Electronics

Computers analyze transients: page 84

How good are plastic packages? page 101

Cooling IC's with liquid dielectrics: page 123

April 17, 1967
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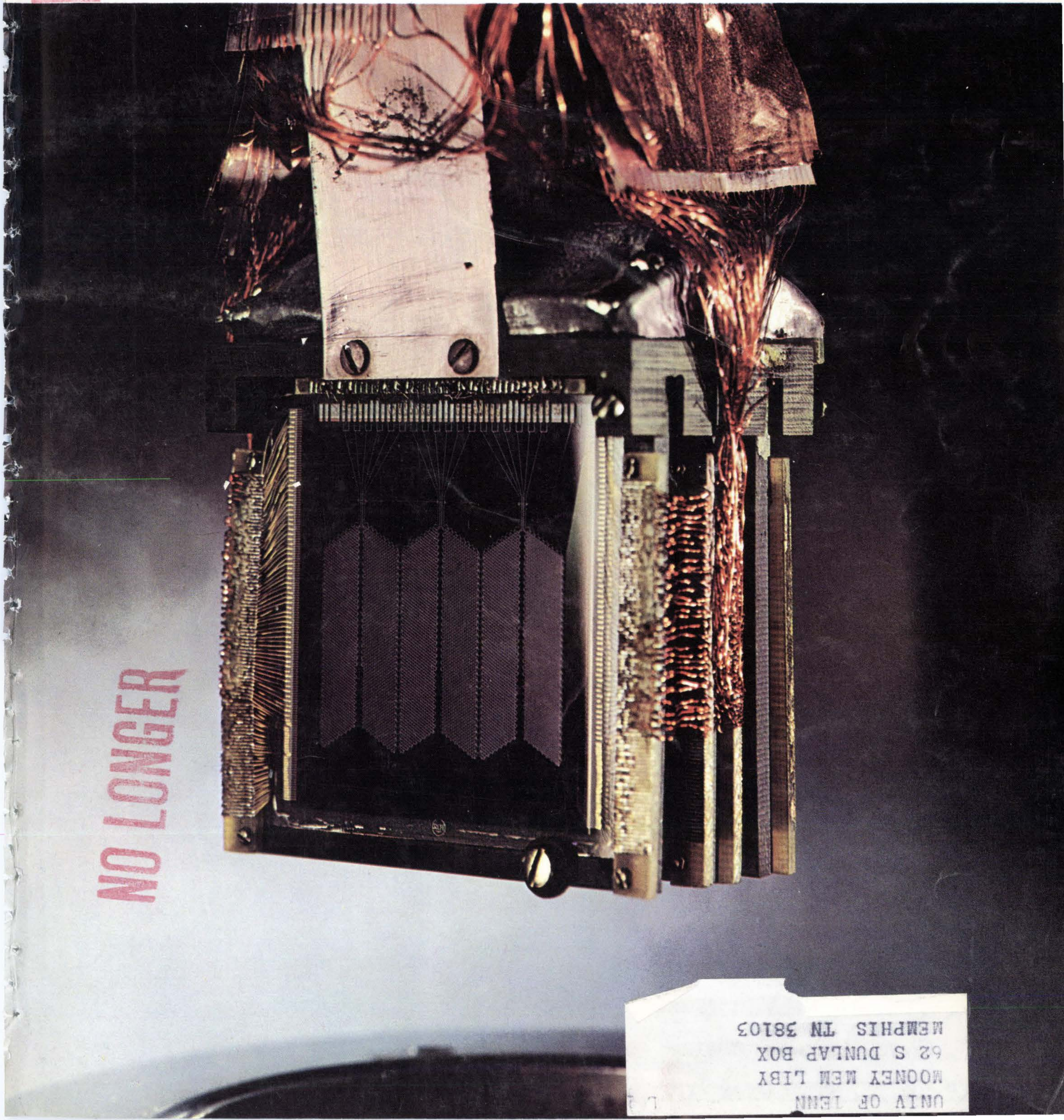
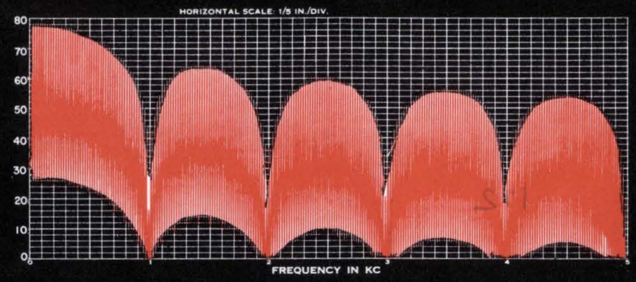
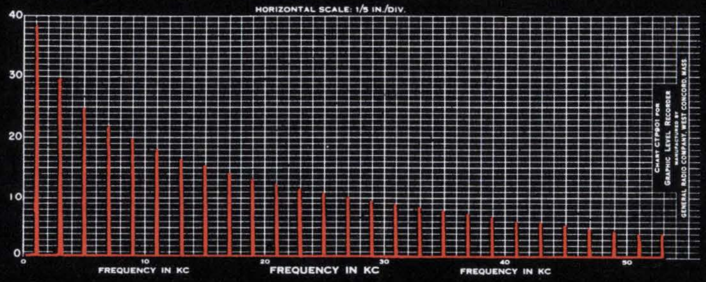
Below: Superconductive loops form big cryoelectric memory, page 111

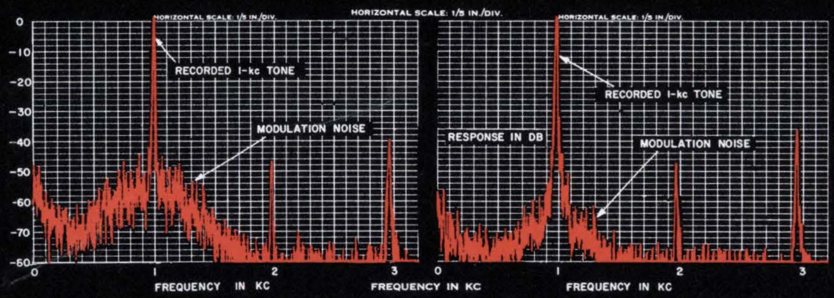




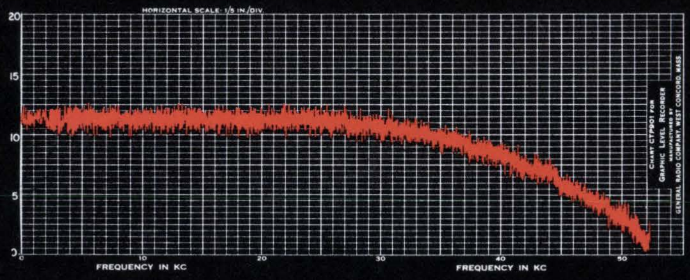
Fourier Components
bandwidth: 3 Hz
recording range: 80 dB



Periodic Wave
bandwidth: 50 Hz
recording range: 40 dB



Modulation Noise
bandwidth: 10 Hz
recording range: 80 dB



Spectrum Uniformity
bandwidth: 50 Hz
recording range: 20 dB

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The 1910-A is a combination of a wave analyzer (Type 1900-A) and a graphic level recorder (Type 1521-B). It automatically sweeps and records input levels of 2 μV to 300 V over a range of 20 to 54,000 Hz with 80-dB dynamic range (when set to read 100 mV, or more, full scale). Included are 3-, 10-, and 50-Hz bandwidths, 40- and 80-dB full-scale recording ranges, and several sweep and writing speeds. Optional accessories (at extra cost) extend the sensitivity to submicrovolt levels, add a 20-dB full-scale recording range and provide still more sweep speeds.

For a complete listing of the many operating modes of the 1910-A, write General Radio Company, 22 Baker Avenue, W. Concord, Massachusetts 01781; telephone (617) 369-4400; TWX 710 347-1051.

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- Economy model, 1 mv-10 v/in.; Model 7035A, $895.

11" x 17" X-Y RECORDERS

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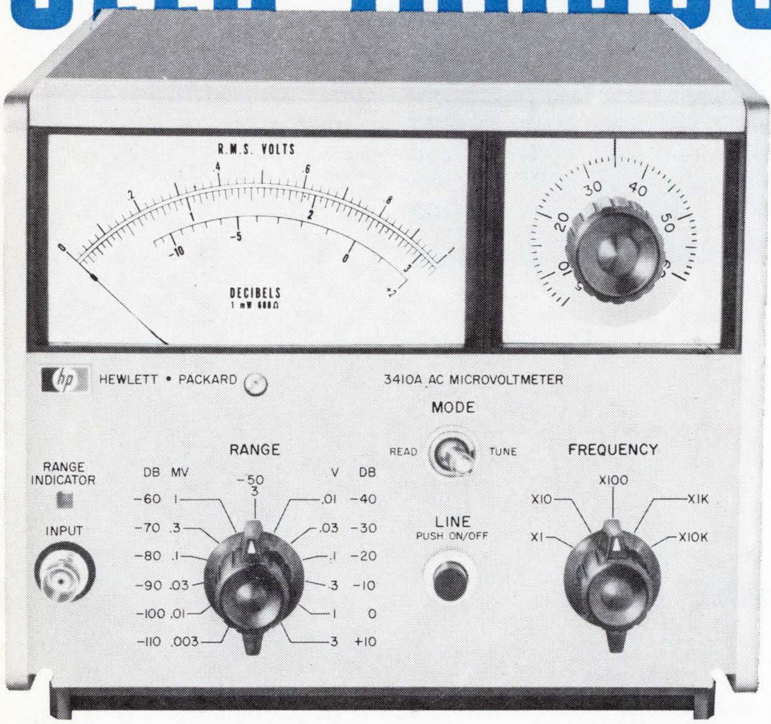
- Economy model of 2D Series, 0.5 mv-10 v/in.; Model 2D-4, $1490.
- 2-pen version of 2D Series; Model 2FA, $3375.
- High-sensitivity ac/dc recorder, time base either axis, 0.1 mv-20 v/in. dc, 5 mv-20 v/in. ac; Model 7000A, $2495 (also available without ac input, Model 7001A $2175).
- Automatic data plotting system, null detector and character printer built in, 0.5 mv-10 v/in.; Model 7590C, $1985.

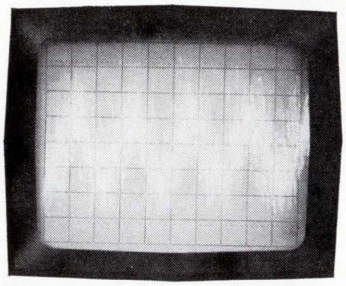
HEWLETT PACKARD hp MOSELEY DIVISION

1790

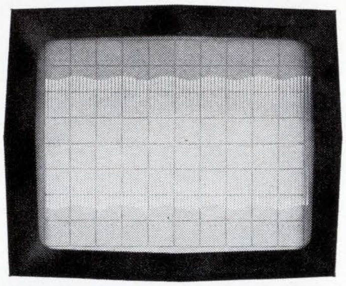
AC MICROVOLTMETER SEES THROUGH NOISE!



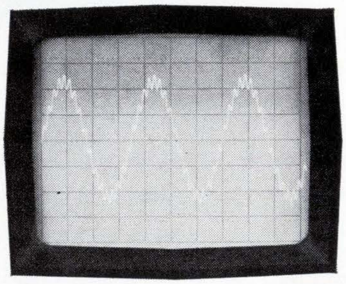
New hp 3410A Measures 300 nanovolts Buried in Noise



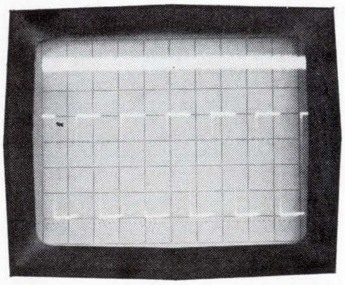
Measure 1 μV, 500 kHz signal out of 40 dB noise.



Measure 10 mV, 5 Hz amplitude modulating 1 V, 400 Hz.



Measure 300 nanovolts, 10 kHz signal superimposed on 10 μV, 1 kHz.



Measure frequency of signal in noise up to 560 kHz by using square wave output, i.e. as a counter preamplifier.

New hp Model 3410A AC Microvoltmeter measures low level repetitive signals obscured by noise—3 μV to 3 V full scale—accuracy ±3%. RMS noise voltages up to 20 dB above full scale *do not affect* readings. Sensitivity, low cost and ease of operation are the 3410A's contribution.

This new microvoltmeter uses an hp designed phase-locked synchronous detector to separate effects of noise from signal. The detector is an electronic gate controlled by an oscillator phase-locked to the input signal. No external reference is required to lock to the input signal. Simply adjust front panel tuning control within 1% of signal frequency and phase-lock circuits *lock-on and track* input signal with ±5% variation in the 5 Hz to 600 kHz frequency range. Phase-lock circuits track 0.5%/sec change in signal frequency without a change in voltmeter accuracy. Input impedance is 10 MΩ shunted by 20 pF.

The new Model 3410A has two outputs on the rear panel. One is a dc recorder output for monitoring long term drifting ac voltage amplitudes. The other is an output for driving an electronic counter to make precise frequency measurements.

For full specifications on the new hp Model 3410A AC Voltmeter, call your hp field engineer. Or, write to Hewlett-Packard, Palo Alto, California 94304, Tel. (415) 326-7000; Europe: 54 Route des Acacias, Geneva. Price: hp Model 3410A, $800.00.

097/11

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Electronics

April 17, 1967

Volume 40, Number 8

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Electronics Abroad

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II. Applications

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Readers Comment

One approach

To the Editor:

In response to the article "No wane in brain drain" [March 20, p. 171], may I suggest that a possible solution to the problems lies in having more U.S. companies establish subsidiaries in Europe. These subsidiaries could operate those laboratories and departments in which the shortage of engineers at home is most acute, staffing them mostly with locally recruited engineers, while maintaining a close working relationship with the parent companies. In addition to solving the brain drain problem to the satisfaction of everyone concerned, such an approach may hold in the balance, some direct, as well as indirect, advantages for the companies themselves.

Uri F. Gronemann
Research engineer
Electronic Systems Laboratory
Massachusetts Institute of Technology
Cambridge, Mass.

▪ Some companies have earned the "international" in their name in this way. Others have established cross-licensing arrangements or have farmed out a particular development problem to an overseas specialist. But these are not direct solutions to a critical gap in the engineering staff at home.

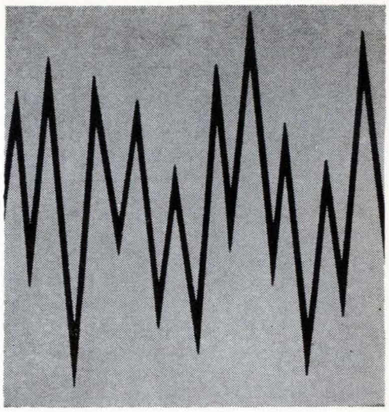
No help needed?

To the Editor:

I agree that government research and development contributes significantly to technical progress, as pointed out in your editorial, "Transferring technology" [Jan. 23, p. 23]. However, I am surprised that you cited the transistor as a development which might have remained a laboratory curiosity without pressure from a Federal program.

A solid state amplifier was a dream of many communications engineers in the 1930's and 1940's, and Bell Telephone Laboratories' research in semiconductor physics was stimulated by this hope. Therefore, after invention of the tran-

Sprague has what it takes to cope with any problem in electromagnetic interference or susceptibility control



And we mean any problem . . . arising at any point in the development of any equipment or system!

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Regional Service: Wherever you may be, this integrated EMI capability is readily available to you from strategically located Filter Development Centers in North Adams, Mass.; Annapolis Junction, Md.; Vandalia, Ohio; and Los Angeles, Calif. Each is fully equipped and staffed to evaluate, modify, or qualify your equipment.

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sistor, we formed a group in 1948 to develop the transistor for communications use. Bell Laboratories contributed to rapid dissemination of transistor technology by its policy of immediate publication and by symposia held in 1951 and 1952 for military and licensee engineers. In 1956, a symposium for licensees disclosed the diffusion technology that permitted low-cost mass production.

Your impression that the Bell System began putting transistors into telephone systems only a few years ago probably stems from recent announcements of new electronic switching systems, which certainly will make more use of transistors than ever before.

Transistors have been used in telephone equipment since the early 1950's. The junction transistor, first realized in 1951, was immediately put to use in the headset amplifier for telephone operators, in rural telephone carrier amplifiers, and by other companies in radios and hearing aids. By 1958, transistors were also used in amplifier telephone sets, signaling sets, card translators, and other equipment. And we were experimenting with electronic switching, pcm transmission, microwave and video amplifiers, electronic PBX's and other transistor equipment.

Bruce E. Strasser
Technical information manager
Bell Telephone Laboratories
Murray Hill, N.J.

▪ Strasser's letter goes on to cite significant military and space equipment developed at Bell Labs with transistors. It still seems to be a chicken-and-egg question. Could other developers of semiconductor devices have survived the early years if the Government had not been ready to pay $100 or so for a transistor and $200 for an integrated circuit?

Radio astronomy

To the Editor:

In the Newsletter from Abroad item, "Soviets discount far-out broadcasts" [April 3, p. 258], the pass frequencies are indicated as 1 hertz and 0.1 hertz. Shouldn't this be 1 hz and 0.1 khz?

Daniel C. Weinstein
Brooklyn, N.Y.

▪ No. One problem in attempting to receive signals from other worlds is that the time spent searching for signals could also become astronomical. Therefore, the Russians suggested simultaneous reception on many channels with pass bands as narrow as 1 to 0.1 hz.

An earlier version

To the Editor:

In my article, "Space for small computers" [March 20, p. 127], the diagram on page 128 is the data system of the early IMP spacecraft, rather than the single-channel-encoder data system described in the caption and referred to on page 129.

Rodger A. Cliff
Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Md.

▪ The drawing that should have been used shows a commutator on the left of the telemetry encoder and a single pfm oscillator on the right, feeding the transmitter.

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People

Relying almost exclusively on Pentagon purse-strings isn't a problem for **Burton Cutler,** new president of ITT Gilfillan, Inc., a Los Angeles-based producer of radar systems, countermeasures, and displays.

Burton Cutler

"Our sales are about 95% to the military," says the 6-foot-6-inch, 40-year-old official, adding that he doesn't plan to alter the picture significantly. Air-traffic control radars for foreign governments account for the remainder of Gilfillan's volume.

Cutler notes that as one of more than 400 members of the International Telephone & Telegraph Corp. family, Gilfillan doesn't have to concern itself with an unfavorable military-to-commercial ratio. "We're seeking maximum penetration of the area assigned to us, which isn't at all limiting," he says. However, the company is moving quietly to broaden its foundation in systems other than the ground-control approach radars for which it is probably best known.

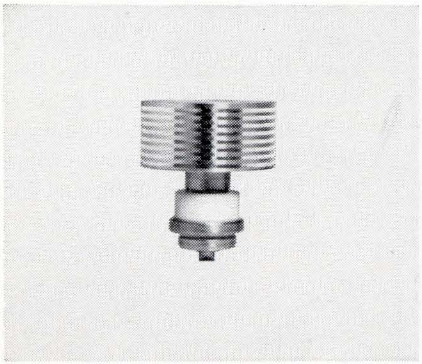
The executive is sold on the future of solid state phased-array radar, and Gilfillan's most important current research effort is concentrating on that technology. The program began in January and is expected to run three years.

Cutler succeeded E.S. Phillips, who was named chairman of the ITT subsidiary last month. The new president, formerly a vice president and director of engineering, has an MSEE from Stanford University, and holds several radar patents.

Gilfillan employs about 2,600 and had sales last year of about $40 million. Cutler predicts a volume rise this year to $50 million, with the initial production of newly developed three-dimensional air defense radars accounting for most of this gain. Already operational with the Navy is the firm's AN/SPS-48 3-D radar, the primary sensor for Tartar and Terrier surface-to-air missiles. Another 3-D radar system, the long-range AN/TPS-32, is being developed for the Marine

MACHLETT

1967 Guide to Machlett and Machlett-Penta Electron Tubes



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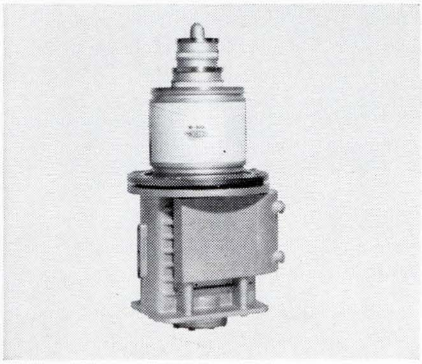
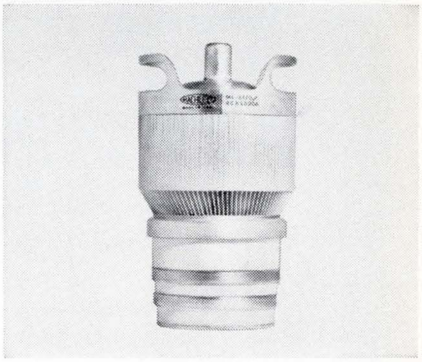


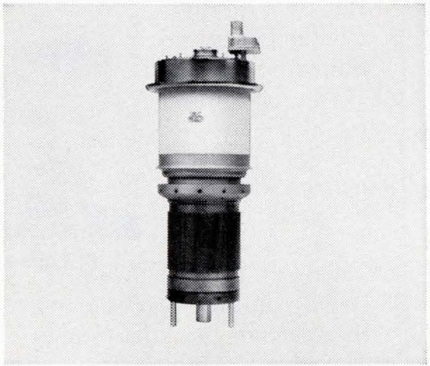
Magnetic Beam Triodes.

Pulsed ratings to 6 Mw with only 2.5 kw drive. CW ratings to 200 kW with only 0.7 kW drive.



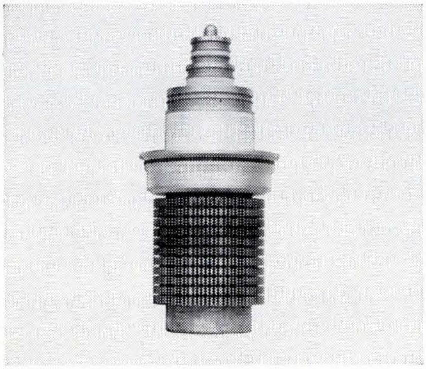
Heavy Duty Tetrodes.

Includes vapor cooled tetrodes, to 300 kw CW.



Pulse Modulators.

Shield grid triodes (oxide cathode) to 4.5 Mw, 80 kv peak. High voltage triodes (thoriated tungsten cathode) to 20 Mw with plate voltages to 200 kv peak.



Heavy Duty Triodes.

Includes vapor cooled triodes, to 440 kW CW.

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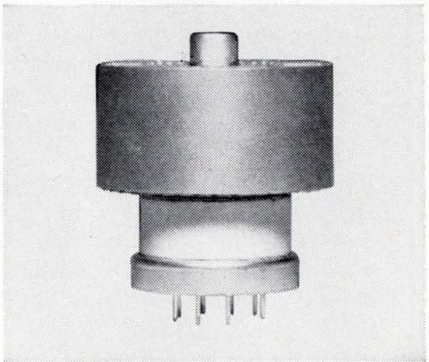
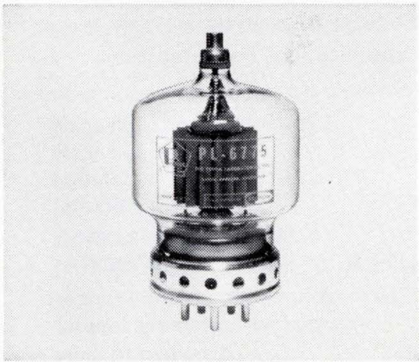


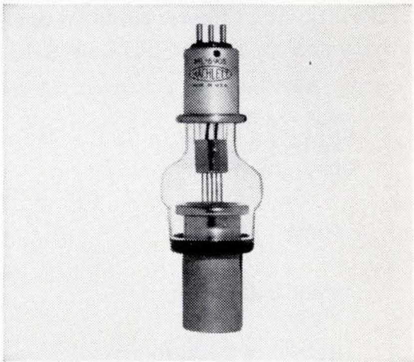
Machlett-Penta Intermediate Power Pentodes.

Vane suppressor pentodes to 300 w PEP with −40 db 3rd order IM without feedback; to 10,000 w PEP, −35 db 3rd order IM without feedback.



Machlett-Penta Intermediate Power Tetrodes and Triodes.

Power to 3.4 kW CW.



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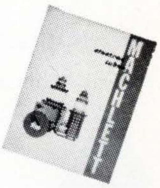

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People

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But Cutler isn't ignoring opportunities to apply Gilfillan's experience to new fields. The firm has embarked on a campaign to recruit a team of systems engineers with aerospace backgrounds, for example. It's also working to enhance its expertise in the field of electronic countermeasures, and is quite proud of winning an Army contract to develop a battlefield surveillance radar.

Robert B. Lomerson, 37, built a better integrated-circuit package and engineers began to beat a path to the door of his Flying L Co. in Saginaw, Texas. His packages could be made smaller than conventional IC flatpacks, yet were easier to solder than large, plug-in packages because they stood on stiff, square legs. The idea looked great; requests for information came in from most of the nation's major electronics firms and from companies as far away as Argentina and Finland.

R. B. Lomerson

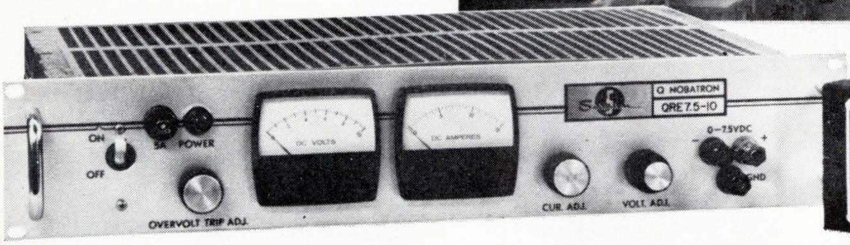
Last fall and winter, Lomerson kept a few employees busy building sample packages while he crisscrossed the country talking to potential customers. Between trips, he worked on new versions of the package and assembly methods [Electronics, April 3, p. 139].

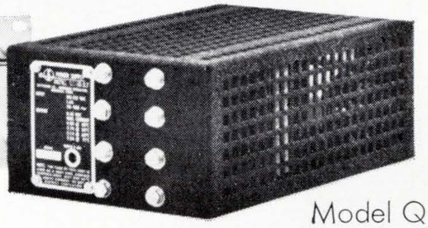
Assembling sample packages was one thing, but assembling the capital needed to mass produce them was another. Lomerson's pleas to banks fell on deaf ears. For a while, he fended off electronics companies' offers to buy Flying L, clinging to the idea of a company of his own. But finally his savings ran out.

Two weeks ago, he sold his firm to Varo Inc. of Garland, Texas.

Lomerson will continue to work on his packages as Varo's senior development engineer. He says the company plans to produce his packages and keep Flying L in Saginaw.

Model QRE 7.5-10





Model QRE 10-3.7

Sorensen Off-the-Shelf Power Supplies Designed for Integrated Circuits:

Sorensen has provided stock availability of the new QRE Series. This series was designed specifically for use with integrated circuits, micro miniature chips, and digital logic circuitry. QRE provides overvoltage protection within 10 microseconds, voltage regulation, line and load combined, is ±0.005% or ±0.01%.

All QRE units include these Sorensen features, series/parallel operation, remote sensing, remote programming and high stability. Designed as a space saving system the QRE Series may be selected from either modular or 3½" high rack units.

MODEL	V/A RANGES	PRICES
QRE 10-2.2	0-10V, 0-2.2A	$135
QRE 10-3.7	0-10V, 0-3.7A	155
QRE 7.5-10	0-7.5V, 0-10A	295
QRE 7.5-20	0-7.5V, 0-20A	465
QRE 7.5-50	0-7.5V, 0-50A	595

For QRE details, or for information on other stock or custom DC power supplies, AC line regulators, frequency changers, or for our free catalog #662A, contact your Sorensen rep., or Raytheon Company, Sorensen Operation, Richards Ave., Norwalk, Conn. 06856. Tel: 203-838-6571.

RAYTHEON

PATENT NO. 3,260,902: ISOLATED BURIED LAYER TRANSISTORS FOR INTEGRATED CIRCUITS

Nanosecond switching. A shortcut through the basement. Isolated buried layer transistors. Invented here.

FAIRCHILD

SEMICONDUCTOR

Meetings

Spring Joint Computer Conference, IEEE; Atlantic City, N.J., **April 18-20.**

Southeastern Instrument Conference, Instrument Society of America; Cocoa Beach, Fla., **April 18-20.**

Conference on Semiconductor Device Research, IEEE; Federal Republic of Germany, **April 19-22.**

Southwestern IEEE Conference and Exhibition, IEEE; Dallas, Texas, **April 19-21.**

Semiconductor Device Research, IEEE; Bad Nauheim, West Germany, **April 19-22.**

Symposium on Vacuum Science & Technology, New Mexico Section of the American Vacuum Society, Holiday Inn, Albuquerque, New Mexico, **April 19-21.**

Meeting on Welding Design and Reliability, Engineering Institutes; University of Wisconsin, Madison, Wis., **April 20-21.**

Textile Industry Technical Conference, IEEE; Charlotte, N.C., **April 20-21.**

Seminar on Computer Graphics and Time-Sharing Systems, Association for Computing Machinery, Holiday Inn, Atlantic City, N.J., **April 21-22.**

Aeronautic Meeting, Society of Automotive Engineers; Statler-Hilton Hotel, New York, **April 24-27.**

Conference For Protective Relay Engineers, Electrical Engineering Department; Texas A&M University, College Station, Tex., **April 24-26.**

Engineering Conference, American Society of Tool and Manufacturing Engineers; McCormick Place, Chicago, **April 24-28.**

Conference on Integrated Circuits, IEEE; London, **April 24-May 1.**

Simulation and Training Conference, Society of Automotive Engineers; Statler-Hilton Hotel, New York, **April 24-27.**

National Relay Conference, National Association of Relay Manufacturers; Oklahoma State University, Stillwater, Okla., **April 24-25.**

Frequency Control Symposium, U.S. Army Electronics Command; Shelburne Hotel, Atlantic City, N.J., **April 24-26.**

Institute on Management Technology and the Optimization of R&D, American University; Twin Bridges Marriott Motor Hotel, Washington, D.C., **April 24-27.**

Joint Railroad Conference, IEEE and American Society of Mechanical Engineers, Erie, Pa., **April 25-26.**

Symposium on Test Methods and Measurements of Semiconductor Devices, Scientific Society for Telecommunication; Budapest, **April 25-28.**

Symposium on Advanced Technology Available for Commercialization, North Carolina Science & Technology Research Center; Research Triangle Park, N.C., **April 26-27.**

Aerospace Instrumentation Symposium, Instrument Society of America; Marriott Motor Hotel, Philadelphia, Pa., **May 2-4.**

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

Call for papers

International Pulse-Symposium, International Federation of Automatic Control; Budapest, April 9-11, 1968. **May 1** is deadline for submission of papers to International Pulse-Symposium, Budapest 112, POB 63, Hungary.

Electronics and Aerospace Systems Technical Convention, IEEE; Sheraton Park Hotel, Washington, Oct. 16-18. **June 1** is deadline for submission of papers to Donald Hagner, Bellcomm Inc., 1107 17th St. N.W., Washington, D.C. 20036.

Marine Sciences Instrumentation Symposium, Instrument Society of America; Florida, January 1968. **June 15** is deadline for submission of abstracts to Fred Alt, director, Testing division, Naval Oceanographic Officer, Washington, D.C. 20390.

*** Meeting preview on page 16.**

Use the new Fluke 931A to measure virtually any waveform within 0.05% from 30 Hz to 50 KHz. Make these measurements without losing null sensitivity as the voltage decreases. For in the Fluke 931A, the null meter indicates percent deviation from the dialed voltage. Overall frequency response is 10 Hz to 1 MHz. Range is 0.01 to 1100 volts. Ten to one crest factor takes care of effects caused by voltage spikes and pulse trains. Other features include low capacitance, high resistance input, inline digital readout with lighted decimal point, all solid state design, and linear recorder output. Meets MIL-SPEC shock and vibration requirements. Ten percent overranging cuts down range changing. Available with or without probe in both line and combination line rechargeable battery powered versions. Base price $895. Call your full service Fluke sales engineer (see EEM) for a demonstration or write us for full information.

Meeting preview

Telemetry trends

The program of the National Telemetering Conference, to be held May 16-18 in San Francisco, continues last year's trend away from aerospace and military applications. Scheduled talks will concentrate on oceanographic, industrial, and biological uses for telemetry gear, and will emphasize techniques and problem-solving more than new products.

Six sessions to brief attendees on recent advances in the state of the art will cover the latest in transducers, signal conditioning, detection and modulation theory, multiplexing and encoding systems, and data management. Later workshop meetings will give engineers the chance to compare notes and possibly find solutions to their particular telemetry problems.

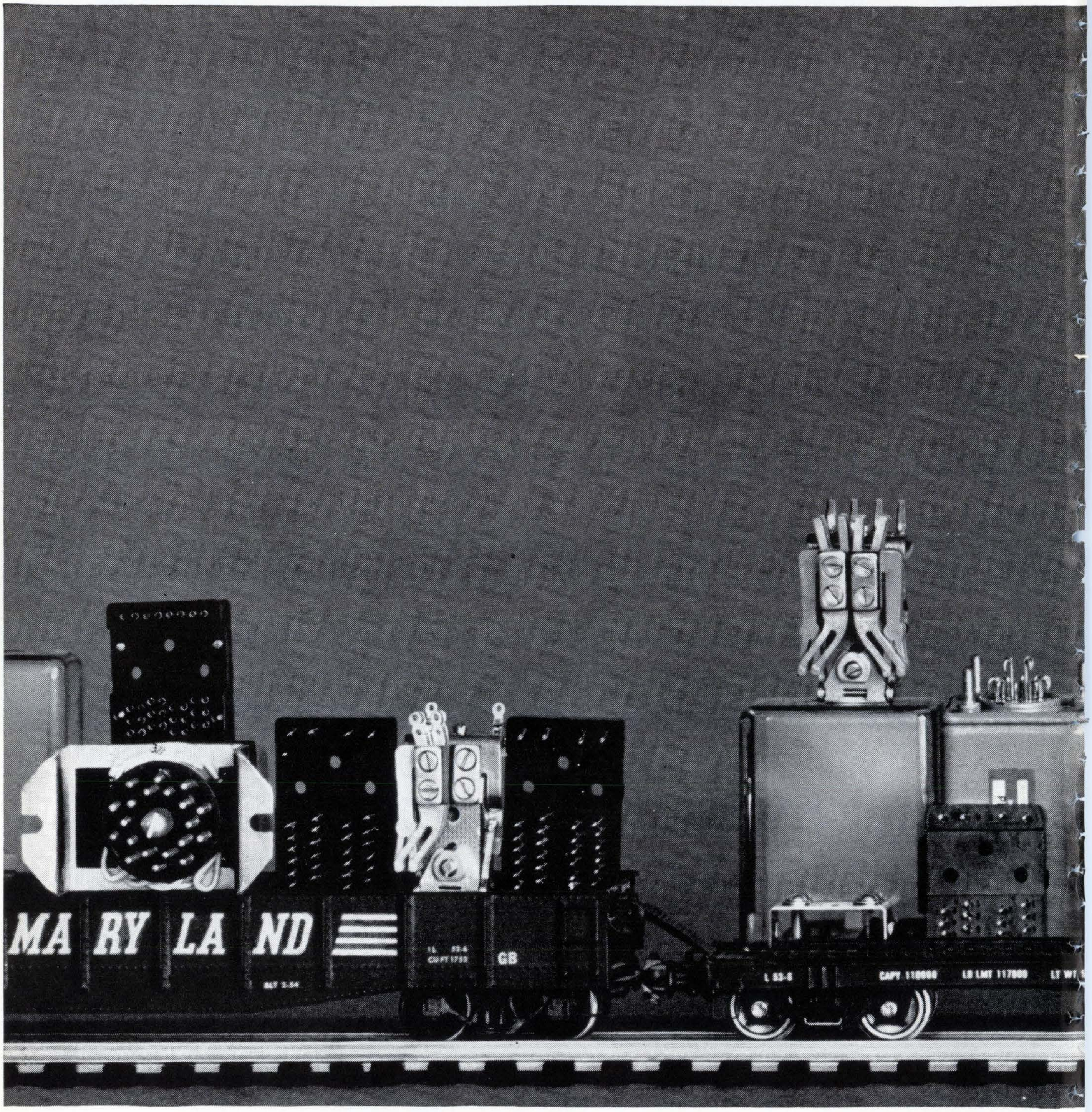
Ocean links. The problem of moving data through the water will be the major topic at the oceanography sessions. R.F. Hill of the University of Rhode Island and L.R. LeBlanc of Raytheon Co.'s Submarine Signal division will present papers on the ocean as a data-transmission medium. They will describe their techniques for modeling the ocean as an acoustical communications channel to determine the available bandwidth and the amount of data that can be transmitted through it.

Other papers discuss work at the Navy's Underwater Weapons Laboratory and Underwater Sound Laboratory, and ocean communications experiments at Pennsylvania State University's Ordnance-Research Laboratory.

At a medical telemetry session, members of the Bioengineering Research Laboratory at the Women's Medical College of Pennsylvania will present a paper on a multichannel telemetry system that has been used to monitor amniotic fluid pressure in the human womb, as well as fetal respiration and heartbeat, just before and during childbirth.

The problems of rapid transit will be discussed in a paper on the automatic train system for Canada's Expo-67 World's Fair in Montreal.

Try to find a connection



The growing popularity of AE's Class E Relay as the "workhorse of the industry" has set off a demand for a wide variety of mounting techniques.

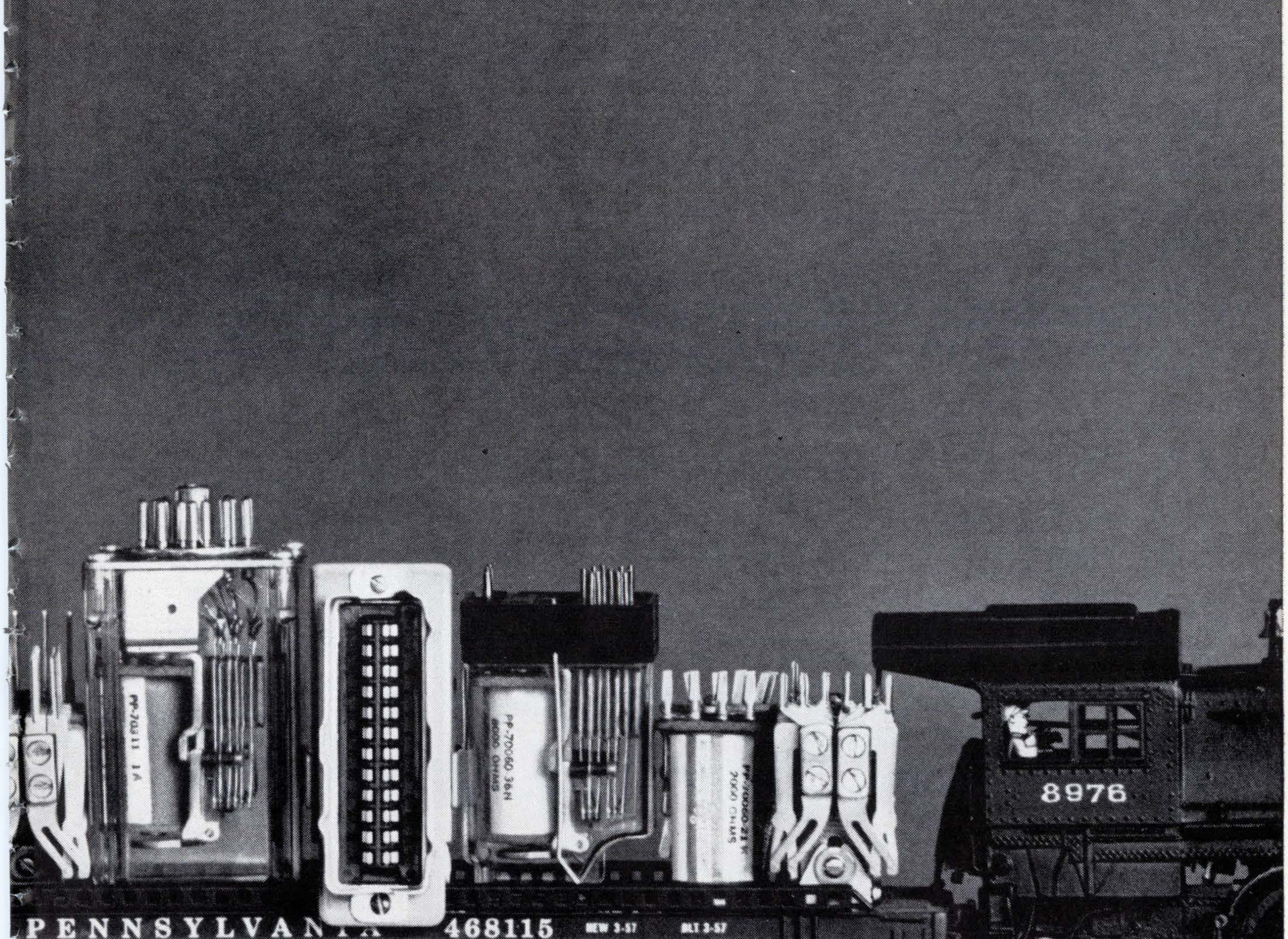
Now AE can accommodate virtually every type of circuit connection or mounting used in electrical and electronic equipment designs.

Wherever designs call for "wiring in," AE Class E Relays are available with solder-type, wrapped-wire, taper-tab and printed-circuit terminals.

AE has also developed special sockets for chassis or printed-wiring board mounting, that accommodate Class E Relays with PC or taper-tab terminals. And prewired types with octal plug-in bases.

Where extra protection is required, AE Class

you can't make with AE Class E Relays



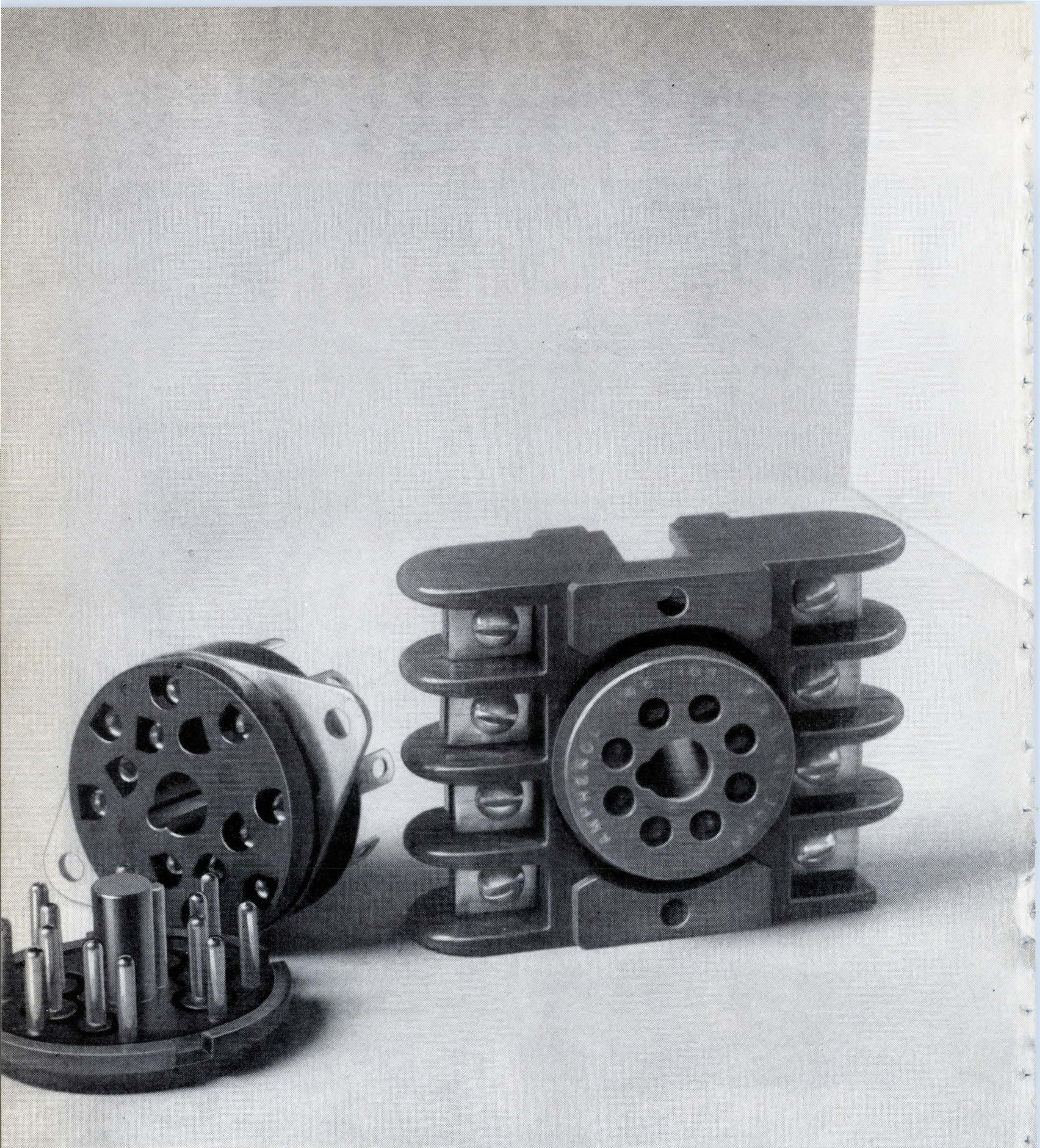
E Relays are available in hermetically sealed enclosures with either hook terminals or plug-in headers. Or plastic dust covers that snap on to the chassis- or printed-circuit type of socket.

For full information on the limitless variations in mounting and connections for AE Class E Relays, ask for Circular 1942-C. Write to the Director, Relay Control Equipment Sales, Automatic Electric Company, Northlake, Ill. 60164.

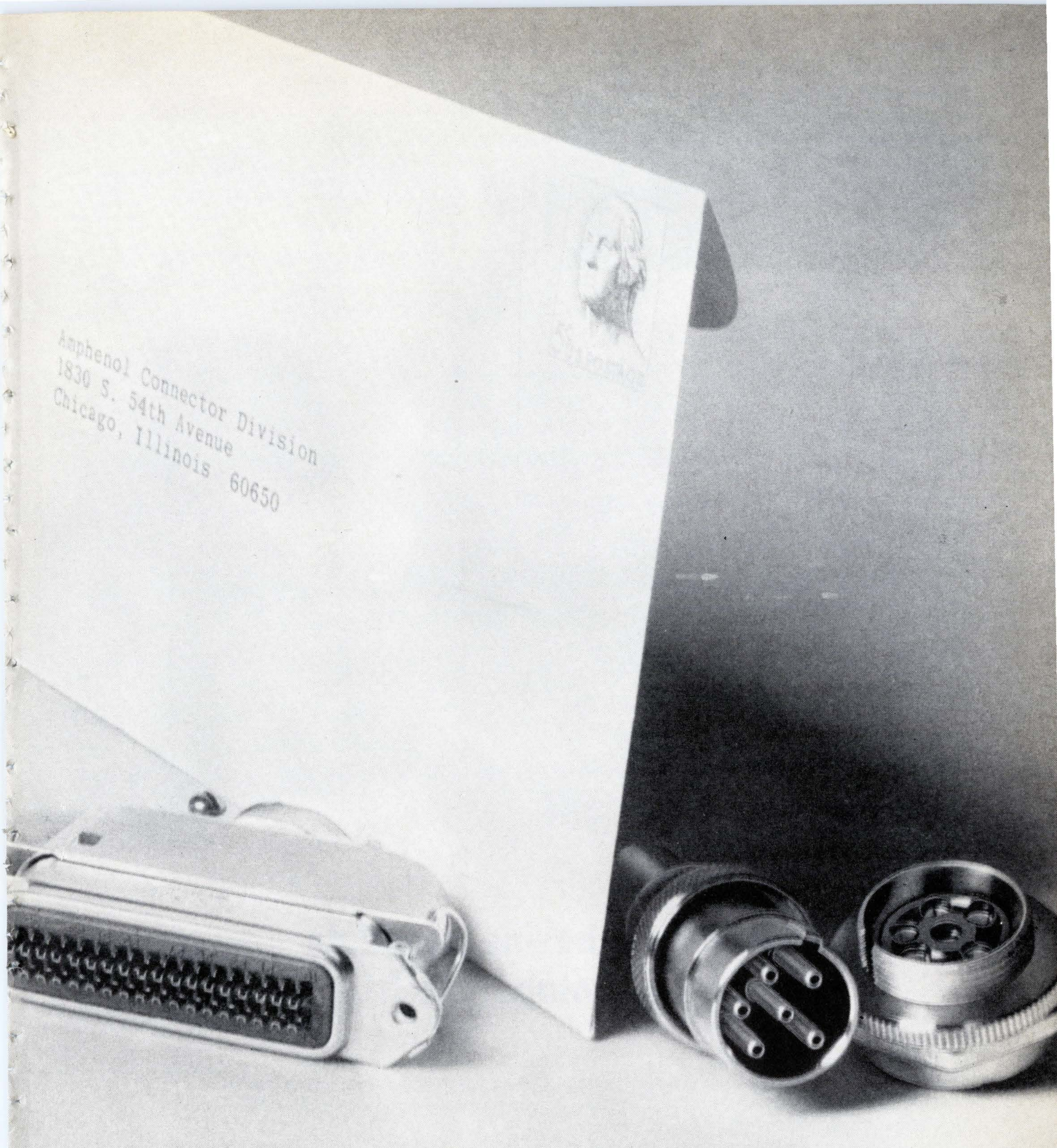
AUTOMATIC ELECTRIC

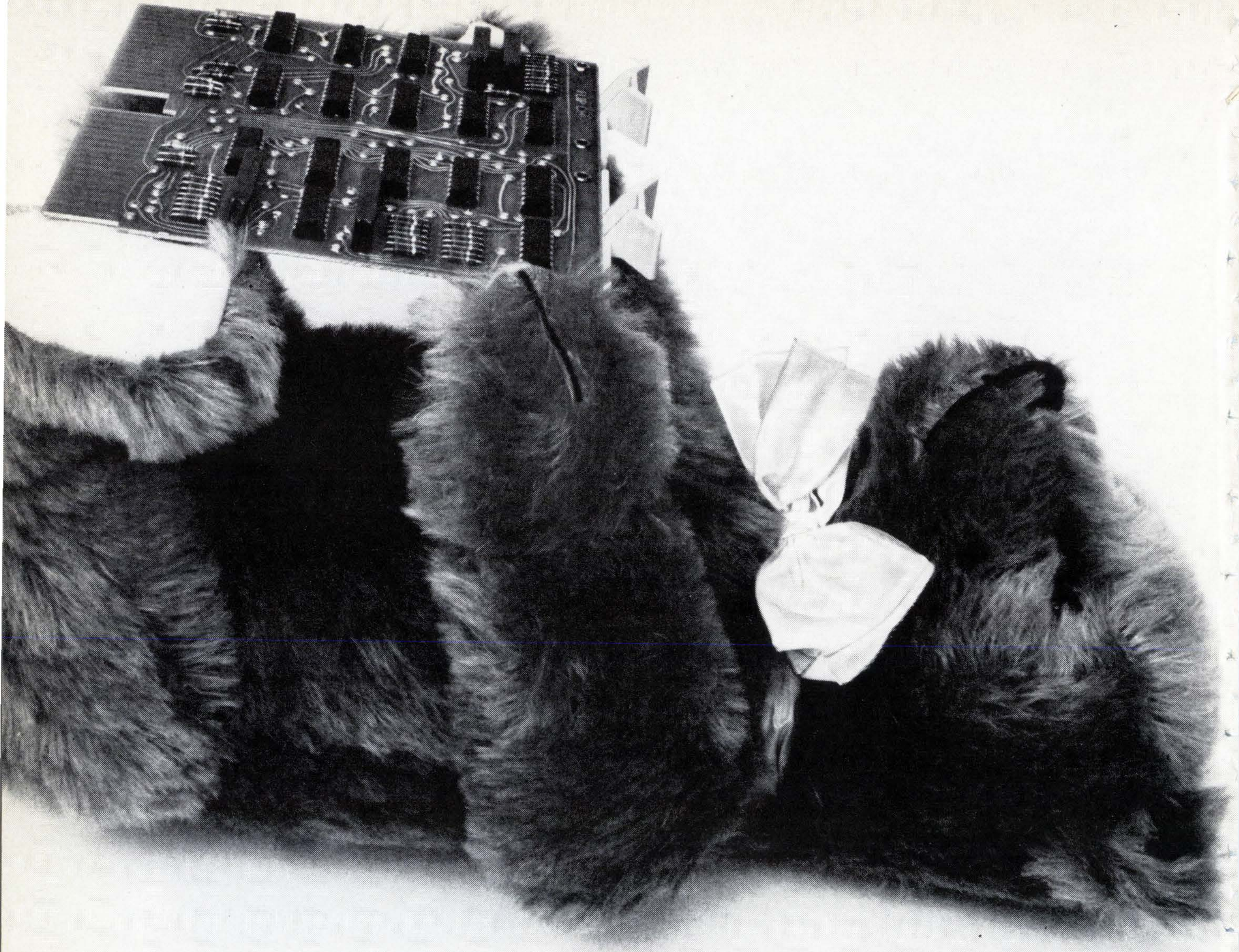
SUBSIDIARY OF GENERAL TELEPHONE & ELECTRONICS GT&E

Circle 19 on reader service card



Five ways to succeed in commercial electronics.


Amphenol Connector Division
1830 S. 54th Avenue
Chicago, Illinois 60650



Editorial

IC's change the industry . . .

With integrated circuits now showing up routinely in new products, companies are worrying that the conversion to IC's will alter the structure of the electronics industry. And it will. Some traditional component makers will see their markets shrink to a few specialized applications where high frequency or high power preclude the use of integrated technology.

But the greatest pressures are on the instrument manufacturers, whose traditional role in the industry is being invaded from opposite directions: semiconductor processors are building instruments that use their integrated circuits, and computer makers are adding instruments to their computers.

The force behind what's happening is a new demand by instrument users for information rather than measurements. These customers no longer are so interested in measuring temperatures, flows, or voltages and amperages. They are demanding complex measurements that correlate or manipulate raw data. To do this a computer is required.

In addition, automatic testing, both on the production line and in the laboratory, is spurring the use of computers to program the tests and produce refined information.

The trend is clear when you see the growing number of computers being designed just for instrument applications. For these computers, integrated-circuit technology has come just at the right time. A small, reliable, and inexpensive general-purpose machine with limited memory and mathematical capacity can be fabricated with off-the-shelf IC's.

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.

. . . and the engineers' role

And engineers are worrying about how their role will change.

Semiconductor specialists have been playing an increasingly prominent part in the development of new products from innovations. In fact, in some recent cases the semiconductor engineers all but took over the development process. They decreed how the circuits would perform, how much would be integrated, and how the equipment would be arranged.

Whether this situation is temporary or is to become the normal way of doing business will depend on how willing other engineers are to learn about semiconductor processing and integrated-circuit technology.

The use of integrated circuits requires a lot broader knowledge than many engineers are used to applying. Embarrassingly, it takes broader knowledge than many engineers have. With IC equipment, the circuit design pales in importance—particularly when off-the-shelf digital units are involved—and other aspects of design gain in significance.

For example, application may determine the kind of package or the method of dielectric isolation used, or how the IC's are assembled and interconnected.

Testing IC's turns out to be one of the trickiest problems. As more components are crammed onto silicon chips, standard electrical tests become less useful and new functional tests have to be devised. Thermal examinations can often show flaws that electrical tests can't detect.

Along with understanding the design, the engineer has to understand semiconductor processing, because the complexities and limitations of fabricating may determine what devices can be put into a circuit.

In the next phase of technical progress, large-scale integration, the gap between the product designer and the semiconductor specialist will grow even wider. The importance of circuit design—the traditional strength of electronics engineers—will be further diminished. With thousands of components built on a single chip, circuit design will be largely a computer's job.

Already, product designers, instrument engineers, and communication specialists are finding it difficult to talk to the integrated-circuit specialist. While the equipment people are concerned with circuit design and end use, the semiconductor specialists are immersed in planar processing technology, the problems of parasitics, and lead-bonding techniques.

To attain a broader view of their new technology, some semiconductor specialists are studying product application. But most product engineers haven't shown the same interest in integrated-circuit processing.

The semiconductor specialist has taken over product planning with IC's mostly by default. He'll hold onto it permanently unless other engineers start learning a little about integrated-circuit technology.

←Circle 22 on reader service card

9 good reasons why Philco Epoxy Transistors (PET) are your best buy.

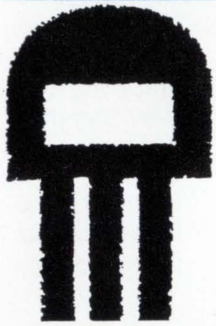
1. PET TO-18 is rated from 360 to 675 mW at 25°C (chip dependent).

2. PET TO-5 is rated from 550 mW to 1.2 W at 25°C (chip dependent).

3. PET packages have reliability factors equal to or exceeding that of *metal* cans.

4. PET's are immediately available in large volume production quantities.

5. PET's have a special deep-well interlock construction that insures hermeticity and reliability.



6. PET packages are permanently and legibly marked—lettered black on white.

7. PET's are packaged in our low-cost Taiwan production facility—to keep *your* cost low.

8. PET amplifiers operate on currents ranging from 10 μA to 1 A; PET switches to speeds 8 ns turn on and 11 ns turn off.

9. PET's cover frequencies from 40 MHz to 1400 MHz.

Call or write: **Philco-Ford Corporation Microelectronics Division Sales Offices:** 2920 San Ysidro Way, Santa Clara, California (408-245-2966) / 999 North Sepulveda, El Segundo, California (213-772-6226) / Northwest Industrial Park, Second Avenue, Burlington, Mass. (617-272-1600) / Benson Manor, Suite 114B, Washington Lane, Jenkintown, Pa. (215-885-0430) / 1215 Drew St., Clearwater, Florida (813-446-0124) / 815 Connecticut Avenue, N.W., Washington, D.C. (202-298-7810) / Suite 208, 700-108th St., N.E., Bellevue, Washington (206-454-5061) / New York, N.Y. (212-244-1373).

PHILCO Ford

PHILCO-FORD CORPORATION
Microelectronics Division
Santa Clara, California • 95051

Electronics Newsletter

April 17, 1967

Microwave device: EIA formats fail to measure up?

A boycott of microwave transistor registration may be shaping up. Because none of the several Electronic Industries Association formats available can accurately characterize such devices, at least one manufacturer, Texas Instruments, may not register any new microwave transistors until the formats are revised. **The scanty information on performance that can be accommodated by the present formats impedes designers in evaluating microwave devices.**

With the present setup, TI says, a specification written for a 3-gigahertz transistor could not honestly guarantee 3-Ghz performance. TI had troubles in registering its new high-frequency 2N5043, the first transistor to be characterized by S parameters; the firm had to stretch some points to fit the format.

The EIA formats use only parameters that can't be accurately measured at 3 Ghz, such as Y parameters. Some engineers think Y parameters are doomed to obsolesence. Below 30 megahertz, they recommend H parameters, above 30 Mhz, S parameters. The latter parameters are based on power ratios rather than the current or voltage ratios that determine the Y and H types.

Photocomposition system uses digital technique

An all-digital photocomposition technique for printing, capable of generating several thousand characters per second on a continuously moving strip of photographic film, has been developed by Alphanumeric Inc. of Hicksville, N.Y. Character and pattern images are displayed on a digitally controlled cathode-ray tube and are exposed on the film, from which printing plates are made.

Alphanumeric now has an off-line system—the APS-2—driven by magnetic tape rather than directly by computer. The computer first prepares the tape, which includes instructions on type size and font as well as the text to be set. This tape is read by the APS-2 into its ferrite core "matrix memory." The APS-2 then decodes the text, and, following the instructions, generates the proper image in the proper position on the crt by drawing a series of short lines for each individual character.

An advanced system—presumably on-line—is in development. **Negotiations are now going on with IBM, but Alphanumeric is silent on whether it's looking at the giant computer maker as a vendor or as a supply source.**

Alphanumeric's system differs from CBS Laboratories' Linotron [Electronics, April 3, p. 113], which uses an analog mask in a tube separate from the crt; from General Dynamic's Charactron, which uses a mask in the crt; and from RCA's Videocomp, which exposes an intermittently moving film a line at a time.

Ultrahigh-speed computer display

A computer display that operates at speeds up to 250,000 characters per second—twice the speed of currently available displays—has been developed by Tasker Industries Inc. Its ultrahigh speed frees the computer for other tasks and makes it practical to hook up several displays to the computer without taking up too much of the machine's time.

A redesigned version of the display, capable of speeds 20% faster, will be used in a new military air traffic control system—the AN/TFX-42. The character generator and display will enable alphanumeric equipment to **display aircraft identification and altitude information digitally on the traffic controller's radar scope during the radar's dead time, eliminating the need for a two-gun cathode-ray tube display.**

Homer G. Tasker, the firm's chairman, attributes the speed capabilities to a redesign of the amplifier circuits used for deflecting the crt beam. Says Tasker: "With our technique, we could go to a speed of 500,000 characters per second if the demand was there."

IBM slates more satellite-link tests

Despite persistent claims that it has no firm plans to link computers by satellite, **IBM will continue to test computer-to-computer hookups via Early Bird.** Some "highly successful" trials were run earlier this year, the company says [Electronics, March 20, p. 59], and more will be conducted in May.

Tunnel diodes face loss of big market

Prospects for tunnel diodes in the 1-to-2-gigahertz range appear bleak, with bipolar transistors finding wider applications in amplifying and some logic-switching jobs. The transistors have always had the edge in stability, noise figures, and packaging, and now that their high-frequency capabilities have been boosted, they are rapidly taking over this multimillion-dollar market.

Spokesmen at KMC Semiconductor, Micro-State Electronics, Polarad, Texas Instruments, and Watkins-Johnson confirm this trend. **One implied that there is an "understanding" among Government agencies to avoid tunnel diodes whenever possible because of their instability.**

TI reports increased sales of high-frequency transistors, even to microwave-amplifier manufacturers making tunnel diodes.

Computer undergoes rigorous time study

Researchers at the University of California at Los Angeles are, in effect, **running a time study on a computer and all its peripheral equipment to measure the efficiency of the machine and its software and to find ways to improve operations.**

The UCLA study is called Computer Instrumentation Automation, and—presumably as a take-off on the acronym CIA—is informally known as "snuper."

Basically, the project involves the counting of the number of times certain key activities occur in programs as the computer executes them. The counting is initially being done by adding instructions to the programs at those key points—a process that slows the program. External equipment will later be added to handle the counting and to monitor the program without slowing it. The researchers say the study, which will be implemented on an IBM 7094 with an SDS Sigma 7 connected to it, **should be applicable to a broad class of general-purpose computers.**

Office copier uses xenon flash lamp

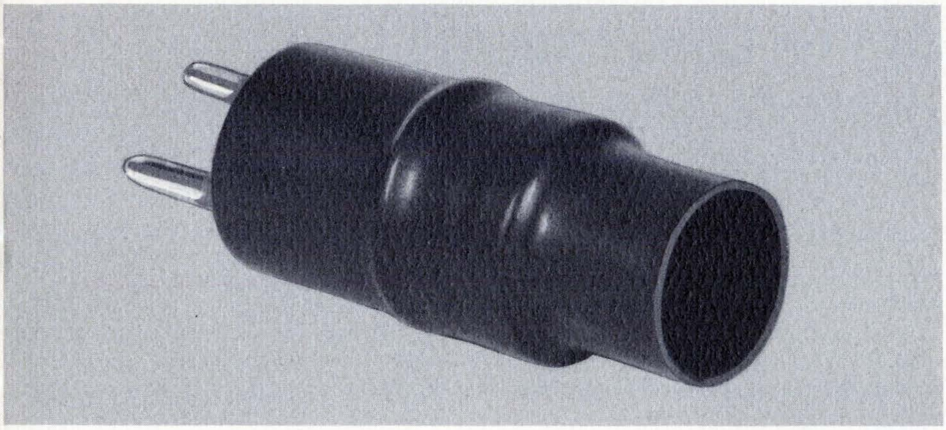
Xenon flash lamps, long used for the pumping of lasers and in stroboscopy and scientific instrumentation, have found a new application—commercial office copiers. The Dennison Manufacturing Co., Framingham, Mass., this month will introduce a high-speed, roll-fed electrostatic copier that uses a xenon flash lamp as a high-intensity light source. The new machine, driven by a precisely regulated high-voltage power supply, will compete with the Xerox Corp.'s copiers.

Component and Circuit Design IDEAS

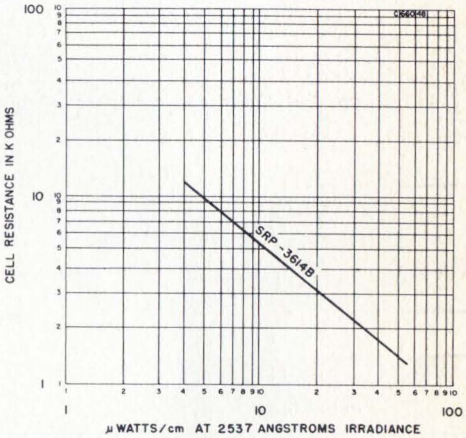
from SYLVANIA Electronic Components Group

PHOTOCONDUCTORS

Now, highly reliable UV detection ...even in IR ambients



Cell Resistance vs UV Irradiance



A shortcoming of many ultraviolet detectors is that they're also sensitive to infrared radiation. Thus it's often difficult, if not impossible, to use them to detect just UV in an ambient containing both infrared and ultraviolet radiation. Last year, Sylvania introduced a UV cell with attenuated infrared characteristics. Now, an improved version of this device has greater sensitivity and shows even better infrared attenuation.

Sylvania's new Type SRP-3614B ultraviolet photoconductor improves further the detection and measurement of UV radiation. Like previous designs, the new device requires only simple low voltage circuits to provide an inexpensive, highly reliable UV detection system. The SRP-3614B does differ from earlier types in two important characteristics: it is less sensitive to IR radiation and uses a more sensitive photocell.

Key electrical ratings for the new unit are a power dissipation rating of 300 mW, an ON resistance of 1,300 ohms at 64 μW/cm^2 irradiance, and a dark resistance of 100,000 ohms. Ascent time is 130 msec (at 64 μW/cm^2) while descent time is 40 msec at the same radiation level.

The SRP-3614B has the proven high reliability of Sylvania's hermetically sealed cadmium-sulfide photoconductors, but with the spectral response characteristic shifted into the ultraviolet region in the range of 2500 to 4000 angstroms.

The excellent electrical character-

(continued)

ELECTRICAL DATA RATINGS (Absol. Max.)

	SRP–3614	SRP–3614A	SRP–3614B
Dissipation			
at 40°C	300mW	300mW	300mW
at 70°C	25mW	25mW	25mW
Temp. Rge.	–40 to +70°C	–40 to +70°C	–40 to +70°C
CHARACTERISTICS			
Cell (Light) Res. (ohms)	2500	5500	1300
Dark Res. (ohms)	1,000,000	1,000,000	100,000
Ascent Time			
at 64 μW/cm^2			130 ms
4 μW/cm^2			720 ms
Descent Time			
at 64 μW/cm^2			40 ms
4 μW/cm^2			260 ms

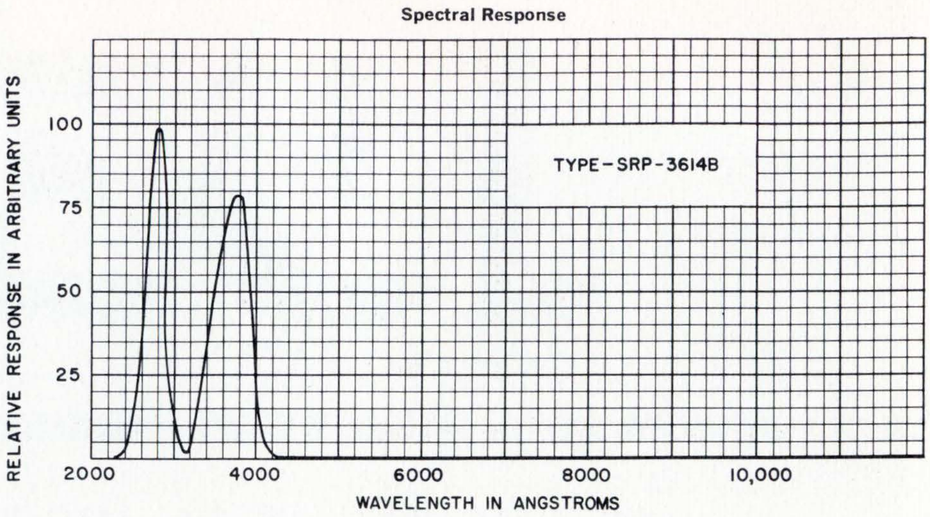
This issue in capsule

PHOTOCONDUCTORS *(continued)*

istics of this improved photoconductor are protected by a small, rugged package with a maximum diameter of 0.70″ and a length of 1.625″.

Coupling the small size, long life, analog response characteristic with the simple associated circuit requirements makes the SRP-3164B ideal for applications where UV detection, measurement, control or regulation are needed, such as intrusion and fire alarm systems. The new photoconductor can effectively and economically replace many avalanche or continuous monitoring devices.

CIRCLE NUMBER 300



MARKETING MANAGER'S CORNER

Circuit Designer–IC Manufacturer... Conflict or Complement?

The rapid growth of the integrated circuit industry has given rise to a pertinent question: whether or not there is a functional conflict between the IC manufacturer and the manufacturer of electronic equipments and/or systems. In other words, are we, as IC manufacturers who produce complete functional circuits, overstepping our bounds and infringing on the functions of circuit designers? What about circuit design engineers? Will they become high priced order clerks, purchasing all the circuits they need to build an equipment out of an IC catalogue?

To aggravate the picture, the trend in the IC industry appears to be headed for even greater density. LSI (large scale integration) is now in the horizon, cramming many more and larger circuits into a single package. It may be possible to eventually encapsulate an entire automated operation or computer function into a single IC package. Will this development turn the computer manufacturers into automated factories, whose purpose it will be to merely assemble various combinations of IC packages?

Not at all! On the contrary, as the electronics industry expands, all its constituent components will expand along with it. With standard circuits such as flip-flops, gates, registers, and counters available as packaged items, the design engineer can concentrate on larger and more complex circuit configuration. Furthermore, many circuits required for equipment design have a unique configuration, in one aspect or another, and, therefore, must be designed by the equipment manufacturer; the IC manufacturer only fabricating these "customized" circuits.

With reference to this last point, it should be remembered that in order to work effectively with the integrated circuit manufacturer, the circuit designer must familiarize himself with integrated circuit technology, its advantages, its applications, and its limitations. He should know the IC circuits that are available as "off-the-shelf items." He should also be knowledgeable of the manufacturing process of integrated circuits so that he can design new circuits which are most applicable to the present state of the art. This will result in a reduction of IC costs, a functionally superior IC, and a better working relationship between circuit designers and integrated circuit manufacturers.

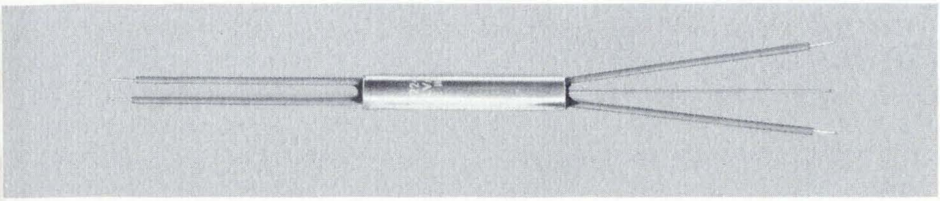
The same situation exists with regard to system designers. No matter how complex and dense ICs become, they will only serve as building blocks for large systems. Furthermore, the systems of today will become the subsystems of tomorrow's larger, more complex and sophisticated systems. Therefore, with the availability of larger and more efficient "building blocks," system design engineers will be able to concentrate on solving the design problems associated with creating larger and more efficient systems.

Finally, it must be noted that the trend toward LSI is not a self-generating movement. IC manufacturers are not simply producing denser ICs just for the sake of cramming more circuitry into a package. This trend, to a great extent, is the result of certain design requirements dictated by military and industrial contractors. The great need for space and weight savings, and the requirement for extended operation reliability within the space program has had a significant effect on IC design. The noise immunity requirements of high frequency circuitry and high speed computers also have dictated the direction which IC manufacturers have had to take. However, when one looks at the total picture, he finds the word that describes the relationship of equipment and systems manufacturers, and IC manufacturers, is "complementary"; each has its own function which complements the other. And the very evident direction of motion is upward. The electronics industry continues to grow; equipment and systems are becoming more complex and sophisticated. Keeping up with this growth in complexity and sophistication is the IC manufacturer.

Roger A. Swanson

R. A. SWANSON

How PL assemblies are making music sound better



Photoconductor-lamp (PL) assemblies are being used to produce special musical effects such as tremolo, vibrato and percussion. What makes these units ideal for these applications is the intrinsic characteristics of the photoconductor-lamp combination. It provides noise-free operation because of electrical isolation between control and signal circuitry. This, of course, eliminates the introduction of hum from the control circuit. Result is an effect pleasing to the listener. Here's how a tremolo circuit using a Sylvania PL assembly makes an electric guitar sound more pleasing.

Tremolo effects—subsonic modulation of an audio signal—can be produced easily and reliably by an electric guitar amplifier which uses Sylvania's PL assembly. The circuit shown uses a PL-8224C assembly and a phase shift oscillator to get the tremolo effect. The oscillator output frequency of 40 to 8 Hz is controlled by a 1-megohm potentiometer in one arm of the phase shift network. Output of the oscillator is decoupled by a 330 K resistor into another 1-megohm potentiometer which varies the level of the control signal voltage fed into the PL driver stage.

The on/off switch can ground the arm of the 'Depth' potentiometer to remove modulation from the light source portion of the PL assembly. The dc operating current of the light source is determined by the setting of cathode resistor in the PL driver stage. The ac output of the 'Depth' control is superimposed on this dc level, providing an ac variation in the resistance of the PL. Shunting this ac varying resistance divider across the volume control gives the desired modulation of the audio signal. Depth of modulation depends on the setting of the 'Depth' control and may approach 100 percent.

