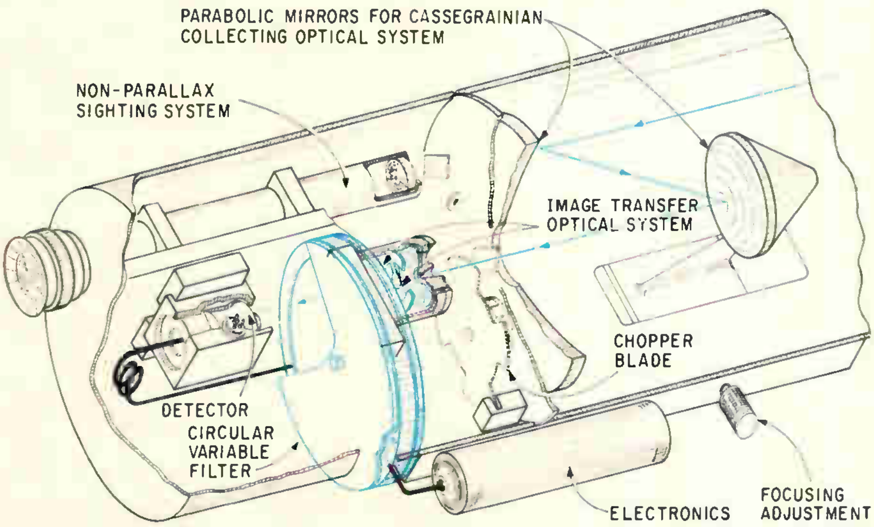


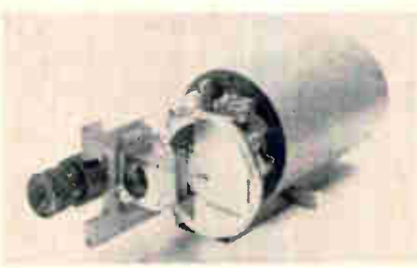
The key element in a spectral radiometer that makes continuous measurements of infrared radiation is a circular variable filter. This component is an optical interference filter whose transmission wavelength varies with the filter's angle of rotation.

Mark XIV radiometers, manufactured by Huggins Laboratories Inc., give readings of the intensity of each wavelength in the band. Previous instruments could not measure continuously and only made discrete measurements at several points in the spectrum.

Applications for the new radiometers include noncontact infrared testing of electronic circuits and mapping the spectral characteristics of aircraft and missile exhausts. The last is becoming increasingly important to the military in developing countermeasures against infrared homing missiles.

The radiometer is being used on the homefront in atmospheric, geological, and meteorological studies for the remote sensing program being conducted for the National Aeronautics and Space Administration, the U.S. Geological Survey, the Department of Agriculture, and the Naval Oceanographic Office. According to the chairman of the infrared section of the program, R.J.P. Lyon of Stanford University, the spectral radiometer provides information needed to analyze different rock types, vegetation, irrigation patterns, and terrain.

The Mark XIV's are basically Cassegrain instruments to which has been added the circular variable filter (CVF) developed by Optical Coating Laboratories Inc. of Santa Rosa, Calif. When the filter is at an angular position of 0°, its transmission wavelength is at a minimum. The transmission wavelength increases linearly to a maximum at 180° as the filter is rotated, and then decreases to its original value as the rotation continues to 360°. It is possible to put octave infrared bandwidths on smaller segments of the filter wheel, resulting in one-, two-, three-, or four-octave bandwidths at infrared wavelengths on only one CVF.



The Huggins instruments have a resolution to 1% or 2% at the center wavelength of the CVF. To achieve these results, the spectral response of the system's infrared detector is matched to the specific wavelength coverage of the filter being used. Huggins furnishes a selection of detectors—cooled and uncooled infrared detectors that cover a wide variety of wavelength bands, from a PbS detector for narrow band use from 1.5 to 2.7 microns, to a thermistor bolometer for wideband use from visible wavelengths to 27 microns.

Another feature of the radiometer is an optical system that maintains a constant energy incident on the filter wheel to eliminate the dependency of the instrument's calibration on the focus position of the secondary mirror. As the secondary mirror of a Cassegrain optical system is moved, the size of the beam on the first image plane tends to change. These changes affect the energy passed through the filter wheel. This image-transfer optical system therefore refocuses the beam on the filter wheel so that the size of the energy bundle is constant.

Since changes in the operating environment of room temperature infrared detectors cause noticeable shifts in the instrument's output, Huggins uses a power transistor as a controlled heat source to keep the detector's temperature constant. The temperature of the detector module is sensed by a thermocouple in a bridge circuit that sets the power transistor's dissipation level.

Aiming is done with a nonparallax sighting system that consists of a 45° mirror that is moved into the field of the radiometer. The visual image is then transferred onto an erecting lens with an etched reticle enabling that portion of the target being viewed to be precisely defined.

Prices for the Mark XIV series start at $8,500 for the standard thermistor bolometer instrument. The filter adds $3,000, $6,000, or $9,000 to the cost depending on whether it is a one-, two-, or three-octave wheel. Delivery is 45 days.

Specifications

Detectors available:	Wavelength range: (Microns)
PbS	1.5 to 2.7
PbS (77°K)	1.5 to 3.9
PbSe	2.0 to 4.5
PbSe (77°K)	2.5 to 6.0
InSb (77°K)	3.0 to 5.5
InSb	vis. to 7.5
Thermistor bolometer	vis. to 27

Huggins Laboratories Inc., 999 East Arques Ave., Sunnyvale, Calif. 94086. Circle 349 on reader service card

Hollow-beam tubes focus on new fields

Frequency of hollow-beam traveling-wave tubes has been pushed down to 200 megahertz, opening up additional applications for twt's in high-power uhf systems.

Microwave Associates says it is the only company making hollow-beam twt's. Others tried it several years ago, according to a company spokesman, but reverted to solid-beam tubes because suitable methods of magnetic focusing and other needed techniques were unavailable at that time. Microwave Associates, entering the market later, exploited newer focusing techniques and has been able to successfully build the hollow-beam tubes.

Chief advantage of a hollow electron beam is greater gain per unit length, according to the company. The new tube, which operates at 200 to 400 Mhz, is 3¾ inches in diameter and 32 inches long—roughly half the size of a conventional solid-beam tube of the same frequency.

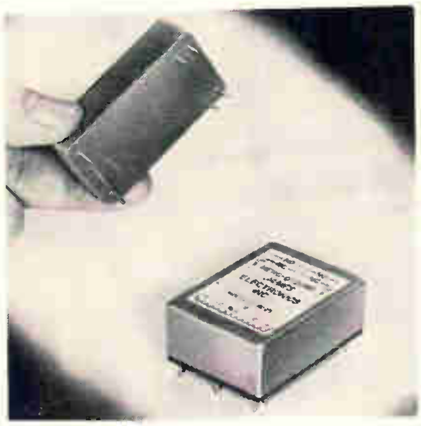
The tube, model MA-2015, has a continuous-wave power output of 1 kilowatt. It is intended for use in ground or airborne countermeasures systems, phased-array radar, communications links, and as a driver or intermediate-frequency amplifier in megawatt radar systems.

Microwave Associates' work on hollow-beam tubes began with an Air Force contract to determine the feasibility of a tube with a wide bandwidth in the frequency range of 300 to 900 Mhz. The company has since pushed the upper frequency to 4 gigahertz and is able to work out most tube design with a computer, avoiding much trial and error.

Microwave Associates Inc., Northwest Industrial Park, Burlington, Mass. 01803. **[350]**

New products in this issue

Mercury-wetted relays mount on p-c boards



Six 2pdt and 3pdt with sealed-mercury-wetted capsule high-speed relays have been introduced for p-c board mounting. Called Merc-O-Scan, they are designed for low- and medium-level switching applications. Typical uses include industrial process control systems, data acquisition, multiplexing, analog instrumentation, and sensing devices such as thermocouples.

Both the two- and three-pole configurations are of the double-throw, form-C type switch circuit with positive nonbridging action of the mercury element. The series 8000 relays are suited for switching rates up to 100 pps and signals as low as 1 μv. They are available in standard driving coil voltages of 6, 12, and 24 v.

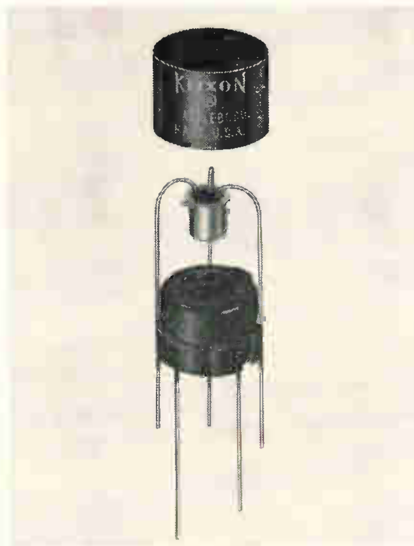
Among the chief electrical operating characteristics are low thermal noise generation (10% duty cycle, single circuit 0.5 mv); an operating life in excess of 20 billion operations when run with switching signals below 10 v and currents below 10 ma; a nominal power requirement for two-pole units of 325 mw and of 600 mw for three-pole. The relays can be driven from both solid state and mechanical sources and from periodic and aperiodic driving transformers.

The metal case of the nine-pin dpdt models C-8001, C-8002, and C-8003 measures $2\frac{1}{16}$ x ⅝ x $1\frac{3}{32}$ in. Case dimension of the 12-pin, 3pdt, models C-8025, C-8026, and C-8027 is $2\frac{1}{16}$ x ¾ x 1½ in. Each unit is supplied with ¼-in.-long gold-plated brass mounting pins for low thermal connection to p-c boards.

The price set for the 8000 series is $9 each in production lots and $26 each in sample quantities.

James Electronics Inc., 4050 N. Rockwell St., Chicago 60618. **[351]**

Uniform temperature in tiny component oven



Claimed to be the industry's smallest, a self-regulating component oven accommodates a TO-18 package. It cuts user cost by at least 50% compared to other temperature compensating arrangements, the manufacturer says. Since the uniform oven temperature keeps parameter changes to a minimum it can be used with inexpensive semiconductors.

Designated the Klixon 5ST1, the oven alloy is 0.570 in. in diameter and has a cavity into which the critical component is placed. It is available in either 80°- or 115°-C control temperatures.

The oven maintains the semiconductor in a near constant thermal ambient and provides uniform performance characteristics over a wide range of external temperatures, and supply voltages. Warm-up time in a −55°C ambient is

RCA integrated circuits

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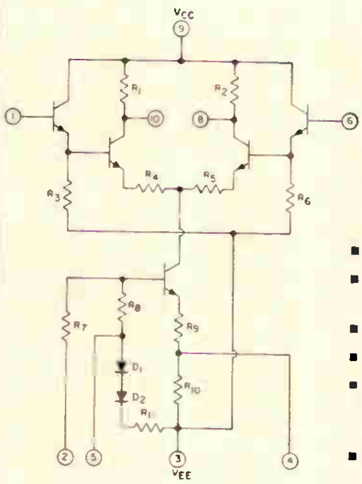
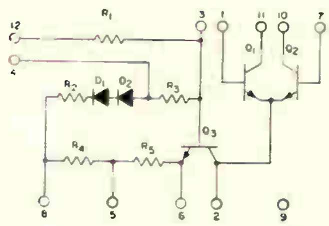
FROM DC



CA3000

- 37 dB Voltage gain (typ)
- 98 dB Common-mode rejection ratio (typ)
- 90 dB AGC range (typ)
- Push-pull input and output
- Temperature range stable operation from −55° to +125°C
- 10-lead TO-5 package

TO RF



CA3005

- 0-100 MHz operation
- 20 dB (typ) Cascode power gain @ 100 MHz
- 16 dB (typ) Differential power gain at 100 MHz
- 101 dB (typ) Common-mode rejection ratio @ 1 KHz
- −60 dB (min) AGC Range @ 1.75 MHz
- 12-lead TO-5 package

ECONOMY $2.95 (1,000+)

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ECONOMY $1.75 (1,000+)

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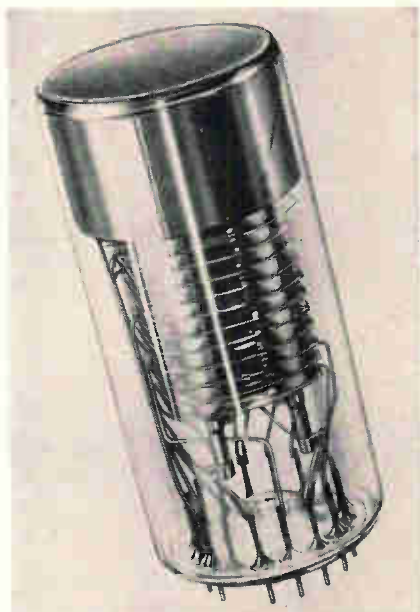
Circle 163 on reader service card

three minutes. Drive power is approximately 1 w at room temperature.

The semiconductors are merely slipped into the oven, and then a retaining cap or plug is placed over the assembly. A polycrystalline oven lining provides heating, sensing, and regulation. A stable thermal environment is maintained over an ambient range of —55°C to 115°C of control temperature. The oven reacts to thermal change and automatically restores the thermal equilibrium state.

Texas Instruments Incorporated, 34 Forest St., Attleboro, Mass. **[352]**

Photomultipliers have 10^{-9}-amp dark current



Recent advances in photocathode design have made possible photomultipliers with improved characteristics. According to the manufacturer, quantum efficiency has been almost doubled and now approaches 30%; the bialkali cathode has a sensitivity of 65 μa/lumen; and, when the tube is operated at maximum gain, the dark current is less than 10^{-9} amp. Spectral range is 3,400 to 6,500 angstroms, peaking at 4,000.

The new tubes are of special value in low light level applications such as scintillation counting with carbon[14], thermoluminescent dosimetry and spectrophotometry. They are 2 in. in diameter with optically flat end windows. The 11-dynode type VMP11/44K and the 13-dynode type VMP13/44K are immediately available.

The tubes are designed as plug-in replacements for conventional types and prices are comparable. Each tube is individually calibrated and warranted for 1,000 hours or 6 months.

Bailey Co., 5919 Massachusetts Ave., Washington 20016. [353]

23 chopper styles: versatile and compact

Electromechanical choppers have been introduced that supply the need for reliability in a small package. Illustrated are two of 23 stock container styles.

Low coil consumption makes these choppers desirable for battery-operated equipment. Using nonresonant armatures, they operate over a range from d-c to 600 hz. Contact ratings cover the entire range from dry circuit to 10 v d-c at 1 ma continuous, and 100 v d-c intermittent.

Units are available in practically any type of container, base, terminals, or coil lead attachments. For example, there are p-c board mountings, socket mountings, and flange-type mountings.

Base connections may be made to solder terminals or 4-pin or 7-pin plug-in configurations. Coil connections may be made to solder lugs or brought in through flexible leads, either permanently attached or removable with separable connectors.

For operation from d-c rather than a-c, there are transistorized drive units. Other accessories include Mu-metal hold-down shields and coil leads with separable connectors.

Stevens-Arnold Inc., 7 Elkins St., South Boston, Mass. 02127. **[354]**

Light modulator provides Q-switching

Precise, electronically controlled Q-switching at high repetitive frequencies is offered by a dual-crystal light modulator. The unit, a Pockels cell, can be used as a Q-switch, optical modulator, or shutter. It features low driving voltage and a high frequency response. Modulator performance is independent of temperature, because two electro-optical crystals mounted in temperature-insensitive crystal holders are employed.

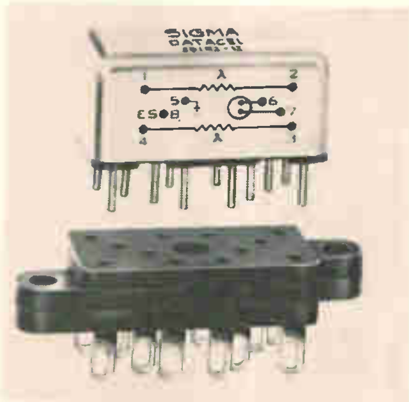
Commercial applications for the rugged, lightweight (approximately 2 lbs) device include image-projection, information-handling, print-out, and communication systems.

The modulator comes in two models. Type LPC-100 has an aperture of ¼ in. and a switching voltage of less than 1,000 v; it can be modified for use at infrared frequencies. Type LPC-101 has an aperture of ⅛ in. and a switching voltage of less than 500 v. The voltage ratings for each type are given at helium-neon wavelengths.

Both models are 3 in. in diameter and 4 in. long, with a contrast ratio of 200 to 1 and optical transmission of 90%.

Westinghouse Electric Corp., P.O. Box 868, Pittsburgh, Pa. 15230. [355]

Solid state relays use optoelectronics



Low-cost switching devices permit electrical isolation between input and output circuits with a lamp-to-photocell light-beam coupling. Insulation resistance is about 10^9 ohms with smooth turn-on and turn-off. Input and output voltages may be either a-c or d-c. Voltage gain is high, with signals as low as 6 v capable of controlling output circuits rated to 250 v.

Called the series 301 Datacels, the devices can control or be controlled by transistors, reed or electromechanical relays, or other Datacels. Functions include isolation interface switching, logic switching (AND/OR gate, inverter, and latch circuits), audio switching, multiplexing, and data sampling. It also provides feedback gain control and acts as a noiseless potentiometer.

Designed for high-density printed circuit packaging, the units occupy ¼ cu in. and weigh ¼ oz. Socket type AD32-1 converts all types for solder-terminal wiring. Apertures at each end permit visual checking of on-off states.

A miniature incandescent or neon lamp is coupled optically to one, two, or four photoconductive cells. Input signals of 6, 12, 24, or 150 v cause resistance to change from an off level of 10 megohms to an on resistance of less than 500 ohms. A switching ratio of 10^5 is achieved smoothly and without transient effects or bounce. Output cells are suitable for switching from millivolts to 250 v, and single cell power dissipation is as high as 500 mw. Response time for 150-v-input neon-lamp types is 5 msec for turn-on to 10 kilohms and 100 msec for turn-off to 100 kilohms. For 6-, 12-, and 24-v incandescent-lamp types turn-on time is 100 or 200 msec and turn-off, 300 to 700 msec, depending on input.

Depending on type and quantity, prices range from $2.30 to $7.40.
Sigma Instruments Inc., 170 Pearl St., Braintree, Mass. 02185. [356]

Transient-free switch eliminates arcing

The ordinary life of power transistors and other solid state circuits can be extended by a switch that eliminates power line voltage transients. Suitable for operating with currents from 0.1 to 50 amps, the switch eliminates high-frequency contact bounce, which prevents spike-deterioration and thus increases the reliability of any component with which it is used. Because the switch does not contain mechanical contacts arcing normally encountered in electrical circuits is completely eliminated.

Sensing the point at which the a-c line voltage goes to zero, the switch allows current flow only after the null voltage is reached, even though mechanical closing of the contacts takes place at another position in the a-c cycle. When the contacts are opened, the sensing element waits until the current through the load goes to zero be-

ELECTRONIC INNOVATIONS IN ACTION

New epoxy transistors

2N3605A

Electrically similar to the 2N914.
Price: 20 to 25¢ in volume.

V_{CBO} 40V	t_s .... 20nsec.
V_{EBO} 5V	t_{on} .... 35nsec.
V_{CEO} 15V	t_{off} .... 45nsec.
h_{FE} .... 30–120@I_C=10ma; V_{CE}=1V	
$V_{CE(SAT)}$ .... 0.25V @ I_C=10mA; I_B=1mA	

This is an excellent medium-speed saturated switch for computers and electronic calculators. These transistors offer low storage times and are available in sample quantities now.

2N5027

Electrically similar to the 2N2539.
Price: 20 to 25¢ in volume.