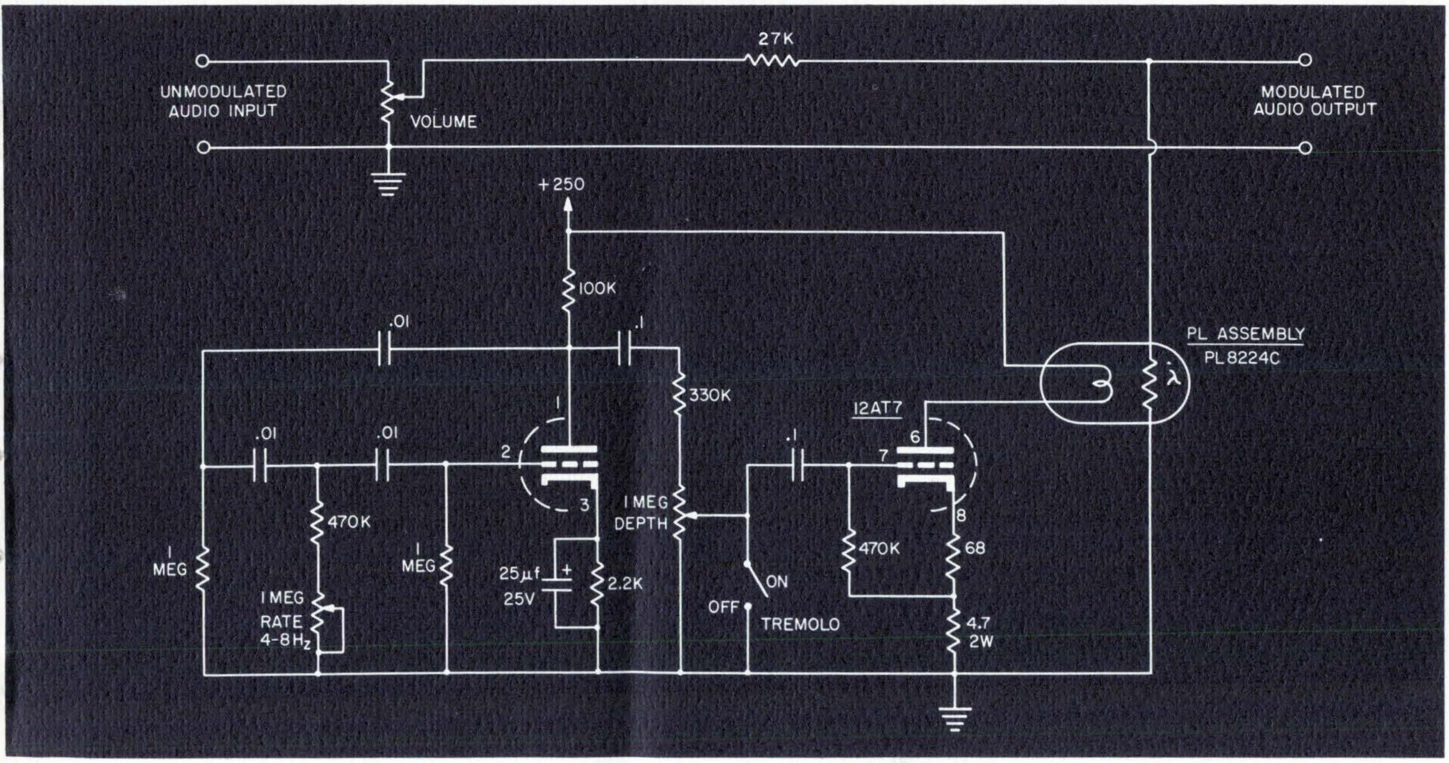
Basic action of this circuit is that of a volume control being varied around its operating point at a sinusoidal rate with the rate controlled by a low frequency oscillator.

The type PL-8224C assembly used in this application consists of a hermetically sealed cadmium sulfide photoconductor and an incandescent lamp potted in a metal cylinder 1.75 inches long and 0.31 inches in diameter. Its cell voltage is rated at 300 V max and can handle up to 50 mW at 25°C. Cell resistance varies from below 60 K (ON) to above 10 megohms (OFF).

The PL-8224C is just one of many standard and custom PL Assemblies available from Sylvania. These PL assemblies, because they have the characteristics of both a switch and a potentiometer, have many other circuit applications in addition to generating musical effects.

Such applications as: On-Off Switch, Sequential Switch, Logic Functions, Gain/Volume Controls, Electrically Controlled Circuit Functions (Delays, Oscillators, Filters), Linear Amplifiers, Voltage and Current Regulators, Motor Speed Regulators and Modulators.

In all these applications the PL assemblies provide moderate power handling capability, noise-free operation, and high circuit isolation.



Preventing unused inputs from degrading IC performance

Frequently, all inputs of an integrated circuit are not required in a particular application. What does the circuit designer do with these unused inputs? They may be left open, but this could degrade circuit operation; or additional components can be added to insure top performance. SUHL™ devices by Sylvania require only simple wiring and no extra components to obtain optimum performance characteristics. Here's the how and why for gates and flip-flops.

The high drive capability of SUHL I and II output networks allows unused gate inputs of these ICs to be tied directly to signal inputs with insignificant sacrifice in speed or static characteristics. In the same way, unused inputs of these SUHL flip-flops can be tied to active inputs or outputs to maintain propagation delay time, clock width, and amplitude. With SUHL gates and flip-flops it's basically a matter of eliminating the effect of the capacitance associated with each of the unused inputs.

In SUHL gates, each input has a capacitance to ground of about 1.2 pF (package and chip). If wiring is also connected to the emitter, then additional capacitance is added. How the capacitance of unused inputs influences circuit operation can be explained by Figure 1. Here, if input A goes to logic "0" and input B is floating, the voltage at B tries to follow the voltage at A. In time, B falls to logic "0." When A rises to logic "1," B is held down until its capacitance charges through the base resistor. This action slows down the recognition of the logic "1" data at A.

To prevent this, unused emitters should be terminated with a voltage greater than the logic "1" threshold voltage. In this way, stray capacitance on the inactive inputs will always be at logic "1" and won't slow circuit operation. There are a number of ways to insure that these gate inputs remain at logic "1."

The unused inputs can be connected to a dc voltage as shown in Figure 2A. For SUHL units, the voltage should never be higher than 5.5 V, the breakdown rating of the inputs. A 5.0 V supply is satisfactory if it never goes above 5.5 V, even during power turn on. Should the supply go above 5.5 V, then a resistor (ranging from 500 to 5000 ohms) is placed between the emitters and the supply as indicated in Figure 2B.

Many emitters can be tied together. One convenient method of supplying the required voltage is to use one NAND gate with its inputs grounded to hold all unused emitters at Logic "1."

A more convenient neutralization technique is to tie unused emitters to one of the signal emitters as shown in Figure 2C. This requires no extra components. Only simple wiring is needed and performance of the system is not degraded. In this approach, when the data signed goes to "0," all capacitance is directly discharged to "0" through the driver. Since this capacitance is small and the drive capability of SUHL is high, there is a negligible effect on speed (about 0.03 nsec/pF). In this configuration, input current is the same as if only one input were used, because the base resistor limits current flow.

In Figure 2C, when the driver rises to logic "1," each input and its capacitance is pulled to a positive voltage. Again, because of the high drive capability of SUHL output networks, pull-up speed is negligibly affected by the small capacitance increase (about 0.4 nsec/pF). The high current capability of the output network of all SUHL elements also means that static characteristics remain constant.

These SUHL output characteristics are shown in Figure 3. Even with many milliamps of loading, logic levels are still high and well above threshold.

In flip-flops, it is extremely important that all inactive inputs be terminated. Not only is propagation delay time effected, but so is clock width, amplitude and the waveform required

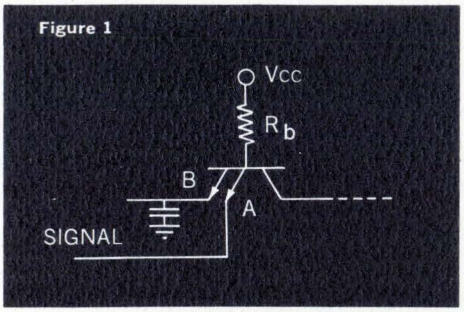


Figure 1

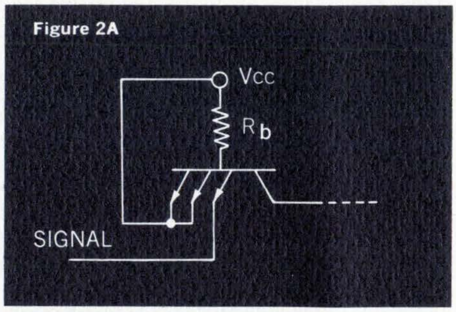


Figure 2A

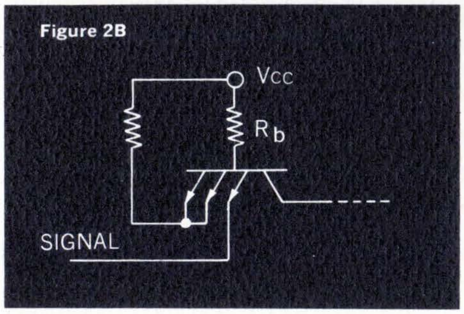


Figure 2B

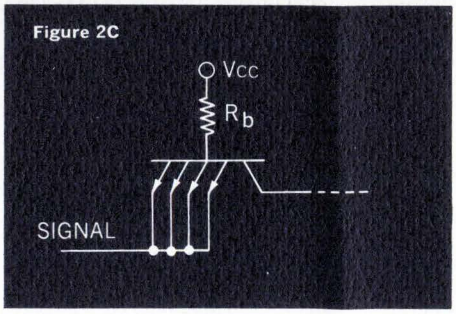


Figure 2C

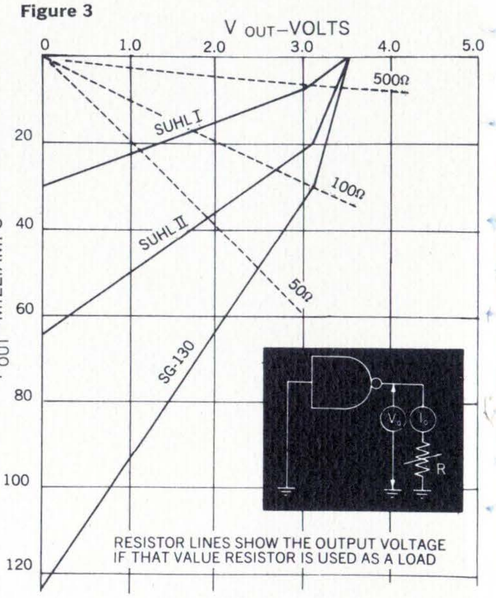


Figure 3

for triggering.

Synchronous or data inputs of flip-flops can be terminated with dc in the same manner as a gate, but for each flip-flop there are signal carrying inputs or outputs to which unused inputs can be connected. Examples are shown in Figures 4 and 5.

Unused asynchronous input terminals (DC Set, Preset, Reset) can also have a degrading effect on performance, particularly if they are connected to wiring or board metalizing which increase capacitance. Even at low frequencies it is important that asynchronous inputs be connected to a positive voltage or terminated in some other way. The same techniques used for gates or those shown in Figures 4 and 5 can be employed.

CIRCLE NUMBER 302

Figure 4

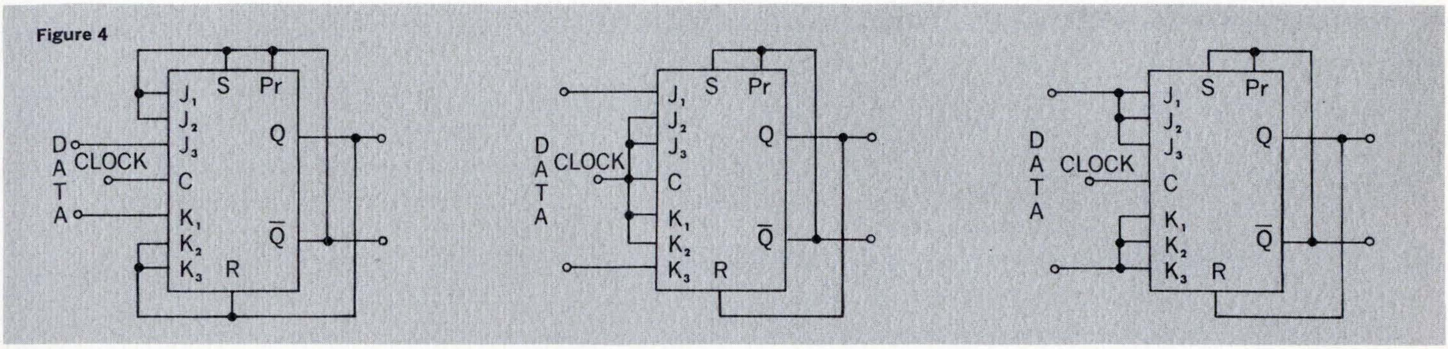
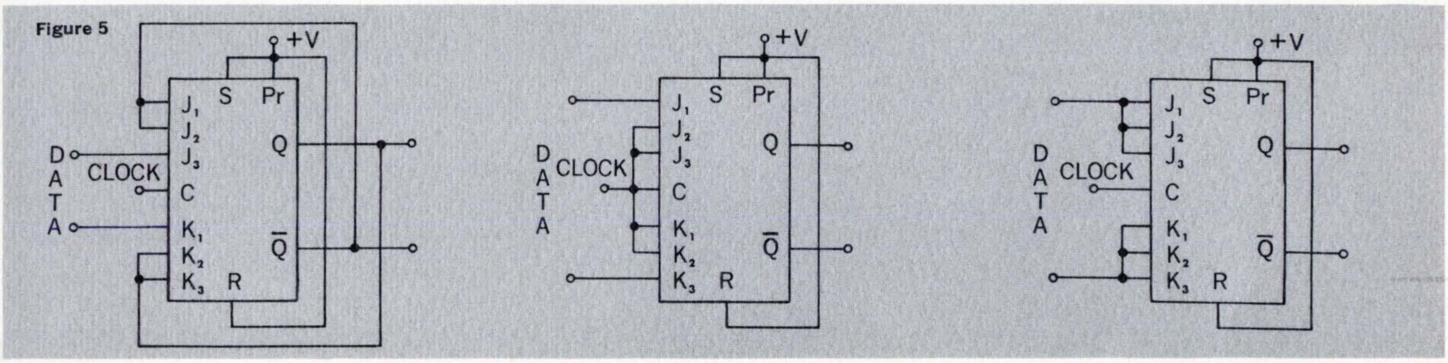
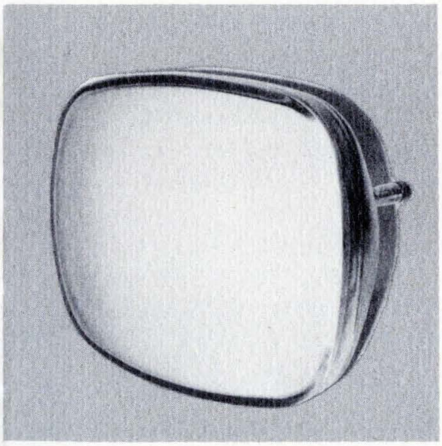


Figure 5



CRTs

Eliminate unnecessary trade-offs when choosing computer displays



The value of a computer often is directly related to how fast the information output can be obtained by the people who need the information. CRTs provide an effective and very fast graphic display of such information. But picking the right tube (and the right tube manufacturer) for computer display applications is not simple. Many factors must be evaluated. A good way to start is to look at the manufacturer's present capability in CRTs for computers.

Years of leadership in CRT technology and display design give Sylvania the full capability needed to meet demands for computer CRTs. This capability is based on a solid background of providing CRTs for the computers of several manufacturers.

These CRT displays offer many advantages. Display of alphanumeric information on a tube face is much faster than waiting for a typed output. A dynamic display also permits on-line program debugging, text editing and revision, and rapid scanning of stored material. Coupled with a camera, these displays can give a hard-copy output. The growing interest in using displays to permit on-line, two-way conversation with the computer opens up a host of applications. For instance, results of calculations can be plotted, and the user can select regions where he wants calculations to be carried out in more detail.

Selecting the optimum tube for such applications can be a difficult chore. Many factors must be considered; such factors as size of display, deflection, focusing method, sensitivity, resolution, brightness, power requirements, and phosphor characteristics. Trade-offs may be necessary. But, at Sylvania these trade-offs are kept at a minimum; because the designer isn't limited to a few off-the-shelf items. Sylvania's wide range of standard and custom tubes permit a better match of tube to application.

TYPICAL COMPUTER TYPES

Basic Type	Deflection Angle	Screen Size	Useful Scan	Overall Length
SC-4649	70°	7″	5-3/4″ x 4-3/8″	10″
8QP-	90°	8″	7-3/16″ x 5-3/8″	9-15/16″
8KP-	90°	8″	7-3/16″ x 5-3/8″	11-15/16″
17DWP-	70°	17″	11-1/8″ x 14-5/16″	19-3/16″
21EYP-	72°	21″	19-1/16″ x 15-1/16″	23-1/32″

CIRCLE NUMBER 303

Punch-through varactors: new route to improved harmonic efficiency

There's a great deal of confusion in the microwave industry regarding high-order multiplier diodes. Names such as step diodes, step recovery varactors, snap diodes, snap-off varactors, etc. are being used to describe diffused diodes having a varying capacitance-voltage relationship. Sylvania uses the term PTV, or Punch-Through Varactor, to better describe a diode which was developed to have a sharp decrease in junction capacitance, as well as a series resistance at a reverse bias 15 to 20% of the rated breakdown voltage. This deflection point occurs when the depletion width "punches-through" the thin epitaxial layer of high-resistivity silicon.

The Sylvania D-4410 PTV exhibits little capacitive nonlinearity in the reverse bias region, but shows a marked nonlinearity in the forward bias region because of charge storage. The relatively flat capacitance change over a large reverse bias range offers several advantages, such as minimal detuning over the temperature range, simplified tuning procedure, and improved dynamic range. Simplified matching techniques can be employed, and under broad band operating conditions improved operating efficiencies can be realized.

If PTVs are driven into the forward bias region, high conversion efficiencies can be obtained as a result of the marked non-linear capacitance curve. The lower average R_s value over the drive cycle also contributes to better efficiency by reducing the power dissipation. Harmonic generators operating with multiplication ratios as high as 27:1 or as low as 2:1 will yield highly efficient performance at frequencies from VHF to Ku-band. These diodes, made from epitaxial silicon, have diffused junctions tailored for punch-through at a reverse bias voltage which is low relative to the breakdown voltage.

Electrical specifications and typical operation in a multiplier circuit for a Sylvania PTV are given in the table.

Carefully controlled fabrication techniques give Sylvania's PTVs these additional advantages: uniformity of performance characteristics, higher power handling capability, improved circuit stability, higher power, and frequency operating range.

All units are baked at a minimum temperature of 200°C for at least 16 hours prior to final hermetic sealing. Finished devices see these test procedures: centrifugal acceleration of 20,000 G, temperature cycling from −65°C to +150°C; breakdown checking at 150°C; 48 hour burn in at 200°C; and gross and fine leak (Radioflo) testing.

Units in the new PTV series are available in four packages: the 017, 023, 075, and 099.

ELECTRICAL SPECIFICATIONS (Type D-4440)	PERFORMANCE IN MULTIPLIER (Type D-4440)
$V_B = 45$ Volts	$F_{in} = 1$ GHz
$C_j\ (-6V) = 1 - 1.5$ pF	
$T_s = 250$ picosec	$F_{out} = 10$ GHz
$T_L = 60$ nanosec	
$R_s = 0.8$ ohms	$P_{in} = 1$ watt
$I_F = 100$ milliamps	
$R_T = 45°C$/watt max	Efficiency = 13%

CIRCLE NUMBER 304

PTV DIODES

In a varactor multiplier, power handling capability and conversion efficiency are determined by the breakdown voltage, junction capacitance, junction conductance, and series resistance. Breakdown voltage is determined primarily by the resistivity of the N-type semiconductor material used in the P-N junction. The other parameters are shown in the simplified equivalent circuit of Figure 1.

The nonlinearity of the voltage-variable junction capacitance is the dominant factor in the frequency multiplication process. Junction conductance and series resistance dissipate power, limiting output power and conversion efficiency. The frequency conversion process also depends on the quality factor Q or cut-off frequency w_{co}. These are given by the equations $Q = 1/wR_sC_j$ and $w_{co} = 1/R_sC_j$.

Specifically, frequency conversion depends on the average values of these factors over the drive cycle of the multiplier. Since both R_s and C_j vary with reverse voltage, their values should be kept at a minimum over most of the drive cycle. The nature of these nonlinear parameters can be examined with the aid of the simplified P-N junction of Figure 2. Here, a thin layer of lightly doped, n-type semiconductor of thickness t is grown epitaxially on a substrate of heavily doped, n-type material, and p-type dopant is diffused to a depth X into the n-type layer.

A reverse bias voltage applied to the varactor sweeps mobile carriers out of the lightly doped n-region. These carriers recombine in the p region, forming a depletion region of width W in the n layer. Width of this region varies with applied voltage as; $W = K_1\ (\phi - V)\gamma$. Where ϕ is the built-in voltage of the junction, K_1 is a constant, and V is the applied reverse bias. The term γ varies from 1/3 to 1/2 depending on the type of junction. The depletion region boundaries act as a parallel plate capacitor with capacitance of:

$C_j = EA/w = k_2\ (\phi - V)^{-\gamma}$,

where E is the dielectric constant of the n-type material, A is the junction area and k_2 is a constant. Increasing the applied reverse voltage V increases w and decreases C_j.

Two additional factors determine

Figure 1

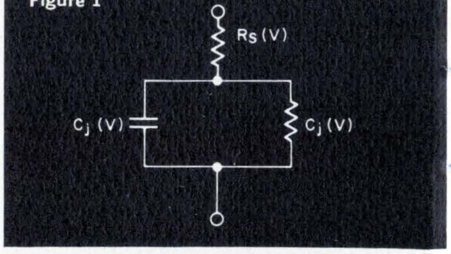


Figure 2

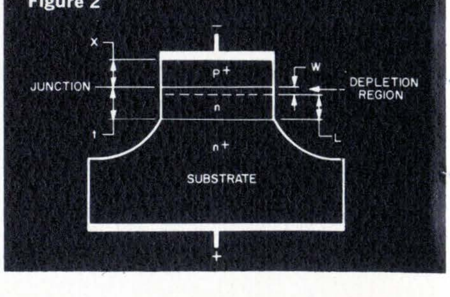


Figure 3

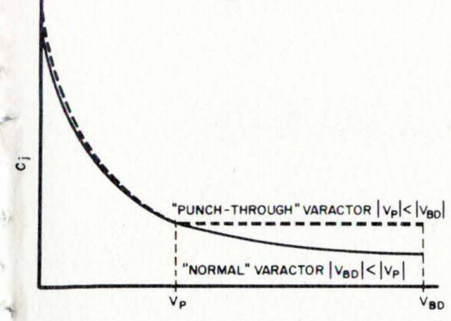


Figure 4

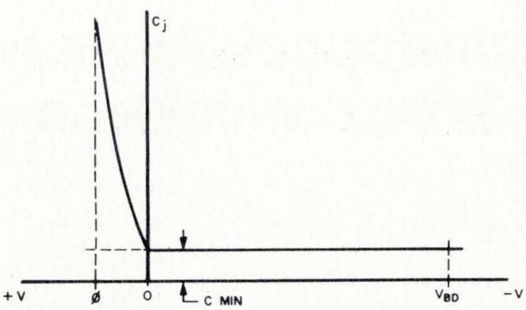
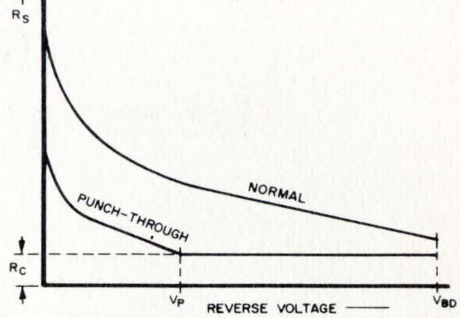


Figure 5



the variation of C_j as V increases. One is the maximum allowable applied reverse voltage, with the reverse breakdown voltage V_{bc}. At V_{bd}, avalanche multiplication takes place and a large current flows through the diode.

The second factor is the thickness t of the n-type layer. Depletion width, w, increases continuously with applied voltage, but it cannot exceed thickness t, because at that point the depletion region boundary is in contact with the heavily doped n^+ substrate. When w = t, no further decrease in junction capacitance can occur.

Depending upon thickness and resistivity of the n-layer, avalanche breakdown may occur at a reverse voltage either lower or higher than that at which w = t. The voltage at which w = t is the punch-through voltage, V_p. Figure 3 shows the junction capacitance and applied reverse voltage relationship for the punch-through and conventional (or "normal") varactors.

If the punch-through voltage occurs at a voltage which is low with respect to the breakdown voltage, then the overall capacitance-voltage relationship approaches the case where $\gamma = 0$ and C_j is constant for any applied reverse voltage beyond the punch-through point.

While the PTV exhibits little capacitive nonlinearity with a reverse bias, a marked nonlinearity occurs with a forward bias. This is due to charge storage. This charge storage capacitance, sometimes called the diffusion capacitance, is an exponental function of forward voltage, and also depends upon the recombination lifetime of the semiconductor material. For effective charge storage, the recombination lifetime should be large compared to a period of the drive frequency. Figure 4 shows an idealized capacitance-voltage plot ($\gamma = 0$) of a punch-through varactor.

The series resistance, R_s, of an epitaxial varactor consists of a sum of four terms: $R_s = R_p + R_n + R_{n^+} + R_c$. Resistance R_p is that of the p-layer; R_n that of the n-layer; R_{n^+} that of the substrate; and R_c that of the ohmic contacts.

In practice, R_c is usually a few tenths of an ohm at uhf frequencies, but may be higher at high microwave frequencies because of skin effect in the connecting leads. For surface concentrations normally used in epitaxial varactors, R_p is usually negligible compared to R_c and R_n.

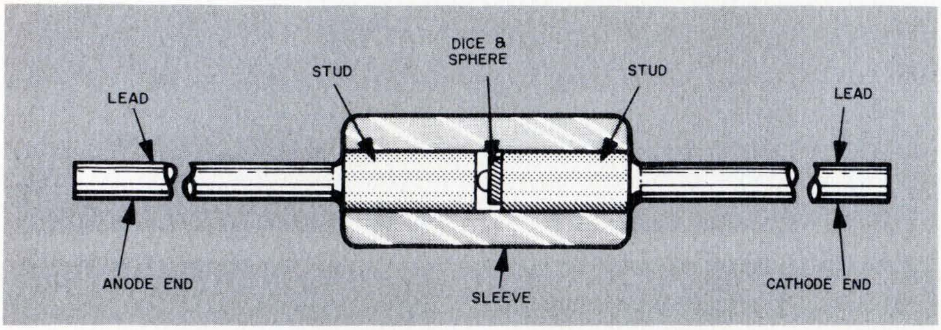
Likewise, R_{n^+} is negligible for a highly doped substrate. Thus, the resistance of the epitaxial layer, R_n, is the dominant component of R_s, and is given by $R_n = P_n L/A = P_n(t-w)/A$. P_n is the resistivity of the epitaxial n-layer, and L is as shown in Figure 2.

Since w varies with reverse voltage, R_n and R_s also vary with V. As with C_j, if $|V_{bd}|<|V_p|$, then R_s decreases continuously as voltages from zero to V_{bd} are applied. If $|V_p|<|V_{bd}|$, then R_n vanishes at V_p. This is because w = t, L = O and the total series resistance is $R_s \approx R_c\,(|-V| \geqq |V_p|)$. Figure 5 shows the variation of R_s, for the normal and punch-through cases. The change in series resistance with reverse voltage may be quite appreciable. For epitaxial varactors with breakdown voltages of 50 to 100V, the ratio of series resistance at zero bias to that at the breakdown voltage may be greater than 2:1 and up to 10:1 for higher-voltage varactors.

Varactors with the same value of R_s at breakdown may have quite different values of R_s at lower reverse voltages. In the PTV, the R_s is lower at zero bias than in a conventional varactor and reaches its minimum value at the punch-through voltage. The result is a lower average R_s over the drive cycle and higher conversion efficiency than in the normal varactor.

CIRCLE NUMBER 304

How whiskerless diodes let you get more components on a board



Designing computers or other equipment which requires fast logic circuits or small signal switching? Here's your chance to get more money for your diode dollar. Use Sylvania's miniature whiskerless diodes to replace DO-7 types, to get significant savings in mounting space, and improve reliability without any increase in cost.

Because Sylvania's miniature dual stud whiskerless diodes are much smaller than DO-7 types, they allow designers to decrease circuit board requirements significantly. Costing no more than their electrical equivalents in DO-7 packages, the rugged whiskerless units have a package volume which is 68 percent smaller. But smaller size is not the only advantage of these newer diodes. The single unit construction makes for higher reliability and for devices able to take shock and vibration environments.

With these 0.075″ dia. by 0.160″ long Sylvania units you get top electrical performance. Typical reverse leakage currents of units in the whiskerless line are a low 15 na. Switching speeds are in the order of 4-10 nsec. Ratings for these silicon epitaxial diodes include average rectified currents of up to 150 mA (with surges of 500 mA) and a power dissipation of 500 mW.

Key construction features of the whiskerless devices are: use of a plated silver sphere to make contact to the junction, dumet studs for good heat conduction away from the junction, and protection of the active area with a soft glass sleeve. What results is a rugged single-piece device capable of taking high-g shocks.

Reliability of this simple structure is enhanced further by the pains taken during the manufacturing process. Sylvania has developed special production techniques to make sure the silicon dice used is more symmetrical and is free from any jagged edges, cracks, or out-of-tolerance parameters.

Sylvania's whiskerless diodes can be used with standard automatic insertion equipment.

CIRCLE NUMBER 305

SILICON EPITAXIAL DIODES

Type	Outline	DO-7 Electrical Equivalent
1N4148	DO-35	IN914
1N4149	DO-35	IN916
1N4151	DO-35	IN3604
1N4152	DO-35	IN3605
1N4153	DO-35	60V IN4152
1N4154	DO-35	IN4009
1N4446	DO-35	IN914A
1N4447	DO-35	IN916A
1N4448	DO-35	IN914B
1N4449	DO-35	IN916B

ABSOLUTE MAXIMUM RATINGS:

Average Rectified Current, Io	75 mA
Peak Forward Current, Ipk	225 mA
Forward Surge Current, (1 sec)	500 mA
Power Dissipation, P_T	500 mW
Junction Temperature, T_J	—65 C to +175°C

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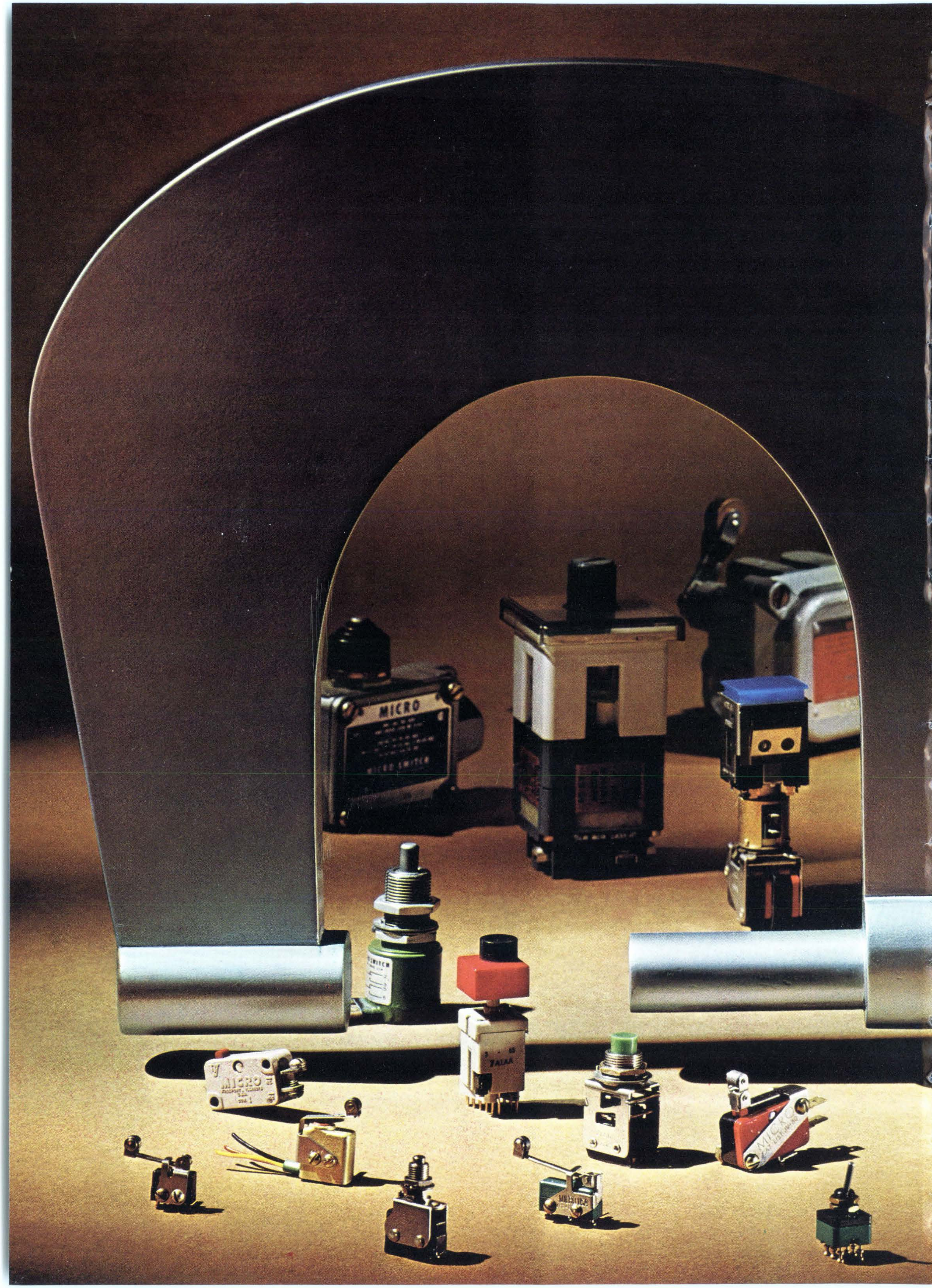
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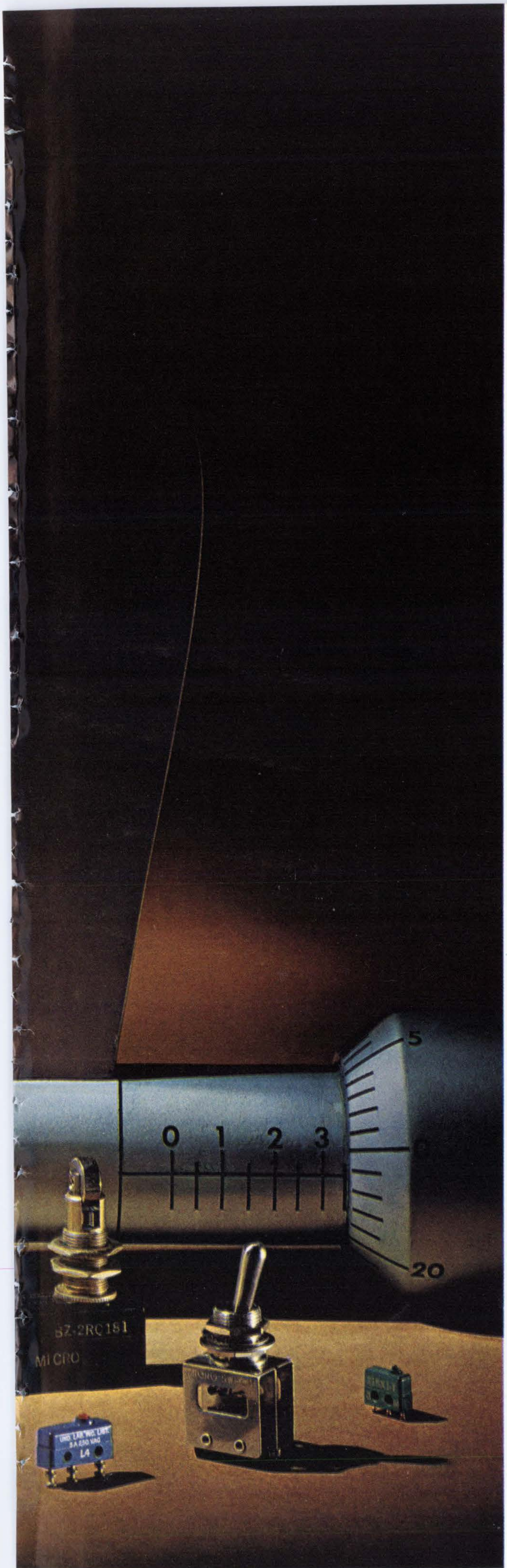
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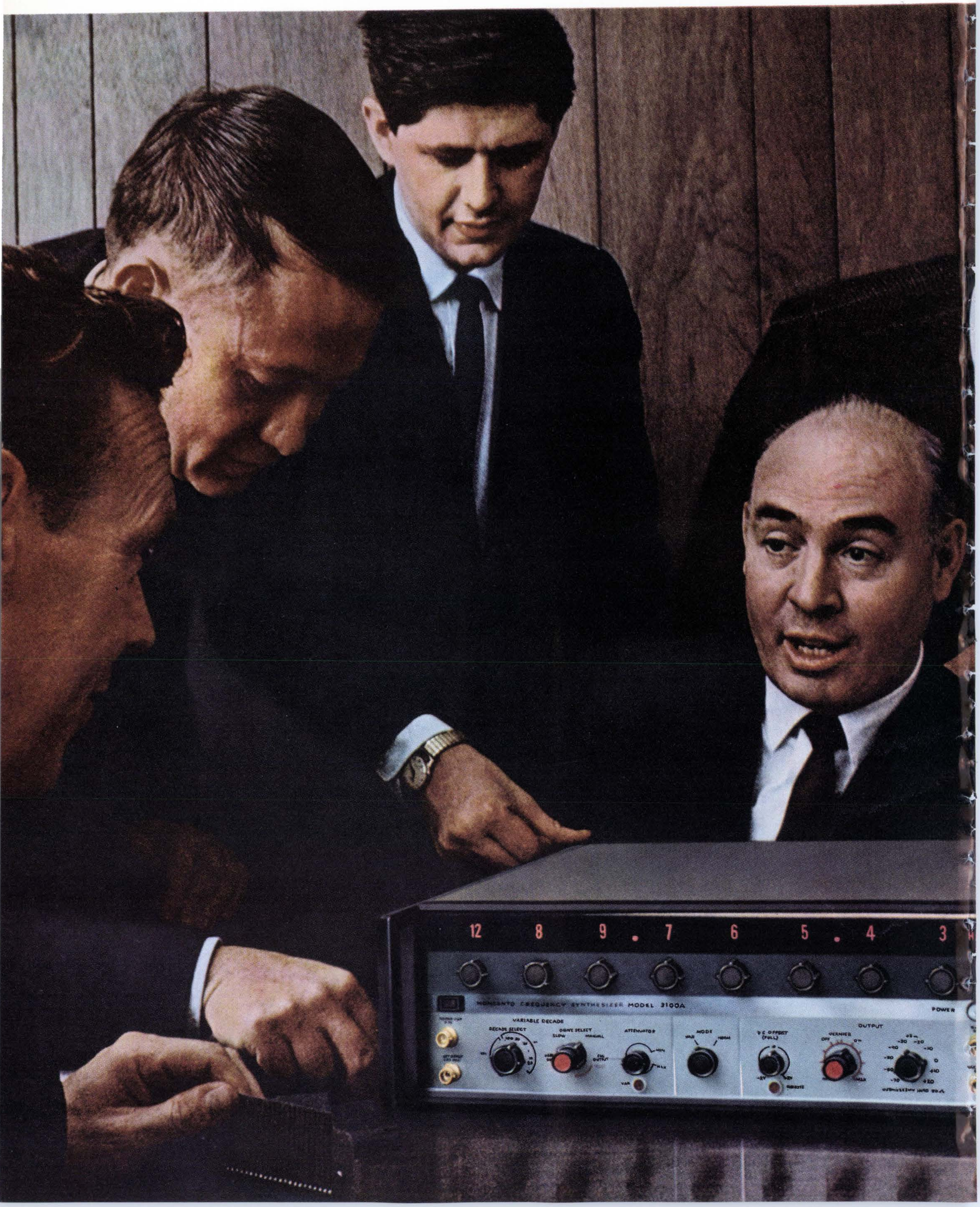
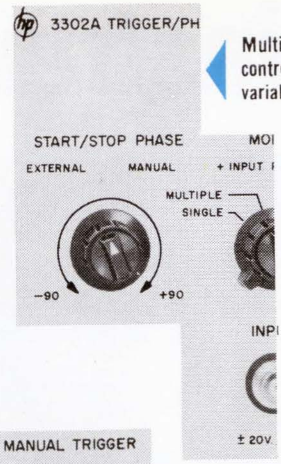
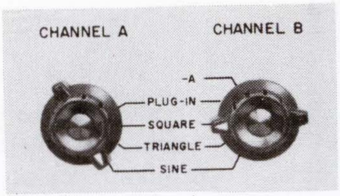




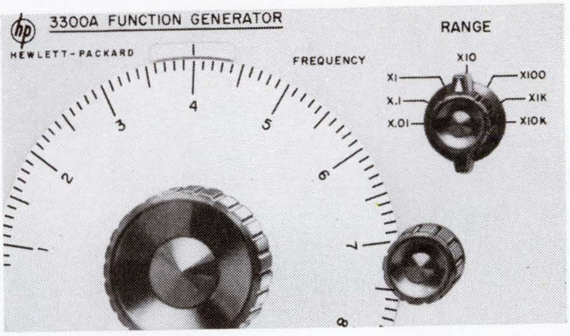
Multiple or Single bursts, controlled by external signal with 360° variable Start/Stop Phase.

$<1\%$ distortion sine, <250 ns square, $<1\%$ linear triangular waveform outputs.

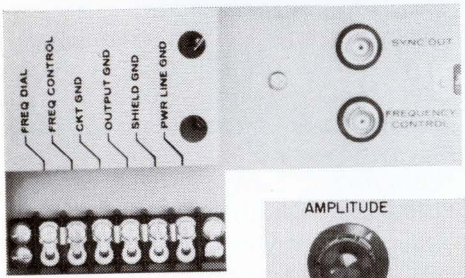


COVER THE SIGNAL SPECTRUM TO 100kHz WITH HP MODEL 3300A FUNCTION GENERATOR AND HP MODEL 3302A TRIGGER/PHASE LOCK PLUG-IN!

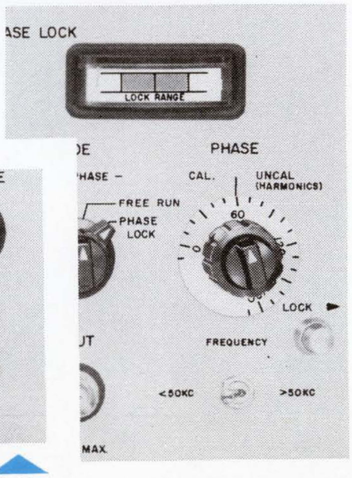
Manually select single or multiple cycles by the push of a button. Frequency is controlled by Frequency dial.

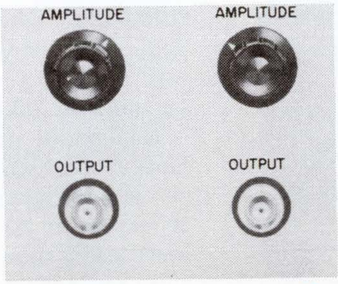


Frequency range 0.01 Hz to 100 kHz through seven decade ranges.



External frequency programming greater than 1 decade can be achieved with 0 to -10 V input.

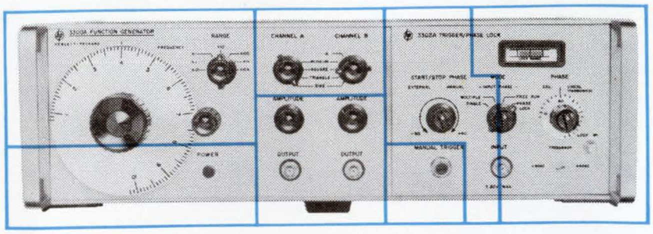




Two independently amplified fully floating outputs with separate controls for 35 V p-p.

Any two functions (sine, square or triangle) can be phase locked to any external periodic signal. Phase can be controlled 360° ±10°.

Price: hp 3300A Function Generator Mainframe, $625.00; hp 3301A Auxiliary Plug-In, $20.00; or hp 3302A Trigger/Phase Lock Plug-In, $190.00. For full specifications, contact your nearest hp field engineer. Or, write Hewlett-Packard, Palo Alto, California 94304, Tel (415) 326-7000; Europe: 54 Route des Acacias, Geneva.



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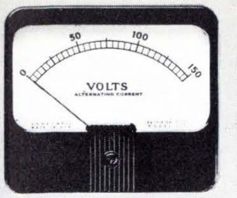
Circle 41 on reader service card →

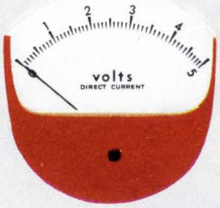


Time's up:

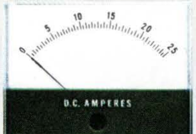
Honeywell now has a taut-band meter that actually goes for even less than a pivot-and-jewel meter. (About 10% less, on the average.)

What kind of a taut-band meter could we possibly sell at those prices?

An ingeniously simple one.



We designed every single unnecessary part right out of it. (Fewer parts: fewer things to go wrong.)



And we make this meter by machine. (This not only gives us a very good cost advantage. It also gives you a more reliable meter.)

It'll last practically forever because there's no friction in the moving parts. It'll mount anywhere without special calibrating because it's self-shielded.

And you can get one of these low-cost taut-band meters in just about any style you like.

But don't make up your mind yet. Take a look at our catalog first. Write Honeywell Precision Meter Division in Manchester, N.H. 03105.

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How long have you waited for a low-cost taut-band meter?

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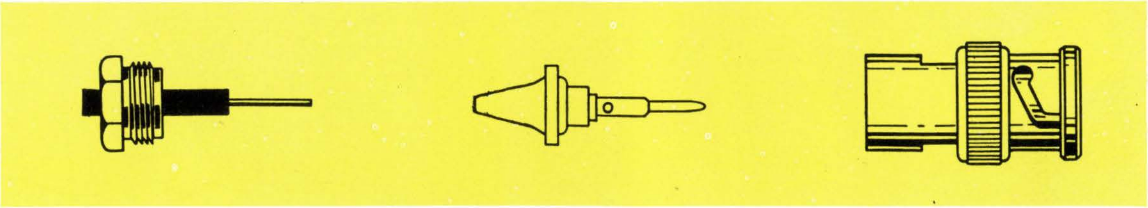
Time-and-money-saving benefits of Square-Cut Connectors are typical of BENDIX/DAGE contributions to the state of the art . . . *practical* ideas that help you design for greater capability in *your* circuitry and equipment.

Write for Square-Cut literature. If you have a special problem, call Dage Engineering Department. Call today!



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An Allen-Bradley announcement of importance to motor designers

The new MO6-C ferrite magnet having 30% higher intrinsic coercive force

The new Allen-Bradley MO6-C ceramic permanent magnets provide at least 30% increase in the highest previously available intrinsic coercive force—obtainable with A-B's MO5-C material. This advance is achieved with the same high residual flux density.

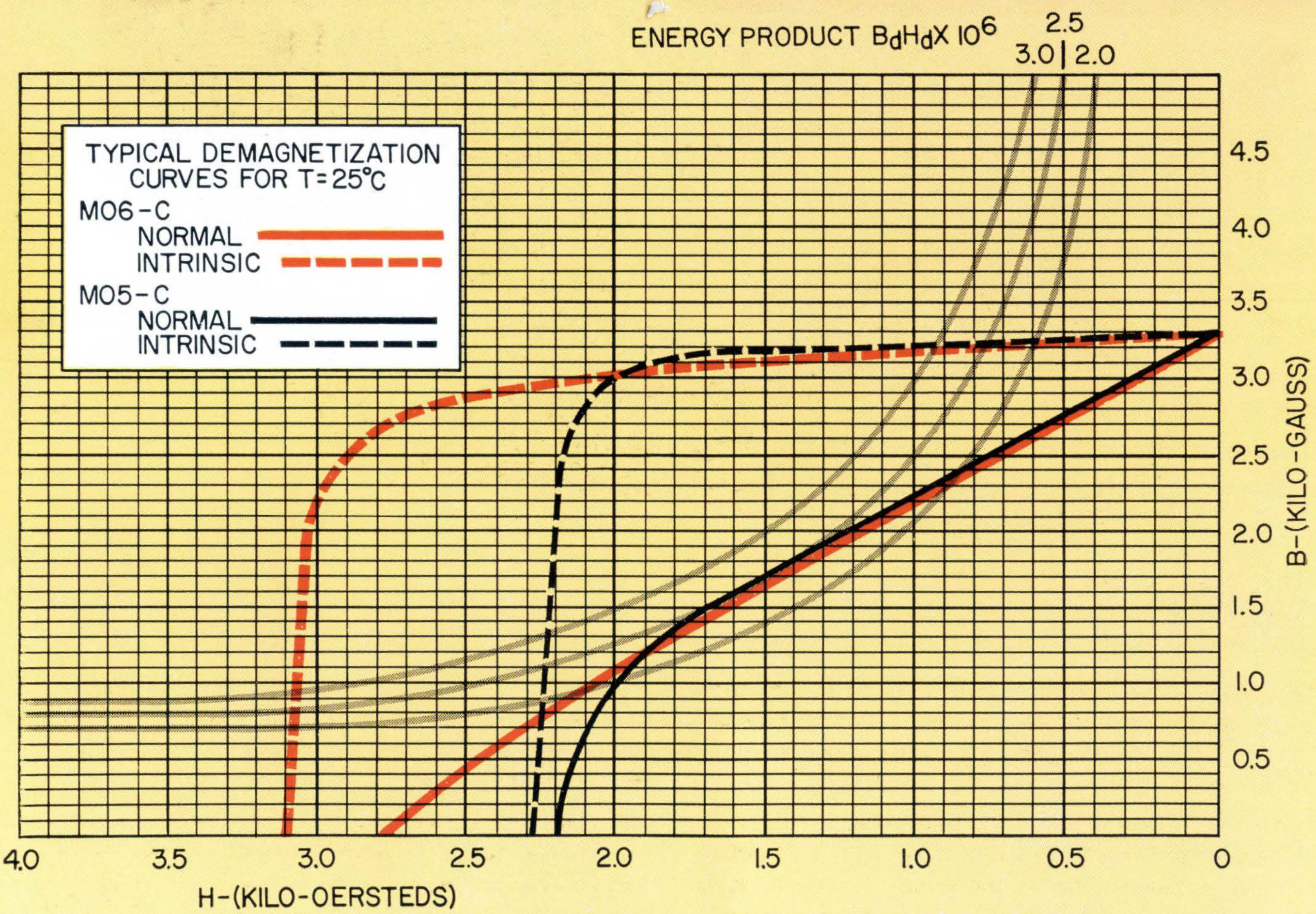
Designers of permanent magnet motors have a choice of these advantages—30% higher resistance to demagnetization, or 30% increase in motor output, or 30% increase in cold temperature protection. In fact, where the higher coercive force is not required, the designer can give himself a 30% reduction in magnet size.

This new Allen-Bradley MO6-C material opens the door to such motor designs where permanent magnets heretofore were not practical, namely for motors used in many portable tools and appliances. Like with the MO5-C material, these new MO6-C magnets are radially oriented, and are available in virtually all sizes and shapes currently being produced in segments for motors from 3/4″ diameter to 10 hp. While MO5-C magnets will continue to satisfy most needs, MO6-C enables designers to satisfy more exacting motor design requirements because of its unusually high intrinsic coercive force.

Allen-Bradley application engineers will be pleased to help you obtain maximum economy in your motor design through optimizing magnet performance. Please let us hear from you. Allen-Bradley Co., 222 West Greenfield Avenue, Milwaukee, Wisconsin 53204. In Canada: Allen-Bradley Canada Limited. Export Office: 630 Third Ave., New York, N.Y., U.S.A. 10017.

TYPE MO6-C CERAMIC PERMANENT MAGNETS
Typical Characteristics
–stated values have been determined at 25°C.

Property	Unit	Nominal Value
Residual Induction (B_r)	Gauss	3300
Coercive Force (H_c)	Oersteds	2800
Intrinsic Coercive Force (H_{ci})	Oersteds	3100
Peak Energy Product (B_dH_d max)	Gauss-Oersteds	2.5×10^6
Reversible Permeability	—	1.09
Curie Temperature	+°C	450
Temperature Coefficient of Flux Density at B_r	%/°C	−0.20
Specific Gravity	—	4.9
Weight per Cu. In.	Lbs.	0.177



Bendix LJT Connectors–first and only to be fully scoop-proof.

No mismating, damaged pins or short circuits.

The Scoop Test is a pretty tough test to give a connector. To pass, you can't damage or short the pins, no matter how much you misalign the plug and receptacle during mating.

Bendix® LJT Connectors *pass* the Scoop Test—and scoop the rest. And it doesn't matter if the pins are in the plug or the receptacle! Because all contacts are totally recessed. They're stronger, too. And mismating is a thing of the past. Five-key polarization assures it.

But that's not half the story. Hard, glass fiber-filled epoxy inserts improve electrical and thermal characteristics, are impenetrable by pins and probes. Plug shells are provided with grounding fingers for EMR and RFI shielding. Safer, too, because the shell is grounded before contacts engage. Insert assemblies are staked and bonded for a sturdy moisture-proof seal. You can specify shell sizes from 9 to 25. Get from 3 to 67 contacts in 16, 20 and 22M sizes, with solder terminations. Select flange mount, line mount, straight plug, jam nut or hermetic types. All built as rugged as you can find.

Write today for complete information on our LJT connectors. The Bendix Corporation, Electrical Components Division, Sidney, New York 13838.

Bendix Electronics

Circle 46 on reader service card

Electronics Review

Volume 40
Number 8

Manufacturing

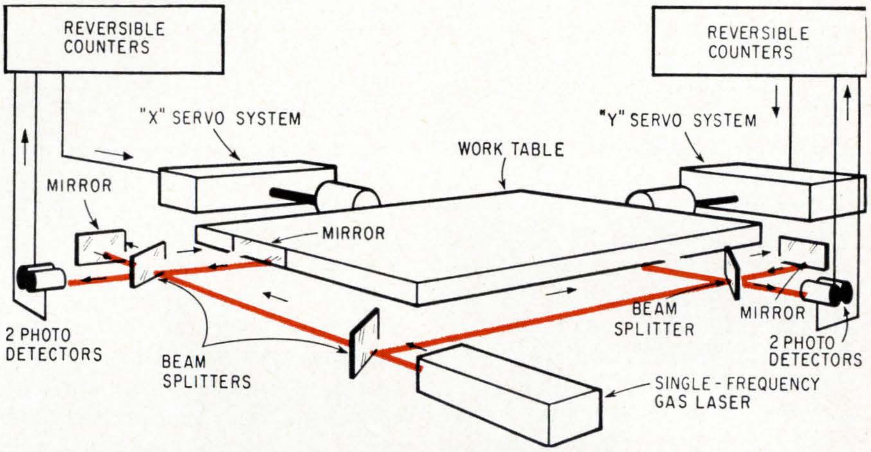
Boosting IC's

To boost integrated-circuit yield and performance, IC mask makers are turning to interferometer-equipped masking cameras. The reason: plate positioning errors in conventional cameras are limiting the potential of IC's by forcing designers to make circuit elements larger and spacing wider to ensure registry of superimposed images on the master plate.

Using light as a measuring tool, the new cameras can place IC's on the master plate with at least four times the accuracy of conventional camera systems. To the IC builder, greater accuracy means higher device and plate yield. Closer circuit and interelement spacing will lead to faster production of more complex IC's.

First to use an interferometer-equipped camera on its IC production line is the Hewlett-Packard Co.; [Electronics, April 3, p. 26]; Motorola Semiconductor Products, Inc., a Motorola Inc. subsidiary and Texas Instruments Incorporated are operating experimental models. ITT Semiconductor Research Laboratories is building one and Spectra Physics Inc. will begin selling such cameras late this year; Optomechanisms Inc. is now selling a small model.

Fringe benefits. The new interferometric positioners use coherent light as a yardstick rather than micrometric gears, scribed grids, or other mechanical references. Because there are no built-in mechanical inaccuracies, the new cameras register or position images with 5- to 12-microinch accuracy. Conventional cameras, at best, can only achieve accuracies of 45-50 microinches. Accuracy with the new cameras are maintained over the entire master plate.



Light beams, shown in color, are the measuring elements in a laser interferometer that servopositions IC master plates with high accuracy.

Interferometers measure distance and find position by counting "fringes"—alternate periods of darkness and light that appear when two beams of coherent light mix. In the new masking cameras, two interferometers are used, one for X-axis and the other for Y-axis positioning.

Each interferometer has one leg of known length and another that becomes longer or shorter as it is reflected from a mirror on the moving plate-positioning stage. The two beams combine at a photodetector and their respective phases cancel out, causing alternating light and dark periods—fringes. A fringe corresponds to a movement of the stage; when a helium-neon 6,328-Angstrom-wavelength laser is used as the light source, a fringe corresponds to a distance of 3,164 Angstroms. The detected fringes pass from the photodetectors to counters or computers.

Beyond the fringe. Various companies use fringe data differently. Hewlett-Packard, TI and Spectra Physics use reversible counters and digital computers to servocontrol stage position, set spacing between IC images, and trigger exposure. Motorola's experimental unit is simpler, with the detectors feeding Nixie-tube counter readouts and the operator positioning the stage manually; he also controls exposure.

The digitally controlled cameras automatically count a preset number of fringes, make exposure, and step to the next position. They can leave unexposed positions in the image pattern, dropping in other images later without degrading positional accuracy. This capability is important to builders of large-scale integrated arrays because many different masks are often used on an LSI plate.

The excellent registration possible with the new cameras may also make possible closer placement of IC images, smaller elements, and closer interelement spacing. Carl Betz, manager of mask-making research and development at Motorola, predicts interelement spacing as close as a half micron. Motorola is already planning to make masks for a highly complex, 80 by 80 mil LSI array with very small elements.

With such accuracy, overall plate yield should be increased; there should be fewer plates shot with out-of-register images to cause circuit rejection. By the same token, it takes less time to "debug" a set of master plates. Each set still has to be inspected, but the new cameras will be able to reshoot bad plates in a single operation. Conventional masking cameras usually need five or six attempts to shoot a well-registered plate because of mechanical inaccuracy.

On the dark side. The new cameras' biggest drawback is cost stemming from their susceptibility to vibration. To get the full benefit of interferometric accuracy, the IC mask maker may need a $200,000-$300,000 stable table in a controlled environment, according to William Winslow, president of Qualitron Inc., the country's largest mask-making firm. Add this to Spectra Physics' predicted camera price of more than $100,000 and it's a large capital investment. TI spent about $500,000 on its camera setup, which includes a 16-ton, spring-suspended concrete stable platform.

Communications

Dial h for help

Complaints about high telephone bills have a familiar ring to most phone companies, but the tone of the grumbles from users of time-shared computer systems is alarming.

Rates levied by the American Telephone & Telegraph Co.'s Bell System are prohibitive and account for a disproportionately high share of data-processing costs, users claim. Some go so far as to say that the giant communications carrier is blocking the growth of computer utilities by not reacting to the technology's needs.

Billing gripe. The most outspoken critic of AT&T is Richard G. Mills, assistant director of the Massachusetts Institute of Technology's Project MAC, a prototype computer utility. Mills would like the Federal Communications Commission to spur AT&T to speedy action [Electronics, April 3, p. 25]. He terms unfair the company's rate structure as it affects computer communications.

A computer service bills the user only for computer use time. The phone companies, however, bill the users for circuit-use, regardless of how much time is actually spent in transmitting data. Mills wants AT&T to charge "by the bit."

AT&T's move to pulse-code modulation, which eventually will replace all of today's analog circuitry, is too slow to suit Mills. "Eventually isn't fast enough," he points out.

Others agree. Says one user: "AT&T's operating companies' representatives don't understand our problems. They just take our suggestions and lose them."

The problem will be further aggravated when the International Business Machines Corp.'s 360-67 and the General Electric Co.'s 645 as well as other time-sharing computers are put into full use—probably within the next couple of years.

Lewis Cimino, a manager of information systems and computers at GE, says his company "has an AT&T representative in here almost all the time and it's a continual debate. The carrier either doesn't understand our needs or seems to lose our suggestions in its daisy-chain of command."

General Electric has data banks around the country and has tried to interconnect them several times using AT&T's coaxial cables, but each time it had to discontinue the links because the transmission costs were prohibitive, says Cimino. GE also has 13 regional time-sharing computer utilities facing the same problem.

Says Cimino: "When the Government becomes a big user of time sharing, it'll feel the communications cost bite just as we do and the FCC will do the rest."

Devil's advocate. James D. Babcock, president of the Allen-Babcock Computing Co., a Los Angeles time-sharing service, won't knock AT&T's refusal to junk $30 billion in plant equipment "just for the stake of a few time-sharing nuts."

Thomas J. O'Rourke, president of Tymshare Inc., in Los Altos, Calif., also backs the carrier. "Our feeling is that it makes good business sense to base commercial use rates on the same basis as the phone company. Admitting the carrier was caught flatfooted by the growth of time sharing, he comes up with a gripe of his own—the unsuitability of AT&T's interfacing. "Teletype terminals may be fine for batting orders back and forth but they are inadequate for a time-sharing computer." He cites low speed and a limited number of characters as causes of inefficient transmission.

The giant communications carrier is taking the attacks in its stride and refuses to comment on them.

Integrated electronics

Complementary samples

Lured by its bright prospects for achieving fast integrated circuits that dissipate little power, the Radio Corp. of America has successfully produced complementary (n and p channels) metal-oxide-semiconductor (MOS) elements in a single chip. The company has used the new complementary technique to build a dual 3-input NOR gate.

The 14-element IC will contain the two gates and an inverter stage in one silicon chip. It is expected to be available on a sample basis to customers within the next two months.

While the complementary concept is well known, its development has proven difficult. Some researchers have slowed their efforts and still others have turned to alternate methods.

RCA's technique was developed by the company's IC department in Somerville, N.J. To produce both n- and p-channel elements on the same chip, a p-isolation region is diffused into the n-silicon substrate. The p region serves as the local substrate for the n-channel MOS device.

RCA attributes the circuit's low standby power—about 10 nanowatts—to the high impedance of the off unit, which blocks the power supply voltage in both the high and low states. Operating power is low, too, since power is dissipated only during switching to charge and discharge capacitance. The gate, when run from an 8-volt supply dissipates 400 microwatts at 100 kilohertz, while driving a capacitance of 30 picofarads. Good speed of the unit is attributed to the output node capacitance always being charged and discharged through the low-impedance on unit. Propagation delay, RCA says, is 25 nanoseconds. While comparable semiconductor bipolar integrated circuits can match these speeds, power dissipation is much greater—of the order of tens of milliwatts.

A difficult road. Last year, Motorola Inc.'s Semiconductor Products division introduced what was probably the first complementary MOS switch. But the device isn't listed in the firm's catalog and its current MOS program is shrouded in secrecy. Nevertheless, Motorola says the MOS device is available for sale. North American Aviation Inc.'s Autonetics division is also putting n- and p-channel elements on one chip, but with some difficulties. Such devices, says Autonetics' Richard Platzek, are usable only in low-voltage systems—12 to 15 volts—because of their low breakdown voltage.

Critics claim complementary devices don't use silicon real estate effectively, since p- and n-channel elements must be isolated. The beauty of MOS technology, the Philco-Ford Corp. believes, is in simplicity of design, fabrication, and high manufacturing yields—not the case with the complementary approach. Gordon Moore, director of research at Fairchild Semiconductor, a division of Fairchild Camera & Instrument Corp., agrees.

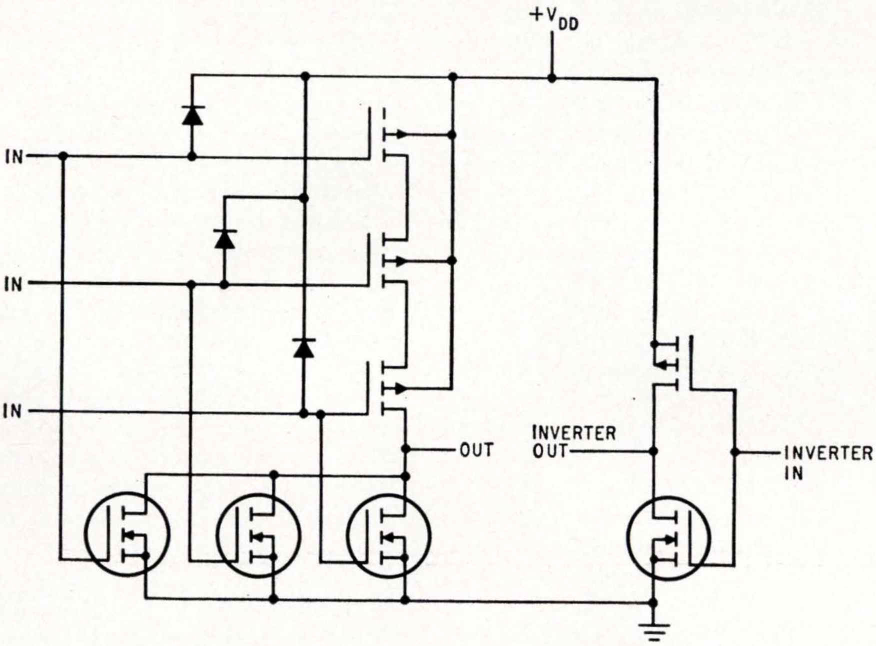
But, RCA engineers say a direct comparison is misleading. The complementary circuitry, they contend, may be built with less precision than comparable single-channel circuits, and also, despite the more complex steps and larger area consumed, yields are potentially very high. They claim for example, that the new dual NOR gate will operate from any voltage between 6 and 12 v, whereas single-channel circuitry often requires a power supply accurate to within 1%.

Where it's tops. The real role of the complementary MOS device, according to engineers at Philco-Ford, is in low-power memory applications. But while the technique may pay off in the combination of low power and higher frequencies, they believe the complementary method is not the basic solution to high speeds. Instead, Philco-Ford sees within a year faster p-channel devices and circuit improvements that will reduce propagation delay to a few nanoseconds.

A better way to achieve the speeds required for computers, says Autonetics' Platzek, could be through the use of a technique in which four separate clock signals, out of phase with each other, are routed through an all p-channel circuit.

Theoretical limits of the two devices—complementary and four-phase clock—are about the same, says Platzek; both are ultimately capable of about 250 kilohertz. He recommends the four-phase clock approach in fabricating complex digital differential analyzers. In comparing the two methods, Platzek says that one advantage of the four-phase clock is that it employs current technology. But it takes up more real estate on the silicon chip and it requires more metal than do complementary devices, decreasing the yield of the device.

Fairchild Semiconductor is working with the complementary MOS



Complementary MOS device to be introduced by RCA is a dual 3-input NOR gate, and inverter on one silicon chip. Only one gate is shown, with the p-channel elements circled in color. Supply voltage may range from 6 to 12 v.

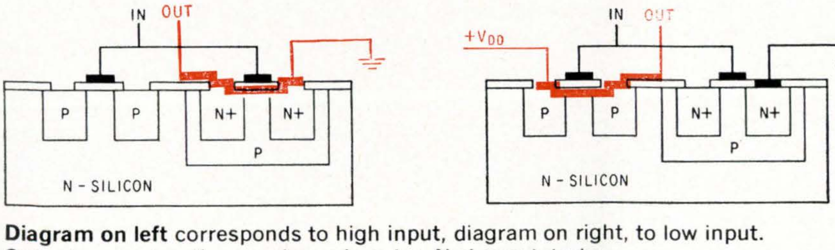


Diagram on left corresponds to high input, diagram on right, to low input. Output current paths are shown in color. N-channel device is at right of section drawings. Output current paths are shown in color.

INPUT	HIGH	LOW
CONDITION	N UNIT ON P UNIT OFF	P UNIT ON N UNIT OFF
OUTPUT	LOW	HIGH

◄**Input and output** waveforms with corresponding high- and low-level circuit conditions.

approach to high-speed, but now favors the single-polarity multiphase clocking system. Using a four-phase clock system, Fairchild has achieved propagation delays of the order of 10 nanoseconds.

Companies

Turnaround in Phoenix

Last week, workmen moved back into the almost empty shell of a plant in Mesa, Ariz., that is to add 300,000 square feet of manufacturing space to Motorola Inc.'s integrated-circuit capability. Construction work had been stalled for about three months as tight money and high interest rates—not slumping sales as reported in Electronics (March 20, p. 54)*—forced the company to stretch out its capital spending plans, which also include new semiconductor facilities in France and Korea.

Slack period. Also, Motorola, like others in the industry, now has an expanding volume of orders for its discrete semiconductor products, but it earlier had to endure a spell of slack demand as some of its customers lived off accumulated inventories during the autumn and winter of 1966. Early last year, some customers, particularly in consumer-oriented industries, stocked up on semiconductor components, fearing that heavy military buying for the Vietnam war would cause materials shortages. The shortages failed to develop—largely because semiconductor production capacity was expanded—and these companies stopped buying until they could work off their stores of diodes, transistors, and silicon controlled rectifiers.

To handle the flood of orders last year's hedge buying created, Motorola increased its production force sharply during the spring of 1966. When customers started drawing from inventories instead of buying, it laid off the extra workers, about 2,700 of them.

Profit record. Fueled by the spurt in orders in early 1966, Motorola's Semiconductor Products division last year recorded its best sales and earnings in history—with profit estimated at more than $10 million. Even during the time when demand for discrete devices suffered the effects of inventory liquidations, the division's operations remained profitable. The report in Electronics that the division sustained a $5 million full-year loss should have specified that the loss applied only to integrated-circuit operations.

The deficit figure represented a giant investment in research and development, mainly for new products. Daniel E. Noble, vice chairman of Motorola, notes that "the division added 151 integrated circuits to its product line" last December and January.

The big IC investment signalled a change in Motorola's marketing strategy. Four years ago, when the company developed integrated circuits with emitter-coupled logic, it put the lion's share of its marketing effort into that one type, which it called MECL. But the move was regarded as premature by many computer designers, who were wary of MECL's sensitivity to external noise. In response, Motorola has added all kinds of IC logic to blanket the market. It now offers the widest range of integrated circuits in the industry—633 digital circuits and 33 linear circuits. Lester Hogan, division general manager, boasts: "Today we will deliver any kind of logic the customer wants." This includes diode-transistor logic, resistor-transistor logic, transistor-transistor logic, and MECL.

Where they go. As a result of this change, says Motorola, the firm in December delivered more IC's than any other supplier. The greatest number were digital circuits for the Radio Corp. of America's Spectra 70 computer, and for Minuteman missile guidance systems, flight simulators, and the R-13 project, a classified National Security Agency program. By adding all kinds of logic to its product line, Motorola has built for itself a steadily growing position as a second source. In addition, the company has been delivering linear IC's to General Dynamics Corp.'s Pomona division for the Redeye missile, an infantryman's rocket using 20 integrated circuits in its guidance system.

During the period of slowed demand for discrete devices last year, Motorola's output of integrated circuits continued to climb steadily. Work forces on the IC lines were reduced slightly, despite the increasing sales, however, because of sharply improved production yields.

Now, with sales of discrete semiconductor products rebounding, Motorola has started hiring again. According to Hogan, "the number of inquiries and requests to bid we received suddenly increased in February and March. A spurt in these always precedes orders." The official expects the production work force in Phoenix to return to its peak 1966 level by next September.

Modular construction. Because Motorola's Mesa plant was built to accommodate growth over the next three years, the company hasn't moved to complete it quickly, and this has given rise to a lot of rumors. In Phoenix, for example, gossip has had it that the company will never occupy the Mesa facility. But at the plant's dedication in November, Noble emphasized that only a portion of the plant was completed, and that it had been designed so that modules in the shell could be completed as needed.

The work on the facility's interior

* **In the story "Motorola rollback,"** put together from industry reports and interviews, several errors appeared. The story reported that the Semiconductor Products division had a $5 million loss in 1966. Commenting on the story, Daniel E. Noble, Motorola's vice chairman and chief technical officer, declared: "Sales and profit records were set by the firm's Semiconductor Products division in 1966. The division was one of the major profit centers of the corporation. The $5 million loss erroneously reported was confused with our 1966 investment in integrated-circuit research and development."

Noble also explained that the layoffs described in the story followed abnormal peak production early in 1966 caused by anticipatory buying by customers. "Inventory balance has been achieved and we are now rehiring," he added.

The report of the drop in deliveries of tantalum capacitors was erroneous. Motorola does not and never has made this product.

Noble minimized the impact on Motorola's Semiconductor Products division of the production cutback in the automobile industry, another point made in the story. "It had only a minor effect on our rectifier sales," he said. "But, as someone recently pointed out, the number of cars being sold today is still quite high." Noble observed that the division manufactures 18 major categories of semiconductors covering 80% of all types required by industry, thus minimizing the company's dependence on any one market.

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Circle 51 on reader service card

that was started up again last week will cost nearly $1 million and will complete about half the plant. The renewed construction allays the rumor that the company plans to abandon the plant.

One reason Motorola is so bullish about its IC operations is that it believes computer designers are finally ready for emitter-coupled logic. Most have learned how to shield the circuits from noise and now know how to package and interconnect them to take advantage of their exceptionally high speed. Motorola believes emitter-coupled logic will surpass transistor-transistor logic in high-speed applications because TTL units may be troubled by internal noise at exceptionally high speeds.

Next, Motorola will develop integrated-circuit memories. The company has already built prototypes of two 16-bit random access memories in IC form. One, for use with saturated logic such as DTL or TTL, will compete with other IC memories already on the market. The other is the first designed for use with emitter-coupled logic. These devices are slated to be the forerunners of the company's proposed line of commercial memory elements, some of which will have logic and memory on the same chip.

Military electronics

Unstoppable shot?

Since spear-and-shield times, the development of a new weapon has been quickly followed by equipment to counter it. Now, however, the Navy thinks its Standard missile will break this cycle.

For one thing, the Navy will be able to modify the versatile Standard with kits, and these modifications, the service believes, will keep the missile one step ahead of any measures an enemy employs to baffle its guidance and homing system. While most of the possible design changes are classified, there is talk of changing the missile's terminal guidance from a semi-active radar mode to an infrared homing mode.

Going out. Tartar missile, here being launched from a destroyer, will be replaced by the Standard starting early next year.

Ten-year hitch. Under terms of a $120 million contract, the General Dynamics Corp.'s Pomona, Calif., division is to supply 4,000 Standards for installation aboard 50 warships. Optimistic officers feel the missile can handle the job of protecting the fleet from surface and air attack for 10 years after the first one becomes operational in early 1967.

There will be two basic shipboard models, identical except in their propulsion units. The extended-range Standard will be able to cover distances of more than 30 miles, while the other version will have a range of more than 10 miles.

The Standards will also use several types of fuses—contact fuses against ships and proximity fuses against planes, for example.

As another measure of the missile's versatility, a model is being developed for launching from aircraft against enemy radar sites. Called the interim ARM (anti-radiation missile), it will replace the Shrike missile that Texas Instruments Incorporated has been building for several years [Electronics, Dec. 26, 1966, p. 36].

Crossing the T's. The shipboard Standards are to replace the trouble-plagued Terrier and Tartar missiles, which, along with the Talos, have cost the Government more than $3 billion. The air-breathing Talos won't be replaced for the time being because its range is greater than the Standard's.

Like the three T's, the Standard —initially, at least—will use current shipboard fire-control radars for guidance [Electronics, Dec. 27, 1965, p. 112]. The radars, with a range of more than 75 miles, will "illuminate" the target with radio beams, and these signals will be followed by the missiles' receivers. Installation of the Standards will require only minor modifications in the shipboard radars.

Long-run production. The Navy's award to General Dynamics runs six years; few defense contracts cover more than three years. General Dynamics did the research and development work on the missile, but it had to face competition for the production order. The contract covers the Standard's guidance, control, and fusing systems.

Ears to see with

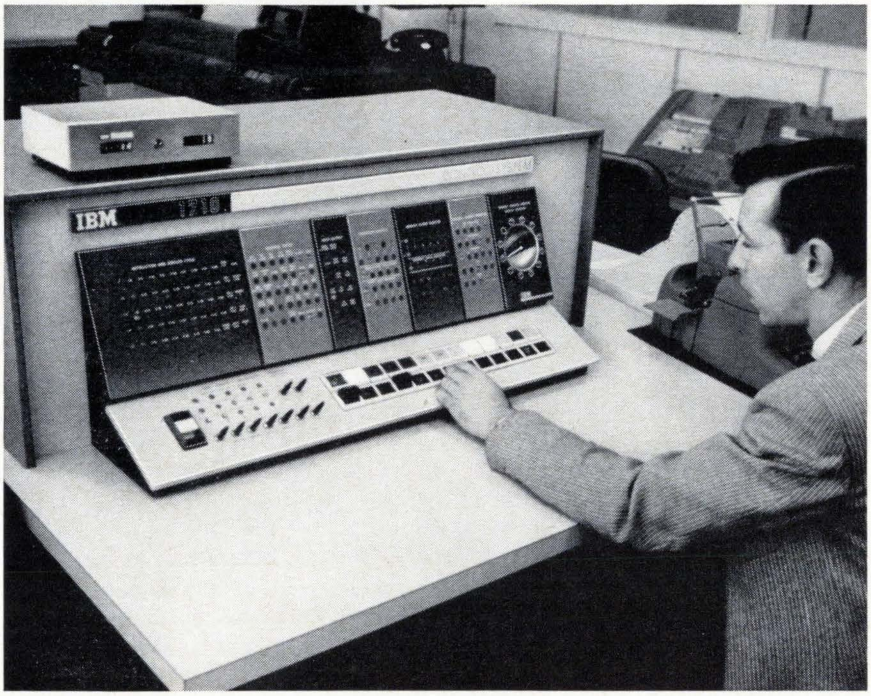
Helicopter pilots flying combat missions in Vietnam often don't know when they are being fired upon from the ground. Noisy engines drown out the sound of the shots, and it's only when the craft is hit that a pilot knows he's the target.

Now being tested in Vietnam is a simple, cheap system that enables helicopter crews to detect and determine the direction of ground fire. It does this by picking up the sound of enemy projectiles as they pass the aircraft. Developed by Philip Lieberman, staff scientist at the Air Force's Cambridge Research Laboratories, the acoustic bullet detector is being tried out by the Army Concept Team in Vietnam.

By telling him that he's being

SPEER COMPONENT COMMENTS

How to get a real reading on a resistor's true function... resistance.



That's right, we mean plain old electrical resistance.

The problem with this particular parameter it that it's just too basic. It doesn't have the exotic intrigue of such items as temperature coefficient, moisture resistance or load life. As a result, almost everyone takes it for granted—and naturally neglects to verify whether or not the resistance is actually being properly measured.

For example, if you don't realize the importance of using the proper test voltage, you can get all kinds of remarkable results.

The culprit in this case is the coefficient, not the component you're measuring. You can decrease the measured resistance of a carbon composition resistor by simply increasing the voltage applied... and vice versa.

Now with low value resistors below 100K improper applied voltage won't wreck your readings since the VC is comparatively insignificant. But if you're measuring resistors above 100,000 ohms this voltage coefficient can throw a real curve.

So what should your test voltage be? According to EIA Specifications RS-172, MIL-R-11, and MIL-R-39008, resistors above 100K must be tested at 80 to 100 volts.

Yet most commercial testing units used by receiving inspection departments and component evaluation laboratories apply, at most a mere 15 volts. So, unless compensation is made for this Voltage Coefficient, many lots of perfectly good resistors which are well within the parameters specified could be indicated as somewhat beyond the limit.

Needless to say, Speer tests and sorts all of its resistors at EIA/military voltages.

In addition, we've prepared an article that explores this entire subject in greater detail. This article has the appropriately basic title: "Resistance —How It Is Measured." If you'd like a copy, just mail the coupon.

Are you and your inductor supplier committing Typical Test Error #6?

If you've been purchasing any of the superb inductors manufactured by our Jeffers Electronics Division, we may well have warned you about this error already.

It consists of failing to obtain correlation between your supplier and your own incoming inspection, in cases where inductance tolerances of less than 5% are involved.

Ideally, this step should be completed before the actual manufacturing operation starts. Your supplier should measure and tag sample parts and then forward them to you for correlation.

There are seven other possible errors that you should also be aware of when you're using MIL-C-15305 testing procedures to measure inductance and Q. We've covered a number of these errors already. The others will be along shortly.

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shot at, the detector enables the helicopter pilot to employ evasive tactics or offensive action against the source of the ground fire.

The system consists of two microphones positioned beneath the helicopter, and a high-pass filter. Critical to the system is the use of an artificial "head." The microphones are attached to either side of this head, simulating human ears. The signal from each microphone is channeled separately to each phone of the pilot's headset which provides natural directional information. The microphones are designed to have the same sound diffraction pattern as the human head.

Amplified signal. Signals received by the microphones are high-pass filtered at 3.5 kilohertz. The filtering removes the major frequency components of the helicopter noise, leaving half of the sound energy of gunfire, which is then amplified. This amplification enhances the gunfire signal-to-noise ratio approximately 30 decibels for most helicopter and certain fixed-wing aircraft. The pilot and crew listen to this signal through the normal intercom system, or through separate hearing aid-type devices inserted into the ear under the headset.

The Cambridge acoustic bullet detector differs from a system now being developed at the Army's Aberdeen Proving Ground in Maryland [Electronics, Jan. 23, p. 153] that would provide a similar warning to helicopter pilots. The more complex Aberdeen system uses a ranging technique in which the differences in the time each acoustic sensor on the craft detects a shot are measured to indicate the source of the ground fire. In this system the pilot has a visual display for readout.

The Cambridge detection system had previously been tested in an H-13 helicopter, a C-47 and a liaison aircraft at Fort Devens, Mass., Eglin AFB, Florida, and at Camp Edwards, Mass. In one of the tests a 7.62-mm machine gun fired short bursts of live ammunition near the helicopter as it flew at altitudes from 100 to 400 feet and at distances to 200 yards.

The system is rugged, self-powered, and uncomplicated. Its electronic components can be miniaturized to less than 10 cubic inches and it can be produced at a cost less than $100 per unit.

Industrial electronics

Still out of control

"Every one of the 58 Sperry traffic controllers we installed failed," gripes New York City's traffic commissioner, Henry A. Barnes, whose comments leave no doubt that the city's problems with its new electronic traffic control system are far from over. In fact, they may only have begun.

Last January, about eight months behind schedule, the city began installing solid state traffic-light controllers, the first elements of the system developed by the Sperry Gyroscope division of the Sperry Rand Corp. [Electronics Jan. 23, p. 26]. At the time it was believed that Sperry had worked out the bugs, but the city found plenty.

Barnes burning. "As far as the radar vehicle-speed detectors are concerned, none of them have even been delivered. "We still don't know if they work," Barnes said earlier this month. "We also found that the sonic detectors supplied by the company didn't work either." Sperry has declined to comment on these problems other than to point out that brand-new hardware often runs into snags. It's known that it is reevaluating the program, originally established under a $5.4 million contract signed in August 1965. This reevaluation should be completed by May 15.

Commissioner Barnes says he will then either agree to a reasonable time extension for components delivery or will cancel the contract. However, the commissioner would probably be reluctant to cancel because of the extra delay involved in evaluating new bids.

The traffic-control system is supposed to tie 2,700 of the city's 9,000 traffic-lighted intersections into a coordinated network. Citywide in-

formation on traffic volume and speed would be collected by the radar sensors and sent over leased telephone lines to about a dozen digital computers. The computers would then determine what overall patterns of "stop" and "go" lights would allow the quickest traffic flow, and would direct local traffic-control equipment to recycle the lights to these patterns. The sonic detectors at key intersections could control traffic lights directly, out of step with the central computers but responding to local conditions.

Foiled again. The solid state traffic controllers were delivered by Sperry to control lights on a fixed timing cycle pending installation of the digital computers. They failed for many reasons.

"Power supplies broke down, transients on the power lines blew up transistors and the cabinets leaked when it rained," says Barnes. "We even found that when the controllers were installed in an east-west direction they might work fine; put them in a north-south direction and some contacts would close when they weren't supposed to or would drop out." Barnes said the trouble was caused by the effect of the earth's magnetic field on the devices.

Computers

Not-so-firm ware

Computer designers have pretty much agreed that firmware offers one way to ease the software problems of computer users. But they are still arguing about whether the firmware—microprograms stored in read-only memories—should be alterable or not [Electronics, March 20, p. 159].

The engineers at Honeywell Inc.'s Electronic Data Processing division in Wellesley Hills, Mass., have chosen the route of electrical alteration. They designed a read-only memory for the H-8200 computer that can be altered, but not by the user.

"Many of the functions and capabilities that were either built into hardware or written into software in previous machines can now be handled by the memory in this machine," says Joseph Phillips, manager of the H-8200 project. The fact that our read-only memory is electrically alterable makes our firmware considerably more flexible—less firm, if you will, but certainly not 'softer'—than the firmware in other current machines."

The memory is actually a read-write unit with a 125-nanosecond access time; but for everyday use, data is only taken from it, not put in. If the contents need changing, a Honeywell maintenance man can do it in milliseconds with a magnetic tape record of the new data and a special loading program that isn't available to the customer.

This isn't the first time Honeywell has used such a memory. Its Alert series of military computers had a read-only unit made of Biax cores, permitting a nondestructive readout [Electronics, Aug. 23, 1965, p. 40].

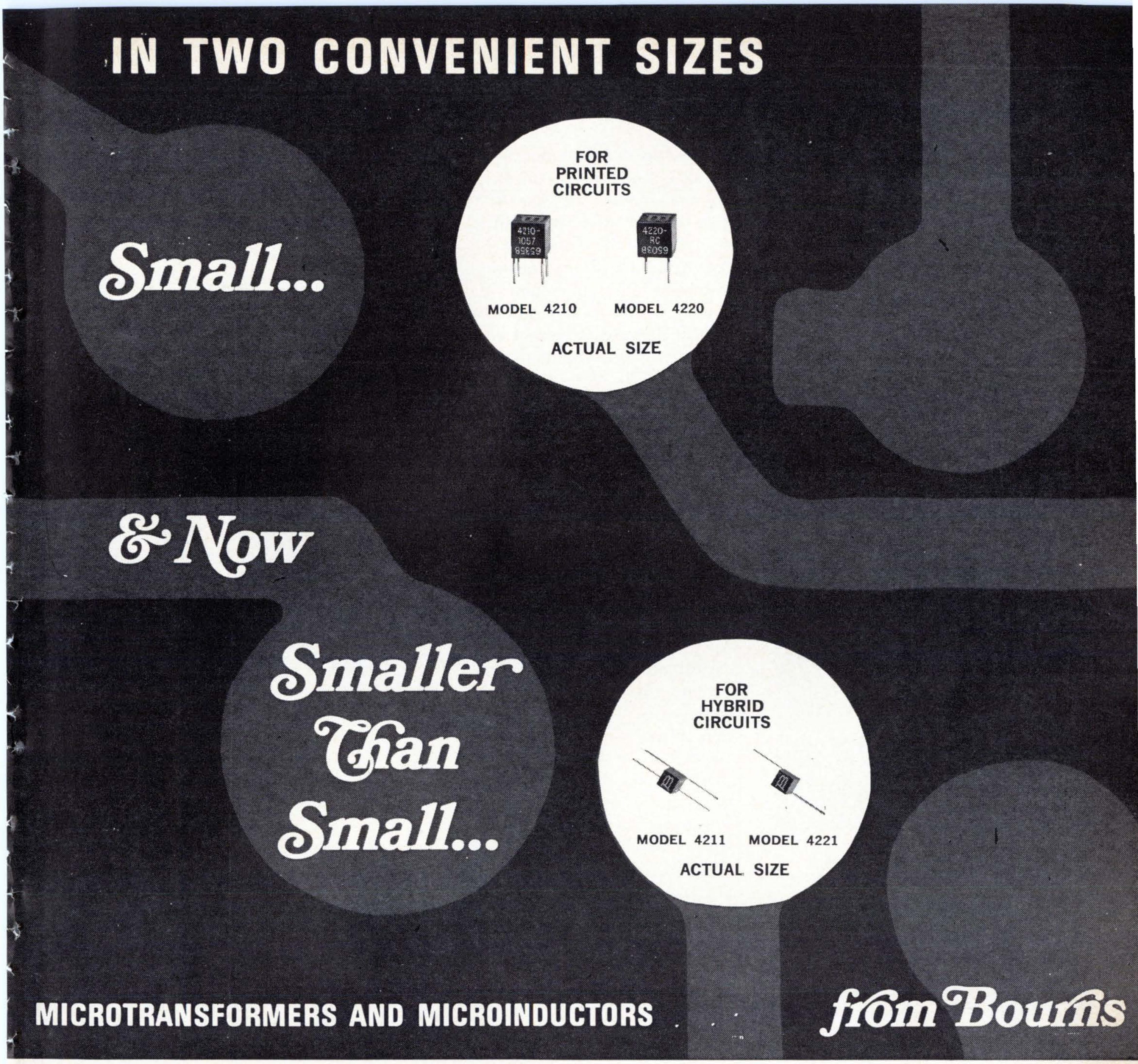
Honeywell's engineers have also made a decision on another controversial type of memory: the all-integrated-circuit scratchpad. In this design, the company is going all the way—using 16-bit chips in flatpacks. The scratchpad contains 256 words of 30 bits each, and is mounted on 20 printed circuit boards that together occupy only one-sixth of a cubic foot.

The prototype of the 8200 is now being debugged; hardware and software will be demonstrated next October, and the first machine will be delivered in April 1968. The 8200 will compete with large-scale computers such as the IBM 360/65, the Univac 1108, and the General Electric 635.

Avionics

View from above

Already hurting for helicopter station-keeping radar, the Army is rushing development of an helicopter-borne formation-flight simulator—the country's first—to give



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SPECIFICATIONS	MODEL 4210 MICROTRANSFORMER	MODEL 4211 TRANSFORMER
Size	¼ x ¼ x ¼	⅛ x ⅛ x ⅛
Maximum operating temperature	130°C	105°C
Frequency response	±2 db, 400 to 250kHz	±2 db, 2K to 500kHz
Maximum distortion	±5% at rated power	±5% at rated power
Power rating	50MW at 1 kHz	25MW at 10kHz
Insertion loss	±3 db max.	±3 db max.
Primary impedance range	100Ω to 100KΩ	10Ω to 10KΩ
Secondary impedance range	3.2Ω to 10KΩ	10Ω to 10KΩ
Turns ratios	to 15:1	to 10:1

SPECIFICATIONS	MODEL 4220 MICROINDUCTOR	MODEL 4221 MICROINDUCTOR
Size	¼ x ¼ x ¼	⅛ x ⅛ x ⅛
Maximum operating temperature	130°C	105°C
Inductive range	.08 to 66 hy	0.1 to 3.5 hy

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TRIMPOT® AND PRECISION POTENTIOMETERS — RELAYS — MICROCOMPONENTS: TRANSFORMERS, INDUCTORS, RESISTORS AND CAPACITORS it a better idea of systems needs. Because many proposed station-keepers have failed to meet the specifications derived from ground simulations, the Army has decided to run flight tests to get more realistic data.

The Army Electronics Command will let a contract for the simulator by the end of April and wants delivery in time for early-1968 tests of the unit. The equipment won't simulate proposed systems; its mission is to record the responses of pilot and aircraft during formation flight. The Army needs formation-flight systems in Vietnam now; the Integrated Helicopter Avionics System's station-keeper will be delivered too late for installation aboard early models of the AH-56A fire-support helicopter [Electronics, April 3, p. 65].

Problems, problems. Since helicopters fly in larger and closer formations than do other aircraft, their pilots need more accurate positional data and more frequent updates. According to the Army, the data rate provided by currently proposed systems is too slow for safety. Also most of the systems lack proximity-warning devices, and there are interface problems between the radar and the helicopter autopilot.

All of these problems will be investigated with the flying simulator, as will the Army's current ranging specification. Currently specified is 25- to 17,600-yard ranging with altitude resolution of 20 feet. Several proposed systems have failed here, but data from flight tests could loosen the requirements.

One problem the simulator won't be able to help overcome is weight. None of the systems proposed or flying is light enough to meet the Army's needs.

To be installed aboard an HU-1B, the simulator will consist of a preprogramed computer, a "proximity locator," data records, and a display to show the helicopter's position in a hypothetical formation.

Follow the leader. The simulator will accept data from the Huey's doppler navigator, radar altimeter, and compass, and will send to the display the craft's distance from a simulated lead helicopter, and its desired altitude and bearing. In next year's flight tests at Fort Rucker, Ala., a pilot will view the computer-generated display pattern showing his position and will maneuver in response to the moves of the simulated lead helicopter.

Just what the simulator will look like when it gets off the ground depends on the winner of the contract. Only size and weight are specified in the request for proposals; the system must fit a 19-inch rack mount, be 3 feet high and weigh no more than 150 pounds.

For the record

Tune in later. Plans for the proposed national educational tv service are still out of focus and it appears that only the Government will be able to tune them in. The Senate will hold hearings later this month in hopes of setting guidelines tc determine who will build, operate, and own the proposed network. Comsat's offer to build a pilot system free is opposed by the Ford Foundation, which wants any decision as to the system's ownership delayed for at least another year. In the interim, the foundation wants NASA to build an experimental system.

Smooth flying. A clear-air-turbulence detection system that promises to give pilots from 2½ to 4 minutes warning of disturbances will be installed in a Pan Am 707 jetliner late this month. The prototype infrared system was developed by North American Avation Inc.'s Autonetics division.

The system picks up infrared radiation from the atmosphere. It has three elements: an infrared sensor head, an electronics processor, and an indicator that will display the direction and severity of the turbulence. On the Pan Am jet, the sensor head will be mounted on top of the fuselage, just aft of the cockpit. Dials on a cockpit display will indicate whether the turbulence is ahead or to the side of the aircraft.

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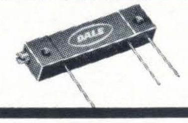
RT-12		Model 1680 P.C. Pin Model 1697 Flex. Leads
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Washington Newsletter

April 17, 1967

Navy orders speedup in work on Poseidon

Navy contractors and subcontractors have been directed to speed up their efforts on the Poseidon ballistic missile. Program officials say the acceleration may get the Polaris successor into submarines one year earlier than originally planned. The Defense Department won't say when the missile will be operational; it indicates only that Poseidon should be ready "in the early 1970's." Congress is now considering a Pentagon request for $900 million for Poseidon funding in fiscal 1968.

One reason for the speedup reportedly is that Pentagon officials aren't sure of the reliability of the Minuteman 2 missile and want the Poseidon ready as soon as possible as a backup system. However, an Air Force spokesman says he knows of no reliability difficulty in the Minuteman 2 program.

Poseidon has improved penetration aids, greater range, and a larger warhead than the Polaris, and will be installed on many of the current Polaris-carrying submarines at a cost of about $3.3 billion. Prime contractor is the Lockheed Missile & Space Co. Fire-control and guidance contracts are held by General Electric, Raytheon, and MIT.

Pentagon takes aim at contractor costs

Overhead costs that companies charge off to military contracts are rising. **The Pentagon is disturbed about it, so much so that it has formed a group to study the problem and to recommend whether special controls are needed to keep these costs down.** Companies can charge to military contracts such overhead as costs of bidding, patents, independent research and development, special tooling, computers, and production engineering.

Defense officials aren't sure why these charges are increasing or by just how much they are growing. But they believe that in a noncompetitive atmosphere, contractors don't feel the normal pressures to keep expenses down. Despite the trend toward more competitive contracting, about one-half the dollar volume of military orders is still awarded on a sole-source basis.

Satellites to detect atom blasts will keep an ear to the ground

America's first two satellites capable of detecting atomic explosions on the earth's surface are to be launched this week from Cape Kennedy. The pair—the first in the Vela Advanced Satellite Program—will also have the job of detecting clandestine nuclear blasts in space, joining six other Velas now in orbit in this duty.

The new satellites are more than 200 pounds heavier than the earlier models, which weigh about 500 pounds. The advanced Velas, built by TRW Systems, have a pneumatic gas system that will keep them 180° apart in their 60,000-mile circular orbits—a spacing enabling them to cover the entire world at all times.

Defense spending is still climbing

Federal spending on defense contracts was supposed to level off by now—at least that's what the Pentagon had expected. **But the procurement surge is continuing because of the military needs in Vietnam.** In the first eight months of fiscal 1967—July through February—military hardware contracts totaled $17.7 billion, up $4 billion from fiscal 1966.

Aircraft contracts, including avionics, rose $2.1 billion, ships, $1 billion, electronics gear exclusive of weapons systems, $318 million; missiles, however, were down $109 million.

War reverses job downtrend

Although the findings haven't been made public, a Pentagon study has verified what industry observers had suspected: **that the war in Vietnam has spurred employment in military electronics.** The survey of 422 plants —about one-third of the defense industry—puts military electronics employment at 228,000 in these plants as of June 1966, up 9% from the previous year and a reversal of a downtrend that started in 1963.

The boost, however, falls short of the 16% overall gain posted by the entire defense industry.

Project Mallard goes on despite British pullout

Three teams of contractors reportedly have been tapped by the Army to carry out program definition studies of Project Mallard—a billion-dollar, multination tactical communications system. Scheduled to be operational by the mid-1970's, the system would provide computer-switched short-range voice and data communication for U.S., Canadian, and Australian troops via ground-station repeaters and possibly satellites.

Meanwhile, Washington is pushing hard to lure back the project's fourth partner—Britain—which pulled out earlier this year fearing another "Skybolt incident." Skybolt was a U.S. missile program that Britain had counted on for its nuclear arsenal before Washington canceled it.

It's hup 2-3-4 . . . rally 'round IC's

The Pentagon's long-awaited directive calling for the consideration of integrated circuits in all new research and development projects is about to be put into effect. Assistant Defense Secretary Paul R. Ignatius is expected to sign the microelectronic policy this week to make it official.

The directive's final form is almost identical to the version first submitted to industry last fall [Electronics, Oct. 31, 1966, p. 26].

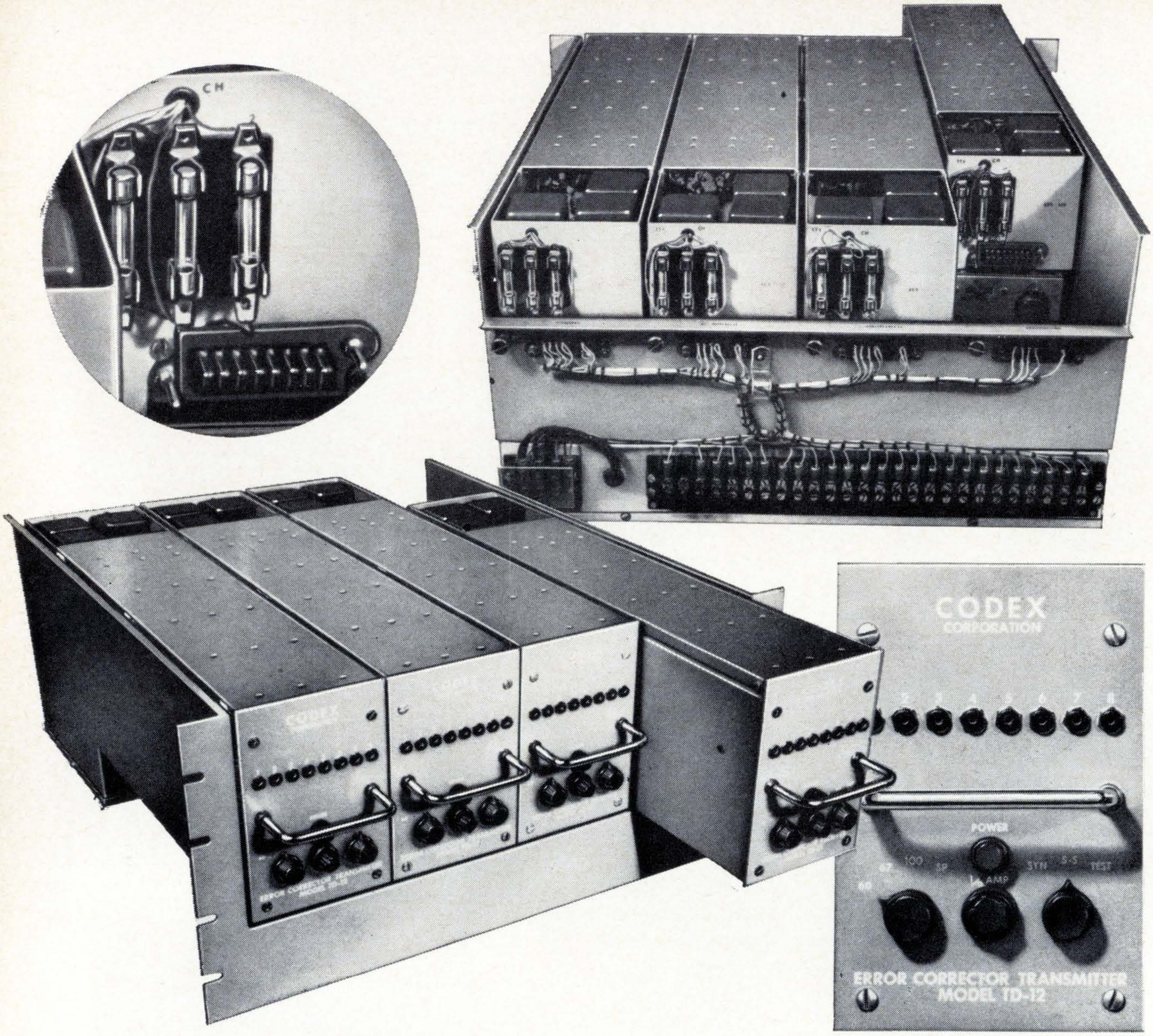
Pentagon contract study backfires

The Pentagon has just supplied its Congressional critics with new ammunition. In defense of concentrating prime contracts in just a handful of states, the Pentagon has long contended that military subcontracts have a wide geographic distribution. This contention has just been shot down, unintentionally.

A recently completed Pentagon study shows that subcontracts are even more concentrated than prime awards. Findings reveal that 65% of all prime contracts is in 10 states, with these same states accounting for 77% of all subcontracting.

Addenda

In its scathing report on the fatal Jan. 27 Apollo spacecraft fire, a NASA-appointed board calls for a detailed design review of the entire spacecraft communications system. The board lashed out at the space agency, prime contractor, and subcontractors, and cited **shoddy workmanship, poor quality control, and deficiencies in the command module design . . .** A $4.5 million contract to improve NASA's Goddard range and range-rate tracking system won by General Dynamics could expand into a $25 million effort. The network's 200,000-mile range will be extended to 350,000 miles.



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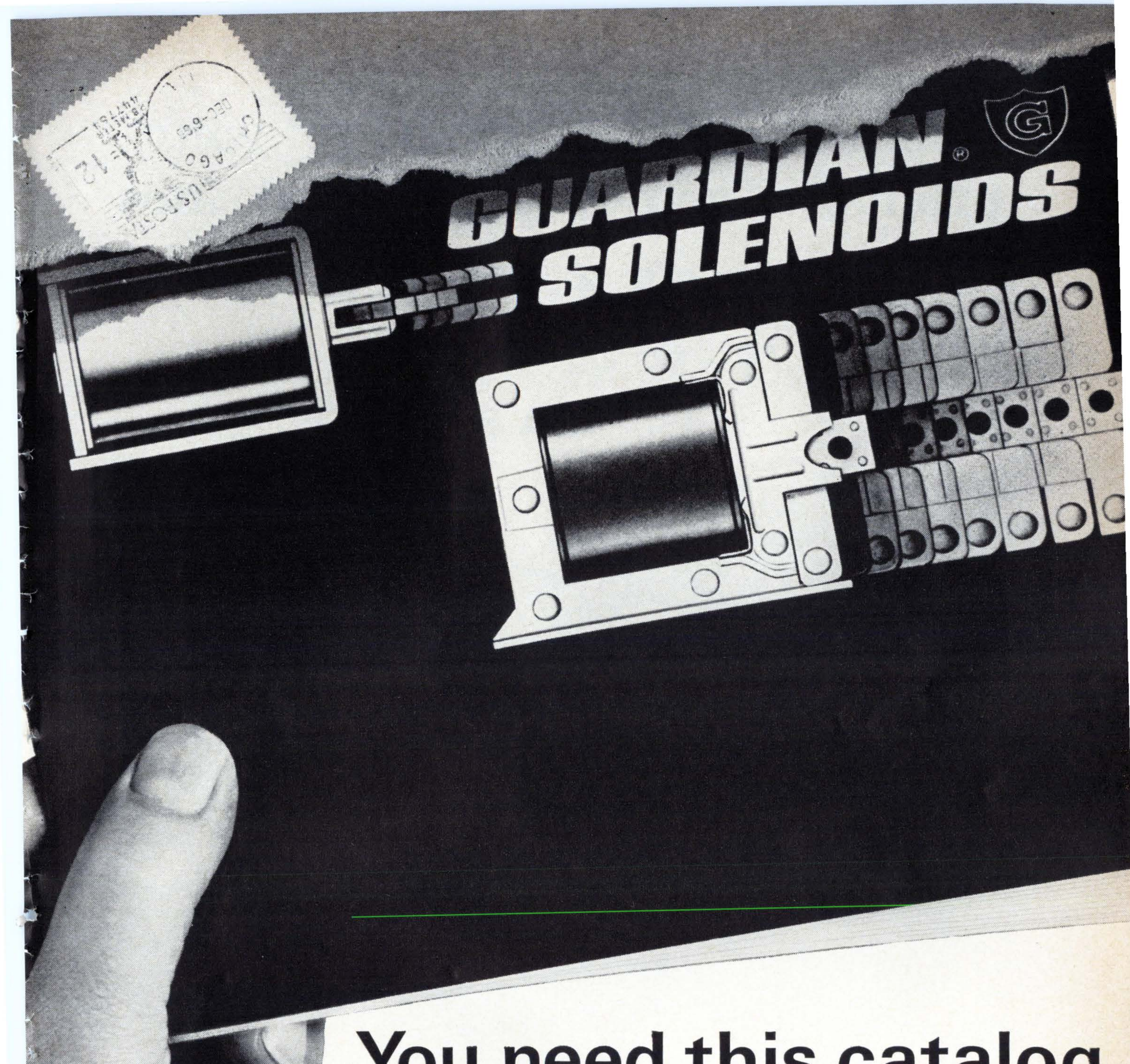

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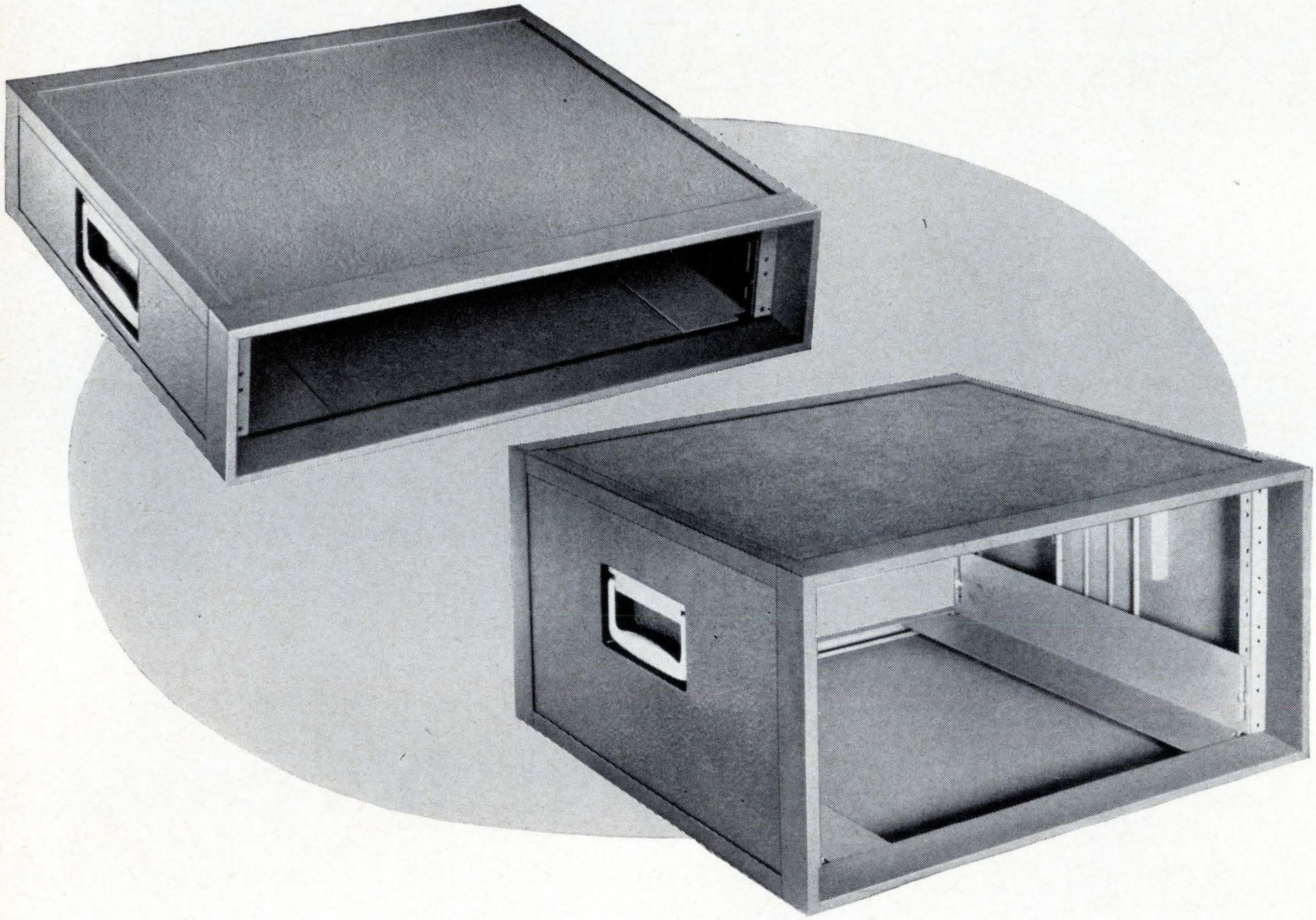

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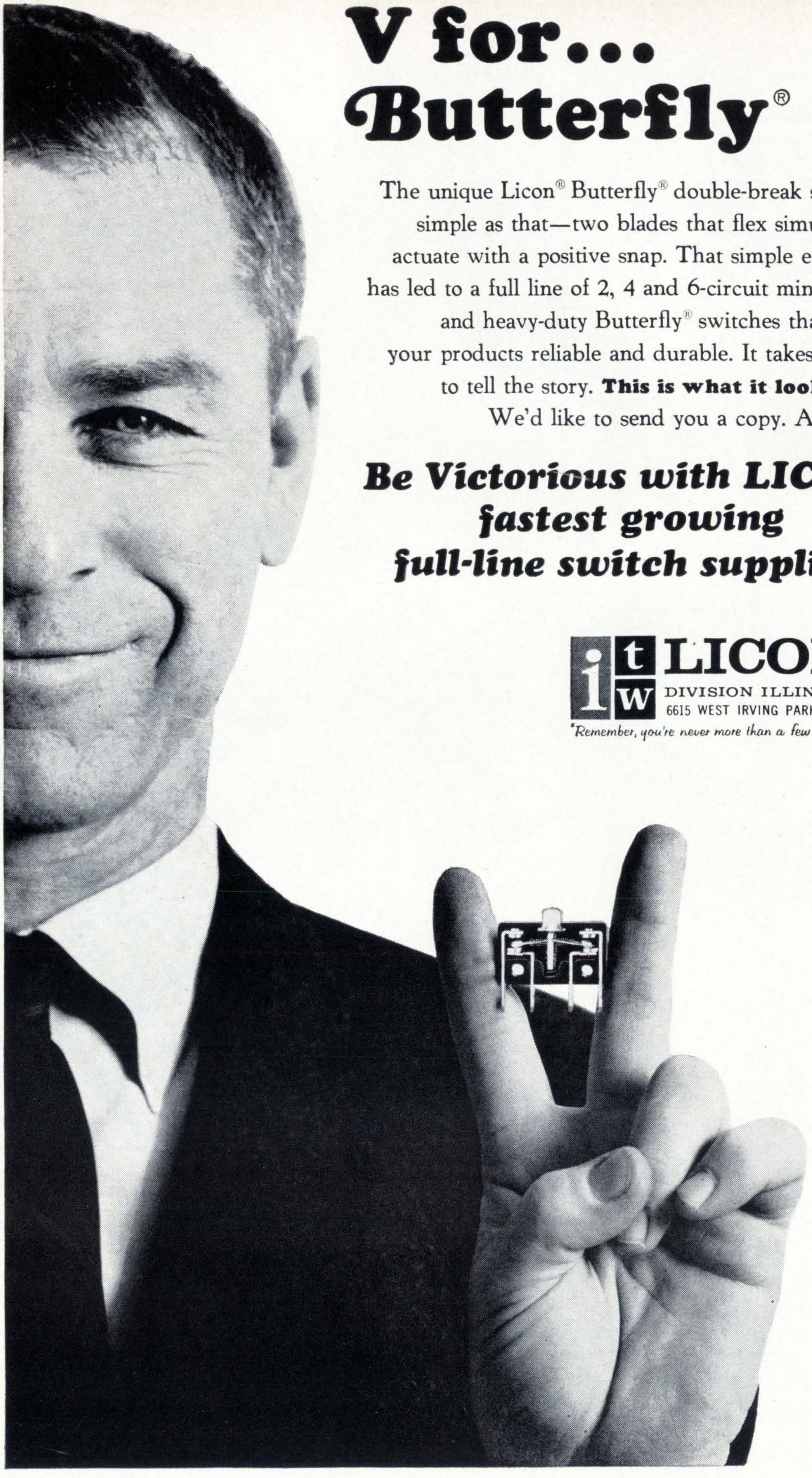

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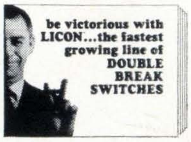

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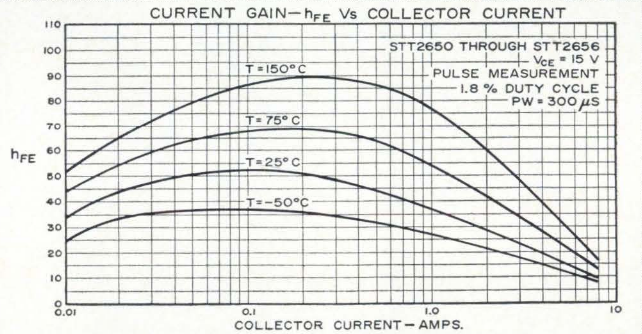

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	Volts	Volts	Volts	Amps	Watts	Volts	Volts	—	MHz	Volts	µA
STT 2650	150	150	12	7.5	75	1.3	0.6	30-90	25	60	1
STT 2651	120	140	12	7.5	75	1.3	0.6	30-90	25	60	1
STT 2652	120	140	12	7.5	75	1.3	0.6	50-150	25	60	1
STT 2653	100	120	12	7.5	75	1.3	0.6	30-90	25	60	1
STT 2654	80	100	12	7.5	75	1.3	0.6	30-90	25	60	1
STT 2655	60	75	10	7.5	75	1.3	0.6	30-90	25	40	1
STT 2656	30	40	10	7.5	75	2.0	1.0	25	25	20	500
CONDITIONS I_C	200mA	5mA	10mA			2A	2A	2A	0.15A		
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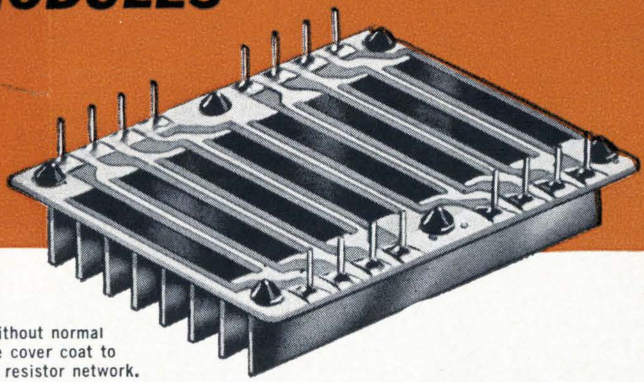

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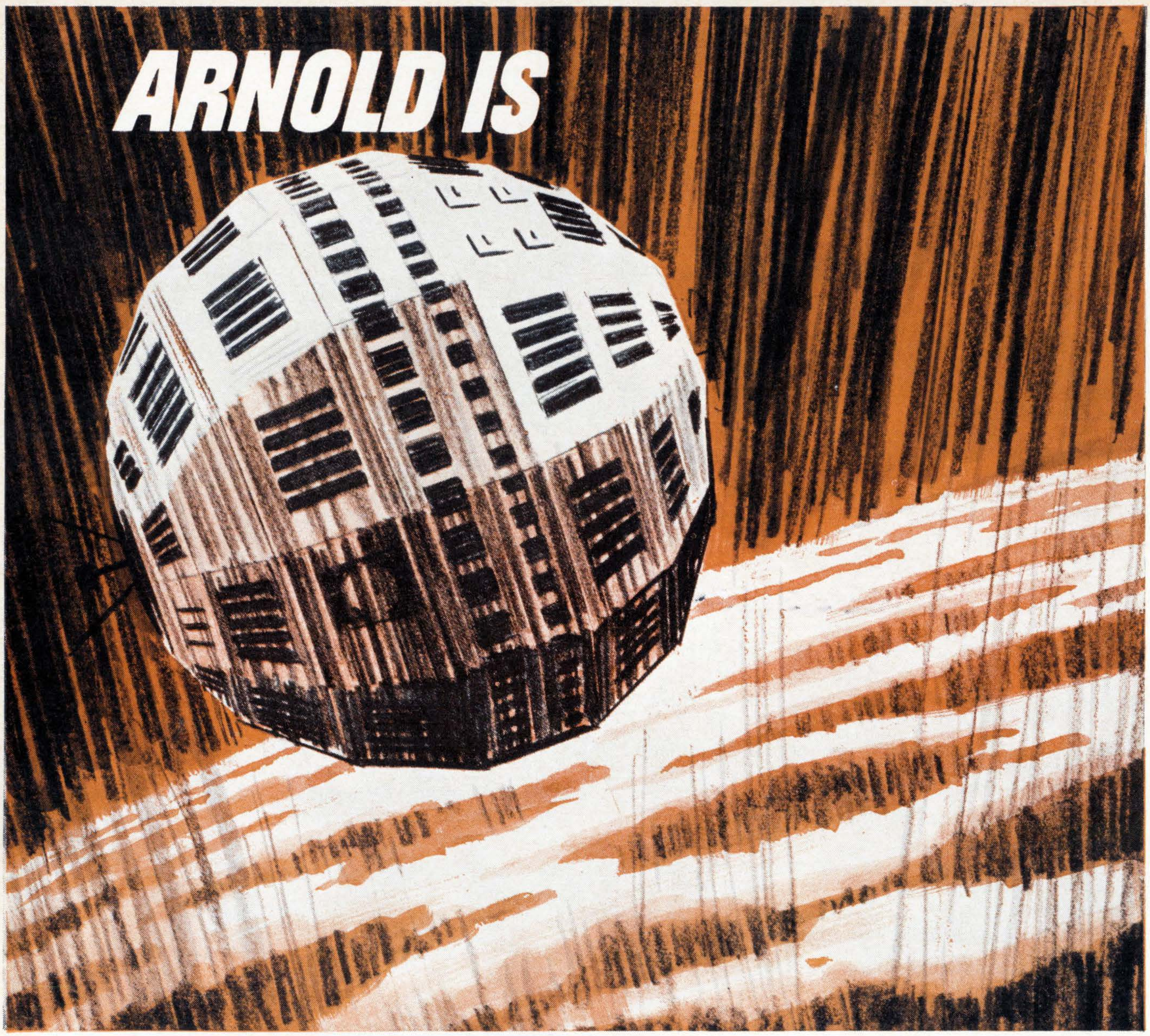

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Circle 75 on reader service card→

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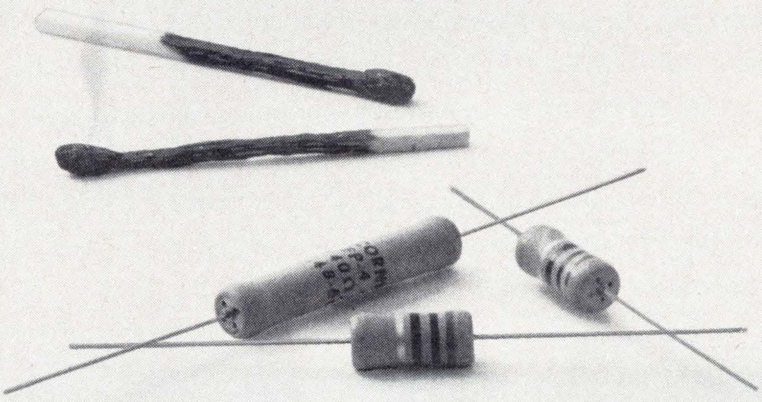
So Corning changed resistor failure.



The fact is, new CORNING® FP Resistors just won't burn.
Even if a circuit smacks one with an overload of a hundred times or more, it won't burn.
It knows how to fail gracefully. It will open up,
but no flame and no short. But don't just take our word. Test this new resistor yourself.

FP resistors come in 2, 3, 4, 5, 7 and 10 watt sizes, from 9 ohms to 90K.

Just write for free samples and complete data.
Meanwhile, we're looking for more changes that will improve resistors. That's how our line of glass tin oxide film resistors has grown to be one of the most extensive and useful. That's how we've earned our qualifications for exceptional stability and reliability.
Corning Glass Works, 3904 Electronics Drive, Raleigh, N.C.

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...when you let FANSTEEL do it!

Let FANSTEEL make your electronic parts for you. What type of parts? For instance:
(1) **FANTORK**T.M. **Chassis-Mounted Heat Sinks** that give you up to 3-times greater shank torque and provide comparable heat dissipation of wrought copper alloys. With a complete FANTORK part . . . all you do is die-bond, attach leads and assemble. Or, we'll do any . . . or all . . . of these steps for you . . . braze the steel threaded shank into the sintered copper base . . . add pre-form backing discs (with or without coatings) . . . put on a steel weld ring . . . coin a projection into sintered copper base for direct ultrasonic welding of can . . . insert pins . . . or plate entire assembly. (2) **Lead Assemblies**—from refractory to conventional lead materials in close tolerance diameters from .025″ to .125″ . . . plated to your specifications. (3) **Semiconductor Backing Discs**—either pressed and sintered . . . punched . . . or cut . . . from tungsten or molybdenum. Fansteel coating technology assures positive wetting action. All sizes throughout the power ratings. Whatever your component parts need . . . LET FANSTEEL DO IT! Our diverse packaging technologies will help you reduce component assembly time and costs. For complete information on value engineered Fansteel parts, call your Fansteel representative . . . or write us.

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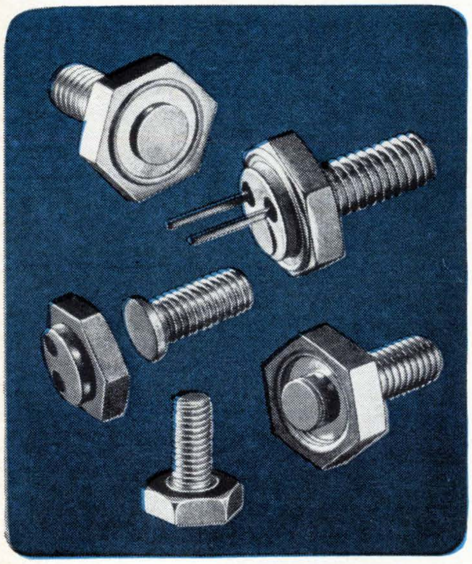

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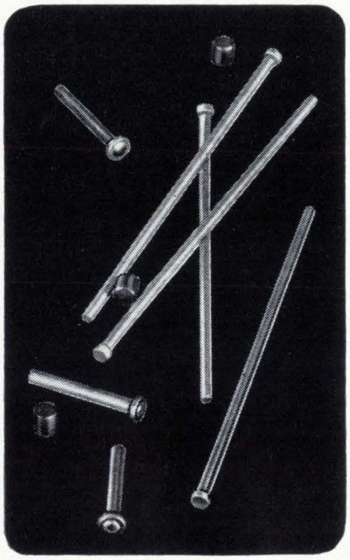

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METALLURGICAL CORPORATION

ELECTRONIC PARTS DIVISION
NUMBER ONE TANTALUM PLACE
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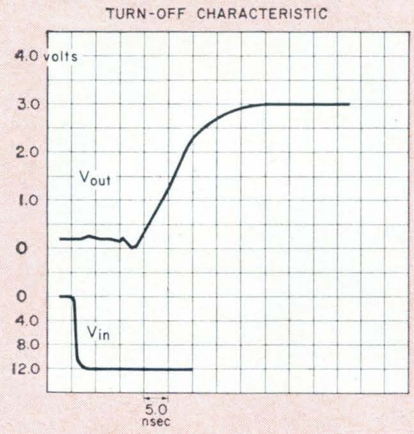
this AMELCO FET combines low R_{ON}, low $I_{D\,(OFF)}$ and low C_{DG} better than ever before... 2N4091



SPECIFICATIONS:

R_{ON}	30 ohms MAX	t_{OFF}	40 nsec MAX
$I_{D(OFF)}$	200 pA MAX	V_P	10 V MAX
C_{DG}	5 pf MAX	I_{DSS}	30 mA MIN
t_{ON}	25 nsec MAX	BV_{DGO}	40 V MIN

Now being mass produced, this FET switch is available from Amelco Distributor stock for only $6.35 in quantities of 100 or more.

Amelco's new 2N4091 FET switch offers extra high speed with the highest switching ratio ever available in a standard device. If you are working with multiplexing, commutating, analog switching or DC chopping, consider these facts . . . R_{ON} is 30 ohms max., the lowest of any FET on the market with C_{DG} of less than 5 pf; I_D (on)/I_D (off) ratio is better than 10^8. Designers may now consider FET devices where previously the requirement for very low on resistance demanded use of bipolar transistors. In addition, applications presently using FET's can benefit from this improved performance.

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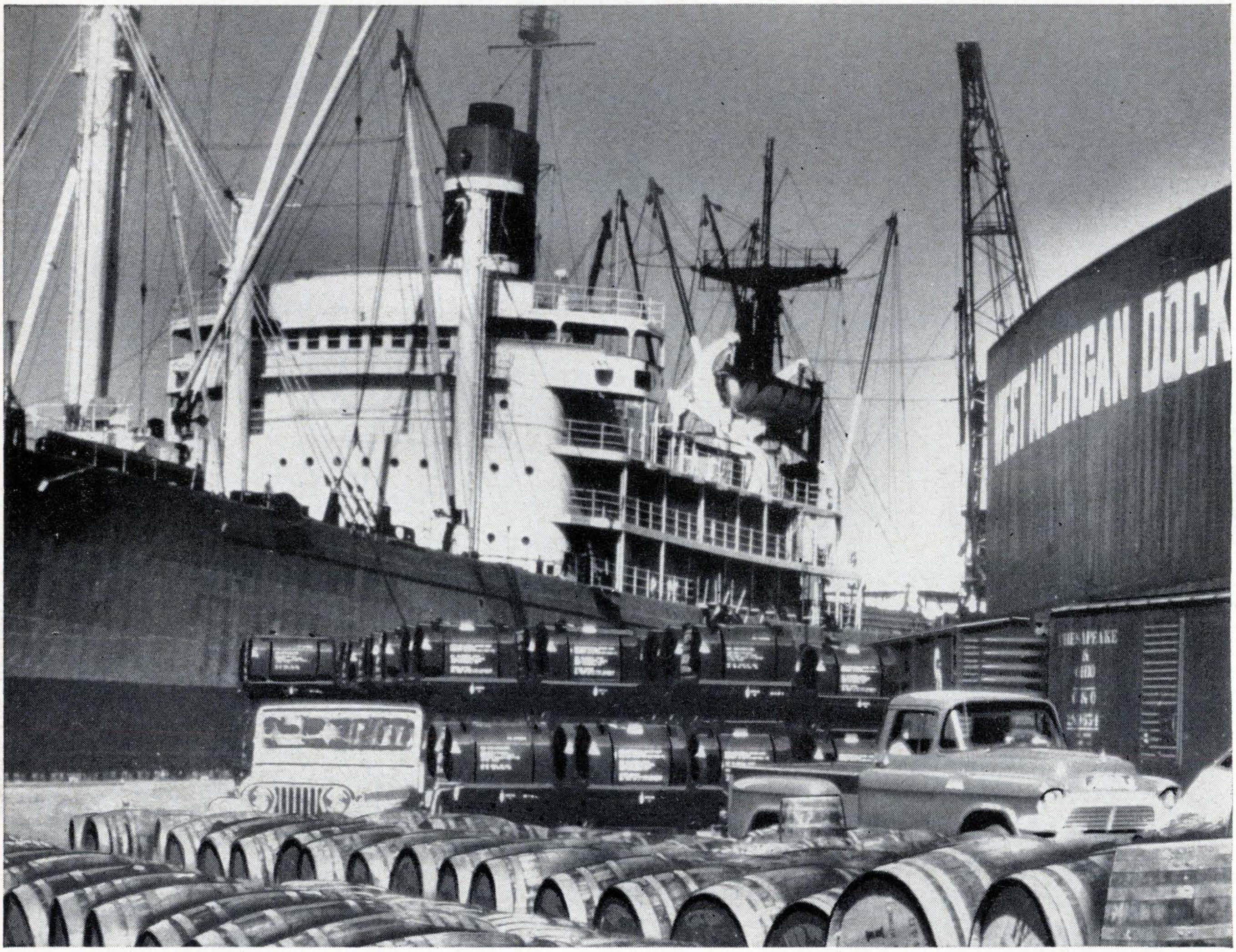
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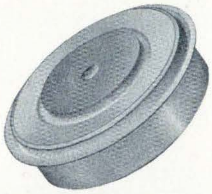
A TECHNICAL DIGEST FOR INNOVATORS OF ***INDUSTRIAL EQUIPMENT***

GE COMPONENT CAPSULES

SCR's in GE's new PRESS PAK . . . another packaging innovation



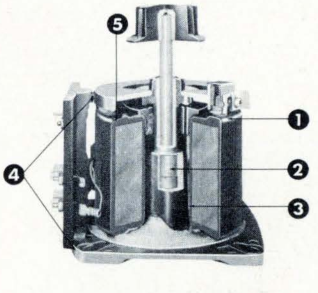
Also available soon: PRESS PAK rectifier diodes rated up to 1200 V.

Forget internal soldered joints. GE PRESS PAK SCR's are mounted by externally applied pressure. Double sided cooling increases their average current rating up to 60%. Reversibility eliminates the need for special reverse polarity units. Rated up to 1300 volts at either 115 amps average or 235 amps average, PRESS PAK SCR's cost 10% less than equivalent stud mounted units. Motor drive control, phase control and electromechanical applications are excellent typical uses. Circle **Number 90** on the magazine inquiry card for more information.

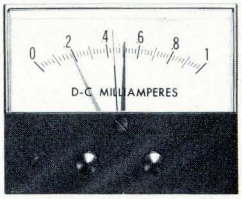
Volt-Pac® variable transformers: maximum life with minimum maintenance

Every GE Volt-Pac transformer features corrosive resistant parts throughout: ❶ Spring-loaded, grain oriented solid carbon brush assures even contact . . . reduces wear. ❷ Self-lubricating nylon bearing causes low friction in voltage selector. ❸ Polyesterimide insulation for coil windings provides extra dependability. ❹ Aluminum radiator and base dissipate heat evenly . . . extend life. ❺ Low-resistant gold plated track lessens heat build-up at brush contact.

Specify precision-built Volt-Pac transformers for continuously adjustable output voltage. A complete line of manually operated and motor-driven models, including plug-in cord units, is now available. Circle **Number 91** for more facts.



New Horizon Line® panel meter relay



Features solid-state, light-sensitive switching

New Type 196 Meter Relay takes advantage of totally new contactless control action . . . gives you exceptional control simplicity and reliability. Install it quickly and easily by just plugging in the unique "piggyback" control module. The module can be readily removed without interrupting measurement circuit, as its indicator mechanism connections are on the rear of the meter. Horizon Line Meter Relays, available in 3½" and 4½" sizes with single or double setpoints, can be front-mounted or back-of-panel mounted. Circle **Number 92.**

What's new for peripheral computer equipment?

Instant response—inertial time constants as low as 1 millisecond—is what you get with the new GE Hyper-Servo* motor. And it accelerates faster than any other motor ever developed by General Electric. Hyper-Servo motors greatly increase the overall capacity of peripheral data processing equipment. They're available in 3.4-, 4.6-, and 4.8-inch diameters. Performances include torque-to-inertia ratios in excess of 350,000 rad/sec^2 and continuous torque ratings from 32 oz-in at 2700 rpm to 326 oz-in at 2800 rpm. A wide variety of models can provide the high performance drive motor for nearly every computer peripheral application. Circle magazine inquiry card **Number 93.**

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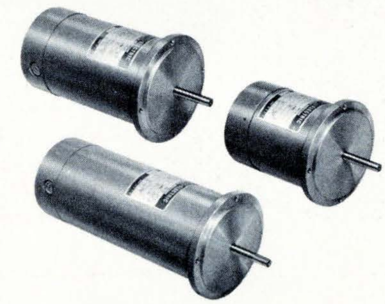

Hyper-Servo* **Motors**

Typical 32-Frame Models

Here's Blue Jay*— GE's newest film foil capacitor

Actual Size

Superior Blue Jay polycarbonate capacitors feature:

- EXCELLENT CAPACITANCE STABILITY over their entire operation range (—55 C to 125 C). Maximum capacitance change at 25 C will not exceed —2.0% to +0.3% over the entire operating range. Capacitance change is negligible over the 25 C to 65 C range, and nearly linear with a negative coefficient in the +65 C to 125 C range.
- HIGH INSULATION RESISTANCE. Typical resistance, measured on units rated 0.1 μf 200 volts, is 2x10^6 megohms.
- LOW DISSIPATION FACTOR—does not exceed 0.3% over the temperature range of 25 C to 125 C at 1000 Hz, making Blue Jays ideal for many AC applications.

Circle **Number 94.**

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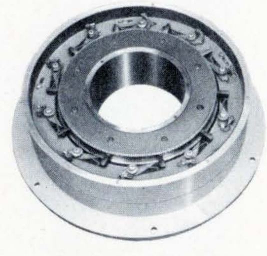
MORE

COMPONENT CAPSULES

A TECHNICAL DIGEST FOR INNOVATORS OF ***INDUSTRIAL EQUIPMENT***

Speeds as low as one revolution per day with GE D-C torque motors

GE d-c Torque Motors, with low speed capability, eliminate gearing with inherent backlash and windups . . . permit direct connection to the driven load. This combined with low inductance and low-reflected motor inertia means you can design your system to accelerate, decelerate, or position high-inertia loads with excellent precision and accuracy. Rapid-response GE d-c Torque Motors, with permanent-magnet or wound field excitation, are available with or without endshields and/or bearings to meet your mechanical requirements. Circle magazine inquiry card **Number 95.**

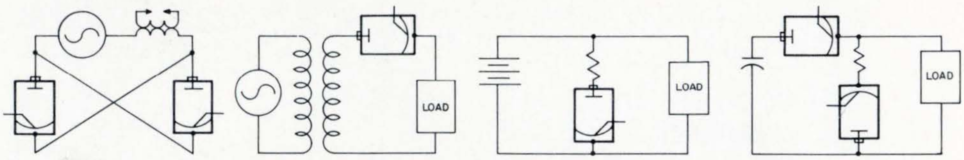


Available with from 30 to 200,000 lb-ft torque

Versatile ignitrons . . . still going strong

GE Ignitrons provide application versatility—year after year in circuit after circuit. They're unmatched for economy and ruggedness in high power applications. Here are four typical circuit applications:

- **Welding**
- **Contactor**
- **Interrupter**
- **Controlled Rectifier**
- **Crowbar**
- **Hi-rate Energy Switching**



Circle **Number 96** for more Ignitron facts.

COMING YOUR WAY—GE'S MICROWAVE TUBE VAN. CIRCLE NUMBER 97.

Insert PTC thermistors automatically

GE Positive Temperature Coefficient Thermistors (PTC's) are small, rugged, hermetically sealed units with weldable/solderable gold-plated Dumet leads. A temperature coefficient of resistance of approximately +0.875% per degree Centigrade operable to 150 degrees Centigrade makes them ideal for temperature compensation in silicon transistor circuits. They can also be used as sensors in temperature indicators and temperature controls. Their small size and uniform dimensions permit automatic insertion into printed circuit boards. Circle **Number 98.**

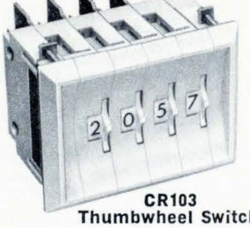
PTC—actual size

Reel drive motors for computer tape transports

Fractional HP DC Motor

GE's full line of fhp direct-current motors includes four frame sizes widely used for reel drives: $3\frac{5}{16}$", $3\frac{13}{16}$", $4\frac{5}{8}$" and $6\frac{5}{16}$" diameters. Special end mountings and shaft extensions meet exacting application requirements. Series, split-series, compound, shunt, and compensated-shunt winding designs offer a broad design choice. Stall torque ratings from 3 to 120 ounce-feet and higher span various application needs, and motor voltage requirements are normally matched to your system design. Circle **Number 99** on the magazine inquiry card for more information.

New thumbwheel switches require less panel space; simplify data input



CR103 Thumbwheel Switch

GE space saving CR103 Type F Thumbwheel Switches—rated 150 volts a-c/d-c—are ideal for welding control, computer systems and numerical control. Manual data insertion is made easy by simply dialing in the information. Both standard-duty and oiltight forms are constructed of unbreakable Lexan*. Large easy-to-read colored numerals (or symbols) are neat in appearance. Assemble your own non-oiltight standard-duty switches, if you prefer, by purchasing individual switch modules, end blocks, spacers and shafts. Circle **Number 100.**

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Technical Articles

Computer-aided design, part 8: picking a transient analysis program
page 84

With a computer, an engineer can thoroughly investigate circuit characteristics that vary with time, such as sensitivities. Most of the major network design programs will do the job, but valuable computer time will be wasted if the wrong combination of program and integration routine is used. One program may require five minutes, another only 30 seconds.

Plastics for packaging: handle with care
page 101

Transistors and integrated circuits cost less in plastic packages, but the controversies about device reliability haven't been settled. Military and space system designers are still unsure about using them in adverse environments. Tests show that chemicals in some plastics degrade the components, but that improved semiconductor passivation and the use of inert plastics can solve this problem.

Taking cryoelectric memories out of cold storage
page 111

Fabrication problems have stalled commercial production of superconducting memories for more than a decade. A new memory element design that depends upon bulk properties of the materials rather than tight process control can lead to cheap, fast, billion-bit memories. On the cover, an experimental system is being placed into liquid helium at the Radio Corp. of America. Each of the four planes is 2 inches square and stores 6,000 bits in loop cells of tin film.

Dielectric bath cools IC's
page 123

Integrated-circuit designers hope to improve digital system speed and reliability by putting many IC's on a chip. This will increase power density and require a 10-fold improvement in cooling. Air cooling and heat sinks won't meet the need, so packaging engineers are looking at a new technique—flowing liquid dielectrics over exposed circuits. The liquid boils, but the chips keep cool.

Coming May 1

- **Braided wires program read-only memories**
- **Apollo spacecraft antenna tracks ground stations**
- **Models simplify integrated-circuit design**
- **Automatic digital pulse analyzer**

Computer-aided design: part 8
Picking transient analysis programs

Employing the proper integration routine is the key to solving transient problems. A really good choice reduces computation time and increases accuracy

By Waldo G. Magnuson Jr.
Lawrence Radiation Laboratory, Livermore, Calif.

Most of the major network design programs can handle transient analysis problems but rarely with equal speed or capacity. Program flexibility also varies widely. Therefore the engineer must evaluate the alternatives carefully so that he makes the best use of both his and the computer's time.

Circuit analysis programs have one primary objective—to obtain responses to prescribed input signals. In a transient analysis program, these responses are expressed as a function of time rather than frequency. Thus, an engineer can investigate circuit rise times, over-shoots, d-c stabilities, switching speeds, circuit sensitivities, and signal level changes at various times during a circuit's operation. The requirement for time-domain analyses occurs frequently and calculating their effects manually is tedious, if not impossible. However, techniques for performing transient analysis have been included in many computer programs.

In a computer-aided transient analysis, either a set of simultaneous first-order differential equations must be established that relate the circuit elements to the node voltages and loop currents or a network transfer function must be formed from topological methods [Electronics, Nov. 14, 1966, p. 112].

The author

Since 1964, Waldo G. Magnuson Jr. has been at the Electronics Engineering Department of the Lawrence Radiation Laboratory working with digital computer network analysis programs as an aid in engineering design.

In the matrix approach, the equations are formed from a branch-node circuit description supplied by the engineer. The currents and voltages are expressed as a function of time by integrating a set of differential equations in the computer. The circuit response at any point in time is then obtained by substituting the appropriate time value into the current and voltage equations. The response at the next point in time is obtained by integrating the set of equations and again substituting the appropriate time value and other variables into the equations.

Selecting integration routines

The solution of a transient network problem is largely controlled by the selection of an integration routine. Typically, the solution procedure begins with known initial conditions and solves the network equations at a particular time, usually time zero. An integration routine is then applied to obtain the initial conditions for the next solution step. If too small a time interval is chosen, excessive computation time results. Conversely, too large a time step reduces the accuracy of the output. Choice of the appropriate time interval is somewhat of an educated guessing game—it is based largely on intuition and a working knowledge of the circuit element values. A good rule of thumb is that the time step should not be larger than the smallest circuit time constant. Some of the analysis programs for electronic circuits make this selection automatically.

There are several integration routines available for solving first-order differential equations. These are usually classified into two groups—single-step or multi-step. The most widely used of the first

How the programs stack up

	Calahan	ECAP	NET-1	Predict	Sceptre
Program input features					
Must use specific labels	No	Yes	Yes	Yes	Yes
Sequential node numbering	Yes	Yes	Yes	No	No
Random location of input	No	Limited	Yes	Yes	Yes
Voltage or current sources	Current sources only	Yes modification of the built-in model (not convenient)	Through a modification of the built-in model (not convenient)	Yes	Yes
Tabular input for branch descriptions	No	No	No	Yes	Yes
Tabular input for signal sources	Yes	Yes	Yes	Yes	Yes
Analytic description of branch elements	No	No	No	Yes	Yes
Analytic description for signal sources	Yes (available from a modified subroutine)	No	No (has several built-in signal sources that may be picked)	Yes	Yes
Automatic modification of input (repeated runs)	Yes	Yes	Yes	No	Yes
Modeling capabilities					
Built-in models	No	No	Yes (transistors-diodes)	No	Yes
Allows small-signal models	Yes	Yes	No (inconvenient)	Yes	Yes
Allows large-signal models	No	No (inconvenient)	Yes (Built-in)	Yes	Yes
Output options					
Transfer functions	Yes	No	No	No	No
Pole-zero locations	Yes	No	No	No	No
Symbolic expression for time response	Yes	No	No	No	No
Time-response output	Output node only—at fixed intervals	Selected variables at fixed intervals	Node voltages and semi-conductor currents at fixed intervals	Selected branch voltages and currents at every time step	Selected variables at fixed intervals
Steady state solution	No	Separate analysis	Yes	Separate analysis	Yes
Programing features					
Programing language	Fortran II, IV	Fortran II, IV	Madcap & FAP	Fortran II & FAP	Fortran IV
Memory capacity recommended	32,000	32,000	32,000	32,000	32,000
Network formulation	Topological	Matrix	Matrix	Matrix	Matrix
Primary integration routine	Runge-Kutta (& inverse Laplace)	Implicit numerical integration	Predictor-Corrector	Runge-Kutta (2 & 4 pass)	Runge-Kutta Predictor-Corrector
Features at Lawrence Radiation Laboratory					
Operating on computers	IBM 7094 CDC 3600 CDC 6600	IBM 7094 CDC 3600 CDC 6600	IBM 7094	IBM 7094	IBM 7094
Graphical output	Calcomp & CRT plots	None	None	Calcomp & CRT plots	Printer
On-line capability (LRL CDC-6600 time-share system)	Yes	Yes	No	No	No

Comparing two key integration routines

Two popular integration routines are the Runge-Kutta and Predictor-Corrector techniques. The first is a one-step method that obtains a numerical solution from a weighted formula without having to carry forward any knowledge of previous steps of the differential equation or its solution. However, to get high accuracy the method requires many small time-steps that increase the computing time greatly. Furthermore, several time-consuming evaluations of the first derivative are needed and the method does not provide an estimate of numerical round-off errors.

The transient analysis starts with a knowledge of the first-order differential equations that describe the network, dv/dt, and the intial conditions at some time, say $t = t_o$. These values are then substituted into the Runge-Kutta prediction formula and a value of voltage, v, is predicted for the time $t_1 = t_o + \Delta t$. The formula is expressed as follows:

$$V_{to+\Delta t} = \frac{1}{6}[K_1 + 2K_2 + 2K_3 + K_4]$$

where

$$K_1 = \Delta t \left.\frac{dv}{dt}\right|_{(vo,\ to)}$$

$$K_2 = \Delta t \left.\frac{dv}{dt}\right|_{\left(vo+\frac{K_1}{2},\ to+\frac{\Delta t}{2}\right)}$$

$$K_3 = \Delta t \left.\frac{dv}{dt}\right|_{\left(vo+\frac{K_2}{2},\ to+\frac{\Delta t}{2}\right)}$$

$$K_4 = \Delta t \left.\frac{dv}{dt}\right|_{(vo+K_3,\ to+\Delta t)}$$

K_1 represents the product of the selected time step, Δt and the value of dv/dt at the initial value t_o, v_o. The other K terms are as indicated.

Substituting the known quantities into these equations yields the first values $t_1 = t_o + \Delta t$, $v_1 = v_o + \Delta v$. To find a third pair of values, the same formulas are used with t_1 and v_1 replacing t_o and v_o, respectively. When t_2 and v_2 are found, use the equations with t_o and v_o replaced by t_2 and v_2, etc. The error of the Runge-Kutta method is not easy to estimate. If $\Delta t = 0.1$, the designer should expect an error in Δv affecting the fifth decimal place.

An example. Find three pairs of values of t and v for the solution of $dv/dt = -t + v$ with the Runge-Kutta formulas if the initial values of the variables are $t = 0$, $v = 2$.

Solution. The first value is $t = 0$, $v = 2$. Choose $\Delta t = 0.1$, $t_o = 0$, $v_o = 2$ in the Runge-Kutta formulas, keep five decimal places during the computation, but round off the value of Δv to four decimal places. This gives

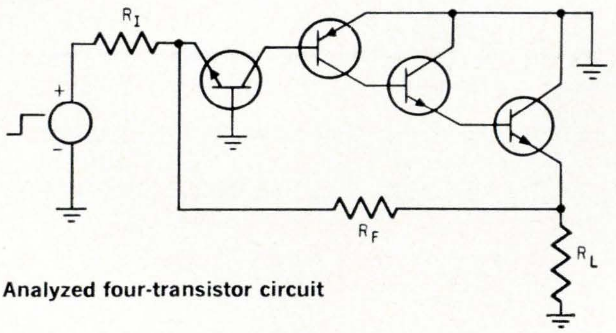
$$K_1 = (-0+2)\,0.1 = 0.2$$

$$K_2 = \left(-0-\frac{0.1}{2}+2+\frac{0.2}{2}\right)0.1 = 0.205$$

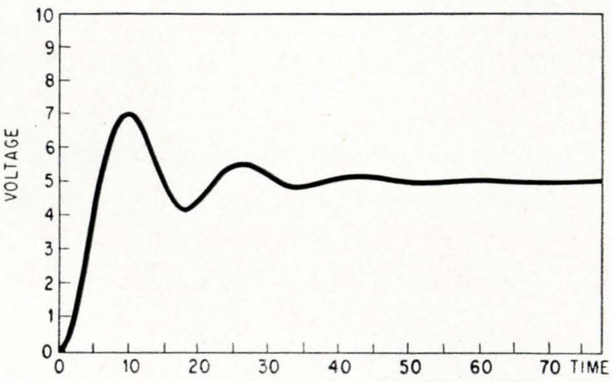
$$K_3 = \left(-0-\frac{0.1}{2}+2+\frac{0.205}{2}\right)0.1 = 0.20525$$

A transient analysis problem

Function	Calahan	ECAP	NET-1	Predict	Sceptre
Computer time required for transient analysis of sample problem in minutes	2.16	5.64	2.0	3.18	0.53
Computer used for sample problem	CDC 3600 (2 to 3 times the speed of IBM 7094)	IBM 7094	IBM 7094	IBM 7094	IBM 7094



Analyzed four-transistor circuit



Output response for sample circuit

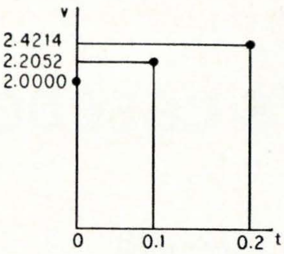
$$K_4 = (-0-0.1+2+0.20525)\,0.1 = 0.21053$$

$$\Delta v = \frac{1}{6}\,(0.2+2(0.205)+2(0.20525)+0.21053)$$

$$= 0.2052$$

Hence, $t_1 = 0.1$, $v_1 = 2.2052$

Substituting these values of t_1 and v_1 for t_o and v_o and $\Delta t = 0.1$ in the Runge-Kutta equations yields: $K_1 = 0.21052$, $K_2 = 0.21605$, $K_3 = 0.21632$, $K_4 = 0.22215$, and $\Delta v = 0.21624$. Hence the third pair of values of t and v is $t_2 = 0.2$, $v_2 = 2.4214$. The next pair of values is computed by replacing t_o and v_o with t_2 and v_2, respectively. The results are plotted at the right.

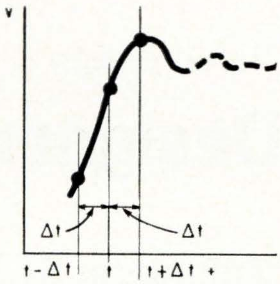


Predictor-Corrector. Unlike the Runge-Kutta routine this is a two-step technique. The first step predicts a value at a specified time for a prediction formula and the second step adjusts the obtained value by applying a correcting formula. Both formulas are based on a weighted interpolation of a Taylor-series expansion.

As before, the transient analysis starts with a knowledge of the differential equation, dv/dt, and the initial conditions for v, for at least one value of time, t. These values can be inserted into the predictor formula and a value of voltage at a time, $t + \Delta t$ can be calculated from the predictor formula:

$$|V|_{t+\Delta t} = |V|_t + \frac{55\Delta t}{24}\left.\frac{dv}{dt}\right|_t - \frac{59}{24}\,\Delta t\left.\frac{dv}{dt}\right|_{t-\Delta t}$$

$$+\frac{37}{24}\,\Delta t\left.\frac{dv}{dt}\right|_{t-2\Delta t} - \frac{3}{8}\,\Delta t\left.\frac{dv}{dt}\right|_{t-3\Delta t}$$



The first term on the right represents the voltage at time t, the second term is dv/dt at time t, the third term is dv/dt at time $t - \Delta t$, etc. See the output response curve above. Next, the program applies a corrector formula and calculates the voltage at the same time interval. The corrector formula is given by:

$$|V|_{t+\Delta t} = |V|_t + \frac{9}{24}\,\Delta t\left.\frac{dv}{dt}\right|_{t+\Delta t} + \frac{19}{24}\,\Delta t\left.\frac{dv}{dt}\right|_t$$

$$-\frac{5}{24}\,\Delta t\left.\frac{dv}{dt}\right|_{t-\Delta t} + \frac{\Delta t}{24}\left.\frac{dv}{dt}\right|_{t-2\Delta t}$$

The program now compares the two calculated results to see if they are in close agreement. If they are, the integration process is speeded up by doubling the length of the time interval for the next integration. If they are not, the process is slowed down by cutting the original time interval in half. When simultaneous equations are to be solved, a sorting technique included in the program integrates in ascending order of time constants.

group is the Runge-Kutta method and of the second, the Predictor-Corrector method. In designing a system for solving the differential equations describing the network response it is desirable to use as large a time step as possible consistent with an allowable error in the results. Both the Runge-Kutta and the Predictor-Corrector methods can allow for increasing or decreasing the integration interval and the choice of which method is used is not always well defined. Sometimes a combination of the methods is used. Although both work well for both nonlinear and linear circuits, Predictor-Corrector is the most popular because it offers a checking routine. The very small time steps of the Predictor-Corrector method compensate for the nonlinearity by assuming the nonlinear function is linear over a small increment of time.