V_{CBO} 60V	t_d @ I_C=150mA .. 15nsec.
V_{CEO} 30V	t_r @ I_C=150mA .. 20nsec.
$V_{CE(SAT)}$ @ 150mA . 0.45V (max.)	t_s @ I_C=150mA .. 35nsec.
$V_{BE(SAT)}$ @ 150mA . 1.3V (max.)	t_f @ I_C=150mA .. 25nsec.

This transistor for medium-current, high-speed saturated switching is available in sample quantities as a core driver for computers. Take advantage of its superior h_{FE} linearity with current (50 @ 150mA min.).

2N4424

Good Beta linearity from 2mA to 100mA.
Price: 25 to 30¢ in volume.

BV_{CEO}	40V min.
I_C	400mA
h_{FE} @ 2mA	180–540
V_{CBO}	40V min.

This general purpose amplifier can add even more epoxy economies to auto radios, TV's, home radios and many other products.

2N5029

Electrically similar to the 2N2369.
Price: 20 to 25¢ in volume.

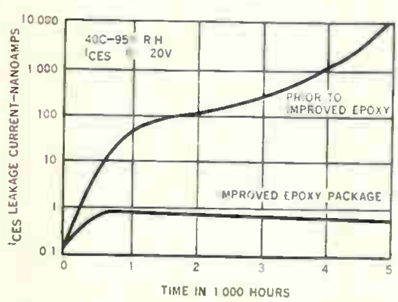
V_{CBO} 40V	t_d @ I_C=10mA .... 10nsec.
V_{CEO} 15V	t_r @ I_C=10mA .... 12nsec.
h_{FE} @ 10mA . 40–120	t_s @ I_C=10mA .... 12nsec.
	t_f @ I_C=10mA .... 14nsec.
$V_{CE(SAT)}$ @ 10mA .... 0.25V max.	
$V_{BE(SAT)}$ @ 10mA .... 0.87V max.	

Now: a high speed saturated switch in an epoxy economy package for computers.

All with the outstanding moisture resistance of GE's newest epoxy package

That's right. These four new NPN planar passivated silicon transistors are as reliable as the hermetically sealed devices you are using now. Yet they cost less than half as much. The reason is GE's newest innovation in epoxy packaging techniques.

General Electric's new epoxy package is far less moisture sensitive than other plastics; and it will improve performance at higher ambients and junction temperatures.



This is just one more example of the total electronic capability you get from General Electric. Call your GE engineer/salesman or authorized distributor for more information. Or write to: General Electric Company, Section 220-51, Schenectady, New York 12305. In Canada: Canadian General Electric, 189 Dufferin St., Toronto, Ontario. Export: Electronic Component Sales, IGE Export Division, 159 Madison Ave., New York, N. Y.

SEMICONDUCTOR PRODUCTS DEPARTMENT

GENERAL ELECTRIC

fore turning off the circuit.

Two models, RFS 115-5 and RFS 115-10, both suitable for operation at 110-125 v a-c, 60 or 400 hz, are rated at 5 and 10 amps, respectively. Special ratings are available on order from 0.1 to 50 amps.

Suitable for panel mounting in a ⅜-in.-diameter hole, the standard models measure 1.5 x 2.8 x 2.5 in., and weigh 11 oz.

Genisco Technology Corp., Genistron Division, 18, 435 Susana Rd., Compton, Calif. [357]

Inertial damped motor is tiny and rugged

A size 8 inertial damped servomotor is suited for high-gain or high-speed servosystem applications. Weighing only 2.6 oz, the component is totally enclosed within a single stainless steel housing measuring only 1.68 in. in length. A rugged and reliable 400-hz unit, the motor has two windings on the control phase, permitting either series or parallel operation. Stainless steel, high-precision bearings assure long, trouble-free service.

Other features of the CM40132 003 include: 115 v phase 1, 33 v phase 2 series input voltage; 1.1 v starting voltage; 0.29 in.-oz stall torque; 5,580 rpm no-load speed; 3.1 w/phase power input; 44.5 ma phase 1, 155 ma phase 2 series current input; 0.48 gm cm^2 rotor inertia; 48,500 rad/sec^2 theoretical acceleration; 0.014 sec time con-

Actual Size

YES, THIS NEW MINIATURE SWITCH ACTUALLY

BREAKS 7 AMPS AT 125 VAC

CARRIES 15 AMPS AT 125 V

Model 711 is a single-pole, nonshorting selector switch that reaches a new high in compactness. It's a load-break, power switch beyond any doubt, but with a 1⅛" body diameter, it is smaller than many instrument switches of much lower rating.

How can Ohmite cram such a whopping rating into such a small "package?" Only because the Model 711 reflects 25 years of experience in switches up to 100 amps. It's your guarantee for reliability and long life.

Small: Only 1⅛" in body diameter; extends 13/16" behind panel.

Breaks: 7 Amps, 125 VAC (75% power factor) load.
Carries: 15 Amps, AC or DC, 125 volts.

Contacts: Solid-silver-alloy to solid-silver-alloy; 2 to 11 contacts.

Dual-Purpose Terminals: Solder 'em, or push on a 3/16" quick-connect terminal.

Slow-Break, Quick-Make Action: Minimizes sparking and increases contact life with AC. Wiping-action contacts are self cleaning. 30° Indexing.

Superb Construction: Melamine-phenolic body has high insulation rating and resists arc-tracking. Unlike most small switches, thick conductors, not thin springs, carry the current. Stainless steel shaft, 3/8"-32 brass mounting bushing.

Singles and Gangs: Single decks can be supplied enclosed; gangs of two or more decks are enclosed. All mount on 1/8" thick maximum panels.

2-Gang Model

NEED SWITCHES UP TO 100 AMPS? Then write for Catalog 400. It covers nonshorting, power-type switches with load-break ratings from 15 to 100 amperes (2 to 12 taps) and an extensive line of unenclosed types with 2 to 77 taps. Many variations are described along with valuable information on switch selection.

Write for Bulletin 403

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Circle 171 on reader service card

stant; 196 dyne-cm-sec flywheel damping; and 4.6 gm cm² flywheel inertia.

The motor operates through a temperature range of —54° to +165°C, is equipped with color-coded leads, and has a pinion shaft. General Precision Inc., Kearfott Products Division, 1150 McBride Ave., Little Falls, N.J., 07424. **[358]**

Low distortion assured with power tetrodes

Two tetrode power tubes are designed for low-distortion linear amplifiers, (class AB) single sideband service. Both the 8679 and 8744 tubes feature high linearity and guaranteed minimum intermodulation distortion. Both are of ceramic and metal conical type construction and cooled by forced air. The construction provides high mechanical strength, low inductance electrode connections, and low thermal resistance paths for effective cooling of the electrodes. Special temperature compensating materials have been incorporated to insure uniform characteristics with changes in operating temperature.

The 8679 has an oxide coated cathode and can dissipate 4 kw. Under class AB conditions it produces 5 kw peak envelope power (PEP) output at a 3d order distortion level of ≦40 db, while the 5th order products are down at least 45 db. At frequencies of 30 Mhz, these figures are ≦—38 and

VERSATILE

You name it

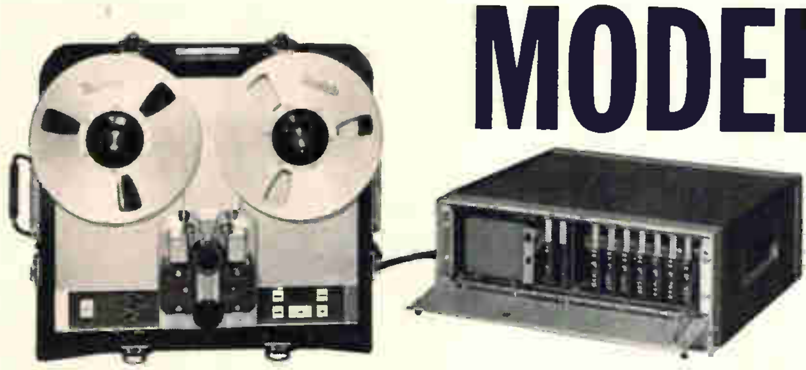
CAPABLE

The Paul Bunyan of 3M Recorders

AFFORDABLE

We're almost ashamed of the low price

MODEL 34



VERSATILE—With direct frequency response to 600 kHz, and IRIG FM to 80 kHz, the Mincom Model 34 does many things in many ways. Rack-mounted or in easily portable carrying cases. $\frac{1}{4}$, $\frac{1}{2}$ or 1-inch tape. $10\frac{1}{2}$-inch or 7-inch reels. Speed options: $\frac{15}{16}$, $1\frac{7}{8}$, $3\frac{3}{4}$, $7\frac{1}{2}$, 15, 30, 60 or 120 ips.

CAPABLE—Practically the only thing that's *not* an option is 3M quality—that's standard on all configurations of the Model 34. Starting with the Isoloop Drive® on the tape transport (the same as on recorders costing several times as much), Model 34 can record 7 or 14 channels of the cleanest data for over twelve hours. All types of record/reproduce modules are interchangeable, allowing any channel combination desired. Push-button controls. Dynamic braking in all modes. Fail-safe braking for AC failure. End-of-tape sensing. Solid state electronics. Input/output meters.

AFFORDABLE—As you can see, there are a lot of different ways to configure a Model 34—and there are just as many prices.

But this we can be definite about: Model 34 is *the* recorder for people who've always wanted 3M quality—but couldn't afford it *before*. Give us a call.

Revere-Mincom Division 3M COMPANY
300 SOUTH LEWIS ROAD • CAMARILLO, CALIFORNIA 93010

Circle 173 on reader service card

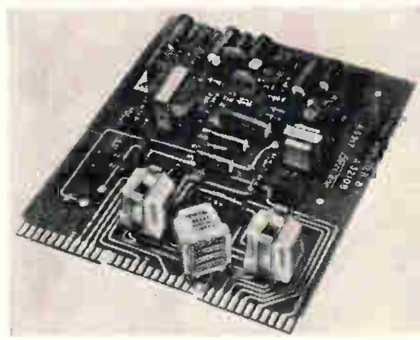
≦—43 db respectively.

The 8744, having 10 kw of plate dissipation, utilizes a thoriated tungsten cathode and produces 10 kw PEP output with a corresponding d_3 and d_5 of ≦40 and ≦38 db respectively. At frequencies of about 30 Mhz these figures are —36 and —45 db.

Electrical specifications for the 8679 and 8744, respectively, are: plate voltage, 5,000 and 6,000 v; two-tone plate current, 1.3 and 2.4 amps; grid No. 1 drive voltage, 160 and 250 v peak; two-tone power output, 5 kw and 10 kw PEP.

Amperex Electronic Corp., Hicksville, N.Y., 11802. [359]

Plug-in relay affords switching versatility



Four-pole standard and latching magnetic relays can switch up to 4 Form A (make) plus 4 Form B (break) in separate circuits, or up to 4 Form C (transfer) contacts, or any combination thereof. The switching versatility of the Printact relay eliminates the need to stock a variety of different units and cuts costs. Among other savings claimed for the relay are space, weight and production time.

Contacts on the rocking armature of the Printact relay mate with rhodium or gold-alloy over nickel-plated fixed conductors on the p-c board module, an arrangement that eliminates sockets and soldering.

More than seven different combinations of switching arrangements can be achieved with a single relay. A variety of suggested configurations and stick-on conductor patterns for a custom p-c

New Components

board layout are provided by the manufacturer.

With an estimated mechanical life of 100 million cycles, reliability test results for the relay indicate a 10-million-cycle meantime-between-failures rate from dry circuitry to ¼ amp, with proportionately good ratings for up to 2-amp resistive loads.

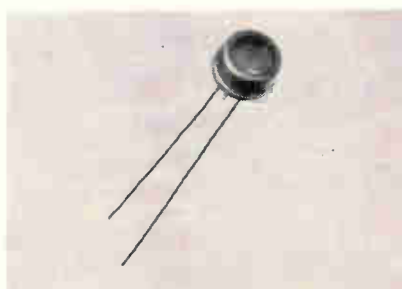
Coils are available for 6, 12, and 24 v d-c. Standard Series G and single-coil latching Series LS relays require 320 mw to pull in at 80% of rated voltage. Double-coil latching relays, Series LD, require 800 mw to pull in at 80% of rated voltage. Operate time is 10 msec max at rated voltage, and temperature range is −30° to +95°C.

The balanced armature of the standard Printact relay resists shock and vibration in excess of 30 g.

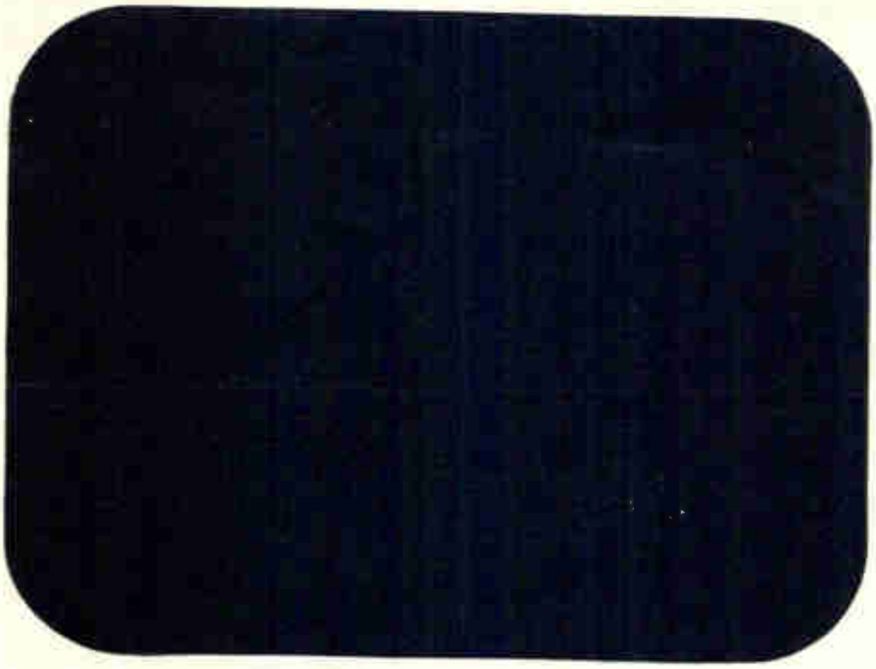
Encapsulated coils offer protection against galvanic action and corrosion. Double-break contact, enclosed housing, snap action and the use of permanent ceramic magnets to eliminate return springs and mechanical linkage are other features of the device. The coil and motor assembly is molded in a ⅞-in., high-impact plastic cube. The relay, with moving armature and mounting clamp, weighs less than 1 oz.

Executone Inc., Printact Relay Division, 47-37 Austell Place, Long Island City, N.Y. 11101. **[360]**

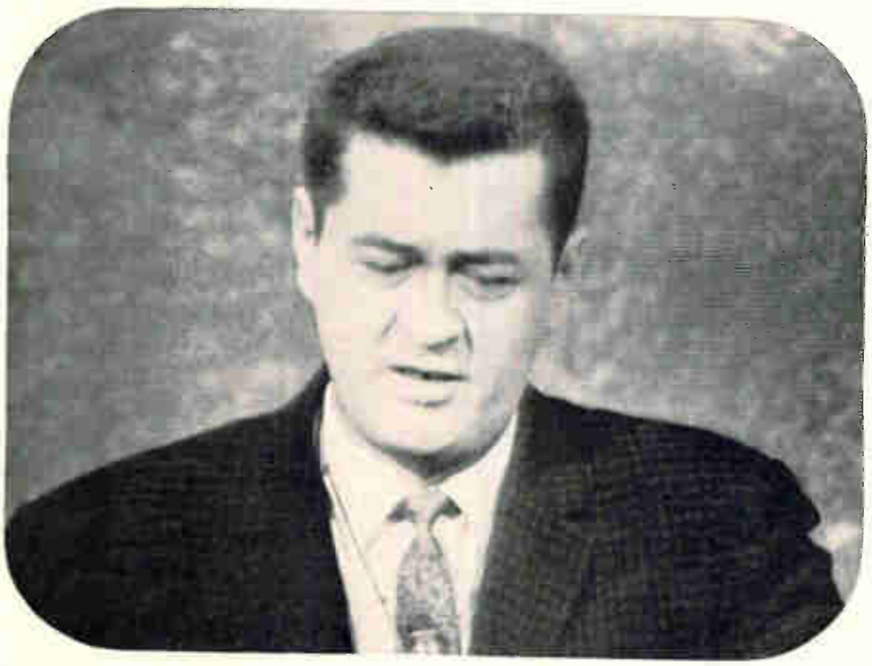
Resistive photocells are fast and stable



Resistive photocells combine cadmium sulfide and cadmium selenide to achieve the high stability of



Cold camera



on the air in 30 seconds at WBAL-TV.

The MTI Image Orth is a problem solver at WBAL-TV in Baltimore. Crash news programs can be on camera in seconds with a flick of the switch. No need to interrupt camera crews who might be in the middle of a taping session. Operational set-up is minimal too. Here's how WBAL-TV makes use of the MTI Image Orth.

Camera is aligned and locked in fixed position in a small announce booth studio. Few lights are used due to the excellent low-light capabilities of the camera. And as a result, no additional air conditioning facilities are required. While desk and chair are fixed furnishings, backdrop can be quickly changed to fit any presentation situation.

WBAL-TV engineers claim camera needs little maintenance, has good depth of focus and needs trimming only once per week. Low light levels do not affect picture quality.

You might have other uses for a camera of this size and quality. If so, give us a call. We'll have a sales engineer to see you quickly—but not as quickly as the MTI Image Orth warm-up period.

mti MARYLAND TELECOMMUNICATIONS, INC.

York & Video Roads, Cockeysville, Md. / 301-666-2727 / World's largest manufacturer of low light level television cameras.

one with the fast decay time of the other. The cells are designed for photochopper service in sensitive low-level d-c amplifiers and instruments, but are also useful in other switching and control circuit applications.

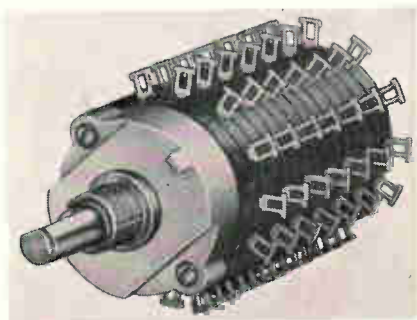
Dark resistance of all the photocells in the 4600 series is typically 500 megohms. Light resistances of 4,000, 10,000, and 100,000 ohms are available. Typical decay time is 1.2 msec (time for resistance to change by a factor of 10 when illumination is removed). The cells are useful in choppers operating at rates up to 500 hz and achieve chopping efficiencies of 95%. Peak spectral response is 6,550 angstroms, making the cells sensitive to neon glow lamps and incandescent lamps.

The photocells are hermetically sealed in a TO-5 package. Maximum permitted voltage (case to leads) is 200 v. A transparent conducting layer on the window is available optionally for shielding a cell from electrical transients generated by switching the illumination.

Prices begin at $2.90 in quantities of 1 to 9, and $2.45 in quantities of 10 to 99. Electrically shielded units cost 15 cents more each. Delivery is from stock.