To determine an output response by any method, v, as a function of time, the designer starts with a first-order differential equation of the form dv/dt $= P\,v + Q$ and the initial conditions for v at a value of time, t. The terms P and Q are matrixes of the circuit elements, where P is a function of the voltage $[P = f(v)]$ and Q is a function of both the voltage and time $[Q = f(v, t)]$. If the circuit is composed of linear elements only, the computer could obtain an output response by direct integration; however, most circuits contain nonlinear elements, thus P varies with time. Integration of such a nonlinear circuit requires repeated multiplication by an inverted matrix.

Both Runge-Kutta and Predictor-Corrector are outlined in the panel above together with a numerical example that demonstrates Runge-Kutta.

Comparing the programs

Five computer programs that perform transient analysis are compared for speed in performing an analysis of a four-transistor circuit in the table on the opposite page. In all of them, the engineer need merely describe the circuit's topology to formulate the network equations. The programs are: Predict (Circuit Analysis Program) developed by IBM's Space Guidance Center, Owego, N.Y.; NET-1 (Network Analysis Program) [Electronics, Feb. 6 p. 76] developed by the Los Alamos Scientific Laboratory, Los Alamos, N.M., ECAP (Electronic Circuit Analysis Program) [Electronics, Feb. 6, p. 82] developed by IBM, Los Angeles, Calif.; Linear Network Analysis Computer Program (designated Calahan) developed by the University of Illinois, Urbana, Ill.; Sceptre (System for Circuit Evaluation and Prediction of Transient Radiation Effects) developed by IBM, Owego, N.Y.

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.

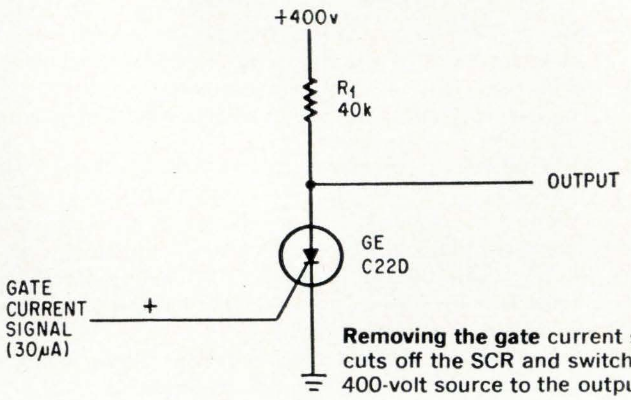
Making an SCR operate as a high-voltage switch

By G.V. Wintriss

Naval Air Station, Patuxent River, Md.

Operating a silicon controlled rectifier below the rated holding current, I_{ho}, produces an inexpensive high-voltage switch. The SCR turns off when the gate current is removed, much like a high-gain transistor switch.

Resistor R_1 is chosen to limit the SCR anode current to below I_{ho}. Up to +400 volts may be switched by a General Electric Co. C22D SCR with an R_1 of 40 kilohms, since I_{ho} for this model is 10 milliamperes. Current gain is quite high; as little as 30 microamperes switch the SCR.



Removing the gate current signal cuts off the SCR and switches the 400-volt source to the output.

With a gate-controlled a-c switch (Triac) such as the GE SC45D, d-c voltages of either polarity can be switched by positive or negative gates.

Monostable multivibrator plus SCR yields chopper

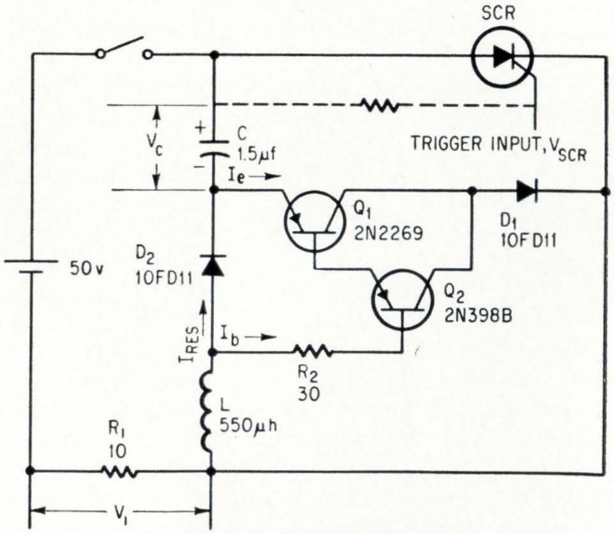
By K. Watanabe, R. Yamada, and M. Ito

Shizuoka University, Hamamatsu, Japan

A monostable multivibrator becomes a highly stable, inexpensive, high-current chopper when combined with a silicon controlled rectifier. The circuit eliminates the saturable reactor and autotransformer of conventional SCR choppers, and produces an output squarewave whose width is independent of the supply voltage.

Transistors Q_1 and Q_2 are connected as a Darlington current amplifier. When the 50-volt supply is switched on, the transistors are forward biased, and emitter current, I_e, charges capacitor C with the polarity shown. At a given time (called t = 0 in the waveform diagram), the SCR is triggered, and power is delivered to the load, R_1. At the same time, the accumulated voltage V_c across C produces a current through C, the SCR, the inductance, L, and diode D_2. This current is referred to as a resonant current, I_{res}, having a frequency of $1/2\pi\sqrt{LC}$. At a time equal to a half-period of resonant frequency, $\pi\sqrt{LC}$, C is charged to the value at t = 0 but of the opposite polarity.

With the SCR conducting, diode D_1 prevents

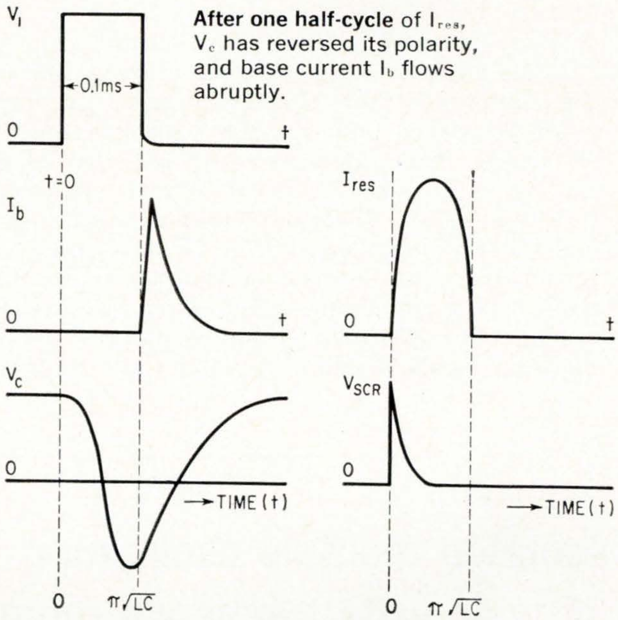


When SCR conducts, resonant current, I_{res}, charges C to a voltage opposite to the polarity shown.

transistor destruction by reverse collector-to-emitter bias. The forward voltage drop across D_2 biases the emitters off and increases the forward breakdown voltage. Diode D_2 also prevents resonant current flow in the reverse direction.

At the end of the resonant half-period, the sum of the supply voltage and the reversed voltage across C causes a large base current, I_b, to flow. The transistors saturate, and V_c reverse-biases the SCR, turning it off. Base current flow is only momentary, because V_c decreases as emitter current flows with the SCR off. Capacitor C is then charged to its original voltage by the emitter current, and the cycle begins again with the next SCR trigger.

The output pulse width is a function of the resonant frequency of C and L; with the values given, a width of 0.1 millisecond is obtained. If the SCR is self-biased with an additional resistor, shown with dotted leads, the circuit becomes an astable multivibrator.



After one half-cycle of I_{res}, V_c has reversed its polarity, and base current I_b flows abruptly.

Telemetry tone oscillator consumes microwatts

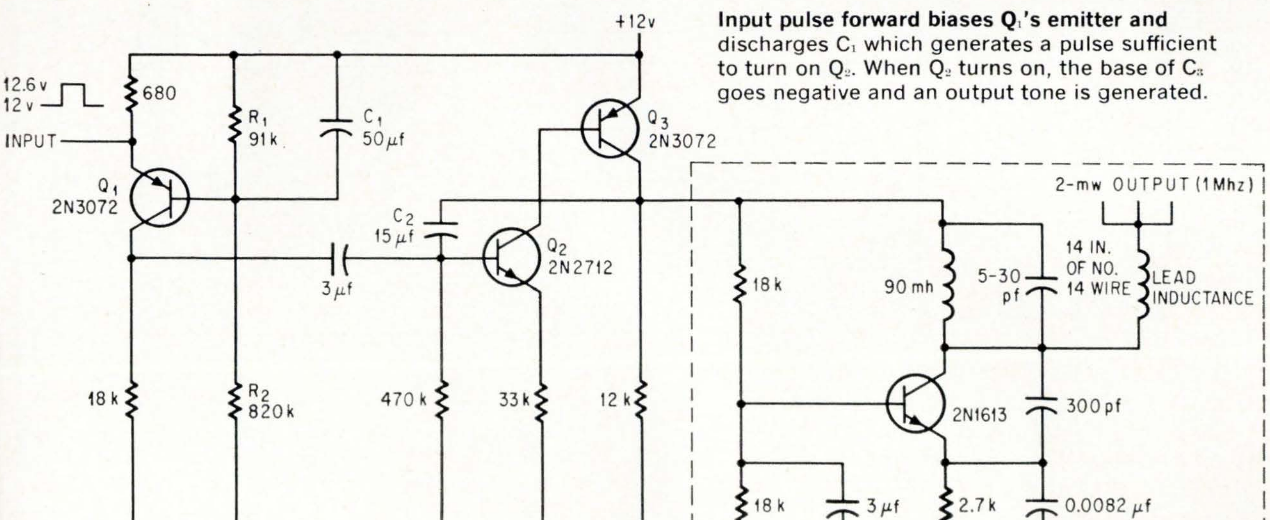
By Anthony C. Caggiano

Safety Research & Development Corp.
Ridge, N.Y.

A tone-oscillator activated by pulses of less than 2 milliwatts provides a telemetry signal. The circuit consumes less than 150 microwatts when dormant and 150 milliwatts when transmitting. Thus, it is ideally suited to telemetry applications where power consumption is critical.

With all transistors biased off between transmissions, the only battery drain is from transistor leakage and the voltage divider formed with resistors R_1 and R_2. Some of the power during the off time is conserved by capacitor C_1, which charges up during this interval.

Although it takes the small current nearly a minute to recharge C_1, slow recovery is not a problem



Input pulse forward biases Q_1's emitter and discharges C_1 which generates a pulse sufficient to turn on Q_2. When Q_2 turns on, the base of C_3 goes negative and an output tone is generated.

in most present-day telemetry applications.

When an incoming 0.6-volt pulse forward-biases the emitter of Q_1, the transistor turns on and forms a low-resistance path through which C_1 quickly discharges. The additional power provided by C_1 enables Q_1 to generate an output pulse sufficient to trigger the one-shot multivibrator formed by Q_2 and Q_3. The output pulse from Q_1 raises the base potential of Q_2 and turns it on. With Q_2 conducting, the base of Q_3 goes more negative and turns on Q_3.

The collector current generated by Q_3 turns on the tone oscillator-transmitter and starts charging C_2, the timing capacitor. During the 8 seconds that elapse before C_2 is fully charged, the tone oscillator transmits a 1-megahertz tone with 2 milliwatts of power via the antenna. When C_2 is fully charged, its bottom plate is sufficiently negative to turn Q_2 off. This shuts Q_3 off and terminates the oscillations. The duration of the power tone may be varied by choosing an appropriate value for timing capacitor C_2.

A similar circuit appeared in Designer's Casebook, Aug. 22, 1966, page 98. That circuit didn't require small power pulses to turn it on.

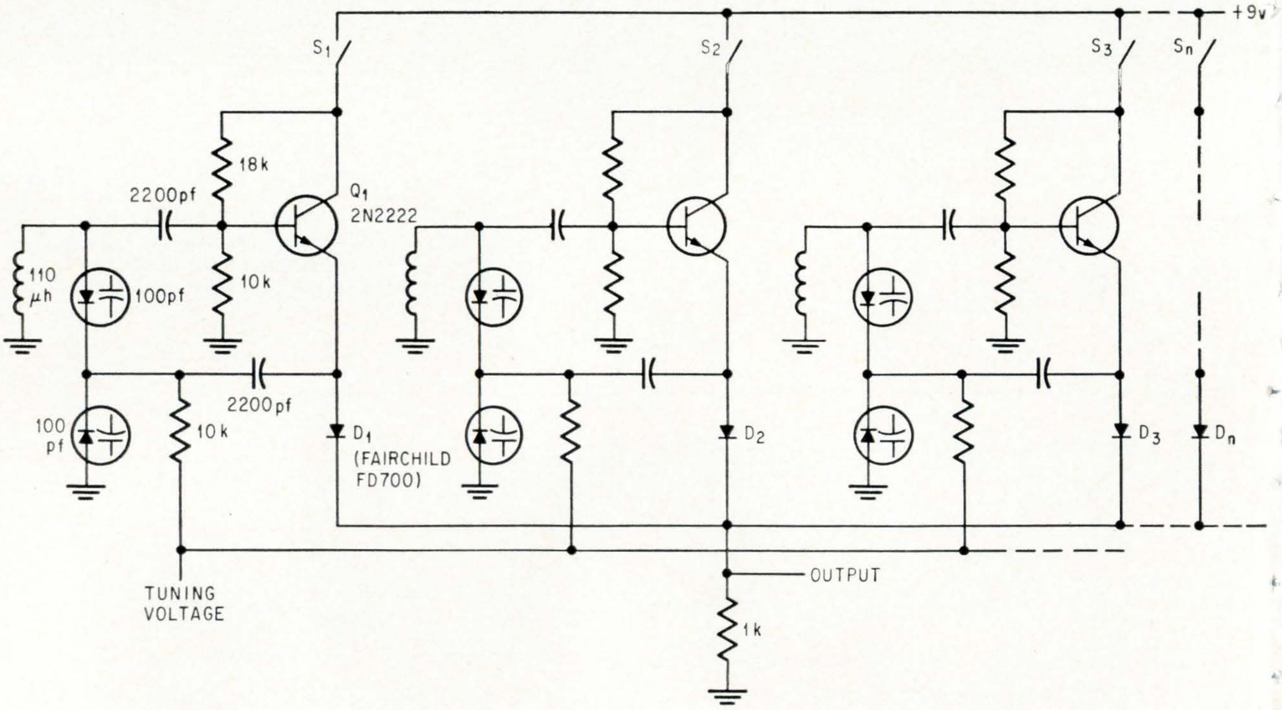
Isolated multiple oscillators provide wide frequency range

By Max E. Peterson

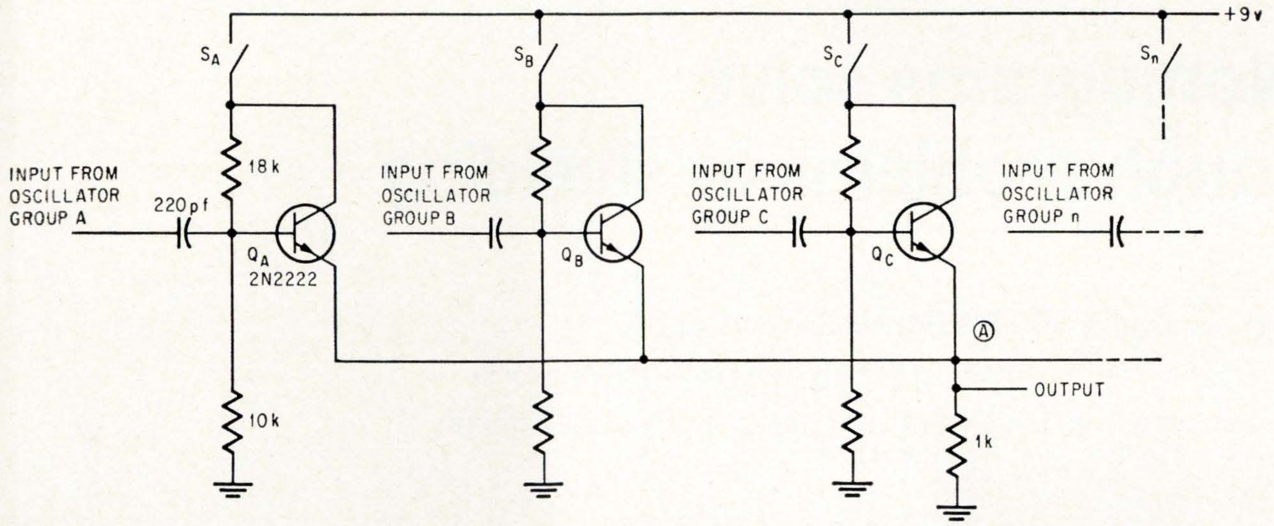
Collins Radio Co., Dallas, Texas

Wideband frequency generation is achieved without mechanical switching by combining the outputs of several oscillators on one line. Interaction between the units is reduced when diodes are inserted between each oscillator and the common output lead. A typical application would be a frequency synthesizer covering the range of 2 to 30 megahertz.

An emitter follower provides power gain in each of the modified Colpitts oscillators shown below. Varactors supply the capacitance for the tank circuits, permitting remote tuning control. Assuming that power switch S_1 (usually a transistor) is closed, diode D_1 conducts and the quiescent emitter voltage of Q_1 is approximately 2 volts. With power removed from the other stages (S_2, S_3 . . . S_n open), diodes D_2, D_3 . . . D_n are back-biased



With Q_1 conducting, diodes D_1, D_2, . . . D_n are back-biased, isolating the respective oscillators from the common output lead.



Conducting transistor associated with an oscillator group back-biases the other transistors, isolating group outputs.

through the base-emitter junction of each corresponding transistor and 10-kilohm bias resistor to ground. The typical capacitance of an FD700 diode, when back-biased to 2 volts, is 0.7 picofarad; this represents an impedance of 120 kilohms at 2 megahertz and 8 kilohms at 30 megahertz. A group of 10 oscillators on a common lead has less than 7 picofarads in parallel with the active varactors.

To extend the frequency band, outputs from groups of oscillators can be combined by the circuit shown above. With S_A closed, Q_A conducts, and the quiescent voltage at point A is between 2 and 3 volts. This voltage back-biases the base-emitter junctions of Q_B, Q_C, . . . Q_n, isolating the operating group from the others.

The circuits have been used to combine 15 oscillators in five groups of three operating between 2 and 33 megahertz. With a 9-volt supply, the total power dissipation was 23 milliwatts.

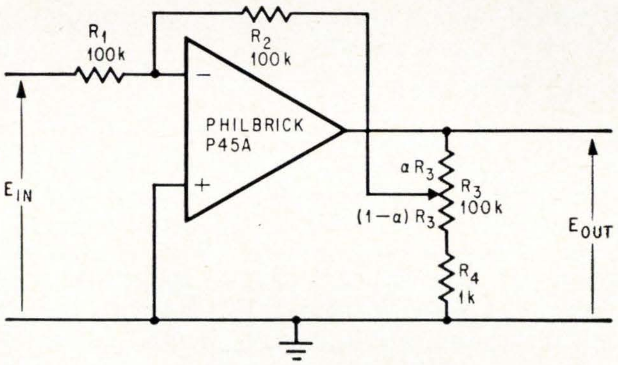
Feedback T yields high input impedance

By George Cook and William F. Elder Jr.

Merrick Engineering Inc., Nashville, Tenn.

Operational amplifiers used as preamplifiers in a servocontrol system require high input impedance and wide-range gain control. A 10-turn feedback potentiometer will provide the desired gain control, but since these potentiometers are not available with resistances greater than 100 kilohms, a 1-kilohm input resistor is required for a maximum gain of 100.

By incorporating the 10-turn potentiometer in a variable T-network feedback control, a 100-kilohm input resistor can be used. The gain of the circuit is given by:



T-network that includes 10-turn potentiometer provides wide gain-adjustment range.

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

where α is the fractional portion of R_3 included in the feedback loop. For the values shown, the gain is -1 when $\alpha = 0$, and -102 when $\alpha = 1$.

Nomograms solve tough problems of shielding

Even nonexperts can design shielded enclosures.
Charts help any engineer to quickly determine the thickness of metal required to eliminate interference or evaluate design

By Robert B. Cowdell

Genistron Division of the Genisco Technology Corp., Los Angeles

Protecting sensitive electronic systems and circuits against extraneous fields is a difficult and complex design problem because a detailed analysis of a shielding problem usually requires cumbersome equations or time-consuming graphical methods. Since the results are not always satisfactory, the work is usually left to specialists in shielded enclosure design.

Now, armed with a newly developed set of nomograms, an engineer who has a knowledge of the frequency and the type of field to be suppressed can determine quickly the thickness of metal shield needed to do the job or to evaluate the effectiveness of a shield.

Shielding effectiveness

A metal enclosure can protect against interference caused by the electromagnetic fields that are generated in nearby circuits. These fields may store energy equally in the electric or magnetic components or, as is more usual, they may be predominantly electric or magnetic fields. [See "Magnetic and electric fields" on page 94]. Although an enclosure's shielding effectiveness varies with the type of field, there are reflection and absorption factors which are important in any shielding problem.

When a field impinges on a shielding material some of the field's energy is reflected from the outer surface, some is absorbed in the material, some is reflected at the shield's inner surface, and the remainder gets through. The shield's effectiveness, S, is given by

$$S = R + A + B$$

where all terms are in decibels. R, the loss due to reflection, is a function of the material, frequency, and the type of field. Absorption losses, A, are a function of the material and frequency but are independent of the type of field. If the absorption loss is greater than 10 db the secondary reflection loss, B, at the shield's inner surface can be ignored. Consequently

$$S \approx R + A$$

where R will be represented as R_E, R_H, or R_P depending on whether the incident field is an electric (E) field, magnetic (H) field, or a radiated plane-wave field (P).

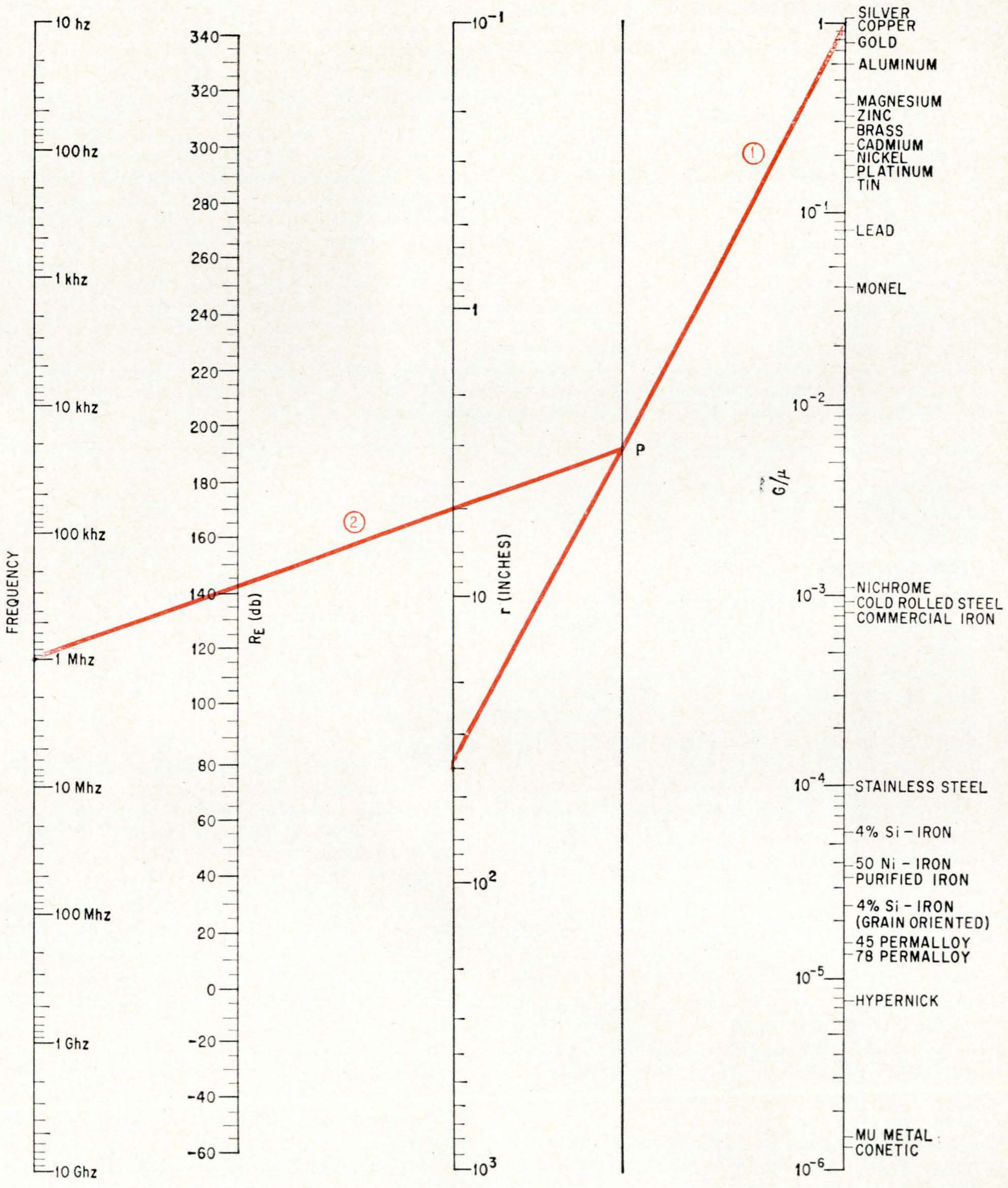
Four nomograms have been designed to make calculating shielding effectiveness easy. The nomograms supply values of the variables needed in the equation. The nomogram on page 98 determines the absorption loss for any type of field. One of three other nomograms is used to determine the reflection loss—R_E, R_H, or R_P—for the particular type of interfering field.

The nomograms are based on equations developed by Schelkunoff[1] and expanded for engineering applications over the years.[2,3] A recent study

The author

Robert B. Cowdell is manager of systems engineering, responsible for Genistron's consulting and research activities on the West Coast. He has worked on electromagnetic interference studies and designs for the Skybolt missile, XB70 weapons system, Minuteman guidance and ground support system, and communications links.

Electric field reflection losses–R_E



Electric field reflection loss is determined from this nomogram. The distance from the source, r, is 40 inches and the material is copper. Line 1 is drawn through these points intersecting the unmarked scale at P. Line 2 through P and the frequency (1 Mhz) intersects R_E at 142 db. Negative values of R_E indicate increased coupling that can occur at certain combinations of parameters.

Properties of magnetic and electric fields

In any simple a-c circuit there is an electric field vector associated with the voltage and a magnetic field vector associated with the current. These field components can interfere with nearby circuits which then must be shielded to prevent trouble.

When the field varies with time, the electric and magnetic components exist simultaneously, although one of the field components can be stronger than the other. If most of the energy is stored in the electric component, the field is referred to as an electric field. If most of the energy is stored in the magnetic component, the field is magnetic.

In general a field that is predominantly magnetic or electric will occur close to the generating source —within one wavelength. For frequencies up to about 1,000 Mhz, a wavelength is a relatively large distance and such fields will cut across many circuits. For example, at 1 gigahertz a wavelength is 1 foot long; at 1 megahertz a wavelength is about 950 feet long. As a consequence many shielding problems involve predominantly electric or magnetic fields.

At a distance of about six wavelengths from a simple radiating source, the field may propagate as a plane wave, in which the field energy is divided equally between the magnetic and electric components. A shield that is effective for either magnetic or electric fields is also usually effective for plane-wave fields.

A useful quantity in any discussion of field theory is the characteristic impedance—defined as the ratio of the electric to the magnetic field components. For a plane wave in free space the characteristic impedance is 377 ohms. For a predominantly electric field the characteristic impedance is greater than 377 ohms and the field is said to be a high impedance field. A magnetic field has an impedance that is less than 377 ohms, and is said to be a low impedance field.

Strong magnetic fields are associated with circuits characterized by low impedance, high current flow, and small voltage drops. A low-impedance magnetic field transfers energy readily to a surface or circuit with low impedance.

High intensity electric fields are produced by conductors with large series impedance, high voltages, and little current flow. Such fields couple energy most readily into a high impedance conductor or surface.

indicates that the shielding theory is valid even at extremely low frequencies.[4] The nomograms indicate maximum values of R_E, R_H, R_P, and A.

Reflection losses

Reflections and associated losses, R, are caused by a difference in characteristic impedance between an incident field and the shield. This is analogous to the situation that occurs in a transmission line not terminated in its characteristic impedance. When the impedance of the incident field is much higher or lower than that of the shield, reflection losses are very high.

At all frequencies, electric fields are high impedance and magnetic fields are low impedance.

A shield's characteristic impedance varies with the frequency and the material's permeability and conductivity. Generally the impedance is low at low frequencies and high at high frequencies.

At low frequencies, magnetic reflection losses R_H, are small because there is a reasonably good match between the low impedance of the shield and the field. Thus most of the energy is coupled to the shield. For good shielding effectiveness, it is usually necessary to employ ferromagnetic materials with high absorption losses. As the frequency increases, the impedance mismatch becomes greater and R_H increases.

For low-frequency electrical fields, the mismatch between field and shield impedance is large and R_E is large. As the frequency increases, R_E decreases because the shield's impedance gradually increases.

R_H and R_E nomograms

The equation for reflection loss in an electric field is given by

$$R_E = 353.6 + 10 \log_{10}\left[\frac{G}{f^3 \mu r^2}\right]$$

For magnetic fields, the reflection loss is

$$R_H = 20 \log_{10}\left[\frac{0.462}{r}\left(\frac{\mu}{fG}\right)^{1/2} + 0.136\, r\left(\frac{\mu}{fG}\right)^{-1/2} + 0.354\right]$$

R_E and R_H are expressed in decibels. In these equations

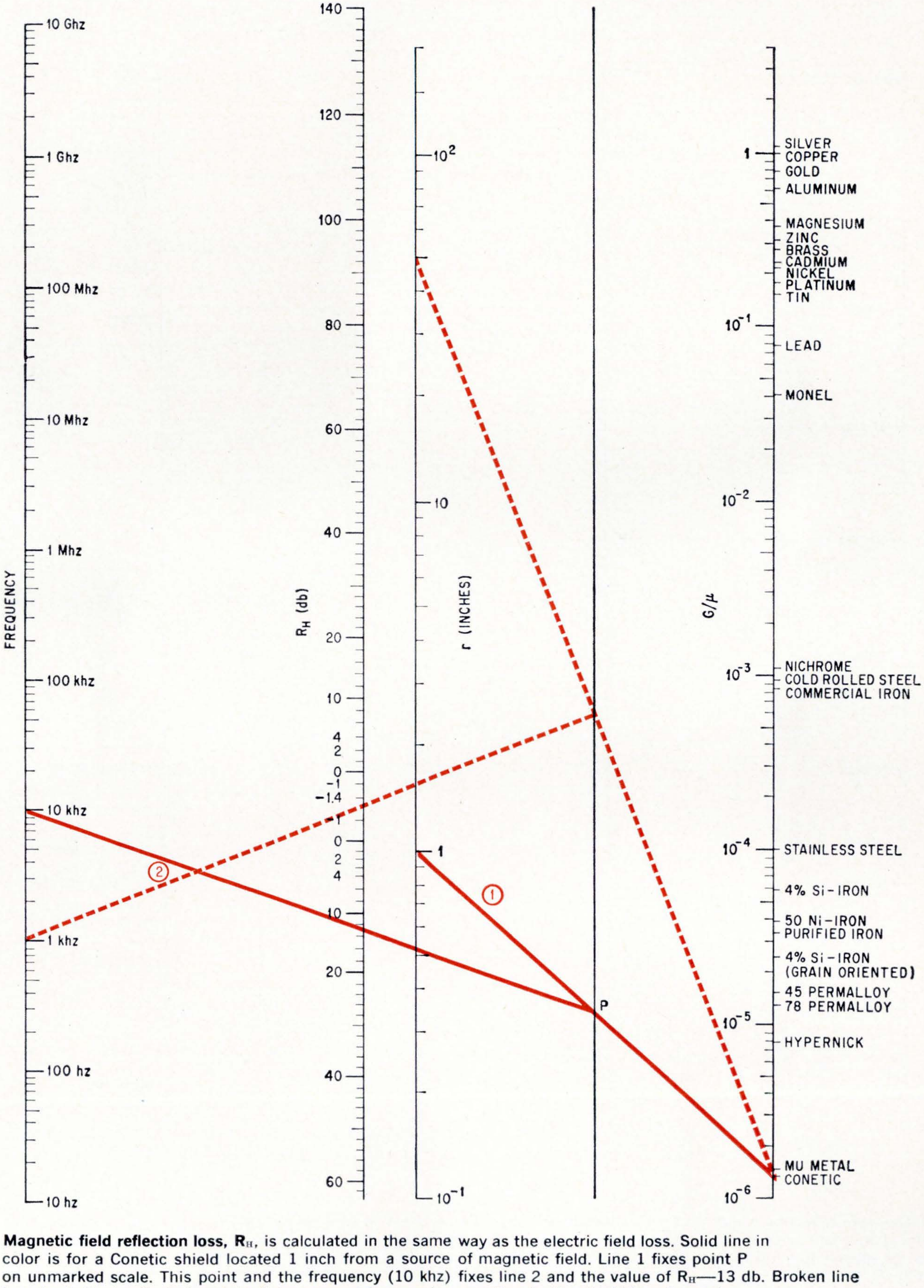
r = distance in inches between the source of energy and the shield.
μ = material permeability relative to copper
G = material conductivity relative to copper
f = frequency in hertz

Both R_E and R_H can have negative values, which indicate enhanced coupling to the shield rather than reflection loss. Such increases in coupling have been observed experimentally and are caused by a resonance between shield and source. Dashed lines in the graph at right plot a negative value of R_H.

Similar procedures are followed for determining either R_E on page 93 or R_H at the right. For example, determine the electric field reflection loss at 1 Mhz caused by a copper shield 40 inches from a source.

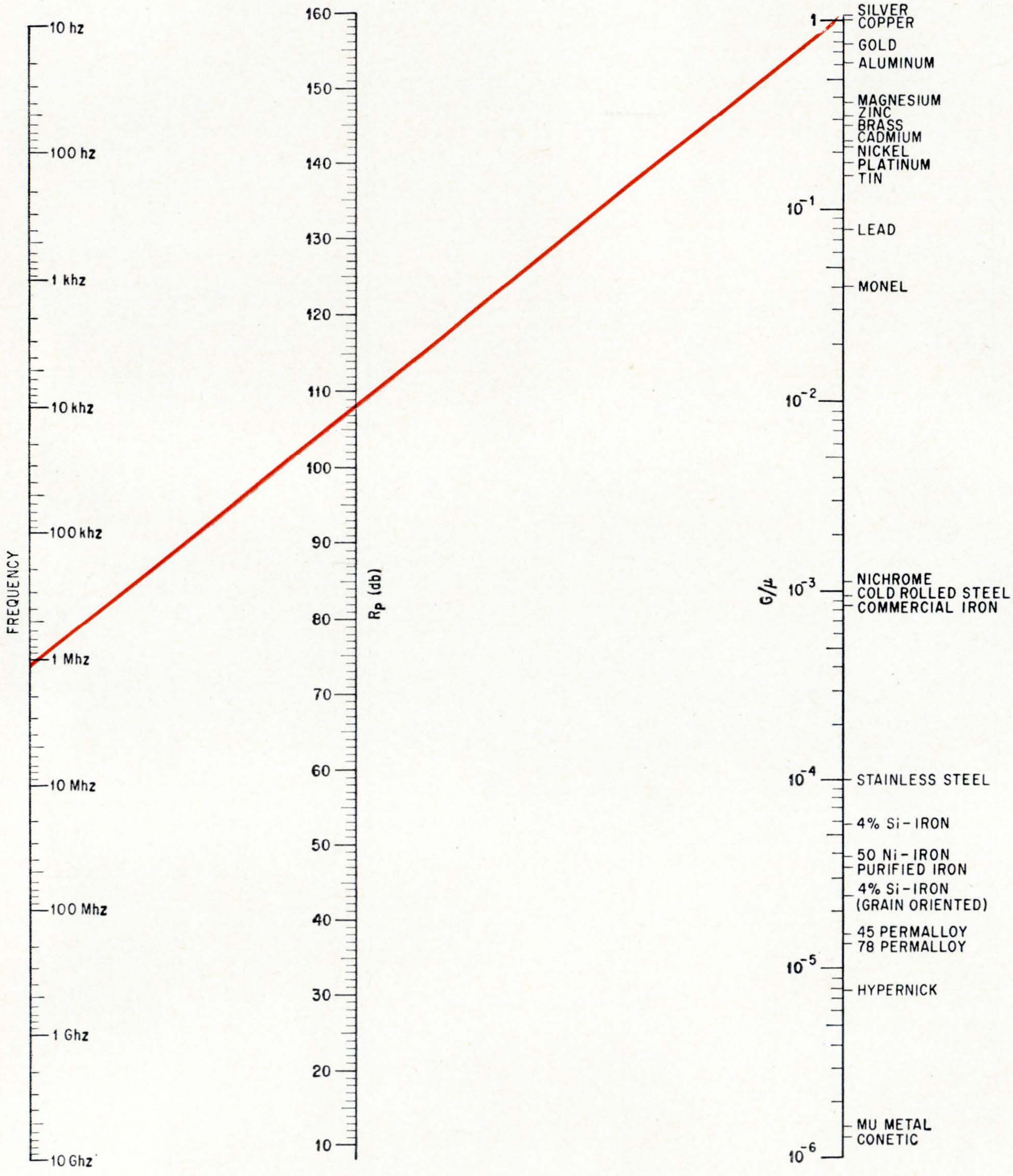
- Locate a point on the G/μ scale corresponding to copper. If a desired metal is not listed, compute G/μ and plot on the numerical scale.
- Locate the distance between the energy source and the shield on the "r" scale (r = 40 inches).
- Place a straightedge between r and G/μ and locate point P on the blank scale.
- Place a straightedge between point P and the

Magnetic field reflection losses—R_H



Magnetic field reflection loss, R_H, is calculated in the same way as the electric field loss. Solid line in color is for a Conetic shield located 1 inch from a source of magnetic field. Line 1 fixes point P on unmarked scale. This point and the frequency (10 khz) fixes line 2 and the value of R_H—13 db. Broken line in color indicates that at certain distances and frequencies coupling to the shield is enhanced.

Plane-wave reflection losses–R_P



Plane-wave reflection losses R_P are calculated easily by a line connecting the frequency with the appropriate value of G/μ. A plane wave will exist only if the source is located at least five or six wave lengths from the circuit that is to be shielded. An enclosure designed for magnetic and electric fields will also be effective for plane-wave fields.

desired frequency on the f scale (f = 1 Mhz in this example).

▪ Read the reflection loss from the R_E or R_H scale. (In the example, the loss, R_E, is 142 db.) By pivoting the straightedge on point P, R_E or R_H as a function of frequency can be determined.

Plane-wave reflection losses

The nomogram for plane-wave losses should be used when the source of radiation is located more than 5 or 6 wavelengths away from the shield. The distance requirement is for simple antennas that have gains equal to or less than a dipole.

The equation for reflection losses in decibels for a plane wave impinging on a metallic shield is

$$R_P = 168.2 + 10 \log_{10}\left(\frac{G}{\mu f}\right)$$

To use the nomogram on above/below, the procedure is as follows:

▪ Locate a point on the G/μ scale corresponding to one of the listed metals.

▪ Place a straightedge between the G/μ scale and the desired frequency.

▪ Read the plane-wave reflection losses from the R_P scale.

Absorption losses

Absorption losses, caused by attenuation through the material, are given by

$$A\ (\text{db}) = 3.38 \times 10^{-3}\ t\ (\mu G f)^{1/2}$$

where t is the metal thickness in mils (10^{-3} inches). For a given thickness, magnetic materials like steel have higher absorption losses than nonmagnetic materials like copper. Therefore, relatively thick, high-permeability materials are needed to increase the absorption loss for good shielding.

As an example of applying the absorption loss nomogram on page 98, assume that it is necessary to determine the thickness of metal needed to give a 10-db absorption loss at 100 kilohertz. The steps are as follows:

▪ Locate the frequency (100 khz) on the frequency scale and the desired absorption loss (10 db) on the A scale.

▪ Using a straightedge, extend a line through these two points until it intersects the unmarked scale at point P.

▪ Draw a line connecting the desired metal on the $G\mu$ scale and point P and extend it to the left, to intersect the t scale. By pivoting the straightedge around point P, thicknesses for a number of metals can be rapidly determined. In this example t is 9.2 mils for copper and 5.2 mils for commercial iron. In the reverse process, the nomogram yields the absorption loss if the frequency, type of material, and thickness are known.

Frequency dependence

Good shielding against electric fields is possible at low frequencies because reflection losses, R_E, are inherently high even though absorption losses, A, are small. In fact since most of the incident energy is reflected, the absorption loss can be neglected at low frequencies.

In contrast, at high frequencies, electric fields undergo small reflection losses but large absorption losses. Thus, even though most of the transmitted energy is coupled to the shield, effective shielding is still possible. In shielding against high-frequency electric fields, the main problem is to maintain high absorption by eleminating all nonconductive openings in the shield. This prevents leakage currents from flowing on the supposedly shielded side of the metal surface.

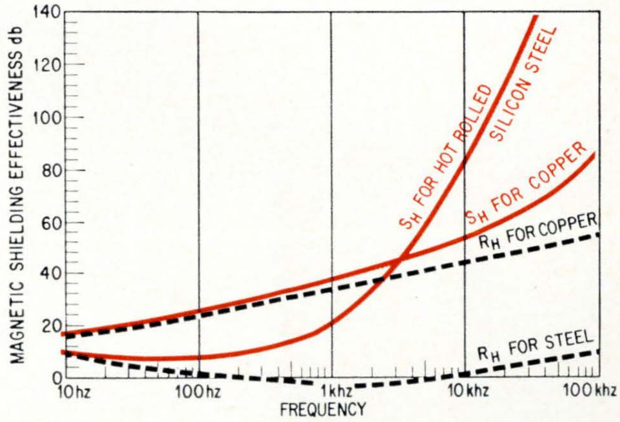
For magnetic fields, both the absorption losses and reflection losses R_H are small at low frequencies. As with electric fields, eliminating all nonconductive openings in the shield maintains the benefit of high absorption losses. At higher frequencies, both R_H and A become very large and shields perform very well.

Selecting a shield

Generally the amount of attenuation required is known, and it is desired to determine the material and the material thickness. In some applications, it may be necessary to find a number of materials that will give the desired shielding effectiveness, and the final choice is based on other factors such

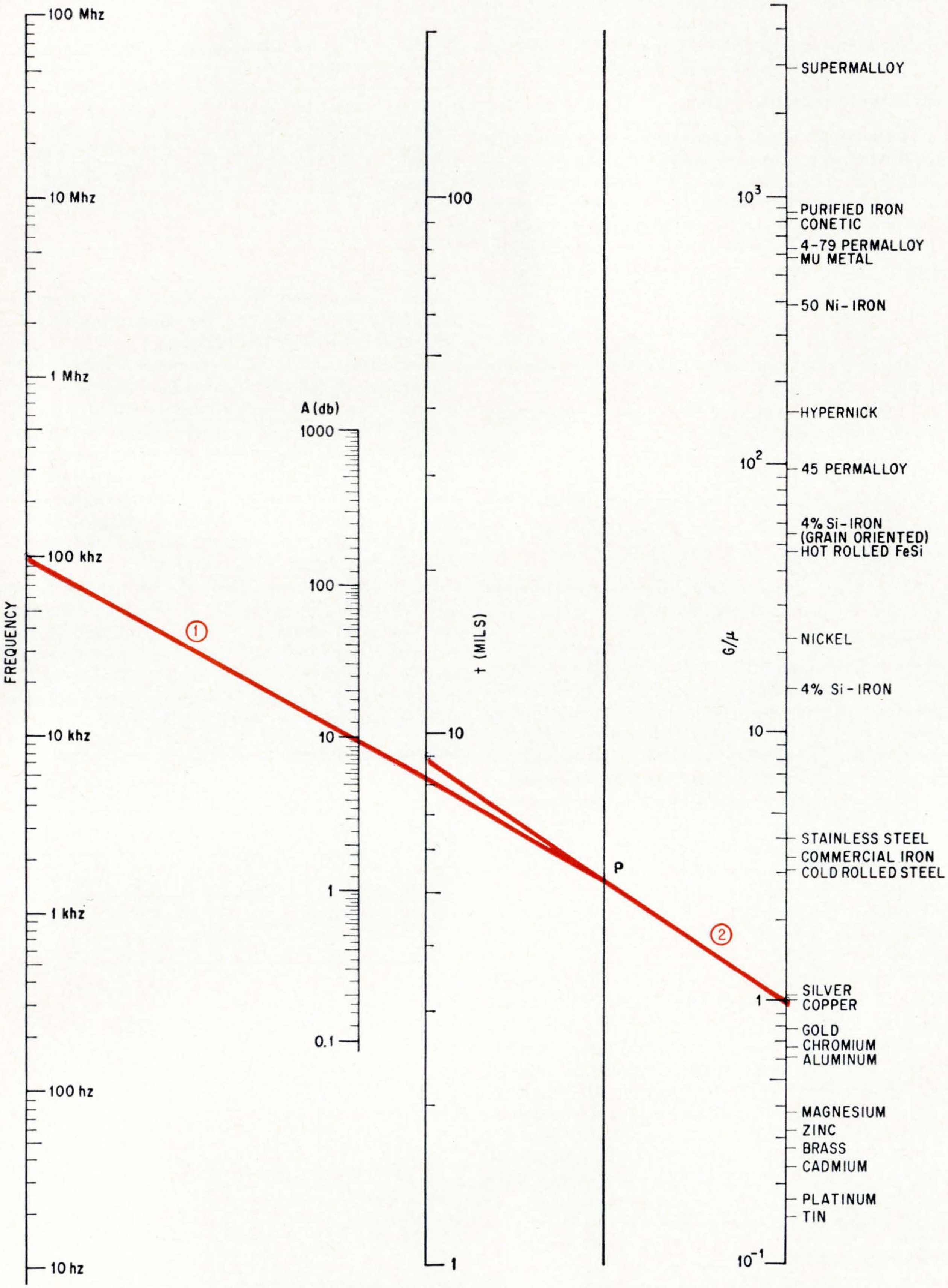
R_E for copper 40 inches from source

Frequency	R_E (db)	Required A (db)	Required t (mils)	A (db) for t=1.2	$S_E=A+R_E$ (db)
1.5 khz	227	0		0.15	227.0
100 khz	172	0		1.3	173.3
1 Mhz	142	0		4.0	146.0
10 Mhz	112	10	1.0	13.0	125.0
100 Mhz	83	37	1.2	40.0	123.0
1,000 Mhz	52	68	0.62	130.0	182.0



Magnetic shielding is plotted for copper and hot rolled silicon steel 15 inches from source of interference. Broken lines are reflection losses; solid lines in color plot sum of absorption and reflection losses.

Absorption losses–A



This graph selects material or material thickness for a specified absorption loss. The lines in color are plots for an absorption loss of 10 db at 100 khz. Line 1 intersects the unmarked scale at P. This new point and the material (copper) fixes line 2 and determines the thickness, 9.2 mils.

Magnetic shielding for materials 1 inch from source

Frequency	Copper			Commercial iron			Purified iron			Conectic			4% silicon-iron		
	R_H (db)	A (db)	t (mils)	R_H (db)	A (db)	t (mils)	R_H (db)	A (db)	t (mils)	R_H (db)	A (db)	t (mils)	R_H (db)	A (db)	t (mils)
1 khz	13	67	>1,000	0	80	300	10	70	22	22	58	21	11	69	90
10 khz	22	58	160	−1	81	120	3	7	8.5	13	67	7.5	4	76	32
100 khz	32	48	45	4	76	<120	−1.4	82	3	5.5	74.5	2.6	−1	81	11
1 Mhz	42	38	12	12	68	<120	2	78	3	−1	81	<1	1	79	<11
100 Mhz	62	18	1	32	48	<120	18	62	<3	6	74	<1	17	63	<11
10 Ghz	82	10	1	52	28	<120	38	42	<3	24	56	<1	36	44	<11

as weight, strength, and cost.

The following example outlines a typical procedure for selecting a material. Assume that a sensitive circuit, highly susceptible to electric fields, is located near a high-voltage terminal. An enclosure located 40 inches from the terminal must provide 140 db of shielding at 1.5 khz and 120 db at all other frequencies between 1 khz and 2 gigahertz.

From the nomogram for R_E and with $r = 40$ inches, determine R_E as a function of frequency for copper, and list the values as in the table on page 97. The shielding at 1.5 khz is already greater than the 140 db desired. However, since R_E falls off with frequency, the thickness required is one that provides sufficient absorption loss to bring the shielding effectiveness up to 120 db at the higher frequencies. Values of A are computed from $A = 120 - R_E$ and are listed in the required A column. With these values of A determine the thickness t from the absorption loss nomogram.

The highest value of t—1.2 mils—maintains the level of shielding at 120 db. To determine the actual shielding effectiveness, values of A are computed using this thickness. The effectiveness against an electric field, S_E, for this thickness is indicated in the last column of the table.

The above example results in an extremely thin shield that is not mechanically self-supporting. For mechanical strength, the actual design would need either a much greater thickness of copper or some other material.

As another example, consider the design of a magnetic shield that is one inch from a source. Shielding effectiveness must be greater than 80 db from 1 khz to 10 Ghz. The table above lists values of magnetic reflection loss R_H, required A and required t for various materials. Again the largest value of t in each column determines the thickness of the material.

Copper—and typically all nonferrous material—would be over 1 inch thick to produce 80 db of shielding. Commercial iron is inexpensive, but requires a 300 mil thickness and would be very heavy. Purified iron—22 mils thick—would have sufficient strength, reduce weight, and be economical. The more expensive Conetic and 4% grain oriented silicon-iron appear to offer no advantages.

Careful does it

No material should be ruled out in a given application. In some situations copper is a better magnetic shield than some ferrous materials. This is particularly true at very low frequencies where R_H for copper is high.

In the case of a shield located 15 inches from a high-intensity magnetic source, copper 30 mils thick is more effective than 30 mils of hot rolled silicon steel at all frequencies below approximately 3 khz as indicated by the lines in color in the graph on page 97.

Selecting a material is only part of the problem in designing a shielded enclosure. In practice, gaps appear in the metal. These are openings for components mounted on the enclosure or seams between metal plates. Low- or high-frequency energy leaking past these discontinuities may seriously degrade the shielding effectiveness.

Although careful design overcomes many of the difficulties resulting from these breaks in the surface, no one has completely solved this portion of the shielding problem.[2, 5] In some applications a simple test fixture can be used to evaluate materials such as gaskets or plates with holes.

For more complicated structures, an r-f signal can be fed directly into an enclosure to determine its shielding effectiveness. An antenna-receiver system outside the unit can measure the signal that leaks out.

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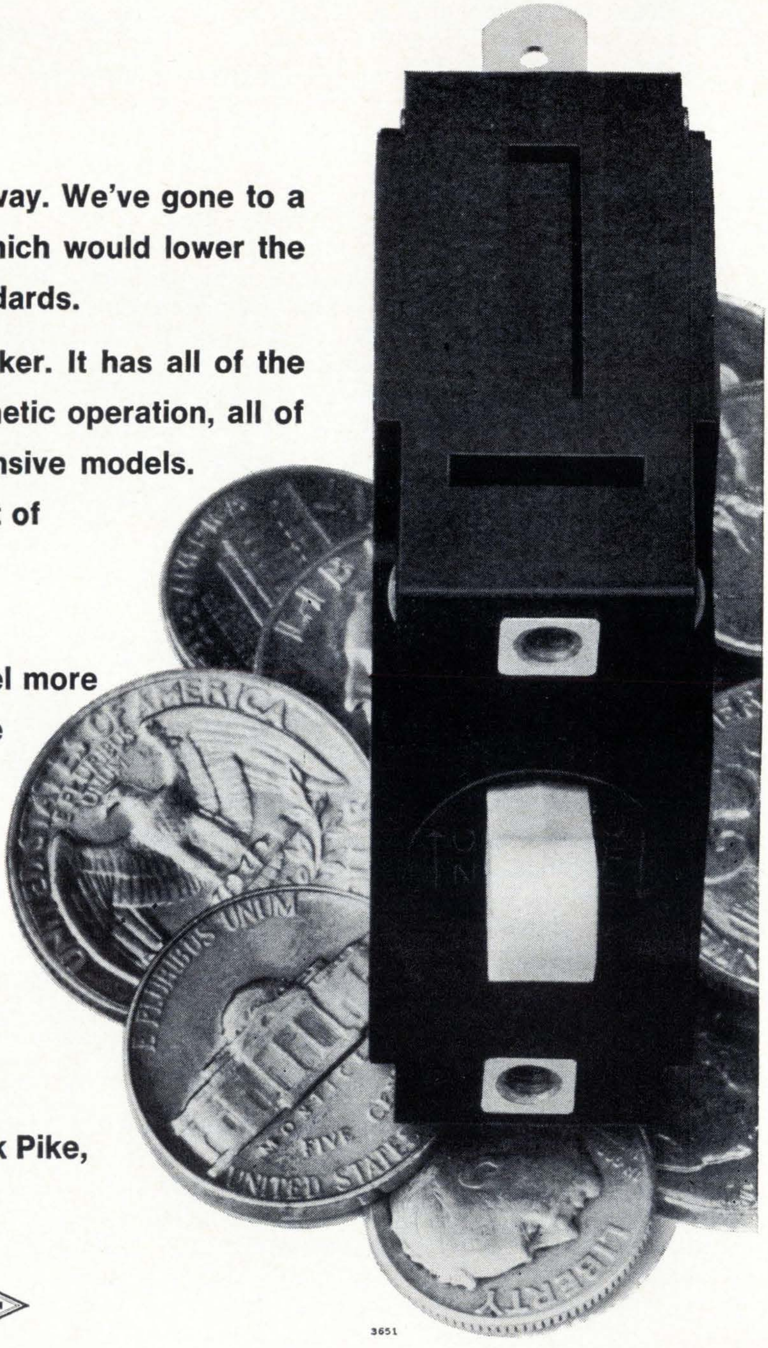

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HEINEMANN

Plastics for packaging: handle with care

Tests have traced some device degradation to impurities stemming from the plastics or the packaging process. Caution is required, therefore, in cases where high reliability and long life are demanded

By J.J. Licari and G.V. Browning*

Autonetics Division, North American Aviation Inc., Anaheim, Calif.

While transistor and integrated-circuit manufacturers and users are generally sold on the use of plastics to package devices for commercial applications, some doubt lingers about the reliability of plastics in military and space applications.

Traditionally, plastics have been used to encapsulate or pot electronic assemblies in which the active devices have first been hermetically sealed in protective casings. But the trend now is to apply plastic covering directly to active device chips that are highly sensitive to moisture, contaminants, or stresses.

Unquestionably, some impurities inherent in the plastics or resulting from plastic processing steps degrade the chips. The appeal of the plastic-packaged transistors and integrated circuits currently on the market lies chiefly in their low cost, though sometimes they've been selected because they resist shock and vibration better than their sealed-can counterparts.

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The reliability of plastic-cased devices, it should be emphasized, isn't a function of the plastic alone, but also depends on the nature of the device being packaged and on the quality of its passivation layer.

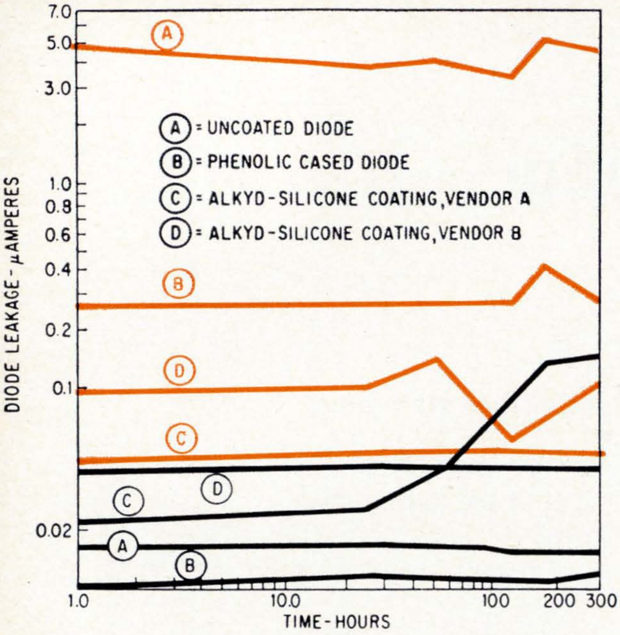
Among the possible drawbacks related to the plastics themselves are permeabilities with respect to moisture and contaminants, dimensional instability that can cause stresses on encapsulated leads, and impurities.

Minuteman II studies

Signs of potential trouble with plastic packages appeared when transistor surfaces were exposed to gases in physics-of-failure studies for the Minuteman II program.[1] Excerpts from those studies are tabulated on page 102. The table shows how reverse leakage characteristics were affected by contaminants such as benzene and carbon dioxide; contaminants have been detected in device packages by gas chromatography, and their presence has been partially correlated with device performance.

One might guess that other organic solvents structurally analogous to benzene, such as toluene or xylene—also used in the synthesis or processing of plastics—may also be entrapped in device packages during processing. Separate studies indicate that small amounts of ammonia gas and organic amines affect parameters such as reverse current.[2, 3]

In the Minuteman II studies, it was shown that with a microdiode packaged in an inner layer of silicone and an outer rigidizing layer of phenolic



Leakage currents of microdiodes react under exposure to dry ammonia (curves in color). The curves in black represent the same devices in a dry nitrogen atmosphere.

plastic, ammonia could be generated by the degradation of the hexamethylenetetramine present in the outer layer as a curing agent.

The ammonia affected the reverse leakage characteristics of the semiconductor diode after it had permeated the inner silicone barrier coating, as shown in the curve directly above. This problem was solved by substituting a silicone molding compound for the phenolic; no ammonia is generated in curing the silicone.

Why leakage increases

Temperature-voltage inversion is the label often applied to the mechanism by which reverse leakage current increases. It is postulated that contaminants such as NH_4^+ ions on the surface are positioned in an orderly fashion in the region of a reverse-biased junction by the fringing electric field that extends through the oxide.[4] This positioning is abetted by either high humidity or high temperature. The ordered ions attract oppositely charged carriers in the underlying semiconductor material, thus effectively inverting that region from its majority carrier status to that of a minority carrier layer. The inverted region provides a much greater junction area and thus increases the leakage current of the original junction. If the device is heated for a time at zero bias, the ions once again assume a random arrangement.

A second mechanism, space-charge buildup within an oxide layer, may also be susceptible to unwanted chemicals from plastics and may also degrade device performance. The sources of contamination relevant here are usually attributed to the device processing.

As an example, space-charge buildup resulting from the migration of ions under the influence of an electrical field is thought to occur in the insulating oxide under the gate of an MOS device when potential is applied to the gate. It's easy to see how such a space charge could influence the performance of the MOS device, since it affects the electrical field the gate exerts in modulating the channel in the silicon under the gate oxide. Indeed, the space charge itself can act as a gate field when the external gate voltage is removed. No exact mechanism for this effect has yet been defined. It has been attributed variously to alkali ion, hydrogen ion, and oxygen vacancy migration.[5, 6]

Permeability factor

The plastic package's permeability is perhaps its most important characteristic. Impurities exert their influence as a function of this permeability whether they are gases and vapors outside the package or chemicals generated internally. The permeability of typical plastic coatings with respect to moisture is tabulated on the opposite page. Note that cellophane, cellulose acetate, and Neoprene are included in the table for comparison purposes. It is unlikely that any of these materials would be used in packaging devices. Coatings most likely to be used are epoxy-anhydride, epoxy-aromatic amine, silicone-alkyd, with or without microdiode coating, polytetrafluoroethylene (PTFE), PTFE dispersion coat, fluorinated ethylene propylene (FEP), polyvinyl fluoride, polyvinylidene fluoride (Teslar), p-polyxylylene (Parylene C and N).

Another important factor is dimensional stability, since shrinkage can lead to induced stresses. Epoxy will decrease in volume during curing, for example, and other plastics will shrink when solvents evaporate. Unexpectedly large forces can result when plastics are solidified from a gel or colloidal state.

Reverse current leakage of dual pnp signal transistors shifts with gas ambient

Conditions	Leakage current, I_{CBO} (anoamps) @ 20 v reverse bias	
	Transistor A	Transistor B
Before vacuum bakeout	3.0	2.5
After exposure to benzene vapor and reverse bias on transistor A only	2,400	—
After exposure to water vapor and reverse bias on transistor A only	10,000	—
Vacuum bake at 300°C and no bias	2.5	2.5
Bias on transistor B in vacuum	2.5	3.0
After exposure to carbon dioxide and bias on transistor B only	3.0	650
Vacuum bake at 300°C	3.0	3.0

If it were feasible in all cases to remove the solvent at its critical temperature, there would be practically no effects from surface tension as the solvent was withdrawn.

Shrinkage stresses produced in a coating formed by solvent removal can be serious enough to fracture an integrated circuit's interconnection wires. In a typical example, several 0.7-mil-diameter wires with individual breaking strengths of several grams were broken in a single IC. The solvent in this case was removed by evaporation from a non-elastomeric silicone coating on the IC.

Typical test results

The varieties of plastic tested by the Autonetics division of the North American Aviation Inc. fall into four categories: epoxies, phenolics, silicones, and fluorocarbons.

In the case of the epoxies, a variety of chemical and ionic species can be formed during their degradation, as shown in the table on page 104. Carry-over and retention of many of these chemicals in the final cured plastic is highly probable. Yet only limited tests have been performed and there is no indication of which impurities are critical to device performance, or of what the threshold levels of impurities are.

Emission spectrographic analysis has been found to be a good technique for determining kinds and relative amounts of metallic constituents down to 0.5 ppm (based on ash content). In tests, plastic samples were deposited and cured directly onto the graphite electrodes, since it was previously determined that curing in glass or aluminum dishes introduces additional impurities from these receptacles. A large variety of metallic impurities were found in the samples tested (see table on page 105), especially in the case of epoxies and highly filled molded compounds. Other silicone coatings, and fluorocarbons such as Teflon, displayed a relatively low metallic content.

Many of these metallic impurities aren't inherent in the resin polymer itself. For example, silicones after synthesis are extremely pure materials. The impurities may be introduced in mixing or in formulating with fillers, or may stem from metal storage cans or drums.

Measuring ionic material

To detect and measure ionic material in plastics, samples of the plastics can be pulverized and then digested in distilled water at 160°F for eight days. The electrical conductivity of the water extracts is then measured.

Although there is uncertainty about the extent of hydrolysis that occurs during the digestion period, the results are useful as a relative indication of the amounts of ionic and ionizable species in the sample, as well as of the hydrolytic stability of the plastic under these conditions. Of the materials tested, the epoxies and phenolics had rather low resistivity values, as shown on page 106. This isn't surprising considering the types of probable contaminants and the emission spectrographic results. The silicone and fluorocarbon extracts, on the other hand, had comparatively low conductivities.

It has also been demonstrated (curves, p. 105) that the deviation from stoichiometry of the epoxy system affects the water extract conductivity. By stoichiometry is meant the exact proportions in which the resin and hardener will combine according to molecular equations.

Electrical effects

In one experiment, plastic coatings were applied to bare microdiodes. To study surface inversion, the diodes were then reverse biased at elevated temperatures. Because of the high insulation resistance values for most plastics (see graph on page 105), ohmic leakage through the plastic coating was assumed to be negligible compared to the reverse conduction current exhibited by the device. With some plastics, however, such as the cast epoxy

Moisture resistance of plastic coatings

Plastic coating	MVTR*	Source
Epoxy-anhydride	2.38	Autonetics data
Epoxy-aromatic amine	1.79	Autonetics data
Neoprene	15.5	Baer (Ref. 11) (39° C)
Polyurethane (Magna X-500)	2.4	Autonetics data
Polyurethane (isocyanate-polyester)	8.72	Autonetics data
Silicone-alkyd	6.13	Autonetics data
Silicone-alkyde (microdiode coating)	7.9	Autonetics data
Olefane, polpropylene	0.70	Avisoun data
Cellophane (type PVD uncoated film)	134	du Pont
Cellulose acetate (film)	219	du Pont
Polycarbonate	10	FMC data
Mylar	1.9	Baer (39°C)
	1.8	du Pont data
Polystyrene	8.6	Baer (39°C)
	9.0	Dow data
Polyethylene film	0.97	Dow data (1 mil film)
Saran resin (F120)	0.97 to 0.45	Baer (39° C)
Polyvinylidene chloride	0.15	Dow data (1 mil film)
Acrylonitrile co-polymer		
Polytetrafluorethylene (PTFE)	0.32	Baer (2 mil sample 40°C)
PTFE, dispersion cast	0.2	du Pont data
Fluorinated ethylene propylene (FEP)	0.46	Baer (40°C)
Polyvinyl fluoride	2.97	Baer (40°C)
Polyvinylidene fluoride (Teslar)	2.7	du Pont data
p-polyxylyene (parylene N)	14	Union Carbide data (2 mil sample)
p-polyxylylene (parylene C)	1	Union Carbide data (2 mil sample)

* (Moisture vapor transmission rates in grams/mil/100 sq. in. in 24 hours)

Contaminants originating in epoxy plastics

Ingredient	Types	Synthesis ingredients	Potential contaminant
Epoxy resin	Epon 828 815 (etc)	Epichlorohydrin	
		Dichlorohydrin	Cl^-
		Allylchloride	HO Cl
		Propylene	
		NaOH	Na^+, OH^-
		Bisphenol-A	$-C_6H_4-OH$, Na^+, OH^-
		Acetone	$(CH_3)_2\,C{=}O$
		Benzene	$C_6\,H_6$
		HCl or HBr catalysts	H^+, Cl^-, H^+, Br^-
		Phenol	$C_6H_5\,O^-$, H^+ CO_2 H_2O, Na^+,
		Sodium orthosilicate	$CO_3{=}Na^+$ SiO_4^{-4}
Curing agents	Ethylene diamine	Dichloro-ethylene	NH_4^+, Cl^-
	Diethylene triamine	NH_3	NH_3
	Polyamides (Versamids)	Polymerized vegetable Oil acids	$RCOO^-$, H^+
		Polyalkylene amines	Cl^-
		Polyalkylene chlorides	
	Acid anhydrides	Carboxylic acids	$R(COO^-,\ H^+)_2$
Fillers	Alumina	—	Al^{+3} Si^{+4}
	Cabosil Silica	—	Trace metal ions
Pigments	Titania	—	Ti^{+4}
	Carbon blacks	—	C
	Calcium carbonate	—	Ca^{+2}, $CO_3{=}$
Solvents	Ketones	—	$(R)_2\,C{=}O$
	Esters	—	$R\ COO^-$, H^+, RO^-H^{+1}
	Ethers	—	ROR
	Halogenated hydrocarbons	—	Cl^-
	Toluene	—	$C_6H_5CH_3$
	Xylene	—	$C_6H_4(CH_3)_2$
	Alcohols	—	ROH
	Cellosolves	—	
Flow control agents	Beetle resins	Urea	NH_4^+, NH_3, CO_2 H_2O, $CO_3{=}H^+$
	SR-82 Butvar	Silicone Polyvinyl butyral	
Fire retardants	Antimony trioxide	—	Sb^{+3}
	Arochlors	Chlorinated polyphenyls	Cl^-
	Brominated or chlorinated resins		Br^-, Cl^-

This table should not be construed as a complete list of ingredients and contaminants. Potential contaminants are those constituents inherent in the material or, under some conditions of temperature, hydrolysis, or other stress, derivable from the material. Unreacted or excess synthesis ingredients due to nonstoichiometry may also act as contaminants. A listing of fillers and reinforcements is given in reference 9; solvent and solvent combinations commonly used with epoxies are given in reference 10.

listed in the graph, ohmic leakage could be a factor. Polyethylene is included in the graph for comparison purposes; it is not a candidate for packaging semiconductor devices.

In the diode experiments, technical-grade and specially purified epoxies (employing molecularly distilled reactant materials), epoxies with stoichiometric and nonstoichiometric ratios of resin to hardeners, and fluorocarbons (TFE and FEP Teflons) were applied to devices and cured according to vendors' recommendations. The devices were then subjected to 150°C heat for varying periods of time, with a reverse bias of 75 volts. After this, they were cooled to room temperature with the voltage removed. Changes in reverse current observed under these conditions are tabulated below.

Similar plastic-coated microdiodes were exposed to 95% relative humidity at 160°F with a 75-volt reverse bias. Typical values of reverse current measured after the diodes were removed from this atmosphere are shown on page 108.

The fluorocarbon-coated and silicone-coated diodes generally exhibited smaller changes in reverse current than did the epoxy-coated diodes. However, large changes in reverse current—from nanoamperes to microamperes—indicate that the commercial-grade epoxies tested contained sufficient amounts of ionic or other contaminants to affect the semiconductor. Also, the epoxies with nonstoichiometric resin-to-hardener ratios displayed high values of reverse current. One or more high values or electrical opens occurred in each category; the latter were probably due to stress or mechanical damage rather than to impurities.

In other studies,[2] microdiodes coated with phenolic material exhibited high I_R; both experimental results and theoretical considerations suggest the presence of large amounts of such impurities as ammonium ions. The table below shows that the reverse-current characteristic decreases after heating for a time without electrical bias, presum-

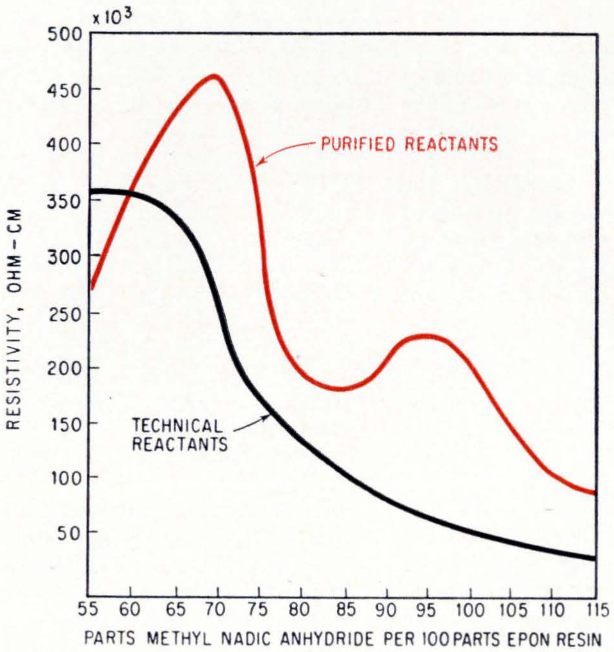
How temperature affects reverse current of plastic coated diodes

Coating systems	Initial reading I_R (na) @ 50v	I_R (na) @ 50v after 20 hours @ 150°C and 75v rev. bias	I_R (na) @ 50v after additional 20 hours @ 150°C no rev. bias
Epoxy, stoichiometric purified	10	548	14
Epoxy, nonstoichiometric purified	9	10×10^3	10×10^3
Epoxy, stoichiometric technical	12	237×10^3	121×10^3
Epoxy, nonstoichiometric technical	12	31×10^3	14×10^3
Fluorocarbon, resin, FEP Teflon	17	18	16

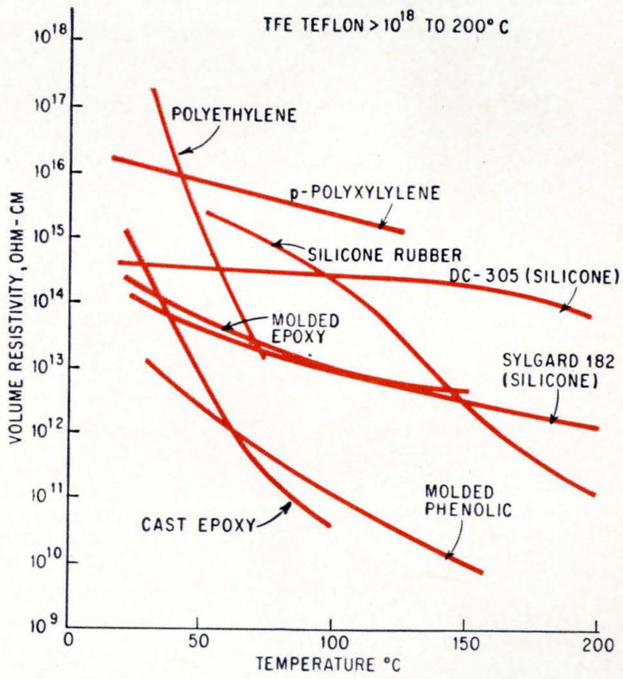
Spectrographic analysis of plastics

Sample	Condition	Metals detected	Relative amounts*
Epoxy, Epon 828	As received	Copper, aluminum, magnesium silicon, calcium	Traces
Epoxy, Epon 828	Still residue after molecular distillation	Silicon,	Major
		Magnesium, aluminum, iron copper, chromium, calcium, manganese	Traces
Epoxy, Epon 828	Distilled, light molecular weight fraction	Copper	Trace
Silicone, Sylgard 182	Cured	Silicon,**	Major
		Titanium, magnesium	Slight traces
Silicone coating, DC 644	Cured	Silicon	Major
		Copper, magnesium	Slight traces
		Zinc	Trace
Silicone molding compound, DC-305	As received and molded	Silcon, chromium	Major
		Lead, titanium, nickel, copper, manganese, aluminum and magnesium	Traces
		Iron, cobalt	Minor
Silicone gel coating, DC-51	Cured	Silicon	Major
Phenolic molding compound	As received	Calcium	Major
		Magnesium	Minor
		Iron, silicon, sodium	Traces
		Copper, manganese, aluminum	Slight traces
Teflon, TFE	Dispersion coating, fused	Copper, magnesium	Slight traces
Teflon, FEP	Dispersion coating, fused	Copper, titanium, magnesium	Slight traces
Teflon, TFE	Molded solid	Titanium	Slight trace
Teflon, FEP	Molded solid	Copper, titanium, magnesium	Slight traces
Kynar	Dispersion coating, fused	Titanium, copper, magnesium	Slight traces

* Major, 5% or more; Minor, 0.10 to 5%; Trace, 0.01 to 0.10%; Slight trace, 0.0001 to 0.01% (percentages are by weight of ash).
** Silicon is a structural constituent of silicones and should not be considered an impurity.



The ratio of hardener to resin affects the volume resistivity of the plastic encapsulant. Technical reactants are commercial-grade chemicals; purified reactants are those that have been further purified to remove contaminants.



Volume resistivity of plastic coatings varies with the type of plastic. It decreases with rises in temperature. Molded epoxy gave results similar to the Sylgard 182, and resistivities for a molded phenolic sample ranged from 10^{13} to 10^{10} ohm-cm.

Water extract resistivities

Material	Average resistivity (ohm-cm) $\times 10^3$
Epoxy-anhydride-epoxy coating	9.0
Epoxy molding compound	107
Phenolic molding compound	4.7
Alkyd-silicone coating (DC 1400)	11.5
Alkyd-silicone coating, Vendor A	14.7
Alkyd-silicone coating, Vendor B	65
Methyl-phenyl silicone coating	270
Silicone molding compound (DC 305)	155
Silicone molding compound (DC 304)	290
Silicone (Sylgard 182)	195
Silicone coating A	60
Silicone coating B	180
Silicone coating C	190
Silicone gel coating, DC-51	360
TFE, Teflon, dispersion coating	93
TFE, Teflon, molded solid	350
FEP, Teflon, dispersion coating	177
FEP, Teflon, molded solid	198
Kynar, dispersion coating	212
Kynar, solid	335
Distilled water (control)	732

ably because ordered ions on the surface are moving to a more random state.

The excellent results with fluorocarbons may be attributed to these plastics' inherently inert, stable, and symmetrical structure. In fact, TFE and FEP Teflons are unique among plastics in their purity, thermal and oxidative stability (up to 500-600 F), chemical inertness, low rate of moisture permeability, and electrical stability.[9] Teflon essentially has a zero temperature coefficient of resistance to temperatures above 200°C, in contrast to the high negative values of most plastics.