HP Associates, 1501 Page Mill Road, Palo Alto, Calif. 94304. [361]

Rugged rotary switch for all environments



Completely enclosed to guard against exposure, contamination, and production damage, a 1⅛-in.-diameter rotary switch is designed for confined space applications. Corrosive atmospheres, dust, dirt,

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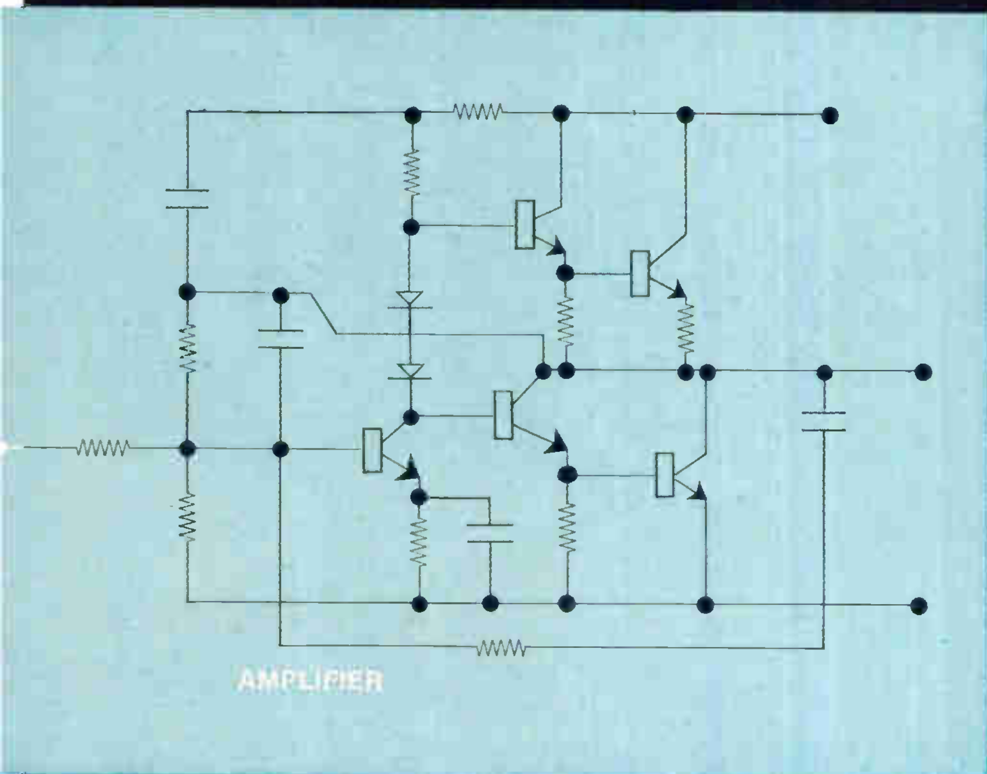

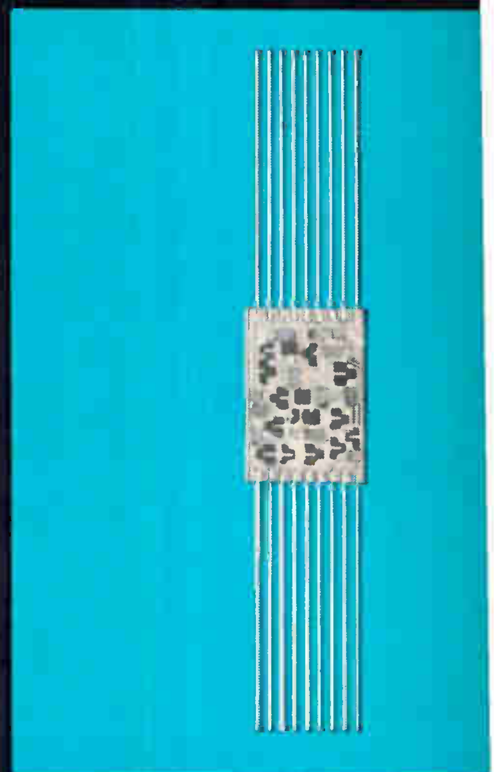

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Circle 179 on reader service card

and moisture are permanently sealed out. Solder and solder flux cannot get into vital switch parts. Rugged one-piece terminals and contacts, precision molded into impact grade thermosetting plastic, are locked into position and will not move even under extreme soldering heat.

Reliable and long-life switching, with low and consistent contact resistance, are assured with a unique mode of switching, the company says. Complex switching arrangements, with intermixed shorting, and nonshorting, are now attainable not only on single sections but also between sections.

Additional features include spacers, intersection shields, dual concentric switches with attached line switches or potentiometers, binary coded switches and high voltage switches.

Stackpole Carbon Co., St. Marys, Pa. 15857. [362]

Antibounce bracket in 10-amp relay

Elimination of armature bounce is claimed for an antibounce bracket now incorporated in a 10-amp, crystal-can relay. This development substantially reduces total bounce time, and greatly increases relay stability, particularly while undergoing shock and vibration, according to the manufacturer.

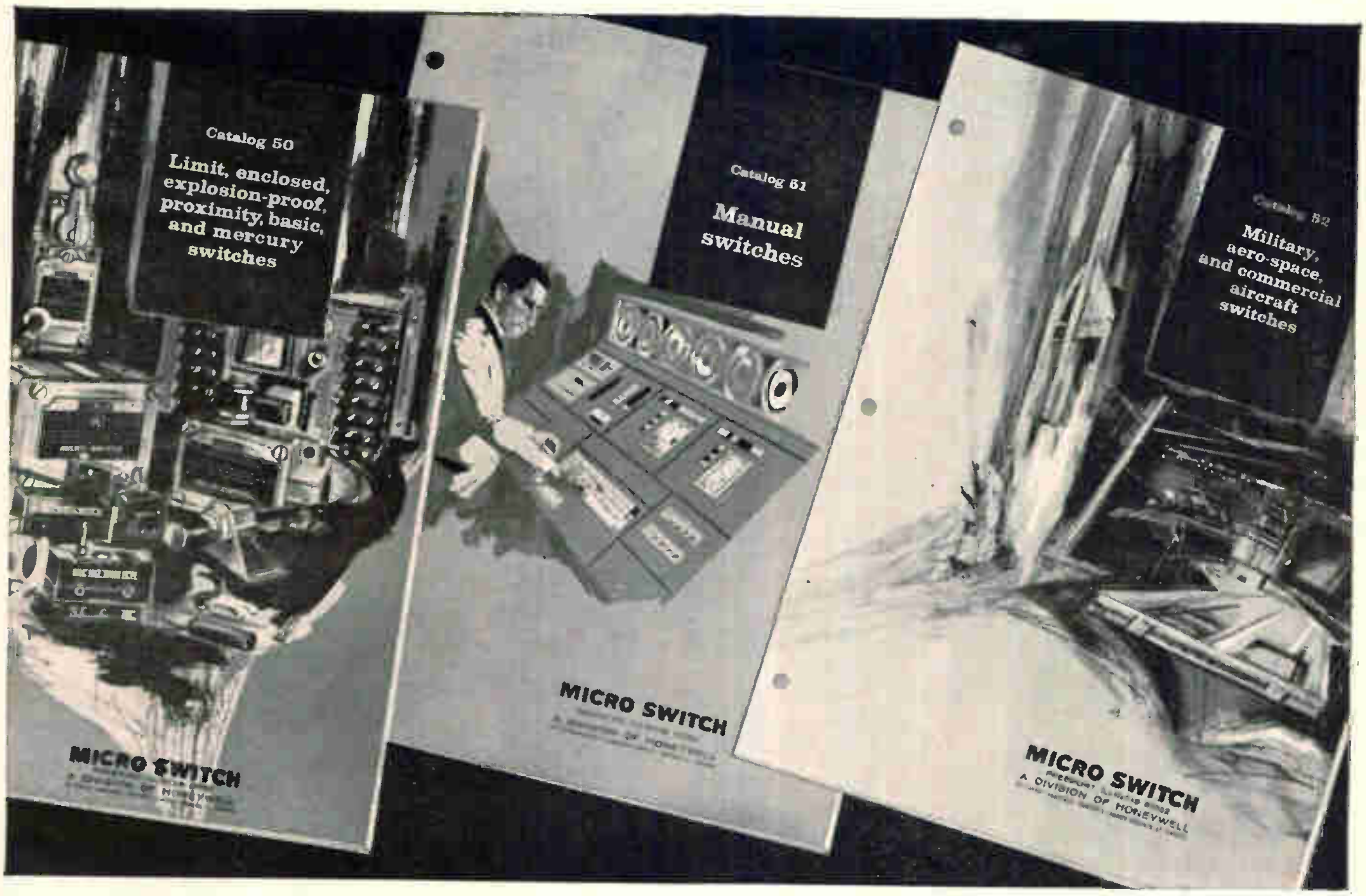
The relay—called the BR7—is designed for critical aerospace applications. It provides dry-circuit switching to 10 amps. The relay withstands shock to 100 g (11 msec) and vibration to 30 g. Operating temperature is —65° to +125°C, and life is 100,000 operations minimum at a load rated at 125°C. Units are offered for both a-c and d-c operation.

It is available in a wide range of pole combinations, contact ratings, terminal styles, and mounting arrangements.

The unit meets the requirements of MIL-R-5757.

Babcock Relays, Division of Babcock Electronics Corp., 3501 Harbor Blvd., Costa Mesa, Calif. 92626. [363]

Have you got these latest switch reference guides?



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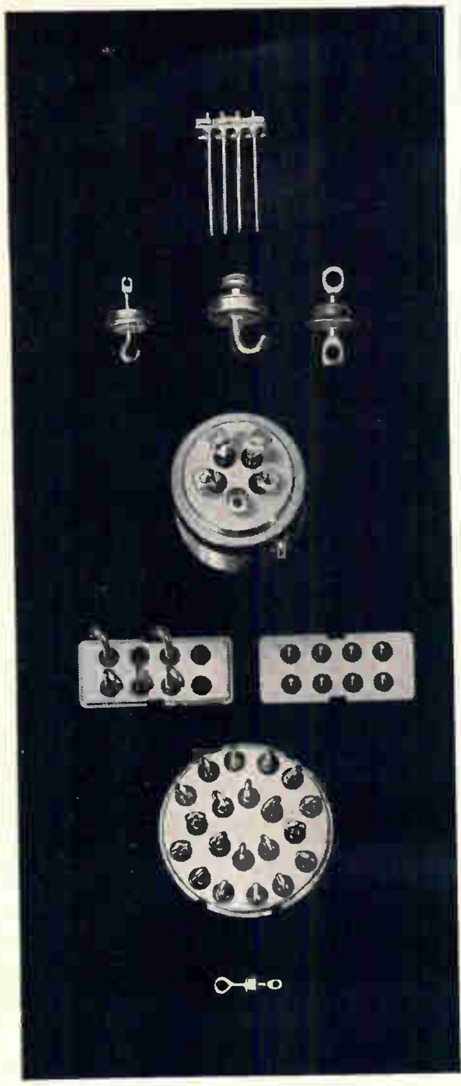


New Semiconductors

Compact, versatile Darlington amplifiers

Useful in military and aerospace applications, a 10-amp silicon Darlington amplifier series in ¾-in. flat-packs is also adaptable to many commercial and industrial circuits.

Designated the SDM 2300 series, the devices have a minimum gain of 2,000 at a collector current of 5 amps with collector-emitter voltage of 5 v. Under the same conditions, base-emitter voltage is 2 v maximum. The saturation voltage (V_{CE}) of the units is 1.5 v maximum at a collector current of 5 amps and a circuit gain of 500. Leakage currents are typically in the nanoampere range for both collector-base and emitter-base current.

The SDM 2300 series features sustaining voltage from 40 v to 100 v, collector-base breakdown from 60 v to 125 v, and emitter-base breakdown of greater than 15 v. Typical gain is 50 when measured at 5 Mhz.

Solitron Devices Inc., 1177 Blue Heron Blvd., Riviera Beach, Fla. **[364]**

Pnp's, npn's stacked for high voltage

A combination of four pnp and npn high-voltage transistors are now being stacked in one TO-5 package. The units can be used for high-voltage switches and solid state relay circuits.

The space savings afforded by incorporating four transistors in one package would be attractive to firms that normally series-stack conventional transistors to reach a required voltage.

Voltages up to 2,000 v (collector to emitter) are obtainable—1,000 v for the pnp, and 1,000 v for the npn. This is the first time, the manufacturer claims, that high voltage pnp and npn transistors have been combined in the same package.

The 10-pin units can be customed to specific voltage requirements compatible with standard hybrid IC computers. For example, two lower voltage standard units could be combined with two h-v transistors, or three lower-voltage standard units could be combined with one h-v transistor.

To manufacture its four-in-one package, the maker uses one metalizing pattern on a ceramic disk. Each disk could accommodate two transistors in the Darlington amplifier configuration. This is often useful in series stacking of h-v transistors. Each base lead is accessible to outside connections.

Industro Transistor Corp. 35-10 36th Ave., Long Island City, N.Y. 11106 **[365]**

CdS photocell rated at 2,000 v

A cadmium sulphide photoconductive cell will find its main application in illumination controls operating at higher voltages such as 220 or 550 v a-c. Yet its low capacitance and high voltage rating may lead to new applications in such areas as h-v power supplies and video attenuators. The new device has a resistance of 10,000 ohms ±40% at 35 footcandles; dark resistance, 100 megohms; maximum voltage, 2000 v peak; maximum dissipation, 1.0 w; capacitance in the dark, 5.0 pf; spectral response, similar to the human eye.

The device, type NSL-1682, is hermetically sealed in a metal and glass case with a 1.1-in. body diameter, 1.25-in. flange diameter, and 0.250-in. height. Its leads are 0.040 in. in diameter, 0.500 in. long.
National Semiconductors Ltd., 2150 Ward St., Montreal 9. **[366]**

Silicon rectifiers rated at 300 amperes

Several manufacturing refinements incorporated in a series of 300-ampere silicon rectifiers include improved materials, assembling techniques, and advanced junction processing. The new devices are supplied in the DO19 package.

The series 300U offers a maximum nonrepetitive peak reverse voltage rating of from 100 to 1,600 v and a maximum repetitive prv rating of from 50 to 1,200 v. Units are available with standard polarity (cathode to stud) or reverse polarity (anode to stud).
International Rectifier Corp., 233 Kansas St., El Segundo, Calif, 90245. **[367]**

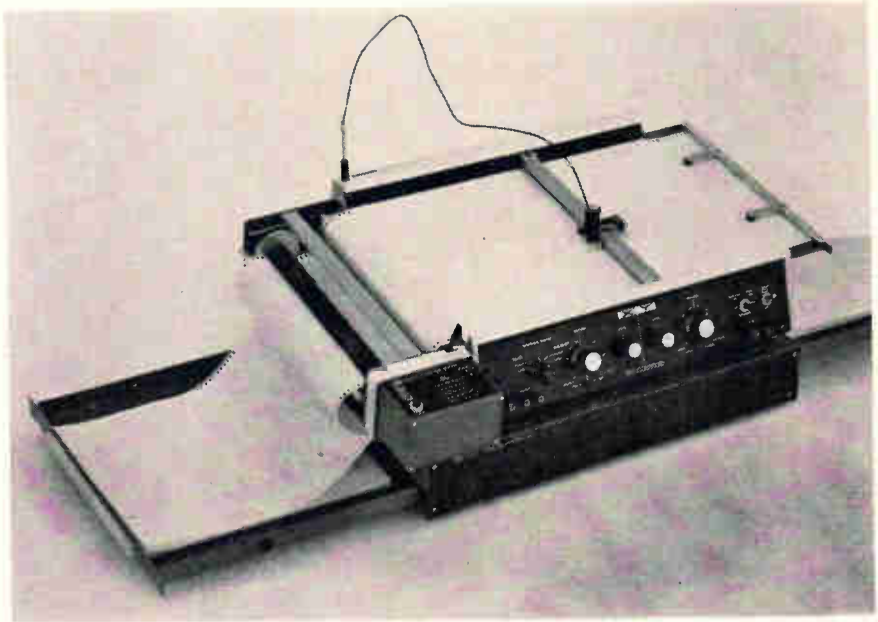
Photodetector with fast response time

A photodetector with standard transistor mounting in a low-profile TO-5 can has been designed for a wide range of radiation-detection systems. Applications include laser, spectrometer, and pattern-recognition systems, star trackers, and light waveform and color-detection systems. The PIN-5 covers three times the wavelength of a photomultiplier, and has a short wavelength response that can't be obtained with ordinary silicon p-n detectors, according to the manufacturer.

Response time of the unit is measured in nanoseconds; it's said to be faster than any other solid state detector type, as fast as a photomultiplier, and 100 times faster than ordinary silicon p-n devices.

Response runs from the ultraviolet to the near infrared range; detectivity is as large as lead sulfide.
United Detector Technology, P.O. Box 2251, Santa Monica, Calif. **[368]**

Paper advance steps up x-y recorder uses



With a new automatic paper advance unit, x-y recorders can be made to perform many other functions besides x-y plotting. The unit allows the recorder to operate in three different modes: incremental paper advance, continuous strip-chart action, and frame-by-frame paper advance, a new mode.

In the incremental advance mode, the 17005A, manufactured by the Hewlett-Packard Co.'s Moseley division for its 11 x 17-inch recorders, uses the input signal pulses to trigger the automatic paper drive. The paper moves ahead in a predetermined increment after each pulse. This feature is particularly useful in nuclear measurements, where pulses occur at variable intervals. In such measurements, it is undesirable either to waste paper by moving it continuously or by not moving the paper at all and allowing pulses to plot over each other.

The size of the step—from 0.005 inch to 0.01 inch—is set by a circuit consisting of a unijunction transistor oscillator, gating circuitry, a ring counter, and a stepping motor. The ring counter has four stages that correspond to the four windings on the motor. The oscillator operates at a frequency set by the variable resistor in its RC network. The gating circuitry—two transistors and a silicon controlled rectifier—allows the oscillator to drive the stepping motor for a preselected number of steps.

The incremental advance supplements the continuous advance mode by expanding the data chart for more detailed analysis.

In the continuous advance mode, the chart paper moves an entire 17-in. frame at a time. This mode enables the recorder to act as a large-scale strip-chart recorder. Chart rates range from 0.01 to 1 inch per second. In continuous drive, the trigger input and gate are eliminated, and the oscillator drives the motor directly. Speed is set by the variable resistor.

Chart paper can be fed from rolls or fan-folds. The rolled paper unit is priced at $895. The device can be retrofitted to most of the Moseley line.

Moseley Division, Hewlett-Packard Co., North Fair Oaks Ave., Pasadena, Calif. 91102. [371]

Pressure transducer provides high output

Accuracy and a high output are combined in a semiconductor pres-

sure transducer designed for aerospace applications. The type 4-420 has an output range of 250 mv d-c for an excitation voltage of 10 v d-c or a-c rms. Units come with integral electronics for an output of 0 to 5 v d-c and an isolated input of 28 v d-c. Weight is less than 3 oz.

Specifications of the unit include linearity and hysteresis accurate within 0.15%, and temperature compensation from 0 to 200°F, with a thermal sensitivity shift of less than 0.010% per °F over the compensated range.
Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif. [372]

A-c power recorder shows voltage, current

A portable power tester and recorder handles voltage, current, or both. The instrument features a time-sharing system that permits the stylus to record independent traces for both voltage and current. This system provides full chart-width resolution with voltage plotted as a continuous trace and current as an interrupted trace for easy identification.

A dual concentric switch selects a-c voltage ranges of 0 to 150, 0 to

300, or 0 to 600 v, and a-c current ranges of 0 to 15, 0 to 30, 0 to 60, or 0 to 150 amps. The model 113B can be calibrated for any frequency from 50 to 400 hz. Accuracy of each parameter is 3% of full scale, the manufacturer reports.

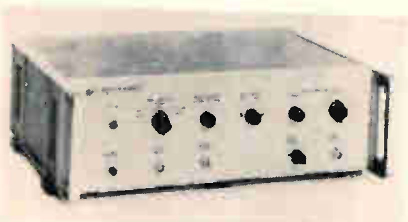
The unit is equipped with a convenient carrying handle that can be used as a tilting support for easy viewing. Clip leads for voltage and a clamp-on transducer for current are furnished with each instrument, and there is a storage compartment on the rear of the case.

The standard chart speed is 1 inch per hour, producing a 30-day record on a roll of chart paper. Other chart speeds are available on order.

The recorder measures 7¼ x 5⅝ x 7½ in. and weighs 6 lbs. Price is $205.

Rustrak Instrument Co., Municipal Airport, Manchester, N.H. 03103. [373]

Pulser furnishes nsec rise time



Pulses with rise and fall times less than a nanosecond are supplied by a new pulse generator. The unit is suitable for testing state-of-the-art oscilloscopes, broadband amplifiers, high-speed solid state switching circuits, nuclear instruments, coaxial cables, (by time domain reflectrometry) and other analog circuits.