MOS studies

Discrete metal oxide semiconductor devices and MOS integrated circuits containing a number of functional MOS elements have been plastic-coated and tested to evaluate the space-charge mechanism described on page 102. Dual MOS transistors without diode-protected gates or surface passivation were mounted in TO-5 cans without lids and were coated with a variety of silicones. Among the parameters measured were those identified in the table on the opposite page as "failure indicators."

When attempts were made to apply Teflon plastics to MOS devices, the high temperatures—500°F to 700°F—needed to fuse the fluorocarbon particles raised havoc. Interconnection-bond failures were probably caused by purple plague or, more generally speaking, by the formation of brittle gold-aluminum intermetallics due largely to the heat.

Plastic semiconductors: like glued-together automobiles?

Caution urged by users such as Autonetics is shared by some device manufacturers; others back their confidence in plastic with guarantees to meet military specifications

The trend to nonhermetically sealed device packages seems irreversible—even for highest-reliability military and aerospace applications.

Last month, both the Signetics Corp. and Motorola Inc. announced that they have accumulated sufficient data to guarantee their dual in-line plastic-packaged integrated circuits over the full military temperature range, $-55°C$ to $+125°C$. In this regard they join Texas Instruments Incorporated, who as long ago as last August was extrapolating the results of 2 million hours of transistor testing to suggest that plastic-covered IC's could meet the military specification.

Today, says TI's manager of IC quality control, James Adams, "we are getting many requests for plastic IC's over the full military temperature range."

Negative vote. Tending to agree with those equipment manufacturers who remain skeptical of the reliability of plastic packages in unlimited applications, Fairchild Semiconductor, a division of the Fairchild Camera & Instrument Corp., files a dissenting opinion among vendors. Says Fairchild's quality control manager, Bryant Rogers, "We only build plastic packages for certain markets—primarily industrial and consumer."

Rogers acknowledges that competitors have published some impressive test results on the performance of plastic-packaged IC's. "The trouble lies," he says, "in correlating those figures with conventional tests. Hermeticity gives a figure of merit for the predictable life of IC's, but you can't test for hermeticity where there is no void. Tests of the plastic package have a different criterion, which you can't yet correlate with the old."

The new tests performed by plastic-device manufacturers may be valid, concedes Rogers, but they are different. "Suppose someone marketed an automobile that was put together with Elmer's glue, and published data to show that it was as good as a welded car. You might believe the data—but would you buy the car?"

For Fairchild, the question of plastics is in some respects moot, since it is banking on a flip-chip dual in-line package [Electronics, Mar. 6, p. 153] to reduce costs. Plastics cost just as much as ceramic, Fairchild insists. "The flip-chip ushers in a new era of reliability," says Rogers, "which will exploit automatic assembly techniques to cut costs."

Inner sanctum. New methods of passivating the semiconductor chip, such as the silicon-nitride approach pursued by Bell Telephone Laboratories and others, may be forerunners of techniques that will get to the heart of the device and make the purity of additional protective coatings not at all critical.

What vendors claim for today's devices depends partially on the

Test results for silicone-coated MOS transistors*

Coating	Sample size	Number of failures		Failure indicator	
		After 77 hours	Additional after 1000 hours	After 77 hours	After 1000 hours
Controls (uncoated canned)	10	none	none	—	—
Coated, Silicone A	7	2	1	$V_{(th)GS}$ 2 failures BV_{DSS} 2 failures I_{DSS} 2 failures	$V_{(th)GS}$ 1 failure BV_{DSS} 1 failure I_{DSS} 1 failure
Coated, Silicone B	13	none	2	—	$V_{(th)GS}$ 1 failure BV_{DSS} 2 failures I_{DSS} 2 failures
Coated, Silicone C	7	2	1	$V_{(th)GS}$ 1 failure BV_{DSS} 2 failures I_{DSS} 1 failure	$V_{(th)GS}$ 1 failure BV_{DSS} 1 failure I_{DSS} 1 failure
Coated,** Silicone dielectric gel	10	none	none	—	—

* Static tested 125°C, 150 milliwatts.
** Gel-coated devices were subjected to an additional 1,000 hours of temperature-power stresses to complete a total of 2,000 hours without in-test failures. Three in-test failures occurred among the controls toward the end of this second 1,000-hour period.

This wasn't a problem in the other tests where fluorocarbons were applied to diodes, because more thermally stable gold-silicon bonds were employed.

While test results indicated little initial reaction to the encapsulant, many silicone-coated devices operating in a static life test at 125°C with power applied failed at about 70 hours.

Notable exceptions were devices coated with a silicone dielectric gel (DC-51); in these cases, 20,000 socket hours were achieved without any in-test failures. Although some failures cropped up in the control units, none occurred with the units coated with DC-51. This can be attributed to the coating's high degree of purity, evidenced by low

kind of plastic used. The Signetics Corp.'s mil spec package is all silicone, but it is made in two layers. The company first tried an epoxy outer layer, but switched to the silicone because it provided better resistance to moisture and made a better thermal match with the initial silicone layer.

TI uses a single-material epoxy system that, like the Signetics package, is transfer molded. Motorola has a two-layer system but won't disclose the materials used.

RCA, after expressing some doubt about the need for plastic IC packages [Electronics, Sept. 5, 1966, p. 38], last month announced plans for IC's in silicone packages.

Bandwagon. Companies such as Sylvania Electric Products Inc., a subsidiary of the General Telephone & Electronics Corp., and the Transitron Electronic Corp., who have experience with discrete semiconductor components in plastic, plan to market plastic IC's.

Transitron envisions a May or June introduction of a line of epoxy-encapsulated IC's. Edward Shaut, the firm's IC product sales manager, says: "We aren't promoting them for military use, but if they turn out the way we expect them to, they will be reliable enough for military equipment."

Sylvania, too, plans to put integrated circuits in epoxy packages. Roger Swanson, marketing manager for the company's semiconductor division, says: "Except for the extreme reliability required for missiles and some other aerospace uses, epoxy packages appear to be adequate for most semiconductor applications, and in fact are being designed into computer, industrial, and consumer gear."

Mufti or military? At least one vendor is surprised that aerospace equipment manufacturers would consider plastic. "If you're going to buy junk, you're going to get junk," he declares. "For military-grade equipment, you just don't use it."

But, TI's Adams feels such comments reflect the "emotion that was prevalent in 1961." There was some trouble with plastic packaging in the early 1960's, he says, "but great strides have been taken since then in both materials and methods."

Engineers at Autonetics plan to conduct physics-of-failure studies of plastic-packaged devices to explain anomalies observed in earlier tests, rather than to intensively study the purity and properties of the plastics. The plastics will, however, be categorized with respect to known or probable impurities and their concentrations.

Such information could be obtained from chemical analysis, manufacturing-process data, or estimates of rates of likely deterioration modes. Also useful, Autonetics notes, is information from degradation studies being carried out for space applications, such as data on plastics in an oxygen space-capsule atmosphere[1] and on radiation effects.[2] But Autonetics cautions that potentially harmful levels of impurities may not be detectable with present instruments.

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water-extract conductivity and the absence of metallic impurities in spectrographic analysis. Since the material is also very soft, it imparts little stress to devices in the curing process. Because of its softness, though, it requires the use of an auxiliary rigidizing plastic to complete the package.

Because such characteristics as dipoles in the molecule or the plastic's adhesion to the devices may contribute to the deterioration of electrical parameters, no one property in the other silicone coatings can be confidently designated as the principal cause of failure. However, it's noteworthy that none of the other three silicone coatings tested exhibited the high purity and resistance to mechanical stress of the DC-51.

How humidity affects reverse current of plastic coated diodes

Coating systems	Condition	Initial I_r (na) @ 50V	I_r (na) @ 50v after 96 hr @ 160°F & 95% RH, 75v rev. bias
Epoxy-anhydride*	Stoichiometric purified	8 8 8 6 8 11	11 7 9 5 8 12
Epoxy-anhydride	Nonstoichiometric, purified	10 8 13 11	10 7 8 69,000
Epoxy-anhydride	Stoichiometric, technical	10 8 9 13	9 9 Open failure 650
Epoxy-anhydride	Nonstoichiometric, technical	9 11 10 16 12 14	9 9 193 Open failure 199 11
Fluorocarbon, FEP Teflon**	Dispersion coating	11 12 8 32 9 17	8 12 8 13 9 19
Fluorocarbon, Kynar	Dispersion coating	8 10 52 17 15 15	8 10 45 13 16 15
Silicone, elastomeric room temperature curing	Dispersion coating	14 20 14 13 19 9 1.16×10^3	15 17 15 9 18 8 Open failure
Uncoated	Not applicable	9 6	Open failure Open failure

* All epoxy-anhydride systems were cured 16 hours at 248°F followed by 1 hour at 356°F.
** Three thin coats were used with fusion at 575°F for 5 minutes after each coat.

Recommendations

Preliminary tests of the interaction of epoxy, phenolic, silicone, and fluorocarbon plastics with semiconductor devices under various environments have indicated that contaminants inherent in or generated by the plastics can affect device performance. Therefore plastics must be classified with respect to contaminants in resins, hardeners, and formulation ingredients, and in terms of their probable effects on semiconductors.

To assess the effects of molecular polymer structure and polarity on semiconductor parameters, ultrapure polymer types will have to be prepared. The task requires new or refined ultramicroanalytical methods.

For the packaging of high-reliability, long-life military and space devices, a more fundamental understanding of plastics' characteristics and their effect on electrical parameters is necessary.

Epoxies or silicones may well be satisfactory for the outer rigidizing coating, which also provides an additional barrier to ambient moisture and contaminants. In this case, the inner barrier should probably be a high-purity flexible coating. However, until long-term exposure data is acquired on the transmission of impurities to the semiconductor through the flexible inner coating, caution should be employed in using such packages for high-reliability, long-life applications. The ideal, of course, would be an ultrapure material for both the surface coating and encapsulant.

However, the purity of the initial plastic layer may become less important as improvements are made in the integrity of the passivation layer and as more reliable passivation materials and techniques are developed.

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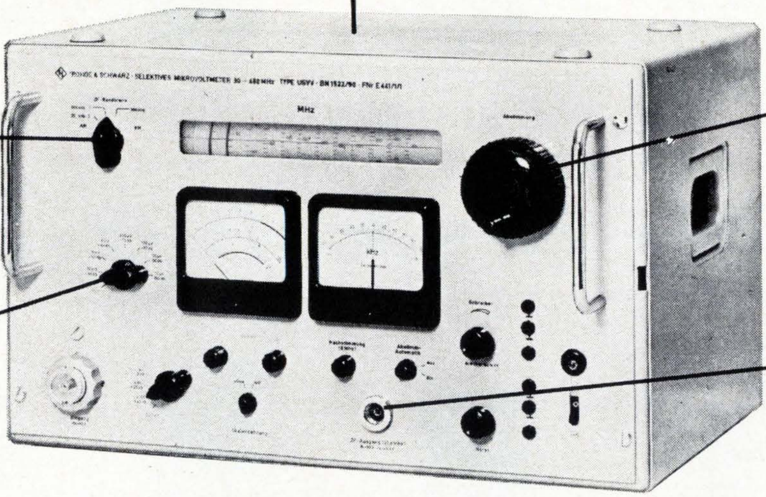

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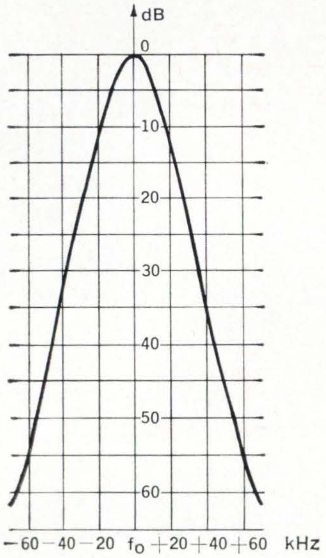

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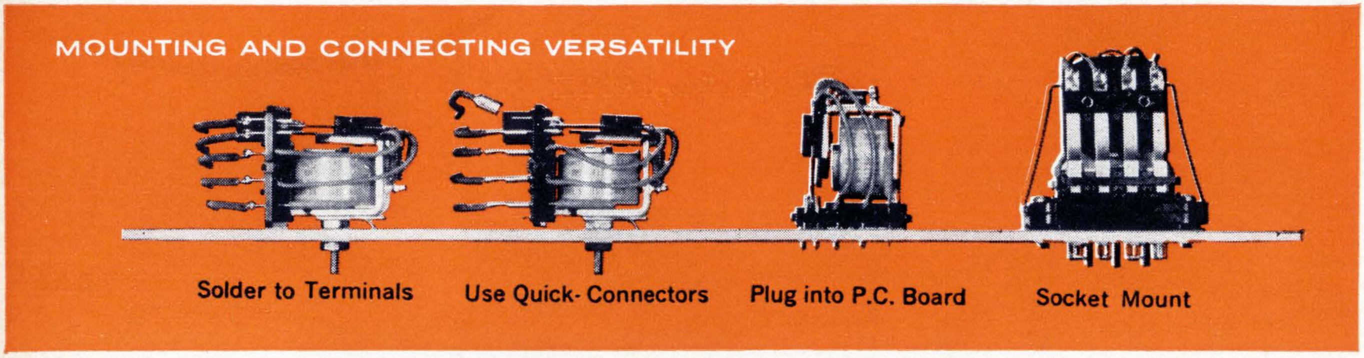

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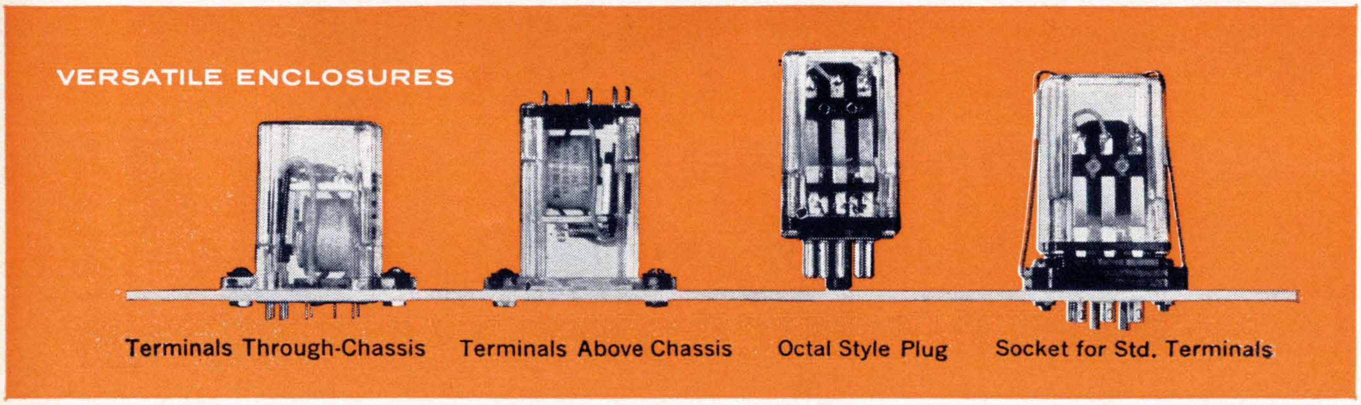

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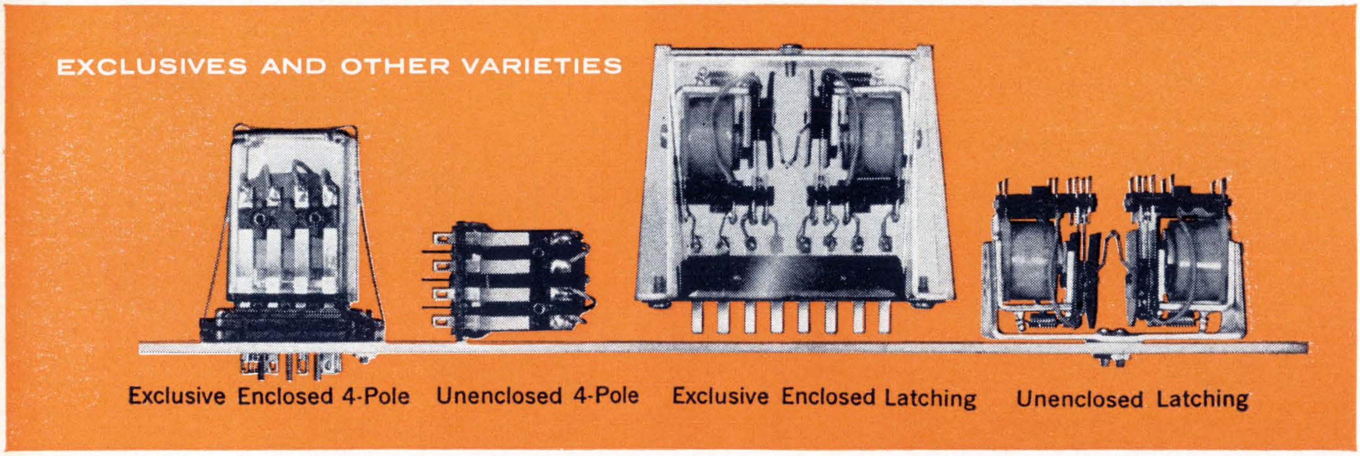

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Advanced technology

Taking cryoelectric memories out of cold storage

A new loop cell operating in a new memory organization renews hope for a low-cost, high-speed cryoelectric mass-storage medium to replace magnetic disks and tapes

By Robert A. Gange

Radio Corp. of America, Electronic Components and Devices Division, Princeton, N.J.

Successful operation of a 14,000-bit cryoelectric memory system that combines a new memory element and a new organization once again thrusts cryoelectrics into contention as a means for attaining a fast, large, low-cost memory. The twin developments should serve to bring new emphasis to a field that has suffered from a marked decrease in interest during the past few years.

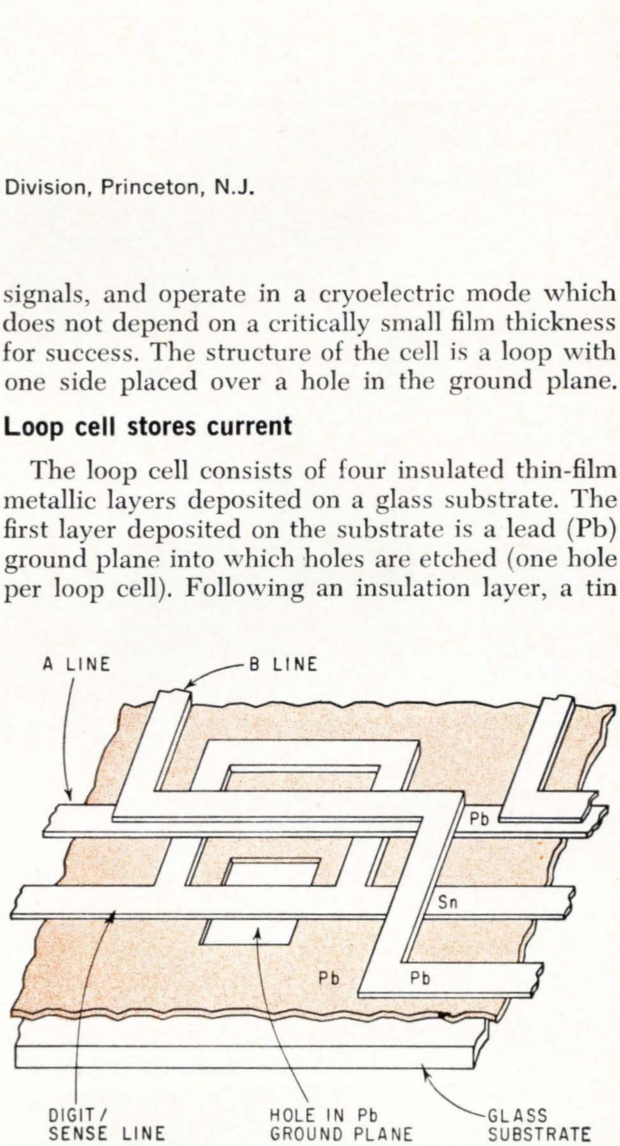
Although many cryoelectric memory elements have been developed in the past, none led to a full-scale memory system. There are three major reasons why success has been so elusive; the memory elements weren't able to take wide ranges of dimensional tolerances, little work was done on designing the optimum memory system, and the address decoding trees were built as cryoelectric switching elements instead of normal, room-temperature decoders. The new system either avoids or overcomes these obstacles.

The first experimental model of the new system uses four cryoelectric memory planes to provide a cycle time of 4 microseconds, $\pm 10\%$ tolerance on drive currents, and operates in a Dewar flask at liquid helium temperature of 3.5°K. Each plane measures 2 by 2 inches and contains 6,000 bits at a density of 6,500 bits per square inch, although a total of only 14,120 bits are actually used in the system. A 250,000-bit plane with 13,200 bits in^2 density now is being assembled to serve as the basic building block of a larger system. The success of the experimental system thus points the way toward systems as large as a billion bits. The economics of a memory of this size is feasible because of low-cost storage and savings in driving circuitry.

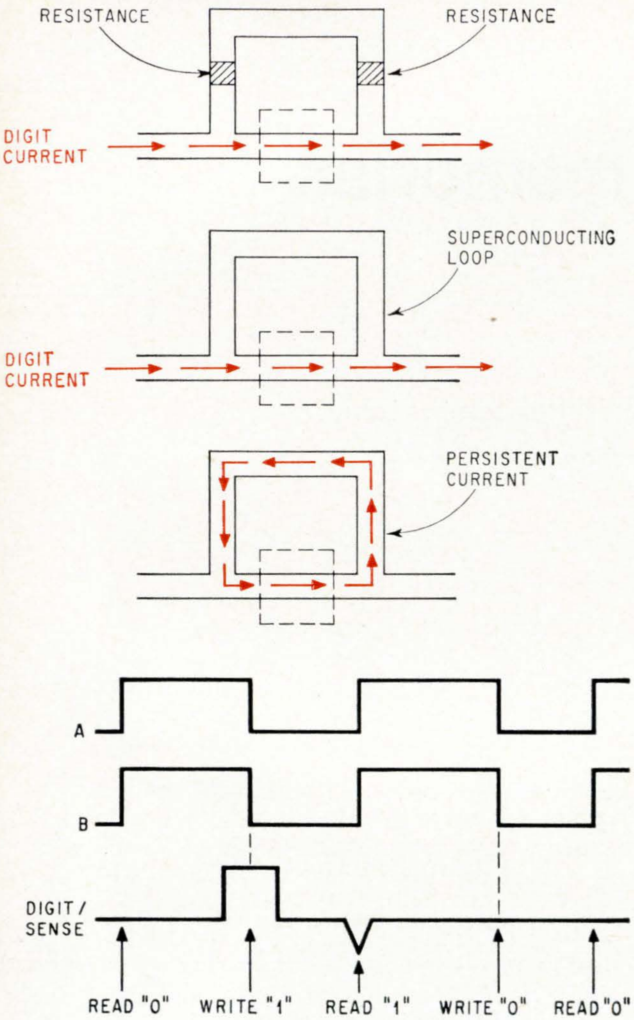
The memory elements are constructed to have no cell-to-cell interaction, provide adequate sense signals, and operate in a cryoelectric mode which does not depend on a critically small film thickness for success. The structure of the cell is a loop with one side placed over a hole in the ground plane.

Loop cell stores current

The loop cell consists of four insulated thin-film metallic layers deposited on a glass substrate. The first layer deposited on the substrate is a lead (Pb) ground plane into which holes are etched (one hole per loop cell). Following an insulation layer, a tin



Typical loop cell has four superconductive layers separated by silicon monoxide insulating layers (the insulating layers are omitted for purposes of clarity). The hole in the ground plane produces more inductance in the portion of the loop which crosses over it than in the other three sides of the loop. The flux produced by current flowing over the hole is trapped in the loop and causes a circulating current, which corresponds to a stored logic binary 1.



Operation of the loop cell: the A and B line current pulses switch two portions of the loop to the resistive state, forcing the digit current to flow through the high inductance path over the hole in the ground plane. When the A and B currents go to zero, the resistance disappears and the flux set up by the digit current causes a circulating current to flow in the loop. The circulating current corresponds to a binary 1. The contents of the cell can be read on the leading edge of the A and B current pulses. If a current is stored in the loop, the resistance caused by the A and B currents force it to decay to zero, inducing a voltage in the digit-sense line.

digit strip, or sense line, containing the rectangular loops is laid down. Three sides of the loop project from the sense line. The fourth side of the loop crosses over the hole in the substrate. Two lead (Pb) drive line layers then are deposited over an insulating layer that covers the layer containing the loops. The drive lines A and B are superimposed, in line and insulated, as they cross the loop perpendicular to the sense line about midway between the sense line and the outer edge of the loop. Current in these drive lines will switch part of the loop to the resistive state.

The inductance of the path that crosses the hole is higher than the inductance of the path formed by the other sides of the loop that pass over the ground plane.

A binary 1 is written into a cell by applying select currents to the A and B lines and a digit current to the sense line and then removing the select currents before removing the digit current. The following events occur in sequence:

The select currents switch the tin to the resistive state, and the digit current flows through the high inductance path over the hole in the ground plane, where it sets up a flux in the loop.

When the select currents are removed, the low inductance path returns from the resistive to the superconducting state.

The flux produced by the digit current passing through the high inductance zero resistance path, however, is trapped in the loop.

When the digit current is removed, a circulating current is established in the loop, which corresponds to the binary 1.

Readout is obtained by monitoring the voltage across the sense line during the leading edge of the select current in the absence of a digit current.

If a 1 had been stored in the cell, the sudden change to the resistive state would cause the circulating current to decay to zero and a voltage would be induced in the sense line as the flux in the loop collapses.

Hybrid organization

The new hybrid system enhances the fundamental advantages of cryoelectric memories over those of conventional ferromagnetic core memory system. The relatively high inductance of the magnetic core memory's drive lines and cells is conducive to noise and necessitates repetition of the electronic hardware as the bit capacity of the system is increased. In addition, the number of bits a single decoder may drive decreases with faster cycle time.

In the cryoelectric hybrid system, essential for this application rather than the word and bit-organized systems, the substantially perfect diamagnetic property of metals in the superconducting state results in negligible inductance of the drive lines even in very large bit capacity memories, and it also effectively eliminates all interaction and noise on the substrate. Thus, only one pair of decoders and drivers is required for the entire hybrid system. The decoders and drivers are quite modest in size and complexity, and the reliability of the electronics can be made very high. The isolation between cells and high signal-to-noise ratio at the substrate permits the unambiguous detection of sense signal levels of very low energy content, which in turn permits very high cell packing density.

The cell's energy density, however, causes interdependencies among the system components which are not present in the conventional, rather large storage elements. Therefore, both the cryoelectric cells and the system in which they are to operate were developed together.

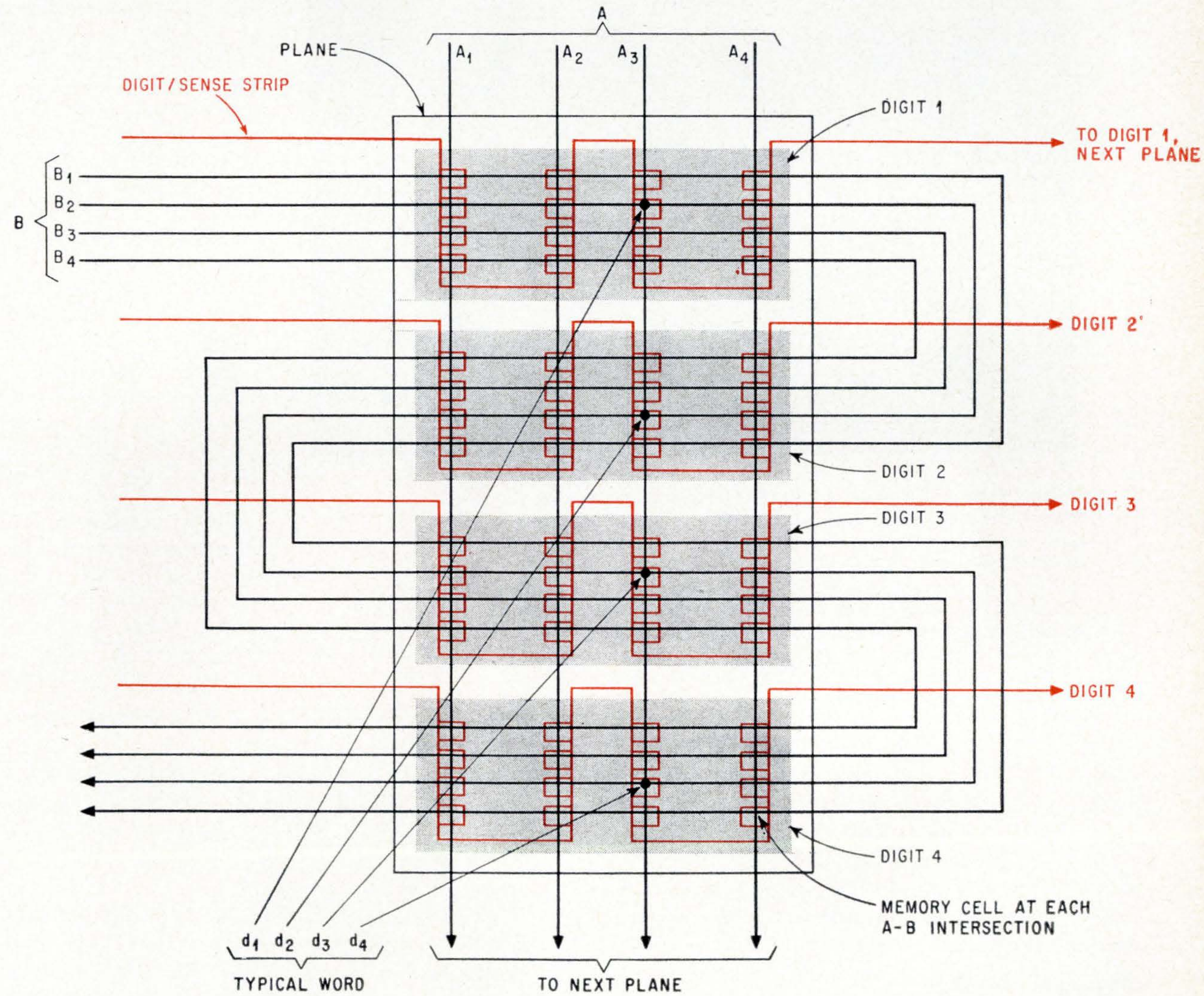
In the hybrid (word-bit) system, the select drive lines are designated as A and B lines. A memory cell or storage loop exists beneath each A and B line intersection. The A drive lines are serially interconnected from plane to plane in the stack. A single A decoder, functioning at room temperature, drives a select A line through all the planes of the stack. Only one A decoder is required because of the negligible inductance of the drive lines.

The B drive lines intersect the A lines many times on a plane, requiring few B lines per plane for a large bit capacity. The selection of a particular A and B line results in the simultaneous activation of a number of bits on a plane, which constitute an entire word. The number of digits in the word is equal to the number of intersections of any A line with any B line on a plane. The B lines on each plane are grouped into digit segments and are independently connected to a decoder at room temperature.

The B line digit segments identify memory cells common to a given digit of all the words on the plane. Each of the storage loops common to a given digit on a plane comprises one digit strip. Therefore, the number of digit strips on a plane is equal to the number of digit segments or digits of a word. The output of all digits of a selected word simultaneously appears across the terminals of the digit strips of the selected plane. Each plane, then, consists of a number of words equal to the product of the number of A and B lines.

A given number of digit strips, one per plane, and common to a given digit of the word, are connected in series and across the primary of the output transformer. Write current is applied serially to the group of digit strips associated with a common digit. The sense signal output from any one of these digit strips appears across the primary winding of the sense output transformer. Since only one B line is activated, for a given address, only one of these digit strips is activated during a given read interrogation.

The hybrid system provides for a length of digit strip substantially shorter than in other memory organizations, which increases the yield and reduces the sense output signal attenuation and the write



Conductor arrangement for the hybrid memory organization is shown for a hypothetical 16-word, 4-digits-per-word memory plane. Shaded areas represent the four digits of the words. The four digits of a particular word are located by the four intersections of a particular A line and a particular B line; lines A_3 and B_2 are shown as an example. One digit-sense strip is used for each digit area. Thus, if a binary one were stored in each of the A_3-B_2 intersections, each of the sense lines would produce a simultaneous readout.

Cryoelectric memories: will they finally make good?

Author Gange examines a 250,000 bit cryoelectric memory plane arranged in 64 modules of 4,096 bits each. Studies indicate that is feasible to build a 10^8 bit memory using 512 of these planes operating in a coincident-current, random-access mode and with microsecond cycle times. Successful operation has already been obtained with smaller, 6,000-bit planes operating in a 14,000-bit cryoelectric memory. The planes are arranged in stacks and operated at liquid helium temperature, 3.5° K.

RCA's success with a cryoelectric memory comes at a time when there is a greater need than ever for a fast mass store to replace magnetic tape and disk memories. Software costs—now greater than hardware costs—could be decreased greatly, since much of the software is devoted to shuffling information back and forth between the main core memory and the large, slow, tape or disk memory. With a high-speed memory as the mass store, these software costs might be cut by as much as 10:1. Further, computer through-put could be increased with a corresponding decrease in cost per computation.

A high-speed mass store would also find ready use in information switching, where data arrives at a central location from many sources, is stored, and then is retransmitted. Though the individual data rate on each line is only moderate, the total rate of data assimilation by the memory in this application is quite high.

The new loop-cell cryoelectric memory is the latest, most promising development in the long, checkered history of superconductivity and its application to computing techniques.

Buck's cryotron. The first application of cryoelectrics to computer elements occurred during the early 1950's when Dudley Buck, an engineer at the Massachusetts Institute of Technology's Lincoln Laboratory, developed a resistance switch, which he labeled a "cryotron".[1] It consisted of a piece of superconducting tantalum wire operating below its critical temperature of 4.4°K, about which was wound a coil of superconducting

noise. The hybrid system, since it is of modular construction, also permits the memory to be evaluated plane by plane instead of in a complete stack. Thus the stacks can be designed for complete plane-to-plane isolation instead of forcing a design where memory cells on different planes must operate simultaneously with no interaction.

Cryotrons eliminated

The use of room temperature decoders endows the system with many advantages over a system that uses cryotron decoders. First of all, if the cryotron decoder is built on the same substrate as the memory cells, it is difficult to evaluate them separately. Ideally, the decoding tree should be evaluated with a fully checked out memory plane and vice versa. But with cryotron decoders, they are substantially inseparable.

With the cryotron decoder, the address currents and the cell drive currents are sent down into the Dewar flask to the decoding tree. One address line is used for each digit of the address. The drive currents are controlled by the address currents in the cryotron tree and routed to the proper cell in the plane. The address currents run serially from plane to plane and since many cryotrons must be niobium whose magnetic field switched the tin from the superconducting to the resistive state. The major disadvantage of the device, however, was its slow speed, caused by the long time constant associated with its high inductance-to-resistance ratio, and the long thermal recovery time of the tantalum.

Soon thereafter, a thin film version of the cryotron was proposed in which the inductances of both the control and the switched element were substantially reduced by the proximity of a superconducting ground plane. Difficulty in the vacuum deposition of thin films of tantalum and niobium soon brought about a change to tin and lead.

Many thin film memory devices were proposed during the 1950's, but each appeared to suffer from one or more serious problems, which, when solved, resulted in a cryoelectric system with minimal advantages over existing magnetic memory systems. A further obstacle to researchers was the lack of a comprehensive theory of superconductivity.

BCS theory. In December 1957, Bardeen, Cooper, and Schieffer, of the University of Illinois published their now celebrated "BCS" theory of superconductivity in which the phenomenon's relationship to basic solid state theory was defined, and basic material parameters were related meaningfully to observed constants.[2] This perspective of the superconducting phenomenon led to an understanding of the behavior of very thin superconducting films in response to normal components of applied field, such as occurred along the edge of the cryoelectric cell.

Sheet memory. In 1960, Burns and his coworkers at the Radio Corporation of America Laboratories published a paper describing outstanding performance characteristics of a "continuous sheet memory," which was void of edges.[3] In the period between 1960 and 1964 many investigators both here and abroad attempted to develop a practical memory of this type. However, the performance could not be systematically reproduced, especially over large areas due to formidable material problems. Work in the area of superconductive random access memories substantially declined thereafter.

Nonlocal mode. Gange and his group made a sober appraisal of the developments between 1954 and 1964 and saw a characteristic essentially common to the many diverse approaches; the devices operated in a "local" mode, where the current density at every point is directly related to the magnetic field at that point, or is "locally" related to the field. The criterion for operation in this mode is that the magnetic field penetration depth must be greater than the distance between two bound electrons, which travel as a pair through the superconductor. If the film is thin, then the superconductor will operate in this mode.

In such a mode, however, the operating current levels are indirectly dependent upon such factors as grain size and orientation, impurity concentration and type, film thickness, dislocations, vacancies, interstitial atoms, and point defects. At the state of the art which existed at that time (and which still exists) it was impossible to control these parameters to the extent necessary for the realization of a practical memory and therefore the cells had uniform electrical characteristics.

Thus, in 1964, an operating mode which depended only on the gross bulk material properties was seen as a requirement for achieving a practical cryoelectric memory. To operate in this "nonlocal" mode, it is necessary to ensure a film thickness larger than the separation between two bound electrons.

However, the film thickness cannot be indiscriminantly large or the inductive time constant of the device will be excessive due to the smaller restored resistance value. This film thickness requirement necessitated the reintroduction of structure to the element to ensure flux trapping, and a photolithographic fabrication technology to ensure reasonably systematic elimination of tapered film edges, which would cause local-mode operation.

Hybrid organization. Because of the difficulties with the earlier memory cells, the memory organizations were never fully evaluated. After designing a new memory cell that operated with wide tolerances, Gange, working with J.J. Carrona, manager of the cryoelectric device laboratory, and engineers H.G. Scheible, E.M. Nagle and J.F. Thompson, developed the new memory organization.

The work was partially sponsored by the Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.

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switched, the address currents must be large enough to switch the poorest cryotron.

For example, if the planes were made up of a matrix of 1,024 by 1,024 bits, then 10 address currents would be needed for the A direction and 10 for the B direction. Two drive currents per plane would be used, one for A and the other for B. The address currents steer the drive currents on the substrate, and therefore must be much larger than the drive currents. In turn, the drive currents control the digit currents in the individual cell and are still larger. Thus, the address currents end up being many times larger than the currents in the cells which are eventually used to store the data.

This causes interaction between the cryotron tree and the memory cells close to the tree, and tolerances on the cell operation are affected. The address current must be high enough to assure switching the weakest cryotron in the tree common to a given address. At these high levels, the address currents will start to switch imperfections in the lead film as they pass over the imperfections through the cryotron decoder tree. The flux produced by the high currents will also couple into the memory cells and disrupt operation. At high current levels, the generation of heat can also cause undesirable thermal switching of the cryotrons, which is particularly difficult to detect during check out of a memory plane.

Additional current tolerance losses are incurred because of the inductive division of currents in the cryotron tree. At the first instant of current application to the tree, the current inductively divides among the branches and, as resistance is introduced in the unwanted paths, inductively decays and collects in the desired path. The time constant for this in a cross film tree is in the 20-microsecond range, so the cycle time is in the 60 to 80-μsec range, which would be unacceptable for the high-speed mass store originally intended for the memory. The time could be decreased by putting more drive current into the apex of the tree but extra current might be so high as to cause partial switching of the undesired cells.

With room temperature decoders, we can reduce the heat load on the cryogenic refrigerator, we can increase the number of memory cells on the plane with the space we gain, we can reduce the cycle time since we will not have to wait for the decay of the drive current to switch the cryotrons, and we can make significant cost reductions through redundancy techniques on the plane not heretofore applicable. We also can increase the plane yield because fewer film layers are required.

The absence of the decoders from the substrate reduces the number of decoding elements by two or three orders of magnitude and also reduces evaluation costs. Thermal requirements of the system are also greatly reduced.

Ambient decoders cut heat

Although room temperature decoders require many more lines to enter the Dewar flask, only a few lines are carrying current at a time, and the currents are quite low compared with the high currents used with the cryotron decoders. The I^2R loss thus is negligible.

For the lines into the Dewar flask, a conductor material having a low thermal conductivity and an electrical resistivity that is not excessive is desirable. Of the materials considered, lead appears to offer great promise. Lead's thermal conductivity is only about 10% of copper's. Although its electrical resistivity is higher than copper by a factor of 10, the total resistance of a conductor is only a few ohms.

As an example, the over-all thermal requirements of a 10^8 bit memory system have been evaluated assuming lead conductors of 10-mil width, and 3 mil, 1 mil, and 0.33 mil thickness, respectively, between the three heat-exchanger staging temperatures of 300° to 90°, 90° to 15°, and 15° to 3.5°; lengths of 25 cm, 35 cm, and 35 cm were assumed, respectively, between the same staging temperatures. With A and B line currents of 100 milliamps and a sense-line current of 20 ma, the load for each heat exchanger due to lead-ins is 81 mw, 443 mw, and 4.50 w, respectively, at 3.5°K, 15°K, and 90°K heat stations, which is well within the present state of the art for cryogenic refrigerators. The I^2R heat including nonsuperconducting contacts is calculated to be 4.2 mw. Thus, with a hybrid organized memory, capacities as high as 10^8 bits will not put unreasonable burdens on the refrigeration system. Estimates of older systems put the thermal requirement at the 3.5°K station at about 1 to 5 w for comparable memory capacities.

Standard planes in large memories

For the multimillion-bit memories, the capacity of the basic memory plane must be carefully chosen. The low interconnection costs of a high bit-capacity plane must be balanced against the decreased yields that would be experienced with a high capacity plane. The higher the bit capacity, the fewer interconnections needed, but the lower yields raise processing costs. A cost minimization analysis reveals that 250,000 bits is a reasonable estimate of the optimum bit capacity. This will be used as a standard plane. The discussion that follows is based on this figure.

The standard plane concept is akin to the building block philosophy. Synthesis of large memory systems with a standard plane has several advantages: hardware and evaluation processes can be shortened and hardware fabrication can be improved through repetition. The hybrid design also allows redundancy techniques.

The standard plane contains 512 A lines, eight B lines and 72 digit-sense lines designed to conform to the loop cell array. The plane is designed to give a word length of 64 bits; therefore, it contains a digit line redundancy provision of eight lines, or about 12%. The 512 A lines and eight B lines should be sufficient to give redundancy potential in these lines when incorporated into a memory system.

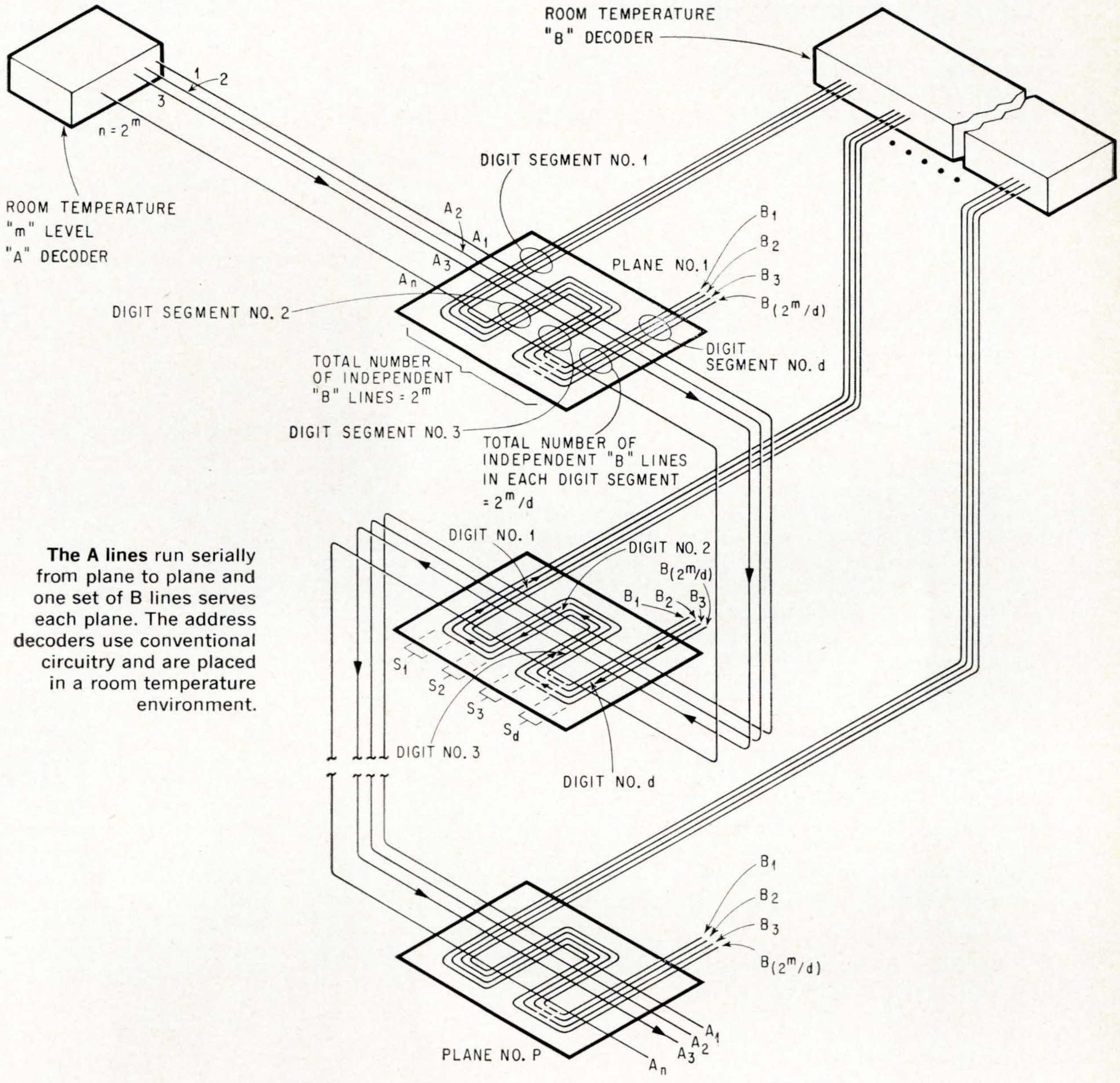
To synthesize very large hybrid memory systems with standard planes, the planes must be interconnected to fit the particular specifications of the memory system. In this way, electrical path lengths can be custom cut for a given system, and compatible delays of the A and B select pulses over the stack may be realized. The hybrid organization provides sufficient flexibility to permit the necessary interconnections.

The interconnection patterns can be of two general types: a single interconnection pattern which defines the over-all system organization or an interconnection pattern common to a local region which repeats itself over the entire system. The second pattern strongly suggests a basic building block philosophy, in which the block is a plate or frame defined by the judicious interconnection of two or more standard 250,000-bit planes.

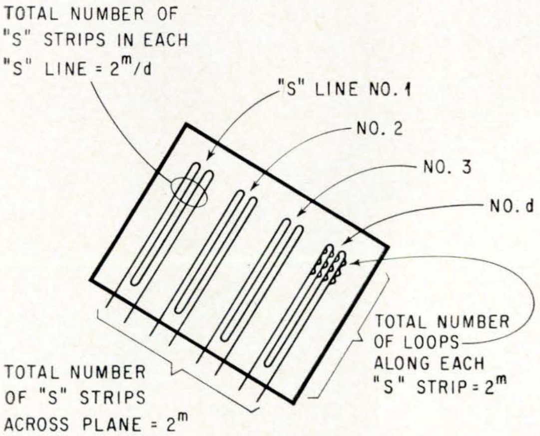
Four memory building blocks

The specific configuration of the basic block or plate is determined through practical considerations, such as existing interconnection technology. Sufficient flexibility exists with the hybrid system organization to allow selection of a plate configura-

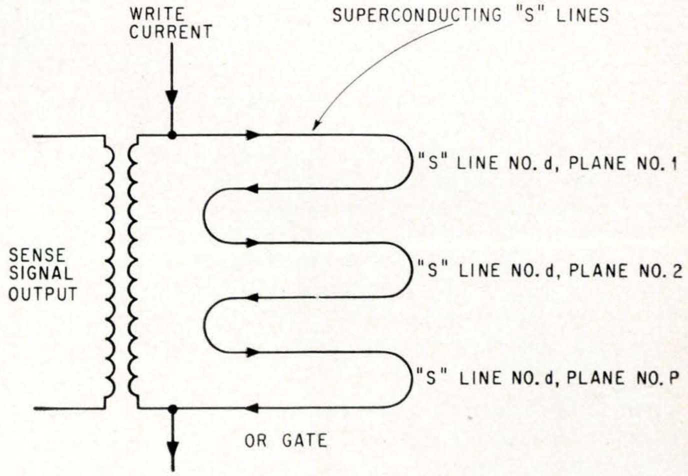
Hybrid memory organization



The A lines run serially from plane to plane and one set of B lines serves each plane. The address decoders use conventional circuitry and are placed in a room temperature environment.



Each sense line on a plane runs through all the memory cells on the plane associated with a common digit.



The sense lines serving a common digit on each plane are connected in series through the stack.

Choosing optimum bit capacity

The hybrid memory organization lends itself well to modularization but deciding on the number of bits to include in each module is not a simple matter. The two extremes are impractical: if only a few bits were used per module, then the wiring costs are far too high; if millions of bits are used per module, then the yield decreases drastically since many modules would have to be made before one completely functioning module is achieved. Between these two extremes lies an optimum number of bits which should be placed on each module. [Note that magnetic core memories are in the first category, with high interconnection costs. Plane yields are high since each core can be tested separately and the bad ones discarded, but the wiring costs are very high.]

Thus, finding the optimum number of bits to be placed on a single module is one of the most important aspects of practical cryoelectric memories.

There is a maximum substrate area which can be processed with existing deposition equipment. Call this area A, which might practically be about six inches by six inches. This area will contain a total number of bits B, which will be proportional to the area:

$$B = K_1A$$

The plane is exposed to various hazards during processing. These hazards are either area dependent or area independent. Examples of area independent hazards are a technician accidentally scratching the thin films or a wrong exposure due to a defective ultraviolet bulb. Area dependent hazards include defects in the substrate, an occasional module during film deposition, or a piece of dirt.

The larger the area, the greater the area-dependent defects, the lower the yield, and the higher the cost. The yield may be increased by partitioning area A into n subareas a of a bit capacity b. In this way, defective modules may be discarded, resulting in higher overall bit yield.

$$B = nb$$

$$A = na$$

In the following analysis we assume that:

- Parallel processing is feasible.
- The area independent hazards are interdependent of the partition n.
- The determination or classification of a particular defect as repairable or unrepairable is independent of the partition n.

The increase in cost attributable to the repair of n units of area a over the cost to repair a single unit of area A is offset by the savings afforded by the option to discard a fraction of the n units during defect inspection.

Let 1-P denote the probability that all b bits are satisfactory over unit area a. The probability of failure P is some function $P(b)$ where P increases with increases in b.

Processing Cost. If C_1 is the cost of all necessary process sequences to produce a perfect multilayered structure for $P = 0$ of area A, and C_{of} is some fixed cost, then the total fabrication cost C_f to produce B satisfactory bits is:

$$C_f \approx C_{of} + \frac{C_1}{1-P}$$

The cost C_{oe}, which excludes interconnections, is the cost of evaluating n times b bits including material, labor, and overhead and is comparable to that required to evaluate B bits.

The total number of interconnections i per module of b bits is approximately related to b as:

$$i \approx K_2b^{1/2}$$

where K_2 is some constant.

Interconnection cost. If C_2 is the cost per interconnection then the total interconnection cost is C_2ni.

The total evaluation cost C_e over all necessary runs per machine to evaluate B bits is then:

$$C_e \approx C_{oe} + C_2\,ni$$

The total cost is given in terms of a fixed cost C_o, a device cost, $\frac{C_1}{1-P}$, and an interconnection cost C_2ni as:

$$C = C_o + \frac{C_1}{1-P} + C_2K_2\frac{B}{b^{1/2}}$$

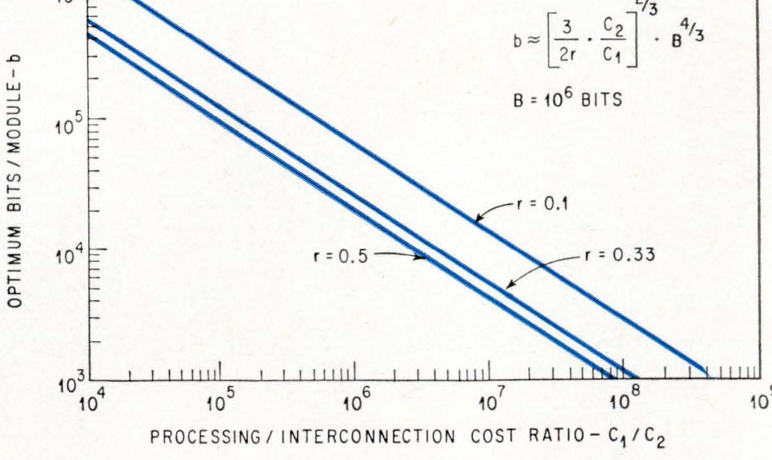
Since $\frac{dP}{db} > 0$, a minimum in the total cost C occurs at a value of b for which:

$$b^{\frac{3}{2}}\frac{dP}{db} - \frac{1}{2}K_2B\frac{C_2}{C_1} = 0$$

If the variation of P with b were known, we would now be able to find the optimum b.

Consider a probability of failure P which varies linearly with area and thus varies linearly with the number of bits, b, in a module. Let the quantity K_3 denote the number of bits over the area A for which a defective bit is reasonably certain; if K_3 bits were put on a substrate of area A, a failure in at least one bit would occur. If K_3 were partitioned into smaller modules with bit capacity b, the probability of failure in each b-bit module would decrease and would be inversely proportional to the total number of bits K_3:

$$P = \frac{b}{K_3}$$



Optimum bit capacity varies with processing- interconnection cost ratio and a confidence parameter, r, related to memory plane production.

Note that if b equalled K_3, the probability of failure would be 1, which follows from the definition of K_3.

Confidence factor. Since the occurrence of at least one defective bit is likely in K_3 bits, and since B bits corresponds to an area A beyond which one defective bit is likely, the quantities K_3 and B are of the same order of magnitude. One may therefore introduce a confidence parameter "r" of the form:

$$B \approx r K_3$$
$$0 < r < 1$$

Therefore if K_3 bits were placed on the plane at least one failure would occur, but if a fraction of K_3 were placed on the plane, there is a chance at success. The parameter r is this fractional confidence factor and denotes the percentage of K_3 bits over which adequate yield is likely. Thus, combining the above two equations,

$$P = r \frac{b}{B}$$

Optimum bits. The number of bits b at which the minimum cost occurs now may be obtained as:

$$b_{opt} \approx \left[\frac{K_2}{2r} \cdot \frac{C_2}{C_1} \right]^{2/3} B^{4/3}$$

Unlike semiconductor integrated circuits, cryoelectric devices are relatively insensitive to defects, and a value of 10^6 for B may not be unreasonable for the loop structure.

A logarithmic plot of b as a function of C_1/C_2 is shown for $r = 0.1$, 0.33, and 0.5, and for $K_2 = 3$ (a typical value). The curves show that the device and interconnection costs, C_1 and C_2 respectively, have a significant effect on the optimum number of bits b per substrate. As an example, a cost $C_1 = \$10.$ and $C_2 = 0.01$ cents ($C_1/C_2 = 10^5$) gives a value of about 127,000 bits for b while a cost $C_1 = \$500.$ and $C_2 = 0.001$ cents ($C_1/C_2 = 5 \times 10^7$) gives a considerably smaller value of b, about 1,500 bits (both estimates at r about 1/3).

Standard plane. As another example, a cost ratio of 3.5×10^4 with a confidence parameter of 0.33 gives an optimum substrate bit capacity of 250,000 bits. A plane with this capacity is referred to as a standard plane.

tion satisfying both the interconnection schemes for which A and B electrical path lengths are compatible, and the interconnection technology through which manufacture of the system may be realized. We will consider basic building blocks for four systems: 1.6×10^7 bits, 3.2×10^7 bits, 6.4×10^7 bits and 1.28×10^8 bits.

- The basic block from which a 1.6×10^7-bit memory may be synthesized consists of two standard planes back-to-back to form a 0.5-million bit plate. The system requires 32 plates. The A lines run serially through all the planes while the B lines are brought out separately from each plane.
- The basic block from which a 3.2×10^7-bit memory may be synthesized consists of four standard 250,000 bit planes, two coplanar pairs back-to-back to form a 1-million bit plate. There are 32 such plates. The number of A lines in the system is 1,024, 512 of which run serially through all planes stacked on the left, and 512 of which run serially through all planes stacked on the right. Separate B lines run serially through each pair of planes on each surface of each plate in the system.
- The basic block which characterizes a 6.4×10^7 and a 1.28×10^8-bit memory consists of eight standard planes, four of which are back-to-back with the four which are coplanar. The number of A lines in both systems is 2,048, 512 of which run serially through each plane stacked in each of the four quadrants of the systems. In the 6.4×10^7-bit system, separate B lines run serially through each pair of planes on each surface of each plate in the system. There are 32 plates, each consisting of 2 million bits, and a total of 1,024 B lines.

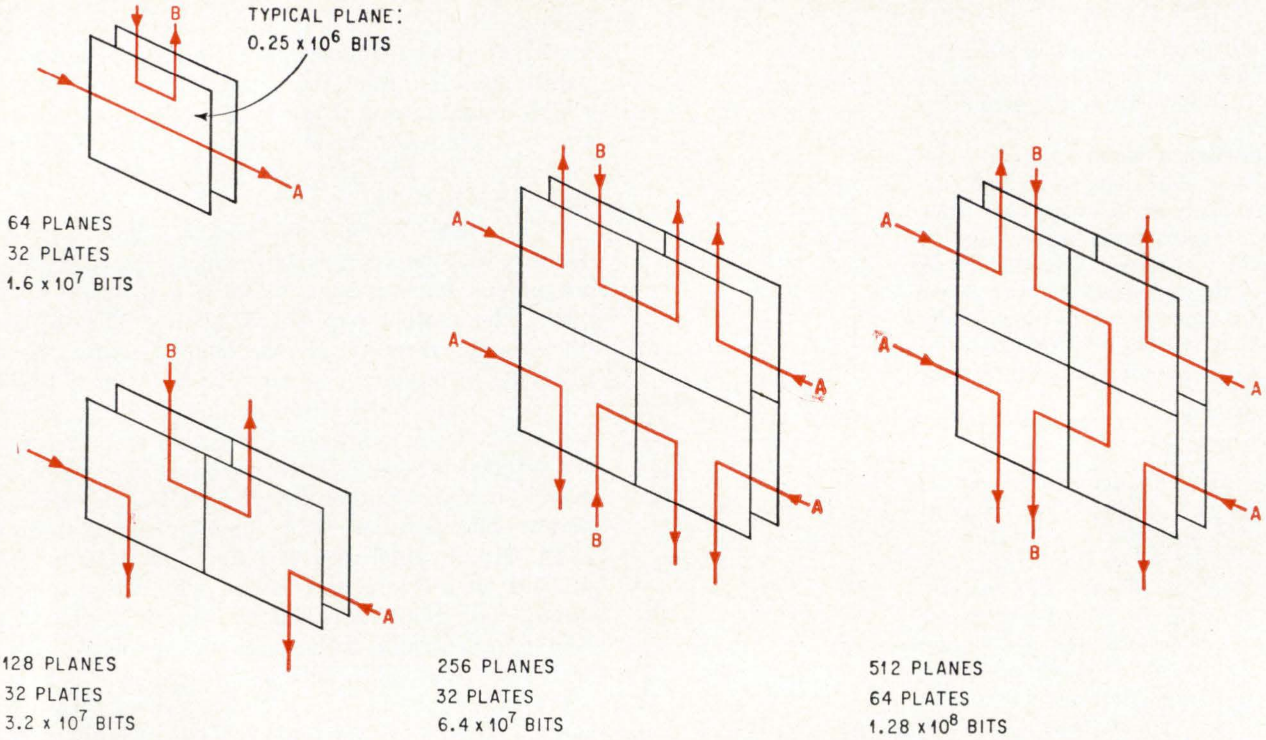
In the 1.28×10^8-bit system, separate B lines run serially through all planes on each surface of each plate in the system. There are 64 plates, each of 2 million bits, and a total of 1,024 B lines.

The various plate configurations on page 120 may be redefined by performing the folds along different axes, provided the basic interconnection pattern remains unaltered. For example, the 1.28×10^8-bit memory plate configuration may be altered to permit the A lines to run across pairs of planes on each surface of each plate in the system. The pair of A lines so defined would then run serially through all halves which were in common through each plate in the system. The total number of A lines would remain at 2,048.

The B lines would run serially through a pair of planes common on each surface of a plate. The B lines (two on each side of the plate) are orthogonal to the two planes per plate through which each A line runs, permitting the unique selection of one plane in the system at any one time. The total number of B lines remains at 1,024, and the electrical path lengths remain the same for either plate configuration.

100-million bit memory

A memory system of 10^8 bit capacity may be synthesized from the basic plate consisting of eight standard planes. The over-all volume occupied by



With a 250,000-bit memory plane as the basic building block, four ascending-order memory plates are depicted with A and B select lines. Each plate uses the basic planes arranged back-to-back. A 10^8-bit memory thus may be built with 512 planes of 250,000 bits each. The A and B line currents would be 100 milliamperes, and the sense line current 20 ma. Power dissipation is estimated as 81 milliwatts at 3.5° K.

the resulting 64-plate stack at the liquid-helium environment is about 1 cubic foot.

In the memory, 512 A lines run serially through each plane stacked in a common quadrant. The total number of A lines is 2,048; the total number of A wires including returns is 4,096. The B lines are serially interconnected through each of the four planes at each surface of each plate in the system. The total number of B lines is 1,024, the total number of B wires is 2,048. A number of sense lines, say 32, each common to a given digit of the word, and each on separate planes, may be serially interconnected and connected across the primary of an output transformer.

Room temperature amplifiers

In this case, each of the quadrants of the memory system will have four output transformers for each digit of the word. The outputs of these transformers are connected to amplifiers at the room temperature environment, and correspond to a particular digit of the word. The total number of lines per quadrant is the product of the number of planes per quadrant (128) and the number of lines per plate (digits per word =64). Therefore, the number of sense wires per quadrant, including returns, is 512, and the total number of sense wires over the entire memory system, including returns, is 2,048.

The number of wires required for write current is determined by permitting independent write current to exist at each quadrant. The total number of digit wires including returns is 512. The total number of wires required for the entire 10^8-bit system memory system, including returns, is 8,704.

Reliability and cost aspects

Another major advantage of the new cryoelectric memory over conventional random access magnetic memories is that only one set of decoders will be required for the million bit memory. In conventional memories, a separate decoder is required for about each 4,000 bits because of the high inductance of the drive lines. This reduction in the quantity of the electronic circuitry not only delivers substantial cost savings, but, more important, it greatly improves reliability.

The cryoelectric memory does, of course, require a refrigerator, but the feasibility of continued cryogenic operation has been amply demonstrated in recent years by such systems as masers. The extremely low cost of the cryoelectric memory on a per-bit basis should serve to lessen the importance of the initial cost of the cryogenic refrigeration system.

The author

Robert A. Gange received his A.B. degree in physics from Rutgers University in 1958. He is now a group leader in the cryoelectric device applied research laboratory of the Radio Corp. of America's Electronic Components and Devices Division.

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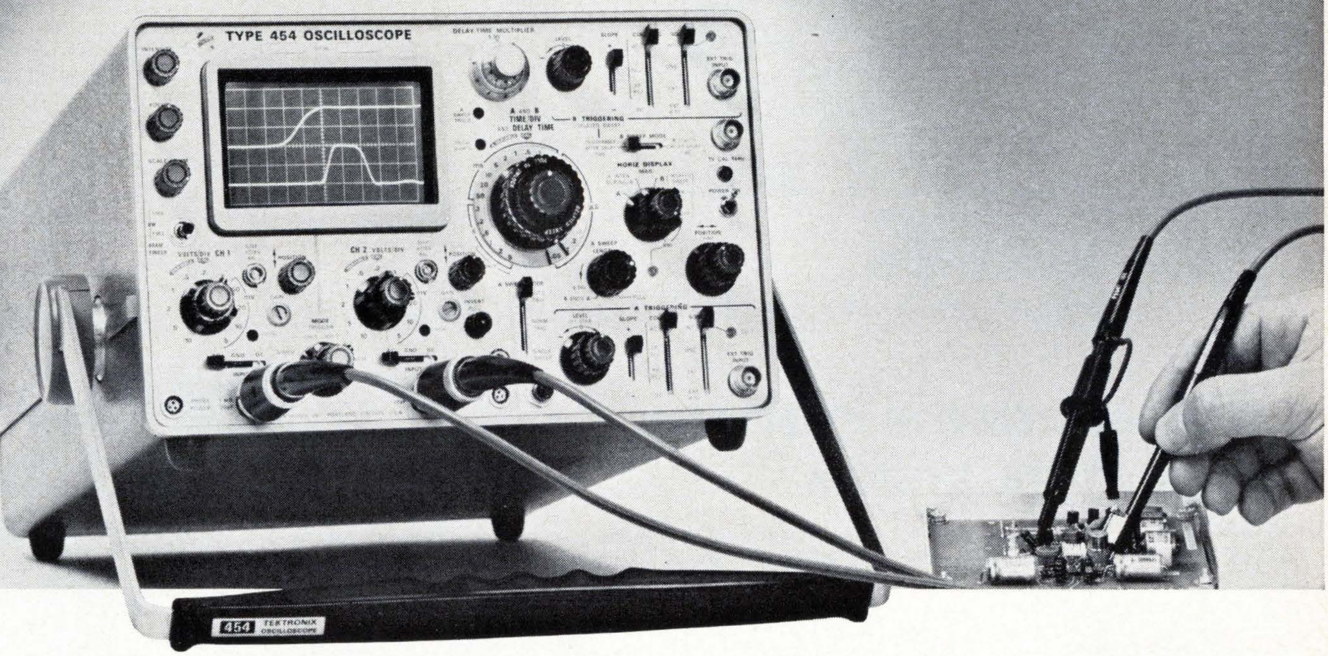

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*Front panel reading. Deflection factor with P6047 is 10X panel reading.

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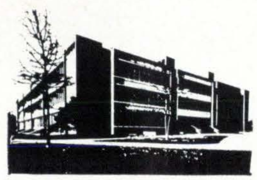

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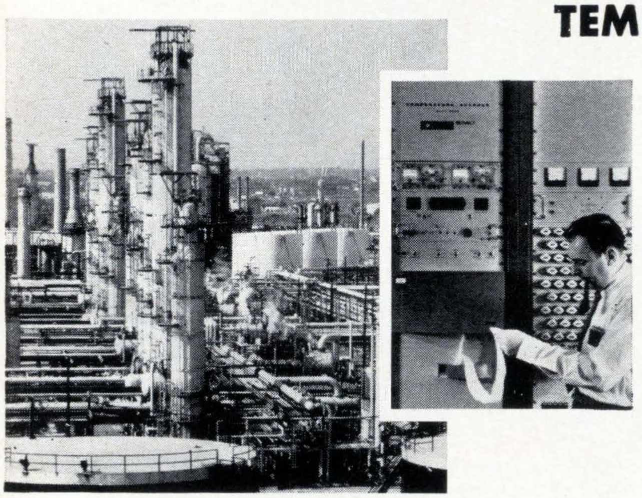

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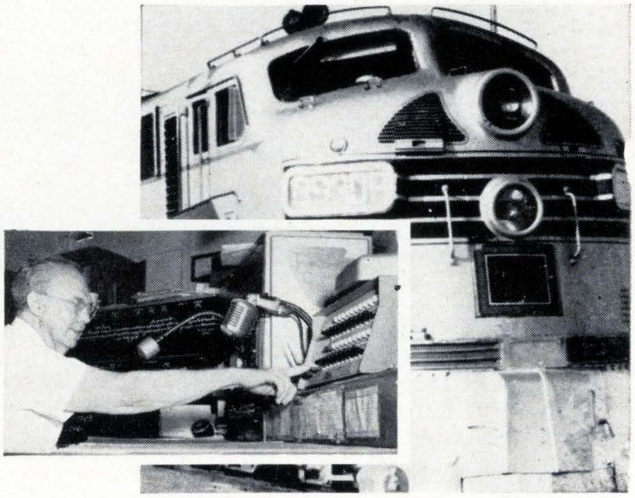

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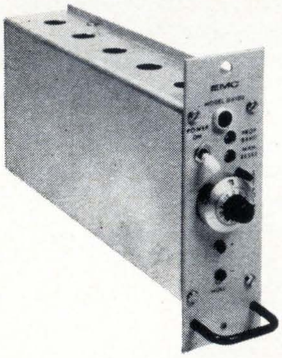

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Dielectric bath promotes togetherness in IC's

Liquid cooling may be the answer to the heat dissipation problem that is a major barrier to shrinking the size and expanding the operating speed of integrated circuit systems

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Naked integrated-circuit chips may be bathed by liquid coolants in the future. The technique is being explored as a solution to the thermal problems posed by developments that will raise component density in systems. A 10-fold improvement in heat removal methods will be needed when IC's are packed closely together in two-dimensional arrays.

Power density—the number of watts dissipated in a cubic foot of system volume—is the crux of the problem. The density will increase as large-scale integration and other means of packaging circuits come into use,[1, 2] and so will the amount of heat that must be removed.

Today, IC packages transfer heat from the semiconductor chip to either the surrounding medium, usually air, or a heat sink. Forced air, cold plates, and other conventional ways of cooling IC packages have already been exploited, but they limit density.[2]

Liquid cooling of the chip itself may be a better method. It is estimated that a packaged digital IC that becomes overheated in air at a power level below 250 milliwatts would be safe in a dielectric coolant even if the power applied to the circuit were to be raised above 10 watts. Not that a digital IC could or should be expected to dissipate that much power—but a large number of IC's could go into that cubic foot.

Speed and power

Thermal transfer calculations indicate that unpackaged chips, bonded directly to a substrate, could match the power dissipation of packaged and air-cooled circuits. Chips could be placed in large numbers on a common substrate, with each chip dissipating between 250 and 325 mw.

The rise in power density that liquid cooling allows is significant to both system and circuit design. It can mean higher system speed and lower packaging costs. In general, denser packaging results in a faster system because wiring delays are less [see "Smaller systems are faster systems," page 129]. Better electrical performance and reliability, reduction in weight, and savings in construction materials, connectors, and other packaging components are also possible when more circuits are put on either a monolithic IC, a substrate or a circuit board.

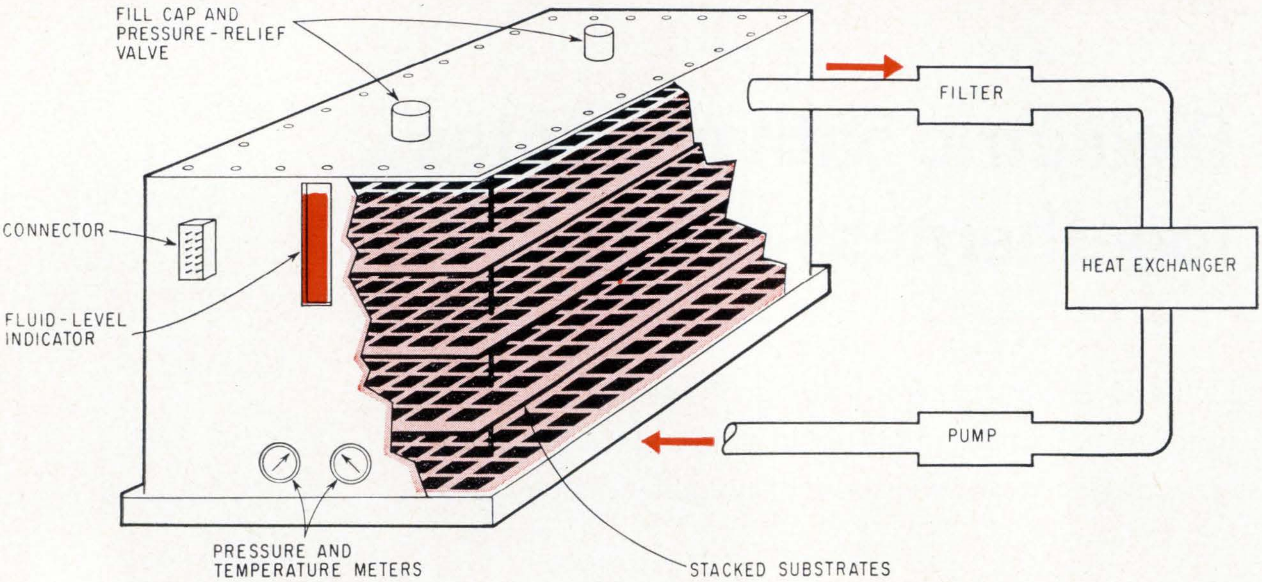
The speed of some types of logic circuits are also power-dependent. If the designer can count on using more power, he can drive the circuit output further and improve the fanout to other circuits.

Picking a dielectric

Liquid cooling has proved to be highly efficient in power tubes—cooled by water jackets—transformers immersed in oil, in engines and many other applications.

However, the effect of liquid cooling on tiny, relatively fragile IC's wasn't known when the experiments began at Motorola Inc. last July. The results thus far have been encouraging.

Ample proof has been accumulated that liquid cooling allows a multiplication of power density. Assemblies have been operated for several months in dielectric baths without degradation of the IC's or interference with their electrical operation. At



Integrated-circuit chips or packages could be put close together on substrates stacked in liquid-cooling housing. In some applications, external heat exchanger could be replaced by cooling fins on the housing.

first, there was some fear that boiling and circulation of the liquid around the exposed IC chips could rip lose the lead wires bonded to the chips. That hasn't happened during the experiments and fluid mechanics studies indicate it to be highly unlikely.

Water couldn't be used as a coolant, since it degrates IC's—chips in water failed in a few days. Most of the conventional liquid dielectrics are unsuitable because they lack the necessary physical, electrical, or chemical characteristics.

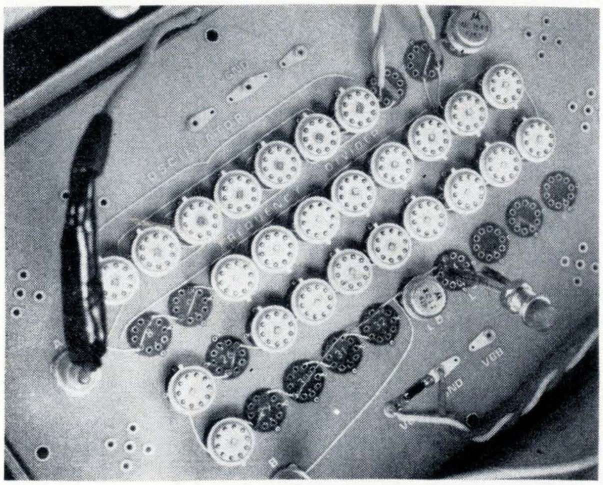
The choice of coolants boiled down to the Freons made by E.I. du Pont de Nemours & Co. and fluorochemicals made by the Minnesota Mining and Manufacturing Co. (3M). These meet the following requirements:

- Chemically, they are highly inert to semiconductor-device materials.
- Electrically, they have a low dielectric constant, which keeps signal propagation velocity high in the IC intraconnections and losses low.
- Thermally, they have a high heat of vaporization and other desirable thermodynamic properties, so heat easily flows from the IC into the liquid. Their boiling points are lower than the IC's safe operating temperature, but high enough to allow heat transfer when the ambient temperature is well above normal room temperature.
- Physically, they are viscous enough to be pumped without difficulty.