Overshoot and ringing on leading edges are less than 3% of pulse amplitude (6% on trailing edges). Pulse tops are flat within 2%. Pulse amplitude is continuously variable from 0.04 v to 10 v across 50 ohms. Polarity can be either positive or negative with respect to ground. Pulse width is also continuously variable, from 100 nsec to 500 nsec, and jitter is less than 100 picosec.

Pulse repetition rates between 100 hz and 200 khz are generated internally. The pulser can be triggered externally at rates from zero to over 200 khz; a countdown circuit allows locking to external frequencies up to 10 Mhz. For single pulses, there's a front-panel pushbutton.

Oscilloscopes, counters and the like can be triggered by the pulser's trigger output. The main pulse can be moved anywhere from 100 nsec ahead of the trigger pulse to 300 nsec after it.

Tests for double-pulse resolution, narrow-pulse impulse, and pedestal linearity can be made by combining the outputs of two pulsers in a model 1504A pulse adder. One adder is furnished with each pulser.

Model 8001A is 5½ in. high and can be mounted in a 19-in. rack. It weighs 17 lbs. Price is $990; delivery from stock.

Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif. 94304. [394]

Go-no-go tester checks transistors

A go-no-go type, battery-operated instrument determines whether transistors are operational or faulty. Model 20 will show, in two steps, whether the transistor type is npn or pnp, if it is operating properly, and its d-c beta.

Checking is accomplished by setting two controls—a slide switch and a knob. The nature of the transistor fault, whether an open or shorted junction, is interpreted from the meter reading. Open or shorted junctions on diodes and rectifiers are also determined by the model 20.

The transistor checker's small size and battery operation suit it for many work areas while the low cost makes it practical to have permanently stationed units. Since the battery is used only when a semiconductor is being tested, battery life approaches shelf life.

Among the applications for the model 20 are: troubleshooting breadboards and prototypes; manufacturing tests; component inspections, and maintenance and repair activities.

Price in small quantities is $19.95.

Lucci & Co., 3216 Clark Road, Sarasota, Fla. 33581. [375]

Time interval counter spans wide range

Time interval such as pulse length, pulse spacing, and time between electrical events can be measured by a wide-range counter that features d-c level gating. Measurements of from 10 μsec to 100,000 seconds are possible. Model CF-530R has start-stop d-c levels which are adjustable from +30 to −30 v with ± slope control. A switch is provided for single-line or two-line gate inputs.

Display is furnished by long-life, wide-angle Nixie tubes with range and lighted decimal point selected by front-panel switch. Digital readout may be displayed for an adjustable interval or the display may be held indefinitely until reset.

Designed for either rack or bench mounting, the unit measures 1¾ x 19 x 13½ in. The unit with five digits is priced at $845.

Anadex Instruments Inc., 7833 Haskell Ave., Van Nuys, Calif., 91406. [376]

Lightweight, portable vector voltmeter

A portable, battery-operated vector voltmeter can test control systems where common line voltages may be unavailable.

Standard type-D flashlight cells

Circle 189 on reader service card

New Instruments

provide the power for all transistorized circuitry. Model 300PB measures in-phase voltage, quadrature voltage, true rms voltage, and phase angle. It operates over a wide frequency range, and rejects noise and harmonic voltages without the use of filters.

Specifications include a frequency range of 50 hz to 10 khz; a voltage range of 1 mv to 300 v full scale; accuracy, ±2% to full scale; input impedance, 1 megohm shunted by 20 pf; reference voltage, 0.4 to 130 v rms; phase angle range, 0° to 360°; phase angle accuracy ±1%; noise and harmonic rejection, 40 db down (without filter); crest factor (for rms measurement), 3; size, 7 x 9¼ x 7¼ in.; weight, approximately 9 lbs.

Industrial Test Equipment Co., 20 Beechwood Ave., Port Washington, N.Y. [377]

Plug-in counter-timer is small and reliable

Use of IC's provides top reliability and compactness (3½ in. high) in a 125-Mhz mainframe plug-in counter-timer. The mainframe has built-in programability. Additional features of the 1500A are adjustable trigger lever, overflow and gate indictators, and provision for a 100-hz to 10-Mhz external time base.

Plug-ins for the 1500A are the 1102A preset unit priced at $645; the 1103A converter, with a frequency range from 50 to 500 Mhz, priced at $495; and the 1104A converter, with a frequency range from 300 Mhz to 3 Ghz, priced at $795. Additional plug-ins will be announced.

Price of the 1500A mainframe is $2,850.

Monsanto Co., 620 Passaic Ave., West Caldwell, N.J. 07006. [378]

New Subassemblies and Systems

Servopower amplifier in modular design

Designed for control of direct-drive d-c torque motors, a modular 300 watt d-c servopower amplifier has a full-output bandwidth of 1,000 hertz.

The amplifier, known as 300B Hyband, includes a high-gain operational preamplifier, with negative voltage internally generated. The amplifier operates directly from a +28 v d-c supply. An internal plug-in board provides for custom preamplifier compensation.

Protective circuitry includes a current-limiting adjustment effective over ±15 amps, and a thermal trip circuit that opens if baseplate temperature exceeds 95°C. The amplifier contains a detachable heat sink and fan assembly, permitting versatile packaging arrangements.

Amplifier dimensions are 5.5x2.5 x4.9 in. without the heat sink assembly, and 5.5x5.5x4.9 in. including the sink assembly.

Inland Controls Inc., 342 Western Ave., Boston, Mass. 02135. [381]

D-c/d-c converter stingy with losses

Suitable for airborne and ground-based applications, a d-c to d-c voltage power supply (converter) is all solid state and permits doubling of voltages over a range of 10 to 18 v input. Power loss is very small.

The unit, designated FR-0004, operates efficiently under varying load conditions and provides up to 500 ma of current. A mean time between failures of 50,000 hours is another feature. Operating temperature range is —22° to +185°F.

The converter measures 1 in. square x 2 in. long and weighs less than 3 oz.

Fairchild Controls Division of Fairchild Camera & Instrument Corp., 225 Park Ave., Hicksville, N.Y. 11802. [382]

Incremental plotters are fast and accurate

The first of a new family of incremental plotters operates at 800 steps per second. The series features high speed and accuracy, with a resolution up to 0.0025 in. According to the manufacturer, this increase in incremental performance will extend the use of digital plotting for applications previously requiring high-precision drafting systems.

Series models 8125 and 8325 feature an 0.0025-in. step size. Models 8105 and 8305 feature 0.005-in. step size. All models use a technique that the manufacturer calls Delta Control Logic to save computer overhead costs. This technique generates multiple plotting commands from a minimum of digital input. Over an average run of plotting applications, it saves from 50% to 90% of computer write-time. By shrinking plotter command lists, the same principle also reduces input media.

The 8000 series operates on-line with computer, multiplexed to a time-sharing system, or off-line with magnetic tape input. Used off-line, the plotters accept either 7-track or 9-track magnetic tape.

Plotter output formats can be produced up to 30 in. in width, 120 ft in length.

The line is supported with field-proven software, including comprehensive 360 programing.

Purchase price is $38,000. Lead time on delivery is 90 days.
Benson-Lehner Corp., 14761 Califa St., Van Nuys, Calif. [383]

Data set transmits over low-cost lines

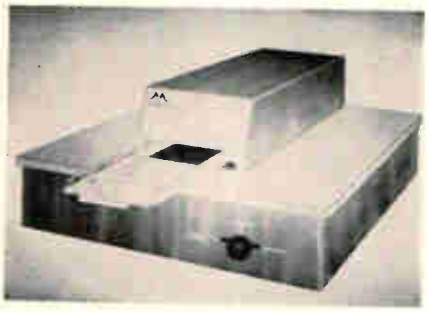
Transmission of digital data at a 4,800-bit-per-second clip over unconditioned Schedule 4 telephone lines is the key ability of a new data set. The unit, called the Model 4400/48 uses a relatively narrow bandwidth to transmit over the lowest cost lines. It avoids the frequencies that are severely distorted on such lines.

Before this development, transmission at the rate of 4800 bps required high-cost custom-equalized lines, plus frequent adjustments of the transmission equipment to compensate for varying line characteristics, the manufacturer says.

Since mid-March, the company has been holding advance demonstrations of the 4400/48, transmitting over a 3,000-mile, unconditioned Schedule 4 telephone line. Despite the use of the lowest-cost transmission line, errors were held to a rate of less than one in 1 million bits.

Milgo Electronic Corp., 7620 N.W. 36th Ave., Miami, Fla. 33147 [384]

Test adapter checks p-c boards



Quick, low-resistance connections to internal test points on p-c and multilayer interconnection boards are provided by a test adapter that checks for both continuity and insulation resistance. The Model TA101 connects to both sides of a four-layer board, checking the two sides simultaneously by means of some 700 plated-through holes on 0.100-in. centers.

The board under test is positioned in a sliding holder that is manually moved into the measurement sector. A battery of pneumatically operated test probes then make contact with the network of test points; the unit under test is energized and the probe contact is maintained as long as test continues. Any defect in continuity or resistance is instantly signaled by a separate automatic circuit tester to which the adapter is connected.

Nominal contact resistance is 50

milliohms. The test adapter can operate safely under test voltages of 500 v d-c with an insulation resistance of 200 megohms.

The unit is priced at $5,000.
McKee Automation Corp., 7315 Greenbush Ave., North Hollywood, Calif. 91605. [385]

Miniature oscillator uses IC for heater

A self-contained oscillator has been designed primarily for use in portable test equipment. The unit, designated type F 3181, uses an integrated circuit as a heating element for temperature stabilization. The IC is enclosed in a tiny transistor can, together with a temperature-sensing device and the quartz crystal that controls the frequency of the oscillator.

The complete unit occupies 2 cubic in. and weighs less than 1¾ oz. Preset frequencies are available in the range of 10 to 20 Mhz. A long-term frequency stability of one part in 1 million is obtained over the complete temperature range from 0 to 60°C without the use of conventional ovens.
Marconi Co., Chelmsford, Essex, England. [386]

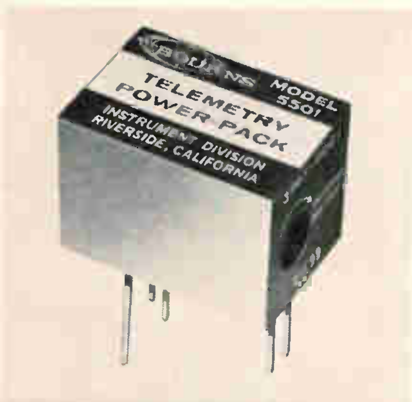
High-vacuum system for bench-top use

Production evaporation work, material testing, laboratory demonstrations, space-simulation studies lasting 10,000 hours, and various high vacuum experiments are possible with a bench-top high-vacuum system.

The VI-221 system offers base

pressures below 5x10^{-9} torr. Rapid cycling is obtained with the high-throughput 140 liter per sec VacIon pump and its optional isolation valve. High performance is achieved when the VacIon pump is used with the 3,800 liter per sec titanium sublimation pump. A large working space is provided by the 11¾ in. i-d stainless steel base chamber with 10 usable feed-through ports and the 12x12-in. Pyrex bell jar. A choice of roughing systems and port closures is also available.
Varian Associates, 611 Hansen Way, Palo Alto, Calif., 94303. [387]

Small power supply used in telemetry



Transducer excitation in advanced instrumentation applications is provided by a telemetry power supply that measures 0.73 x 0.52 x 0.50 in. and weighs 0.24 oz. It features reversible polarity, overvoltage and short-circuit protection. It also has adjustable output voltage, isolation of output from input and

excellent regulation.

Standard specifications for the model 5501 include an input voltage range of 24 to 32 v d-c; output voltage, adjustable from 4.8 to 5.2 v d-c; output current, 5 ma; and operating temperature range, —55 to +100°C.

The supply is sealed for humidity and salt spray, and meets stringent environmental requirements of MIL-STD-202. Vibration is rated at 20 g and shock 100 g.

All units undergo 100% in-process and final inspection and are guaranteed.

Bourns Inc., 6135 Magnolia Ave., Riverside, Calif. 920506. [388]

Charge amplifiers feature low noise

Key features of a charge amplifier series are low noise and elimination

of parallax-caused operator errors during gain range selection.

Circuit isolation from power ground and rack prevents ground loops and contributes to the low noise level. A new gain range switch, said to be unique in commercially available amplifiers, provides positive, easily identified gain selection.

The 2710B solid state amplifiers have a calibrated dial for insertion of accelerometer charge sensitivity, an internal 1,000-hz sinusoidal calibration signal, flat frequency response from 2 to 20,000 hz, and an instantaneous overload recovery from loads as high as 55,000 picocoulombs.

Four models of the series include the 2710B with voltage output for tape recorder, oscilloscope, or meter; the 2711B with additional power output for galvanometers and long lines; the 2712B with voltage output and meter; and the 2713B with voltage output, power output, and meter.

Tedious calculation of cable capacitance is eliminated by the 2710B family because the units are used with charge-sensitive transducers whose response is independent of varying shunt capacitance. Thus, long input cables can readily be used without degradation of frequency response or gain characteristics, according to the manufacturer.

Endevco Corp., 801 South Arroyo Parkway, Pasadena, Calif. 91109. [389]

Who's crazy enough to tear down and rebuild $100,000 worth of machinery just to turn out an 18-inch spherical commutator?

Some company called Poly-Scientific.

Sometimes we get pretty strange projects in the house. But we find a way to deliver—even if it means busting up our own expensive equipment to do it. And that's just what we did for a Navy job.

An 18-inch spherical sonar device required 53 concentric circles machined on its hand polished, three-microinch finish, silver contact surface. It then had to be quartered into 212 segments. Angular tolerance of segments .00025 inches.

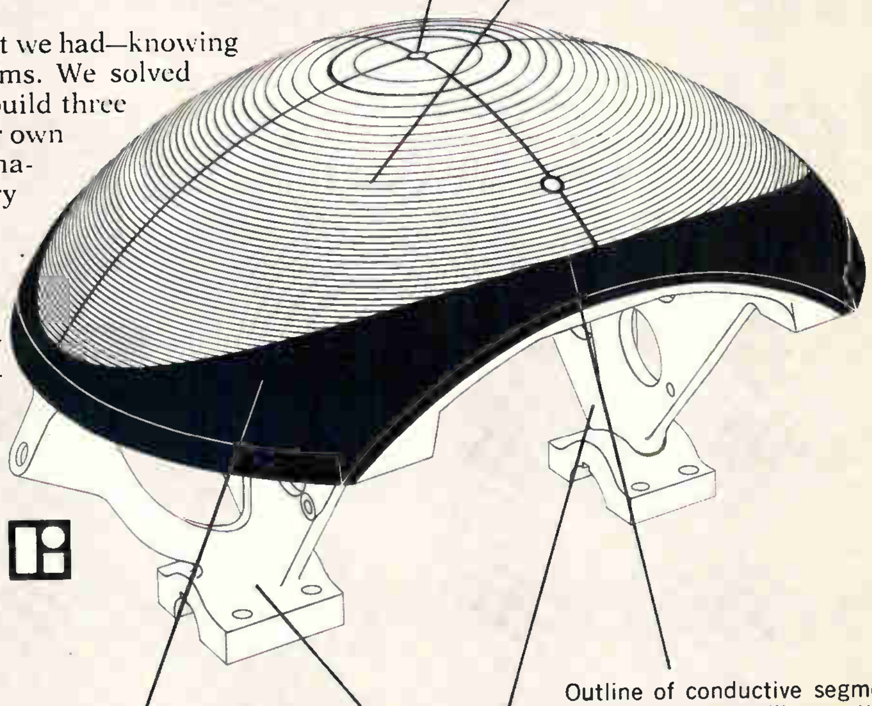
Tough enough order. But with one additional catch: the Navy wanted it in a rush—there wasn't time to test new materials or new processes.

This meant we had to do with what we had—knowing there'd be warping and stress problems. We solved them. But we had to tear down and rebuild three machine lathes, design and develop our own feeds, cutting heads and bonding materials to do it. What's more, delivery was made in less time than promised.

It's been seven years since the first unit was installed in one of our nuclear subs. And it's still there. How satisfied was the Navy? Well, today Poly-Sci is still making these devices—and other, more sophisticated ones.

Care to have a crazy company like this working for you?

POLY-SCIENTIFIC
A DIVISION OF LITTON INDUSTRIES



Miniature switch spans 1 to 18Ghz

Once limited to moderate bandwidths, miniature switches can now range across the 1- to 18-gigahertz microwave band. Somerset Radiation Laboratory Inc. claims that it has the first microwave switch that can cover this frequency range in a single unit.

Although other manufacturers have 60-to-1 bandwidth units operating at lower frequencies, Sam Levine, Somerset's president, maintains that getting an 18-to-1 bandwidth in the microwave range is more difficult. Designated model M400, the coaxial switch is a medium power unit that handles 2 watts continuous wave power and switches in less than 40 nanoseconds.

A better way of using microwave diodes—the basic switching elements—contributes to the wide bandwidth capability. The capacitances of the two diodes are designed into the circuit as part of a low-pass filter consisting of a shunt-input capacitor, a series inductance, and a shunt-output capacitor. The inductor is formed by slightly reducing the diameter of a short section of the coaxial center conductor.

If the diodes are reversed biased, the switch allows a signal at the input to flow to the ouput. When the diodes are forward biased, they produce an r-f short that prevents signal flow.

Another factor is the wideband biasing network that provides d-c current for the diodes while preventing the r-f from flowing in the d-c network. The switch uses a shunt bias network, thus avoiding the problems of placing series capacitors—chip or sleeve type—in the coaxial line. The d-c path runs through an r-f choke between the center conductor and the switch's case, through the center conductor and the diodes, and then back to the bias source via feed-through capacitors. The feed-through capacitors conduct d-c current, but short the r-f signals to the case.

In many other switches, the bias network contains series capacitors to isolate the d-c current from the input and output ports. These capacitors limit the bandwidth and increase the switch's complexity. Somerset's simpler shunt biasing technique eliminates these capacitors.

The M400 has applications in various microwave circuits including pulse modulators and shapers, amplitude modulators, transmit-receive switches, and redundant microwave systems.

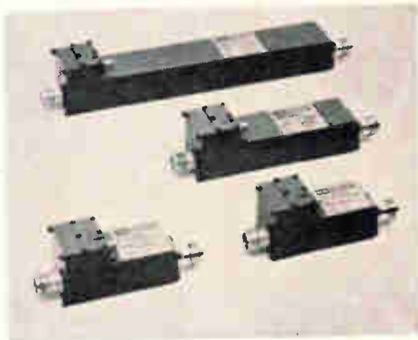
Specifications

Frequency	1 to 18 Ghz
Isolation (at 50 milliamperes forward bias)	20 db above 1 Ghz 40 db above 8 Ghz
Forward bias voltage	0.8 v max
Insertion loss (at zero bias)	0.5 to 2 db
Switching speed	40 nsec max
Power handling capability	
Continuous-wave	2 w
Peak power (for 1 μsec pulse with 1% duty cycle)	100 w
Spurious signals	40 db below output level
Voltage standing wave ratio	2.5 to 1 max (at zero bias)
Impedance	50 ohms
Temperature range	—65°C to 150°C
Size of block (no connectors)	0.5 x 0.5 x 0.75 in.
Connectors	OSM type 215
Weight	1 ounce
Price	$215
Delivery	20 days

Somerset Radiation Laboratory Inc., 2060 North 14th St., Arlington, Va. 22216 [391]

New Microwave

Directional samplers feature flat response



Precision directional r-f samplers covering 0.25 to 2.4 Ghz in four octave bands have an amplitude variation less than ±0.3 db and calibrated detection sensitivity of 10 mv/mw up to 20 mw. Designated models 1009, 1010, 1011, and 1012, each consists of a directional coupler, a built-in crystal detector and a low-pass input filter. The frequency ranges are 250 to 500 Mhz, 0.5 to 1 Ghz, 1 to 2 Ghz, and 1.4 to 2.4 Ghz.

The units are suited for sensing power levels as in automatically controlling the level of sweep oscillators. Power variations caused by cables, connectors, and components between r-f source and load can be virtually eliminated. The crystal detector is square law within 0.2 db up to 20 mw and is usable to 500 mw. The built-in filter attenuates input frequencies above the range of the sampler and thus prevents waveform distortion that can cause errors in the response of the crystal detector. This also reduces distortion in the output.

Body length dimensions range from 2.14 to 6.31 in. Price of the samplers is $290 each, and all are available from stock.

Kruse-Storke Electronics, 790 Hemmeter Lane, Mountain View, Calif. 94040. **[392]**

Variable delay line covers broad band

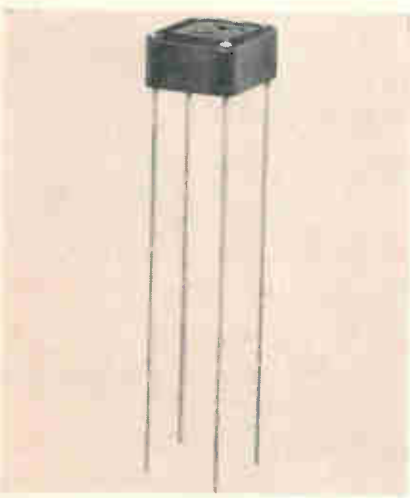
Derived from a traveling-wave tube, an O-type electron-beam vari-

able delay line features a dynamic bandwidth of approximately 2 octaves, making possible a pulse distortion lower than that attainable with other r-f delay devices, according to the manufacturer. The unit's design allows rapid variation of delay, handling of multiple signals without cross modulation, and moderate insertion loss. Among other applications, the delay line, called the MA-2021, has been designed for target simulation in the fields of radar testing and phased arrays.

Specific variable delays up to 250 nsec have been obtained with a minimum residual delay of approximately 30 nsec. Over the frequency range of 1.1 to 2.3 Ghz, the insertion loss is approximately 40 db at 150 nsec of delay. Experiments have shown that this approach will yield variable delays of several tenths of a microsecond at insertion loss and power levels comparable with those of other delay devices, but with substantially wider bandwidths.

Microwave Associates, Burlington, Mass. [393]

Matched junction diode handles uhf range



Closely matched Schottky-barrier junction diodes have been developed for use as balanced modu-

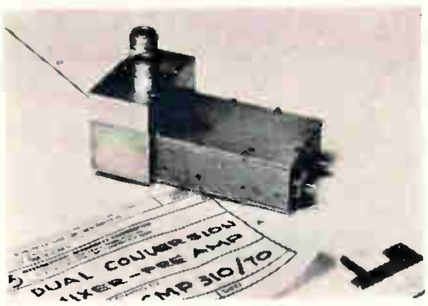
New Microwave

lators for operation at frequencies through the uhf range. The diodes are applicable as single units and matched pairs for detectors and discriminators.

Designated series MA-4860 and MA-4878, the diodes utilize a bilithic process which encapsulates the metal-silicon junction in a hermetic glass seal. This technique produces a large-area for the top contact to the diode junction reducing loss and improving reliability. Pulse burnout is rated at 5 ergs.

Microwave Associates Inc., Burlington, Mass. **[394]**

Dual-conversion mixer-preamplifiers



Mixer-preamplifiers offering dual conversion feature two intermediate frequencies that provide high selectivity and gain at a low i-f while reducing image frequencies of the high i-f. Dual conversion simplifies systems requiring a frequency synthesizer as a local oscillator. A vhf synthesizer can be used as the second l-o, with a crystal-controlled microwave source as first l-o, eliminating the need for an expensive, complex microwave synthesizer.

A high first i-f—in the 100-to-500-Mhz range—permits use of a simple, low-cost microwave low- or high-pass filter for 20-db image rejection. Instantaneous bandwidth can be as high as 100 Mhz.

A second i-f provides high skirt selectivity, high gain at reduced cost, and center frequencies in the range between 15 and 100 Mhz. Bandwidths can range from 2 to 100 Mhz.

The mixer-preamp is complete except for the first l-o, and consists of mixer, first i-f, low-pass image filter, second mixer, second l-o, afc varactor, and second i-f amplifier.

An afc in the second l-o circuit can operate over a 5-to-50-Mhz band and allows use of a fixed-tuned microwave first l-o. Compensation applied to the second l-o can correct for first l-o drift.

The preamplifiers can be designed for applications from 2 to 16 Ghz, and r-f bandwidths up to an octave. Noise figure is from 7 db, depending on diodes used and on selection of first i-f.

Units measure approximately 4⅜ x 2⅜ x 1¾ in., and weigh about 11 oz. Price is from $400 in quantities.

International Microwave Corp., River Road, Cos Cob, Conn. 06807 [395]

Antenna system gets wheels

A complete trailer-mounted microwave antenna system can be put in operation by four men in eight hours. The two-wheel, 1½-ton trailer unit includes a 100-ft pneumatic telescoping mast, 6-ft microwave antenna, azimuth/elevation antenna positioner with remote-control system, 140 ft of Heliax elliptical waveguide, automatic dehydrator, and gasoline-operated air compressor.

The telescoping mast provides for a top load of 600 lbs with windload of 125 mph. The antenna positioner can adjust elevation to ±15° and azimuth to ±45°. Beam deflection of the antenna unit meets EIA Spec RS222.

With the flexible elliptical waveguide, the 140 feet of feeder line can be payed off a reel and installed automatically during the erection of the mast, and recoiled on the reel in dismantling. The jacketed waveguide incorporates the control cables for the antenna positioner and power cable for the obstruction light.

The mobile antenna system was originally developed for the Air Force under a subcontract. As for commercial applications, the manufacturer suggests its use for emergency restoration of disrupted common-carrier microwave links.

Andrew Corp., P.O. Box 42807, Chicago, Ill. 60642. [396]

Circle 203 on reader service card

New Production Equipment

Stitch-shift wire bonder

Like Detroit's newest sports cars, Hugle Industries' newest ultrasonic wire bonder for integrated circuits has a combined manual and automatic shift, and independent suspension.

Manual control of height at which bonds are made allows the machine to bond wires to devices of different thicknesses that are used in hybrid IC's. In automatic operation, it bonds at constant heights at top speed.

The chuck that holds the circuit slides independently on a grease-plate. This provides a movable axis of workpiece rotation that allows bonds to be made quickly anywhere in a 3-inch diameter area. Conventional automatic ultrasonic bonders usually have a ⅜-inch work area. The movable axis facilitates bonding of large hybrid IC's and monolithic IC arrays as large as a complete slice of silicon.

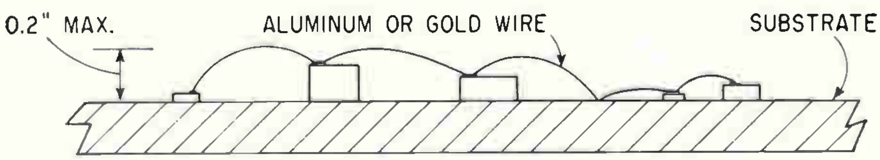
The additional features are provided by a few simple mechanisms worked out mostly by Mrs. William B. Hugle, who is her husband's partner in the company. The features don't raise the price of the machine—the Hughes earlier automatic bonder costs the same.

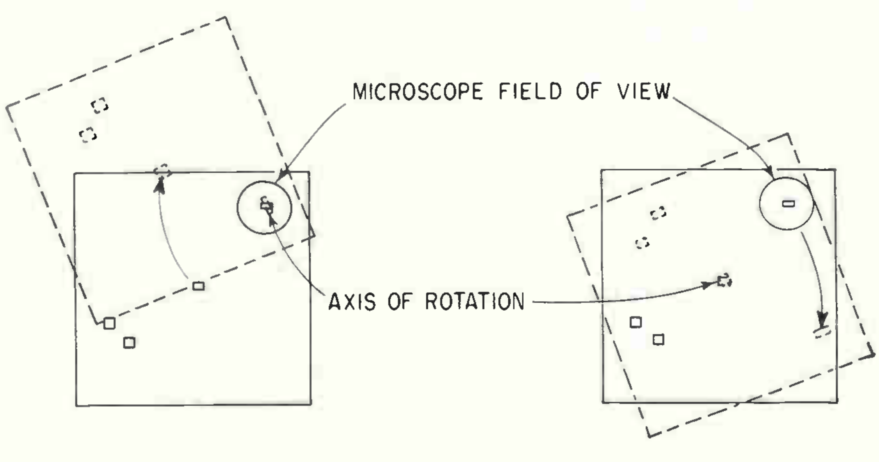
Key to the dual-shift operation is an extra-broad camshaft. At one end, it has an eccentric shape; in automatic operation, a bump raises and lowers the bonding tool a standard distance as the shaft rotates. The other end is perfectly round; when this part of the camshaft is in position, the cam no longer moves the tool. Bonding height is manually controlled by the machine operator.

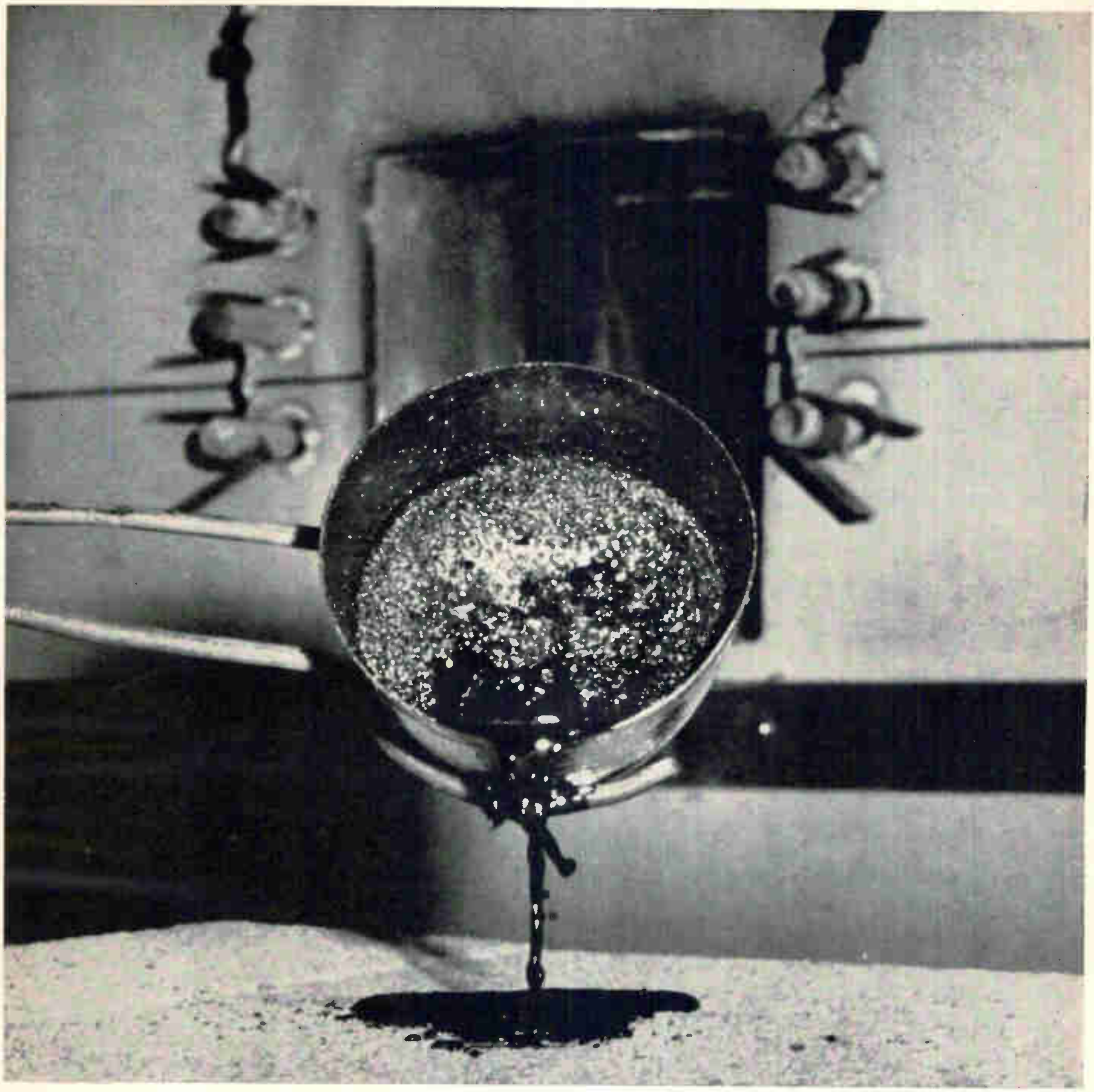
The operator uses two pushbuttons to make the bonding height 100 mils higher or lower than the nominal height. The buttons actuate a motor-driven adjusting screw. One bond can be made to a 3-mil-high silicon chip, another to a 40-mil-high capacitor, and a third to a film resistor on the substrate of a hybrid IC, as in the IC profile shown.

The movable axis of the chuck facilitates stitch-bonding wires to both sides of a device. To do this properly, either the device or the bonding tool must be rotated to align the tool tip and the device. It is quicker to rotate the device. However, the field of view of the operator's microscope is only 30 mils. If the device is revolved by rotating the chuck about its center, the device moves out of view when the substrate is large, as shown by the right-hand sketch.

Putting the chuck on a grease-







ENGELHARD Platinum Rhodium helps growth of YIG crystals.

Thanks to Engelhard crucibles, the Xtalonix Products Div. of Harshaw Chemical is able to supply the laser and ultrasonic industries with the larger, higher quality YIG (Yttrium Iron Garnet) crystals they now require. In fact, Xtalonix finds the crucible absolutely vital in this production. It retains its shape at high temperatures and resists chemical action, which could cause crystal impurities and crucible erosion.

Production begins when a mixture of yttrium oxide, iron oxide, lead oxide, lead fluoride and boron oxide are poured into the Engelhard crucible. Within 24 hours the loaded crucible is heated to 2500-2600°F and held at this temperature for another 24 hours. Then, the temperature is lowered 1-3°F per hour to 1652°F, accurately controlled by an Engelhard platinum vs. platinum 10% rhodium thermocouple. After excess flux is removed, the furnace is turned off. When brought to room temperature, the crystals are removed from the crucible by leaching with nitric acid. Then the crystals are ready for polishing and further processing.

For information on Engelhard precious metals to improve your product or process, write our Technical Service Department.

ENGELHARD
INDUSTRIES, INC.
EXECUTIVE OFFICES:
113 Astor Street, Newark, New Jersey 07114

740

Circle 205 on reader service card

Production Equipment

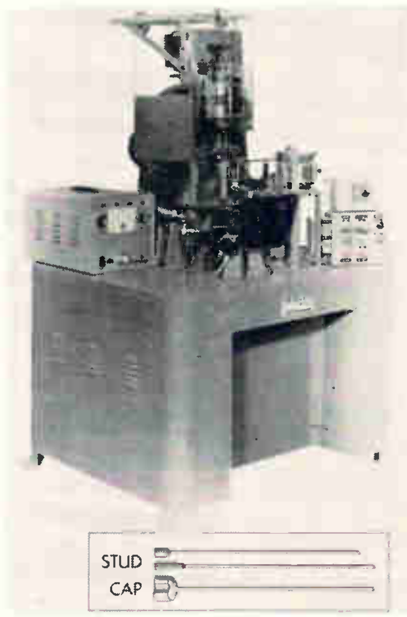
plate keeps the device to be bonded within the field of view, as in the left-hand sketch. The chuck can be swung freely about the device.

Specifications

Work area	3 inches diam.
Manipulator ratio	6:1
Wire size	0.0007 to 0.004 in.
Speed (automatic model)	16,000 bonds per shift typical
Bonding height range (manual)	±100 mils
Size	22¼ x 8 x 21½ in.
Power supply	110 v a-c, 50 or 60 hz
Price	$3,770, plus optics
Availability	Six weeks

Hugle Industries, 587 North Mathilda Ave., Sunnyvale, Calif. 94086. **[401]**

Automatic stud welder is fast and reliable



A high-precision stud welder produces a two-piece lead wire by butt welding a precut molybdenum slug to a Dumet wire. The slug is automatically fed into a six-head indexing turret, and the wire is then straightened, cut, and welded to the slug. The machine produces two-piece lead wires with the components in various lengths, diameters, and materials.

The machine has a variable speed drive, a sliding motor-driven straightener and a motor-driven wire payoff device. It produces less than 1% rejects, at speeds up to 6,000 per hour, and can also weld wires to end caps.

Weight is 2,000 lbs. Dimensions are 6 x 3 x 3 ft.

Kahle Engineering Co., 3,328 Hudson Ave., Union City, N.J. 07087. [402]

Machine drills p-c board stacks

Though the prime purpose of a new production drill is to make holes in stacks of circuit boards, it is also useful for drilling very small holes, to exact specifications.

Among the latter applications would be the drilling of graphite and carbon blocks for semiconductor boats; the production of stepped holes; the drilling of flat-bottomed holes in aluminum; the drilling of Mylar films for welded circuits; and work in Teflon, Melamine, brass, and a wide range of other materials.

For use with circuit boards, a stack is positioned beneath a template containing tapered drill-location holes. As a stylus drops into a location hole from above, the stack is automatically clamped in position, and the drill advances upward from below the table.

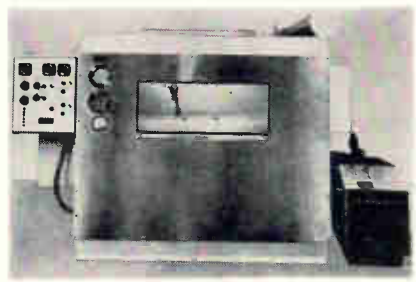
Fully adjustable feed-rate and drill-speed controls cut down on glaze, burrs, and drill breakage, through stacks up to ⅝ in. deep in the standard model and up to 1 in. deep in a special version.

The automatic drill cycle with stylus centering provides hole location to an accuracy of 0.001 in. Spindle speeds in the standard model are up to 45,000 rpm, continuously adjustable; a 100,000-rpm spindle is also available.

Other features of the model 105 Palomar inverted drill machine include an accessory rear-projection microscope with high-intensity light source, and a target reticule to focus on the drill location.

H&M Mfg. Co., P.O. Box 6022, San Francisco, Calif. 94101. [403]

Vapor system applies coat of photoresist



Silicon wafers and substrates of glass, ceramic, and thin-films of any size and shape can be automatically coated with photoresist on a large-scale production basis by a vapor carrier system. The process applies pure, uniform coatings in the angstrom range, thereby assuring fine line definition.

Production quantities of printed circuit boards with plated-through holes can be coated without puddling or depositing photoresist in the holes.

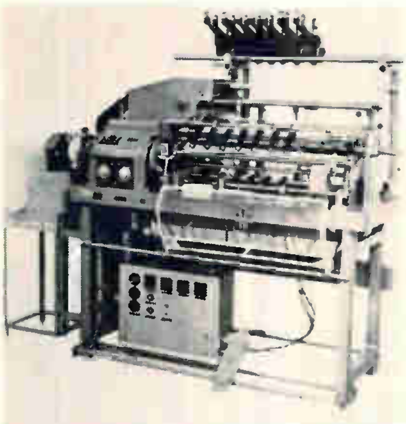
The system includes a patented vapor generating unit, automatic traversing unit, and ultraclean spray chamber. A fluid circulating system is available.

An atomizing agent such as Freon TF113 is superheated to a vapor. The heavier-than-air vapor is fed into a low-pressure spray gun where it atomizes the material to be sprayed. A traversing unit is automatically programed for each coating process. While the speed-adjusted spray gun moves from side to side the table holding the substrates moves from front to rear in preset indexed steps. The traverse unit is enclosed in the company's class 100 ultraclean spray chamber. Highly purified laminar-flow air filtered to 0.3 micron moves horizontally across the surface of the substrates. It removes overspray, solvent vapor, and controls flash-off of solvents in the coating material while keeping contamination low.