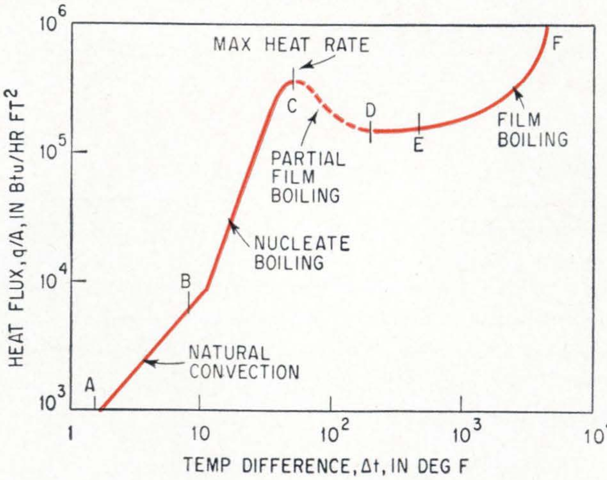
The heat transfer and physical stress computations that follow are based on the properties of Freons.

Experiment startup

In the initial tests, one circuit was operated in Freon C51-12 six weeks without detectable degra-



Experimental cooling chamber is simply a housing with a close-fitting plastic cover and tube sockets for connections through housing walls. Lamp at front of housing flickers when test circuitry is operating.



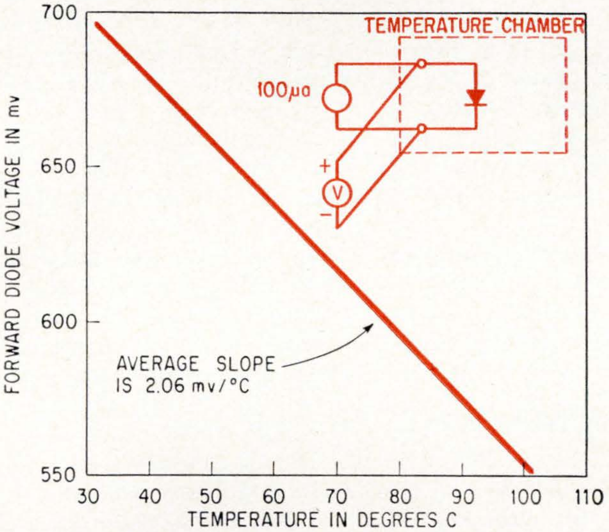
Boiling curve indicates relationship between heat flux and difference between temperatures of heat source and liquid. Heat is removed rapidly from heat source until at point C vapor film forms and impedes heat transfer.

dation. This is a perfluorodimethylcyclobutane that boils at 45° C [see table on page 127]. Approximately the same results have been obtained with FC-78, a 3M fluorochemical with properties similar to Freon C51-12.

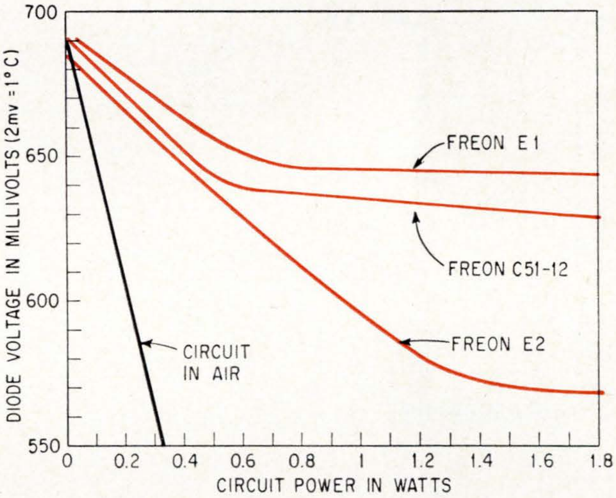
Initial tests with single circuits showed that liquid cooling tends to stabilize the temperature of an IC, even though power applied to the circuit continues to increase [see graphs below and on page 128]. In contrast, an IC operated in air gets hotter and hotter as the applied power is increased.

To monitor chip temperature, a diode in the test IC was calibrated. With a constant forward current of 100 microamperes, a diode forward voltage drop of 2.06 millivolts corresponds to a temperature rise of 1° C, graph below, left. The adjoining graph shows the results of using different types of Freon to cool sample circuits mounted on TO-5 headers. The package tops were left off, so the coolants were in direct contact with the bare chips.

Examination of the graphs will show that an IC mounted on a TO-5 header and cooled in Freon will have a temperature of around 140° F at a power dissipation of about 2 watts. This same circuit, operated in air, would reach that temperature at a power dissipation of only 200 mw. If the package were in air, but cooled by either forced air or a heat sink with radiating fins, power dissipation might safely be raised to 300 mw or so.



Temperature of IC's is monitored by measuring diode voltage. This calibration curve was obtained with the test setup shown in color.



Integrated circuit operated in air quickly heats up, as indicated by sharp drop in diode voltage (black curve). In dielectric fluids, same circuit remains relatively cool at several times the applied power (color curves).

Boiling point

Liquids transfer heat by convection, conduction, and boiling. Once a liquid reaches its boiling point, it remains at about that temperature if the vapor pressure is constant. The chip temperature also remains close to the boiling point if the coolant has a sufficiently high specific heat—defined loosely as its capacity to absorb heat. The chip won't overheat unless it dissipates so much heat that a wall of vapor forms between it and the liquid.

A boiling curve clarifies the heat transfer process. The curve on page 124 is the heat flux, q/A, versus the temperature difference, Δt, when water is boiled by an electrically heated platinum wire.[4] The temperature difference is that between the wire temperature, t_w, and the liquid's saturation temperature, t_s. The curve is a general one, not restricted to the case of a heated wire.

Natural convection removes the heat from the wire until—at point B on the curve—vapor bubbles start rising from the wire. The bubbles stir the liquid and heat is transferred more rapidly than by natural convection so q/A rises sharply. The section of the curve from B to C is known as the nucleate boiling region.

At point C—the peak of the nucleate region—so many bubbles have formed that they tend to merge and spread over the entire wire surface. Here, the circuit begins to run into trouble. The curve from point C to point D is known as the partial nucleate, or partial film boiling region. An unstable film of vapor may form on the wire, collapse and reform due to circulation currents. The heat flux drops to point D. This type of boiling heat transfer is abnormal.

Usually, the curve will jump from point C to point D and rise until the metal melts at point F, unless the power input is reduced or an auxiliary heat sink is placed on the package. The chip surface temperature will rise rapidly because the temperature difference between the surface and the liquid must be large before a large amount of heat can be rapidly transferred across the vapor layer by conduction and radiation.

Heat flux is raised if the boiling liquid is forced to flow over the hot surface. Heat flux due to forced convection is then added to boiling heat transfer, as in equation 1 [all equations are given on page 126,

Cooling equations

1 $$\left(\frac{q}{A}\right)_{total} = \left(\frac{q}{A}\right)_c + \left(\frac{q}{A}\right)_b$$

2 $$\frac{\left(\frac{q}{A}\right)_{max}}{\rho_v h_{fg}} = 0.18\left[\frac{\sigma(\rho_f - \rho_v) g g_o}{\rho_v}\right]^{1/4}\left[\frac{\rho_f}{\rho_f + \rho_v}\right]^{1/2}$$

3 $$\frac{C_f(t_\omega - t_s)}{h_{fg}} = C_{sf}\left[\frac{\frac{q}{A}}{\mu_f h_{fg}}\sqrt{\frac{g_o}{g(\rho_f - \rho_v)}}\right]^{1/3}\left[\frac{\mu_f C_f}{k_f}\right]^{1.7}$$

4 $$\frac{q}{A} = 6.063\ (t_\omega - t_s)^3 = 6.063\ \Delta t^3$$

5 $$\frac{q}{A} = 125\ \Delta t^3$$

6 $$\left(\frac{q}{A}\right)_{min} = 0.09 \rho_v h_{fg}\left[\frac{g(\rho_f\rho_v)}{\rho_f + \rho_v}\right]^{1/2}\left[\frac{g_o\ \sigma}{g\ (\rho_f - \rho_v)}\right]^{1/4}$$

7 $$\Delta t_{min} = 0.127\ \frac{\rho_v h_{fg}}{k_v}\left[\frac{g(\rho_f - \rho_v)}{\rho_f + \rho_v}\right]^{2/3}\left[\frac{g_o\ \sigma}{g(\rho_f\rho_v)}\right]^{1/2}\left[\frac{\mu_f}{g_o(\rho_f - \rho_v)}\right]^{1/3}$$

8 $$q = h\ A\ (t_\omega - t_f)$$

9 $$h = 0.664\ K_f\left(\frac{\mu_f C_f}{K_f}\right)^{1/3}\left(\frac{V_\infty}{\nu L}\right)^{1/2}$$

10 $$h_x = 0.332\ K_f\left(\frac{\mu_f C_f}{K_f}\right)^{1/3}\left(\frac{V_\infty}{\nu X}\right)^{1/2}$$

Stress equations

11 $$V_b \approx 1.18\ \frac{t_c}{t_c + t_d}\left[\frac{g_o g \sigma(\rho_f - \rho_v)}{\rho_f^2}\right]^{1/4}$$

12 $$\frac{F_D}{A} = C_D\left(\frac{\rho_f V_b^2}{2}\right)$$

13 $$N_{RE} = \frac{V_b D}{\nu_f}$$

14 $$S = \sqrt{\left(\frac{F_D L^2}{8_f}\right)^2 + \left(\frac{F_D L}{2}\right)^2}$$

Chip cooling values

Value	E2	C51-12
q/A_{max} in Btu/hr ft^2	48,500	64,000
Δt_{max} in °F (gold surface)	20	8
q/A_{min} in Btu/hr ft^2	2,320	2,350
Δt_{min} in °F	135	321
h in Btu/hr ft^2 °F	650	650
h_x in Btu/hr ft^2 °F	458	460
C_{sf} (see equation 3)	0.0105	0.00111

terms are defined on page 127, and values given in the tables below and on page 127].

A still higher heat flux can be achieved by pumping the liquid away from the chip, cooling the fluid, and reflowing it over the chip. Heat flux will depend upon the liquid velocity as well as the chip-liquid temperature difference.

Heat transfer characteristics of Freons E2 and C51-12 near the peak point of nucleate boiling can be estimated with equation 2.[5, 6] The q/A_{max} values for a gold surface have been calculated and are tabulated below. Du Pont researchers have experimentally determined the temperature difference, Δt, at q/A_{max}. Values for silicon or glass surfaces aren't known yet because of experimental difficulties. However, to calculate heat transfer from an IC chip, Δt can be assumed to be about the same as for gold.

Equation 3 is used to estimate heat flux when Δt is less than that of q/A_{max}.[7]

The constant, C_{sf} in, equation 3 is 0.0105 for Freon E2 and 0.00111 for Freon C51-12, when the given values of q/A_{max} and Δt are used to solve equation 3. Now, equation 3 can be simplified to equation 4 for Freon E2, and to equation 5 for Freon C51-12.

Heat flux can be calculated conveniently with the plots on page 129 of equations 4 and 5. The curves correspond to the boiling curve between points B and C. The C to D portion of the curve can be predicted from the minimum heat flux and temperature difference, found with equations 6 and 7.

These equations yield q/A_{min} and Δt_{min} values tabulated below. The minimum and maximum values are plotted as the black curves on page 129.

A header helps

Under adverse conditions, a 50-mil-square IC chip mounted on a TO-5 header will dissipate at least 2 watts in Freon E2 and 3 watts in Freon C51-12 before the circuit burns out. This would be the power limit if many IC's were placed in a small container or if the ambient temperature was high.

The chip would withstand more than 10 watts if the Freon E2 is pumped out of the container at a velocity of 10 feet per second, cooled to 77° F, and then returned to the container. If Freon C51-12 is used, dissipation should be at least 8 watts.

Most of the heat is given off by the header, whose surface is much larger than the chip's. If the bare chips are mounted directly to a circuit board, the maximum boiling heat transfer rate per chip will be 0.327 watt per chip in C51-12 and 0.248 watt per chip in Freon E2.

The rate can be greatly stepped up by pumping and cooling the liquid. The rate would vary from chip to chip. The rate depends on a chip's distance from the leading end of the circuit board for two reasons: the coolant becomes warmer as it flows over the chips, and the board may act as an airplane wing to alter the liquid flow (this is known as the boundary-layer effect).

If the boards carrying the headers or circuits are

Properties of Freon dielectric coolants

Property	near boiling point E1	E2	C51-12	At 77° F E1	E2	C51-12
Boiling point, °C	39.0	101.0	45.0			
°F	102.2	213.8	113.0			
C_f = specific heat in Btu/lb. °F	0.254	0.274	0.285	0.245	0.244	0.253
h_{fg} = heat of vaporization in Btu/lb.	41.4	31.3	40.1			
K_f = thermal conductivity of liquid. (est.) in Btu/hr. ft. °F	0.050	0.0501	0.060	0.05	0.05	0.06
K_v = thermal conductivity of vapor. (est.) in Btu/hr. ft. °F.	0.0080	0.0089	0.0070			
Molecular weight	286.03	242.08	300	286.03	242.08	300
μ = dynamic viscosity in lb./hr. ft.	1.09	0.714	1.82	1.21	2.66	2.38
γ = kinematic viscosity in ft.²/sec.	0.325×10^{-5}	0.215×10^{-5}	0.505×10^{-5}	0.364×10^{-5}	0.715×10^{-5}	0.632×10^{-5}
ρ_f = liquid density in lb./ft.³	93	92.1	100	96.0	103.5	104.4
ρ_v = vapor density in lb./ft.³	0.70	0.92	0.730			
σ = surface tension in lb./ft.	5.85×10^{-4}	4.18×10^{-4}	6.61×10^{-4}	7.13×10^{-4}	8.85×10^{-4}	7.96×10^{-4}

angled about 10 degrees from the horizontal, freshly cooled liquid will strike each circuit. The convection heat rate will rise, the circuits will cool more quickly, and the power dissipation can be increased significantly. Also, the boiling heat rate can be raised still higher by ultrasonically agitating the liquid.

Resistive wire bonds, incidentally, are hot spots. The liquid boils more quickly above these spots. This could provide a means of identifying faulty bonds in liquid cooled assemblies.

Boiling heat transfer

The estimates above are ball-park figures obtained by calculations. To keep the estimates of boiling heat transfer conservative, it was assumed that the liquid container is a poor heat conductor. Therefore, the heat from the circuits would build up in the liquid. Even a low power input would cause the liquid to approach its boiling point.

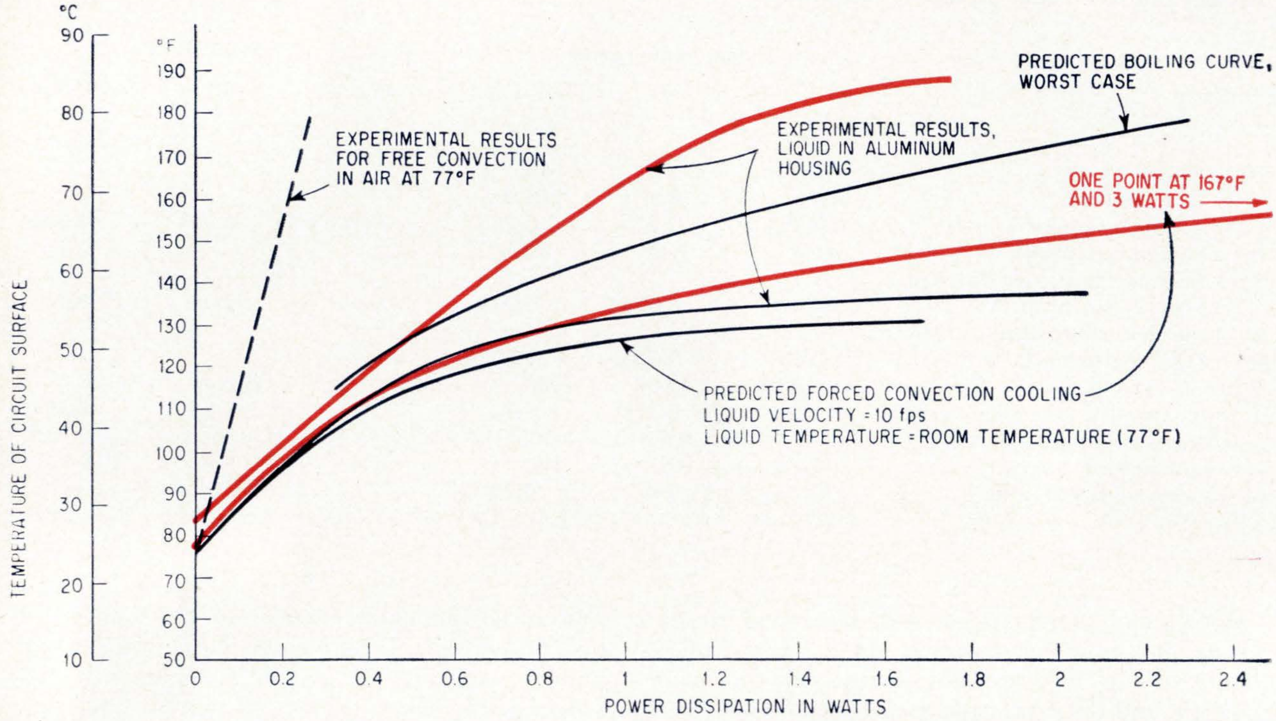
As a starting point, profiles of the temperature gradient across a TO-5 header were estimated and plotted, see page 128. Stable dissipation was assumed. Using these profiles as a guide, temperatures of different header surface areas were estimated. The heat dissipation from each area on the top and bottom of the header was obtained from the graphs on page 129.

Thermal resistance of the IC chip and its bonding area was assumed to be 3° F an hour per British thermal unit (Btu). This gave an estimate of the chip's surface temperature and allowed the chip's heat dissipation to be taken from the graphs.

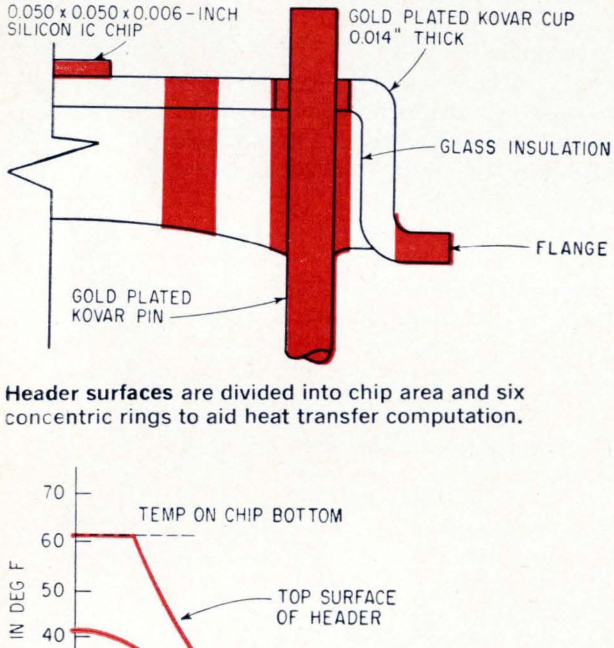
The predicted heat transfer for Freon C51-12 is given by the upper curve in black in the graph on page 128. The lower curve in the graph represents experimental results when the liquid was in an aluminum container, a good heat conductor. Since calculations were based on the worst conditions and the experiments on best conditions, real-

Definitions of terms

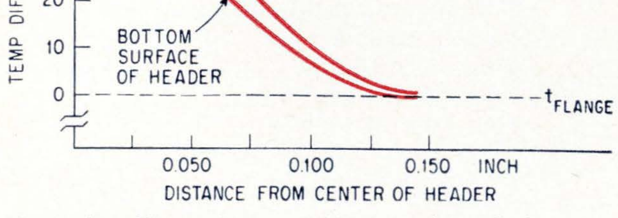
A = surface area in square feet
C_D = drag coefficient
C_f = specific heat
C_{sf} = constant dependent on surface-fluid combination
D = diameter of wire (0.001 inch in examples given)
f = sag of wire
F_D = fluid drag over a given area
g = gravitational acceleration
g = gravitational constant (32.16 ft./sec./sec.)
h = average coefficient of heat transfer in Btu/hr. ft.² °F
h_{fg} = heat of vaporization in Btu/lb.
h_x = local heat transfer coefficient
K_f = thermal conductivity in Btu/hr. ft. °F
K_v = thermal conductivity of vapor in Btu/hr. ft. °F
L = length of surface in feet
N_{RE} = Reynolds number
q = heat dissipation in Btu/hour
q/A = heat flux in Btu/hr./ft.²
$(q/A)_b$ = boiling heat transfer
$(q/A)_c$ = convection heat transfer
S = stress in pounds per square inch
t = temperature in degrees Fahrenheit
t_c = temperature of the chip
t_d = temperature of dielectric
t_f = liquid temperature
t_s = saturation temperature of liquid
t_w = surface temperature of heat source
Δt = difference between temperature of heat source and saturation temperature of liquid
V_∞ = velocity of liquid flow
V_b = bubble velocity in ft./hr.
X = distance from leading edge in feet
μ = dynamic viscosity in lb./hr. ft.
ν = kinematic viscosity in ft.²/sec.
ρ_f = liquid density in lb./ft.³
ρ_v = vapor density in lb./ft.³
σ = surface tension in lb./ft.



Experimental results are contrasted with calculated cooling rates for Freon C51-12 (black curves) and Freon E2 (color curves). Even without forced convection, a circuit in Freon E2 gets no hotter than a circuit in air despite a five-fold increase in applied power.



Header surfaces are divided into chip area and six concentric rings to aid heat transfer computation.



Thermal profiles at the top and bottom of a typical header. Heat flows from chip toward the flange.

istic values would most likely fall between the two curves.

Lower temperatures than those indicated by the curves would result if the container had cooling fins or more liquid were used, but these would be impractical for most applications.

The lower curve is an estimate based on pumping the liquid out of the container at a rate of 10 feet per second and cooling it to room temperature, 77° F. This curve is obtained by combining the heat transfer calculations and convection heat transfer calculations, using equations 8, 9 and 10. Values of the heat transfer coefficients h and h_x are tabulated on page 126; h_x is used to calculate convection heat transfer from the chip surface.

Heat transfer by convection and boiling can now be calculated and the total heat dissipation obtained with equation 1. The results are those plotted in the lower curve in black on the graph above.

If the ambient temperature is below 113° F (45° C), Freon C51-12 is the better choice because it dissipates more heat at any given circuit temperature. However, Freon E2 must be used when the ambient temperature is only slightly below 113° F or above that temperature. The curves in color in the graph above are heat transfer curves for Freon E2.

No estimate was made for Freon E2 in a poorly conducting chamber that lacks an external heat exchanger. The chip temperature would be close to the burnout point when Freon E2 approaches its boiling point. For instance, the header will dissipate only about 2.3 watts at 300° F (150° C) under the adverse conditions.

Sloshing around

Some packaging engineers have worried about the possibility of the moving liquid tearing loose lead wires bonded to the chip. There was no damage to the test IC's and analysis shows it to be unlikely as long as moderate coolant flow rates—for example, 10 feet per second—are used.

Three forces act on the wire: buoyant force, the weight of the wire, and drag due to fluid flow and circulation currents in the rapidly boiling coolant. In Freon, the buoyant force is about 0.42×10^{-4} pounds per inch of wire and the weight is 0.548×10^{-3} pounds per inch.

Assume the liquid velocity on the header top equals the velocity of the rising bubbles. This is calculated by equation 11[6,7] as 0.16 feet per second. Then the next equations may be used to calculate drag force.

The resultant drag force, F_D, on the wire is negligible compared with the wire's weight and therefore too small to affect the bond strength. Drag caused by boiling alone in Freon E2 is calculated as about 0.30×10^{-4} pounds per inch of wire, from equation 12. The term C_D in equation 12 is usually found in fluid mechanics tables, from the Reynolds number. The Reynolds number is calculated with equation 13.

If the coolant is pumped past the wire at a rate of 10 fps, in a convection cooling system, the drag force will still be too low to break the wire bond. F_D will be about 0.03 pounds per inch of wire.

An approximate stress analysis can be made using the catenary equations for flexible wires,[8] since the gold lead wires are only 1 mil in diameter and have a span of 100 mils (0.1 inch). Assuming the curvature stress is negligible, equation 14 gives a stress of 9,000 pounds per square inch when the coolant

Smaller systems are faster systems

If all the integrated circuits in a 10,000-circuit digital system were placed end to end, the designer would probably be fired. He might try putting the IC's cheek-by-jowl in a two-dimensional plane—on a circuit board.

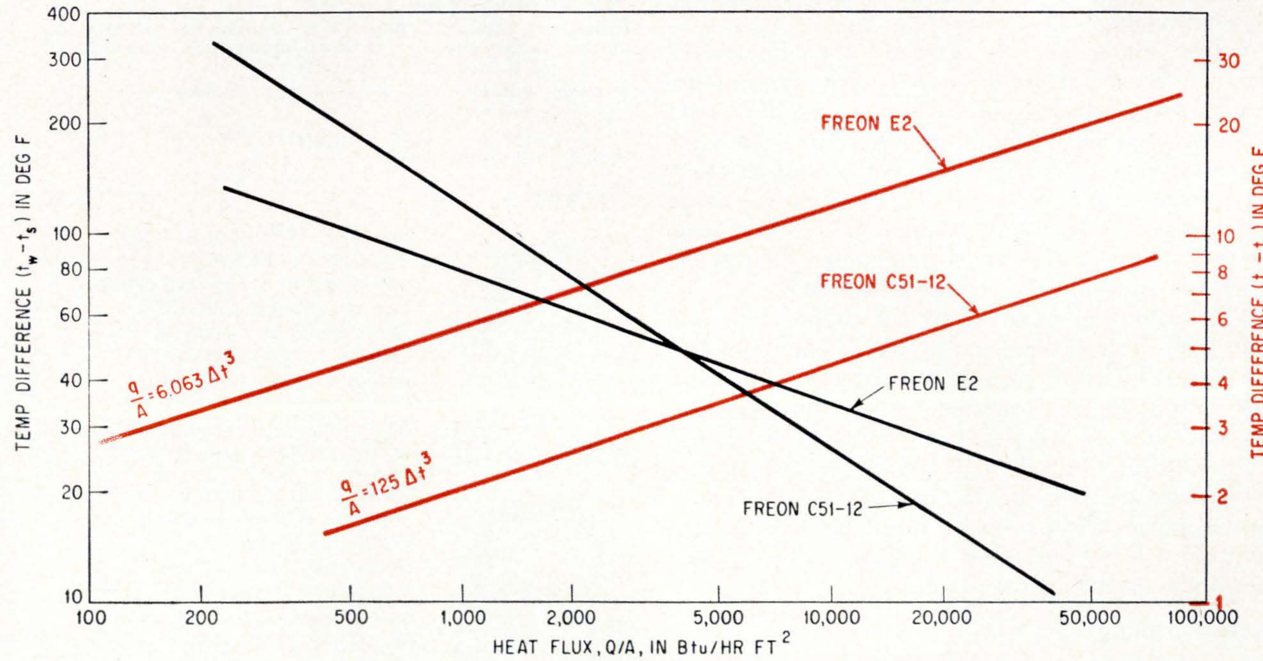
If the IC's are in flatpacks or TO-5 cans, the linear assembly would be nearly 100 yards long, causing some ridiculous wiring delays. However, the planar assembly would pare down the worst-case wiring length to 33 inches. Each package forces a spacing of about 1/3 inch between centers of neighboring circuits. On the average the path length would be around 15 inches. An electromagnetic signal takes some 2½ nanoseconds to travel 15 inches in an epoxy-glass printed-circuit board.

Such a planar assembly would be a resonable design only if the propagation delay per logic stage is far less than 2½ nsec. There is no point in using the design to interconnect the fast logic gates, which have a propagation delay of less than 1 nsec. The wiring delays reduce the effective speed of the gates to 3½ nsec.

To capitalize on the circuit speed, the designer would have to reduce path lengths by putting more circuits in a package—that is, large-scale integration.[1] In the extreme case, he might try to put the entire system in one package.

This approach may bring some cost advantages also, since packages represent much of the cost of conventionally packaged IC's. Furthermore, the protection of the circuits from contaminants would depend on only one hermetic seal rather than 10,000.

Liquid cooling alone certainly won't make 10,000-circuit IC's feasible. But it could allow the designer to put the IC's into a relatively small number of large-scale integrated arrays or onto small substrates packed closely together.



Heat transfer rates of IC's in two types of Freon. Curves and temperature scale in color represent solutions to equations for nucleate boiling and those in black for partial nucleate boiling.

flow is 10 fps. The tensile strength of gold is 20,000 pounds per square inch, so the safety factor is 2.2.

System tryout

As a realistic test, a 32-chip test system was put into a liquid-filled housing [photo on page 124] to determine whether the liquid would degrade the IC's.

The circuits ran in Freon C51-12 for 14 weeks with no IC failures and then four weeks in FC-78 fluorochemical liquid, again without failures. A very slight pitting of the chips occurred, but did not affect operation. The system operated continuously except for short periods when the housing was opened to replenish coolant lost through a slow leak.

The housing has a tight-fitting Plexiglass cover. As the coolant evaporates, the vapor pressure raises the boiling point slightly and prevents outside contaminants from diffusing into the housing. The vapor condenses on the upper walls and cover, and returns to the bath.

The system tested is a ring oscillator, frequency divider, and lamp. The oscillator frequency of 6 megahertz is reduced by the divider to 23 hertz at the lamp, causing it to flicker. A glance tells if the system is working.

There are 14 OR/NOR gates in the oscillator, a total of 28 gates. The average propagation time of these circuits is less than 1.5 nanoseconds and maximum power dissipation per package is 360 mw. The 18 master-slave flip-flops in the divider can be toggled at 250 Mhz. Effective delay per flip-flop is 4 nsec and maximum power dissipation is nearly 300 mw.

The OR/NOR gates have a single layer of thin-film wiring and the flip-flops have two layers. Both types are mounted on 10-pin TO-5 headers. Two octal-pin tube sockets are the connections through the housing walls.

Before immersion, the a-c and d-c characteristics of the IC's were measured, and microphotographs made of three of each type of chip. After immersion, when the liquid temperature stabilized, photos were taken of the oscillator period, risetime and waveforms, and the divider's waveform. There has been no detectable change in the operation and only minor changes in appearance of the IC's since the experiments began in mid-1966.

To monitor temperature by the diode technique described earlier, connections were made through the circuit board to a diode in each type of circuit. The gate diode was found to be shorted. However, measurements of a flip-flop diode showed that chip temperature stabilized at 52° C when the system power was 1 ampere and the bias voltage 5.2 volts—normal power dissipation for these IC's. The IC temperature was held at about 75° C below the normal maximum operating temperature.

System cooling

An actual operating digital system would have a much higher power density than the test system. Liquid would be circulated through an external heat exchanger, and methods of monitoring liquid level, temperature, and pressure would be provided, as in the sketch on page 124.

Circulation of the liquid through the heat exchanger might be eliminated by making the chamber walls cold plates. Or, the chamber could be made lower and wider to increase the radiative cooling area. For additional radiation the chamber walls could be finned.

Miniature circuit boards or other substrates could be stacked in the housing and coolant flowed between them. Bare chips would be bonded to the substrates and interconnected by wiring on the substrates.

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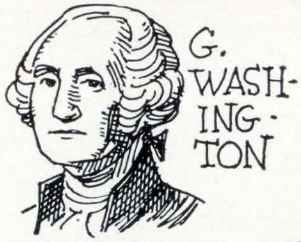

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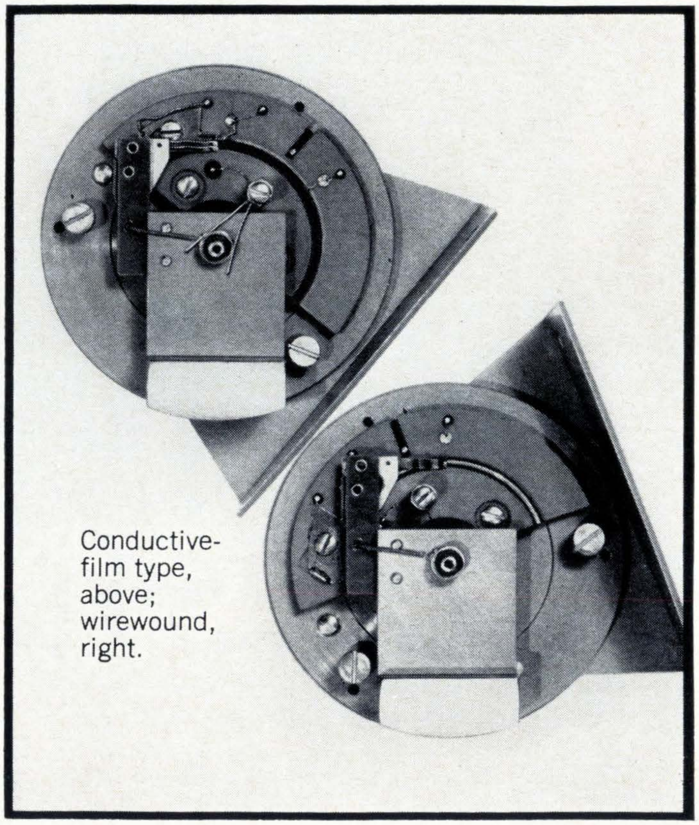

Conductive-film type, above; wirewound, right.

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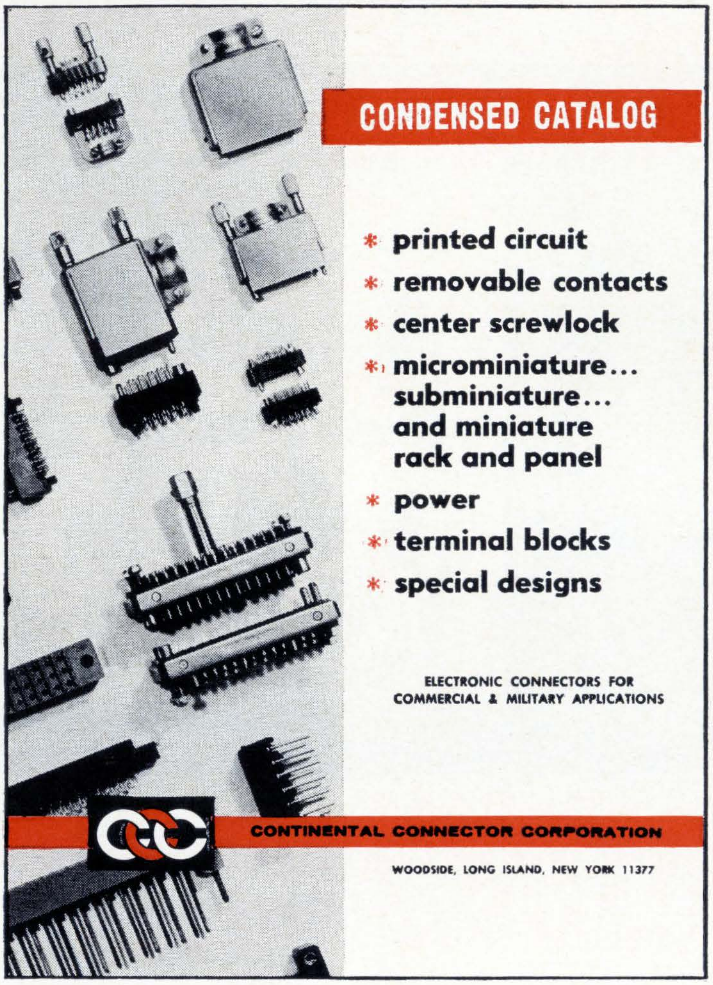

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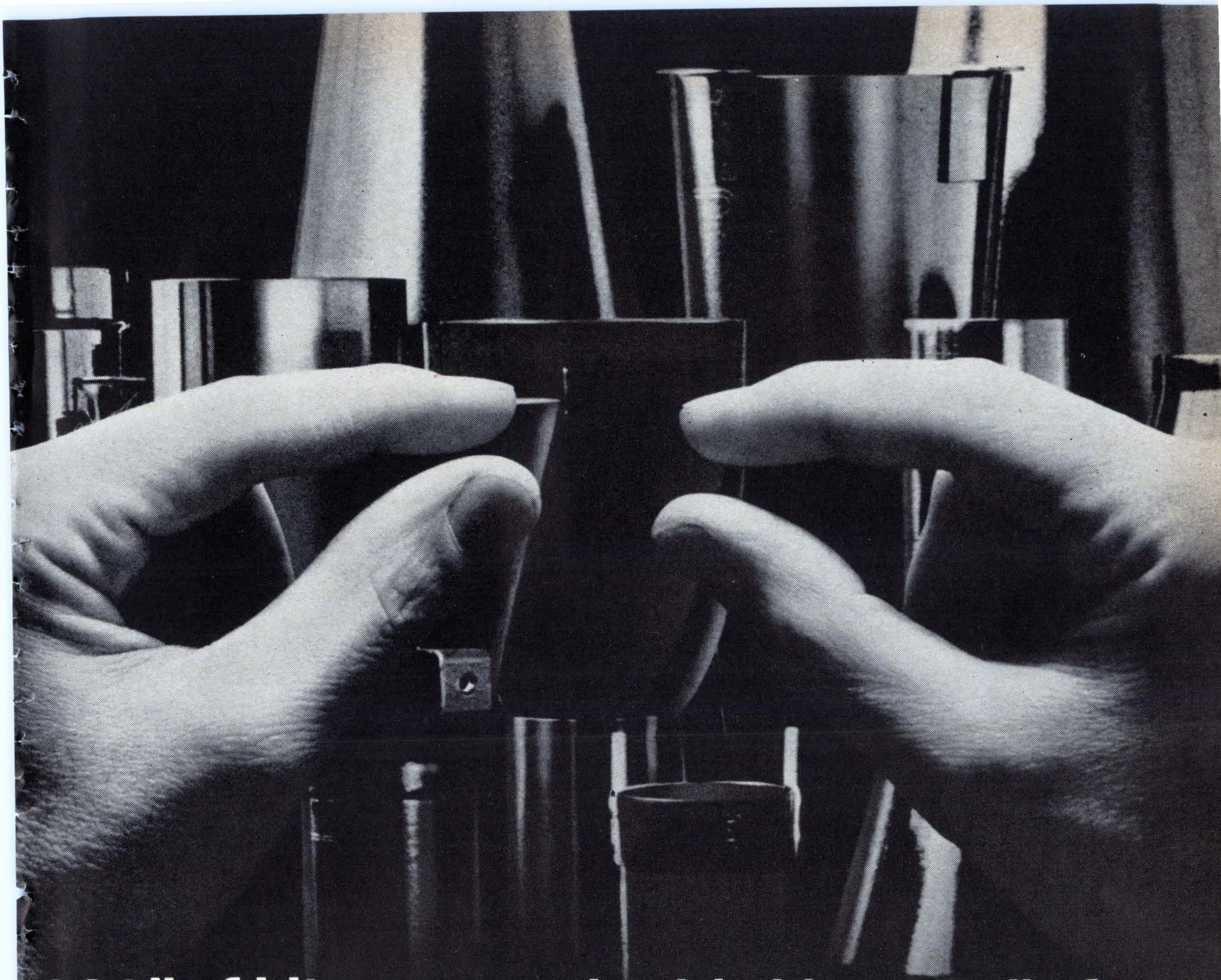

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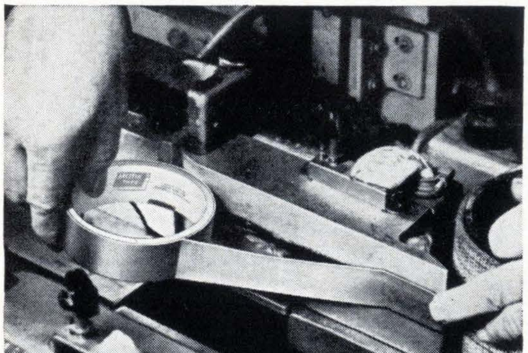

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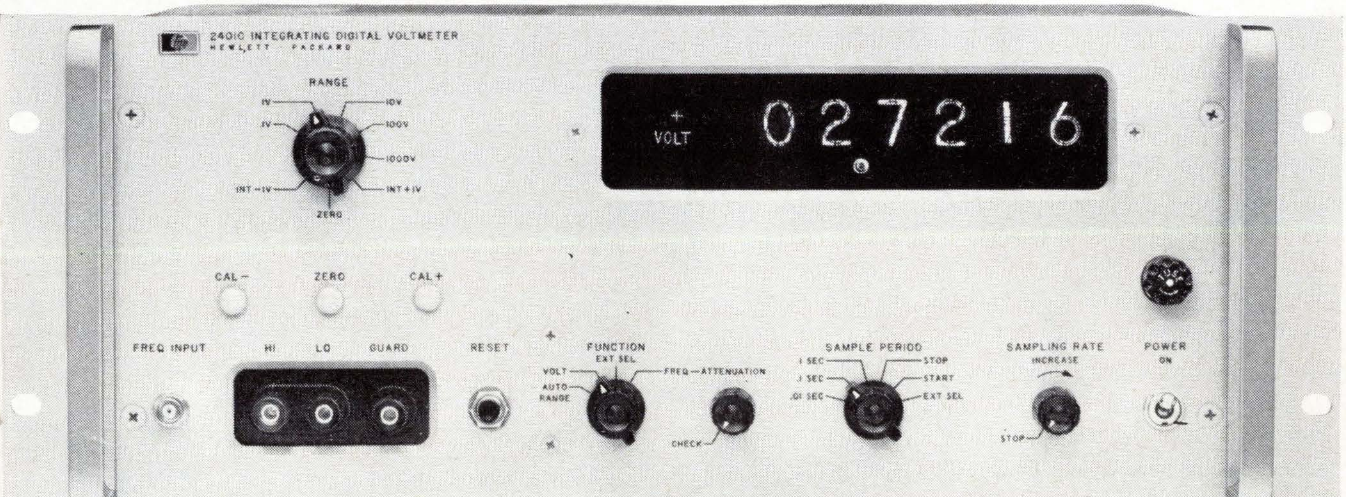

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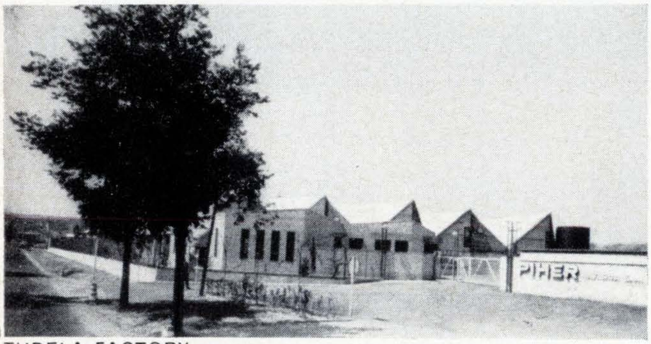

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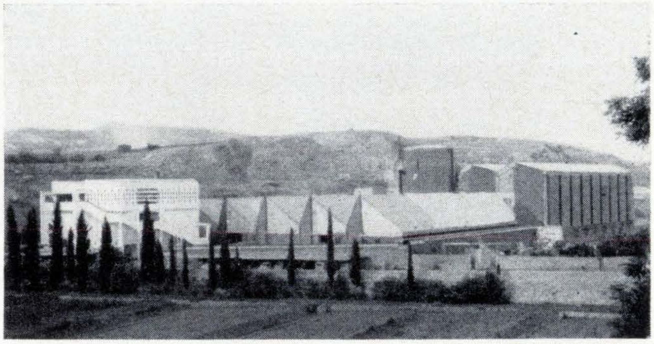

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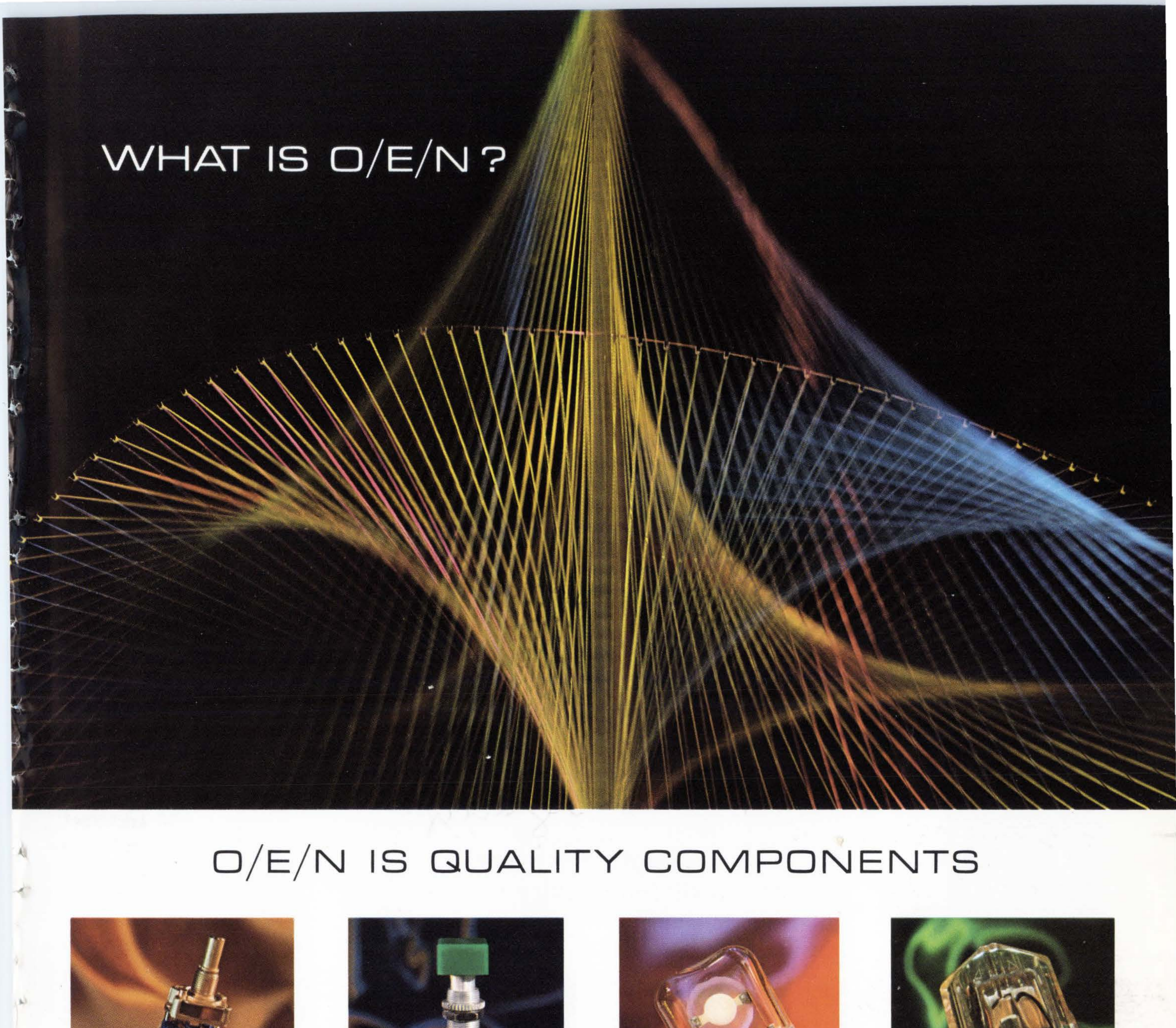

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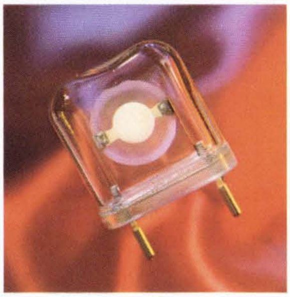

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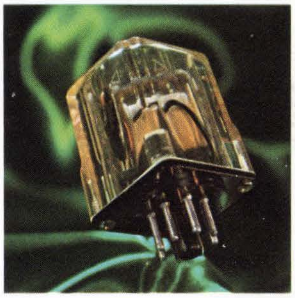

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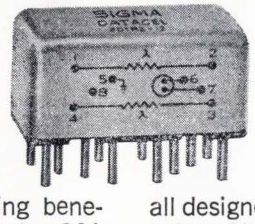

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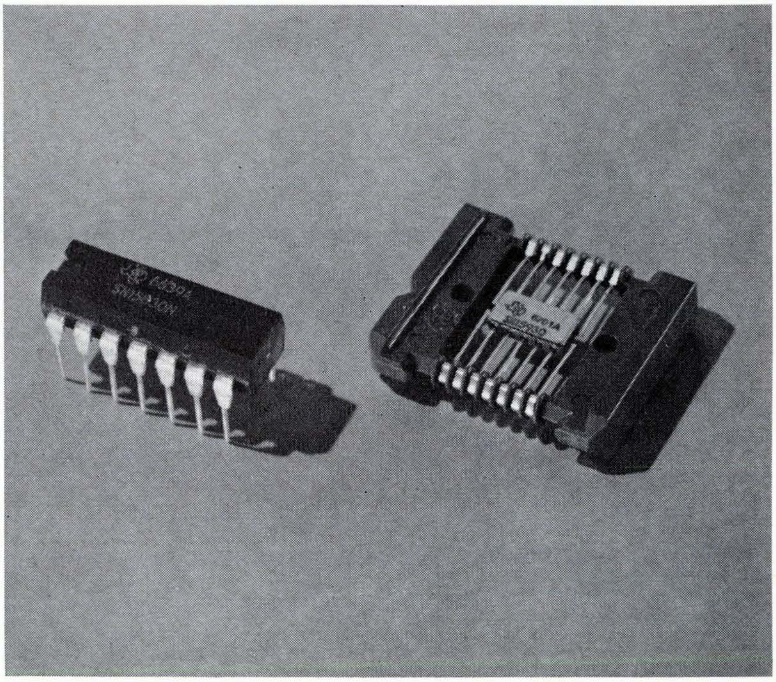

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Probing the News

Electronics markets

Bloom's gone from 1967's rosy outlook

Softness in consumer markets, a shift in Government outlays slows boom; industry starts to prune year's sales projections

Barely four months ago, growth-conditioned executives in the electronics industry were virtually unanimous in their belief that the boom would continue in 1967. Electronics' markets survey forecast a 9.4% boost in sales.

Now, however, with the first-quarter results in, these same executives are having second thoughts. Although there's no recession, or even a slump, gaps have shown up to turn the great expectations of year-end 1966 into a more realistic appraisal of 1967.

The high level of expenditures for Vietnam has kept most military electronics markets close to or ahead of estimates, and space outlays are holding their own. But a slowdown in the five-year expansion of the economy has softened certain civilian outlets. In particular, a shift in consumers' buying patterns has hurt such profitable big-ticket items as monochrome and color television sets. Similarly, the auto makers' winter of discontent during which new car sales fell over 20% from year-earlier levels has taken a toll from Detroit-oriented electronics concerns. Uncertainties also beset industrial electronics and instrument firms.

Despite what at first appears to be a dismal picture, indications are that 1967 will still be a good year. Available evidence suggests that the selective "minislide" will be arrested by the end of the third-quarter—a little later than hoped by most—and that the business trend will turn upward thereafter. Such recent Government actions as the proposed restoration of the 7% investment tax credit and the Federal Reserve Board's lowering of the rediscount rate to member

Selected consumer electronics markets
(millions of dollars)

	1st quarter 1967	2nd quarter 1967	3rd quarter 1967	4th quarter 1967	Total 1967
TV receivers, b&w	110.0	82.5	154.0	203.5	550.0
TV receivers, color	256.5	216.0	395.0	472.5	1,340.0
Home & portable radios	39.5	25.1	50.3	64.7	179.6
Auto radios	40.5	52.1	26.1	40.5	159.2
Phonographs, portable	33.6	55.4	60.8	68.7	218.5
Hi-fi sets & components	16.0	13.4	25.2	29.4	84.0
Kits (except toys)	13.1	12.0	8.6	16.5	50.2
Musical instruments, electronic	25.6	23.6	20.7	28.5	98.4

Selected electronics components markets
(millions of dollars)

	1st quarter 1967	2nd quarter 1967	3rd quarter 1967	4th quarter 1967	Total 1967
Resistors, fixed	44.7	49.5	53.4	55.4	203.0
Potentiometers	40.0	42.0	42.9	46.1	171.0
Capacitors, electrolytic	46.4	47.2	52.9	55.4	201.9
Capacitors, other	57.1	57.4	61.2	62.5	238.2
TV yokes & flybacks	6.5	6.5	7.2	8.7	28.9
Tubes, receiving	62.4	68.2	80.0	77.1	287.7
Tubes, picture CRT, b&w	29.9	26.3	36.5	43.7	136.4
Tubes, picture, CRT, color	106.6	119.5	160.0	202.5	588.6
Transistors, silicon	69.8	75.1	81.0	85.8	311.7
Transistors, germanium	35.8	32.6	40.5	49.4	158.3
Diodes, silicon	53.4	55.6	49.0	64.5	222.5
Diodes, germanium	7.5	7.8	7.2	8.8	31.3
Silicon controlled rectifiers	12.6	13.2	13.7	14.3	53.8
Loudspeakers	24.0	27.2	29.3	24.0	104.5
Magnetic tape	46.8	47.7	45.8	50.5	190.8
Integrated circuits, monolithic	49.3	53.8	58.0	62.9	224.0
Thick films	5.7	6.1	6.7	7.5	26.0
Thin films	2.6	2.8	3.0	3.2	11.6
Power supplies, lab type	11.1	12.2	12.9	10.3	46.5
Power supplies, OEM type	19.8	22.0	20.2	19.2	81.2

Selected instruments markets
(millions of dollars)

	1st quarter 1967	2nd quarter 1967	3rd quarter 1967	4th quarter 1967	Total 1967
Oscilloscopes	30.4	30.2	30.0	32.2	122.8
Signal generators	6.7	5.8	6.0	5.5	24.0
Sweep generators	3.2	3.5	3.3	2.8	12.8
Counters	9.4	10.0	7.5	11.4	38.3
Digital voltmeters	7.0	7.0	7.3	7.3	28.6
Components testers	6.2	5.5	5.5	4.7	21.9

banks should furnish additional momentum to the recovery.

I. The reluctant consumer

Any industry registering a better than 25% sales gain for the first quarter—as color tv set makers did—would normally be overjoyed. But producers expected to do twice as well and made their manufacturing and marketing plans accordingly. As a result, a lot of spanking new capacity, added in anticipation of a continuing bonanza, will be standing profitlessly idle. Sales predictions of 7 to 8 million units have been trimmed to a more realistic level of about 6 million.

If the demand for color is dull, the market for black-and-white sets is bleak. So far this year, black-and-white sets are off by 30%—about 16% below earlier estimates.

Such staple consumer items as radios, phonographs, and tape recorders are holding up well in the makers' difficulties, sales of autofidelity components are making gains. However, reflecting the car makers' difficulties, sales of automobile radios are running 26% below expectations.

Think small. Tv marketing men are taking some comfort in the sales curve of small-screen sets (up to 15-inch screen). J.L. Myers, marketing manager of the General Electric Co.'s personal television department, says sales are off only 8% and are beginning to turn upward. With summer approaching, Myers is looking for a boom.

S.R. Herkes, marketing vice president at Motorola Inc.'s Consumer Products division, is optimistic beyond 1967. "We may even have bigger years in black and white than we have had in the past," he says. "Transistorization will bring the price down to $49.95 by 1970. And at that price, tv sets will be an impulse purchase."

Portable color tv will also get more attention, accounting for about 10% of total sales this year, predicts GE's Myers. General Electric already has three 10-inch color sets on the market, two of which were introduced this year. And last month, the Radio Corp. of America entered the field with a 14-inch set. By the end of the year, there should be as many as 10 manufacturers in the portable color field.

Selected communications equipment markets
(millions of dollars)

	1st quarter 1967	2nd quarter 1967	3rd quarter 1967	4th quarter 1967	Total 1967
Land mobile	42.5	42.5	42.5	42.5	170.0
Radar	15.5	17.0	16.0	15.0	63.5
Airborne & ground links	44.5	50.0	56.5	39.4	190.4
Broadcast equipment	20.9	41.9	53.2	45.1	161.1
Citizens band equipment	8.8	9.7	10.8	10.7	40.0
Telemetry	45.5	46.0	42.2	52.6	186.3

Now that the color market has toned down a bit, manufacturing of home entertainment products may bring some of the developments that were in a state of "suspended animation" to bear upon next year's tv and stereo sets. But a caution light on costs has been lit.

Says William Buschmann, vice president for marketing at the Sylvania Electric Products Co., a subsidiary of the General Telephone & Electronics Co.: "Anything that adds a dollar to the price of a tv set presents a problem in sheer economics."

One such innovation could be a new 1,200-volt silicon transistor introduced last month at the IEEE exhibition by the Delco Radio division of the General Motors Corp. The device can switch the 3,800-volt-ampere load line needed to operate a 25-inch color set horizontal deflection system. Another new entry could be voltage-variable capacitors for tuning black-and-white and color tv sets from the International Telephone and Telegraph Corp.'s Semiconductor division.

II. Bits and pieces

When an important market like color tv receivers fails to grow as expected, the impact upon components suppliers can be severe. Color tv tubes, resistors, capacitors, and other discrete devices have been hard hit, resulting in a lag in sales.

In another sector of the components field, silicon transistors are taking a real beating as a result of price deterioration and slackening demand. Expected to rack up $480.4 million in sales during 1967, these devices are now running at an annual rate of only $311.7 million. At the Dickson Electronics Co., demand for solid-state tantalum capacitors dipped during the first quarter. But sales coordinator Milton Jesman attributes the slide to a more competitive pricing situation and prior stockpiling of devices by computer makers.

Components companies serving military markets report volume was right on target during the first three months of the year. However, marketing officials at these firms show signs of nervousness about the immediate future. Dan Schwadron, senior sales engineer at Bourns

Inc. points out that while hardware outlays are up, military spending for research is down—a situation that will adversely affect the sales of components for instrumentation systems and other laboratory equipment. Carryover orders from last year are almost exhausted, says Schwadron, and no new bookings are in sight.

Problem areas. At Westinghouse Electric Corp.'s Semiconductor division, marketing manager John Morris notes that February sales were just about the same or a little higher than last year, but fell by 5% to 10% in March. Westinghouse had anticipated a 35% growth rate in 1967.

The softness at Westinghouse shows up in parcels of products. For example, diodes for use in color tv receivers and industrial equipment are not doing as well as expected. Division manager Don Gunther is still hoping the industry will build 7 million sets. But if sales slide to less than 6 million, the division's sales performance will be very disappointing for 1967.

Sales of large silicon-controlled rectifiers for use in speed controls of locomotives are also very slow. Gunther attributes this to the loss of the investment credit which curtailed railroad's capital-spending plans more sharply than was the case in other industries. On the plus side of the ledger, sales of power transistors and thyristors (silicon-controlled rectifiers) smaller than railroad size are still outstripping production capacity.

IC picture. For the past year and a half, the "monkey has been on the integrated circuit manufacturers' back," from the point of his being unable to fill orders, says a source at the Signetics Corp., a subsidiary of the Corning Glass Works. The consensus is that most added capacity now being installed will be on line by summer—and the result could be some softening due to a reduction of backlogs.

Sylvania continues to see an IC market of about $230 million in 1967. For Sylvania, first-quarter sales have been on target with its estimates, says Roger Swanson, semiconductor marketing manager. Orders have been "a bit lighter in the consumer area than anticipated," but such business is only a negligible percentage of the total.

The largest manufacturer of diodes in the world, ITT's Semiconductor division, sees its markets "holding on target." Robert Hostage, manager of market research and planning for semiconductor operations, notes that while his division holds 30% of the germanium diode market and enjoys a better than 10% penetration of the entire diode market, over 90% of ITT devices are sold for computers. In that area, sales have gone largely according to plan. The softening in the entertainment products market has not seriously affected ITT's diode business, and only about 2.5% of sales are to the auto market—mostly germanium units for radios.

III. Instrumentation

With few exceptions, the 1967 instrumentation outlook is gloomy and most sources concede that sales are lagging behind the original forecasts.

Alan B. Dallas, manager of instrument marketing for Honeywell Inc.'s Test Instruments division, says, "1967 will not be a disastrous year but it won't be the growth year predicted last July." According to Dallas, many instrument manufacturers are faced with increased inventories and are offering off-the-shelf deliveries.

Because test instrument sales are tightly linked to research and development, many companies are reeling from the diversion of Government funds to production. Many have had to make major readjustments. Some, including the Consolidated Electrodynamics Corp., a subsidiary of the Bell & Howell Co., have even had major layoffs.

Others haven't been as seriously affected. Honeywell Inc., for instance, has experienced lower sales of its larger oscillographs designed for research and development applications. At the same time, the company is selling more apparatus for use by less skilled personnel. "But," says Dallas, "the increase in the one line does not offset the loss in volume in the other." The reorientation of Government spending has also lowered sales of the more complex signal and sweep generators, and even the digital voltmeter market has been affected.

Gains in industrial instrumentation have caused marketing managers to view this segment of the instrumentation market with some optimism. [See "Instrument makers are measuring up to systems engineering standards," page 161.] Most feel that the reinstatement of the 7% tax credit will boost sales in this area. But as Keith Williams, manager of oscilloscope marketing at Tektronix Inc., puts it, the effect of the restoration will be more psychological than anything else.

Bright side. Component test equipment is enjoying an excellent year. The Instrumentation division of the Fairchild Camera & Instrumentation Corp. indicates automatic transistor and integrated-circuit tester sales are ahead of forecast. Similarly, the automatic component test systems recently introduced by the General Radio Co. are enhancing the company's total volume.

But the market for machine tools also reflects the economy's softness. Although deliveries for the first two months of 1967 are some 10% ahead of the comparable period a year ago, new orders have suffered a sharp decline of about 25%.

This drop may not affect sales until 1968, however, because of the close to 11-month backlog of orders with which manufacturers began 1967. On the whole, deliveries for 1967 should be about the same as last year, according to a spokesman at the Bendix Corp.'s Industrial Controls division.

Because an increasing percentage of machine tools are being sold for numerically controlled applications, manufacturers of the controllers will see their volume rise during the year—up to $100 million says Bendix. Last year 20% of all metal-cutting tools sold had numerical control. This year this percentage could reach 25%.

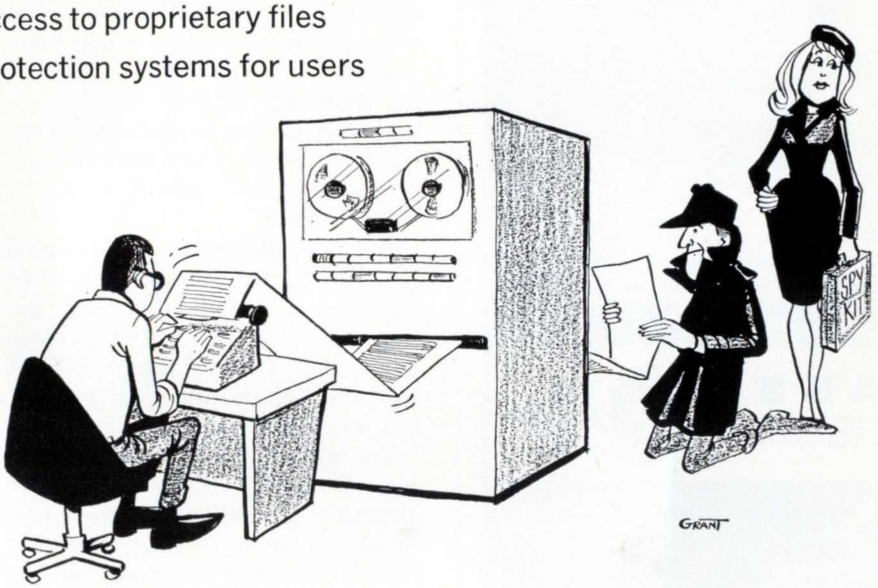
Restoration of the 7% investment tax credit by the Federal Government would certainly be the biggest stimulant to an increase in numerical-control tool sales, according to James Gray, executive vice president of the Tool Builders' Association. The suspension of this credit last October had an almost immediate effect on all kinds of capital equipment manufacturers. By December, new orders for machine tools were already starting to drop.

Circle 235 on reader service card

WHO PINNED A MEDAL ON THIS TINY TRW CAPACITOR?

Safeguarding time-sharing privacy —an all-out war on data snooping

The problem of unauthorized access to proprietary files spurs development of tighter protection systems for users



Recognizing that time-sharing could also mean unauthorized data-sharing, the computer industry is coming to grips with the gnawing problem of safeguarding privacy in multiaccess processors. So important is the privacy-snooping dilemma that it has been put in the spotlight at the Spring Joint Computer Conference opening this week in Atlantic City, N.J.

The problem became a national issue last summer when Congress held hearings on the proposed national data bank. Backers wanted to collect information from such Federal agencies as the Census Bureau and the Internal Revenue Service and store it in one computerized repository. But opponents, fearing that user-agencies would have unrestricted access to data regardless of whether they had filed it, succeeded in getting the enabling legislation killed in committee—at least for this session.

Snooping fear. The problem of privacy in a commercial or industrial application centers on the prevention of unauthorized access—whether inadvertant or intentional—to proprietary computer files. Destruction of data by other data stored in the wrong place is a problem, as are tapped telephone lines carrying subscribers' data between terminals and the computer.

As far as Government agencies are concerned, privacy is a security problem that is compounded by varying classification levels. Although no Government unit has as yet entrusted classified data to a time-shared computer system, the Air Force has taken the first step [Electronics, March 20, p. 26].

I. By the numbers

Time-sharing systems offer a variety of safeguards against unauthorized access. In common with other systems, Control Data Corp.'s 6000 computer series relies on software backed by the hardware organization. Two kinds of files—private and public—are kept in the system. When a user sets up a new private file, he tags it with a confidential key or password. Thereafter, access is restricted to those who can submit the proper identification.

Programs available to anyone, like compilers to translate programs written in Fortran and other languages into machine language, are kept in the public file.

"There's no such thing as a hardware lockout," says Robert Korsch, an applications analyst at Control Data. "Any hardware you install to protect the files must be under software control." Keeping protection schemes in the software has the advantage of flexibility. Software can be changed simply by punching out new cards and feeding them into the computer.

Hard stuff. Despite Korsch's doubts, Honeywell Inc. has developed a hardware approach for its H-8200 time-shared computer. Keys for up to nine blocks in the memory and nine input-output assignments are kept in hardware registers. As in Control Data's machines, these keys must match keys supplied by the user for access to private files for reading or writing. Taking advantage of a read-only memory that is unique in the H-8200, the comparison is performed in hardware. [For more on Honeywell's read-only memory, see page 56.]

II. Customers always write

Clients of Allen-Babcock Computing Inc., a Los Angeles-based time-sharing service, are restricted to Fortran, Cobol, and PL/1 languages. Since they can't modify the supervisory program with these languages, users can't bypass the memory protection system.

At Project MAC (for machine-aided cognition) at the Massachusetts Institute of Technology, there are no language restrictions and skillful users can modify the supervisor from remote terminals. According to James D. Babcock, Allen-Babcock's president, this is one reason why Project MAC has been having privacy problems.

Another Allen-Babcock method of preventing invasion of privacy is what Babcock calls an "early cutoff." Any user is allowed as

... a user can restrict access to his files to certain times of the day ...

much memory space as he needs—for which he is charged. But anyone trying to corner more than 20 blocks at a time is automatically cut off. "He can dial in again immediately," says Babcock. "But when he does, we are on with him, watching everything he does. If we didn't do something like this, a user could go on grabbing more blocks of memory and crowd everything else out, taking over the whole system."

Systems go. In some time-shared facilities, the central processor must be in a particular status before a user can get into the system. When the General Electric Co.'s 645 computer is in the slave mode, the machine can't execute privileged instructions—like input-output commands. If a privileged instruction should appear in a program, the computer automatically transfers control to the monitor program that operates in the master mode. The offending user is disconnected. If a user requires a privileged operation, he can set up the necessary information in his own restricted portion of memory and request the master mode to take over. Similar restrictions exist in other time-shared systems.

The International Business Machines Corp.'s System 360 computer has two modes called problem state and supervisor state, corresponding in some respects to GE's slave and master modes.

III. What's ahead

Major efforts at devising new safeguards are being made at MIT. Edward L. Glaser, an associate professor of electrical engineering, heads the design group responsible for protection of privacy in Multics, a computer-utility project being developed jointly by Project MAC and the Bell Telephone Laboratories.

"In Multics," says Glaser, "various parts of the file have different conditions of access and different levels of privilege." The user must specify all of these—including his name, problem number, account to which charged, and password—to get into the system. But he is restricted to his particular section. If he manages to get into somebody else's section by accident or intent he is blocked from wandering through the entire file by a programable partitioning system.

Whatever a user does is automatically recorded and can be audited later, just as transactions in a bank can be examined by bank examiners. The protection system cannot be changed on-line and the auditing procedure must be performed off-line by two or three people.

Despite the safeguards, Multics' security system will still have one weak spot—the public telephone system, which can be tapped. Because of this, individuals using the system over such lines will be barred from certain files.

General Electric has experimented with telephone line scramblers—similar to those used on military communications lines—for one of its in-house systems. "They offer some security for transmitted data but they aren't foolproof," says Louis F. Cimino, manager of computer operations at GE's Missiles and Space division in Valley Forge, Pa.

Word changes. An additional level of sophistication in the use of passwords is suggested by Brian W. Pollard, manager of product planning at the Radio Corp. of America's Electronic Data Processing division. "Passwords can be easily changed," he says. "Suppose a file were set up in such a way that a different password was required each time the file was used. Only the person authorized to use the file would know that it had been used, and he would know the sequence of passwords, so that he should have no trouble. Anyone else who perhaps learns the sequence wouldn't know which one to use at any particular time, and trying them all on a random basis would be easily detectable."

To an extent, General Electric leaves protection up to the client. A user can put in as many levels of security as he wants, depending on the degrees of privacy required for his data. At Allen-Babcock, a series of keys or passwords is necessary to get into the system. But a user can restrict access to his files to certain times of day or provide other safeguards. If a client's employees are permitted access only during normal business hours, the system can be programed to turn down anyone trying to get into the system outside these hours.

This approach does have disadvantages: "The name of the game is response time," says Gerald Galler, product manager for GE's 600 line. "The more verification you require of a legitimate user, the longer it takes to get information out of the system. You can overdo it."

Joel Erdwinn, senior staff scientist at Computer Sciences Corp., a software house in El Segundo, Calif., acknowledges that a privacy problem exists in time-shared systems. But, he says, protection against accidental release or destruction of data is adequate for most industrial users. Spying is another story. "No one has ever convinced the military that a time-shared system can be guarded," he says. "And the military is probably right."

Erdwinn looks for improvement at remote terminals. The executive system, entailing a series of routines which must be performed before data is released, is particularly effective, he says. Encrypting equipment at the data printout terminal provides another safeguard. But such procedures are costly, requiring vaults and guards to protect the code manuals.

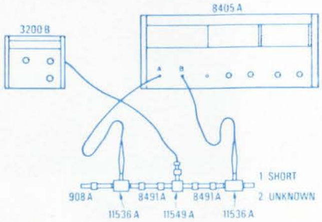
Memorable. Walter Bower, president of the Data Products Corp.'s subsidiary, Informatics Inc., a software firm in Sherman Oaks, Calif., regards security in time-shared systems as "essentially a people problem." He concedes there are technical difficulties in both hardware and software design but considers them tractable. But Bower sees one area in which provision for security could alter the design of time-shared computers—memory size.

He anticipates a day when 10% of a computer's memory will be devoted to routines needed to qualify users requesting information. In some applications, according to Bower, the figure could be as high as 20%.

Measurement of Complex Impedance

with the HP 8405A Vector Voltmeter

The measurement of complex impedance in the 1 to 1000 MHz range using slotted line or bridges has always been a time-consuming and cumbersome process, particularly when determining phase angle. Now, with the HP 8405A Vector Voltmeter, faster and simpler techniques are possible.



Below 100 MHz, the method illustrated above is especially convenient. Signal power is equally split, and the voltage drop across the unknown impedance is compared against the drop across the known. Results are easily entered on the Smith Chart for rapid determination of impedance.

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Free Application Data

Application Note 77-3 discusses "Measurement of Complex Impedance". For your copy write Hewlett-Packard, 1501 Page Mill Road, Palo Alto, Calif. 94304; Europe: 54 Route des Acacias, Geneva.

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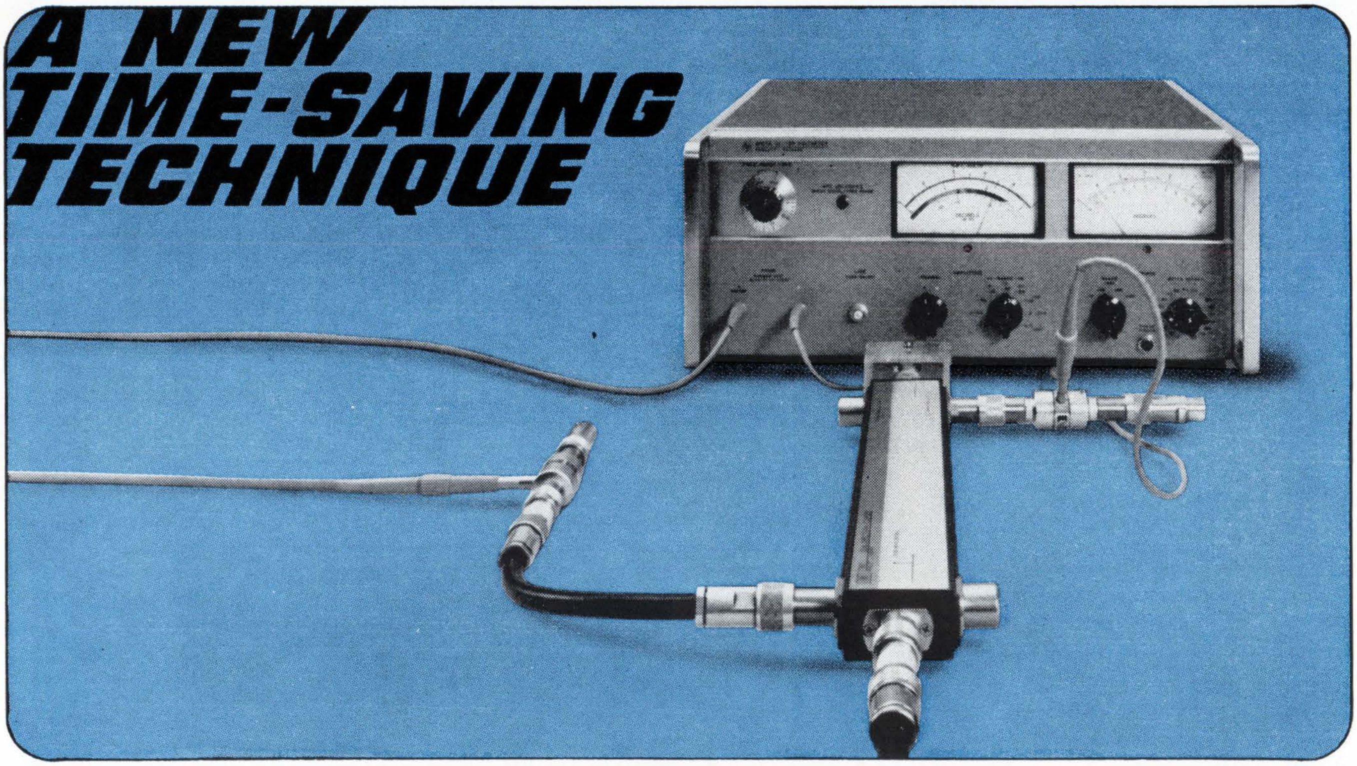
Price: $2500.



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Instrument makers are measuring up to systems engineering standards

Availability of low-cost computers coincides with the emergence of a market for fast and accurate gear to test complex circuitry

By Carl Moskowitz
Instrumentation editor

Since the phrase "systems engineering" entered the lexicon of instrument men six short months ago, the once staid instrument field has undergone a startling change. Manufacturers no longer think in terms of single, special-purpose units; they are developing and selling complex, computer-based packages capable of providing a wealth of test data almost instantaneously.

"Before long, instrument systems will be as common in the engineering laboratory as the slide rule is today," says Richard Anderson, manager of the network analyzer section at the Hewlett-Packard Co.'s Microwave Laboratory.

Necessity was the stepmother of the computerized instrumentation systems now making their debut. Conventional test apparatus could no longer cope with the complexities of recording, reducing, and analyzing data for intricate new circuits and devices. But it was the availability of efficient, low-cost computers that really triggered the stampede into systems that make a myriad of measurements and provide results in real time [Electronics, Feb. 20, p. 203].