The vapor generating unit weighs approximately 300 lbs and measures 29 x 23 x 20 in. The spray chamber and traverse unit pictured weigh approximately 1,500 lbs and measure 72 x 68 x 72 in.

Systems are available in a wide range of sizes for large-scale production, pilot-line operation and laboratory use.
Zicon Corp., 63 E. Sandford Blvd., Mount Vernon, N.Y. 10550. **[404]**

Transformer winder takes the wrinkle out



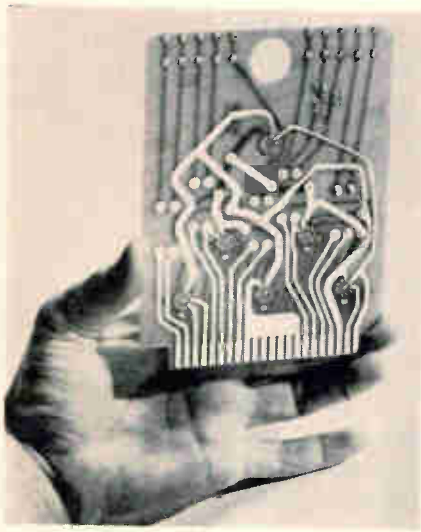
A new ballast-transformer winder uses an automatic paper-insertion technique that eliminates paper wrinkles and speeds the winding process. The paper is fed laterally so that its fibers are always kept parallel to the winding arbor, or coil stick, preventing wrinkles. Paper length is preset simply by adjusting a dial.

Other features of the model AM99 include: 99 feeds that can be set for different wire diameters by turning just two dials; a new dereeler system for wire from pail packs; a special reversing clutch; and a new static electricity eliminator. A differential gear box eliminates gear changing, and adjustable end stops eliminate cams.

Individual pulley-type wire guides are located above the winding arbor where they can quickly be set up or changed. The finished coil stick is taped with one strip of tape.
Associated American Winding Machinery Inc., 111 Plain Ave., New Rochelle, N.Y. 10801. **[405]**

New Materials

Plating grows easily in preseeded boards



Dielectric impregnated with a chemical catalyst eliminates several of the steps needed to convert a copper-clad laminate into a printed circuit board with plated-through holes. No matter where the holes' walls will be presensitized, boards or in multilayer boards, the hole's wall will be presensitized, ready for plating with copper. The copper plating makes a good bond to the board because the catalyst is more than skin deep. Since smooth hole walls are no longer needed because of the improved bonding, less expensive hole punching can replace drilling.

These are some of the advantages claimed by the NVF Co. for its Catabond copper-clad laminates.

In a conventional copper-clad laminate, after the holes are drilled, the board is immersed in a catalytic seeding bath because copper will not bond to an untreated hole. The catalyst acts as a fluxing agent so that a very thin film of copper can be built up chemically on the walls of the holes.

The chemical coatings on the board's surfaces usually are removed by sanding and scrubbing. Then the holes are electroplated with more copper. The sanding, however, can damage the contact of the hole coating where it meets the copper cladding.

Sanding off the chemically plated copper is necessary because the catalyst adheres poorly to the clad copper. The combined chemical plating and electroplating could peel off the board surfaces. The Catabond material eliminates the sanding because no seeding bath is needed.

Five grades of Catabond laminates are produced with properties that correspond to existing NEMA grades such as XXXPC, FR-2, FR-4 and G-10.

Copper-clad laminates are made in cured sheets up to 48 by 39 inches in size. Thicknesses range from 0.031 to 0.250 inches. Copper foil is available on both sides in 1- or 2-ounce thicknesses.

NVF Co., Maryland Ave. and Beech St., Wilmington, Del. 19801. **[406]**

Thermopoxy coating pots and protects

Extensive printed circuit applications are anticipated for a thermopoxy compound that is also an effective coating for electronic components where resistance to moisture, humidity, and vibration is required.

The compound, designated Y-697-126, is a 100% solid, semirigid, unfilled pre-evacuated system. It affords good pot life, a convenient mix ratio, low viscosity, high film build, and controlled thixotropy.

The material can be cured in 24 hours at 25°C or in 2 hours at 75°C. It can be applied by dipping, spraying, or brushing.

Sterling Varnish Co., Sewickley, Pa., 15143. **[407]**

New Books

Sound designing

Circuit Design for Audio, AM/FM, and TV
Engineering staff of Texas Instruments Incorporated
McGraw-Hill Book Co., 352 pp., $14.50

Serving as a practical guide for the circuit designer working in consumer electronics, this book is the fifth in the Texas Instruments Electronics Series. It's an updated, hardcover version of two earlier TI paperbacks, "Audio and AM/FM Circuit Design Handbook" and "Television Circuit Design Handbook."

The chapters on audio design begin with the basic considerations such as operating classes, coupling schemes, and transistors, but quickly move on to design procedures for output and driver stages for class A and B operation. The procedures are discussed in a number of design examples that cover a wide range of output powers.

The sections on a-m and f-m concentrate on intermediate-frequency amplifier design, giving a practical approach to meeting gain and bandwidth requirements for low-cost systems as well as high-cost component-quality systems.

Separate chapters are devoted to each major block in a television receiver. Step-by-step procedures emphasizing time- and cost-saving techniques accompany most of the design examples given. Mathematical clutter is reduced by grouping the derivations of significant equations in a separate section.

Time for everyone

On-line Computing: Time-shared Man-computer Systems
Edited by Walter J. Karplus
McGraw-Hill Book Co., 336 pp. $14.50

This is a creditable, though limited, collection of articles on time-shared systems.

Major concepts are concisely illustrated by descriptions of a small time-shared system, the software and hardware requirements for a graphic display console, and the design philosophy and hardware for a specialized remote console.

The economic aspects of on-line computers are explored thoroughly, from the standpoint of batch versus on-line processing, configuration decisions, and the factors affecting additions to hardware and software. Even such mundane business matters as deciding what to charge the customer are touched on.

The editor has wisely included B.E. Fried's chapter on solving mathematical problems with on-line techniques, including graphic displays. This is a particularly outstanding discussion of how mathematical explorations are aided by a computer terminal.

Unfortunately, less attention is given to the sociological, psychological, and physiological aspects of on-line systems design, and little insight is gained on the human factors which affect the man-machine relationship.

Despite its limitations, the book is worthwhile for those in the data processing field who want to know more about on-line computing. The applications-oriented reader will not learn much from it unless he is a mathematician, although he will come away from the book with some understanding of why his own little real-time terminal cannot deliver miracles.

Frank Yee
International Business Machines Corp.
White Plains, N.Y.

On Targets

Modulation, Resolution and Signal Processing in Radar, Sonar and Related Systems
R. Benjamin
Pergamon Press, 184 pp., $8.50

The author, an expert in resolution problems of radar and sonar systems, shows the relationship between modern resolution techniques, the associated devices used to implement them, and the resultant performance. While extensive background in the subject is required to digest fully the subtle concepts presented, anyone familiar with basic principles will find this a challenging and rewarding work.

This is not a reference work in

which to look up mathematical formulations applicable to a detailed analysis of resolution techniques. The author purposely avoids the clutter of complex mathematics and uses elementary relationships and simple, yet effective, illustrations. Smoothly, he progresses from a logical extension of simple pulse and continuous-wave doppler principles to the most advanced target resolution techniques.

A discussion of long-pulse modulation and the use of short pulses to aid resolution leads to a consideration of doppler effects on various pulse compression techniques. An examination of methods of doppler extraction relate the system's performance to time and bandwidth and other equipment requirements. The author describes how basic antenna characteristics relate to and interact with range and doppler resolution techniques.

In later chapters, Benjamin introduces ambiguity functions, relating range and doppler resolution as a natural outgrowth of the earlier discussions. He then applies ambiguity functions to a consideration of sidelobe effects, and the effects of "noisy" signal sources on matched receiver design. Also included are the effects of varying propagation paths on signals with large time-bandwidth characteristics and the use of logical and nonlinear processing.

Dean D. Howard
U.S. Naval Research Laboratory
Washington

Painless primer

Electronic and Magnetic Behavior of Materials
Allen Nussbaum
Prentice-Hall Inc., 155 pp.,
cloth $5.95, paper $2.95

Too often, an engineer searching the library stacks for a basic book on an unfamiliar subject finds only turgid tomes. It's refreshing to come across a book that promises, in 155 pages, to give at least a fundamental understanding of semiconductors, dielectrics, magnetism, and quantum electronics. Professor Nussbaum of the University of Pennsylvania should be congratulated for accomplishing this and the publishers should be commended on making the book available in paperback form.

The book isn't much more difficult to read than many of the latest novels and may even be more enjoyable. The first chapter, on electric and magnetic fields, could be skimmed or even skipped, but it provides a handy reference when reading later chapters. In the second chapter, Nussbaum presents a neat treatment of energy bands and manages to make the mathematics of semiconductors palatable.

The chapter on dielectrics contains an interesting physical description of such ferroelectric materials as barium titanate, $BaTiO_3$. After describing the cubic crystal structure, Nussbaum suggests that the remanent dipole is due to molecular asymmetry. The titanium ion that should lie at the center of the cubic structure actually has six stable positions slightly off center which give a dipole moment to the molecule.

The atomic basis of diamagnetism, where the induced magnetic polarization tends to reduce the total internal field, is given eight pages in the chapter on magnetism. Ferrimagnetism is covered well with a series of illustrations of the molecular structures.

Problems are interspersed throughout the five chapters and represent challenges, but no insurmountable ones. The concepts can be understood without solving the problems, but once the reader gets in the spirit of the book, it would be surprising if he didn't reach for pencil and paper and find himself playing undergraduate.

Recently published

Fundamentals of Silicon Integrated Device Technology—Vol. 1: Oxidation, Diffusion, and Epitaxy, Edited by R.M. Burger and R.P. Donovan, Prentice-Hall, Inc., 495 pp., $15.00

The editors prepared a comprehensive source of information on three basic technologies employed in the fabrication of silicon integrated circuits. Each process is discussed theoretically, and followed with practical details about its implementation.

Computers: Their Impact on Society, AFIPS Conference Proceedings, Vol. 27, Part 2—1965 Fall Joint Computer Conference, Thompson Book Co., 181 pp., $6

A supplement to the basic proceedings volume, including the remarks of invited speakers, records of the panel sessions, and final versions of papers not appearing in the earlier work.

Technical Abstracts

Picturing the problem

OLCA: an on-line circuit analysis system
Hing C. So
Bell Telephone Laboratories,
Murray Hill, N.J.

To make the computer an effective tool for network design, the coupling between the designer and the machine should be as efficient as possible. The designer would like to tell the computer what he has, what he wants to know, and be able to get an instantaneous solution. Using tapes and punched-cards that follow a rigidly specified format is too unwieldly and time consuming. A new technique for achieving the desired effective coupling is an on-line computer analysis program developed at Bell Laboratories, called OLCA.

With OLCA, a user at a specially designed console can maintain a continuous dialogue with a main computer while using it to implement his design. The console contains a cathode-ray tube linked to a small local computer that is used to set up circuit problems at the console. The main computer actually performs the circuit analysis. Thus, there is no need to interrupt the central computer for every local task.

Using a light pen, the designer draws the circuit under study on the crt. Numerical data, such as circuit element values and frequencies, are inserted via a teletypewriter. If the designer wishes to perform a tolerance or sensitivity analysis he can easily set up trial circuits that represent deviations from the initial circuit. After the entire problem has been defined at the console, it is sent to the main computer for analysis.

OLCA has the following features:

- No control button. Instead, instruction words—called light buttons—are displayed on the oscilloscope. Whenever a light button is pointed at by the light pen, programs written for the local computer take over and perform the corresponding function. For example, to delete unwanted material the operator points to the "delete" function.
- Step-by-step guide. At any stage of the problem-defining process, OLCA displays only those light buttons that the user needs. In addition, whenever action is expected of the user, a guiding comment is displayed. The user cannot proceed without heeding the instruction. Thus, the user is steered step by step through all operations. Complicated operating rules needn't be memorized by the user.
- Error prevention. For example, if at some stage the user is expected to select a node, the local computer checks the displayed item selected to prevent the accidental selection of a wire or a component by the light pen.
- No punched cards or tapes. Data is fed directly to the machine by a teletypewriter.
- Speed. Solution is not delayed because no turn-around time occurs.

Presented at the Computer-Aided Circuit Design Seminar, Cambridge, Mass., April 11-12

MOST memorable

Integrated MOS-transistor, laminated-ferrite memory
A.D. Robbi and J.W. Tuska
RCA Laboratories, Princeton, N.J.

Batch-fabricated mass memories with capacities of up to 10^7 bits are possible with a specially designed laminated ferrite memory plane driven by an array of metal oxide semiconductor transistors. Operating in a word-organized mode to allow wide tolerances in the integrated drivers, an experimental 25,600-bit version has cycled in 2 microseconds.

The memory plane consists of a MgMnZn ferrite sheet with two sets of laminated embedded platinum conductors—256 word conductors and 100 sense-digit conductors. Over-all thickness of the plane is 8 mils.

The 256 word lines are driven by groups of 64 MOS transistors integrated on four chips measuring 700 by 100 mils each. The relatively large size of the chips is necessitated by the 90-millampere current drive required for the read operation. The transistors are n-channel depletion-mode devices

Technical Abstracts

that need 10 volts to turn them on and -9 volts to turn them off.

The switches are controlled by a second set of MOS devices acting as a decoding tree. Digit currents are also controlled by MOS devices, but these can be smaller and less densely packed because the currents are in the 5-ma range. Bipolar integrated amplifiers serve as sense amplifiers for the 2- to 3-millivolt sense-line signals.

Presented at the Intermag Conference, Washington, D.C., April 5-7.

Numbers for blocks

Considerations in block-oriented systems design
Dana H. Gibson, Systems Development Division, International Business Machines Corp., Poughkeepsie, N.Y.

A computer simulation of block-oriented memory operation shows the optimum size of data blocks, the number of blocks to be kept in a local storage unit, and the rules to be followed in replacing used blocks.

Block-oriented memories can reduce the processor's waiting time after data fetch from the main memory is initiated. Data is fetched in blocks containing many words, and stored in a small, fast, local unit from which the processor has access to one word at a time. The usefulness of this memory operation depends on the location of the desired data in the main memory. Its efficiency is maximized when successive words are fetched from consecutive locations. However, this type of operation could be more of a nuisance than an aid if successive words are fetched from randomly scattered locations.

Twenty programs from IBM 7000-series customers were analyzed. The simulation tested the programs with varying block and local storage sizes, and several different replacement algorithms. In general, the smaller the block, the more often the processor must go to another block for its next word; and the smaller the local store, the more often another block must be fetched. When a block is fetched, another block in the local store is returned to the main memory.

The simulation showed that small blocks of from four to 16 words were better than large blocks, and that fairly large local stores of from 2,000- to 4,000-word capacities were better than stores of less than 100 words. It also showed that the amount of swapping is related to the program's address pattern rather than its size.

Presented at the Spring Joint Computer Conference, Atlantic City, N.J., April 18-20

Behind the IC mask

Automatic mask and wiring pattern generation

H. Freitag and W.E. Donath
IBM Watson Research Center,
Yorktown Heights, N.Y.

One of the most serious obstacles to building more complex integrated circuits is the artwork needed to generate the masks. Two computerized techniques have therefore been developed—one to design and fabricate the artwork for device diffusion masks, and the other to design and fabricate the circuit interconnections.

The artwork-generating technique includes a language to enable the designer to describe the patterns and structures required in the masks, a computer procedure for translating the language into commands, and equipment to take commands and generate masks.

To obtain the highest possible level of integration on the chip, the programed interconnection process (PIP) was developed to generate the interconnection pattern despite the presence of faulty circuits. With PIP, a semiconductor wafer is fabricated with an array of circuits, but without wiring. Each circuit is probed and the result is fed to a computer for evaluation. The computer then designs an interconnection pattern for the usable circuits.

The computer's output, a magnetic tape, controls a light table. The wafer, having been coated with a metalization layer and then a photoresist layer immediately following the probing, is placed on the light table. The photoresist is exposed in the desired interconnection pattern. Every wafer has its own interconnection pattern determined by its particular pattern of good and bad circuits.

Presented at the Computer-Aided Circuit Design Seminar, Cambridge, Mass., April 11-12.

New Literature

Analog multiplier. Transmagnetics Inc., 134-25 Northern Blvd., Flushing, N.Y., 11354, offers a two-page description of the series 380 analog multiplier for d-c wideband use.
Circle **420** on reader service card.

Delay line. Sealectro Corp., 225 Hoyt St., Mamaroneck, N.Y. 10543. Bulletin DT-25 discusses the Deltime Model LD-100 magnetostrictive delay line with 5 to 100 μsec adjustable delay. **[421]**

Microminature commutator. Sonex Inc., 20 E. Herman St., Philadelphia, Pa. 19144, has issued a bulletin describing a microminiature electronic commutator designed for the time division multiplexing of high-level analog signals. **[422]**

Electronic glass. General Electric Co., Lamp Glass Department, 24400 Highland Road, Cleveland, Ohio 44121. A technical specification sheet gives the characteristics of Type 012 high-resistivity electronic glass. **[423]**

Solid state modules. BRS Electronics Division of Tech Serv Inc., Beltsville, Md., has published an 88-page catalog containing information on DigiBit solid state modules and related equipment. **[424]**

Microwave catalog. DeMornay-Bonardi, division of Datapulse Inc., 1313 N. Lincoln Ave., Pasadena, Calif. 91103, has published a microwave equipment catalog and reference handbook designated C-6. **[425]**

Dielectric ceramics for capacitors. American Lava Corp., Manufacturers Road, Chattanooga, Tenn. 37405. Bulletin 673 contains 36 pages of data, charts and graphs on AlSiMag dielectric ceramics for capacitors. **[426]**

Electronic counters. Computer Measurements Co., 12970 Bradley Ave., San Fernando, Calif. 91340. An eight-page brochure on the series 700 instruments covers four solid state electronic counters capable of measuring frequencies up to 500 Mhz. **[427]**

Voltage reference standard. Instrulab Inc., 1205 Lamar St., Dayton, Ohio 45404, has prepared Evenvolt data sheet 700-29, which discusses the 771-PK series voltage reference standard. **[428]**

Germanium power transistors. KSC Semiconductor Corp., 437 Cherry St., West Newton, Mass. Germanium power transistors featuring greatly improved secondary breakdown characteristics are described in three new data sheets. **[429]**

Precision-machined connectors. Frazar & Hansen, 150 California St., San Francisco, Calif. Detailed specifications on more than 1,000 connectors—both standard and waterproof types—in sizes from 1/4 in. to 1 5/8 in. in diameter are contained in a 16-page catalog. **[430]**

Power supply modules. ACDC Electronics, 2979 N. Ontario St., Burbank, Calif. A 16-page catalog provides detailed specifications for a full line of d-c power supply modules that carry a "guaranteed forever" warranty. **[431]**

Spectrum-analyzer preselector. Hewlett-Packard Co., 1501 Page Mill Road, Palo Alto, Calif. 94304, has available an application note describing techniques for improving wideband spectrum analyzer displays by use of a wide-range, electrically-tunable preselector. **[432]**

Punched-card readers. Taurus Corp., Academy Hill, Lambertville, N.J. 08530, offers a catalog on punched card readers that are used for multiple switching and control functions in military, commercial and industrial applications. **[433]**

Thermistors and varistors. Victory Engineering Corp., 122-48 Springfield Ave., Springfield, N.J. 07081, has prepared a condensed catalog to acquaint engineers, designers and purchasers with a large variety of thermistors and varistors, and the various assemblies and special instrumentation which are available. **[434]**

Pulse instruments. Datapulse Inc., 10150 Jefferson Blvd., Culver City, Calif. 90230. A six-page 1967 condensed catalog describes outstanding features and provides major specifications and prices for over 30 pulse generators. **[435]**

Directional couplers. Elpac Inc., 3760 Campus Drive, Newport Beach, Calif. 92660, has issued a two-page data sheet on a line of solid state, stripline directional couplers that are available in 27 stock models. **[436]**

Peripheral equipment tester. Scientific Data Systems, 1649 Seventeenth St., Santa Monica, Calif. 90404. Publication 64-14-05A covers Model 7901, a self-contained, compact unit that allows the manufacturer's peripheral devices to be checked out without interrupting computer operation. **[437]**

Phase-angle devices. Dytronics Co., 4800 Evanswood Drive, Columbus, Ohio 43224. Catalog No. 467-PA describes a complete line of phase-angle standards and phase-angle measuring devices. **[438]**

Components. James Millen Manufacturing Co., 150 Exchange St., Malden, Mass. An eight-page catalog illustrates and describes a broad line of components for the electronics industry. **[439]**

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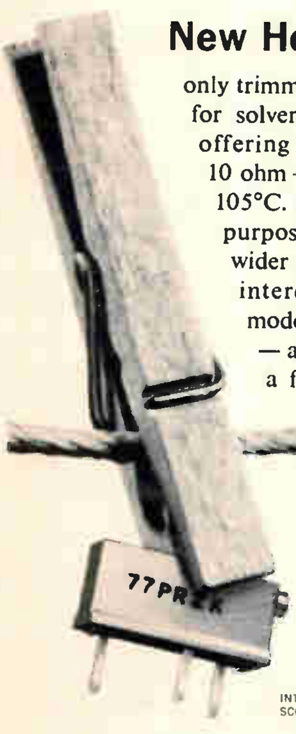

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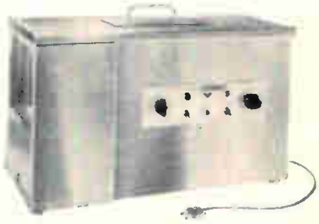

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Circle 219 on reader service card

New Literature

Diode catalog. Unitrode Corp., 580 Pleasant St., Watertown, Mass., has available a 36-page catalog on controlled avalanche rectifiers and zener diodes. [440]

Coil-winding machines. Geo. Stevens Mfg. Co., 6001 N. Keystone Ave., Chicago, Ill. 60646. A 68-page catalog contains complete data on 62 machines for virtually every coil-winding need in high production, prototype or laboratory applications. [441]

Pulse generators. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif. 91343, has issued a catalog sheet describing models PG-111 and PG-112 silicon-transistor, crystal-controlled pulse generators. [442]

Silicon transistors. Industro Transistor Corp., 35-10 36th Ave., Long Island City, N.Y. 11106. An eight-page catalog details a complete line of high-voltage, pnp silicon transistors. [443]

Power modules. Electronic Research Associates Inc., 67 Sand Park Road, Cedar Grove, N.J. A two-page catalog sheet describes the ST series of wide range, silicon d-c power modules. [444]

Induction motors. McLean Engineering Laboratories, Princeton Junction, N.J. 08550. Data sheet CM671 contains complete specifications for a line of computer designed induction motors. [445]

Rotary switch. Daven, a division of Thomas A. Edison Industries, Manchester, N.H., has published a catalog sheet describing the series X subminiature, multideck rotary switch. [446]

Logic modules. Honeywell Inc., Computer Control Division, Old Connecticut Path, Framingham, Mass. 01701, has issued a 12-page brochure on a line of 5-Mhz IC modules designed for digital systems applications. [447]

FET micromodulators. James Electronics Inc., 4050 North Rockwell St., Chicago, Ill. 60618, offers a bulletin containing data on FET micromodulators for operational amplifiers and modulator/demodulator switching. [448]

Integrated-circuit soldering. Development Associates Controls, 725 Reddick Ave., Santa Barbara, Calif. An eight-page catalog presents a lineup of equipment and accessories for temperature-controlled, flatpack IC soldering. [449]

Operational amplifiers. Nexus Research Laboratory Inc., 480 Neponset St., Canton, Mass. 02021. A 12-page catalog includes all of the latest additions to the company's product line of operational amplifiers, logarithmic modules and power supplies. [450]

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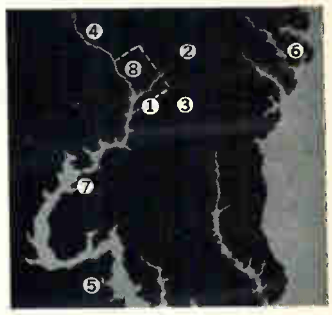

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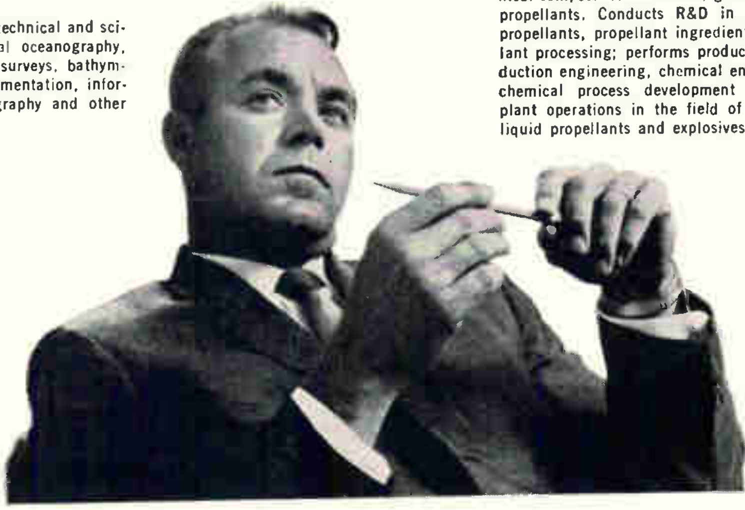

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Newsletter from Abroad

May 15, 1967

ICT plans to run computer printout with fluid logic . . .

An experimental computer printout system controlled by fluid-logic circuits will probably be built in Britain this summer. **Success would mark one of the first inroads by fluidics into a major preserve of electronic circuits.** Because fluid logic is much slower than its electronic counterpart, it has generally been used only when reliability in extreme environments has been demanded.

But a spokesman for International Computers & Tabulators Ltd. asserts that **the electronic-control circuits now used in computer peripherals are unnecessarily fast.** The speed of a printer, for example, is limited by electromechanical components that operate in milliseconds. ICT expects to build the printer this summer, but doesn't anticipate full-scale production of fluid-logic systems for several years.

. . . along with integrated groups of circuits

ICT hopes to cut the cost of its peripheral equipment by using fluid logic, while retaining the size advantages of integrated circuits. To produce the fluid-logic circuits, it is developing a method of vacuum-casting epoxy resins to make integrated groups of the circuits. An interface between the fluid-logic and electrical portions of the equipment is required. An electrical-pneumatic interface used in the development program is simply a moving-coil loudspeaker element.

The use of unpackaged IC's in the central processors of its computers is also being considered by ICT as a means of **cutting costs and raising speed.** Miniature multichip assemblies are being developed, containing an average of four gate circuits per chip. The assembly of about 50 chips would be bonded face-down to the wiring, providing about 200 circuits per module.

Modules in experimental production measure about 1 by 2 inches. After ground and power planes are prepared on a ceramic substrate, insulation layers and two layers of signal wiring are formed by vacuum deposition and etching.

ITT subsidiary has 'mini-station' for rural markets

Standard Telephone and Cable Ltd. will try to open a largely untapped market—rural communities in Asia and Africa—with a miniature medium-wave radio station. **The Australian subsidiary of the International Telephone & Telegraph Corp. plans to start selling the $5,000 station package in August.**

Along with a completely solid-state medium-wave transmitter with a range between 300 and 800 square miles, the package includes two microphones, a turntable, tape recorder, mixer, control console, and a small generator. The complete station is 5½-feet high and less than 1-foot wide. STC's export manager Bruce Wight says the station "can be operated by any bloke off the street."

Telefunken devices may mend color tv split in Europe

Europe's two incompatible color television standards may prove less divisive than first appeared to be the case [Electronics, June 13, 1966, p. 161]. This month, West Germany's Telefunken AG introduced a color transcoder that converts Secam signals into PAL signals without degrading picture quality. Developed by Telefunken, **the PAL (for phase-alternation-line) system has been adopted by most West European and**

Nordic countries; the Secam (for sequential-and-memory) system was developed in France. It will be used there and in the Soviet bloc.

Telefunken unveiled its color transcoder at the Telecommunications Conference held during Hanover's Industrial Fair. At the same time, the company previewed a technique, dubbed Tripal, for taking the output from a black-and-white home video tape recorder and reproducing it as a PAL picture in color.

Japan's EIA breaks with French FNIE

Japan's Electronic Industries Association and the French Federation Nationale des Industries Electroniques are at odds over a five-year-old accord engineered to help Japanese producers get around restrictive French trade regulations.

The Japanese claim the agreement has backfired and, as far as they are concerned, it is finished. The French maintain the deal remains in force until they complete their investigation of the Japanese claims, which will take another two or three weeks.

The deal set up between the two trade associations provided for imports of Japanese products by "counterpart" manufacturers in France rather than through regular trading-company channels. But in most cases producers found their counterparts half-hearted or ineffective marketers. Japanese manufacturers were especially unhappy when French components makers who lacked access to the appropriate consumer outlets wound up with import rights on items like tape recorders.

End result, say the Japanese, was at best a negligible reduction of trade barriers. Balked in France, the Japanese have broken the agreement and figure to step up their marketing effort in West Germany.

Computer makers seek reassurance on U. K. utility plan

British computer makers are concerned about the upcoming competition from a nationwide computer utility the General Post Office is planning [Electronics, April 17, p. 217]. The computer makers, some of whom run commercial data-processing enterprises themselves, say such a utility could stifle growth of competing services because the Post Office controls all the transmission lines linking customers to computer centers.

The computer makers have gone to the government for reassurance on fair access to data links in the future. But so far neither the government nor the Post Office has replied.

Elliott petitions government to buy scientific computers

Elliott-Automation Ltd. has revived a year-old proposal for the British government to underwrite a large general-purpose computer system for scientific and research applications. **Elliott's system is based on a hierarchy of processors to sidestep the internal organization problems** that plagued IBM's lame-duck 369/90 machines.

Design studies are half-finished and Elliott says it could deliver the first complete system within 3½ years. However, before it goes into production, Elliott wants the government to order a minimum of six systems for the nation's universities and research labs. Without such backing, the company feels, the risks and costs of the undertaking are too high. The government, although greatly interested in establishing a viable national computer industry, is reportedly waiting for reaction from Elliott's principal competitors—ICT and English Electric—before finally acting on the proposal. A year ago, the government ignored Elliott's project.

INDUSTRIAL APPLICATIONS FOR FAIRCHILD INTEGRATED CIRCUITS

11
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The Switch to IC's:

In The Best Families

Before you marry your design to integrated circuits you should look into their family credentials. Both the cost and the performance of the equipment you are designing will be influenced by the family characteristics of the integrated circuits you pick. And even the best families have their limitations. Obviously what you are looking for is the best performance and the lowest cost. But sometimes these two parameters are incompatible, at least within a single family. You have two choices: either decide in favor of the parameter most important to you, or look for some way to optimize your system by selecting circuits from different families. The second choice is the better one, but you may run into problems of incompatibility if you don't plan ahead.

WHAT IS COMPATIBILITY? In the simplest terms, compatibility means that similar functions from different families are interchangeable. For example, you should be able to use a quad 2-input TTL gate instead of a quad 2-input DTL gate, if the families are compatible. Put in another way, you should be able to design by function, picking for each function the circuit best suited to it from a performance standpoint. This is a logical way to design. Unfortunately you are at the mercy of the manufacturer: if his circuits are compatible you can proceed on this rational basis. If they are not, then you have to compromise or pick a different manufacturer.

LOGIC TYPES: In spite of the proliferation of family names, there are really only three types of logic: current sourcing logic, which drives current out of its output when in the high state; current sinking logic, which draws (or "sinks") current when in the high state; and current mode logic, which can either draw or drive current. There are several conventional family divisions within each type: current sinking logic encompasses DTL, TTL and LPDTL. If these families are compatible in a manufacturer's line, you have Compatible Current Sinking Logic (CCSL).

OPTIMIZING YOUR SYSTEM: To get back to your design problem, suppose your system must accept inputs at a rate in excess of 3MHz, but the output is at the rate of only 300KHz. The input rate clearly points to TTL logic as the only family with sufficient speed. But does that mean you should use it throughout the system? The 300KHz output rate is well within the limits of DTL and LPDTL. If you try to design your complete system with TTL you will not only pay more for the circuits, but you will also use more of them and you will increase your power consumption by a significant factor. With CCSL you can pick TTL circuits for those functions for which you need the speed, and use DTL circuits for the rest of the functions. The circuits are compatible: They are mechanically interchangeable, they perform the same functions, and they obey the same loading rules. Note that you don't give up anything in performance: you are still meeting all the input and output requirements. But you reduce your power dissipation and save money doing it.

USE THEM NOW: Fairchild is now committed to the compatible logic concept, and other manufacturers will, no doubt, follow suit. This means that you can expect most of the new developments to happen within the Compatible Current Sinking Logic group. There will be more functions to choose from, more functions per device, and greater compatibility between families. Increasingly you will become concerned with the total system instead of designing sub-systems and isolated functions. You will become a systems designer instead of a circuit designer. But the time to get started is now, so that you'll accumulate some experience with the concept and the devices. A good way to start is to write us on your letterhead, and ask for our CCSL literature pack.

Integrated Readout Circuitry

Integrated circuits have gained wide acceptance in applications which involve pulse counting. And for good reasons. It is often possible to substitute a single monolithic counting circuit for 20 or 30 discrete components required to do the same job. NanoFast, a Chicago manufacturer of analog and digital measuring equipment, has built an integrated circuit module which is used to count pulses and drive the visual output devices in a variety of the firm's instruments.

LASER RANGE MEASURING UNIT: One of the more interesting new instruments in which this module is put to work is a laser range measuring computer. The instrument is compact and portable and can be used in mapping, surveying and other range finding applications. The standard instrument has a range of 19,995 meters, a resolution of 5 meters, and a magneline readout. Modified versions are available, however, with tube readout and/or resolutions up to ¼ ft. The use of integrated circuits in this instrument made the unit small and portable, and in addition made the circuitry deceivingly simple and highly reliable, for the complex, accurate functions it performs.

OPERATION: The flow-chart illustrates the main principles of operation. The range measurement is accomplished by counting pulses during the interval between Start and Stop pulses, which are generated by the laser beam. The Start pulse begins the count by setting the B flip-flop to 1. A crystal oscillator provides the frequency time base and its pulses are counted until the Stop pulse resets the B flip-flop to 0. The counting itself is performed by decade counters which channel their output into the Magneline Indicator drivers in BCD code (1248). Two flip-flops are also used. The decade counters, the storage readout and the drivers are Fairchild Counting Micrologic® integrated circuits (9958, 9959 and 9960). Other Fairchild IC's are used in the gating and flip-flop functions.

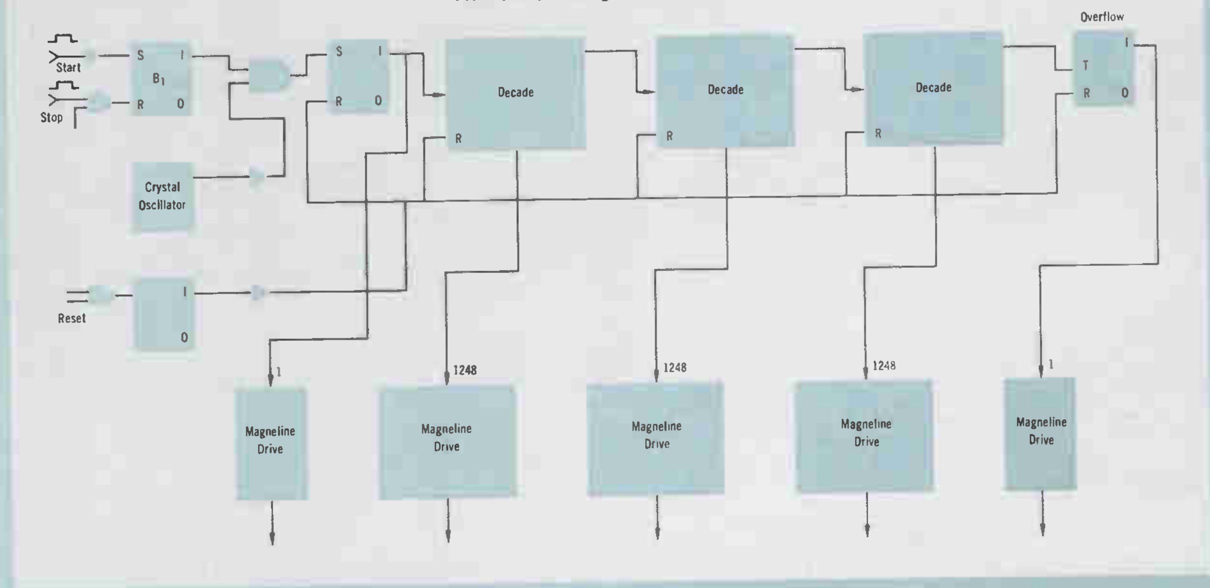
ADVANTAGES OF IC's: The principal benefit, in this application, for the use of IC's is their small size and the simplicity of the circuitry. A reduction in components count of about 30 to 1 was achieved in the sections of the circuitry where the integrated circuits are used. The simplification also resulted in greatly reduced labor costs, offsetting the higher costs of the integrated circuits. As integrated circuits of the type used by NanoFast come down in price, further savings will result.

Model M 53645 Range Measuring Unit

Integrated Readout Module

OTHER APPLICATIONS: NanoFast also uses the integrated circuit readout module in a Particulate Analysis System which it manufactures for several industrial customers. The system is equipped with optics that scan particles present in the substance to be analyzed and classify these particles by size. The number of particles in each classification is totaled by the readout modules, and directly displayed in digital form.

Flow-chart of Range Measuring Unit



For additional integrated circuit applications circle Reader Service No. 480

Electronics Abroad

Volume 40
Number 10

Great Britain

The connection

Like many a semiconductor maker, Britain's Standard Telecommunications Laboratories believes that discretion—in the interconnection of cells on a silicon chip—is the better part of valor in attempts to build custom subsystems from mass-produced standard large-scale arrays.

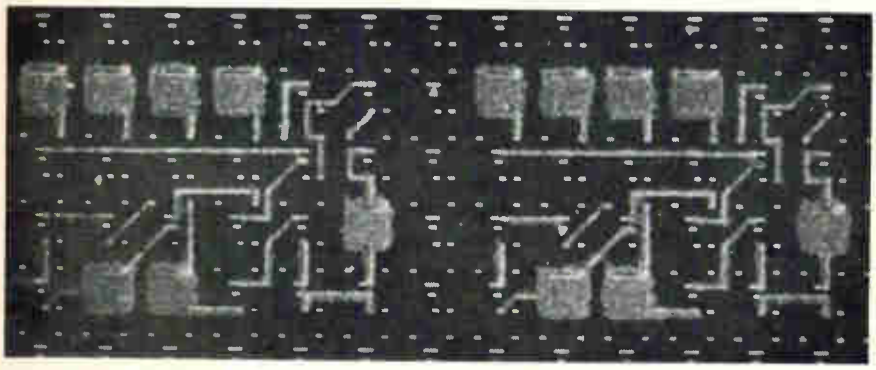
In their approach to low-cost discretionary wiring, engineers at Standard Telecommunications have turned to laser machining under computer control. The technique can be used to cut masks for interconnection patterns, but the long-range goal is direct deposition of connections onto substrates.