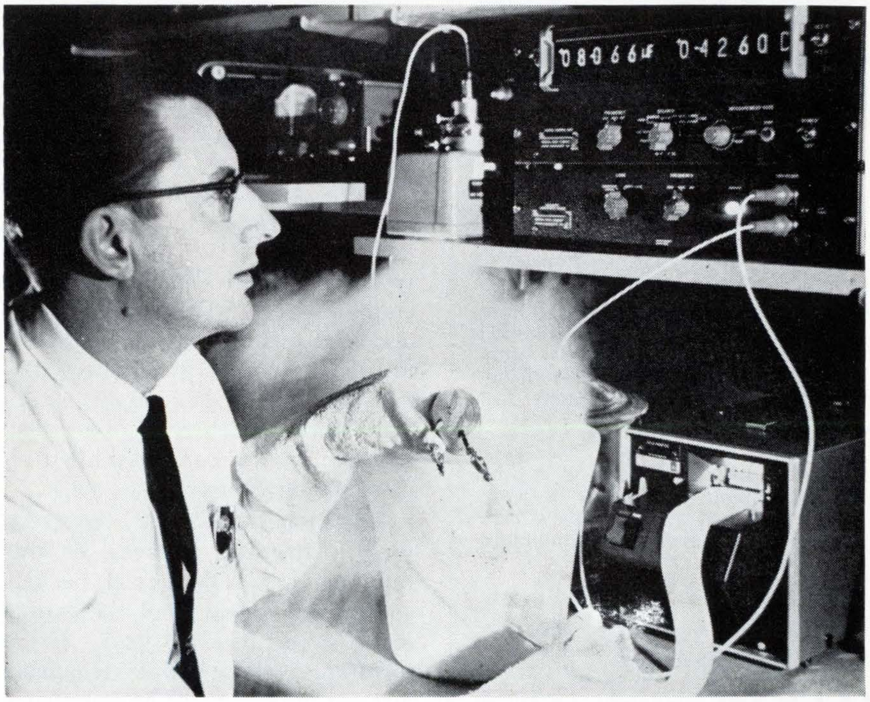
Old hat. Instrument "systems" are not new. Engineers have often "tied" groups of instruments to speed testing and data recording without sacrificing accuracy. But such jury-rigged packages, connected by mazes of cables, were limited in scope because they were adapted from existing equipment. Little attention had been paid to the problems of interface. These rigs also lacked the computational capacity to perform data reduction and analysis.

Computerized systems eliminate the inaccuracies of point-by-point measurements. By furnishing continuous data during experiments, they also reduce the waste in time, energy, and money in repeating steps and calculations to collect missing information. Even homegrown instrument systems, when combined with a computer, offer this advantage. A perfect example is the system built by the U.S. Coast Guard and placed aboard the cutter Evergreen. Designed to measure ocean currents and to plot and temperature charts, the system includes the Digital Equipment Corp.'s PDP-8/S computer. Because the computer enables immediate calculations of the output data, data gaps can be prevented.

I. Selling points

"An engineer's talent should really be used for design," says H-P's John Cardoza, a product manager. "But he has to spend too much time getting data." Since an instrument system can handle 90% to 95% of measurements like amplitude, phase, gain, and impedance, engineers and designers can be freed from purely clerical chores.

Because an instrument system



Down cold. General Radio's automatic capacitance bridge permits faster cryogenic tests than are possible with conventional instrumentation.

enables the designer to work with a precise mathematical model of a device rather than a theoretical model, circuit design can be speeded. By putting the system through its paces, the computer can calculate such things as optimum gain and the proper terminations for the design of the real model. This brings computer-aided design to the engineer at the bench. However, some design work requires large, specially programed computers.

A computerized instrumentation system yields a more accurate picture of device characteristics than is possible with discrete readings. Data gaps exist between the measured points with discrete readings; thus, while a plotted curve might be fairly smooth, there would still be uncertainty about what occurs between the points. But a computerized system can sweep through a range, analyzing every possible point. The resultant curve might reveal discontinuities not disclosed by the point-by-point technique.

Self-help. Shortening the experiment and eliminating the time lost between getting the data and reviewing the analysis also speeds design work. At Hewlett-Packard, engineers test semiconductors for certain circuits under a variety of conditions—frequency, bias, load, and temperature, for example—to obtain a characteristic profile. Data is accumulated by the engineers with pad and pencil and then entered on punch cards for analysis on a time-shared computer at Stanford University, Palo Alto, Calif. Results are available about 24 hours later.

The same tests are now being performed with an experimental computerized instrument system and the results are immediately available. In fact, the system permits the changing of circuit parameters while a device is under test, and the results can be studied almost instantaneously.

Teaching machines. Anderson sees instrument systems of this type playing a dual role. Besides serving as a design tool, the system can also be used to teach design techniques to neophyte engineers just out of college. "The experience can be put on punched tape and programed into the computer's memory for the time that another engineer may seek the solution to that particular type of design problem," says Anderson.

Computerized systems also speed design work by permitting more flexibility in test setups and by removing any ambiguities that may exist from measurement to measurement. For instance, a microwave setup with a coaxial coupler that samples signals traveling in a transmission line has a measurement ambiguity from test to test. The computer can store data taken prior to the tests or before each measurement and apply it to the results to make necessary corrections. Because the system calibrates itself, test setups do not have to be painstakingly built to minimize errors.

II. Building bridges

Two years ago, the General Radio Co. developed an automatic capacitance bridge that selects the range, balances capacitance and loss simultaneously, generates a coded digital output, and displays measured values—all in about a half-second. The bridge—the instrument that launched the firm into the automatic systems field—has increased the speed of capacitance measurements by more than 12 times. In one application, at Electronics Associates Inc., it is coupled to a computer and measures capacitors as they are temperture cycled; output data are the temperature coefficients of the capacitors. Electronics Associates reports errors have been reduced to less than 1% at a rate of almost 100,000 measurements per week.

General Radio is now developing a more complex system which will utilize a computer, in this case Digital Equipment's PDP-8/S. The new equipment—based on the capacitance bridge—will make more measurements and solve equations. The computer will signal which measurement to make and will determine whether more measurements are necessary.

Cost-yield tradeoffs. According to Harold T. McAleer, engineer in charge of General Radio's systems group, instrument systems can be used to increase the yield of discrete components at today's costs or maintain today's yields at lower costs. For instance, with General Radio's capacitance bridge, limit

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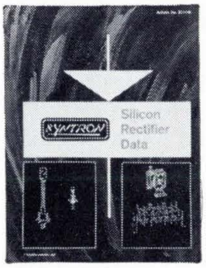

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comparators, and a bin sorter, capacitors manufactured to a tolerance of 10% can be automatically tested and sorted by grades. This system can measure and sort up to 120 capacitors a minute.

Instrument systems increase accuracy as well as speed: Julie Research Laboratories Inc. has developed automatic resistance-measuring apparatus that measures to an accuracy of 40 parts per million. Julie's system is based on the company's Ratiometric technique where the unknown is compared to a nominal value. In the automatic system, the comparison unit is a digital ratiometer that records the deviation from the nominal value. A programable standard resistor sets up the nominal value for comparison to the unknown. "This permits resistance measurements to be made to standards laboratory accuracies even within a production environment," says Loeb Julie, the company's president.

Changing image. Instrument systems are changing the character of many manufacturers. As recently as two years ago, a systems engineer at an instrument company would have been out of place. Now companies like General Radio not only have systems engineers, but also systems divisions. Almost every major instrument maker has developed and sells some type of measuring system capable of working with computers.

Hewlett-Packard has systems groups in all divisions, each concerned with devising systems to solve measurement problems within specific areas. One of the most noticeable results of this change is that the company now makes computers that are designed specifically to interface with measurement instruments.

In many ways, the Digital Equipment and Hewlett-Packard computers are alike: both have expandable core memories with about 4,000-word capacity; both are built with integrated circuits and easily adapted to measurement and analysis tasks. But unlike Digital Equipment's general-purpose PDP-8/S, H-P's 2116A machine accommodates test instruments within the input-output structure instead of with coding or interfacing equipment. The various classes of instruments and the priorities the computer should give to the signals from different instruments are taken care of by plug-in cards in the input-output section, thus tailoring the computer to the specific measurement system.

III. Changing of the guard

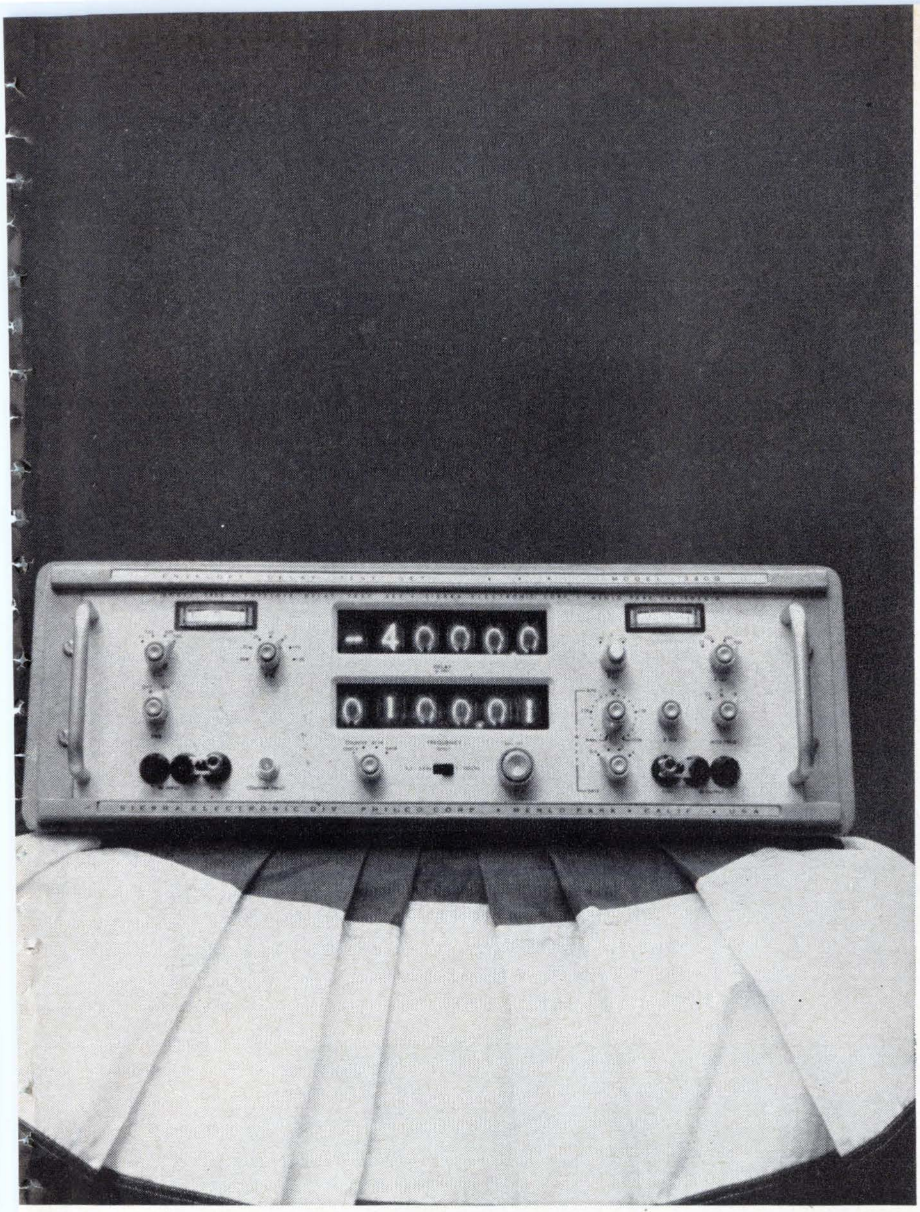
Product lines are also changing. General Radio, for example, now sells digital-to-analog converters, limit comparators, scanners, and other conditioning, handling, and processing devices.

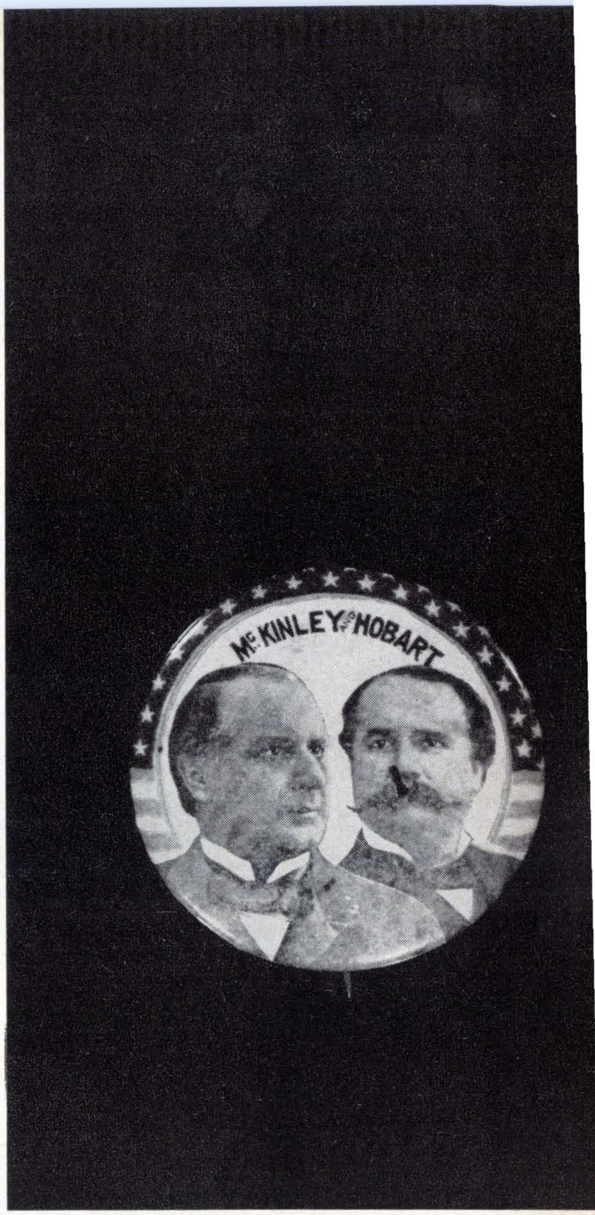
Progress in instrument systems may, however, be impeded by the incompatibility that exists between the major building blocks supplied by different companies. Both Hewlett-Packard and General Radio equipment require all instruments to be designed with binary-coded decimal outputs and to be programable. But characteristics like logic levels and codes may differ. Standardization would put an end to these discrepancies. But no move has as yet been made in this direction.

Shifting markets. To be marketable, of course, instrument systems must be economical. Development of digital computers priced from \$10,000 to \$20,000 has made this possible. According to Bill Landis, marketing manager for the PDP-8/S at Digital Equipment, the new economics opened previously barred instrumentation markets to computers. His firm projected new computer sales at 200 per year, but the machine is now moving at a rate about three or four times the original estimate.

Digital Equipment is now eyeing the test systems market itself. John MacKeen of the company's digital test systems group, indicates that a \$10,000 computer is priced low enough for computer-based memory testers to find wide use—even as a design tool. These systems would enable design engineers to make maximum-minimum parameter searches, automatic distribution plot analysis, and Shmoo plotting [Electronics, July 25, 1966, p. 127].

And eventually, companies like Digital Equipment may be competing with their customers, the instrument manufacturers, for the same business in the same manner as the instrument maker is encroaching on the computer maker's territory.





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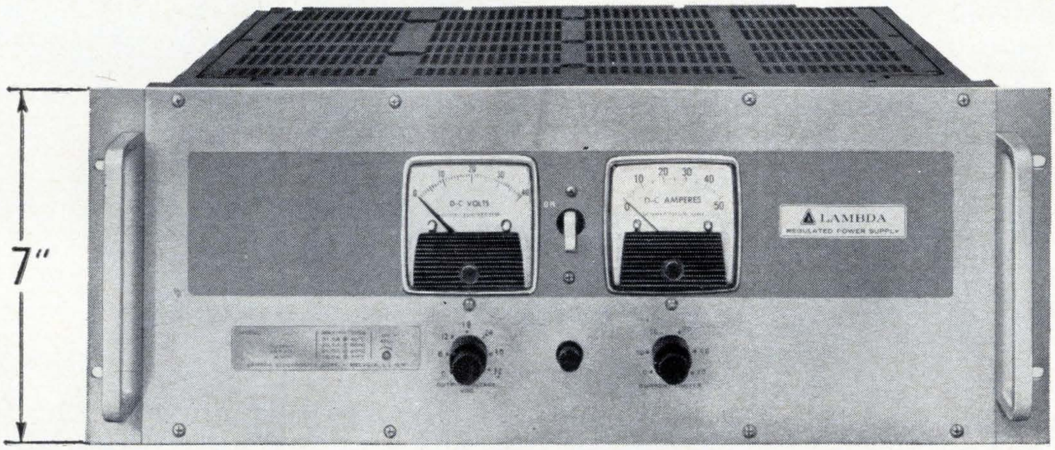

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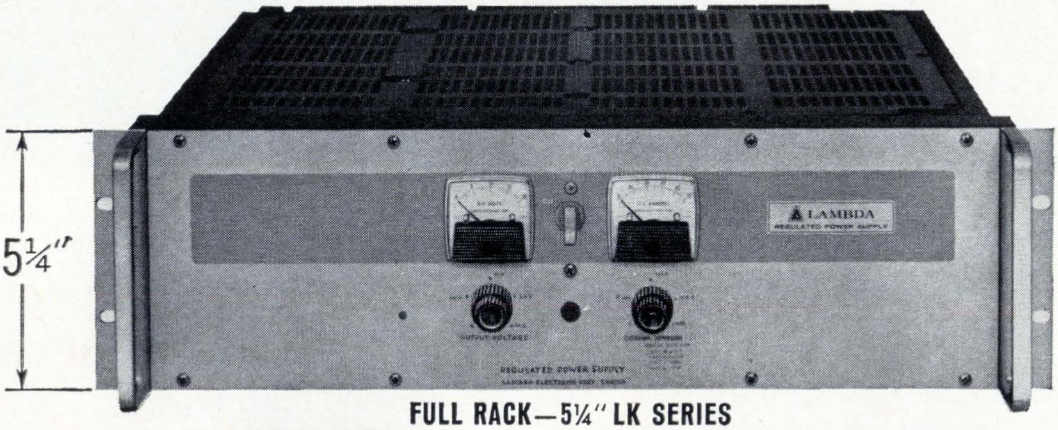

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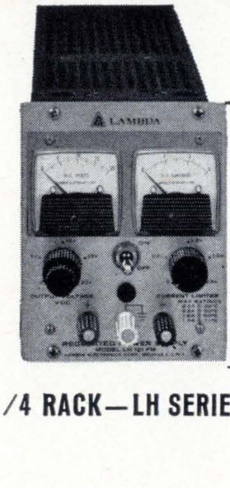

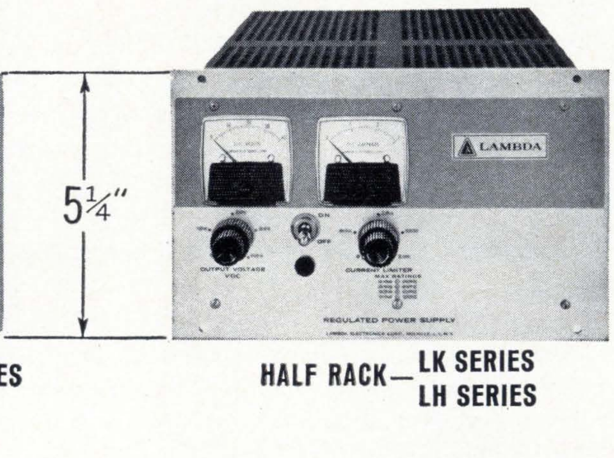

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Model[2]	Voltage Range	CURRENT RANGE AT AMBIENT OF:[1]				Price[2]
		40°C	50°C	60°C	71°C	
LK 360 FM	0–20VDC	0–66A	0–59A	0–50A	0–40A	$995
LK 361 FM	0–36VDC	0–48A	0–43A	0–36A	0–30A	950
LK 362 FM	0–60VDC	0–25A	0–24A	0–22A	0–19A	995

3 Full-rack Models — Size 5¼" x 19" x 16½"

Model[2]	Voltage Range	CURRENT RANGE AT AMBIENT OF:[1]				Price[2]
		40°C	50°C	60°C	71°C	
LK 350	0–20VDC	0–35A	0–31A	0–26A	0–20A	$675
LK 351	0–36VDC	0–25A	0–23A	0–20A	0–15A	640
LK 352	0–60VDC	0–15A	0–14A	0–12.5A	0–10A	650

5 Quarter-rack Models — Size 5³⁄₁₆" x 4³⁄₁₆" x 15½"

Model[2]	Voltage Range	CURRENT RANGE AT AMBIENT OF:[1]				Price[2]
		30°C	50°C	60°C	71°C	
LH 118	0–10VDC	0–4.0A	0–3.5A	0–2.9A	0–2.3A	$175
LH 121	0–20VDC	0–2.4A	0–2.2A	0–1.8A	0–1.5A	159
LH 124	0–40VDC	0–1.3A	0–1.1A	0–0.9A	0–0.7A	154
LH 127	0–60VDC	0–0.9A	0–0.7A	0–0.6A	0–0.5A	184
LH 130	0–120VDC	0–0.50A	0–0.40A	0–0.35A	0–0.25A	225

11 Half-rack Models — Size 5³⁄₁₆" x 8⅜" x 15⅝"

Model[2]	Voltage Range	CURRENT RANGE AT AMBIENT OF:[1]				Price[2]
		30°C	50°C	60°C	71°C	
LH 119	0–10VDC	0– 9.0A	0– 8.0A	0– 6.9A	0–5.8A	$289
LH 122	0–20VDC	0– 5.7A	0– 4.7A	0– 4.0A	0–3.3A	260
LH 125	0–40VDC	0– 3.0A	0– 2.7A	0– 2.3A	0–1.9A	269
LH 128	0–60VDC	0– 2.4A	0– 2.1A	0– 1.8A	0–1.5A	315
LH 131	0–120VDC	0– 1.2A	0– 0.9A	0– 0.8A	0–0.6A	320

Model[2]	Voltage Range	CURRENT RANGE AT AMBIENT OF:[1]				Price[2]
		40°C	50°C	60°C	71°C	
LK 340	0–20VDC	0– 8.0A	0– 7.0A	0– 6.1A	0–4.9A	$330
LK 341	0–20VDC	0–13.5A	0–11.0A	0–10.0A	0–7.7A	385
LK 342	0–36VDC	0– 5.2A	0– 5.0A	0– 4.5A	0–3.7A	335
LK 343	0–36VDC	0– 9.0A	0– 8.5A	0– 7.6A	0–6.1A	395
LK 344	0–60VDC	0– 4.0A	0– 3.5A	0– 3.0A	0–2.5A	340
LK 345	0–60VDC	0– 6.0A	0– 5.2A	0– 4.5A	0–4.0A	395

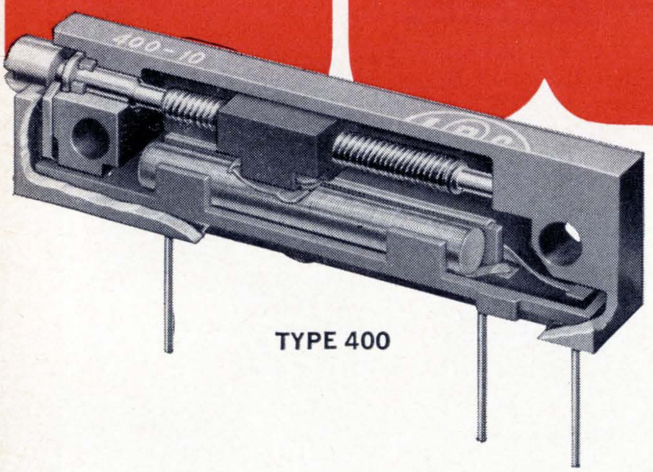
[1] Current rating applies over entire voltage range.
[2] Prices are for non-metered models (except for models LK360FM thru LK362FM which are not available without meters). For metered models, add suffix (FM) and add $25 to price of LH models; add $30 to price of LK models.
[3] Overvoltage Protection: add suffix (OV) to model number and add $60 to the price of LH models; add $70 to price of half-rack LK models; add $90 to price of 5¼" full-rack LK models; add $120 to price of 7" full-rack LK models.
[4] Chassis Slides for full rack models: Add suffix (CS) to model number and add $60 to the price.

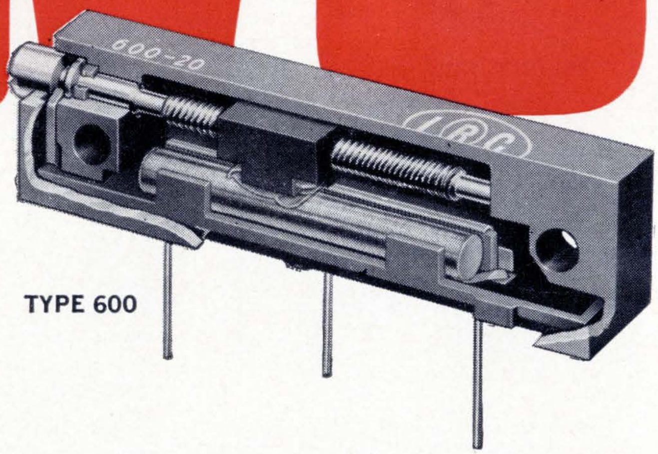
SEND FOR NEW LAMBDA CATALOG

LAMBDA ELECTRONICS CORP.
515 BROAD HOLLOW ROAD • MELVILLE, L.I., NEW YORK 11746 • (516) 694-4200
A Veeco SUBSIDIARY

Circle 167 on reader service card

save





Military quality at industrial prices

IRC wirewound rectangular trimmers save space and dollars

IRC's CIRCUITRIM potentiometers offer MIL characteristics at the same price as industrial types. Benefit by upgraded performance and reliability for your industrial needs and impressive savings for your MIL applications.

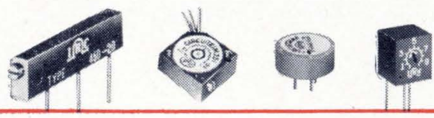
Both series are designed to perform under environmental requirements of MIL-R-27208. Molded diallyl phthalate cases are rugged, light and practical for use in any military or high grade industrial application. A one-piece, corrosion-resistant shaft and specially designed wiper block system isolate electrical elements and assure "set-and-forget" stability.

The 600 series is designed to MIL-Style RT-11 and is offered with staggered P.C. pins or teflon insulated leads. The 400 series is designed to MIL-Style RT-12 with P.C. pins in-line or teflon insulated leads. It is also available in a thin-line version of RT-11 (Type 400-20) with staggered P.C. pins which offer 30% space savings and complete interchangeability on pre-printed boards.

These low-cost MIL-type units are the result of IRC's years of experience in building high-quality trimmers. Samples available from local sales offices. For prices and data, write: IRC, Inc., 401 N. Broad St., Philadelphia, Pa. 19108.

ONLY IRC OFFERS ALL 4 POPULAR STYLES

Wirewound or infinite resolution elements



CAPSULE SPECIFICATIONS

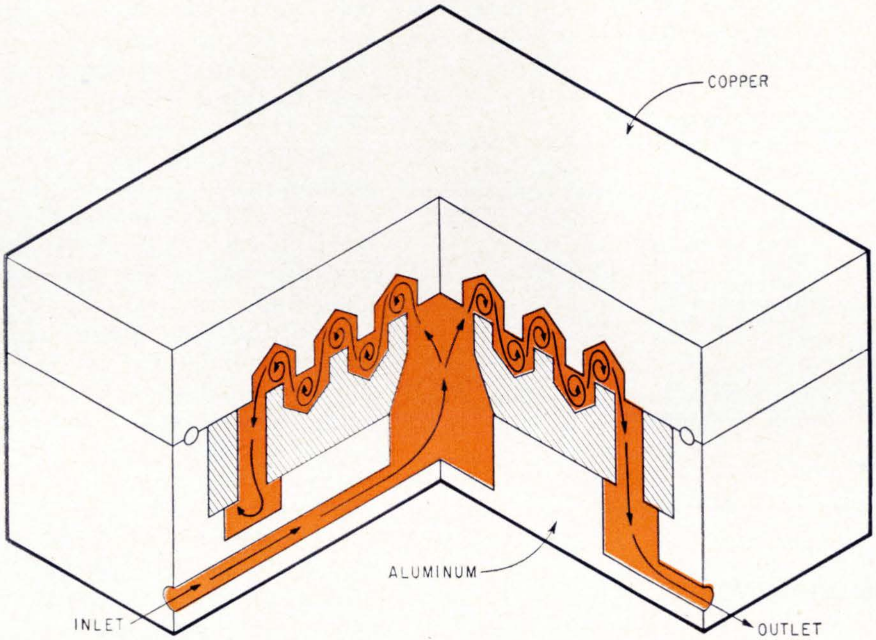
	TYPE 400	TYPE 600
MIL STYLE	RT-12*	RT-11
POWER	1 W @ 70°C	1 W @ 70°C
TOLERANCE	±5%	±5%
RESISTANCE	10Ω to 50KΩ	10Ω to 50KΩ
TEMPERATURE	−55°C to 150°C	−55°C to 150°C

*Plus thin-line version of RT-11 (Staggered P.C. pins)

IRC

Water takes the heat off thyristors

Labyrinth bath boosts power dissipation of conventional as well as 'hockey puck' silicon controlled rectifiers



New water cooling methods may be the solution to the gnawing problem of power dissipation when high currents are demanded of thyristors. A cooling labyrinth has been designed that promises to boost the current-carrying capability of the silicon wafer—the heart of the thyristor or silicon controlled rectifier.

Developed by the Westinghouse Electric Corp. with the aid of a computer, the labyrinth—through which water is pumped—can be clamped to a thyristor. The assembly consists of three parts: an aluminum body, a machined insert, and a copper counter-body. The insert, now made of stainless steel, can be copper, aluminum, or even plastic, its developers say, and it could be cast instead of machined to reduce cost.

Water is pumped into the center of the block directly below the silicon wafer and circulates radially through the labyrinth, creating low velocity eddy currents. A collector ring circles the labyrinth and a resilient O-ring seals the halves.

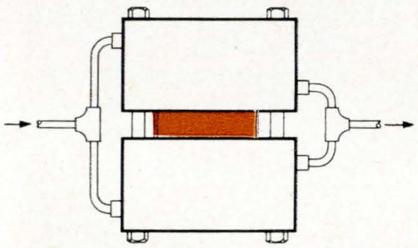
The labyrinth was designed so that it can be used on either side of a "hockey puck" or disk-cell type thyristor, as well as with a conventional stud mounted thyristor. The hockey puck type enables the removal of heat from both sides of the silicon wafer simultaneously. A pair of these operating as an a-c switch can handle 1,200 amperes root mean square.

The first device to use the new labyrinth is the type 224, a conventional single-sided thyristor. It can carry currents of 630 amperes rms compared with 400 amperes for the

New products in this issue

air-cooled type 229. Westinghouse has conducted tests of the hockey puck version cooled from both sides using the labyrinth and reports results "quite close to the full current carrying capability inherent in the silicon wafer." The only way to beat these results, says one Westinghouse engineer, is to use Freon-cooled systems.

Westinghouse hasn't decided whether to market the hockey puck thyristor and associated labyrinth coolers as a package. Instead, it may encourage customers to buy its thyristors and put together their own coolers using the labyrinth approach. In the meantime, the water-cooled 224 is available at prices ranging from $135 to $755 depending on voltage ratings (50 to 1,400 volts) on a four-to-six week delivery.



Specifications

Package	One-sided stud, water-cooled labyrinth
Water flow	1.5 gal. per minute
Current ratings	
Half wave average	400 amps
Rms	630 amps
Half cycle surge	5500 amps
Voltage ratings	
Forward and reverse	50-1,400 v
Price	$135-$755 in 1-24 quantities

The Westinghouse Electric Corp., Pittsburgh, Pa. **[349]**

Versatile receiver scrimps on power

A bantamweight champion of versatility, the all-purpose receiver developed by Defense Electronics Inc. is also penurious with battery power. So miserly is the GPR-20 on battery drain that it can operate on land, sea, or air for 250 hours on its power supply of 10 standard flashlight cells. This frees the unit, which weighs less than 10 pounds, from the fetters of an a-c line cord, and enables it to perform an extraordinary number of sophisticated jobs in the field as well as in the laboratory.

With an all solid state lineup of 40 silicon transistors, 11 silicon diodes, and 40 germanium diodes, the receiver operates over a frequency range of 55 to 260 Mhz, and can detect amplitude and frequency modulation, continuous wave, and pulse transmissions. This flexibility qualifies it for applications in telemetry, communications, spectrum analysis, medical instrumentation, radio frequency interference investigations, and surveillance.

According to Ray Rosenberg, president of DEI, the portability of the GPR-20 is important in rugged field applications like quick-look telemetry and surveillance. "Getting the receiver off the power line makes it immune to power surges," he says, "and eliminates the noise of gasoline generators. Furthermore, it isn't necessary to lug gasoline into the remote and rugged terrain where these receivers may be used."

Rosenberg claims that the receiver will do more with less size and weight than any other receiver designed for the same class of applications—and at low cost, too: $1,250.

Design features that give the receiver unique performance characteristics include an f-m demodulator with a high capture ratio that assures locking onto the strongest signal in a multipath distortion environment, and a stretched pulse audio monitor, which elongates pulse inputs, allowing detection of high speed pulse codes that might otherwise slip by during a surveillance frequency sweep. Measuring 3¾ x $11\frac{13}{16}$ x $11\frac{13}{16}$ inches, the receiver has a noise figure of only 5.5 decibels maximum below 200 Mhz, and 6.5 db maximum above that range. Local oscillator stability is less than 100 hz per minute after a 30 minute warmup.

Bandwidth and phase response make it suitable for tv reception without modification. With a facsimile printer, the unit can be slightly modified to receive satellite weather photos.

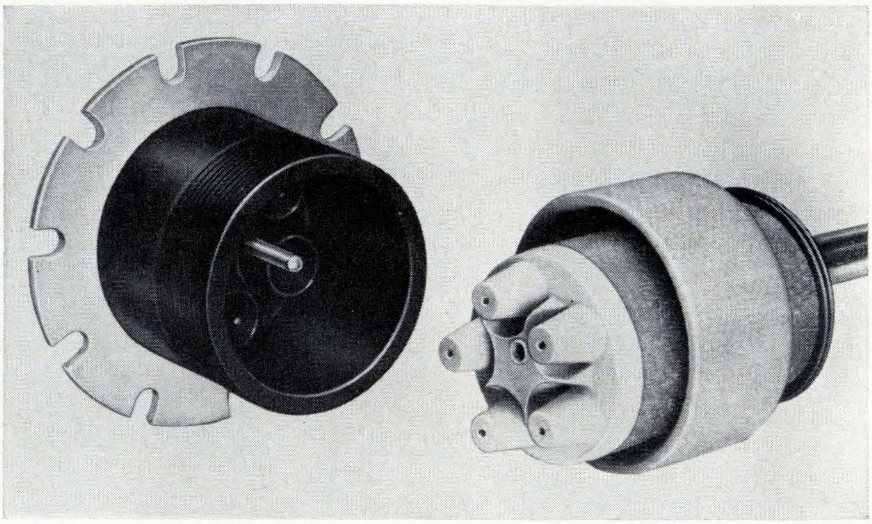
The GPR-20 is housed in a splash-resistant case with carrying handle, and has a built-in telescoping antenna that can be swiveled for either horizontal or vertical polarization. Two front panel meters provide indication for tuning, relative signal strength, and battery condition. The unit has a calculated mean time between failures of 25,000 hours.

Specifications

Tuning range	55-260 Mhz
I-f bandwidth	1 Mhz [f-m, a-m, pulse, c-w]; 10 khz [a-m, c-w] other i-f bandwidths available on special order.
Video response	20 hz to 500 khz into 600 ohms
Antenna-conducted local oscillator radiation	Less than 15 μv
Image rejection	40 db min., below 150 Mhz 30 db min., above 150 Mhz
F-m distortion	Less than 1% with 1 khz modulation rate, 200 khz peak deviation
A-m distortion	Less than 3% for 50% modulation with 1 khz modulation rate and r-f input from <10 μv to 50 mv
Options	Standard 19-inch rack adapter, carrying case including headphones and tool kit, 115/230 volt 50-400 hz plug-in power supply
Price	$1,250
Delivery	30-45 days

Defense Electronics Inc., Brookville, Maryland. **[350]**

Plastic connectors make airtight case



There's still a good bit of controversy about the hermeticity of plastic packages [Electronics, March 20, p. 25]. Most of the attention has been focused on semiconductor device packages, but now a line of high-voltage connectors is being introduced that features hermeticity with a plastic to metal seal. The connectors use a high-temperature plastic dielectric which the manufacturer claims can stand up under wide temperature fluctuations that often adversely affect units using glass or ceramic insulators. The connector's application, rather than the dielectric, thus determines the choice of optimum contact material. For example, copper alloys, which permit the incorporation of high-conductivity contacts, can be used instead of such special metals as Kovar.

Built by the Capitron division of AMP Inc., Elizabethtown, Pa., the connectors are designed to maintain a hermetic seal when cycled from $-55°C$ to $+125°C$. When tested with a helium mass spectrometer, they show no leakage; sensitivity ranges from 1×10^{-7} to 1×10^{-9} cubic centimeters per second.

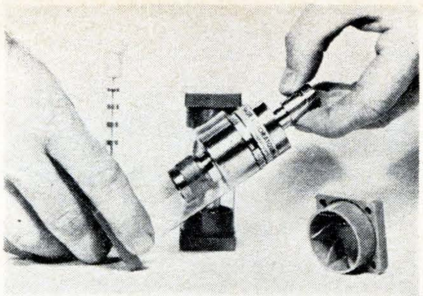
Capitron is convinced its bonding process sidesteps a number of the difficulties involved in making connectors with conventional dielectrics to military specifications. Glass, the company says, is vulnerable to heat-cracking during soldering operations and it can also shiver if contact pins are bent or straightened. An alternative, ceramic, is more resistant to cracking and provides stronger bonds to metal than is the case with glass. But ceramic's high costs may outweigh these advantages, and any special geometry that may be required in the device will lengthen fabrication lead times.

As a result of the ability of its plastic dielectric to be fused with a wide variety of metals, Capitron says, the choice of materials for a connector's outer shell is not limited by the insulation. In fact, the outer shell can be eliminated for "O" ring mounting. Threaded holes can be molded directly in the insulator—a feature that would be impracticable with glass or ceramic.

Capitron Division, AMP Inc., Elizabethtown, Pa. 17022. **[351]**

Protective containers with finned end caps

Designing a package for delicate, expensive electronic parts has for years been a problem to manufacturers. Now a series of simple, shockproof, low-cost, transparent



containers provides lightweight protection for such items.

Key to the effectiveness of the new container is the specially designed injection molded polyethylene end cap, the inner part of which has fins that grip the enclosed part tightly. If the container is dropped, the shock is absorbed by the flexible end closures and dissipated over the surface of their rims. The end closures can be color-coded for product identification.

The manufacturer is also making available a cutting machine for users wishing to produce their own package lengths. Standard 6-foot lengths of tubing can be quickly and economically cut into specified lengths.

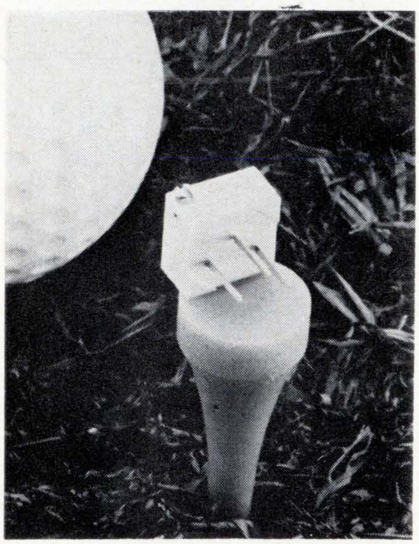
At present, the acetate tubing is available with outside diameters of from 1/4 to 1 1/4 in. in 1/4-in. increments. End closures come with corresponding o-d's. Wall thicknesses are 0.020 in. for the 1/4-in.-diameter tube, 0.025 in. for the 1/2- and 3/4-in.-diameter tube, and 0.030 in. for the 1- and 1 1/4-in. diameter.

Tiros Plastics Corp., 543 Tarrytown Road, White Plains, N.Y. **[352]**

Commercial trimmer in square design

The first commercial trimmer in a square configuration is claimed for a wirewound 3/8 in. trimming potentiometer. Its p-c pins fit the cards of any standard 3/8 in. or 1/2 in. square trimmer. It also offers a 0.200 in. trimmer height for low card spacing applications.

Because of this geometric design, the model 3600 trimmer permits a longer mandrel than that of rectangular units and, therefore, offers up to 131% better resolution than that offered by the best 3/4 in. rectangular trimmer, the company re-



ports. Because the wire is wound on a small diameter mandrel, the new design offers up to 85% better resolution than that specified by MIL-R-27208B, RT24.

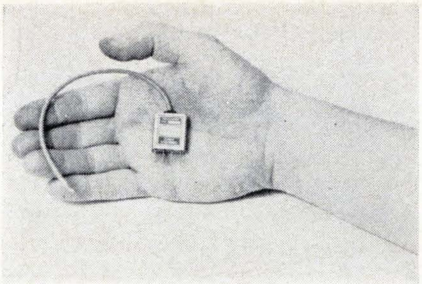
Resistance values are available from 100 to 20,000 ohms. Power rating is 0.5 w at 40°C. Operating in a temperature range from —65° to +125°C, the new trimmers feature silver-brazed terminations, gold-plated terminals and a damage-proof clutch. The model 3600 trimmers are production-priced at less than $2 each.

Amphenol Corp., Amphenol Controls Division, 120 S. Main St., Janesville, Wis. 53545. **[353]**

Temperature-stable photochopper modules

Stable high efficiency over a wide temperature range is the specialty of a line of photochopper modules. Designated CM-1 and CM-2, the devices utilize high-speed cadmium-sulfide photocells with low temperature coefficient for applications to 1,000 hz.

The modules consist of two photocells illuminated by a neon glow lamp. Model CM-1 has a nominal input impedance of 300 kilohms at 60 hz. The CM-2 has a nominal input impedance of 10,000 kilohms at 60 hz. Input impedance is claimed to be unusually stable over a temperature range from —25° to +75°C, and efficiency



varies less than 5% over this range from the value at 25°C. Typical module conversion efficiency is 99% at 60 hz and 25°C.

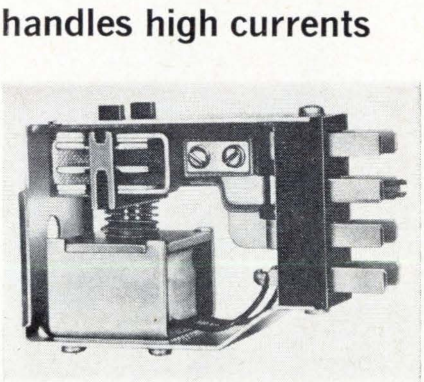
Low driving power, low microvolt noise, and low offset are other features of the modules. Offset is less than 1 μv. Life, which is limited only by the life of the neon lamp, exceeds 10,000 hours and can reach 50,000 hours when lamp supply voltage is high and average current is low.

Internal offset effects due to electrostatic coupling between lamp and cells have been eliminated by internal shielding, and a shielded lamp lead is included. Thermal offset has been minimized by design and selection of materials including Sealmet leads.

The extremely low inherent noise and offset voltages of the modules allow for use in spst modulator-demodulator configuration where low cost is a prime consideration. They may also be used in spdt configuration for maximum efficiency and output voltage.

Clairex Corp., 1239 Broadway, New York City 10001. **[354]**

Electromagnetic relay handles high currents



Problems of heavy current loads are expected to be answered by a plug-in, dpdt, double break relay. The LA57 electromagnetic relay can handle 15-amp tungsten lamp loads as well as resistive loads up to 50 amps, at 120 v a-c. The compact ($3\frac{1}{4}$ x $1\frac{5}{8}$ x $2\frac{1}{4}$ in.) unit's simplicity of design, the manufacturer says, is the key to its long-life capabilities. Tests indicate a minimum life of 2,000,000 operations under its fully rated 15-amp tungsten lamp load.

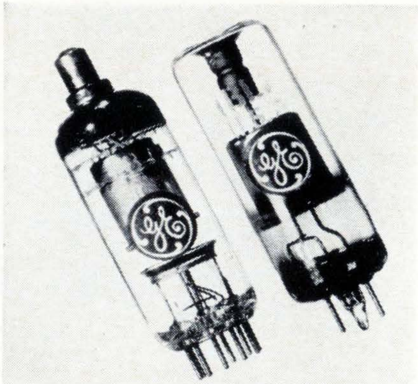
In addition, the relay rapidly and thoroughly dissipates high temperature build-up due to repetitive make-and-break operations. Carefully controlled over-travel reduces bounce and increases contact life.

Another feature of the LA57 is the plunger type solenoid. It supplies higher contact force (50 grams minimum), to help carry heavy currents with minimum heat and the lowest possible voltage drop. The solid bus members and associated jacks eliminate solder connections in the current carrying components of the relay. A safe manual-type method to pulse the movable contact system is also incorporated. Buttons on top of the relay are depressed for quick circuit checks.

The LA57 is directly interchangeable with the LAS57 relay currently used in many of the company's vehicular traffic signal controllers.

E.W. Bliss Co., Eagle Signal Division, 736 Federal St., Davenport, Iowa **[355]**

Television diode rated at 18 kv

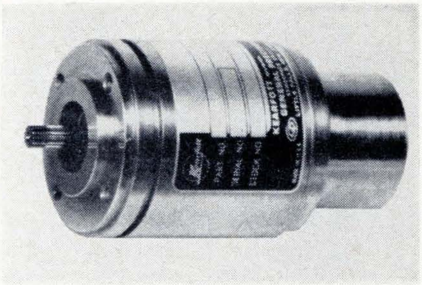


Designed as a rectifier tube for the high-voltage power supplies of black-and-white tv receivers, the miniature, double-ended 1BL2 diode has a two-pin base and features an inexpensive recessed anode connector that holds corona to a minimum.

The anode connector is supported in cantilever fashion by the tube glass. The diode is conservatively rated at 18 kv.

General Electric Co., Owensboro, Ky. **[356]**

Braked servomotor withstands shock



High torque-to-inertia ratio is offered in a 400-hz braked servomotor. Consisting of a size 15 servomotor and a friction brake controlled by an electromagnet, this component, designated CTO-1711 006, can maintain a constant reference position in a servosystem subjected to shock and vibration extremes. In operation, the brake element, when deenergized, effectively stops and holds the motor's rotor and shaft at a desired position.

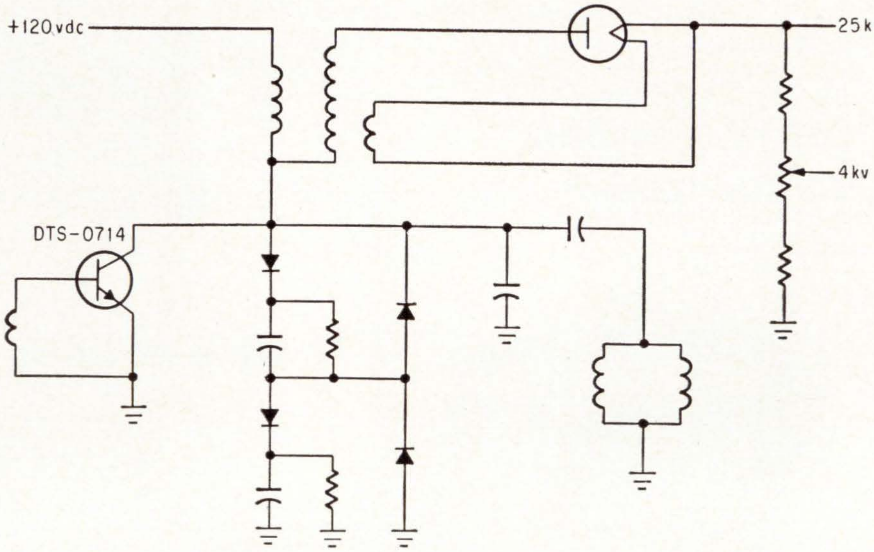
Weighing 8.5 oz, the braked motor is equipped with a pinion shaft and has color-coded leads. Motor characteristics include: phase 1 and phase 2 voltage, 115 v; starting voltage, 3 v; stall torque, 1.45 in.-oz; no load speed, 5,000 rpm; power input, 6.1 w; current input, 110 ma; effective resistance, 2,200 ohms; d-c resistance, 154 ohms; rotor inertia, 3.6 gm cm^2; theoretical acceleration, 30,200 rad/sec^2; time constant, 0.017 sec.

Brake characteristics include: torque, 4 in.-oz; excitation voltage, 18 to 29 v d-c; input power, 5 w; resistance, 168 ohms; response time, 0.021 sec. Measuring slightly more than 2 in. in over-all length, the component's brake element has a diameter of less than 1 in.

General Precision Inc., Aerospace Group, 1150 McBride Ave., Little Falls, N.J. 07424. **[357]**

New Semiconductors

High-voltage transistor sweeps color tv



A silicon transistor has been developed that can withstand a retrace voltage pulse above 1,000 volts generated in the horizontal deflection system of a large-screen television set. The Delco Radio division of the General Motors Corp. is now demonstrating a modified 25-inch Zenith color set in which the new 1,200-volt transistor can switch the 3,800 volt-ampere load line of the horizontal deflection system (see circuit).

Previously, a vacuum tube or a pair of lower-voltage DTS-402 transistors operating in series were needed to do the job (present production sets use only tubes, though some manufacturers have been evaluating the 402 transistors). A series resistance-capacitance network connected between a center tap on the primary winding of the flyback transformer and the midpoint between the two series-connected DTS-402's would be required to force the equal sharing of the 1,050-volt retrace pulse by the two transistors. The DTS-402 is rated at 700 volts.

In the circuit shown, the 1,050-volt pulse is transformed in the flyback transformer to 25 kilovolts for the ultor anode of the picture tube. The horizontal transistor switches about 4 amperes; it's protected during fault-arcing conditions by a peak rectifier network consisting of the two diode and RC networks connected across it. This could be replaced by a single, higher-voltage diode-and-RC combination.

The 1,200-volt silicon transistor, type DTS-0714, is a triple-diffused mesa device in a strip-mounted epoxy package. Limited samples will be available this month.

Specifications

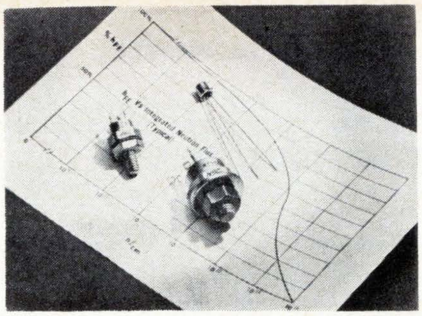
Type	DTS-0714
V_{CEX}	1,200 V
V_{sus}	750 V
Linear current gain N_{FE} at 2.5 amperes	10 min.
Reverse voltage V_{EBO}	5 V
Thermal resistance	1.2°C/watt
Package	Strip-mounted epoxy

General Motors Corp., Delco Radio division, Kokomo, Ind. **[361]**

Silicon transistors resist radiation

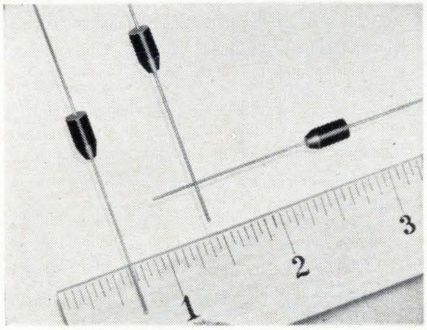
Three npn transistors operate in environments subjected to neutron bombardment where radiation levels may reach 3×10^{14} nvt (the time integral of neutron flux). The units are silicon epitaxial planar types designated NS9726 and silicon epitaxial planar power transistors designated NS9608 and NS9609. Case sizes are TO-18, TO-60, and TO-61, respectively.

Operating and storage tempera-



tures for all three are $-65°$ to $+200°C$. Total device dissipation at 25°C case temperature is 1.2 w for the NS9726, 12 w for the NS9608, and 25 w for the NS9609. National Semiconductor Corp., Danbury, Conn., 06810. [362]

Avalanche rectifiers deliver high power



Four tiny (0.07 cu. in.) avalanche rectifiers in a single phase bridge will deliver as much as 2 kw at 50°C ambient temperature.

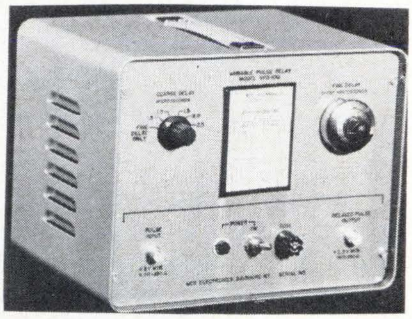
Three different versions have maximum recurrent peak inverse voltage ratings of 1,500, 2,000, and 2,500 v respectively. At 25°C, types F-15 and F-20 are rated at 1 amp d-c and 30 amps surge. Type F-25 is rated at 500 ma d-c and 20 amps surge. The devices can be operated at temperatures up to 140°C, at which point they are derated to 10% of their 25°C current rating.

Applications for the rectifiers include amateur equipment, ulrasonic generaors, test equipment, oscilloscopes, medical equipment, spot welders, television monitors, and transmitters.

Prices for the avalanche units are reportedly the lowest for comparable ratings. Type F-20 is priced at \$1.50 in single quantity, and 73 cents in maximum quantities.

Sarkes Tarzian Inc., 415 North College Ave., Bloomington, Ind. 47401 [363]

Pulse delay has 1-nsec resolution



An all-solid-state unit capable of delaying pulses up to 3 microseconds with a resolution of better than 1 nanosecond has been introduced by MCC Electronics. Two or more of these pulse-delay lines can be connected in series to increase delay times.

According to the manufacturer the best previous digital pulse-delay unit costs twice as much as the new unit and has but a 10-nsec pulse-resolution capability.

The new instrument, model VPD-100, can be used in the laboratory or at production test facilities. Connected to a pulse generator, it can act as a reference delay line for pulse jitter studies, or as a quick means of calibrating other delay lines and oscilloscope time bases.

The delay time is controlled by switching between five fixed lumped-constant delay lines and a variable delay line connected in series. Each fixed delay retards the pulse for 0.5 microseconds; the variable delay line delays the pulse from 0 to 750 nsec.

The variable delay line's input pulses are conditioned by integrated-circuit NAND gates, which were chosen for this task because they switch rapidly and are relatively insensitive to pulse shape. Also, the NAND gates' output is constant in amplitude and rectangular in shape.

The undelayed pulses from a signal generator are used as triggers to switch the NAND gates on and off. The variable delay line's initial input pulse switches the first gate from logic 0 to logic 1 and the output of the first gate switches a second gate. The 2.5-volt signal from the second gate feeds the lumped-constant delay line and triggers the third and fourth NAND gates at the unit's output. Each succeeding input pulse switches the gates in like manner.

During its passage through the VPD-100's internal delay lines, the signal from the second NAND gate is attenuated by almost half and its shape degraded, so the third and fourth NAND gates at the output are used to regenerate the original 2.5-volt rectangular wave.

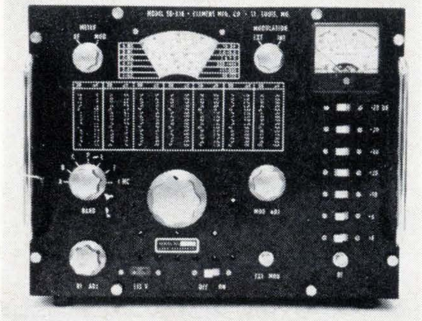
The rise and fall times of the output pulse are only 10-nsec, regardless of pulse width. A 3-μsec rectangular pulse through an ordinary lumped-constant delay line will have a rise and fall time of about 300 nsec, 10% of the pulse width.

Specifications

Pulse input	
Amplitude	2 to 5 v
Pulse repetition rate	1 Mhz at 25% duty cycle
Pulse output	
Pulse delay	50 nsec to 3 μsec
Resolution	1 nsec
Amplitude	2.5 v into 150-ohm load
Pulse rise and fall times	Less than 15 nsec
Supply voltage	115 v a-c
Size	10½ x 8 x 8 in.
Weight	6 lbs
Panel connectors	BNC

MCG Electronics, 11-22 Joselson Ave., Bay Shore, N.Y. **[371]**

Signal generator runs on battery power



A solid state standard signal generator is claimed by the manufacturer to be the only one available which can be operated from either internal battery or the 115-v a-c line. This suits it for use in the field or in screen rooms when complete isolation from the power line is desired.

The SG-83B covers 50 khz through 54 Mhz in six bands, with a seventh bandswitch position in which it is crystal controlled at 1 Mhz. The output is accurately calibrated from 0.6 μv to 0.16 v, $\pm$2 db. Frequency calibration is 1% or better. Modulation is variable from zero to 50% from an internal 400-hz oscillator or by an external signal.

Price is $295. Delivery is from stock.

Clemens Manufacturing Co., 630 S. Berry Road, St. Louis, Mo. 63122 [372]

Current indicator also integrates

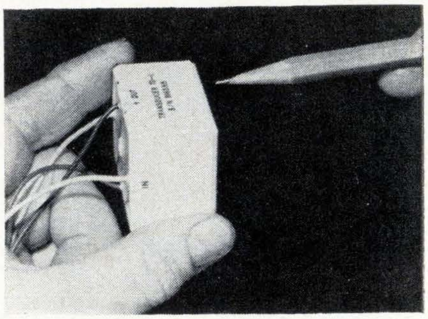
Accurate to within 1%, a self-calibrated, solid state instrument measures current flow and displays an integral digital value. The current indicator and integrator is suited for a variety of applications involving accurate integration of continuous current values. The unit features pushbutton start and stop controls that are adaptable for remote operation.

Sensitivity of the instrument can be varied from 0.1 milliamp to 0.3 nanoamp for either positive or negative current measurement. Individual current inputs are shown on the d-c indicator. The integral is displayed digitally and is calibrated by a 10-turn precision potentiometer. The instrument can be preset to terminate integration and control a wide range of auxiliary equipment. Both the indicating and integrating values are accurate to 1%. Calibration requires no external instrumentation and is achieved by internal current sources and front-panel calibration controls.

The new model A310C measures

19 in. wide x 5¼ in. high x 12 in. deep. Price is $1,798 with present shipping being one to three weeks. Elcor, a division of Halliburton Co., 2431 Linden Lane, Silver Spring, Md., 20910 **[373]**

Squaring transducer operates to 1 Mhz



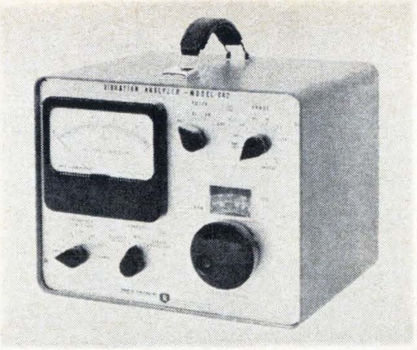
Requiring no power supply for activation, a solid-state, voltage-to-current analog squaring transducer serves as an accurate, low-energy, completely passive squaring device. Model TD-1 Transquare performs accurately for all input levels up to 200 mv. Operating frequency is d-c to 1 Mhz.

The unit is made up of stable, solid-state elements arranged and matched in a network so that the instantaneous output current is proportional to the square of the instantaneous input voltage. The transducer output, therefore, is nonlinear; its characteristic, a true parabola. The output is $\pm 0.1\%$ of theoretical squared-value.

The instrument is 1⅝ in. wide x 1 in. high x 1¼ in. deep. It has a center mounting hole for a No. 6 screw and four pigtail leads for input-output connections. The unit is available from stock. Price for small quantities is $200 each.
Greibach Instruments Corp., 315 North Ave., New Rochelle, N.Y. **[374]**

Vibration analyzer has a dual role

Measurements of vibration amplitude and frequency can be obtained with a single, lightweight, portable instrument. The unit de-



tects and measures vibration, shock, and impact in rotating members.

Model 642 and its accessories provide the information for detailed vibration analysis and in-place balancing of operating machinery. The unit also functions as a strobo tachometer. Vibration amplitudes as little as 10 millionths of an inch to as great as ⅜ in. may be measured using the model 023 velocity pick-up.

The same meter and scaler used to indicate direct frequency also indicate vibration levels. A tunable wave filter provides narrow-band observation of vibration signals to isolate their components. Connectors are provided on the rear panel for attaching recording equipment, oscilloscopes and audio equipment.
Reliance Electric and Engineering Co., 24701 Euclid Ave., Cleveland, Ohio 44117. **[375]**

A-c microvoltmeter rejects noise

Signals as small as 300 mv rms in the frequency range between 25 hz and 60 khz are measured with full-rated accuracy by an a-c microvoltmeter. The instrument has 13 sensitivity ranges, from 3-μv full scale to 3-v full scale in a 1-3-10 sequence. It also measures signals in a frequency range between 5 and 25 hz with full-scale ranges of 30 μv to 3 v. Basic accuracy is ±3% of full scale up to 60 khz, and ±5% of full scale above 60 khz. Input impedance is 10 megohms shunted by 20 picofarads.

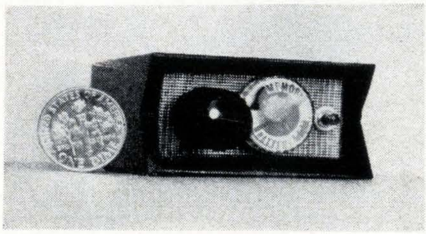
The high sensitivity of model 3410A is made practical by its ability to tolerate large amounts of noise with the signal. Rms noise voltages up to 20 db above full scale do not affect the accuracy of the reading, even for signal levels that are only $\frac{1}{10}$ of full scale (40 db below noise that is 20 db above full scale).

The new microvoltmeter uses a phase-locked synchronous detector rather than narrow-band filters to separate the effects of noise from the signal. The detector is an electronic gate controlled by an oscillator phase-locked to the input signal. Alternate half cycles of the input signal are passed by the gate, and the output of the gate is smoothed by a low-pass filter to obtain a d-c voltage proportional to the average value of the input waveform. Since both the positive and the negative excursions of noise and other randomly varying signals pass through the gate when open, these average out to zero and do not affect the reading.

Price of the model 3410A is $800, and delivery time is estimated at 60 days.

Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, Calif., 94304. **[376]**

Peak voltage sensor has floating input



A peak voltage sensor to be used with solid state circuitry detects transients as short as 10 microseconds. The Memorette variable-threshold peak indicator has a completely floating input, making it possible to monitor positive or negative levels from 50 millivolts to 50 volts at any point in the circuit. An external resistor extends the upper end of the range to the thousands of volts. Front-panel controls include a sensitivity adjustment, a reset control, and a memory readout.

The sensor is supplied with an internal mercury battery and both are warranted for one year of continuous duty. Cabinet dimensions are 2 x 2 x 1 inches. Source impedance is 20,000 ohms per volt; frequency response is d-c to 20 khz.

Price of the unit is $44.50, with lower prices quoted for quantities. Delivery is 2 to 4 weeks.
Roveti Instruments, 1643 Forest Drive, Annapolis, Md. 21403 **[377]**

Digital meter unites 3 instruments in 1

A general-purpose digital meter combines the features of three commonly used laboratory instruments in one compact, economical unit: a 100-μv-resolution, d-c digital voltmeter, a greater than 1-Mhz multifunction electronic counter, and an electronic integrator. The extensive use of IC's and plug-in modules in the DM5000, along with circuit sharing, enhances maintainability, and accounts for the $950 price.

No external plug-ins or adapters are required and simplified operation is assured by using a minimum number of controls. A long-life, four-digit, buffered Nixie display with illuminated legends indicates the units being measured, as well as over-range and polarity.

As a dvm, this instrument offers automatic polarity, five d-c voltage ranges from ± 100 mv to $\pm 1{,}000$ v, calibrated over-ranging to 40%, an accuracy of $\pm 0.1\%$, 100-μv resolution, and an input impedance

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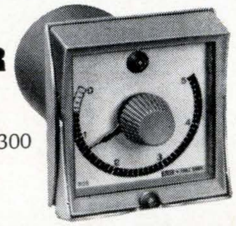

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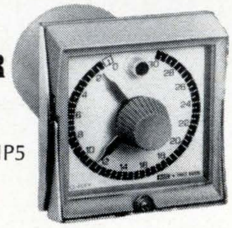

HP5

The Man from E.A.G.L.E.* *offers you a range of accurately controlled Cycl-Flex time delays that run all the way from 1/20 second to 60 hours. These timers, housed in their now famous plug-in cases, may in fact be interchanged. The HP5 Cycl-Flex is a synchronous, motor driven, precision instrument providing accurate delay between control-circuit actuation in the operation of load circuits. Maximum settings range from 5 seconds to 60 hours with minimum settings from 1/6 second to 2 hours. The CE300 Cycl-Flex is a solid state timer that overlaps the HP5 in the lower time ranges. The 300 series offers dial ranges of 10 seconds and shorter, with minimum settings from 1/20 second to 1/2 second. Depending on contact load, average mechanical life is more than 10,000,000 operations.*

Whether you need short time cycles at a fast repetitive rate, or longer but still precisely-controlled delays, the Cycl-Flex Series will give you exactly the right answer...for specifications, get our HP5 Series Bulletin 125 and our CE300 Series Bulletin 155. Write Eagle Signal Division, E. W. Bliss Company, 736 Federal Street, Davenport, Iowa 52808; or call (319) 324-1361.

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greater than 100 megohms on all ranges.

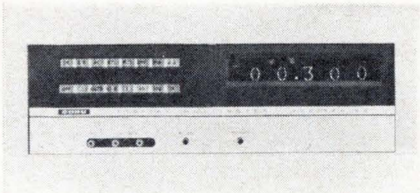
When functioning as an integrator, the DM5000 displays the digital value of the time integral of the analog input signal. Inhibit and reset functions are controlled by either front-panel switches or remotely by external voltage inputs. Three distinct counter modes are offered: rate, period, and count. Sensitivity, level, and coupling features permit operation with a variety of input waveforms.

In the rate mode, pulse rates or frequencies to greater than 1 Mhz are measured and displayed with a time base derived from a $\pm 0.005\%$ crystal-controlled clock. Four full-scale ranges are provided from 9.999 khz to 9,999 khz, corresponding to gate periods from 1 to 0.001 second.

In the period mode, pulse interval, pulse width, or period are displayed with a resolution of 10 nsec over full-scale ranges from 99.99 msec to 99.99 sec. Count range is from 0 to greater than 250 khz with a resolution of one part in 10^4.

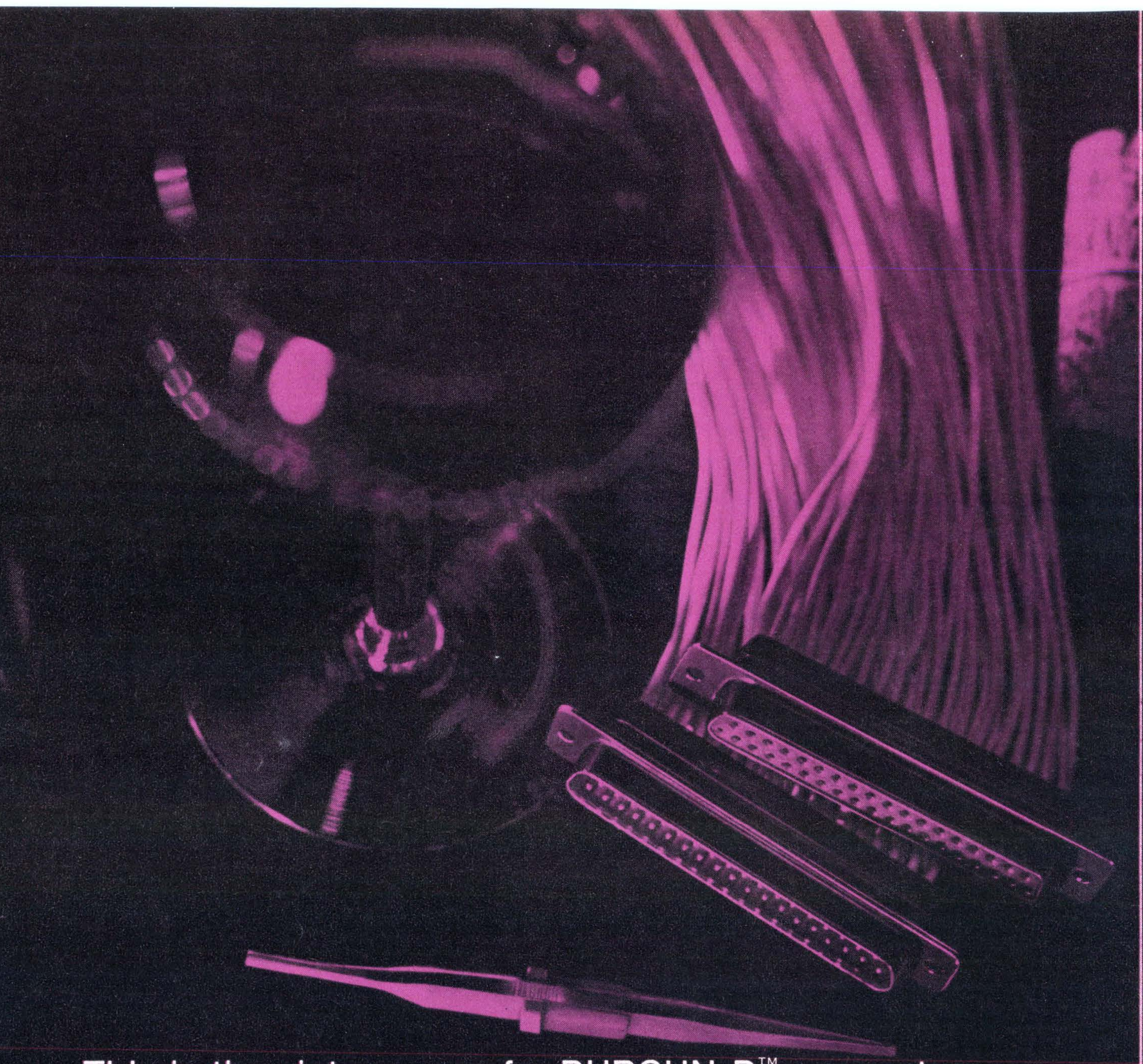
Technology Inc., 7400 Col. Glenn Highway, Dayton, Ohio 45431. **[378]**

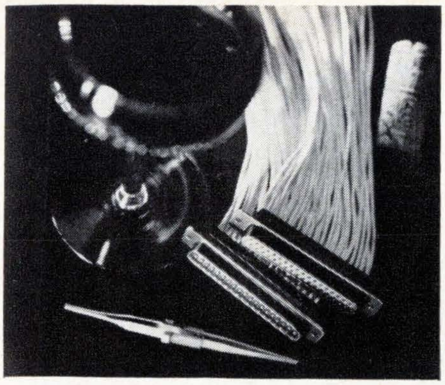
Digital multimeter tracks two ways



D-c volts, d-c current, resistance, a-c volts, and d-c/d-c ratios can be measured by a new 5-digit digital multimeter. Bidirectional tracking logic gives fast and accurate measurements of small variations in critical parameters, such as those that occur when trimming or adjusting. A stable zener diode reference supply and a precision digital potentiometer assure maximum accuracy.

The push-button instrument offers automatic ranging on the d-c





voltage function (1 μv to 1,000 volts); resistance measurements from 0.1 ohm to 100 megohms; a-c voltages from 1 mv to 1 kv; d-c/d-c voltage ratios with 100-μv sensitivity; d-c currents from 0.1 na to 100 ma.

The 530 series is available in either rack or cabinet models. Price of the basic model is $1,495; the complete package, $2,750. Delivery takes three weeks after receipt of order.

Cohu Electronics Inc., Box 623, San Diego, Calif. 92112 **[379]**

Pressure transducer is small and rugged

Heavy-duty construction with low weight and small size are the features of a high-line differential pressure transducer. The instrument accurately measures small changes in differential line pressure with full line pressure overloads up to a maximum line pressure of 5,000 psi. The rugged transducer will operate in ranges of ±30, ±75, ±150, and ±300 inches of water.

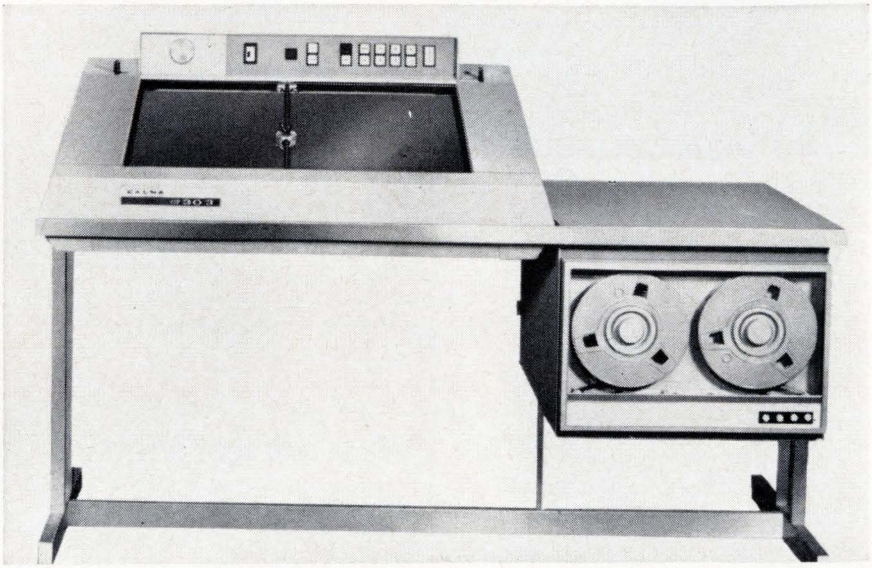
The high sensitivity of the PM393TC is achieved by use of a four-leg Wheatstone bridge transducer encased in a single-chamber cavity filled with silicone oil. Protection from pressure overload is provided by mechanical stops, thus permitting a maximum pressure differential of 5,000 psi without danger of damage to the instrument.

The transducer measures 3 in. in diameter and 2 in. in length. Weight is 4 lbs. Nonlinearity is less than 0.25% of full scale and hysteresis does not exceed 0.15% of full scale. Output is compatible with present day recorders and controllers.

All metal parts are stainless steel, which permits use with many fluids, including those incompatible with each other. No recalibration is necessary, allowing for easy remote installation.

Statham Instruments Inc., 12401 W. Olympic Blvd., Los Angeles, Calif., 90064 **[380]**

Tracing curves by the numbers



Working almost as an x-y recorder in reverse, a new graphical digitizing system allows an operator to trace curves with a stylus without worrying about outpacing the digital output recorder. Heart of the system, says the manufacturer, is "variable interval programed" digitizing.

Developed by the Calma Co., it is claimed to be the only analog graphical data digitizer capable of efficiently reducing both contour and point-to-point data directly to digital magnetic tape. Basically, the system adjusts the size of the sampling interval to the complexity of the curve being traced. On complex data, an operator will move the stylus slowly to record precisely the sharp peaks and changes in direction, but on straight sections can move the stylus quickly. In conventional systems, the operator has to abide by the speed capability of a magnetic tape recorder. He couldn't move the stylus quickly if he wanted to maintain resolution.

In the new system, points are read off the curve at intervals of 0.01 inch, digitized, and entered in a buffer storage. The points are sent out from storage to the magnetic tape at a rate of 250 points per second. Thus, at speeds up to 2.5 in. per second, the magnetic tape keeps pace. However, if the operator moves the stylus at a faster rate, the points are stored temporarily and taken out at wider intervals, but with the same resolution as at 0.01 in. intervals.