On the table. T.M. Jackson, A.D. Brisbane, and C.P. Sandbank, a trio of engineers from the company, a subsidiary of the International Telephone and Telegraph Corp., reported on their laser-machining experiments at an integrated circuits conference held in England a fortnight ago.

Using digital data picked off a computer-prepared design for the circuit layout, STL develops a punched-tape that controls the movement of a machining table carrying the substrate. The table has total travel of about 2 inches in both X and Y directions and moves in steps of 12.5 microns. The punched tape also has on it instructions for turning the machining laser off and on. The laser, which operates in the infrared region, has a peak output of 200-watt pulses of 500-nanosecond duration.

Across the gap. To deposit interconnection patterns directly on a large-scale array, the Standard Telecommunications researchers mount it on the machining table just below a transparent donor substrate carrying a metal film. The film and the array are so close together that both lie for practical purposes at the focal point of the lens that focuses the laser beam. (Standard won't disclose the exact gap but hints that it's next to nothing.) When the beam hits the film, a small spot on the film evaporates and deposits as a dot on the substrate below. Interconnection lines build up as a series of overlapping dots; the line widths run down to 25 microns. Good adhesion has been obtained, Standard says, with connection patterns showing a sheet resistivity of 1 ohm per square.

Standard Telecommunications Laboratories admits there's much work to be done before the laser-machining process can be used on production lines. One problem is reevaporation of deposited metal film back onto the donor substrate. A way out seems to be an additional film of nonevaporizing material between the transparent substrate and the metal film. The intermediate film would transmit the burst of laser heat needed to vaporize the metal film but afterward act as a filter.



Unmasked. Standard Telecommunications Laboratories is working on a laser-machining technique that deposits—without using masks—interconnection patterns on large-scale integrated circuit arrays.

Classy chassis

Convinced that a bold technological move now will lead to a strong competitive position as Britain's mass market for color-tv sets develops, Thorn Electrical Industries Ltd. is producing an all-transistor 25-inch set.

The move makes Thorn the first major tv producer in the world to go completely solid state for a production large-screen color set. Other British set makers plan to enter the color market with hybrid sets, as do most European producers [Electronics, May 1, p. 161]. Hybrids also prevail among U.S. color sets; but in America, integrated circuits most likely will turn up in the first solid state receivers.

Pay now. Thorn quite frankly admits its all-transistor set costs a lot more to make than a hybrid at present. The Thorn receivers will sell at the outset for \$870 to \$970, depending on the cabinet. That puts them in the upper half of the price range for British color-tv receivers.

But Thorn figures that within a year or two the total cost for the transistors in its set will drop below the tube cost for an equivalent set. Thorn then expects to have an edge on the field since competitors will have to redesign their receivers to take advantage of low-cost plastic-encapsulated transistors.

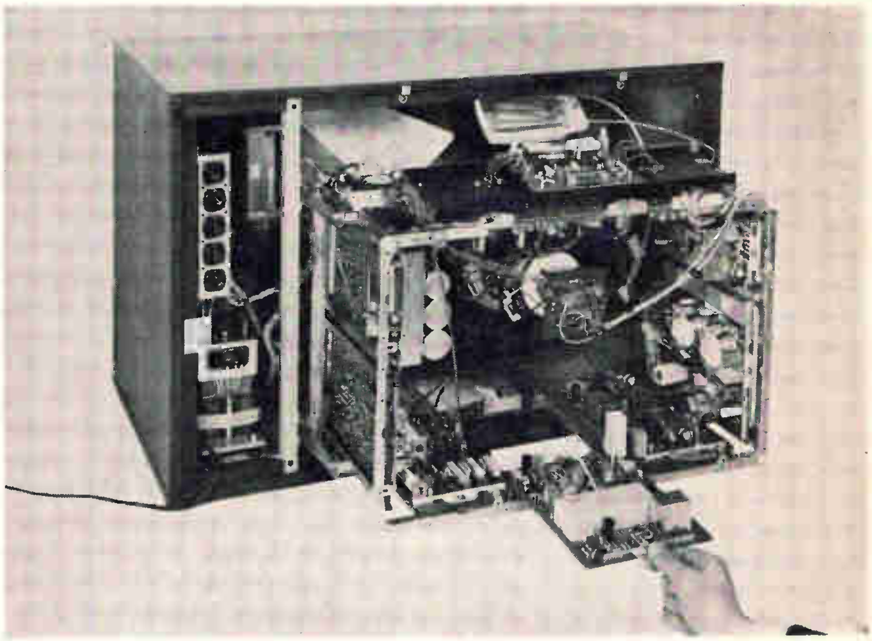
Collect later. Even when transistor costs drop, Thorn feels there'll be cheaper hybrids on the market. That's because its set has an inherently expensive modular design usually found only in computers and military hardware. But Thorn thinks the added construction cost will pay off in the British market. There, most tv sets are rented, rather than bought outright, and the rental contracts include free servicing. Thorn plans to set up a circuit-board exchange scheme so that repairmen will have only to find the faulty board and replace it.

Plugged in. Thorn's basic color chassis consists essentially of a rectangular metal frame fitted with 10 plug-in circuit boards that hold the set's 90 transistors and their associated passive components. The chassis is entirely isolated from the high d-c voltages.

In addition to the boards, there are seven other major assemblies mounted on a second frame and the shadow-mask tube. They include the tuner, the power transformer, a high-voltage rectifier-tripler, and the convergence coils. Any of these assemblies, Thorn says, can be unplugged and replaced in two minutes or less.

Specials. About 90% of the transistors are standard catalog units and most are supplied by Mullard Ltd., a British subsidiary of N.V. Philips' Gloeilampenfabrieken. The most critical—and most expensive—transistors in the set are two used in the high-voltage generator for the picture tube and two others in the line time-base board. The high-voltage board output, for example, is between 8 and 9 kilovolts. This is boosted to 25 kv in a "jelly pot" rectifier-tripler mounted on the picture tube. To protect the transistors against high-voltage flashover, Thorn uses individual spark gaps in the electrodes and series impedances in their leads.

For the critical transistors, Thorn went to Texas Instruments Incorporated. To hold down the prices of the specials, the two companies worked out a package deal under which Thorn bought standard TI transistors along with the specials. Mullard developed two special transistors for the output stage of the frame board.



Fast service. Thorn opted for an easily serviced modular design for its all-transistor color-tv set. Most of the components are contained in 10 circuit boards that plug into a metal frame that slides out for servicing.

France

G whiz

A French government research center has developed for the country's space effort what may be the most sensitive accelerometer anywhere.

The three-axis device, says Michel Delattre, chief of the electronics section at the Office National d'Etudes et de Recherches Aerospatiales, can detect displacements caused by near-infinitesimal forces—down to 10^{-9}G.

In the U.S., accelerometers with like performance are generally destined for military hardware and are therefore under security wraps. Apprised of the French development, a research executive of a leading U.S. accelerometer producer hinted he'd be concerned if a U.S. competitor had readied a device with 10^{-9}G sensitivity.

Delattre anticipates application of the accelerometer both in space research probes and in inertial navigation systems for satellites. The sensitivity level of 10^{-9}G, he points out, was selected for the device so that it could measure, with an accuracy of 10%, the braking effect of solar radiation on a 220-pound spherical satellite with an effective frontal surface of 1 square meter.

Suspended sphere. The high sensitivity of the Onera accelerometer comes from an electrostatic suspension system. At its heart is a beryllium sphere 40 millimeters in diameter. The sphere lies inside an evacuated cage whose inside diameter is about 40 microns larger than the sphere's diameter. The electric field set up by three annular electrodes on the wall of the cage holds the sphere centered.

Any upset in the sphere's equilibrium is sensed by dome-shaped sensing electrodes inside the annular electrodes. The sensing electrodes form part of a capacitance bridge fed by a 500-kilohertz reference voltage. When the sphere starts to move, the bridge is unbalanced and its output amplified to develop a compensating voltage. This voltage, applied to the annular electrodes, recenters the beryllium sphere. The compensating voltage needed to keep the sphere centered is a measure of the force acting on the accelerometer.

Vacuum inside the cage is maintained by a small ionic pump that holds internal pressure to less than 1 microtorr. The entire unit—cage, pump, and electronics—weighs 6.6 pounds and consumes 10 watts.

West Germany

Playing the field

Although it's been known for more than a century that some materials change resistance sharply in a magnetic field, the magnetoresistive phenomenon was little exploited until West Germany's Siemens AG developed its so-called "field plates" two years ago.

Now it looks as if a mild boom could develop for the devices, especially in analog computers and control systems. The reason: a new semiconductor crystal combination that extends the range of resistance change and at the same time simplifies the manufacture of field plates.

Herbert Weiss, a Siemens scientist, reported on the new crystal combination at the European meeting on semiconductor device research at Bad Nauheim last month.

Meandering. For the field plates, Siemens deposits a layer of indium antimonide about 20 microns thick onto an insulating substrate, either a ferrite or a nonmagnetic ceramic material. A typical plate measures 4 by 5 by 0.5 millimeters. Depending on the length and width of the meandering InSb path, a plate's basic resistance—with no magnetic field applied—can run from a few ohms to several thousand ohms. This resistance rises drastically in a magnetic field. At a field strength of 10 kilogauss, for example, the resistance may be up to 17 times the basic value. The exact increase depends on the doping of the basic material.

Needled. To get large field-induced resistance variations, though, it's necessary to eliminate the Hall effect—the electric field set up across a current-carrying conductor in a magnetic field. Siemens' first field plates had small metal bars placed across them to short out the electric field. In the new versions, needle-like nickel antimonide structures dispersed within the indium antimonide perform this function.

The nickel antimonide needles have a mean length of about 50 microns and a diameter smaller than 1 micron. Their conductivity is 7×10^4 (ohm-cm)$^{-1}$, some two orders of magnitude greater than the surrounding InSb material. When there's no magnetic field present, electrons travel in a straight line through the device. But when a field is applied, the electrons are deflected and forced to travel for a distance along the needles, oriented at right angles to the current flow. The net result is a longer current path through the device and thus a higher resistance.

Stepping out. Siemens expects field plates made of the InSb/NiSb material to turn up more and more in electronics equipment. In analog computers and control systems, they can be set up to multiply, divide, or square inputs or outputs. Field plates, too, can modulate signals at microvolt levels. Potentiometers made up of field plates mounted on an armature inside a permanent-magnet field structure have linearity of a few tenths of a percent and practically unlimited life since they have no wipers.

Austria

Better armed

After building some 200 electronically-controlled artificial hands for clinical tests and evaluation at a government-run rehabilitation center near Vienna, a small Austrian electronics company this month started volume production of its prosthetic hand.

The company, Viennatone Hoergereate, expects to turn out nearly 200 units during May and then continue at a pace of 2,000 units a year. Viennatone has a substantial backlog of orders from Austrian social security organizations, the quasi-official insurance institutes that handle the country's health benefits program.

The company hopes to find export markets as well. Experimental forearm-hand prosthetics with electronic control have been developed in Russia, Great Britain, West Germany, and the United States. But only Viennatone is producing in volume.

Viennatone has set a $420 price for its Myomot MM2, as the prosthetic hand is called. The price includes everything but the polyvinylchloride sleeve that attaches to the forearm stump. The sleeve must be custom made for each user. To facilitate fitting the devices Viennatone has developed a special test instrument. It helps spot the best location on a patient's forearm for the two electrode pairs that pick up the muscle-voltage signals. These signals control the hand's movements.

Muscle control. Like most electronic prosthetics available now, the Myomot uses as its input control signals the low-level electromyographic (EMG) potentials developed in muscles when the brain signals them to contract or relax. In the Myomot, the EMG potentials are amplified in three transistor stages, rectified, shaped, delayed for 80 milliseconds and then used to trigger a circuit that drives a small motor in the artificial hand. Finger movements are accomplished through gearing driven by the motor; the gripping force is just under 15 pounds.

Selective. The amplifier circuits operate from 200 to 3,000 hertz. This range protects the user from unwanted finger movements that could be triggered by radiation from electric power lines and the like. The gain against the 50-hz power frequency used in Europe is about 20 decibels, for example. The circuitry, together with a 12-volt dry cell supply, is housed in a case that the user carries in his pocket.

The test set Viennatone devised

Steady. Electromyographic-controlled artificial hand manufactured in Austria has selective amplifier circuits that protect users from spurious finger movements.

to help fit the artificial hand is essentially an electronic voltmeter that handles two low-level inputs (30 to 100 microvolts is a typical value for EMG potential) at the same time. Two inputs are needed because the difference between the potentials of adjacent groups of muscles is the most important factor in finding the optimum location for the two electrode pairs, one to control opening, the other closing, of the hand.

International

Mavericks

President Charles de Gaulle long has held that Europe couldn't afford to let the United States control Western-world space communications. Now he's signed on a partner—Kurt Georg Kiesinger's West German government—to help break the U.S. stranglehold.

The two countries agreed this month to build a communications satellite that they hope to launch by the end of 1970. Cost of the program still has to be fixed, but French space planners say the binational bird will closely resemble their Saros project whose tab—exclusive of ground stations—was estimated at about $32 million.

The Franco-German move came as no particular surprise to U.S. space circles. In recent months there's been increasing discontent by other countries over the 54% share that the U.S. Communications Satellite Corp. holds in the International Telecommunications Satellite Consortium, the 50-nation organization set up to handle multinational programs. As it now stands, the Intelsat agreement won't come up for a thoroughgoing review until 1969; but delegates from the member countries will meet in Tokyo later this month to work out ground rules covering regional or domestic satellites.

Long reach. The proposed Franco-German satellite, though, can't be classed as regional. It will be put into a stationary orbit over the mid-Atlantic and from there could cover most of Europe and Africa, the Middle East and northern Latin America. The satellite will weigh about 400 pounds and have a capacity of 1,000 telephone channels.

Launching site for the satellite will be the French space center now being constructed in French Guiana. To get the satellite in orbit, the two partners plan to use the improved Europa rocket under development by the six-nation European Launcher Development Organization.

France and West Germany, both of whom had tentative national communications satellites projects on the drawing boards before they decided to go it together, will split costs and ownership equally. The hardware will be built half in Germany and half in France. Centre National d'Etudes Spatiales will oversee the French part of the program and Gesellschaft fuer Weltraumforschung the German part.

Japan

Time to share

Unlike most computer makers the Tokyo Shibaura Electric Co. doesn't think only of big machines when it comes to time sharing. Toshiba sees time sharing as a way of cutting desk calculator costs and is backing its view with a system that ties up to eight desk keyboard units into a single central processor.

Toshiba sells the full system—with eight desk consoles—for $5,840. That works out to $730 a calculator, lowest price in Japan for a 12-digit machine with a memory register. The company says the time-shared desk calculator system holds a clear-cut edge in price whenever there's a need for six to eight desk calculators.

In the U.S., Wang Laboratories Inc. has done the same thing but on a smaller scale. Wang's time-shared calculator introduced last fall handles up to four desk units.

IC packages. In Toshiba's new system, common logic circuits of the central processor are shared by time division. Along with the arithmetic logic, the processor has a pair of registers plus a memory register for each desk-top console. Except for the memory registers, the central-processor circuitry is made up of diode-transistor-logic integrated circuits developed by Toshiba—in all, 460 IC packages. For the memory registers, Toshiba uses diode-capacitor circuitry. Total power consumption for the system is 150 watts.

Clock frequency for the common logic circuits is 50 kilohertz, relatively slow for time-sharing. But Toshiba maintains that operators working out problems on the desk consoles normally won't notice any wait for access to the central processor. For the worst case—eight operators calling simultaneously for a long division—it takes less than 4 seconds for the answer to appear on the last desk console.

Toshiba's specifications for the system set a maximum of 98.4 feet for the distance between desk consoles and the central processor.

But company engineers say they've run tests successfully at distances up to 328 feet. Because it expects requirements of users to vary, Toshiba will build each time-shared calculator system to order. Initial plans call for production of about 10 systems a month.

Around the world

Japan. Researchers at the government's Electrotechnical Laboratory say they're well along in development of a new thyristor that will operate at 5,000 volts, double the rating for current commercially available thyristors. The new device has a p-i-n structure rather than the pnpn structure of conventional thyristors.

Great Britain. Technology Minister Anthony Wedgwood Benn has moved to counter the outflow of British engineers and scientists to the United States [Electronics, March 20, p. 171]. Benn's ministry has hired a London firm to recruit graduates of American universities for jobs in British industry.

Thailand. The Thai Ministry of Communications has awarded a $5.75 million contract to the General Telephone & Electronics Corp. for construction of a satellite ground station at Sriracha, about 60 miles southeast of Bangkok. The facility will have a dish antenna 97 feet in diameter and transmitting-receiving equipment to handle 300 channels simultaneously. It is scheduled to go into service on April 1, 1968.

South Africa. Work has begun on a $70 million underseas cable that will link Cape Town with Lisbon, 6,000 miles away. The project involves 643 transistorized repeater-amplifiers, spaced at intervals of 9½ nautical miles, plus 51 equalizers. The cable's capacity will be 360 channels. Standard Telephone & Cables Ltd., a British subsidiary of the International Telephone & Telegraph Corp., has the prime contract for the job, which will take about 18 months to complete once cable-laying starts later this year.

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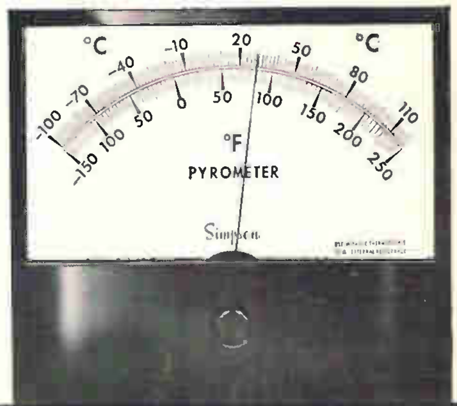

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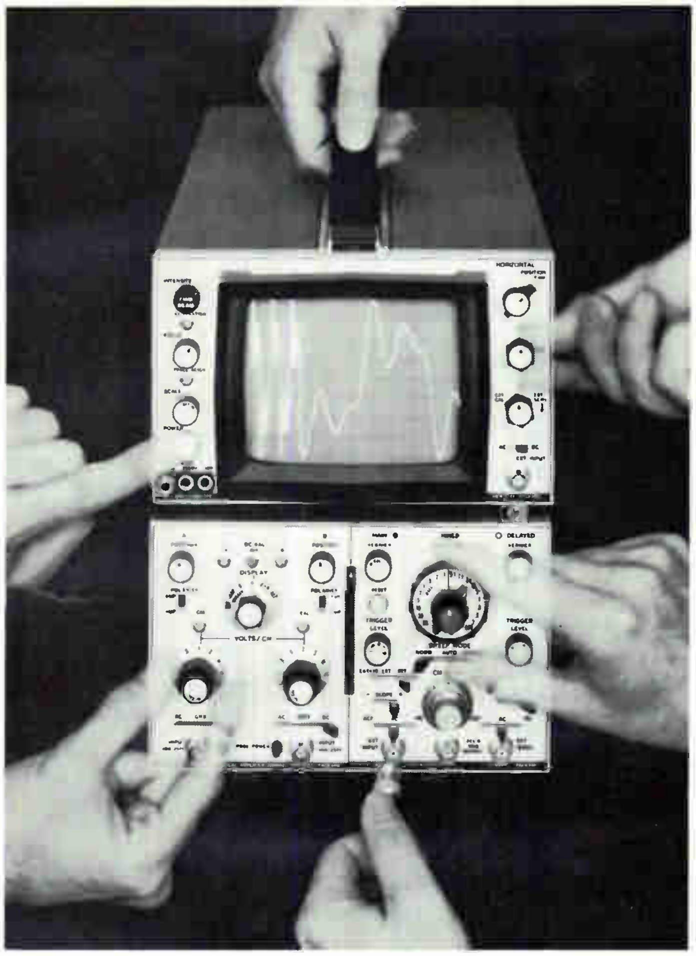

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