The effective recorded interval increases as the operator's tracing speed increases, stepping up 0.01 in. for each 2.5 in. per second increase in tracing speed. Maximum speed is 37.5 in. per second and maximum interval is 0.15 in.

Accessories are available to permit reduction of data from projected 16-mm, 35-mm, and 70-mm film images and to interface the digitizer, on-line, with an IBM 1130 computer.

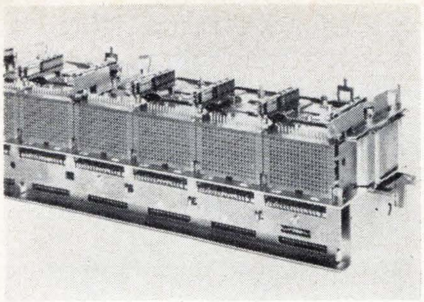
Specifications

Tracing area	18 x 24 in.
Maximum tracing bed area	22 x 28 in.
Paper hold-down	Mechanical
Dimensions	58½ x 30 x 34 in.
Weight	400 lb.
Price	$22,500

The Calma Co., 346 Mathew St., Santa Clara, Calif. 95050 **[381]**

Binary code switch has 2,040 contacts

A compact matrix for memory, programing, data, voice, and broadband switching applications contains 2,040 switching contacts in

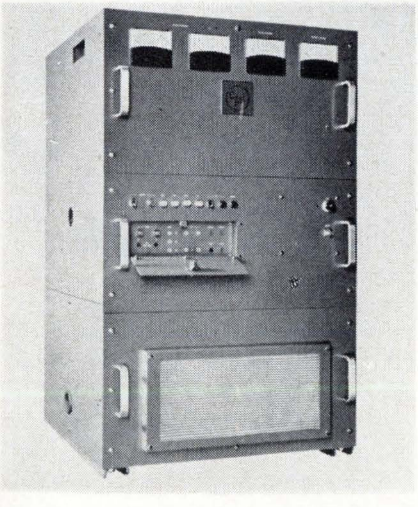


670 cubic inches. Binary operation with a wide range of input-output arrangements is provided. Palladium-silver contacts require no wetting voltage. Due to V-type positive-lock contacts, no sustaining power is needed. Power interruption will not affect the locked program.

The switch includes 10 modules, each with 17 multiple positions having 12 make-contacts per position (photo shows only five full modules, each with 204 contacts). Maximum power voltage is 56 v; minimum, 44 v. The code coils and the code-release vertical coils operate on 48 v d-c. The unit measures 25½ by 6 by 4½ in.

Price is \$600, with quantity discounts. Availability is 60 to 90 days. The Ericsson Corp., 100 Park Ave., New York, N.Y. 10017 **[382]**

Power amplifier spans 100 to 10,000 hz



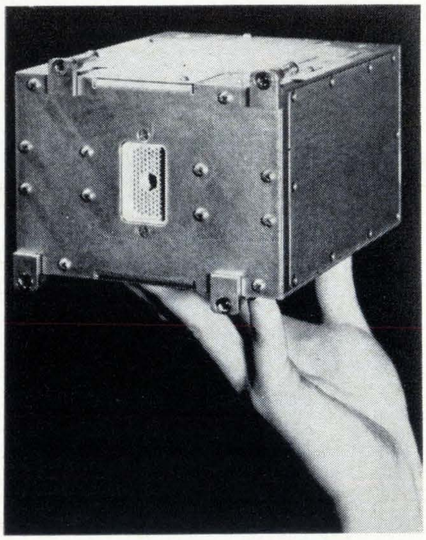
Audio and ultrasonic testing is provided by a 5-kva power amplifier that has numerous applications in sonar calibration systems, high intensity acoustic systems, vibration test systems, and industrial process control. Measuring 24 x 24 x 45 in., including casters, the unit is rated for continuous duty over a frequency range of 100 to 10,000 hz.

Model B5K is suitable for operation with keyed input signals, and features responses of ±0.5 db over the frequency range. Distortion in output waveform is less than 3% over the range.

Features include six output impedance taps ranging from 8 ohms to 1,152 ohms. The air-cooled amplifier delivers full rated output into load power factors between ±0.1 and unity. The hinged front panel section provides test points for critical voltages.

CML Inc., subsidiary of Tenney Engineering Inc., 350 Leland Ave., Plainfield, N.J. 07062. **[383]**

Compact, aerospace core memory systems



Designed to meet the high reliability requirements of military and aerospace computers, four new core memory systems feature small size and low weight and low power. Switch-core selection techniques eliminate a number of semiconductor components and allow a corresponding reduction in system prices.

The LCM710 provides a combination of coincident current addressing and linear select operation. This technique permits wide current and voltage tolerances and high-speed performance, and it eliminates the necessity of drive current compensation at speeds of 4 μsec or slower. These memories are available as complete systems or with modified electronics for specific applications. Standard expandable memory capacity is 256 to 4,096 words with up to 32 bits per word. Larger word and bit sizes can be provided.

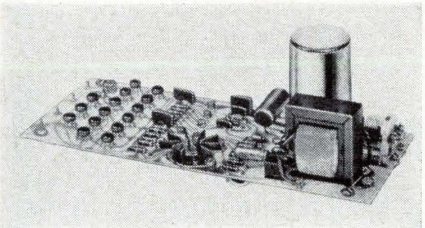
These systems are effectively nonvolatile digital delay lines that have already found applications in the Y and R register memories of a specific aerospace computer. Plugging-in of additional sections of computer core storage to change the delay line length is convenient.

The systems can store both electrically alterable and fixed data in the same array. The basic storage matrix of these dual core units consists of a one-core-per-bit, two-wire-per-core arrangement. The same core simultaneously stores read-only and electrically alterable information through time sharing of the system's electronics. Standard expandable memory capacity is 512 to 8,192 words with up to 32 bits per word, with larger word and bit sizes available.

The LCM220 is a hard-wired read-only memory, utilizing very few semiconductor components. Unlike conventional hard-wired units, it can be readily filled without difficulty and easily modified with external fill equipment. Its expandable memory capacity is 256 to 4,096 words with up to 60 bits per word.

Litton Industries Inc., 9370 Santa Monica Blvd., Beverly Hills, Calif. 90213
[384]

Versatile and stable vlf signal source



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where a precise timing signal or vlf frequency standard is required.

The module illustrated, model PC-6, has an output voltage of 60 hz $\pm 0.00001\%$, when operated from an input voltage of 108 to 130 v a-c, 50 or 60 hz nominal line frequency. Output voltage is a 50/50 duty cycle square wave rising from 0 to +4 v d-c, when connected for internal collector supply; or 0 to +30 v d-c, when the output amplifier is connected to an external supply.

This unit is available at any output frequency from 0.1 hz to 10 khz. Various packaging arrangements are available. Prices start at $185 each, in lots of 50 or more. Some frequencies can be shipped in less than 3 weeks after receipt of the order.

Metric Engineering, a division of Greenray Industries Inc., 5235 E. Simpson Road, Mechanicsburg, Pa. 17055. **[385]**

Military inverter is compact and rugged

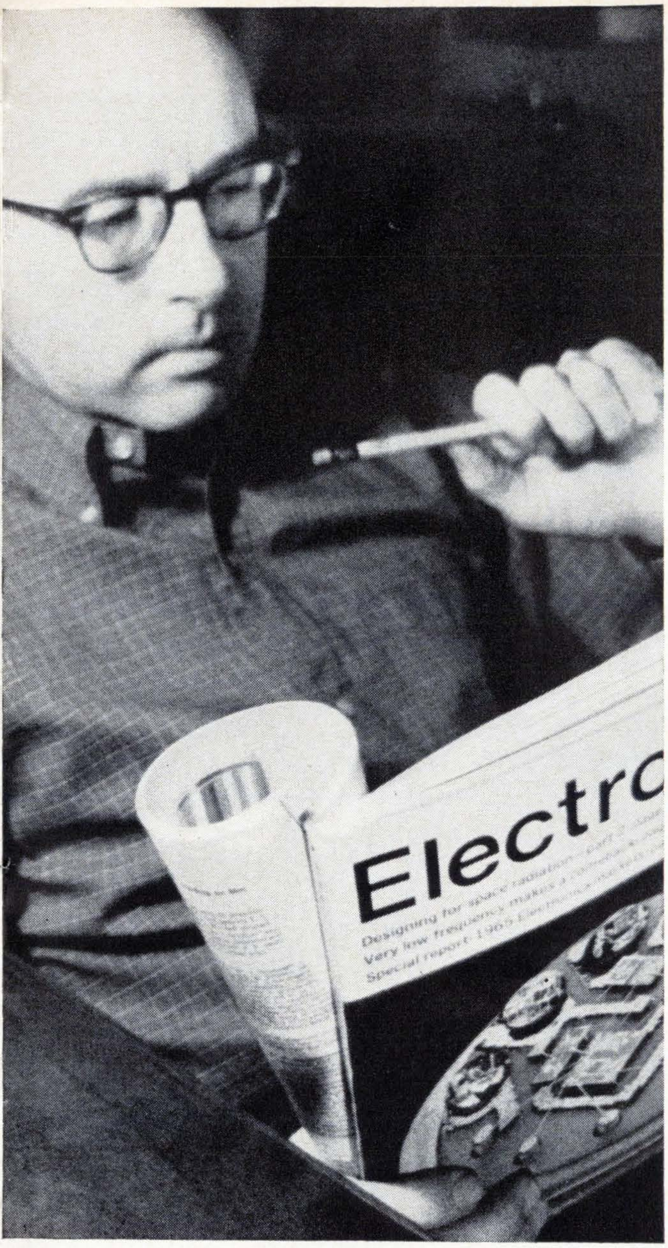
Used to power any 400-hz device, a static inverter converts 28 v d-c to 400-hz sine-wave voltages of 115 or 26 v a-c. With continuous full load operation at 100°C, model S12D supplies an output power of 120 v-a.

Modular design techniques provide a compact unit of 6 x 4 x 4 in. which weighs less than 7.6 lbs. Hermetic sealing and full encapsulation allow the inverter to meet the environment of MIL-E-5272C at 100°C.

Regulation is 0.2% for input variations of 24 to 30 v d-c. Other features include complete isolation of inputs and outputs, and an output voltage adjustment range of 12% from the nominal output voltage. The module is also protected against short circuit conditions, input voltage transients, and reverse polarity damage.

Price is $1,285. Normal delivery takes six weeks.

Abbott Transistor Laboratories Inc., 5200 W. Jefferson Blvd., Los Angeles, Calif. 90016. **[386]**



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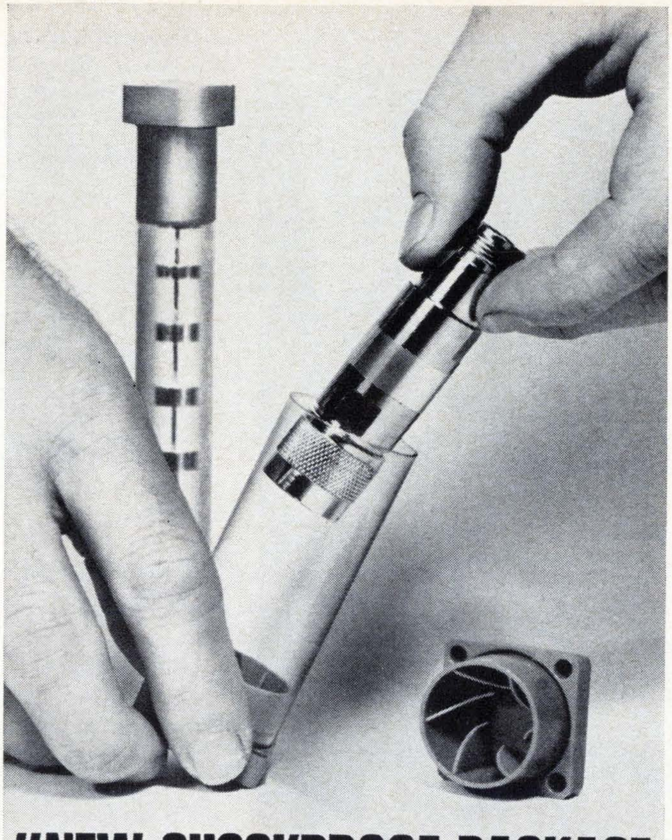

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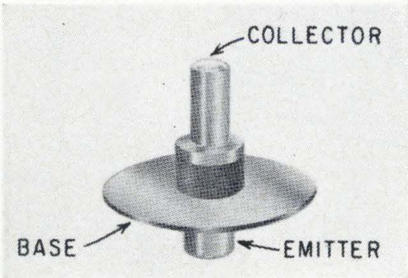
Coaxial package lifts transistor power



A new overlay transistor in a coaxial package takes 0.316 watt at its input and delivers a 2 gigahertz output of 1 watt. The manufacturer claims this is about 4 times the power previously available from commercial transistors operating at the same frequency. As an oscillator, the transistor has produced 1.5 watts at 1 Ghz.

The coaxial package reduces the device's parasitic inductances, which in turn minimizes degenerative feedback and thus increases power gain. An additional advantage of low inductance is that the transistor can be used in wideband circuits.

Designed by the Radio Corp. of America under a Signal Corps contract, the new unit—the TA7003—is being offered as a developmental transistor at a cost of $90. Although it is RCA's first coaxially packaged transistor, it is not the first ever. The Fairchild Camera & Instrument Corp.'s Semiconductor division introduced a lower power coaxial transistor last year.

Hon Lee, an engineering leader at RCA's Somerville, N.J. plant, says that the coaxial package produces the minimum case inductance of any transistor package. "The inductance is less than 0.1 nanohenry and can't be measured," says Lee.

The TA-7003, an epitaxial silicon npn transistor, is an overlay design. The transistor chip has 16 emitter sites that are connected in parallel and operate with a common collector region. The overlay structure permits a substantial increase in emitter periphery, which allows higher current or power operation. At the same time, the collector and emitter areas are smaller, which reduces the input and output capacitances and permits high frequency operation.

RCA will not divulge details on construction of the device except to say that the TA-7003's design incorporates very-low resistivity material, a thin epitaxial layer and narrow base widths.

The transistor produces its high power in coaxial air lines where it must be employed in a common-base circuit. A suitable line has a characteristic impedance of about 20 ohms and requires a 0.25 inch center conductor and 0.35 inch outer conductor. The transistor itself has an over-all length of 0.470 inch and its largest diameter—the flange that is the base lead—is 0.500 inch.

RCA says the TA-7003 will find use in L and S band equipment including telemetry, radar and electronic countermeasures equipment, and as a driver for varactors and microwave tubes. Various RCA divisions are already using the transistor in solid state circuits for the military.

The company is presently working on a higher power coaxial type transistor. Under an 18-month contract with the National Aeronautics and Space Administration, RCA is designing a unit that will produce 5 to 8 watts at 2.3 Ghz.

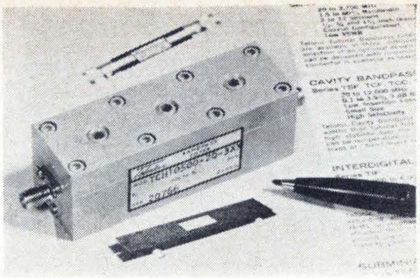
Specifications

As a 2 Ghz amplifier	
Minimum power output	1 watt
Gain with 0.316 w input	5 db
Minimum efficiency	30%
Collector-to-base voltage	28 v
Output capacitance	3.5 pf
Gain-bandwidth product, f_t	Over 2 Ghz
V_{CPO}	55 v min.
Price	$90

Commercial Engineering, Radio Corp. of America, Harrison, N.J. [391]

Bandpass filters operate to 12 Ghz

Bandpass filters with center frequencies from 6 to 12 Ghz are slightly more than 2 in. long and



are capacity loaded, iris-coupled TM_{010}-mode cavities of 0.05-db Chebishev design. The devices are narrow band, with 3-db bandwidths from 0.1% to 1%. Power capability, although high, is limited by the type of connector used on the filter.

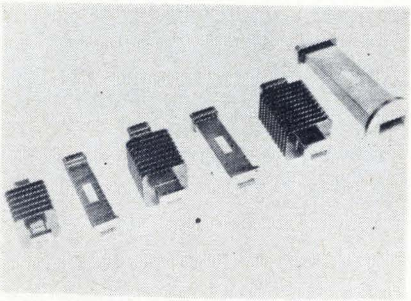
Performance features are low insertion loss, high Q, and low vswr and ripple in the passband.

The filters, series TCH are available with a choice of two, three, or four sections and are constructed of precision bored aluminum blocks with a finish to minimize insertion loss.

Price is from $195 to $280 in single quantities.

Telonic Industries Inc., Box 277, Laguna Beach, Calif. **[392]**

Air-cooled loads handle high power



Twenty-one air-cooled dummy loads are lightweight devices, yet handle very high power levels. For example, the model LKuM1 weighs 4.8 oz and handles 25 w average power, while the model LCH100 weighs 3.6 lbs and handles 2,000 w of average power.

Available in finned or unfinned versions, the new loads are offered to operate over uhf, L, S, C, X, and K bands. The loads are used to terminate waveguide transmission systems, eliminating the need for additional cooling devices.

Prices start at $150.

Raytheon Co., 130 Second Ave., Waltham, Mass. 02154. **[393]**

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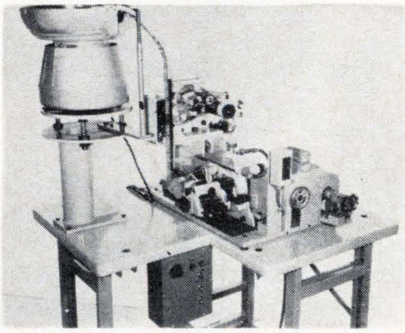
New Production Equipment

High-speed printer labels transistors



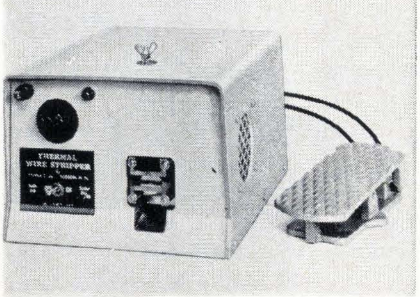
Up to 12,000 transistors an hour can be labeled by a machine designed to print the tops and sides of transistors in TO-5 and TO-18 cans and other configurations. Two transistors are printed with the completion of each cycle of the U-1166 machine.

Components are placed in a vibrating bowl which feeds and correctly positions them as their tops are printed. They then continue down a chute and are positioned to have their sides printed. The components are then automatically ejected.

The U-1166 employs two U-1146 printing heads which hold two sets of messages. Clean and legible imprints are obtained with accurate control of the inks.

Markem Machine Co., Keene, N.H. **[401]**

Bench wire stripper used on production lines



Any type of plastic covering, including Teflon insulation, can be removed by a bench wire stripper designed for continuous use on production lines. Strip length on the model, BWS-100A, is adjustable up to 2½ in. The diameter adjustment is made at the top of case; correct setting of this locking nut prevents conductor damage. Electrode blades normally are drilled to correct wire size by the user, but drilled blades can be obtained from the factory.

The electrode jaws are air operated and are started by a pneumatic foot switch, leaving the operator's hands free for handling the wire.

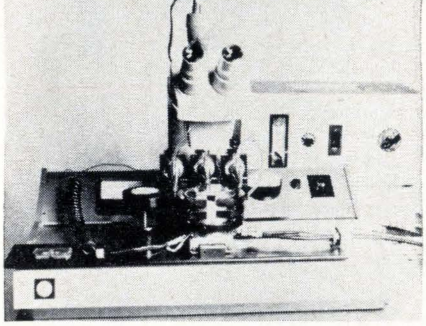
A variable transformer controls the heat setting and a 55-cfm blower pushes the fumes out through a 2-in. rear exhaust. Fuse protection, pilot light, and off-on switch are front-panel mounted. Pneumatic foot switch and three-wire grounded line cord are standard.

The unit operates on 115 v a-c, 60 hz. Air required is 40 psi. The fiber glass case measures 12 x 10 x 7 in.

Price is $315, and availability is immediate.

Contact Inc., Elm Ave., Hudson, N.H. 03051. **[402]**

Ultrasonic die bonder for film devices

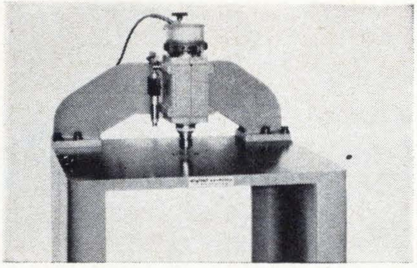


Thick and thin film devices are ultrasonically die-bonded by a multiple-head instrument. Incorporating three transducers, each with a different bonding tip, permits feeding of devices of different sizes.

Substrates are held on a heated vacuum chuck, flooded with forming gas, and heated to eutectic temperature before the dice are ultrasonically scrubbed into the mating film. Dice are vacuum lifted into the bonding tips and edge-held to prevent damage to their cricital areas.

Axion Corp., 6 Commerce Park, Danbury, Conn. 06810 **[403]**

Rotating-pin router for p-c boards



Continuous - duty printed - circuit board routing of materials from $\frac{1}{16}$ to ½ in. thick as well as stack routing up to ¼-in. thickness is accomplished with an accurate, heavy-duty machine. Several design features incorporated in the Model 9001 minimize template wear, increase positioning accuracy, and assure efficient cutting.

The position pin is set in the table in precision preloaded bearings, rather than rigidly mounted, so the pin rotates when the template moves against it and around the pin. Pin sizes range from $\frac{1}{16}$- to ½-in. diameter to accommodate various router bits.

The entire vertical head assembly is lowered or raised by a foot-operated air valve, and remains in the up or down position. This allows cutting within the circuit board. An adjustable positive stop is provided in the down position to compensate for cutter bit length. The head moves vertically on 60° dovetails with preloaded gib adjustment to maintain accuracy.

An optional red light or audio warning signal can be incorporated to warn the opeartor if the feed rate is excessive.

Model 9001 has a 2-hp electric motor with variable speeds from 5,000 to 24,500 rpm and 2% speed regulation. Table dimensions are 20 x 30 in.

Digital Systems Inc., 1078 E. Edna Place, Covina, Calif. 91722. **[404]**

Who's foolhardy enough to pay people to try to put his business out of business?

Some company called Poly-Scientific.

For years we've been in the slip-ring business. We make them in every size and shape. And to any parameter. So we like to think we're experts in the field. But we've often thought "Maybe something else would work better."

Recently, we decided to explore the idea.

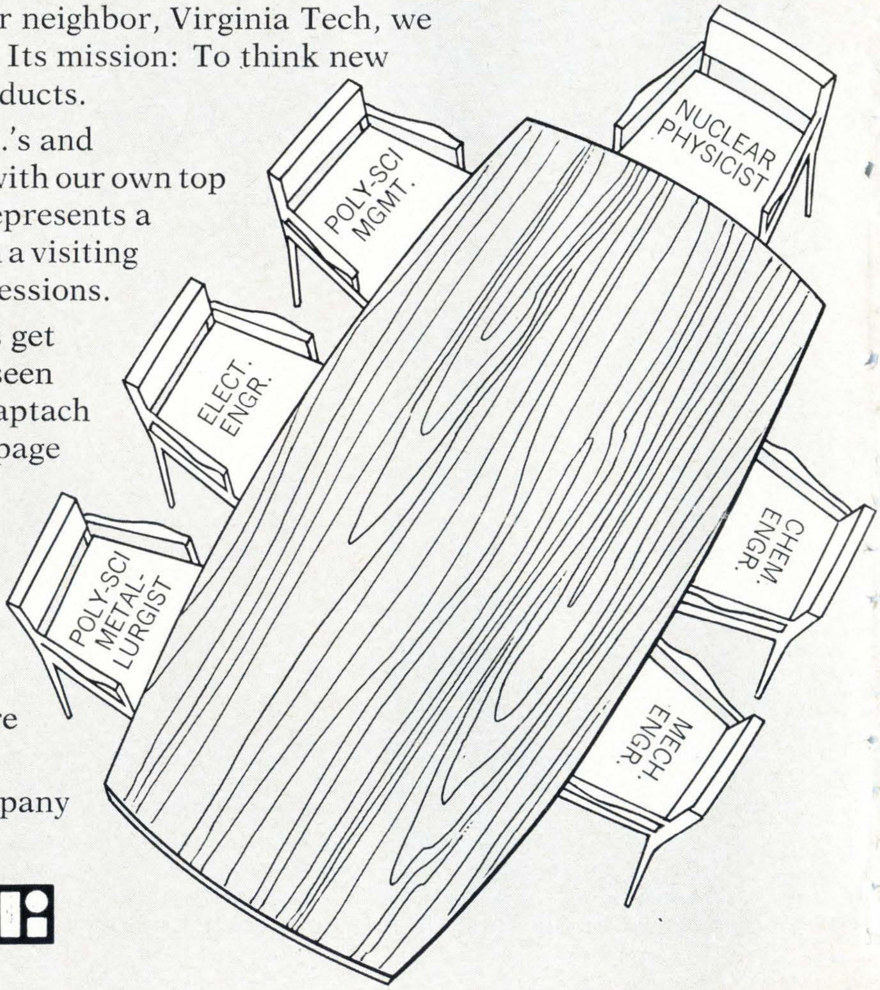
With the help of our next-door neighbor, Virginia Tech, we set up a Scientific Advisory Board. Its mission: To think new processes, new materials, new products.

Four regular members— Ph.D.'s and professors who periodically meet with our own top people—make up the SAB. Each represents a separate scientific discipline. Often a visiting VIP sits in on the brainstorming sessions.

Naturally, some of their ideas get pretty far out—but we've already seen some practical benefits. Our new Captach Switch described on the opposite page is an example.

It's just one of the many useful ideas resulting from our Scientific Advisory Board. You'll be hearing about more in the future. If anybody puts us out of business—we're going to make sure it's us.

Care to have a foolhardy company like this working for you?



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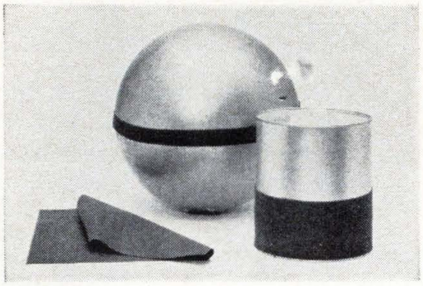
New Materials

Silicone sheet blocks microwaves



A high-loss, flexible silicone material, when bonded to a metal surface, prevents the flow of microwave currents. It reduces the backscatter or reflectivity of metal structures in cases where this is caused by surface currents. It can also be draped over objects to alter reflectivity characteristics. Radiation patterns of antennas can be modified by the application of Eccosorb GDS, to elements, dishes, and horns.

In some microwave devices it may be used as a gasket material, since it is easily cut. This provides both a hermetic and a microwave-energy seal.

Since it is based on silicone rubber, the material is impervious to moisture, and can withstand temperatures up to 400°F.

Eccosorb GDS is available 0.030 in. thick in 1 ft by 3 ft sheets. Greater lengths are available on special order. It can be easily bonded to itself to form large blankets. It weighs approximately ½ lb per sq ft. Price is in the $10-per-sq-ft range.

Emerson & Cuming Inc., Canton, Mass. 02021 **[406]**

Polyurethane rubber pots and encapsulates

Silicone rubber can be replaced in many applications by a polyurethane rubber developed for potting and encapsulating pressure-sensitive components, especially glass components, such as diodes and resistors.

The comparatively low viscosity of HumiSeal 2B71 permits it to penetrate dense electrical assembly packages. Dielectric strength of 1,500 volts per mil provides excellent protection in thin cast sections.

The hardness and elongation factor of 180% protect fully against shock and vibration.

The product is available clear or black.

Columbia Technical Corp., 24-30 Brooklyn-Queens Expressway West, Woodside, N.Y., 11377. **[407]**

Epoxy resin cures at low temperature

Pressure-sensitive components can be encapsulated with a black, semi-flexible epoxy resin, which has a low temperature curing cycle. Curing starts at 65°C and may range as high as 120°C. Gel time is 23 minutes at 121°C.

Called Scotchcast resin No. XR-5140, it is suitable for dipping and encapsulating transformers, coils, motors, modules, strain sensitive circuitry, and other electrical and electronic components. It is stable at high temperatures (155°C) with permanent flexibility for thermal and mechanical shock resistance. The material may be applied by dipping, spraying, extruding, or troweling.

Properties of XR5140 after heat aging at 130°C for 1,000 hours include: dielectric constant (100 hz, 23°C), 3.56; dissipation factor (100 hz, 23°C), 0.054; volume resistivity (ohm/cm), greater than 10^{15}; electric strength (volts/mil, ⅛-in. sample), 375; hardness (Shore D), 65. It passes standard thermal shock tests and resists moisture.

3M Co., 2501 Hudson Road, St. Paul, Minn. 55119. **[408]**

New Books

Tunnel diodes

Analysis and Synthesis of Tunnel Diode Circuits
J. O. Scanlan
John Wiley & Sons, 274 pp., $9.75

This is the second textbook of note to appear on the tunnel diode since the invention of this device nine years ago by Leo Esaki. Chow's 1964 book, "Principles of Tunnel Diode Circuits" (Wiley & Sons), gave a general treatment of the theory and applications of tunnel diodes, while this one is devoted exclusively to theoretical aspects of applications in high-frequency signal circuits.

The author does a creditable job of covering the underlying physics of tunnel diodes, starting from the foundations of quantum theory. Tunneling theory is illustrated by examples to give the reader insight into this concept. Semiconductor band structure, Fermi levels, density of states, degeneracy, and the WKB approximation—all essential to the understanding of tunnel diodes—are discussed in detail. Although the treatment of these subjects probably won't satisfy the physicist or device designer, it should prove valuable to the man to whom the book is primarily addressed—the circuit theorist.

A simple four-element equivalent circuit is developed based on both theoretical and practical arguments. Several equations are given that can be used to approximate the large signal voltage current characteristics of the tunnel diode. One improvement, perhaps, could have been the inclusion of numerical values of the electrical parameters for actual tunnel diodes.

The major portion of the book is devoted to tunnel diode amplifiers using principles of network synthesis in the treatment of broadband amplifiers. The treatment is entirely theoretical; it lacks discussion of both the practical performance limitations of microwave amplifiers and the hardware problems involved in their construction. Also omitted is any treatment of multidiode amplifiers for improved linearity and dynamic range.

One chapter is devoted to oscillators, mixers, converters, and detectors. While the mathematical treatment of these topics is comprehensive, the reader will have to search elsewhere for information on oscillator circuit configurations, oscillator stability, and theoretical treatment of back diode mixers and detectors.

T.P. Sylvan

General Electric Co.
Syracuse, N.Y.

Looking back at the future

Communication Satellite Systems Technology
Edited by Richard B. Marsten
Academic Press, 1,051 pp., $12

In 1945, Arthur C. Clarke proposed a global communications method that would bypass the effects of the ionosphere. He observed that a rocket traveling at five miles per second—"only twice as fast as those already in the design stage"—could put an artificial moon into orbit. A satellite, he said, placed 26,040 miles above the earth would be in stationary orbit; and three such satellites, equipped with receiving and transmitting equipment, could relay signals over the entire world.

Clarke pinpointed the exact latitudes and longitudes for the satellites to best serve Europe and Africa, China and Oceania, and the Americas. He chose microwaves as the carrier frequencies, suggesting that the evidence necessary to prove that radio waves pass into outer space might be obtained "by exploring echoes from the moon." Applying the Federal Communications Commission's standard for minimum signal strength of a frequency-modulated signal (50 microvolts per meter), he arrived at a power level of 1.2 kilowatts for broadcast service.

This amazingly accurate prophecy from the magazine Wireless World is reprinted as the prologue to this collection of papers from the May 1966 conference of the American Institute of Astronautics and Aeronautics.

As with any such compilation, papers now obsolete are placed in

New Books

company with others that will be basic references for years to come. Past achievements, like the Communications Satellites Corp.'s Early Bird, and future possibilities, such as lunar communications satellites, are described. Other papers touch on almost every aspect of communications satellites, including systems for aircraft, station keeping, electronically despun antennas, ground antennas, nuclear power systems, modulation techniques, television systems, and economic and sociological considerations.

Trouble shooting

Electronic Testing
Edited by L.L. Farkas
McGraw-Hill Book Co., 304 pp., $12

A how-to-do-it manual, the book aims to give a broad view of testing. Articles are grouped into three main sections: receiving and transmitting equipment, special equipment, and computers. The last section concentrates on the theory behind computer operation rather than on testing.

The special-equipment section covers sensors and signal conditioners, gyros, inertial-guidance platforms, ordnance devices, flight-control systems, and system displays. If the emphasis on military and aerospace gear seems excessive, it can be explained by the editor's choice of contributors. Of the 13 authors, 11—plus the editor work for the Orlando division of the Martin Co. The other two are also associated with space programs.

Recently published

Japanese Miniature Electronic Components Data 1966-67, G.W.A. Dummer and J. Mackenzie Robertson, Pergamon Press, 461 pp., $19.50

A compilation of Japanese electronics manufacturers' data sheets, cross-indexed by company names, product categories, and Japanese industrial specification standards.

Modern Optical Engineering: The Design of Optical Systems, Warren J. Smith, McGraw-Hill Book Co., 476 pp., $15

The author starts with basics, including a discussion of the eye, and proceeds through prisms, apertures, materials and coatings, and radiometry and photometry. Basic optical devices are briefly described, and there are chapters on computations, image evaluation, and design principles.

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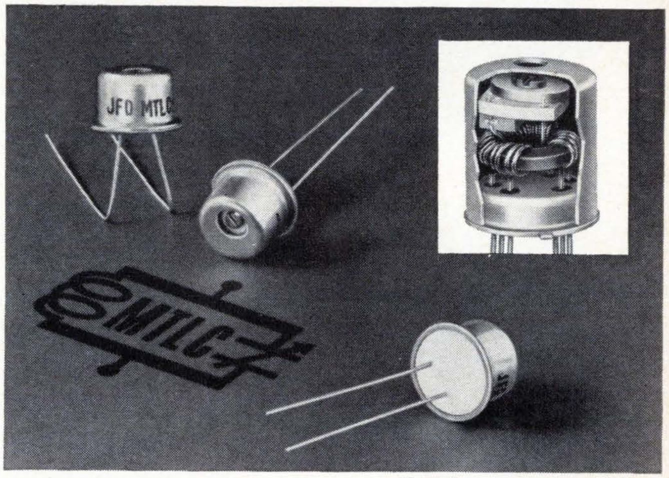

Capacitors shown enlarged 20%

JFD MTLC tuners enable circuit designers to shrink various LC circuits into TO-5 configurations completely compatible with today's miniaturized or hybrid circuitry. The tuning element is a subminiature variable ceramic capacitor measuring: .208 x .280 x .120 inch thick. These variable ceramic capacitors offer high capacitance plus a choice of wide △ Cs in extra small, ultra stable units.

JFD builds these miniature circuits with high quality ferrite and iron inductor toroidal cores, providing maximum Q for any given frequency. Where necessary, special JFD Uniceram fixed capacitors are used with Modutrim units to yield lower center frequencies or to satisfy special circuit requirements.

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Technical Abstracts

Sound from light

Acoustic wave generation through electrostrictive mixing of two light beams

D. E. Caddes
Sylvania Electronic Systems—West, Mountain View, Calif.
C.F. Quate and C.D.W. Wilkinson, Stanford University, Palo Alto, Calif.

The difficulties these researchers experienced with ultrasonic transducers points up the major application of their work; the elimination of electro-mechanical transducers from acoustic propagation studies. They show that acoustic waves at high microwave frequencies can be generated by mixing two optical frequencies in a suitable crystal and taking the ultrasonic difference frequency. The acoustic wave is produced by an electrostrictive effect in which the electric field of the optical wave produces a strain in the crystal. Two optical waves will interact in the crystal, and generate many sum and difference acoustic frequencies, though only the difference frequency is used.

The method requires two optical waves slightly shifted in frequency. Two techniques have been used to obtain the frequency-shifted optical waves. In the first, ultrasound is generated with a conventional transducer and mixed with a light wave to produce a second light wave that is shifted in frequency by the acoustic frequency. The two optical waves are then focused on the electrostrictive material to generate the sound waves. Although this method only takes sound from one part of the laboratory and delivers it at another point—with some loss—it serves to demonstrate the electrostrictive mixing technique.

The second method for shifting an optical wave uses the output of a giant-pulse ruby laser to produce stimulated Brillouin scattering in a liquid, ethyl ether. This method doesn't require an injected sound wave. If the intensity of the radiation from the laser is high enough, the ethyl ether will be driven into coherent acoustic oscillations without external acoustic excitation.

The bandwidth of the generated sound could only be checked in 50-megahertz steps since the researchers work only at the overtones of the piezoelectric zinc oxide transducer that is used as the detector. This coarse measurement indicates a spectral width of less than 150 Mhz at a 3.7-gigahertz center frequency. The transducer also has to be aligned to a tight tolerance to detect the ultrasound.

Presented at the Polytechnic Institute of Brooklyn Symposium on Modern Optics, New York, March 22-24.

Plugging leaks

Packaging for Electromagnetic Compatibility

Herman Jankowski
Apollo Support Department, General Electric Co., Daytona Beach, Fla.

Equipment failure can result from adherence to the tried and supposedly true methods of preventing electromagnetic interference among the subsystems of a complex electronic system.

For example, bonding straps are commonly used to connect interference shields to a ground plane. However, a strap will always be resonant at some frequency, and if corrosion occurs at the junction with the ground plane, a nonlinear resistance may be created. The junction then becomes a mixer producing spurious frequencies. As a mixer, the junction is inefficient, but if the signals in the strap are large enough, the equipment can fail.

This is one of scores of electromagnetic compatibility problems—some old and some new to integrated circuits—that the author quickly reviews. He balances off the problems with dozens of ways—again, some old, some unusual—to stop electromagnetic leaks by paying closer attention to subsystem packaging, transmission lines, and system design.

One way the strap problem can be avoided, to continue the example given, is to use copper tubing as the ground conductor. Any stray magnetic fields will induce a circulating current in the copper, but the skin effect keeps this current on the outside of the tube. If the

circuit is grounded on the inside surface, the ground current is isolated from the induced interference and no ground loops can occur. This technique has been used in the Apollo ground-support equipment. If the tubing method cannot be used the next best choice is a solid circular conductor.

If rectangular conductors must be used, the corners should be well rounded. Skin effect forces the current to the corners. Conductor resistance will be high in unrounded corners, due to the low effective cross-section of the conductor. Rounding the corners increases the effective cross section.

Twisted stranded line should never be used as a ground bus. The outer twisted conductors act as solenoids, causing the cable's reactance to increase as skin effect becomes significant. In a short time, the bus would be unable to conduct the ground current in sufficient quantity. Braided wire works up to about 1 Mhz, but isn't recommended for higher frequencies.

Presented at the Electronic Packaging Conference, Society of Automotive Engineers, New York, Feb. 14-16.

Won't help a bit

Performance of random-error-correcting in the switched telephone network
A.C. Franco and L.J. Saporta
Communications Systems Inc., Paramus, N.J.

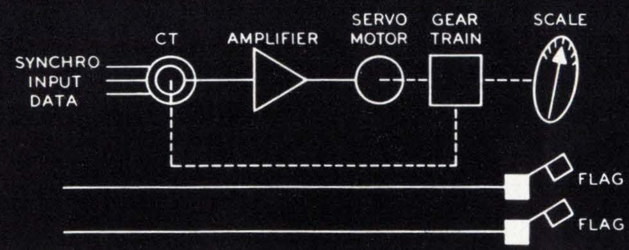
Codes for correcting random errors in data transmissions over switched telephone networks can reduce block error rates, but they hardly make a dent in bit error rates.

Given a block size of 150 bits, of which 75 are assigned to the correction code, block errors could be reduced by a factor of 50, while bit errors—which occur in clusters in a switched phone network—may be pared by a factor of only 4.

After presenting the paper, the authors noted that codes designed to correct groups of errors don't have much effect on bit error rates, either. Systems that automatically cause the repeated transmission of a data block containing an error are often applied to screen out bit errors, but their use involves a tradeoff in equipment costs and transmission speed.

Presented at the 1967 International Convention of the Institute of Electrical and Electronics Engineers, New York, March 20-23.

3 of a series | TRANSICOIL SOLVES SERVO PROBLEMS



Transicoil radar height indicator

Transicoil designed this instrument for the APN-120 Radar Altimeter Set aboard A3J aircraft. It provides a visual display of altitude. In addition, two Weston meter movements warn of "OFF", "FAIL", and "OVERRIDE" conditions. ■ Altitude data transmitted from a CX in the radar altimeter is fed to a matching CT in this assembly. A miniaturized servo, using size 8 components and transistorized amplifier drives the CT to a null, and exhibits this output as a pointer position on an altitude scale. ■ Pictured above without case, the unit is hermetically sealed in a 3¼" instrument can per AN-5727. All wiring is terminated at AN connectors at the rear of the can. ■ Transicoil offers an unusual capability for combining servo components into operating servo systems. Write for our 16-page brochure, SERVO ASSEMBLIES. It describes many of our standard and special-purpose units.

Weston Instruments, Inc., Transicoil Division, Worcester, Pa. 19490.

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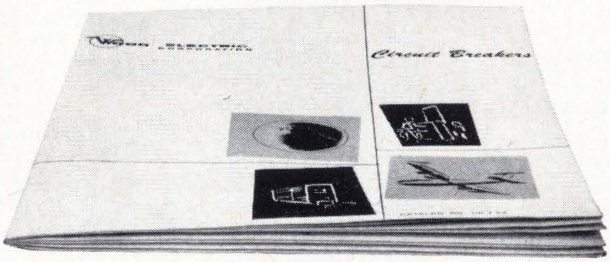

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1074

New Literature

F-m/f-m telemetering system. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif. 91343, has available a bulletin describing the Model 5000 miniature f-m/f-m telemetering system designed for obtaining data from systems in a state of high acceleration or complex motion.
Circle **420** on reader service card.

Precision potentiometers. Beckman Instruments Inc., 2500 Harbor Blvd., Fullerton, Calif. 92634, has released Data Sheet No. 661218 describing the Helipot Series 7260 precision potentiometers. **[421]**

Metalized polycarbonate capacitors. Film Capacitors Inc., 100 Eighth St., Passaic, N.J. Engineering bulletin No. 1501 gives complete technical information on type ME metalized polycarbonate capacitors. **[422]**

Decimal encoders. Theta Instrument Corp., 22 Spielman Rd., Fairfield, N.J. A four-page bulletin describes a complete line of shaft encoders with four-digit, decimally coded outputs. **[423]**

Strain-gauge instrumentation. B&K Instruments Inc., 5111 W. 164th St., Cleveland, Ohio 44142, has released a four-page brochure describing the Model 1516 strain-gauge apparatus, accessories, and related equipment. **[424]**

R-f terminations. Raytheon Co., 130 Second Ave., Waltham, Mass. 02154. A line of r-f terminations, ranging from convection-cooled to calorimetric waterloads, is described in the catalog, "Coaxial and Waveguide R-F Terminations." **[425]**

Small electrical counters. Kessler-Ellis Products Co., 46 Center Ave., Atlantic Highlands, N.J. 07716. Bulletin No. 9 covers a small three-digit predetermining impulse counter and a four-digit totalizing counter. **[426]**

Miniature noise generators. Signalite Inc., 1933 Heck Ave., Neptune N.J. 07753, has published a two-page illustrated bulletin on a standard line of 90° E-plane miniature noise generators. **[427]**

Tooling selector chart. Isochem Resins Co., Cook St., Lincoln, R.I. 02865. A selector chart contains a complete line of tooling resins with instructions. **[428]**

Phase-modulation choppers. Airpax Electronics Inc., Cambridge, Md. 21613. Bulletin C-121R covers the series PM chopper that uses a compact toroidal transformer to achieve high performance. **[429]**

Data communications equipment. Scientific Data Systems, 1649 17th St., Santa Monica, Calif. 90404. Brochure 64-33-11B gives detailed descriptions, specifications, and applications of a series of data communications equipment. **[430]**

Accelerometer. B&K Instruments Inc., 5111 W. 164th St., Cleveland, Ohio 44142, has released a specification sheet on the Model 4333 low-cost accelerometer that provides laboratory standard vibration measurements. **[431]**

Push-button switches. Centralab Electronics division, Globe-Union Inc., 5757 North Green Bay Ave., Milwaukee, Wis. 53201, has published Catalog PBS-1 describing an extensive new line of push-button switches. **[432]**

Electrochemical devices. Curtis Instruments Inc., 351 Lexington Ave., Mount Kisco, N.Y. 10549. A quick-reference catalog discusses Indachron elapsed time meters that utilize miniature ampere hour meters. Typical applications are given. **[433]**

Molded contour cables. Electrical Components division, Bendix Corp., Sidney, N.Y. 13838. Molded contour cables for space conscious designs are described in Bulletin SL-184. **[434]**

Dielectric materials charts. Emerson & Cuming Inc., Canton, Mass. 02021. Two color charts, for notebook or wall mounting, show the dielectric constant and loss tangent at microwave frequencies of a host of materials. **[435]**

Ceramic capacitors. Republic Electronics Corp., 176 E. 7th St., Paterson, N.J. 07524. Catalog C-1 gives complete technical data on the company's Mucon subminiature ceramic capacitor line. **[436]**

Digital multimeters. Fairchild Instrumentation division, Fairchild Camera and Instrument Corp., 475 Ellis St., Mountain View, Calif. 94040. A 12-page, illustrated brochure describes a line of four digital multimeters and their related plug-ins. **[437]**

Power relays. Solid State Electronics Corp., 15321 Rayen St., Sepulveda, Calif. 91343, has published a four-page application note covering the Series 10 Magnereed power relays. **[438]**

Microwave relay systems. Microwave Associates, Burlington, Mass. A short form catalog describes the MA-2A and MA-7A solid state, television microwave relay systems. **[439]**

X-Y recorders. Recorder division, Varian Associates, 611 Hansen Way, Palo Alto, Calif. 94303. A data sheet illustrates and describes, with complete specifications, the Series F-100 X-Y recorders. **[440]**

New Literature

Military resistors. Sprague Electric Co., North Adams, Mass. A guide to military resistors, designated ASP-364A, is primarily devoted to fixed types, but also includes a brief explanation of variable resistor types and style numbers in current military specifications. **[441]**

DTL design data. ITT Semiconductors division, International Telephone and Telegraph Corp., 3301 Electronics Way, West Palm Beach, Fla., has published a DTL design data book. It contains a description of the 930 series, its element characteristics, and a glossary of terms. **[442]**

Single crystals. Semi-Elements Inc., Saxonburg Blvd., Saxonburg, Pa. 16056. A four-page brochure lists a line of single crystals that are in continuous production and are available from stock, pure or doped. **[443]**

Electronic calculators. Wang Laboratories Inc., 836 North St., Tewksbury, Mass. 01876. An illustrated brochure contains features, specifications, and applications for the 300 series electronic calculators. **[444]**

Pulse instrumentation. E-H Research Laboratories Inc., 163 Adeline St., Oakland, Calif. 94607, offers a pulse instrumentation catalog that includes integrated test systems, plus a sophisticated line of system building blocks. **[445]**

Microminiature transformer. The Gudeman Co., 340 W. Huron St., Chicago, Ill. 60610. Engineering Bulletin MMT-1 gives complete technical information on a microminiature transformer that weighs 0.06 oz and measures 0.038 cu in. **[446]**

Transistors. Solitron Devices Inc., 1177 Blue Heron Blvd., Riviera Beach, Fla. A 28-page catalog describes a line of silicon and germanium transistors used for military, industrial, and commercial applications. **[447]**

Audio recorders. Ampex Corp., 401 Broadway, Redwood City, Calif. 94063. A six-page illustrated brochure lists features, specifications, and applications of the AG-440 series audio recorders. **[448]**

Printing calculator. Monroe International Inc., a division of Litton Industries, 550 Central Ave., Orange, N.J. 07051. A 10-page, color brochure (1174-A) describes the EPIC 3000 electronic printing calculator. **[449]**

Small parts production. Federal Tool Engineering Co., 1386 Pompton Ave., Cedar Grove, N.J. 07009. A fully illustrated, 16-page guide to automation equipment for the production of small electronic parts is available. **[450]**

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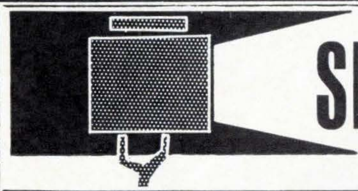

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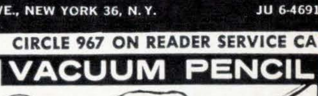

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Newsletter from Abroad

April 17, 1967

Tokyo putting out the welcome mat —but not for all

Expected to relieve some of the pressure from abroad, **Japan's move to liberalize foreign investment won't be a bonanza for U.S. electronics firms.** "It amounts to little more than window dressing and drum beating," says an American executive in Tokyo. It may lead to further liberalization, but few expect to see this affecting computers, integrated circuits, or other advanced electronics areas.

Cabinet approval of the plan is likely next month. The plan is based on an agreement between the Ministry of International Trade and Industry and Japan's Federation of Economic Organizations.

Ceiling on foreign holdings in existing companies, now 15%, will be raised to 20%. The limit for individuals will go up from 5% to 7%. **Unchanged is the 10% ceiling on 19 industries covered by a U.S.-Japan treaty.** To determine allowable foreign investment in new companies, three categories—A, B, and C—will be established. In A industries, foreign interests will be permitted to establish wholly owned subsidiaries; in B industries, foreign investment will be limited to 50%; and in C industries, foreign holdings will be regulated on a case-by-case basis. Companies wholly owned by foreigners will be barred from expanding into B and C industries. **Indications are that electronics firms will be put into categories where complete foreign ownership is barred.**

The plan is unlikely to affect the pending case of Texas Instruments. The U.S. has been putting diplomatic pressure on Japan for permission for the firm to set up a subsidiary [Electronics, April 3, p. 257].

Egalite for French components firms

Strong government backing appears to be in the offing for French semiconductor manufacturers. At last week's International Exhibition of Electronic Components in Paris, Marc Colonna, head of the Industry Ministry's influential Direction des Industries Mecaniques, Electriques, et Electroniques, disclosed that the de Gaulle administration is considering a national components plan. Presumably, the scheme would do for the French semiconductor industry what Plan-Calcul has done for the computer field: **pressure companies to join forces and mount a national effort, largely underwritten by government money, to develop advanced devices bearing a made-in-France label.** Electronics industry sources expect the components plan to be limited to integrated circuits at the outset.

Britain plans computer utility

Britain is taking its first step toward a computer public utility. Postmaster General Edward Short told the House of Commons of plans to have a nationwide computer grid operational by 1971; the system would be available to private industry as well as to the General Post Office. Short estimated the cost of the grid at $34 million. He said computer time on the GPO's current machines will be available to private firms as soon as the enabling legislation he has introduced becomes law.

Russian scientists rap computer lag

Two influential Russians have proposed the centralization of all Soviet computer development efforts. **"It is high time the whole thing was put on industrial lines," declare B. Petrov and A. Smirnov, members of the Soviet Academy of Sciences.** Among hindrances to speedier development of new computers and computer-based work, they cite a scarcity of digital-reading instrumentation, a shortage of even such basic peripheral equipment as magnetic tape, a lack of coordination in compiling computer programs, and a shortage of research and production managers trained to use computers. [See related story on page 219.]

MOS road show to tour Europe

Applying a tried-in-the-U.S. method, an Italy-based subsidiary of the General Instruments Corp. will use a seminar tour to try to stimulate development of applications for metal oxide semiconductor integrated circuits in Europe. A group from General Instruments Europe headed by Marcello Corradetti, an IC specialist formerly with IBM, will describe MOS technology to school groups, engineers, and businessmen throughout Europe.

Some segments of European industry see a need for multiple sources of microcircuitry in the near future, and expect equipment makers there to jump from earlier work with germanium transistors to IC designs.

Summer debut seen for British color tv

It begins to look as if Britain will get its first color telecasts in late June or early July. **The debut, on a single network, is officially scheduled for "late this year," but the British Broadcasting Corp. is already sending out test signals.**

The color cameras for the BBC-2 network's telecasts will use Plumbicon pickup tubes developed by Philips of the Netherlands. The BBC's research department has been working with two prototype cameras, one with three Plumbicons and the other with four.

Britain's Independent Television Authority is also gearing up for color, hoping—along with the BBC's other network—to get on the air with it by 1969.

Emerson in line for F-111 test job

The Emerson Electric Co. is said to be the front-runner in bidding for a contract to furnish computerized test sets for Britain's 50 F-111's. **If Emerson gets the order, the planes' weapons system will be serviced with the U.S. firm's general-purpose automatic sets for a price believed to be about $10 million.** Emerson, whose test equipment is now in operation at several U.S. Air Force repair and supply depots, is competing against Elliott-Automation Ltd. for the British award.

Nippon automates step in producing thin-film IC's

Japan's Nippon Electric Co. has automated one stage of thin-film integrated-circuit production. **Postcard-size ceramic wafers are fed continuously through a series of vacuum chambers,** with the sputtering done in the central chamber. The wafers are afterwards fabricated into IC's by manual operations.

The process is similar to an earlier one developed at Western Electric. **Only resistors are being produced by this method currently.** The unadjusted accuracy of the tantalum resistance elements on the wafer is about 5%; chemical techniques can improve this to about 0.05%.

The thin-film circuits are now being delivered for experimental electronic telephone exchanges and pulse-code modulation systems. They are also expected to be used in sense amplifiers for magnetic core readout, in test equipment, and in other relatively high-cost applications.

April 17, 1967

Electronics Abroad

Volume 40
Number 8

Great Britain

Trends and trials

Computer-based instrument systems are in their infancy, but their potentials for reliability prediction, device "signatures," and production trend alarms are emerging [see page 161].

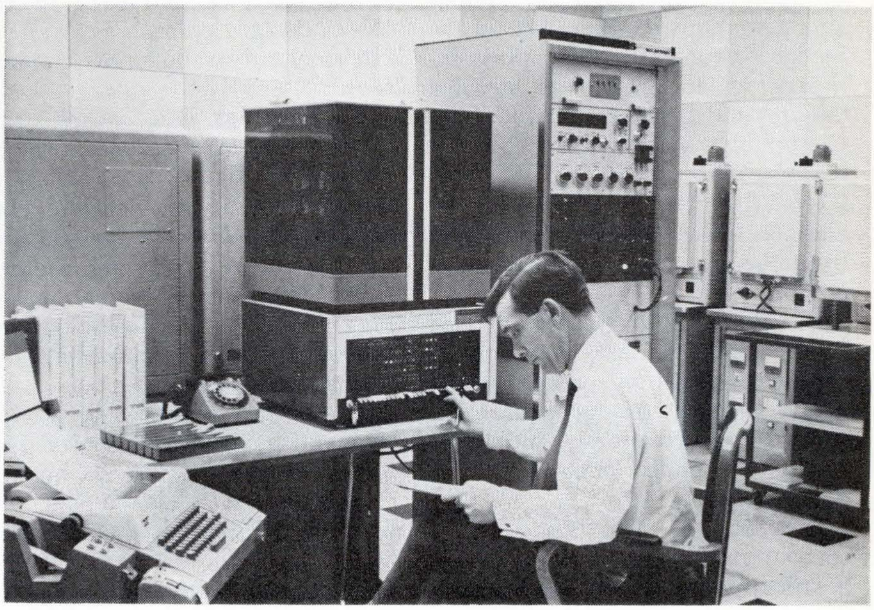
Near Southampton in Southern England the Plessey Co. operates a computer-controlled reliability testing center which provides long-term measurements and also reliability trials of components.

A key part of Plessey's product assessment laboratories, the system tests thin-film circuits under varying environmental conditions.

Failure rates are being obtained from the performance of 5,840 circuit elements — some resistive, some capacitive—at their maximum ratings of power and temperature over a one-year period. Short-term tests, up to 10 weeks, are also being conducted on weekly samples of 96 elements under high-stress conditions.

These tests are designed to take more than 200,000 measurements in the first year, says Plessey. The system is linked to an on-line computer which measures and analyzes performance via data input and output, and controls the equipment as well. The computer is a PDP-8 made by the Digital Equipment Corp., with software using Fortran, symbolic assemblers, mathematical subroutines, utility, and maintenance programs.

To test thin-film circuits, Plessey researchers designed a series of identical enclosures which provide environmental stress for components mounted on interchangeable doors. Chambers are available to test for both dry heat, and humidity at a stabilized reference temperature of 20°C.



Components on trial for reliability characteristics are closely monitored and analyzed by computer in center of product test facility. Mounting frameworks for thin-film circuit modules are attached to the doors of test chambers at right.

Logging the data. The system, says Plessey, is basically a data-logging system. Component parameters are measured on digital instruments whose output is transferred to the computer for checking, calculation, and statistical analysis. Input to measuring instruments is by a special switch which is stepped under computer control. The outputs are printed format and punched tape.

Resistance measurements come as a percentage deviation of the unknown resistance from a preset standard value. Parameters of capacitive elements are provided by readings of both capacitance and dissipation. The system can also do d-c or a-c voltage measurements over a wide range.

In a reliability trial, the system measures component parameters and checks them simultaneously against prescribed limits, with subsequent statistical analysis. It can also act as a watchdog, with a checkout program starting at preset intervals to monitor the life test equipment. Voltage and current levels in life test circuits and temperatures of the chambers are selected, measured, and tested against preset limits. An alarm goes off when a fault shows up.

Soviet Union

Corporate comrades

A few months ago, the Vilnius electric meter works in Lithuania voluntarily turned over 4,400 square feet of scarce production space to the Telyash meter plant for the manufacture of special instruments.

"If anyone had tried to tear that space away a couple of years earlier," says Vinzas Babilus, chief engineer and second-in-command at Vilnius, "we would have complained to the (Communist) Party Central Committee."

The difference now is that both plants, plus five others in Lithuania, are subsidiaries of a common parent company and pool some of their profits. If the Vilnius experiment in cost-accounting works, it will probably be followed by similar amalgamations in other parts of the Soviet instrument and computer industry, which, on April 1, became the first entire industry to adopt the Communist version of a "profit" system. "Profitability" in this case is the difference between income and costs, excluding such gifts from the state as land, plant, and equipment.

The seven Lithuanian enterprises were combined last year into a single organization, called Sigma, which designs, produces, installs, and services computers and other equipment under contract to its customers.

Bureaucracy. The rest of the computer and instruments industry is still fragmented. Designers, producers and users operate in almost complete isolation from one another. Instead of acting on feedback gained from direct contacts with their customers, computer plants are subjected to a bewildering array of edicts from above and to sudden changes in orders from below. The products are distributed by 26 separate agencies.

Relations of distributors to manufacturers are entirely administrative. K. N.Rudnev, Minister of Instrument Building, Automation, and Control Systems, says distributors "have no material responsibility, no obligations to popularize our products or advertise them. Nor are they answerable materially for the correctness of the orders they place with us."

Sigma itself isn't free of bureaucratic red tape, but by maintaining contact with the customer from the design stage through installation and servicing, it has a better idea of what users want.

Sigma's participating organizations operate largely as they did before the amalgamation. But two new offices have been created: a service bureau to install and service computers and train operators, and a headquarters to coordinate operations.

The "head office" is a venerable Gothic-style building on Communar Street in Vilnius. Here Algis B. Tchuplinscus directs a staff of 46 people and a "board of directors" made up of chiefs from each of the seven factories and each of the three design offices, as well as chairmen of trade-union committees.

Naked kings. The consolidation was the principal technical change, but not until the central office received financial powers was Tchuplinscus able to wield any real control over his sprawling empire. "Until then we were like naked kings," he says. "We were entitled to do everything by ourselves, but we had no money."

The system seems to be paying off handsomely in the seven factories. During the last six months of 1966, after amalgamation, output rose 21% from the first half pace and profit increased 40.7%.

However the three design bureaus haven't fared as well, apparently because the Russians haven't yet figured out how to charge for intangibles such as design and counsel.

Reforms are less sweeping in the other plants under Rudnev's ministry. There seem to be no Sigma-type amalgamations and no direct dealings with customers.

Last year, the 51 "reformed" enterprises, representing nearly 50% of the industry's production and 75% of its workers, boosted sales 16.4% and profit 41.6% from the 1965 level. But these figures are far from representative of the overall industry. The first plants reformed were generally those that had been operating well or where improvements could be easily made.

Computers ahoy

A system of 16 Minsk computers is helping to direct construction and deployment of the Soviet Union's 1,300 cargo vessels, according to Viktor G. Bakayev, the Soviet Minister of Merchant Marine.

He said each of 15 shipping districts has a computer that feeds data into a central machine in Moscow.

Computers assist in construction scheduling and are linked by radio to shipboard equipment on every major Russian cargo vessel now afloat, the official said. By 1970, he added, there will be a "computer" aboard every Soviet cargo ship. He didn't say whether this would be an electronic machine, or a mechanical calculator, which Russians sometimes classify as a computer, but he clearly left the impression that he meant electronic equipment.

These computers, Bakayev said, will perform navigational tasks as well as helping to plan shipboard chores. They will substantially reduce the vessels' personnel requirements, he noted.

France

Maskless marvel

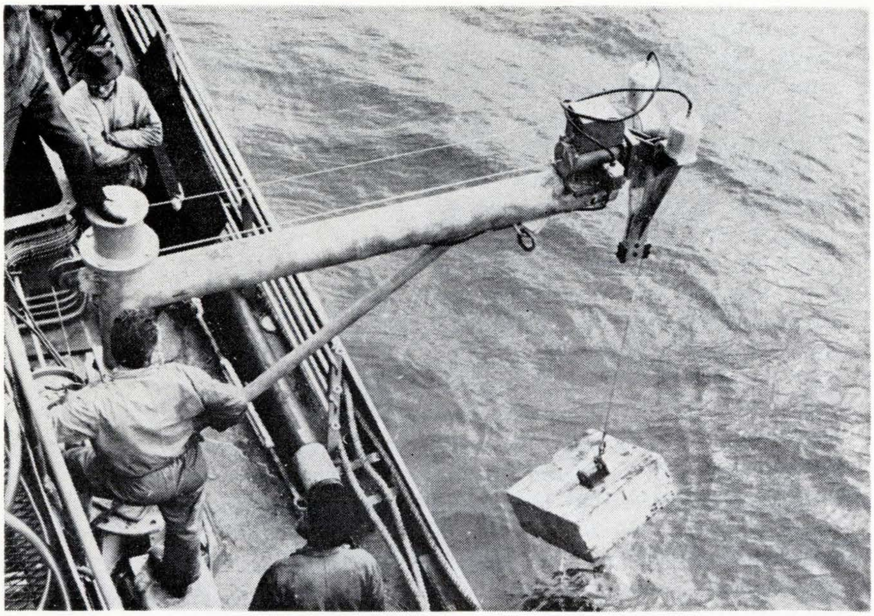
Now that France's long-heralded color-television tube has arrived, its developer is further heralding it as a big step toward all-solid-state receivers.

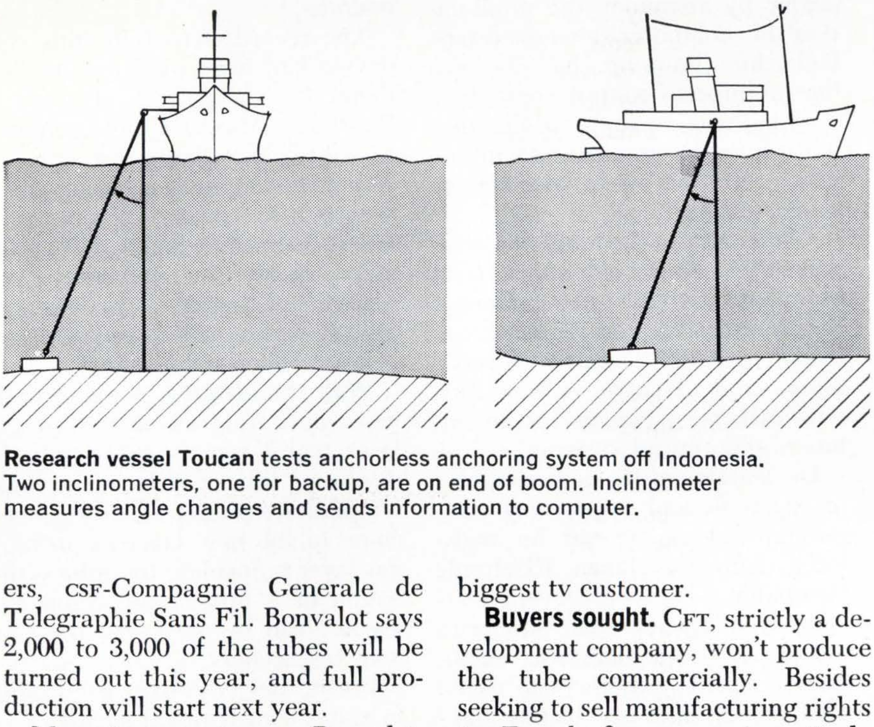
Concurrent with the Paris components show, but not at it, Compagnie Francaise de Television (CFT) unveiled the image tube, which the French call a successor to the Radio Corp. of America's shadow-mask tube.

CFT, which also developed the Secam color tv system, claims that the new 19-inch tube requires three times less power than the shadow-mask, a power requirement that may clear the way for solid state receivers. To emphasize the implications of the development, the firm also showed prototype transistor receivers at its Levallois plant, where the tube made its debut.

The new tube is also brighter and more rugged than the RCA device, according to Pierre Bonvalot, director of CFT's tube department.

Bigger models. A hundred tubes have been produced in a pilot run that began earlier this year at a plant owned by one of CFT's hold-





Research vessel Toucan tests anchorless anchoring system off Indonesia. Two inclinometers, one for backup, are on end of boom. Inclinometer measures angle changes and sends information to computer.

ers, CSF-Compagnie Generale de Telegraphie Sans Fil. Bonvalot says 2,000 to 3,000 of the tubes will be turned out this year, and full production will start next year.

More important, says Bonvalot, is CFT's decision to start work on a 23-inch model; this unit is slated for introduction this summer, and for full production in 1969, just when the French tv industry expects color sales to take off.

The CFT tube should be a big money maker, according to observers. So far, there's only been one contract—for a pilot production plant that CFT and CSF will help set up in the Soviet Union. Russia, the only major country besides France to buy the Secam system, thus seems destined to become France's biggest tv customer.

Buyers sought. CFT, strictly a development company, won't produce the tube commercially. Besides seeking to sell manufacturing rights to French firms, CFT is actively hunting a U.S. customer. This buyer may well be RCA, insiders report; the two companies have declined to comment on this.

The essential difference between the RCA and CFT devices lies just behind their screens. Instead of a shadow mask, CFT uses a grill of 550 stainless steel wires strung vertically in parallel 75 millimeters apart. Bonvalot puts the transparency of the grill at 80%, four times greater than that of the RCA mask.

Because of the grill's construction, Bonvalot says, the new tube is also more rugged. It's an integral part of the tube, strung tightly into the glass separating the screen from the bulb; the RCA shadow mask is hung on an interior frame.

Bonvalot asserts that the CFT tube provides far better contrast than the shadow-mask tube in a lighted room, and about equal contrast in a dark room. This level of contrast was achieved, he says, by improving the graphite deposit on the screen.

Anchors away

It's tough to "stay put" in the ocean. But precise positioning is essential for ships that lay cable, explore the ocean bottom, or track missiles and satellites.

Two French research vessels, one in the North Sea and the other off the coast of Indonesia, are testing a dynamic anchoring system designed to compensate for drift—without using anchors. The system was developed by Compagnie Francaise Thomson-Houston-Hotchkiss Brandt, working with the French Petroleum Institute.

The basic reference is a taut cable from the ship to a known position on the ocean bottom. Movements of the cable away from the vertical generate error signals to a computer.

Hold or steer. The system can also be used as an automatic pilot —without additional equipment— for river, harbor, and coastal navigation. Thomson-Houston says tests show the technique holds drifting to less than a meter and heading to less than 5° in 70-mile winds and 10-knot currents.

The system includes an analog computer and two omnidirectional auxiliary engines, one in the ship's bow and the other in the stern. Control sticks—one for each engine —permit manual operation without use of the computer. For semiautomatic operation, the control sticks can be set and the computer used to determine the power and direction of each engine; or, the course or position can be preset and the computer takes over to navigate or stabilize the vessel.

At anchor, the computer keeps

the auxiliary engines in continuous operation to enable the system to respond instantly to displacement. The computer manages this in calm seas by setting the engines' operation directly against each other.

Senses angle changes. A cable—at constant tension—is dropped from a boom on the ship's side to a fixed point at the sea's bottom. An inclinometer is attached to the boom. The inclinometer senses variations in the angle between the cable and an imaginary line directly beneath the inclinometer. It responds to movements on two axes: foward-reverse motion and transversal. A gyrocompass supplies data on a third axis: changes in heading.

The data, converted to volts representing degrees of position change, is amplified and cleared of noise—cable vibration and superfluous ship movement—in three operational power-amplifier and active-filter chains, one for each axis. Equations are fed to the computer, which compares them to the preset axes. From the differences, the computer determines the direction and thrust for the auxiliary engines. The engines are activated by signals sent from the computer to the engines' servomotors.

The entire operation can be monitored on a cathode-ray tube display located on the ship's bridge.

Although the system employs inclinometers for measuring, it can be adapted to most other aeronautical and nautical methods based on fixed reference points.

Japan

A new entry

With the introduction of its multipurpose NEAC 3100 computer, the Nippon Electric Co. opened the door for its entry into the control computer field.

Suitable for scientific calculations, process control, and message-switching applications, the new system uses Nippon's own diode-transistor-logic integrated circuits—similar to those used in the company's Series 2200 computers. The number of IC packages in the computer varies from 2,500 to 4,000, depending on the installation.

Market potential. Besides using the computer in its own process-control installations, Nippon will market it to process instrumentation and control companies—including Yamatake Honeywell Inc., a joint Honeywell-Japanese venture, and the Hokushin Electric Co.

Japan's powerful Ministry of International Trade and Industry had prevented Yamatake Honeywell from importing technology to manufacture Honeywell's H-20 computer, now out of production. The move was designed to strengthen Japan's electronics industry by stemming the proliferation of computer manufacturers. Hokushin, however, has its own line of process-control computers, used in the company's installations, but it turns to other manufacturers' data processors when specified by its customers.

While putting the brakes on companies that don't belong to a select group of computer manufacturers, the ministry has also "administratively guided" Nippon Electric away from head-on competition with makers of process instrumentation and control systems.

Designation of the new computer for scientific and engineering computation means it can be registered with the Japan Electronic Computer Co., the government-sponsored agency that purchases computers from domestic manufacturers and rents them to users. The agency does not handle computers made only for control applications.

Time-Sharing. Although demand for data transmission switching applications is small, it is expected to increase soon. The 3100, when combined with a 2200 computer, can switch up to 36 lines at the input, thus providing a time-sharing capability.

The smallest system will sell for about $40,000.

The 3100 is a word-oriented machine, with words measuring 18 bits plus one parity bit. Internal core memory varies from a minimum of 2,048 words to 32,768 words. Memory cycle time is two microseconds. Computer add time is four microseconds, multiply time 20 microseconds, and divide time 24 microseconds.

West Germany

Plus-power laser

An argon$^+$ laser emitting a continuous-power output of "about 100 watts"—almost double the previous high—has been developed at West Berlin's Technical University. The device emits in the blue region of the spectrum at about 0.4 microns.

The record output for this type device had been held by the Raytheon Co.'s Research division in Waltham, Mass., which achieved 53 watts more than a year ago.

A power input of 60 kilowatts is required for peak emission, says Hans Boersch, who, with G. Gerziger, heads the university's research staff that developed the new argon$^+$—also called ionized-argon—laser. Efficiency is 0.16%.

Wall stabilization. A major problem confronting researchers in gas laser technology is protecting the discharge tube wall from the high-temperature plasma. This was overcome in the new laser by using a gas layer to insulate the tube walls. Argon or a mixture of argon and argon$^+$ can be used, say the German researchers.

Earlier devices either used built-in water-cooled metal segments or confined the laser beam to a narrow sector by employing magnetic fields focused along the axis of the tube. The trouble with a magnetic field—in addition to limiting the laser emission—is that it's both cumbersome and expensive. Water-cooled segments have also proved undesirable.

Argon$^+$ lasers are being investigated for applications in microwelding, materials processing, and communications. Boersch also believes the devices have potential in color holography and photosynthesis.

Stressing the heart

The beat-by-beat story of what happens to the human heart in the vastness of outer space may have dramatic impact, but doctors and scientists are still groping with down-to-earth mysteries of the heart—particularly under stress.

A portable electrocardiograph (EKG) remote transmission system has been developed by Fritz Hellige GmbH of Freiburg that can help study the heart under a variety of special conditions. It was used earlier this year to record the heart action of a chutist during a skydiving event near Colmar, France.

The system is also being used in hospitals to monitor patients' hearts during intensive care or rehabilitation periods.

Lightweight. The battery-operated transmitter weighs 17 ounces and can be carried in a jacket pocket. It has an output of 50 milliwatts and its range runs from 600 yards in congested city areas to 1.8 miles in open country. The unit operates at the low end of the 150-180-megahertz frequency range used in most European countries for telemetering.

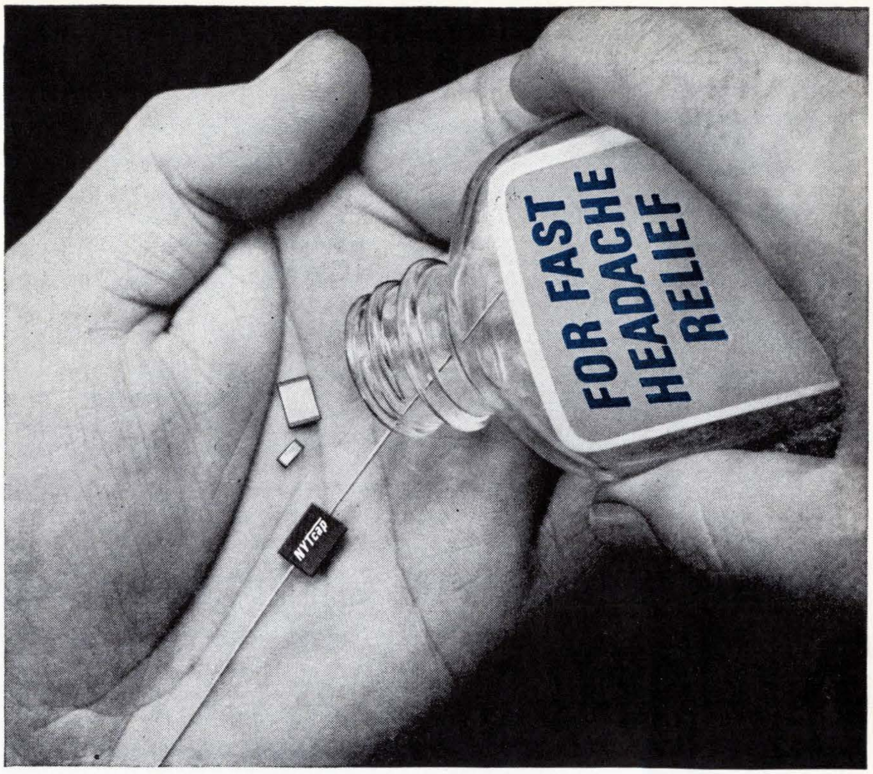
Depending on receiver-recorder configuration, the Hellige system is priced in the $1,500-$2,500 range. Hellige is a subsidiary of Litton Industries Inc.

The transmitter consists of a cardiograph amplifier and the carrier frequency modulator. The heart-beat signal—derived from two electrode contacts—modulates the 1,300-hertz carrier frequency, which, in turn, modulates the transmitter's ultrahigh frequency, around 151 Mhz.

Quartz-stabilized. The receiver is fixed-tuned to the transmitter frequency and has a sensitivity of 1 microvolt. Noise suppression starts at 0.75 microvolts. Both transmitter and receiver frequencies are quartz-stabilized.

An output that can be fed to an oscilloscope or an oscillograph to display the EKG waveform is provided by the receiver.

The electrode contacts, made of a silver-silver chloride alloy, pick up muscle voltages that appear on the skin when the heart beats.



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